

Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

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ABSTRACT: This study examines how agroforestry technology strategies influence sustainable rural development in Rwanda, focusing on farmer cooperatives in Muhanga District. Rwanda faces severe land pressure and soil erosion, making agroforestry a vital solution for improving soil and farmer livelihoods. This research specifically looks at how tree species selection, soil and water conservation practices, and cooperative training services affect rural development. The study was guided by the Land Equivalent Ratio (LER) Theory and the Sustainable Livelihood Framework (SLF). The research used a descriptive design with both quantitative and qualitative methods. The target population consisted of members from the KIABR cooperative (Koperative Imparaniramusaruro y'Abahinzi-Borozi ba Rugeramigozi). Out of this population, a sample size of 255 farmers was selected using simple random sampling for the questionnaires, while purposive sampling was used to choose cooperative leaders for interviews. To ensure the quality of the data collection tools, a pilot study was conducted with a small group of farmers outside the final sample. For the quantitative data, validity was checked through expert review, and reliability was confirmed using a Cronbach's alpha test. For the qualitative data, credibility and dependability were achieved through member checking and keeping a clear audit trail of the interview transcripts.

Data were collected using questionnaires and semi-structured interviews, and analyzed using SPSS for quantitative data and thematic analysis for qualitative data. The findings showed that all agroforestry models had a strong positive effect on rural development, with Beta values ranging from .842 to .910. The R^2 values ranged from .709 to .828, showing that these agroforestry strategies explain a large part of the improvements in rural development. Soil and water conservation practices were the strongest predictor of positive livelihoods. Based on these findings, it is recommended that the Rwanda Cooperative Agency (RCA) and other agricultural institutions should strengthen cooperative training programs so farmers can access modern farming technologies. Additionally, KIABR and other cooperatives should encourage farmers to diversify their tree species to balance soil health with market value.

KEYWORDS: Agroforestry, agroforestry technological strategies, agroforestry tree species, agroforestry technological practices, agroforestry system strategies, sustainable rural development.

INTRODUCTION

This paper aims to analyze the influence of agroforestry technological strategies related to sustainable rural development. The previous research studies, such as those conducted by Umuhoza et al. (2023), about evaluating ecosystem-based adaptation approaches under the LDCF-II project in Eastern Rwanda, the major intent was to analyze the effectiveness of hedgerow agroforestry systems for landscape restoration and sustainable livelihoods. The results showed that farmers widely adopted hedgerow planting along field boundaries to restore degraded land and access fuelwood. However, challenges such as termite infestations and drought stress limited tree survival in some areas. The authors recommended increased access to drought-tolerant tree seedlings, technical training, and better pest management strategies. The similarity with the current project is the focus on agroforestry technologies adopted at the household level, while the difference lies in the emphasis on hedgerow systems for ecosystem restoration.

In Urayeneza's study (2024), about understanding the factors influencing smallholder farmers' willingness to adopt agroforestry in Gomba Village, Rwanda, the main objective was to assess the factors influencing smallholder farmers' willingness to adopt agroforestry in Gomba Village, Rwanda. It demonstrated that 85% of households had fruit trees, with *Persea americana* (74%), *Carica papaya* (65%), and *Mangifera indica* (56%) being the most popular species. The authors recommended improving input access, strengthening extension services, and providing agroforestry adoption incentives. The similarity with the current project is the focus on tree species integrated with crops, while the difference lies in the specific community studied.

Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

The previous study by Mukundente (2019), about agroforestry practices implemented by small-scale farmers in Rwanda's Southern Province. the main objective was to examine agroforestry techniques employed by small-scale farmers in Rwanda's Southern Province. The results showed that 68% of farmers practiced boundary planting, kitchen gardens as shown by 14%, alley cropping as shown by 11%, and scattered trees on farms as shown by 7%. The authors recommended promoting awareness and training programs to enhance adoption. The similarity with the current project is the focus on agroforestry practices, while the difference is the regional focus on the Southern Province.

