

Journal of Agriculture & Environmental Sciences



ISSN Online: 2616-8456

Stratford
Peer Reviewed Journals & books

Assessing the Impact of Community Engagement on Natural Resource Sustainability, A Case of Nyaruguru District, Rwanda

Augustin Musabyimana & Dr. Jonas Nzabamwita

ISSN: 2616-8465

Assessing The Impact of Community Engagement on Natural Resource Sustainability, A Case of Nyaruguru District, Rwanda

Augustin Musabyimana¹ & Dr. Jonas Nzabamwita¹ (PhD)

¹*Faculty of Environmental Studies, University of Lay Adventists of Kigali, Kigali, Rwanda*

How to cite this article: Musabyimana A., & Nzabamwita J. (2026). Assessing The Impact of Community Engagement on Natural Resource Sustainability, A Case of Nyaruguru District, Rwanda. *Journal of Agriculture & Environmental Sciences* Vol 10(1) pp. 49-67. <https://doi.org/10.53819/81018102t2562>

Abstract

Natural resources are fundamental to human well-being and sustainable development, supporting livelihoods, food security, and ecosystem services. However, increasing pressure from population growth, climate variability, and unsustainable resource use has accelerated environmental degradation in many developing regions. In Rwanda's Nyaruguru District, challenges such as deforestation, soil erosion, biodiversity loss, and land degradation continue to threaten long-term sustainability and rural livelihoods. Recognizing the importance of participatory approaches, this study examined the influence of community engagement on the sustainability of natural resources in Nyaruguru District. The study assessed the level of community engagement in natural resource management, evaluated sustainability outcomes before and after community-based interventions, and analyzed the relationship between community engagement and key sustainability indicators. A mixed-methods approach was used, involving 396 households including 8 sector agronomists, and 2 environmental officers. Data were collected through structured questionnaires, key informant interviews, field observations of practices such as Umuganda, agroforestry, terracing, and reforestation and document review. Quantitative data were analyzed using SPSS version 29.0, while qualitative data were analyzed thematically. The results revealed high levels of community engagement in natural resource management, particularly in Umuganda, tree planting, soil conservation, and environmental education. Sustainability outcomes improved significantly following increased community participation, with mean scores rising from 2.90 before interventions to 3.80 after. Pearson correlation analysis showed a strong positive relationship between community engagement and sustainability outcomes ($r = 0.92$, $p < 0.01$). Regression analysis further confirmed that community engagement had a statistically significant positive effect on multiple sustainability indicators, explaining between 23% and 36% of the variation in sustainability outcomes. These findings provide valuable insights for strengthening community-driven natural resource management in Rwanda and similar contexts.

Keywords: *Community engagement; Environmental degradation; Natural resource; Rural development; Sustainability.*

1. Introduction

Environmental degradation is a growing global challenge that threatens ecosystems, human well-being, and sustainable development. Natural resources such as forests, water, soil, minerals, and biodiversity are essential for livelihoods, economic growth, and ecological balance (Kumar and Sharma, 2025). However, these resources are increasingly threatened by deforestation, climate change, overexploitation, poor land management, and rapid population growth (Mondal and Palit, 2022). Countries such as Brazil and Indonesia have experienced severe forest destruction due to illegal logging and agricultural expansion, resulting in biodiversity loss and increased carbon emissions (Dockendorf et al., 2022; Abram et al., 2017). Even developed countries like the United States continue to face challenges such as soil erosion and water shortages in drought-prone regions (Gomiero, 2016).

In Africa, environmental degradation is particularly severe, with more than 65% of arable land considered degraded, threatening food security and economic stability (Ezeaku and Alaci, 2018). The Sahel region faces desertification, while Nigeria's Niger Delta suffers from oil pollution and deforestation (Abayomi et al., 2021). East African countries also face environmental pressures. Kenya's Mau Forest has been heavily encroached upon, threatening water catchment systems, while Uganda experiences deforestation, wetland degradation, soil erosion, and environmental damage from artisanal mining (Michael, 2020; NEMA, 2021).

Rwanda heavily depends on natural resources, especially land and water, to support its predominantly agricultural population. However, increasing population pressure, unsustainable farming, deforestation, soil erosion, and wetland degradation continue to threaten environmental sustainability (Bizimana and Hategekimana, 2024). Although the Government of Rwanda has introduced policies such as the Green Growth and Climate Resilience Strategy, implementation challenges and limited community involvement persist (Government of Rwanda, 2017).

In Nyaruguru District, degradation of forests, soil, and water resources threatens agricultural productivity, biodiversity, and rural livelihoods (MINAGRI, 2018). Limited community participation in environmental management has reduced local ownership and compliance with conservation practices (REMA, 2019). Therefore, this study seeks to assess the impact of community engagement on natural resource sustainability in Nyaruguru District, Rwanda.

1.2 Objectives of the Research

1.2.1 General objective

The general objective of the study is to examine the community engagement in influencing the sustainability of natural resources in Nyaruguru District, for the period between 2020 to 2025.

1.2.2. Specific objectives

- i. To evaluate the level of community engagement in natural resource management activities in Nyaruguru District.
- ii. To assess the status of natural resource sustainability in Nyaruguru District.

- iii. To examine the relationship between community engagement and the sustainability of natural resources in Nyaruguru District.

2. Research methods

2.1 Description of the study area

Nyaruguru District is Rwanda's southernmost district, located in the Southern Province and bordering Burundi, Rusizi, Nyamasheke, Huye, Gisagara, and Nyamagabe. The district consists of 14 sectors, 72 cells, and 332 villages, with headquarters in Kibeho, a well-known pilgrimage site. Its mountainous landscape, including part of the Congo–Nile Divide, makes it an important watershed area. Nyaruguru experiences a tropical highland climate with annual rainfall ranging from 1,200–1,600 mm and temperatures between 15°C and 23°C. However, steep slopes increase vulnerability to soil erosion and landslides. With about 320,000 residents (NISR, 2022), most households depend on agriculture and livestock rearing. Part of Nyungwe National Park lies within the district, supporting biodiversity and water conservation. Community initiatives such as agroforestry, terracing, improved stoves, and Umuganda promote environmental sustainability

