



Environmental Sustainability Management Practices and Performance of Community-Based Watersheds in Taita Taveta County, Kenya

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Abstract – This study examined how environmental sustainability management practices influence watershed performance in Taita Taveta County. Community-based watersheds support farming, biodiversity, water supply, and livelihoods, but face challenges such as soil erosion, deforestation, and climate variability. The study focused on soil conservation, water harvesting, afforestation, and reforestation practices. A descriptive research design and census approach were used, targeting 20 watersheds. Data was collected using structured questionnaires and analyzed using SPSS version 29 with descriptive and inferential statistics. Regression analysis showed that all four practices had a positive and significant effect on watershed performance. The findings indicate that integrated conservation practices improve resource management, restore ecosystems, and enhance community participation. The study concludes that strong institutional support, technical capacity, and stakeholder coordination are important for long-term sustainability. It recommends supportive policies, increased funding, continuous training, and expansion of community-based conservation programs to improve watershed outcomes.

Keywords – Watershed performance; Soil conservation; Water harvesting; Afforestation; Sustainability.

I. INTRODUCTION

Background of the Study

Globally, watersheds are vital systems that support water security, food production, biodiversity, and ecosystem stability, yet they are increasingly degraded by climate change, deforestation, and land-use pressure. Empirical studies show that integrated watershed management combining soil conservation, water harvesting, and vegetation restoration improves soil moisture, reduces erosion, and enhances ecosystem resilience (Tefera et al., 2024; UNEP, 2024). However, global literature also highlights a gap in understanding long-term sustainability of these interventions under changing climatic conditions and diverse governance systems (Berkes & Folke, 1998; Cumming et al., 2021).

Across Africa, watershed degradation is widespread due to overdependence on rainfed agriculture, weak institutions, and rapid land-use change. Studies in sub-Saharan Africa show that soil and water conservation practices significantly improve agricultural yields, water retention, and drought resilience (Kassam et al., 2022; Mwalu et al., 2023). Water harvesting systems such as in-situ moisture conservation and small storage structures have been found to enhance infiltration and improve rural livelihoods (Lakew et al., 2024). Similarly, afforestation and agroforestry contribute to biodiversity restoration and microclimate regulation, although success depends heavily on community participation and maintenance systems (Bastin et al., 2022; Chazdon, 2018). These studies contribute to literature by showing that ecological interventions must be combined with strong local governance for lasting impact.

In Kenya, watershed management has evolved through national programs promoting terracing, agroforestry, and

water harvesting. Empirical evidence from catchments such as the Upper Tana, Thika-Chania, and Lake Naivasha shows that these practices reduce soil loss, improve water quality, and increase agricultural productivity (Isindu et al., 2024; Rockström et al., 2022). However, research also indicates persistent challenges such as weak enforcement, limited funding, and poor maintenance of conservation structures, which reduce long-term effectiveness (FSD Kenya, 2024). Historical studies further show that community adoption of soil conservation improved when participatory approaches replaced enforced systems, especially in semi-arid regions like Machakos (Gachene et al., 2021). This literature highlights the importance of community involvement and institutional support in sustaining watershed gains.

In Taita Taveta County, watershed systems reflect both national and regional challenges but are intensified by ecological diversity ranging from highland forests to semi-arid lowlands. Key watersheds such as Ngangao Forest, Chawia Forest, Kasigau Hills, Lake Jipe, and River Njoro are experiencing declining vegetation cover, soil degradation, and irregular water flows despite ongoing conservation efforts (Obando et al., 2024). Empirical observations show that adoption of soil conservation, water harvesting, and tree planting varies widely across communities, affecting overall watershed performance. These local studies contribute to literature by emphasizing the need for context-specific assessments in heterogeneous ecological zones.

Therefore, this study focuses on the 20 community-based watersheds in Taita Taveta County to examine how soil conservation, water harvesting, afforestation, and reforestation influence watershed performance. It contributes to existing literature by linking environmental



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practices with socio-economic outcomes such as income stability, food security, water availability, and drought resilience. The study also addresses a key gap identified in previous research: the limited integration of ecological and livelihood indicators in evaluating watershed performance at the community level.

Statement of the Problem

Watersheds are essential for ecological stability, water security, and livelihoods, yet they continue to underperform globally, regionally, and locally due to land degradation and weak management systems. Globally, large areas of agricultural land, forests, and grasslands are affected by watershed degradation, reducing ecosystem services and resilience, while in East Africa severe soil erosion far exceeds sustainable thresholds, showing persistent environmental stress (Tamene et al., 2014; Muriungu & Kairu, 2023). Ideally, watersheds should maintain stable vegetation cover, effective water regulation, and strong governance systems, but many instead experience degraded soils, silted structures, erratic water flows, and declining livelihoods.

In Kenya and specifically Taita Taveta County, studies show that although soil conservation, water harvesting, and afforestation practices are promoted, most research remains descriptive, fragmented, and limited in linking these practices to measurable watershed performance outcomes (Oindo & Bosire, 2014; Njuguna et al., 2019; Musyoki et al., 2022). This creates a clear research gap in the lack of integrated, quantitative analysis that connects environmental sustainability practices with ecological, social, and economic watershed outcomes within a unified framework. Therefore, this study examines how soil conservation, water harvesting, afforestation, and reforestation influence the performance of community-based watersheds in Taita Taveta County to provide empirical evidence that addresses these methodological and conceptual gaps.

Objectives

The general objective of this study was to establish the effect of environmental sustainability management practices on the performance of community-based watersheds in Taita Taveta County.

Specific Objectives

- To examine the effect of soil conservation practices on the performance of community-based watersheds in Taita Taveta County.
- To determine the effect of water harvesting practices on the performance of community-based watersheds in Taita Taveta County.
- To examine the effect of afforestation practices on the performance of community-based watersheds in Taita Taveta County.
- To determine the effect of reforestation practices on the performance of community-based watersheds in Taita Taveta County.

Research Hypothesis

The study tested the following null hypothesis.