In a recent study by Kiyani et al. (2017) on the benefits and challenges associated with agroforestry adoption, the main objective was to examine. The advantages and obstacles associated with adopting agroforestry in Musebeya Sector, Nyamagabe District. The results played a role in increased income, improved soil fertility, and reduced deforestation. The authors recommended providing subsidies, training, and quality seeds to enhance adoption. The similarity with the current project is the focus on agroforestry systems, while the difference is the specific location studied.

In a study conducted by Gahutu and Nahayo (2020), on Impact Assessment of Agroforestry Practices on Community Socio-Economic Livelihoods in Rwanda. The results showed that agroforestry practitioners (AFP) had a significantly higher mean annual income (0.49 million Rfw) compared to non-agroforestry practitioners (NAFP) (0.40 million Rfw). Additionally, AFP households saved an average of 480 minutes per week on firewood collection and reduced their weekly expenditure on firewood by 2,000 Rfw compared to NAFP households. The authors recommended promoting agroforestry practices to enhance rural livelihoods and reduce environmental degradation. The similarity with the current project is the focus on evaluating the socio-economic benefits of agroforestry, while the difference lies in the specific geographical area studied.

The project objectives were structured to analyze the impact of agroforestry technological strategies related to sustainable rural development. Specifically, the study aimed to: (i) to identify the agroforestry technological strategies adopted by farmers on sustainable rural development, (ii) to ascertain the influence of agroforestry tree species selection strategies on sustainable rural development, (iii) to evaluate the effects of agroforestry technological practices on sustainable rural development, (iv) to analyse the contribution of agroforestry system strategies on sustainable rural development.

The interest of this scientific study was that the researcher expected to gain more information about the functioning of farmers in using agroforestry technological strategies. To the researcher, the study was very important since it helped in improving his knowledge in carrying out scientific research. The MKU may use the copy of the book as the added body of knowledge. The results from this research helped the decision makers, institutions related to agroforestry programs.

MATERIALS AND METHODS

For the methodological details, this study employed a descriptive research design and a mixed-methods approach was employed, combining both quantitative and qualitative techniques. The study was conducted at KIABR farmers' cooperative is located in the Rugeramigozi Marshland, within Nyamabuye Sector, Muhanga District, in the Southern Province of Rwanda. The target population of the study consisted of smallholder farmers who are registered members of the KIABR Farmers' Cooperative, located in Rugeramigozi Marshland. As of 2024, the cooperative has 852 active members (10). For sampling, a sample size of 255 farmers was randomly selected from a total number of 852 farmers. In conducting this research, a purposive random sampling approach was employed. The KIABR Cooperative, which comprises 852 farmers, served as the basis for participant selection". Stratified sampling was appropriate to ensure fair representation across the groups. Also, multiple tools were utilized to gather information related to the research topic including documentation, questionnaires, and interviews were used as practical means of data collection (11). For data analysis, Statistical Package for the Social Sciences (SPSS) version 21.0 was utilized for data entry and analysis and the Pearson correlation coefficient (r) was calculated to assess the relationship between variables, employing a simplified method (12).

RESULTS

Table 1: Agroforestry technology strategies used by farmers in their activities

Strategy	SA	A	N	D	SD	Total	Mean	SD
Precision agriculture (sensors, GPS)	95	120	20	10	5	250	4.16	0.78
Digital mapping and monitoring tools (GIS map)	90	115	25	15	5	250	4.10	0.81
Data analytics (recording/analyzing from data)	100	115	20	10	5	250	4.20	0.76
Alley cropping	130	100	15	5	0	250	4.42	0.65
Home gardens	140	95	10	5	0	250	4.48	0.62

Source: Primary data, (2026)

Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

Table 2: Correlation between agroforestry technological strategies and sustainable rural development

			Agroforestry technological strategies	Sustainable rural Development
Agroforestry strategies	technological	Pearson Correlation	1	
		Sig. (2-tailed)		
		N	250	
Sustainable development	rural	Pearson Correlation	.865**	1
		Sig. (2-tailed)	.000	
		N	250	250