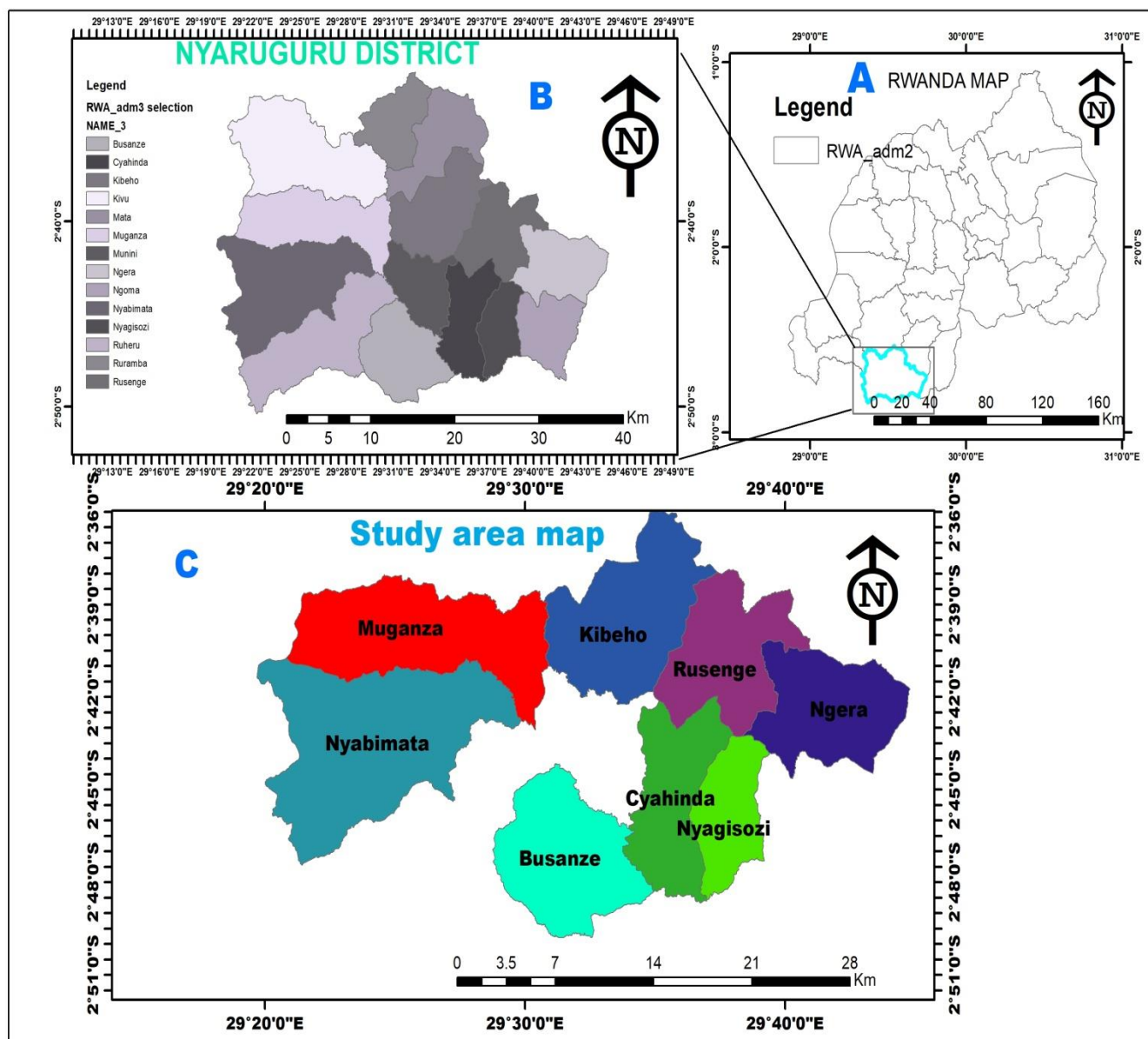


Table 3.1. Geographical location map, (A) showing Rwanda map with location of Nyaruguru District, (B) Nyaruguru District map, (C) Map of study area.

Source: Researcher mapping in Arc GIS 10.8, 2025

2.2. Research design and data collection methods

The study employed a mixed-methods research design, combining quantitative and qualitative approaches to examine the impact of community engagement on natural resource sustainability in Nyaruguru District. This design was selected to capture both statistical trends and contextual insights, ensuring triangulation and improving validity and reliability. The target population included households, cooperative members, local leaders, sector agronomists, and environmental officers involved in natural resource management across eight sectors: Nyabimata, Muganza, Kibeho, Rusenge, Ngera, Cyahinda, Nyagisozi, and Busanze. According to the National Institute of Statistics of Rwanda (2022), these sectors contain 44,599 households.

The sample size was determined using Yamane's formula (1967) at a 95% confidence level and 5% margin of error, resulting in 396 household respondents. In addition, 8 sector agronomists and 2 district environmental officers were included, giving a total sample of 406 respondents. Stratified random sampling was used to ensure proportional representation across sectors, while simple random sampling selected households from lists provided by local authorities.

Primary data were collected using structured questionnaires, key informant interviews, focus group discussions, and direct observation. Questionnaires captured data on participation in environmental activities such as tree planting, terracing, agroforestry, Umuganda, and perceptions of environmental change. Key informant interviews provided expert views on policy implementation and challenges, while observation assessed actual land management practices. Secondary data was obtained from government reports, policy documents, and institutional sources such as REMA and MINAGRI, ensuring comprehensive analysis.

3.6. Data analysis and processing

The data for this study were systematically processed and analyzed to ensure accuracy, consistency, and meaningful interpretation in assessing community engagement and natural resource sustainability in Nyaruguru District. Both quantitative and qualitative approaches were integrated. Quantitative data from 396 household questionnaires were analyzed using SPSS version 25, while qualitative data from interviews and observations were analyzed using thematic analysis. Before analysis, all data were edited, coded, cleaned, and tabulated to prepare them for processing.

Editing involved checking questionnaires and interview transcripts for completeness, errors, and inconsistencies, while coding transformed responses into numerical and thematic categories for analysis. Data were presented using tables, charts, and graphs, supported by descriptive statistics such as frequencies, percentages, means, and standard deviations. These techniques were used to summarize socio-demographic characteristics, levels of community engagement, and sustainability indicators across the selected sectors.

Inferential statistics, including Pearson correlation and simple linear regression, were used to examine the relationship between community engagement and natural resource sustainability. The regression model used was $\text{Sustainability} = \beta_0 + \beta_1(\text{Community Engagement}) + \epsilon$, where sustainability represented environmental outcomes such as soil fertility, forest cover, and water availability, while community engagement reflected participation in conservation activities and decision-making processes.