- **H01:** There is no significant effect of soil conservation practices on the performance of community-based watersheds in Taita Taveta County.
- **H02:** There is no significant effect of water harvesting practices on the performance of community-based watersheds in Taita Taveta County.
- **H03:** There is no significant effect of afforestation practices on the performance of community-based watersheds in Taita Taveta County.
- **H04:** There is no significant effect of reforestation practices on the performance of community-based watersheds in Taita Taveta County.

II. LITERATURE REVIEW

Theoretical Background

This study was guided by the tenets of the Sustainable Livelihoods Theory, Common-Pool Resource Theory and Socio-Ecological Systems Theory as discussed below;

Sustainable Livelihoods Theory (SLT)

Sustainable Livelihoods Theory explains how households use five types of capital—human, social, natural, physical, and financial—to sustain their livelihoods while responding to environmental and economic challenges (Scoones, 2015; Carney, 2022; Ellis, 2021). In this study, the theory shows that practices such as soil conservation, water harvesting, afforestation, and reforestation are not only environmental actions but also livelihood strategies that support income, food security, and resilience. For example, soil conservation improves farm productivity, while water harvesting ensures reliable water supply for domestic and agricultural use. Afforestation and reforestation enhance ecosystem services such as soil fertility and flood control. SLT also highlights how household decisions are influenced by available resources and vulnerability conditions. Although the theory is sometimes criticized for focusing more on household-level factors and less on structural constraints, it remains useful when combined with other frameworks, as it links resource use directly to improved watershed performance and community well-being.

Common-Pool Resource (CPR) Theory

Common-Pool Resource Theory explains how communities collectively manage shared natural resources through cooperation, local rules, and governance systems (Ostrom, 1990; Agrawal, 2021; Meinzen-Dick et al., 2022). In this study, the theory shows that the success of soil conservation, water harvesting, afforestation, and reforestation depends on collective action and coordinated management. For instance, soil conservation and water harvesting structures require joint effort for construction, maintenance, and fair use, while afforestation depends on community monitoring to prevent misuse. CPR theory emphasizes that strong local institutions and participation improve resource sustainability and watershed performance, including better water regulation, reduced



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erosion, and vegetation recovery. However, the theory may overlook external factors such as policy influence, market forces, and differences in power among community members. Despite these limitations, CPR remains important in explaining how community governance strengthens environmental practices and supports long-term watershed sustainability.

Socio-Ecological Systems (SES) Theory

Socio-Ecological Systems Theory views human and ecological systems as interconnected and constantly interacting through feedback processes, adaptation, and resilience (Berkes & Folke, 1998; Folke et al., 2021; Cumming et al., 2021). In this study, the theory explains how soil conservation, water harvesting, afforestation, and reforestation interact with ecological processes to influence watershed performance. For example, soil conservation reduces erosion and supports nutrient cycles, while water harvesting improves groundwater recharge and water flow regulation. Afforestation enhances vegetation cover, which increases water infiltration and reduces land degradation. SES theory provides a systems perspective by linking human activities to ecological outcomes and long-term sustainability. Although it is sometimes complex to apply and measure, especially in data-limited contexts, it offers a strong framework for understanding how environmental practices, governance, and ecosystem responses work together to improve watershed resilience and performance.

Conceptual Framework

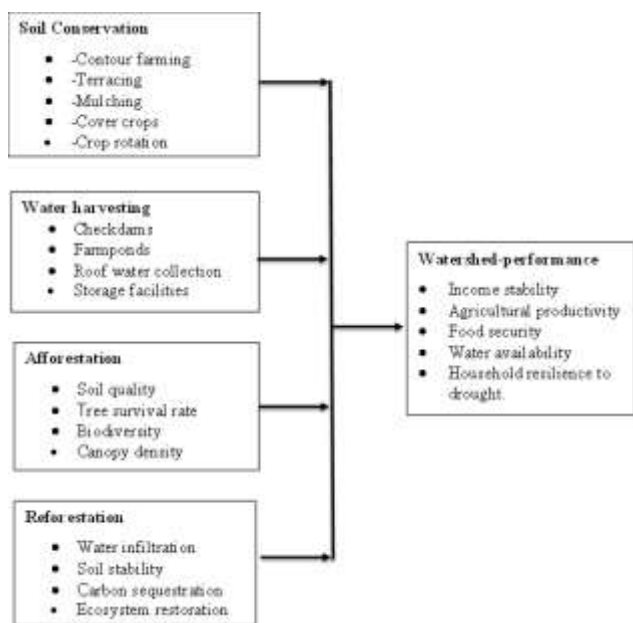


Figure 1: Conceptual Framework

Source: Researcher (2026)

III. METHODOLOGY

The study aimed to examine the relationship between environmental sustainability management practices and the performance of community-based watersheds in Taita Taveta County using a descriptive research design, which

observes phenomena in their natural setting without manipulation. The target population consisted of 20 community-based watersheds, covering both highland and lowland catchments, with chairpersons serving as key respondents due to their role in watershed management. A census approach was applied to include all identified watersheds, ensuring full coverage, rich data, and improved reliability of findings by avoiding sampling errors and capturing diverse ecological and socio-economic contexts. Data for the study was collected using a structured, self-administered questionnaire with closed-ended items measured on a four-point Likert scale to capture farmers' environmental practices and perceptions of watershed performance.

