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Assessing the Impact of Agroforestry Diversification on Livelihoods in Nyanza District, Rwanda (Period: 2014-2024)

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Abstract: **Agroforestry is increasingly recognized as an effective strategy for promoting environmental sustainability and improving the livelihoods of rural households through income diversification and enhanced resilience. This study assessed the impact of agroforestry diversification on the livelihoods of smallholder farmers in Nyanza District, Rwanda. Specifically, it examined the extent of agroforestry diversification, identified livelihood outcomes among smallholder households, and evaluated the relationship between agroforestry adoption and livelihood improvement. A mixed-methods research design was employed. Quantitative data were collected using structured questionnaires administered to 396 smallholder farmers selected from the sectors of Busasamana, Cyabakamyi, Nyagisozi, and Rwabicuma. Qualitative data were obtained through semi-structured interviews with key informants, including agricultural extension officers and cooperative leaders. Quantitative data were analyzed using descriptive and inferential statistics with SPSS version 20, while qualitative data were analyzed using thematic content analysis. The findings reveal that agroforestry diversification has a significant positive effect on household livelihoods. A strong positive correlation was established between agroforestry diversification and livelihood outcomes ($r = 0.819$, $p < 0.01$), indicating that increased adoption of diversified agroforestry practices is associated with improved household welfare. Respondents reported that agroforestry substantially increased income diversification (mean = 4.54), strengthened food security, and enhanced resilience to climate variability. The integration of trees with agricultural production enabled households to access multiple income sources while improving environmental sustainability and reducing vulnerability to climatic shocks. The study concludes that agroforestry diversification is an effective approach for improving the socio-economic well-being of rural households in Nyanza District. To maximize its benefits, the study recommends strengthening land tenure policies to encourage long-term investment in agroforestry, improving farmers' access to quality tree seedlings and technical extension services, and enhancing community participation in agroforestry initiatives. These measures are expected to promote sustainable rural development, increase household resilience, and contribute to national efforts toward climate-smart agriculture and poverty reduction.**

Keywords: **Agroforestry Diversification, Livelihoods, Nyanza District, Rwanda.**

1. INTRODUCTION

Agroforestry, defined as the deliberate integration of trees with crops and/or livestock on the same land management unit, has re-emerged globally as an effective nature-based solution for promoting sustainable agriculture, enhancing rural livelihoods, restoring ecosystems, and mitigating climate change (Ballón Ossio, 2020). By combining agricultural production with tree cultivation, agroforestry provides multiple ecological and socio-economic benefits, including increased farm productivity, improved soil fertility, enhanced biodiversity, carbon sequestration, and diversified household income sources. Recent evidence indicates that agroforestry contributes significantly to food security, climate resilience, and environmental sustainability, although its adoption continues to be constrained by factors such as insecure land tenure, inadequate extension services, limited access to finance, and weak market linkages (Sahoo & Prasad, 2024).

In developed countries, agroforestry has become an integral component of climate-smart agriculture and sustainable land management policies. In the United States, practices such as alley cropping, windbreaks, and riparian forest buffers have improved farm income through diversified agricultural products while enhancing ecosystem services, including water quality, biodiversity conservation, and carbon storage (Udawatta et al., 2021). Similarly, Germany has promoted agroforestry through European Union Common Agricultural Policy (CAP) incentives that encourage tree integration for renewable biomass production, soil conservation, and climate adaptation (Alix et al., 2024). In the United Kingdom, post-Brexit agricultural reforms increasingly support multifunctional farming systems where agroforestry enhances farm resilience by diversifying production through timber, fruits, nuts, and biomass while reducing environmental degradation (Atkinson, 2023).

Across developing countries, agroforestry plays an even more significant role in improving rural livelihoods because agriculture remains the primary source of income for millions of smallholder households. In India, agroforestry contributes substantially to household welfare by providing timber, fruits, fodder, medicinal plants, and fuelwood, accounting for nearly 30% of annual household income in some rural communities (Chavan et al., 2024). Brazil has widely adopted silvopastoral systems that integrate livestock with trees to improve soil fertility, reduce deforestation, increase carbon sequestration, and generate diversified farm income (Peri et al., 2024). Likewise, Indonesian smallholder farmers increasingly integrate trees into cocoa and coffee production systems, improving crop productivity while generating additional income from fruits, timber, and fuelwood (Octavia et al., 2023).