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

Source: Primary data (2026)

Table 3: Agroforestry tree species selection strategies

Strategy	SA	A	N	D	SD	Total	Mean	SD
Valid	Soil fertility improvement							
	120	100	20	5	5	250	4.32	0.72
	Multipurpose benefits (fuelwood, fruits, etc...)							
	130	95	15	5	5	250	4.38	0.70
	Low-maintenance, pest/disease resistance							
	115	105	20	5	5	250	4.30	0.73
	Market value/high demand							
	125	100	15	5	5	250	4.34	0.71
	Long-term environmental conservation							
	120	105	15	5	5	250	4.32	0.72
Cooperative advice/training								
	110	110	20	5	5	250	4.28	0.74

Source: Primary data (2026)

Table 4: Correlations between influence of agroforestry tree species selection strategies and sustainable rural development

			Tree selection strategies	Sustainable rural Development
Tree species selection strategies		Pearson Correlation	1	
		Sig. (2-tailed)		
		N	250	
Sustainable development	rural	Pearson Correlation	.842**	1
		Sig. (2-tailed)	.000	
		N	250	250

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

Source: Primary data (2026)

Table 5: Agroforestry technological practices

Practice	SA	A	N	D	SD	Total	Mean	SD
Valid	Alley cropping							
	125	105	15	0	5	250	4.40	0.66
	Scattered trees							
	120	105	20	0	5	250	4.38	0.67
	Home gardens							
	135	100	10	0	5	250	4.48	0.62
	Boundary planting							
	115	110	20	0	5	250	4.34	0.70
	Riparian buffers							
	110	115	25	0	5	250	4.30	0.72
Windbreak/shelterbelts								
	105	110	30	0	5	250	4.26	0.74

Source: Primary data (2026)

Table 6: Correlations between effects of agroforestry technological practices and sustainable rural development

			Effects of agroforestry practices	Sustainable rural Development
Effects of agroforestry practices		Pearson Correlation	1	
		Sig. (2-tailed)		
		N	250	
		Pearson Correlation	.910**	1

Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

Sustainable development	rural	Sig. (2-tailed)	.000	
		N	250	250

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

Source: Primary data (2026)

Table 7: Agroforestry systems strategies

System	SA	A	N	D	SD	Total	Mean	SD
Agrisilvicultural (trees + crops)	125	110	10	0	5	250	4.44	0.64
Valid Silvopastoral (Trees + livestock)	115	110	20	0	5	250	4.34	0.70
Agrosilvopastoral (trees + crops + livestock)	120	110	15	0	5	250	4.38	0.67

Source: Primary data (2026)

Table 8: Correlations between contribution of agroforestry system strategies and sustainable rural development

			Contribution of agroforestry systems	of Sustainable rural Development
Contribution of Agroforestry systems	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	250		
Sustainable development	Pearson Correlation	.888**		1
	Sig. (2-tailed)	.000		
	N	250		250

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

Source: Primary data (2026)

Table 9: Correlations between agroforestry technological strategies and sustainable rural development

		Agroforestry technological strategies	Tree species selection strategies	Effects of agroforestry practices	Contribution of agroforestry systems	Sustainable rural Development
Agroforestry technological strategies	Pearson Correlation	1				
	Sig. (2-tailed)	.000				
	N	250				
Tree species selection strategies	Pearson Correlation	.812**	1			
	Sig. (2-tailed)	.000	.000			
	N	250	250			
Effects of agroforestry practices	Pearson Correlation	.845**	.838**	1		
	Sig. (2-tailed)	.000	.000	.000		
	N	250	250	250		
Contribution of agroforestry systems	Pearson Correlation	.830**	.820**	.860**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	250	250	250	250	
Sustainable rural Development	Pearson Correlation	.865**	.842**	.910**	.888**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	250	250	250	250	250