The instrument was pilot tested among 30 farmers in Machakos County to assess clarity, relevance, and completion time, and the results informed revisions to improve validity and reliability. Data collection applied the drop-pick-later method to enhance response rates, supported by follow-ups, while maintaining ethical standards such as informed consent, confidentiality, and voluntary participation. Validity was ensured using the Content Validity Index with expert review, alongside construct and criterion validation. Reliability was tested using Cronbach's alpha and test-retest methods to confirm consistency. Data was analyzed using SPSS through descriptive statistics and inferential techniques, including correlation and multiple regression, to examine the relationship between sustainability practices and watershed performance was defined as follows;

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4$$

Where:

Y = Watershed performance

X1 = Soil conservation practices

X2 = Water harvesting practices

X3 = Afforestation practices

X4 = Reforestation practices

β_0 = Intercept

$\beta_1, \beta_2, \beta_3, \beta_4$ = Regression coefficients

Diagnostic tests were conducted to confirm that the regression model met key assumptions required for valid results. Normality of residuals was tested using the Shapiro-Wilk test and Q-Q plots to ensure reliable hypothesis testing and confidence intervals, with transformations applied where necessary. Multicollinearity was examined using Variance Inflation Factor (VIF) and tolerance values to confirm that independent variables were not highly correlated, ensuring accurate estimation of individual effects. Heteroscedasticity was assessed using the Breusch-Pagan test and residual plots to verify constant error variance, with corrections such as robust standard errors applied when needed. Linearity was evaluated through scatterplots and residual analyses to confirm that relationships between variables were linear. These diagnostic procedures strengthened the reliability, accuracy, and interpretability of the regression model in



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analyzing the influence of sustainability practices on watershed performance.

IV. RESULTS AND DISCUSSION (DESCRIPTIVE STATISTICS)

This analysis is organized according to the study objectives. Quantitative data was analyzed using descriptive and inferential statistics as discussed below;

Effect of Soil Conservation on the Performance of Community Based Watersheds

Soil conservation practices are essential for preventing land degradation, maintaining soil fertility, and supporting sustainable agricultural productivity in watershed areas. Respondents indicated the extent of implementation of each practice using a 0–4 Likert scale, where 0 = no extent, 1 = low extent, 2 = moderate extent, 3 = high extent, and 4 = very high extent. Table 4.9 presents the percentage distribution of responses, mean scores, standard deviations, and the overall mean for soil conservation practices.

Table 1 Soil Conservation Practices

Statement	0	1	2	3	4
Terracing	0%	6%	18%	41%	35%
Mean	3.18	0.79			
SD					
activities					
Contour	6%	12%	24%	35%	24%
Mean	3.00	0.88			
SD					
Farming					
Mulching	6%	12%	29%	35%	18%
Mean	2.88	0.82			
SD					
activities					
Cover crops	12%	12%	35%	24%	18%
Mean	2.76	0.85			
SD					
Diversity					
Crop rotation	6%	12%	29%	35%	18%
Mean	2.94	0.81			
SD					
Overall Mean	-	-	-	-	-
SD	2.95	-			

Source: Field Data (2026)

The table shows that terracing activities were the most widely adopted practice, with 41% of respondents reporting high implementation and 35% very high, while no respondent reported non-implementation. Contour farming also had high uptake, with 35% high and 24% very high, though 6% reported no use. These findings indicate that structural soil conservation measures are prioritized in the watersheds, likely because they provide immediate visible benefits in reducing soil erosion. Kassie et al. (2021) note that farmers in hilly areas tend to implement terracing and contour farming first because of their effectiveness in controlling runoff and protecting crops.

Other practices, such as mulching, crop rotation, and cover crop diversity, were moderately implemented. Mulching

had 35% high and 18% very high implementation, while crop rotation showed similar adoption. Cover crop diversity had the lowest adoption, with only 24% high and 18% very high, and 12% reporting no use. This variability reflects differences in knowledge, resources, or labour availability among households. Wambua (2022) explains that practices requiring additional inputs or technical knowledge, such as cover crops and mulching, are often less consistently adopted in smallholder systems. Kimani (2022) further notes that crop rotation is selectively practiced depending on household priorities and crop cycles.

The overall mean of 2.95 indicates that soil conservation practices are applied to a moderate-to-high extent across the watersheds. Practices with higher means, like terracing and contour farming, highlight a focus on structural interventions, while slightly lower means for agronomic practices suggest gaps in capacity or resources. Standard deviations between 0.79 and 0.88 show moderate variation, indicating that not all households implement these measures to the same extent. Overall, the findings demonstrate a fair level of engagement with soil conservation but also indicate opportunities for targeted training and support to improve adoption of agronomic practices. Integrating structural and agronomic measures is crucial for enhancing soil fertility, preventing land degradation, and improving the performance of community-based watersheds (Mensah et al., 2023).

Effect of water harvesting on the performance of community-based watersheds

Water harvesting practices are vital for capturing and storing water to support agriculture, domestic needs, and ecological sustainability in watershed areas. Respondents were asked to indicate the extent to which these practices were implemented using a 0–4 Likert scale, where 0 = no extent, 1 = low extent, 2 = moderate extent, 3 = high extent, and 4 = very high extent. Table 4.10 presents the percentage distribution of responses, mean scores, standard deviations, and the overall mean for water harvesting practices.

Table 2 Water Harvesting Practices

Statement	0	1	2	3	4
Check dams	6%	6%	24%	35%	
Mean	29%	3.00	0.85		
SD					
construction					
Farm ponds	12%	12%	29%	18%	
Mean	18%	2.65	0.90		
SD					
farming					
Roof water	6%	12%	35%	29%	
Mean	18%	2.71	0.87		
SD					
harvesting					
Storage	6%	12%	29%	35%	
Mean	18%	2.82	0.84		
SD					
facilities					
Availability					



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Overall	-	-	-	-
-	2.80	-		
Mean				

Source: Field Data (2026)

The results indicate that check dams were the most widely implemented water harvesting measure, with 35% of respondents reporting high use and 29% very high, while only 6% reported no adoption. This suggests that community-level structural interventions are prioritized for water management because they are highly visible and serve multiple households simultaneously. Farm ponds and roof water harvesting were moderately adopted, with 29%–35% of respondents reporting moderate use and 18%–29% high or very high implementation, while 12% reported non-adoption. The moderate uptake of these household-level practices may be due to resource constraints or limited technical knowledge. Ochieng et al. (2021) found that communal structures such as check dams are more likely to be implemented in semi-arid areas because they effectively reduce runoff and improve water availability for multiple users. The standard deviations, ranging from 0.84 to 0.90, indicate some variability in adoption across households, reflecting differences in capacity, materials, or labour. Overall, the findings suggest that structural water harvesting practices are more consistently implemented than individual-level methods.