Throughout Africa, agroforestry has emerged as an essential strategy for addressing land degradation, enhancing food security, and strengthening climate resilience among smallholder farmers. Studies across Sub-Saharan Africa demonstrate that tree-based farming systems improve soil fertility, reduce erosion, increase agricultural productivity, and diversify household livelihoods through products such as fruits, fuelwood, fodder, timber, and non-timber forest products (Sarkar et al., 2024). In West Africa, agroforestry parklands dominated by shea and baobab trees provide significant economic opportunities, particularly for women engaged in processing butter and fruit products that contribute substantially to household income (Roudaut, 2023). In East Africa, countries such as Kenya, Uganda, and Tanzania have successfully integrated agroforestry into smallholder farming systems, enhancing farmers' participation in timber, fruit, charcoal, and tree seed value chains while improving household food security and environmental sustainability (Muthee et al., 2022).

At the continental level, agroforestry has been prioritized within major African development frameworks. The African Union's Agenda 2063 and the African Forest Landscape Restoration Initiative (AFR100) recognize agroforestry as a strategic intervention for restoring degraded landscapes, improving rural livelihoods, enhancing biodiversity, and mitigating climate change (Hetemäki et al., 2023). Despite these policy commitments, several constraints continue to limit widespread adoption, including insecure land tenure systems, inadequate access to quality tree seedlings, insufficient technical support, poor access to financial services, and underdeveloped markets for agroforestry products (Onyancha, 2024).

In Rwanda, agriculture remains the backbone of the economy and employs the majority of the rural population, making sustainable land management a national development priority. The Government of Rwanda has incorporated agroforestry into key national development strategies, including Vision 2050, the National Strategy for Transformation (NST1 and NST2), the Green Growth and Climate Resilience Strategy, and the National Forest Policy, recognizing agroforestry as an important mechanism for improving agricultural productivity, restoring degraded land, reducing soil erosion, enhancing climate resilience, and diversifying rural household incomes (Lal et al., 2020). Through collaboration with organizations such as the Centre for International Forestry Research and World Agroforestry (CIFOR-ICRAF), Rwanda has implemented nationwide programs promoting tree planting on farms, distribution of improved seedlings, extension services, and fruit tree development to strengthen both environmental conservation and rural livelihoods (Lal et al., 2020).

Among Rwanda's districts, Nyanza District represents an important context for agroforestry due to its predominantly smallholder farming systems, high susceptibility to soil erosion, and increasing pressure on agricultural land. Farmers in the district have increasingly adopted agroforestry practices to improve soil and water conservation, increase farm productivity, produce fuelwood and timber, and diversify household income through the sale of fruits and tree products. Although government and development partners continue to promote agroforestry across the district, empirical evidence remains limited regarding the extent to which diversification of agroforestry systems has translated into measurable improvements in household livelihoods. This knowledge gap underscores the need for this study, which seeks to assess the impact of agroforestry diversification on the livelihoods of households in Nyanza District, Rwanda.

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2. METHODOLOGY

2.1 Research Design

This study employed a mixed-methods research design, combining both quantitative and qualitative approaches to comprehensively assess the impact of agroforestry diversification on livelihood in Nyanza District, Rwanda.

2.2 Study Area

The study was conducted in Nyanza District, a predominantly rural district in Rwanda's Southern Province where agriculture is the main source of livelihood for most households.