Reliability was ensured using Cronbach's Alpha in SPSS, with values above 0.7 indicating acceptable internal consistency. Validity was confirmed through expert review, pilot testing, and a Content Validity Index (CVI) of at least 0.60. Ethical considerations were strictly followed, including informed consent, confidentiality, and voluntary participation. Key limitations included self-reported data bias, limited access to secondary data, and initial respondent reluctance, which were minimized through triangulation, pilot testing, and engagement with local leaders.

3. Results

3.1. Socio demographic characteristics of respondents

The socio-demographic characteristics of respondents in Nyaruguru District present a diverse and multidimensional profile that significantly shapes community engagement and

natural resource management practices. Understanding attributes such as age, gender, education level, marital status, and years of residence is essential for interpreting how different population groups participate in, perceive, and influence natural resource sustainability initiatives. These characteristics provide critical insights into the social context that underpins community participation, decision-making, and the overall effectiveness of local natural resource management strategies.

Table 3.2. Combined table of the three demographic variables: Gender, Age, Marital status, Education level, and Occupation

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	204	51.5
	Female	192	48.5
	Total	396	100
Age	18–30	42	10.6
	31–45	89	22.5
	46–55	118	29.8
	56–65	83	21.0
	Above 65	64	16.2
	Total	396	100
Marital Status	Single	83	21.0
	Married	243	61.4
	Widowed	62	15.7
	Divorced	8	2.0
	Total	396	100
Education Level	No formal education	99	25.0
	Primary	138	34.8
	Secondary	87	22.0
	Tertiary	72	18.2
	Total	396	100
Occupation	Farming	241	60.9
	Business	81	20.5
	Salaried workers	74	18.6
	Total	396	100

The socio-demographic results show a fairly balanced gender distribution in Nyaruguru District, with males at 51.5% (204) and females at 48.5% (192), ensuring representative perspectives. Most respondents are within economically active ages, particularly 46–55 years (29.8%), followed by 31–45 years (22.5%) and 56–65 years (21.0%), indicating a population with strong experience in agriculture and natural resource management.

In terms of marital status, most respondents are married (61.4%), suggesting strong household responsibility influencing resource use decisions. Education levels are generally low, with 34.8% having primary education and 25.0% having no formal education, which may affect awareness of sustainable practices.

Occupation results show that farming dominates (60.9%), followed by business (20.5%) and salaried work (18.6%). This highlights high dependence on natural resources for

livelihoods, emphasizing the importance of sustainable environmental management to support community well-being and agricultural productivity.

3.2. Community Engagement in Natural Resource Management

This section presents the findings on community engagement in natural resource management in Nyaruguru District. Community engagement is a critical component of sustainable environmental management, as it determines the extent to which local people actively participate in the planning, implementation, and monitoring of conservation activities. Understanding the role of engagement provides insight into how effectively communities contribute to the protection and sustainable use of natural resources.

3.2.1. Participation in Activities

Table 3.3. Participation in Activities

Statement	Mean	Std. Dev
Tree planting participation through community engagement(Umuganda)	4.21	0.73
Attend community meetings	4.08	0.76
Soil & water conservation	4.15	0.70
Biodiversity initiatives	4.02	0.78

The results indicate that community members in Nyaruguru District are actively engaged in environmental initiatives, reflecting strong support for sustainable natural resource management. Tree planting participation recorded the highest mean ($M = 4.21$, $SD = 0.73$), showing widespread and consistent involvement driven by national reforestation efforts and benefits such as soil protection and fuelwood supply. Soil and water conservation practices ($M = 4.15$, $SD = 0.70$) also indicate strong and uniform engagement, reflecting the community’s reliance on agriculture and awareness of erosion control.

Attendance at community meetings ($M = 4.08$, $SD = 0.76$) shows active participation in decision-making and environmental planning processes, suggesting effective local governance and information sharing. Biodiversity initiatives ($M = 4.02$, $SD = 0.78$), although still positive, recorded the lowest mean, indicating relatively lower prioritization and varying levels of awareness compared to other activities.

Qualitative findings confirm strong involvement in umuganda, tree planting, and terracing. Key informants emphasized that community participation is driven by environmental education and government programs. Field observations in sectors such as Muganza and Kibehe further validated the quantitative results, showing visible terraces, agroforestry systems, and reforestation efforts across the district.

3.2.2. Awareness and Education

Table 4.4. Awareness and Education

Statement	Mean	Std. Dev
Awareness of conservation importance	4.45	0.62
Environmental education improved knowledge	4.32	0.65
Understanding consequences of misuse	4.28	0.68
Awareness programs encourage sustainability	4.36	0.64

The results on awareness and education in Nyaruguru District indicate a very high level of environmental consciousness among respondents, with all mean scores above 4.0. Awareness of conservation importance recorded the highest mean ($M = 4.45$, $SD = 0.62$), showing strong and widely shared understanding of the need to protect natural resources. Awareness programs encouraging sustainability ($M = 4.36$, $SD = 0.64$) also scored highly, suggesting that environmental campaigns effectively motivate sustainable behaviors.

Environmental education improving knowledge ($M = 4.32$, $SD = 0.65$) confirms that training and sensitization activities have significantly enhanced community understanding of environmental issues. Understanding consequences of misuse ($M = 4.28$, $SD = 0.68$) remains strong, though slightly lower, indicating minor variations in depth of awareness about environmental degradation.

Qualitative findings support these results, with key informants emphasizing the role of environmental campaigns, school programs, and community training in improving knowledge and attitudes toward conservation. Field observations also confirmed the presence of awareness materials such as posters and community notices reinforcing environmental messages. Therefore, the findings suggest that environmental education initiatives are effectively strengthening awareness and supporting sustainable natural resource management practices in the district.

3.2.3. Decision-Making Involvement

Table 3.5. Decision-Making Involvement

Statement	Mean	Std. Dev
Participation in decision-making	3.74	0.82
Community opinions considered	3.89	0.79
Empowerment to influence policy	3.65	0.85
Governance supports participation	3.92	0.77

The results on decision-making involvement in Nyaruguru District reveal a more moderate level of community engagement compared to awareness and participation activities. Participation in decision-making ($M = 3.74$, $SD = 0.82$) indicates that respondents are involved in environmental forums, but their role is often limited in depth and influence. Community opinions considered ($M = 3.89$, $SD = 0.79$) shows that views are sometimes acknowledged, though not consistently integrated into final decisions.

Empowerment to influence policy recorded the lowest mean ($M = 3.65$, $SD = 0.85$), highlighting a significant gap in real decision-making power and suggesting unequal access to influence environmental policies. Governance supports participation ($M = 3.92$, $SD = 0.77$) is relatively higher, indicating that institutional frameworks generally encourage participation, even if this does not always translate into meaningful authority.