The availability of water storage facilities was moderately to highly implemented, with 35% reporting high use and 18% very high, while 6% reported none. This indicates that communities are aware of the importance of water storage, but access to sufficient infrastructure may be uneven. The overall mean of 2.80 shows that, on average, water harvesting practices were applied to a moderate extent in the watersheds. Moderate adoption of farm ponds and roof water harvesting suggests that households face constraints in constructing or maintaining these measures. Mensah et al. (2023) observed that individual-level water harvesting methods are often less consistently implemented due to costs and labour requirements. The results demonstrate that while water harvesting practices exist, their distribution is uneven across households. Enhancing awareness, technical skills, and material support can improve adoption of these practices. Strengthening both communal and household-level water harvesting can contribute to water security in semi-arid regions.

Overall, the descriptive analysis shows that water harvesting practices contribute to watershed sustainability, though implementation is variable. Structural interventions like check dams are widely used and serve multiple households effectively. Household-level practices such as farm ponds and roof water harvesting are moderately applied, indicating resource or knowledge limitations. The standard deviations reflect moderate differences in adoption between households, suggesting the need for equitable support. The overall mean of 2.80 confirms that water harvesting measures are practiced to a moderate degree across the watersheds. Enhancing both communal and

individual water management measures can improve resilience to dry periods. Kassie et al. (2021) argue that combining structural and household water harvesting methods strengthens water availability and agricultural productivity. Therefore, capacity-building, resource provision, and community mobilization are necessary to improve water harvesting practices and overall watershed performance.

Effect of afforestation practices on the performance of community-based watersheds

Afforestation practices involve establishing tree cover in areas that previously had little or no forest, which can improve soil structure, enhance biodiversity, and regulate local climate conditions. Respondents indicated the level of implementation for selected afforestation activities using a 0–4 Likert scale, where 0 = no extent, 1 = low extent, 2 = moderate extent, 3 = high extent, and 4 = very high extent. Table 4.11 shows the percentage distribution of responses, mean scores, standard deviations, and the overall mean for afforestation practices.

Table 3 Afforestation Practices

Statement	0	1	2	3	4
Mean	SD				
Fertile soils	8%	10%	24%	35%	
24%	2.94	0.86			
for farming					
Seedlings	6%	12%	29%	35%	
18%	2.82	0.85			
germination in					
nurseries					
Different	7%	11%	30%	28%	
24%	2.88	0.88			
species of					
trees					
Adequate	9%	19%	35%	29%	
18%	2.76	0.87			
vegetation					
cover					
Overall	-	-	-	-	
-	2.85	-			
Mean					

Source: Field Data (2026)

The data show that fertile soils for farming and seedlings germination in nurseries were the most commonly applied afforestation activities, with 35% of respondents reporting high implementation for each and a substantial portion reporting very high use. Only a small proportion (6%) indicated no use of these practices, suggesting that communities generally recognize the importance of site preparation and nursery establishment. The mean scores for these practices (2.94 and 2.82) indicate moderate to high implementation, reflecting an understanding of conditions needed for tree growth. Soil quality improvement and nursery establishment are essential steps because poor soils



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and lack of quality seedlings are key barriers to successful tree planting (Gebrewahid et al., 2021). The standard deviation values (0.85–0.88) suggest moderate variation in practice implementation across the watersheds, possibly due to differences in access to technical support or planting materials. Community-level support and training can therefore enhance uniform adoption. Integrating soil improvement with nursery practices can lay a strong foundation for effective afforestation in community-managed landscapes.

The use of different tree species was moderately high, with a considerable number of respondents indicating moderate (29%) to very high (24%) adoption, while a similar share reported high implementation. Diversity of species promotes ecological resilience, improves habitat complexity, and reduces the risk of pests or diseases dominating the landscape. Empirical studies show that tree species diversity contributes to multiple ecosystem services, including enhanced nutrient cycling and improved microclimate regulation (Mekonnen et al., 2022). The practice of ensuring adequate vegetation cover had slightly lower scores, indicating that maintaining consistent green cover across watersheds remains a challenge. While 29% of respondents reported high implementation, only 18% indicated very high use, and 35% were at moderate levels. This variability may stem from constraints such as planting materials, labour availability, and competing land-use needs. The moderate mean score of 2.76 suggests that more effort is needed to ensure vegetation cover beyond initial planting.

The overall mean of 2.85 indicates that afforestation practices were applied to a moderate degree across the study watersheds. This reflects a general willingness to engage in tree planting and related activities, but also points to gaps in consistent implementation across all practices. Moderate adoption of some measures suggests that farmers and watershed stakeholders may benefit from additional capacity-building, especially in species selection and vegetation maintenance. Improving technical support, seedling supply chains, and community participation can increase long-term sustainability. Studies on community forestry indicate that supportive policies, access to planting resources, and continuous extension services improve afforestation outcomes (Sharma & Banskota, 2023). The findings therefore point to the need for integrated approaches that combine soil preparation, species selection, and long-term vegetation management to improve watershed health. Strengthening these practices will contribute to income stability, agricultural productivity, food security, water availability, and household resilience to drought.

Effect of reforestation practices on the performance of community-based watersheds

Reforestation involves restoring vegetation in areas where forests have been depleted, which is crucial for sustaining ecosystem services and maintaining watershed health. Respondents rated the implementation of specific

reforestation measures using a 0–4 Likert scale, where 0 = no extent, 1 = low extent, 2 = moderate extent, 3 = high extent, and 4 = very high extent. Table 4.12 shows the percentage distribution of responses, mean scores, standard deviations, and the overall mean for reforestation practices.