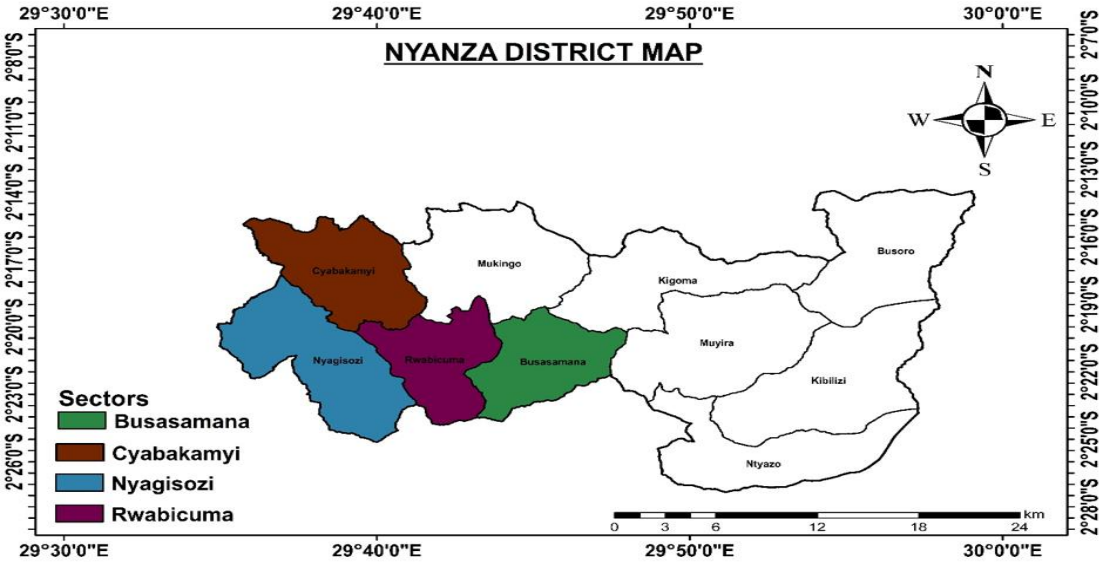

Figure 1: Nyanza district map

2.3 Target Population

The target population comprised smallholder farmers in Nyanza District, specifically those in Busasamana, Rwabicuma, Nyagisozi, and Cyabakamyi sectors, who practice agriculture and have integrated agroforestry into their farming systems.

2.4 Sampling Techniques

A stratified sampling technique was used to categorize farmers based on their level of agroforestry diversification across the four selected sectors of Nyanza district Busasamana, Rwabicuma, Nyagisozi, and Cyabakamyi.

2.5 Sample Size

The sample size was determined using Yamane's formula (1967) to ensure representativeness of the population. A total of 396 respondents were selected, including households from four sectors of Nyanza district. The sample size ensures statistical validity and allows for meaningful inferences on the relationship between agroforestry diversification and livelihood.

The formula is: $n = \frac{N}{1+Ne^2}$ Where;

n = Sample size

N = Total population

e = Margin of error (assumed to be 5%, or 0.05).

$$n = \frac{32536}{1 + 32536\ (0.05)^2}$$

$$n = \frac{32536}{82.32}$$

n =395.1421 = 396

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The above formula shows N as the target population, which is 32536, while n is the sample size of 396 respondents and e is the margin error at a 95% confidence interval. Therefore, this shows that the study consists of 396 households.

2.6 Data Collection Instruments

The study employed a combination of structured questionnaires, semi-structured interviews, and observation checklists as the main data collection instruments.

3. RESULTS AND DISCUSSION

3.1 Identification of respondents

In this study; gender, level of education, age, position in cooperative and experience ranges are demographic variables which take part in influencing the dependent variables.

Table 1: Demographic characteristics of respondents

Variable	Category	Frequency	Percent	Valid Percent	Cumulative Percent
Gender	Male	166	41.9	42.2	42.2
	Female	227	57.3	57.8	100.0
	Missing	3	0.8	-	-
Age	<25 years	42	10.6	10.6	10.6
	25–35 years	151	38.1	38.1	48.7
	36–45 years	72	18.2	18.2	66.9
	46–55 years	100	25.3	25.3	92.2
	>55 years	30	7.6	7.6	100.0
	Missing	1	0.2	-	-
Marital Status	Married	251	63.4	63.4	63.4
	Single	85	21.5	21.5	84.9
	Divorced	60	15.1	15.1	100.0
Residence Years	<2 years	33	8.3	8.3	8.3
	3–4 years	49	12.4	12.4	20.7
	≥5 years	314	79.3	79.3	100.0
Education Level	Illiteracy	54	13.6	13.6	13.6
	Primary	140	35.4	35.4	49.0
	Secondary	157	39.6	39.6	88.6
	University	45	11.4	11.4	100.0

Source: Primary data; 2026

The demographic characteristics indicate that the study was dominated by female respondents (57.8%), suggesting strong participation of women in household and community related activities. The age structure shows that most respondents fall within the economically active group of 25-55 years, representing a productive population capable of providing reliable information on livelihood and environmental practices.

In terms of marital status; the majority of respondents were married (63.4%), indicating that most participants belong to family-based households that are central to resource use and livelihood decisions. Additionally; a large proportion of respondents had lived in the area for five years and above (79.3%), which strengthens the reliability of their responses due to long-term experience with local conditions. Regarding education; most respondents had primary to secondary education levels, indicating a generally literate population capable of understanding agroforestry and livelihood related issues. Thus; the demographic profile reveals that the sample is well suited for assessing the impact of agroforestry diversification on livelihoods.