Qualitative findings from key informants confirm this gap, showing that while communities are consulted in environmental matters, their input often has limited impact on final decisions. Therefore, the results suggest a clear distinction between participation and empowerment, where involvement exists but does not always lead to shared decision-making power in environmental governance.

3.2.4. Community-Led Practices and Collaboration

Table 3.6. Community-Led Practices and Collaboration

Statement	Mean	Std. Dev
Community initiatives	4.18	0.72
Collaboration with NGOs/government	4.25	0.69
Practices improve sustainability	4.22	0.71
Stakeholder collaboration effectiveness	4.27	0.68

The findings on community-led practices and collaboration in Nyaruguru District show a highly positive and coordinated approach to environmental management, with all mean scores above 4.0. Stakeholder collaboration effectiveness (M = 4.27, SD = 0.68) recorded the highest score, indicating strong and consistent partnerships between communities, government institutions, and NGOs. Collaboration with NGOs/government (M = 4.25, SD = 0.69) further confirms that external actors provide valuable technical, financial, and policy support, with broad accessibility across respondents.

Practices improve sustainability (M = 4.22, SD = 0.71) shows strong agreement that community-led initiatives produce tangible environmental benefits such as improved soil, water management, and ecosystem health. Community initiatives (M = 4.18, SD = 0.72) also indicate active local engagement, reflecting strong ownership and responsibility in environmental management.

Qualitative findings support these results, with key informants emphasizing that partnerships enhance implementation capacity and sustainability outcomes. Field observations further confirmed joint environmental activities involving communities, NGOs, and government institutions, demonstrating practical collaboration on the ground. Overall, the findings suggest that effective multi-stakeholder collaboration plays a key role in strengthening sustainable natural resource management in the district.

3.3. Status of Natural Resource Sustainability

This section presents the findings on the status of natural resource sustainability in Nyaruguru District. Assessing sustainability involves evaluating how well forest resources, water resources, soil, and biodiversity are conserved, maintained, and managed to ensure long-term ecological balance and livelihood support. It provides a measure of the effectiveness of community engagement and other interventions in promoting environmentally sustainable practices.

3.3.1. Forest Resource Sustainability

Table 3.7. Forest Resource Sustainability

Statement	Mean	Std. Dev
Forest cover maintained	4.11	0.74
Reforestation improved health	4.20	0.71
Reduced deforestation	4.05	0.76

The results on forest resource sustainability in Nyaruguru District show a generally positive trend, with all indicators scoring above 4.0, reflecting effective community-based forest

management. Reforestation improved forest health ($M = 4.20$, $SD = 0.71$) was the highest-rated indicator, suggesting strong perceptions of improved forest conditions such as increased tree cover, biodiversity, and soil stability. Forest cover maintained ($M = 4.11$, $SD = 0.74$) also indicates that existing forests are being preserved through conservation and community stewardship. Reduced deforestation ($M = 4.05$, $SD = 0.76$), though slightly lower, still reflects a perceived decline in forest loss, with some variation across communities.

Qualitative findings confirm that improvements are driven by reforestation programs, enforcement measures, and community participation in forest protection activities. Key informants highlighted the role of government-led initiatives and local engagement in restoring degraded forest areas.

Documentary evidence further supports these findings, showing increased forest cover due to reforestation and afforestation programs, as well as widespread adoption of agroforestry systems. These practices have improved soil fertility, biodiversity, and climate resilience. However, reports also indicate that deforestation persists in some areas due to agricultural expansion and population pressure, suggesting the need for continued conservation efforts (FAO, 2020).

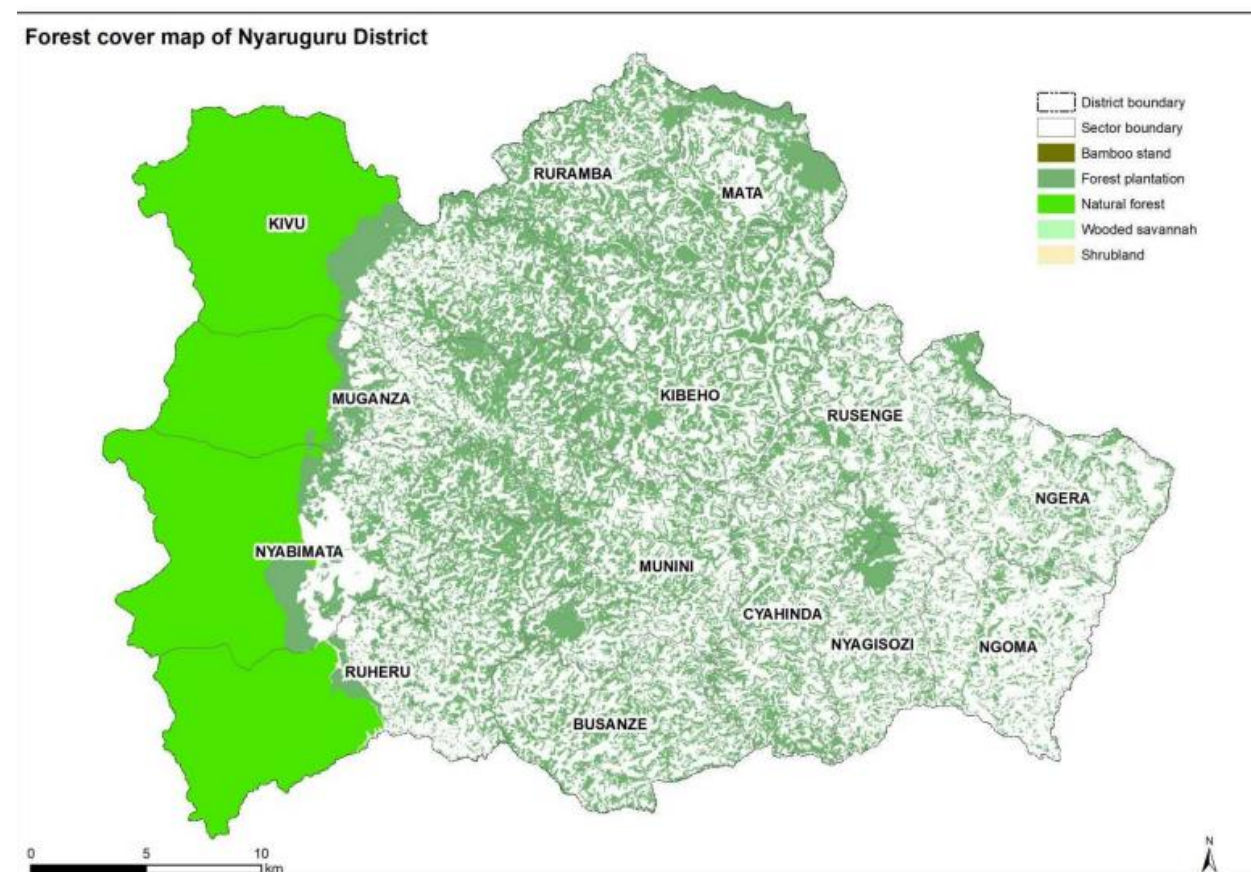


Figure 3.1. Forest cover map of Nyaruguru District

Source: (Global Land Analysis and Discovery, 2025).