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

Source: Primary data (2026)

DISCUSSION AND CONCLUSIONS

In light of the pre-determined objectives of the study, the author interprets data and draw conclusions. The empirical findings from this study show that smallholder farmers within the KIABR Cooperative actively integrate both traditional and modern agroforestry technology strategies to secure their livelihoods. A major revelation in the dataset is that farmers' choices regarding tree species are strongly guided by immediate, practical benefits. Species that promote soil fertility improvement, possess high market value, and

Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

offer multi-purpose uses such as avocado (*Persea americana*) for seasonal nutrition and *Grevillea robusta* for timber and fuelwood received almost universally high agreement scores.

These findings match the observations of Urayeneza (2024), who reported that integrating fruit trees with seasonal crops provides vital food security and swift cash injections for rural families in Rwanda. Furthermore, the strong preference for soil-improving trees like *Calliandra calothyrsus* aligns with the work of Bucagu (2013), who found that leguminous species are essential for repairing degraded soils in smallholder environments.

The study revealed a widespread and highly systematic application of physical agroforestry conservation practices among the cooperative members in the Rugeramigozi Valley. Practices such as alley cropping along hillside terraces and boundary planting stood out as the most dominant systems. The perceived environmental and operational effects of these conservation strategies were overwhelmingly positive. The sampled farmers reported distinct, visible benefits on the ground, including heavily reduced soil erosion on the steep mountain slopes, improved moisture retention in their crop fields, and significantly increased seasonal crop yields. These physical setups also provided a steady supply of local fodder and wood, directly translating into better household food security and lower rural malnutrition rates.

These results strongly support the earlier findings of Mukundente et al. (2021) and Umuhoza et al. (2023), which both emphasized that physical boundary trees and hedgerows act as crucial buffers that mechanically stop topsoil from washing away during heavy downpours in hilly Rwandan landscapes.

The research confirmed that KIABR Cooperative members actively implement diverse integrated farming systems, including Agrisilvicultural (trees and crops), Silvopastoral (trees and livestock), and Agrosilvopastoral (trees, crops, and livestock) systems. Among these, the Agrisilvicultural system was the most dominant, reflecting its perfect suitability for dense marshland and valley farming. The data showed that the cooperative's internal training and extension networks are the primary drivers behind the successful adoption of these complex systems. While structural challenges like high initial costs, land shortages, and occasional seedling scarcity were widely noted by farmers, the inferential correlation and regression analyses confirmed that cooperative-led agroforestry adoption remains a powerful statistically significant cornerstone of sustainable rural development, explaining a major portion of the improvements in household income, asset growth, and community resilience.

This outcome mirrors the economic impacts discovered by Gahutu and Nahayo (2020) and Kiyani et al. (2017), where trained agroforestry adopters in Rwanda consistently earned a significantly higher mean annual income compared to non-adopters who lacked institutional training support. The critical takeaway from this study's discussion is that top-down government extension programs are not the only solution; localized, cooperative-led training networks provide the vital technical skills and peer encouragement that farmers need to overcome financial barriers, ensuring long-term technology adoption and continuous rural development.

Author Note

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Influence of Agroforestry Technology Strategies on Sustainable Rural Development in Rwanda, A Case of Farmer's Cooperatives in Muhanga District

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7.ADDITIONAL MATERIALS

List of Tables

- 1) Table 1 Agroforestry technological strategies used by farmers
- 2) Table 2 Correlation between agroforestry technological strategies and sustainable rural development
- 3) Table 3 Agroforestry tree species selection strategies
- 4) Table 4 Correlations between influence of agroforestry tree species selection strategies and sustainable rural development
- 5) Table 5 Agroforestry technological practices
- 6) Table 6 Correlations between effects of agroforestry technological practices and sustainable development
- 7) Table 7 Agroforestry system strategies
- 8) Table 8 Correlations between system strategies and sustainable rural development
- 9) Table 9 Correlations between agroforestry technological strategies and sustainable rural development



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