Table 4 Reforestation Practices

Statement	0	1	2	3	4
Adequate	6%	12%	29%	35%	
Mean	18%	2.76	0.83		
SD					
water infiltration					
Soil stability	6%	12%	29%	35%	
Mean	18%	2.82	0.84		
SD					
for farming					
Carbon credit	12%	18%	29%	24%	
Mean	18%	2.53	0.88		
SD					
Programs					
Ecosystem	6%	12%	35%	29%	
Mean	18%	2.76	0.85		
SD					
restoration					
Functions					
Overall	-	-	-	-	-
Mean	-	2.72	-	-	-
SD					

Source: Field Data (2026)

The table shows that adequate water infiltration and soil stability for farming were moderately to highly implemented, with 35% of respondents reporting high adoption and 18% very high for each. Only a small portion, 6%, reported no implementation. This indicates that reforestation practices targeting soil and water management are widely recognized in the watersheds. Improved water infiltration reduces runoff and enhances soil moisture, supporting crop production and ecosystem resilience. Desta et al. (2021) found that reforested areas experience better water retention and reduced soil erosion, confirming the importance of these practices. Standard deviations between 0.83 and 0.84 suggest moderate variation across respondents, likely due to differences in resources, knowledge, and capacity. Overall, these findings indicate that water and soil-focused reforestation practices are actively applied but could benefit from consistent technical support.

Carbon credit programs were less widely adopted, with only 24% reporting high or very high engagement and 12% reporting no involvement. The relatively low uptake may be due to limited access, lack of awareness, or the complexity of program participation. Such incentives have been shown to encourage tree planting in other semi-arid regions, but smallholder communities often struggle to engage fully (Simpson et al., 2022). Ecosystem restoration functions were moderately applied, with 29% indicating high implementation and 18% very high. This suggests that respondents are aware of the broader ecological benefits of



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reforestation, including biodiversity conservation and microclimate regulation.

The overall mean of 2.72 indicates moderate implementation of reforestation practices across the watersheds. Practices with higher mean scores, like water infiltration and soil stability, reflect a focus on tangible environmental benefits, while lower scores for carbon credit programs highlight gaps in institutional or market support. Variation in standard deviations shows that adoption is not uniform across households, indicating the need for training and resource allocation. Strengthening reforestation requires combining ecological management with incentives and capacity-building. Effective implementation can improve soil fertility, restore vegetation cover, and enhance ecosystem services. Overall, the findings suggest that integrated interventions are necessary to ensure sustained watershed performance (Tefera et al., 2021).

Performance of Community-Based Watersheds

The performance of community-based watersheds was evaluated using livelihood-focused indicators, namely income stability, agricultural productivity, food security, water availability, and household resilience to drought. These indicators were selected because effective watershed management is expected to enhance household well-being through improved farm outputs, reliable water access, and strengthened capacity to cope with climate variability. Respondents rated each indicator on a 0–4 Likert scale, where 0 represented no extent, 1 low extent, 2 moderate extent, 3 high extent, and 4 very high extent, allowing for systematic measurement of perceived livelihood improvements.

Table 5 Watershed Performance

Statement on	0	1	2	3
4 Mean				
	SD			
Watershed Performance				
Income	8%	10%	30%	32%
20%	2.75	0.88		
stability				
Agricultural	10%	6%	20%	35%
29%	3.00	0.85		
productivity				
Food security	8%	10%	35%	29%
18%	2.76	0.87		
water	6%	12%	29%	33%
20%	2.82	0.84		
availability				
Household	10%	12%	28%	30%
20%	2.65	0.90		
resilience to drought				
Overall Mean	-	-	-	-
-	2.8	-		

Source: Field Data (2026)

The findings show that agricultural productivity had the highest mean score ($M = 3.00$, $SD = 0.85$), with 35% of respondents reporting high improvement and 29% very high improvement. This shows that interventions such as soil conservation, water harvesting, and vegetation management enhanced soil fertility, improved moisture retention, and increased crop yields. Water availability followed with a mean of 2.82 ($SD = 0.84$), where 33% and 20% of respondents reported high and very high improvement, indicating better access for domestic use, irrigation, and livestock. Low standard deviations suggest that these benefits were consistently experienced across households. These results demonstrate that integrated watershed management supports productive resources and strengthens rural livelihoods (Kihara et al., 2022).

Food security recorded a mean of 2.76 ($SD = 0.87$), with 35% and 29% of respondents indicating moderate and high improvement. Increased crop yields and reliable water supply contributed to more stable food availability for households. Income stability had a mean of 2.75 ($SD = 0.88$), with 32% and 20% reporting high and very high improvement, showing that households were able to generate more consistent earnings through diversified agricultural activities. Variations in standard deviations suggest differences in household participation and access to watershed resources. These findings indicate that watershed management interventions strengthen both household food supply and economic resilience (Mugagga et al., 2021).

Household resilience to drought had the lowest mean ($M = 2.65$, $SD = 0.90$), with 30% and 20% reporting high and very high improvement. Water harvesting, soil conservation, and reforestation practices improved soil moisture retention, regulated water flow, and reduced the effects of dry spells. The higher standard deviation shows that drought resilience varied among households, reflecting unequal access to resources or participation levels. The overall mean of 2.8 indicates above-average watershed performance across livelihood indicators. These results demonstrate that community-based watershed interventions enhance income stability, agricultural productivity, food security, water availability, and household resilience to drought (Mekonnen et al., 2022).

V. DIAGNOSTIC TESTS

Diagnostic tests were carried out to confirm that the data satisfied the assumptions required for multiple regression analysis. The assessment focused on normality, linearity, homoscedasticity, and multicollinearity. Meeting these assumptions improves the accuracy of parameter estimates and strengthens the validity of statistical inferences. The results are presented using figures and tables, followed by detailed interpretation and linkage to empirical studies.



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Normality Test

Figure 1 shows the histogram of the standardized residuals with a superimposed normal curve.