Nyaruguru District's forests span 54,018 hectares, or roughly 55% of the district's total land area. Of these, 33,957 hectares are forest plantations, accounting for 62.8% of the district's total forests, while 21,801 hectares are Nyungwe National Park's wild forests, accounting for 40.3% of the district's total forests. Ngoma, with 965 ha (21% of the sector land), is the least forested sector. In terms of forest density as a production indicator, Figure 88 illustrates that Nyaruguru District has a mix of medium to high density (40–70% and above) forests, with the exception of certain sectors like Ngoma, Ngera, Nyagisozi, and Rusenge, where low to medium (10–40%) dominates other density classes. In order to increase the productivity of the current forests, it is advised that the Nyaruguru District Forest Management Plan (DFMP) give priority to the establishment of concessions for the forestry industry while reforesting the Ngoma, Ngera, Nyagisozi, and Rusenge sectors. Plots larger than two hectares make up 28,357 hectares, or 84% of the district's total forest plantings. Other sectors typically have large-scale forest plantations of more than two hectares per forest plot, with the exception of Ngera and Ngoma, which have smaller regions with large-scale plots (983ha for Ngera and 504ha for Ngoma).

Kibeho has 3,584 ha (95% of all sector forest plantations), followed by Mata with 3,003 ha (94% of all sector forest plantations), Nyabimata with 2,486 ha (88%), Kivu with 2,360 ha (82% of all sector forest plantations), Ruramba with 2,243 ha (88% of all sector forest plantations), and Ruhuru with 2,212 ha (80% of all sector forest plantations). The Ruhuru, Nyabimata, and Muganza sectors' high rate of afforestation is mostly due to the Nyungwe buffer zone plantations (Ministry of Environment, 2025).

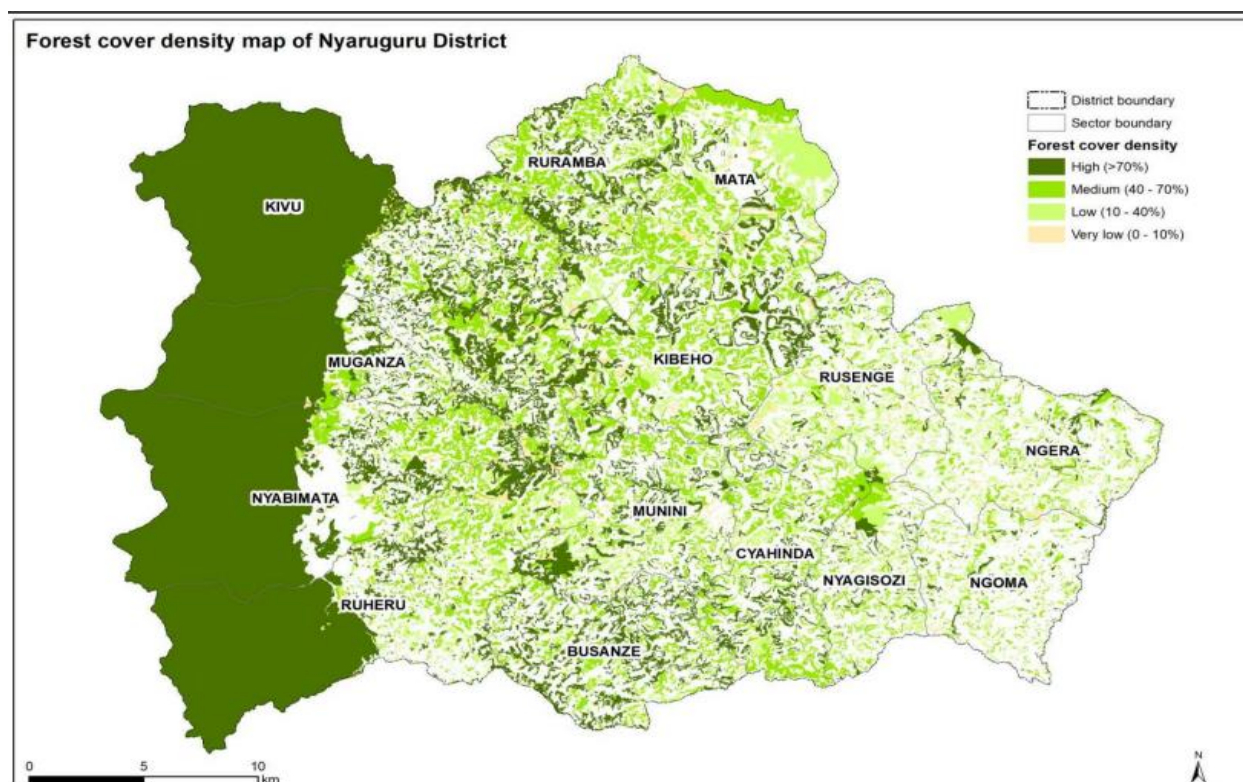


Figure 4.2. Forest cover density map of Nyaruguru District

Source: (Global Land Analysis and Discovery, 2025)

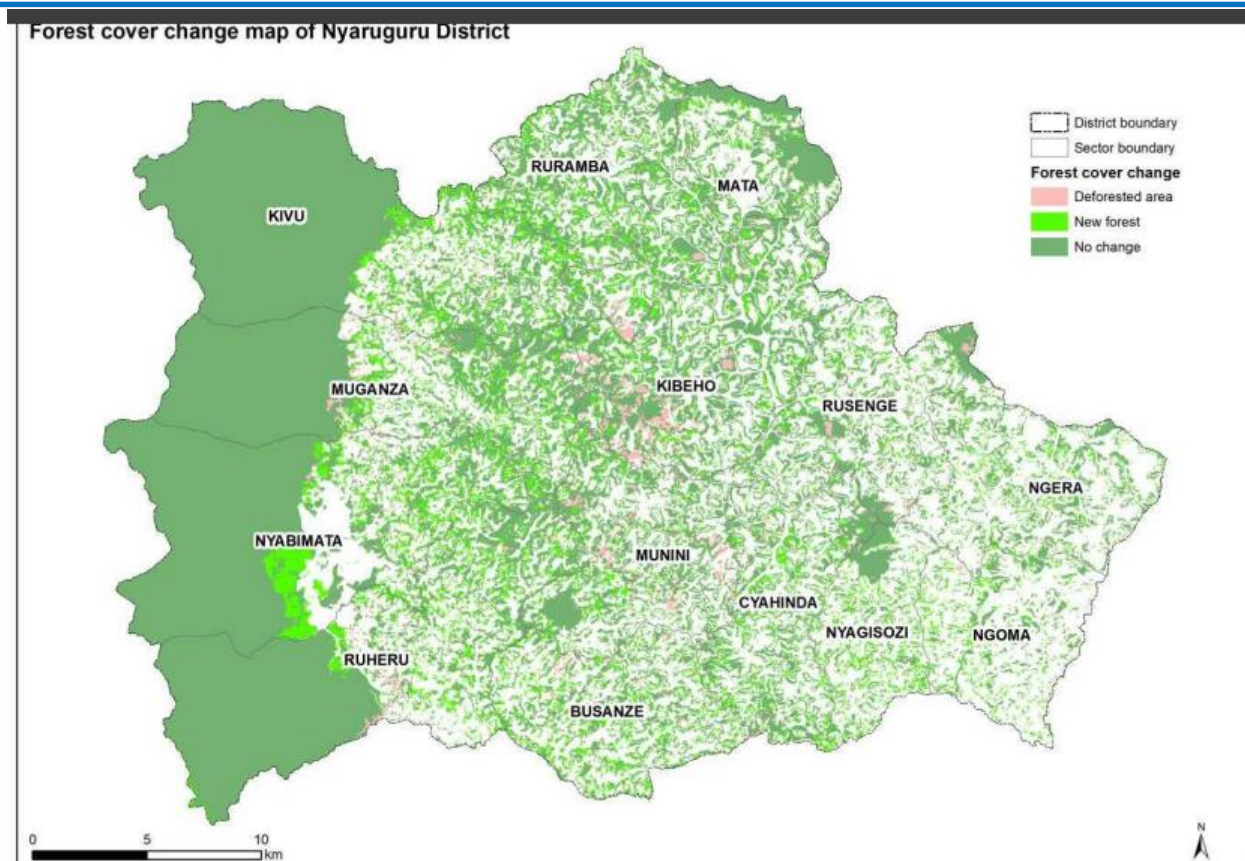


Figure 4.3. Forest cover change map of Nyaruguru District

Figure 4.3 shows how the forest cover in Nyaruguru District has changed during the past ten years. The findings indicate that throughout a ten-year period, afforestation was roughly 20.3% and deforestation was 6.3%. The Ngoma sector's 72% afforestation against 13.7% deforestation, Nyagisozi sector's 59.8% afforestation against 8.3% deforestation, and Busanze sector's 54.2% afforestation against 12% deforestation from 2016 are all quite impressive. With a 14% increase in forest cover during the last ten years nearly 1.4% of Nyamagabe district's annual forest gain the overall trend is encouraging (Global Land Analysis and Discovery, 2025).

3.3.2. Biodiversity Conservation

Table 3.8. Biodiversity Conservation

Statement	Mean	Std. Dev
Biodiversity preserved	3.98	0.81
Reduced biodiversity threats	4.06	0.78
Awareness of endangered species	3.85	0.84

The results indicate a moderately positive performance in biodiversity conservation in Nyaruguru District, with mean scores ranging from 3.85 to 4.06. Reduced biodiversity threats (M = 4.06, SD = 0.78) were the highest-rated indicator, suggesting perceived progress in limiting habitat destruction and overexploitation, although responses varied across communities. Biodiversity preserved (M = 3.98, SD = 0.81) shows only moderate confidence in conservation outcomes, indicating that existing efforts are not strongly visible or widely felt. Awareness of endangered species (M = 3.85, SD = 0.84) recorded

the lowest score, highlighting significant knowledge gaps and uneven awareness among respondents.

Qualitative findings confirm that biodiversity conservation receives less attention compared to soil and water conservation. Key informants noted that communities prioritize activities with immediate livelihood benefits, such as farming and tree planting, while biodiversity protection is less emphasized. Environmental education largely focuses on general conservation rather than species-specific awareness, contributing to limited knowledge of endangered species.

Field observations showed few direct biodiversity conservation initiatives, such as wildlife protection programs or habitat monitoring. Instead, biodiversity protection occurs indirectly through agroforestry and reforestation. Overall, the findings suggest that biodiversity conservation remains underdeveloped and requires stronger awareness, targeted interventions, and community engagement.

3.3.3. Water Resource Management

Table 3.9. Water Resource Management

Statement	Mean	Std. Dev
Water sources protected	4.14	0.73
Reduced water pollution	4.09	0.75
Water conservation practiced	4.18	0.70

The results show strong water resource management in Nyaruguru District, with all indicators scoring above 4.0, indicating high community involvement and effectiveness. Water conservation practiced ($M = 4.18$, $SD = 0.70$) was highest, showing consistent behaviors such as efficient water use and catchment protection. Water sources protected ($M = 4.14$, $SD = 0.73$) reflects strong efforts in safeguarding rivers, springs, and wetlands through buffer zones and reforestation. Reduced water pollution ($M = 4.09$, $SD = 0.75$) was slightly lower, suggesting some inconsistencies in pollution control across locations.

Qualitative findings confirm that watershed management programs, including riverbank protection and catchment rehabilitation, have improved sustainability. Community participation through Umuganda supports cleaning water channels and planting vegetation. Local bylaws further regulate activities near water sources to reduce contamination.

Field observations in Nyabimata and Rusenge confirmed buffer zones, terraces, and agroforestry near water catchments. However, challenges such as sanitation gaps, population pressure, and infrastructure limitations still affect water quality. Overall, improvements are evident, but continued investment and awareness are needed (Ministry of Environment, 2021).