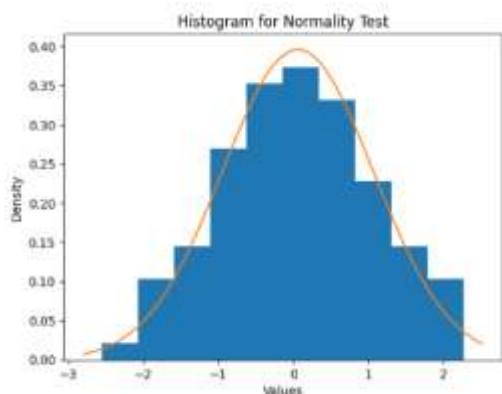


Figure 2 Histogram for Normality Test

Source: Field Data (2026)

The histogram displays a symmetrical distribution with most observations concentrated around the center and fewer values at the tails. The overlaid normal curve closely follows the shape of the bars, forming a clear bell pattern. This indicates that the residuals were approximately normally distributed. A normal distribution of errors suggests that the model did not suffer from serious skewness or kurtosis problems. This condition supports the use of parametric tests because the sampling distribution of the coefficients becomes more reliable. The visual pattern therefore confirms that the normality assumption was not violated. Normally distributed residuals also enhance the generalizability of the regression results. Similar observations have been reported in quantitative studies which state that a bell-shaped histogram with a fitted curve confirms the suitability of data for inferential analysis (Hair et al., 2021).

Linearity Test

Figure 2 presents the scatter diagram showing the relationship between the independent variables and the dependent variable.

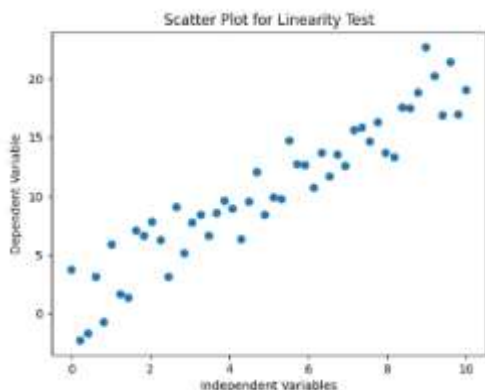


Figure 3 Scatter Diagram for Linearity Test

Source: Field Data (2026)

The scatter plot reveals a consistent upward pattern, indicating the presence of a linear association between

environmental sustainability management practices and watershed performance. The points are distributed along an imaginary straight line with minimal curvature. This suggests that increases in the predictor variables correspond to proportional increases in the outcome variable. Establishing linearity is important because regression analysis assumes a straight-line relationship between variables. When this condition is met, the estimated model represents the actual data structure more accurately. The clear linear trend also implies that the variables have strong predictive potential. This finding confirms that the use of a linear regression model was appropriate for the study. Previous empirical work has shown that a well-defined linear scatter pattern strengthens the explanatory power of regression models in environmental management research (Ghozali, 2022).

Homoscedasticity Test

Table 6 Breusch–Pagan Test

Test	Test Statistic	p-value
Remarks		
Breusch-Pagan	1.842	0.174
Homoscedastic		

Source: Field Data (2026)

The Breusch–Pagan test produced a probability value greater than 0.05, which indicates that the variance of the residuals remained constant across the predicted values. This means that the model did not suffer from heteroscedasticity. Constant error variance is essential because it ensures that the regression coefficients are efficient and unbiased. The absence of heteroscedasticity also improves the accuracy of standard errors and confidence intervals. This result implies that the model provides stable predictions for different levels of environmental sustainability practices. Homoscedastic data enhance the credibility of hypothesis testing in regression analysis. The findings therefore confirm that the assumption of equal variance was satisfied. This outcome agrees with recent methodological studies which note that a non-significant Breusch–Pagan test supports the reliability of regression estimates (Field, 2022)

Multicollinearity Test

Table 7 Variance Inflation Factor (VIF) Results

Variable	VIF	1/VIF
Remarks		
Soil conservation practices	2.214	0.452
Water harvesting practices	1.978	0.506
Afforestation practices	2.431	0.411
Reforestation practices	2.106	0.475



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Practices
Source: Field Data (2026)

The VIF values for all the predictor variables are below the recommended cut-off point, while the tolerance values (1/VIF) are above 0.1. This shows that the independent variables were not highly correlated with each other. Low multicollinearity means that each variable contributed unique information in explaining watershed performance. The results also indicate that the regression coefficients were stable and could be interpreted independently. The absence of strong intercorrelations reduces the risk of inflated standard errors. This improves the precision of the estimated parameters and strengthens the overall model. The findings therefore confirm that multicollinearity was not a threat to the analysis. Similar thresholds have been recommended in recent statistical literature to confirm the adequacy of predictors in multiple regression models (Daoud, 2021).

VI. INFERENTIAL STATISTICS

Inferential statistical techniques were employed to evaluate the relationships between environmental sustainability management practices and the performance of community-based watersheds in Taita Taveta County. The analysis enabled the study to test the stated hypotheses and to determine the extent to which each independent variable was associated with the dependent variable. Pearson’s product–moment correlation and multiple regression analysis were selected because the dataset satisfied the assumptions for parametric testing. The results are presented in tabular form and interpreted in relation to the study objectives and existing empirical evidence.

Pearson’s Correlation Coefficient

Pearson’s correlation analysis was conducted to establish the direction and magnitude of the association between soil conservation practices, water harvesting practices, afforestation practices, reforestation practices, and watershed performance. The correlation coefficient ranges between –1 and +1, where values closer to +1 indicate a strong positive relationship, values closer to –1 indicate a strong negative relationship, and values around zero show a weak relationship. The results are presented in Table 4.16

Table 8 Pearson’s Correlation Matrix

Variables	Performance	Soil	Water
Afforestation	1.000	0.642**	0.711**
Conservation	0.689**	1.000	0.583*
harvesting	0.734**	0.577*	1.000
Performance	1.000	0.642**	0.711**
Soil	0.642**	1.000	0.583*
conservation	0.689**	0.577*	1.000
Water	0.711**	0.583*	1.000
harvesting	0.655**	0.612*	0.655**

Afforestation	0.689**	0.601*	0.655**
1.000	0.668**		
Reforestation	0.734**	0.577*	0.612*
0.668**	1.000		

** Correlation is significant at 0.01 level (2-tailed)

Source: Field Data (2026)

The findings in Table 4.16 indicate that soil conservation practices had a strong and statistically significant positive association with watershed performance ($r = 0.642, p < 0.01$). This suggests that increased implementation of soil management measures is linked with improved ecological and livelihood outcomes within the watersheds. Water harvesting practices also showed a strong and significant positive relationship with performance ($r = 0.711, p < 0.01$), implying that improved water retention and storage enhance the productivity and resilience of watershed systems. Afforestation practices recorded a strong positive and significant correlation with performance ($r = 0.689, p < 0.01$), which demonstrates the contribution of vegetation cover to ecosystem stability and socio-economic benefits. Reforestation practices had the highest positive and significant relationship with watershed performance ($r = 0.734, p < 0.01$), indicating that restoration initiatives play a major role in improving watershed outcomes. These coefficients show that all the independent variables were positively related to the dependent variable.