3.3.4. Soil Conservation

Table 3.10. Soil Conservation

Statement	Mean	Std. Dev
Reduced soil erosion	4.23	0.69
Terracing practiced	4.30	0.66
Improved soil fertility	4.19	0.71

The findings indicate strong soil conservation practices in Nyaruguru District, with all indicators scoring above 4.0, showing high adoption and effectiveness. Terracing recorded the highest mean ($M = 4.30$), followed by reduced soil erosion ($M = 4.23$) and improved soil fertility ($M = 4.19$), confirming visible environmental and agricultural benefits. Qualitative results support these findings, with key informants emphasizing terracing and agroforestry as key strategies supported by government and partners. These practices improve soil fertility, moisture retention, and provide additional resources such as fuelwood. Field observations confirmed widespread use of contour farming, mulching, intercropping, and composting, especially in hilly areas like Muganza, Nyagisozi, and Busanze. Overall, integrated soil management has reduced erosion, improved productivity, and strengthened food security, consistent with earlier evidence on sustainable land management practices (MINAGRI, 2018).

3.4. Relationship between Community Engagement and Sustainability of natural resources

This section examines how community engagement influences the sustainability of natural resources in Nyaruguru District. Understanding this relationship is crucial because local communities are both custodians and primary users of resources such as forests, water, soil, and biodiversity. Their participation, awareness, collaboration, and decision-making involvement play a pivotal role in determining the effectiveness of conservation and sustainable management initiatives.

3.4.1. Regression Results for Community Engagement and Individual Sustainability Outcome Variables

Regression analyses conducted in Nyaruguru District demonstrated a strong positive and statistically significant relationship between community engagement and different dimensions of natural resource sustainability.

Table 3.11. Regression Results for Community Engagement and Individual Sustainability Outcome Variables

Dependent Variable	R	R ²	Adj. R ²	P-value	Std. Beta (β)	Unstd. B	Significance	Interpretation
Forest Resource Sustainability	0.66	0.44	0.43	< 0.001	0.59	0.60	Significant	Strong and statistically significant positive effect; community engagement explains 44% of the variation in forest sustainability outcomes.
Biodiversity Conservation	0.63	0.40	0.39	< 0.001	0.56	0.57	Significant	Significant positive relationship; increased community engagement contributes meaningfully to biodiversity conservation.
Water Resource Management	0.67	0.45	0.44	< 0.001	0.60	0.62	Significant	Strong positive and statistically significant effect; community engagement enhances water resource management practices.
Soil Conservation	0.70	0.49	0.48	< 0.001	0.64	0.65	Significant	Very strong positive effect; community engagement explains 49% of the variance in soil conservation outcomes.

The regression results in Table 4.2 demonstrate that community engagement has a consistently strong and statistically significant positive effect on various natural resource sustainability outcomes in Nyaruguru District. Specifically, the analysis shows that community engagement explains 44% of the variation in forest resource sustainability ($R^2 = 0.44$), indicating that higher levels of participation, awareness, collaboration, and community-led initiatives are closely associated with improved forest management practices. Similarly, biodiversity conservation is positively influenced by community engagement, with an R^2 of 0.40, suggesting that active involvement of local communities contributes meaningfully to preserving species diversity and ecological balance.

Water resource management also benefits from community engagement, with an R^2 of 0.45, reflecting that community-led initiatives such as watershed protection, sustainable water usage, and local monitoring significantly enhance the management and conservation of water resources. Among all the sustainability outcomes, soil conservation exhibits the strongest relationship with community engagement, with an R^2 of 0.49. This indicates that nearly half of the variation in soil conservation practices can be attributed to community participation, aligning with earlier descriptive findings where soil protection measures, such as terracing and erosion control, were reported as the most widely adopted strategies.

3.4.2. The figure presents a graphical illustration of the relationship between community engagement and sustainability outcomes.

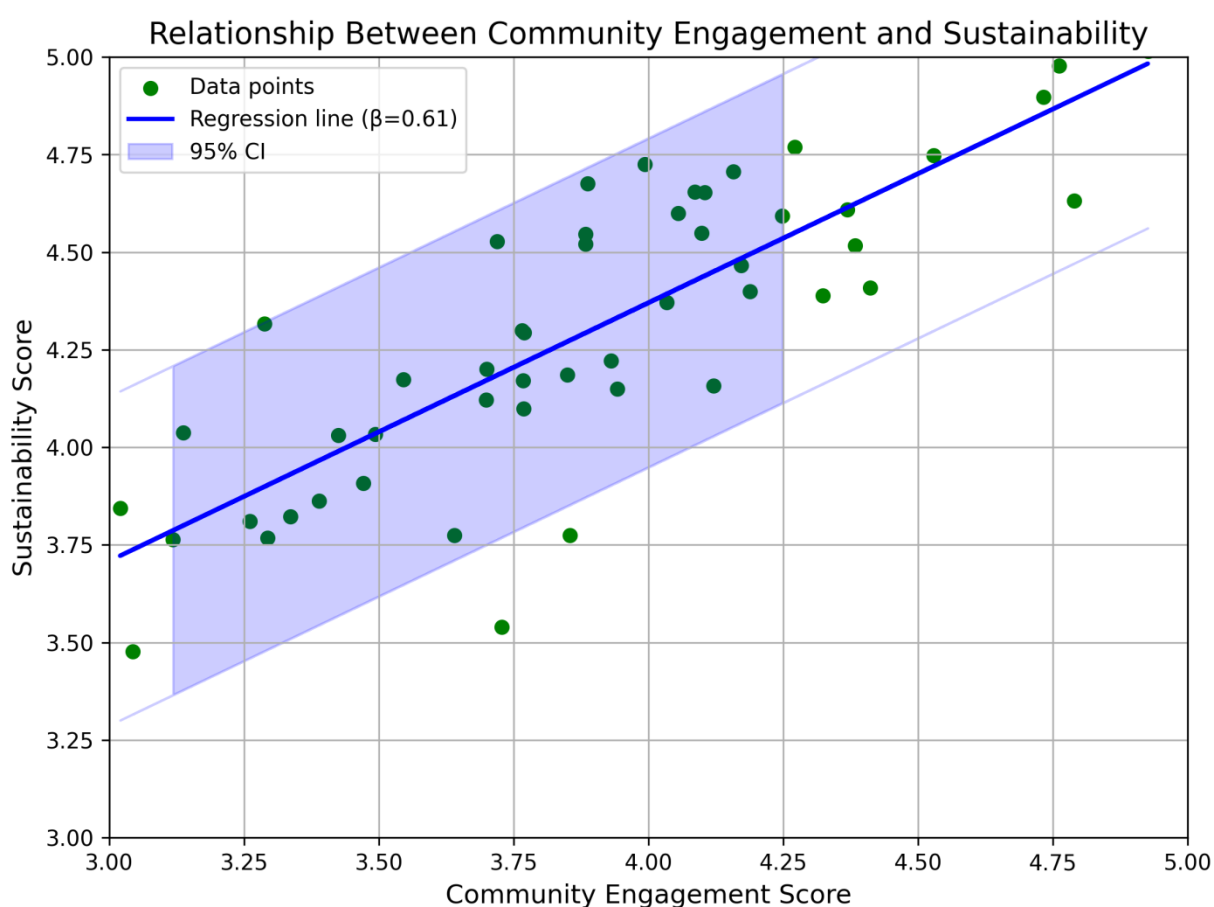


Figure 3.4. Relationship between Community Engagement and Sustainability

The scatter points represent individual respondents' scores on community engagement and sustainability, showing the distribution and pattern of the data. The general upward trend of the points indicates a positive association between the two variables.

The regression line ($\beta = 0.61$) demonstrates the direction and strength of this relationship. The upward slope of the line confirms that increases in community engagement are associated with increases in sustainability outcomes, supporting the results obtained from the regression analysis.

The shaded area surrounding the regression line represents the 95% confidence interval, based on a two-tailed test at $\alpha = 0.05$. This interval indicates the range within which the true population regression line is expected to lie with 95% confidence. The relatively narrow band suggests that the estimates are precise and reliable, with limited variability around the predicted relationship.

3.4.3. ANOVA TABLE

Table 3.12. ANOVA TABLE

Source of variation	Sum of squares (SS)	Df	Mean square (MS)	F	Sig. (p-value)
Between Groups	12.45	2	6.225	45.32	0.000**
Within Groups	53.98	393	0.137		
Total	66.43	395			

The ANOVA results show a statistically significant difference in sustainability outcomes in Nyaruguru District, $F(2, 393) = 45.32$, $p < 0.05$. Since the p-value is below 0.05, the null hypothesis is rejected, confirming that community engagement significantly influences environmental sustainability outcomes. The large F-value indicates that differences between group means are much greater than within-group variation, meaning sustainability outcomes are strongly associated with levels of community engagement.

The results further show that between-group variation ($SS = 12.45$) is higher than expected random variation, confirming a meaningful relationship. Respondents with higher engagement in activities such as Umuganda, reforestation, environmental meetings, and resource monitoring report better outcomes in forest, soil, water, and biodiversity conservation compared to those with lower engagement. Overall, the findings demonstrate that strengthening community engagement improves sustainability through enhanced participation, compliance, and stewardship of natural resources.

3.8. Discussion

The study reveals high community engagement in natural resource management in Nyaruguru District, particularly in tree planting, soil and water conservation, and participation in Umuganda and community meetings. Strong environmental awareness and education indicate effective conservation programs and government support promoting sustainable practices. However, despite high participation, decision-making involvement remains limited, suggesting that community members are often consulted but have minimal influence over final decisions, resulting in weak empowerment.

Soil conservation is the strongest sustainability outcome, followed by water and forest resource management. Practices such as terracing, agroforestry, and reforestation have improved soil fertility, reduced erosion, increased agricultural productivity, and enhanced food security. Water management is also strong, although challenges such as seasonal shortages and localized pollution persist. Forest sustainability has improved through reforestation, with increased forest cover, though deforestation from agricultural expansion

remains a concern.

However, biodiversity conservation is the weakest area due to low awareness, limited targeted interventions, and reduced community prioritization. Overall, while community participation significantly enhances sustainability outcomes, the study highlights the need to strengthen decision-making empowerment, biodiversity protection, and integration of livelihood needs with environmental conservation.

4. Conclusion

The study concludes that community participation plays a crucial role in promoting sustainable natural resource management in Nyaruguru District. Activities such as Umuganda, tree planting, reforestation, agroforestry, and soil conservation are widely practiced, reflecting strong collective responsibility. These community-based initiatives have significantly improved forest cover, water protection, soil fertility, and sustainable agricultural practices, demonstrating the practical value of local engagement in environmental management.

Statistical results from correlation and regression analyses confirm a strong positive relationship between community engagement and sustainability outcomes. Increased participation enhances resource availability, biodiversity conservation, ecosystem productivity, and adoption of sustainable practices, while reducing environmental degradation. However, participation in decision-making and monitoring remains limited, indicating gaps in inclusive governance and empowerment.

Therefore, the study concludes that although community-based initiatives have greatly advanced environmental sustainability, long-term success requires stronger institutional support, inclusive decision-making, and continuous environmental education to ensure equitable and lasting benefits.

5. References

- Abayomi, O., Emmanuel, O. T., & Ogungbade, T. (2021). Environmental pollution and its ecological consequences on the Niger delta: A review of the literature. *African Journal of Environment and Natural Science Research*, 4 (4), 27-42.
- Abram, N. K., Meijaard, E., Wilson, K. A., Davis, J. T., Wells, J. A., Ancrenaz, M., et al. (2017). Oil palm community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives. *Applied Geography*, 33~44.
- Bizimana, P. J., & Hategekimana, S. (2024). Ecosystem Services and Land Degradation in Gishwati-Mukura Corridor, Rwanda: Cost-Benefit of Sustainable Land Management Practices. *Rwanda Journal of Engineering, Science, Technology and Environment*, 6 (1).
- Dockendorf, C., Fuss, S., Agra, R., Guye, V., Herrera, D., & Kraxner, F. (2022). Committed to restoring tropical forests: an overview of Brazil's and Indonesia's restoration targets and policies. *Environmental research*, 17 093002.
- Ezeaku, P. I., & Alaci, D. (2008). Analytical Situations of Land Degradation and Sustainable Management Strategies in Africa. *Journal of agriculture and social sciences*, 42–52.
- FAO. (2016). *Climate Change and Food Security: Risks and Responses*. ROME: FAO.
<https://doi.org/10.53819/81018102t2562>

- FAO. (2025). *Addressing Land Degradation for a Sustainable Future*. FAO.
- Gomiero, T. (2016). Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge. *Sustainability*, 8(3), 281.
- Michael, L. N. (2020). Food and Nutrition Security in East Africa (Kenya, Uganda and Tanzania): Status, Challenges and Prospects. (B. Mahmoud, Ed.) *Environmental Sciences and Human Health*.
- Mondal, S., & Palit, D. (2022). Challenges in natural resource management for ecological sustainability. *Natural resource conservation and advances for sustainability*, 29~59.
- REMA. (2019). *State of Environment Report 2019*. Kigali, Rwanda.
- Tian, Q., & Lemos, C. M. (2018). Household Livelihood Differentiation and Vulnerability to Climate Hazards in Rural China. *World Development*.