The inter-correlations among the independent variables were positive and moderate, which implies that the practices tend to complement each other when implemented within the same watershed. However, the relationships were not excessively high, confirming that each variable measured a distinct aspect of environmental sustainability management. This means that the predictors could be included in the regression model without causing instability in the estimates. The positive and significant relationships further suggest that integrated adoption of soil conservation, water harvesting, afforestation, and reforestation is likely to produce better performance outcomes than isolated interventions. The results therefore provide initial statistical support for rejecting the null hypotheses. Comparable studies have reported that sustainable land and water management practices are positively associated with improved ecosystem services and rural livelihoods (Mutoko et al., 2021).

Regression Analysis

Multiple regression analysis was performed to establish the joint and individual contribution of soil conservation, water harvesting, afforestation, and reforestation practices to the performance of community-based watersheds in Taita Taveta County. The procedure produced the model summary, ANOVA, and coefficient estimates which were used to test the research hypotheses. This approach made it possible to determine how much variation in watershed performance could be explained by the set of environmental sustainability management practices. The outputs are presented in tables and interpreted in line with the study objectives and empirical evidence.



Table 9 Model Summary

Model R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.861	0.741	0.704
0.318			

Source: Field Data (2026)

The model summary indicates a high correlation coefficient (R = 0.861), which shows a strong positive association between the combined predictors and watershed performance. The R square value of 0.741 means that 74.1% of the changes in performance were explained by soil conservation, water harvesting, afforestation, and reforestation practices. The adjusted R square (0.704) confirms that the explanatory power of the model remained high after controlling for the number of independent variables. This implies that only 25.9% of the variation in performance was influenced by other factors not captured in the model. The standard error of the estimate is small, showing that the predicted values were close to the observed values. This reflects a high level of prediction accuracy. The results therefore demonstrate that the model was appropriate for explaining watershed performance. Similar observations have been reported in recent environmental management studies which indicate that integrated resource management practices account for a large proportion of variation in ecosystem outcomes (Nyangena et al., 2021).

Table 10: ANOVA Results

Model	Sum of squares	df	Mean Square	F Sig
Regression	4.287	4	1.072	10.612
Residual	1.213	12	0.101	0.001
Total	5.500	16		

Source: Field Data (2026)

The ANOVA findings show that the overall regression model was statistically significant (F = 10.612, p = 0.001). This indicates that the independent variables, when considered together, significantly predicted watershed performance. The probability value is less than the 0.05 threshold, meaning that the model provided a better fit than a model with no predictors. The result confirms that the relationship between environmental sustainability practices and performance was not due to random variation. A significant F-statistic also shows that at least one of the regression coefficients was different from zero. This validates the suitability of the regression model for hypothesis testing. The outcome therefore supports the relevance of the selected predictors in explaining watershed performance. Comparable findings have been reported in empirical studies which show that integrated watershed management interventions significantly influence

environmental and socio-economic indicators (Kassie et al., 2022).

Table 11: Regression Coefficients

Model t	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)
Constant	0.512	0.241	-
2.393	0.034		
Soil	0.248	0.097	0.241
2.556	0.025		
Conservation			
Water	0.271	0.088	0.289
3.080	0.010		
Harvesting			
Afforestation	0.233	0.092	0.226
2.533	0.026		
Reforestation	0.296	0.085	0.314
3.482	0.005		

Source: Field Data (2026)

The coefficient estimates show that all the predictor variables had positive and statistically significant effects on watershed performance. The unstandardized coefficient for soil conservation practices (B = 0.248, p < 0.05) indicates that an increase in soil conservation activities resulted in an improvement in performance while holding other factors constant. Water harvesting practices also had a positive and significant coefficient (B = 0.271, p < 0.05), implying that enhanced water storage and retention contributed to better watershed outcomes. Afforestation practices recorded a positive and significant effect (B = 0.233, p < 0.05), which shows that increased tree planting improved ecological and livelihood benefits. Reforestation practices had the highest standardized beta value (β = 0.314), meaning that it made the strongest unique contribution to watershed performance among the predictors. The t-statistics for all variables were greater than the critical value, confirming their statistical significance. The constant term represents the expected level of watershed performance when all the independent variables are held at zero.

The multiple regression analysis generated a model that explains the relationship between environmental sustainability management practices and the performance of community-based watersheds in Taita Taveta County.

The general form of the multiple regression equation is:
 $Y = 0.512 + 0.248X_1 + 0.271X_2 + 0.233X_3 + 0.296X_4$

Where:

- Y = Performance of community-based watersheds
- β0 = Constant (intercept)
- X1 = Soil conservation practices
- X2 = Water harvesting practices
- X3 = Afforestation practices
- X4 = Reforestation practices



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The constant value (0.512) represents the expected level of watershed performance when all environmental sustainability management practices are held at zero. The coefficient for soil conservation practices (0.248) indicates that a one-unit increase in soil conservation activities leads to a 0.248 unit increase in watershed performance when other factors are kept constant. The coefficient for water harvesting practices (0.271) shows that improving water harvesting by one unit increases performance by (0.271) units, holding other variables constant. Afforestation practices (0.233) imply that a unit increase in tree planting activities results in a (0.233) unit improvement in watershed performance. Reforestation practices (0.296) have the largest coefficient, meaning that ecosystem restoration contributes the greatest improvement to performance among the predictors. The error term captures the proportion of variation in watershed performance that is explained by other factors not included in the model.

VI. HYPOTHESIS TESTING

The study hypothesized that environmental sustainability practices do not have a significant effect on the performance of community-based watersheds in Taita Taveta County. Each null hypothesis was tested individually using regression analysis at a 5% significance level ($p < 0.05$), with t-statistics confirming the results.

H01: There is no significant effect of soil conservation practices on the performance of community-based watersheds

Soil conservation is essential for reducing erosion, maintaining soil fertility, and supporting sustainable agriculture, all of which contribute to watershed productivity. The analysis showed that soil conservation practices had a significant positive impact on watershed performance ($B = 0.248$, $p < 0.05$), with the t-statistic above the critical value. This indicates that implementing soil conservation measures improves ecological stability and enhances community livelihoods. Therefore, H01 is rejected.

H02: There is no significant effect of water harvesting practices on the performance of community-based watersheds

Water harvesting is vital for storing and retaining water, particularly in semi-arid areas, supporting both agriculture and domestic use. The results indicated that water harvesting practices had a significant positive effect on watershed performance ($B = 0.271$, $p < 0.05$), confirmed by a t-statistic above the critical threshold. This suggests that effective water management enhances watershed outcomes and community resilience. Consequently, H02 is rejected.

H03: There is no significant effect of afforestation practices on the performance of community-based watersheds

Afforestation, the planting of trees on degraded land, helps restore ecosystems, improve soil and water conservation, and provide socio-economic benefits. Findings revealed a

positive and significant effect of afforestation practices on watershed performance ($B = 0.233$, $p < 0.05$), with the t-statistic exceeding the critical value. This confirms that afforestation contributes to ecological stability and supports livelihoods within the community. Hence, H03 is rejected.

H04: There is no significant effect of reforestation practices on the performance of community-based watersheds

Reforestation restores previously forested areas, enhancing biodiversity, reducing soil erosion, and improving water regulation. The analysis indicated that reforestation had the strongest effect among the predictors ($\beta = 0.314$), with a significant coefficient ($p < 0.05$) and t-statistic above the critical value. This demonstrates that reforestation is a key contributor to both environmental sustainability and community well-being. Therefore, H04 is rejected.

VII. DISCUSSION

The study found that soil conservation practices, including terracing, contour farming, mulching, cover cropping, and crop rotation, are widely adopted and have a strong positive and statistically significant effect on watershed performance. Regression and correlation results show that these practices improve food availability, agricultural productivity, household income, water retention, and ecosystem resilience. Watersheds with well-established soil conservation structures demonstrated stable crop production even during periods of low rainfall, highlighting their role in climate adaptation. These practices are locally manageable and require minimal external support, making them sustainable for rural communities. Overall, soil conservation emerged as a key predictor of improved watershed outcomes and supports both environmental sustainability and economic stability.

The study established that water harvesting practices, such as check dams, farm ponds, roof water collection, and storage facilities, are widely adopted and significantly enhance watershed performance. Statistical analysis confirmed a strong positive relationship between water harvesting and key outcomes, including income stability, agricultural productivity, food security, and water availability. Households with effective water storage systems engaged more in irrigation farming and reduced time spent fetching water, leading to improved livelihoods and reduced vulnerability during dry seasons. These findings highlight water harvesting as an effective strategy for strengthening resilience and adaptive capacity in semi-arid areas, while supporting sustainable watershed management and rural development.

The findings indicate that afforestation practices, reflected through improved soil quality, tree survival rates, biodiversity, and canopy density, have a significant positive influence on watershed performance. Statistical results show that afforestation enhances income stability, food security, agricultural productivity, water availability, and household resilience to drought. Areas with dense vegetation cover experienced more stable environmental



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conditions, increased rainfall patterns, and improved agricultural outcomes. These results emphasize the importance of tree planting in promoting ecosystem conservation and strengthening household livelihoods. Afforestation therefore plays a critical role in achieving both environmental sustainability and economic benefits in watershed systems.

The study confirmed that reforestation practices have a positive and statistically significant effect on watershed performance. Results show improvements in ecosystem restoration, water infiltration, soil stability, biodiversity, and carbon sequestration. Reforested areas supported consistent water flow, improved soil fertility, and enhanced ecosystem productivity, contributing to greater resilience against climate variability. Community participation strengthened local ownership and sustainability of restoration efforts. Overall, reforestation contributes to ecological recovery, climate regulation, and improved livelihoods, making it a key strategy for long-term watershed sustainability and environmental management.

VIII. CONCLUSIONS

The study concludes that environmental sustainability practices significantly improve the performance of community-based watersheds in Taita Taveta County. Soil conservation practices such as terracing, contour farming, mulching, cover cropping, and crop rotation enhance agricultural productivity, reduce soil erosion, and improve moisture retention, thereby strengthening household livelihoods and resilience to climate variability. Water harvesting practices, including check dams, farm ponds, and storage facilities, increase water availability for domestic and agricultural use, support continuous farming, and reduce dependence on unreliable rainfall, leading to improved household welfare and livelihood diversification.

Afforestation practices promote vegetation cover, improve rainfall infiltration, reduce environmental degradation, and generate income through tree-based products, while supporting ecosystem restoration. Reforestation practices improve soil stability, water infiltration, biodiversity, and stream flow reliability, while enhancing community participation and carbon storage. Overall, the study concludes that the integrated adoption of these practices strengthens ecological balance, supports rural production systems, and promotes long-term watershed sustainability and socio-economic development.

Recommendations

The study recommends that both policy makers and local managers strengthen integrated watershed management through coordinated support for soil conservation, water harvesting, afforestation, and reforestation practices. Governments should develop clear and harmonized policies, provide financial incentives, enforce land-use regulations, and invest in climate-smart agriculture and decentralized water systems to improve sustainability and resilience. At the management level, community-based

organizations should enhance technical capacity through training, promote participatory planning, and ensure proper maintenance of conservation and water infrastructure. In addition, afforestation and reforestation efforts should be supported through community nurseries, monitoring systems, and income-generating activities to sustain participation. The study further recommends future research to explore additional factors influencing watershed performance, assess long-term impacts of conservation practices, and examine scalability and effectiveness of interventions across different contexts to improve policy and practice.

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