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3.1.1 Assessment of the influence of agroforestry diversification in Nyanza District

Table 2: Access to extension

	N	Mean	Standard Deviation
Agroforestry improves water infiltration into the soil.	396	4.41	.600
Trees help reduce surface runoff and soil erosion.	396	4.66	.521
Agroforestry maintains water flow during dry seasons.	396	4.69	.602
Tree cover reduces water loss through evaporation.	396	4.51	.525
Valid N (listwise)	**396**		

Source: Primary data; 2026

The data from Table 2 demonstrates the substantial benefits of agroforestry diversification in Nyanza district, particularly in enhancing water management and soil health. The mean scores indicate a robust agreement among respondents on the effectiveness of agroforestry practices. The highest mean (4.69) pertains to agroforestry's role in maintaining water flow during dry seasons, emphasizing its critical function in ensuring water availability when it is most needed. Additionally; a score of 4.66 for the reduction of surface runoff and soil erosion highlights the perceived efficacy of trees in protecting the landscape from degradation.

Respondents also noted significant improvements in water infiltration, rated at 4.41, and a mean score of 4.51 for reducing water loss through evaporation further supports the notion that agroforestry systems are essential for optimizing water retention. These findings collectively illustrate a clear recognition among the local population of agroforestry's multifaceted benefits, suggesting that such diversification not only promotes environmental resilience but also contributes significantly to sustaining the livelihoods of residents in the district.

Table 3: Land tenure security

	N	Mean	Standard Deviation
Clear land ownership encourages farmers to invest in agroforesty	396	4.55	.556
Secure land tenure reduces land related conflicts	396	3.99	.201
Farmers with land rights are more willing to plant and manage trees	396	3.99	.225
Land tenure security improves long-term planning for sustainable farming	396	3.98	.275
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 3 provides insights into the significance of land tenure security in supporting agroforestry practices among farmers in Nyanza district. The results reveal a strong recognition of the role that clear land ownership plays in encouraging investment in agroforestry, evidenced by a high mean score of 4.55. This underscores that when farmers perceive their land ownership as secure, they are more likely to commit resources and effort towards planting and managing trees, thereby enhancing agroforestry diversification.

Conversely; while land tenure security is associated with reduced land related conflicts and increased willingness to engage in sustainable practices, the mean scores for these aspects are comparatively lower, both at 3.99. Furthermore; the slightly lower mean of 3.98 for long-term planning reflects a moderate consensus on the impact of secure land tenure on sustainable farming strategies. Therefore; these results illustrate that while farmers in Nyanza district recognize the benefits of land tenure security, there are opportunities to strengthen their understanding and engagement in sustainable agroforestry practices to further promote long-term livelihood improvements.

Table 4: Cultural value

	N	Mean	Standard Deviation
Trees hold traditional significance in many communities.	396	3.99	.195
The agroforestry supports cultural practices like herbal medicine use.	396	4.53	.562
Tree planting is often linked to preserving community heritage.	396	4.52	.597
The agroforestry strengthens the connection between people and their land.	396	4.53	.562
Valid N (listwise)	**396**		

Source: Primary data; 2026

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Table 4 highlights the cultural significance of agroforestry practices in Nyanza district, revealing how trees contribute to traditional values and community heritage. A notable finding is the mean score of 4.53 for both the role of agroforestry in supporting cultural practices such as the use of herbal medicine, and its function in strengthening the connection between people and their land. These high scores indicate that respondents perceive trees not just as agricultural assets but as integral to their cultural identity and community practices.

Additionally; the mean score of 4.52 for tree planting being linked to the preservation of community heritage reinforces this perspective, suggesting that agroforestry is integrated in the social fabric of the community. Conversely; the slightly lower mean score of 3.99 for the traditional significance of trees indicates that while this aspect is acknowledged, it may not carry the same weight as the other cultural dimensions. Thus; the findings underscore the importance of agroforestry as a means of fostering cultural continuity and enhancing community cohesion in Nyanza district, reflecting a broader understanding of livelihood beyond economic factors.

Table 5: Adoption and Practice

	N	Mean	Standard Deviation
The Agroforestry increases the variety of plant and animal species.	396	4.53	.529
Trees provide habitats for birds and insects.	396	4.53	.557
Mixed cropping with trees supports ecological balance.	396	4.53	.557
Higher biodiversity improves farm resilience to pests and diseases.	396	4.53	.562
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 5 illustrates the positive perceptions regarding the adoption and practice of agroforestry in Nyanza district particularly in promoting biodiversity. With a consistent mean score of 4.53 across various statements; respondents largely recognize that agroforestry diversification increases the variety of plant and animal species. This indicates a strong consensus on the ecological benefits of integrating trees into agricultural practices, which not only enhances biodiversity but also contributes to creating habitats for birds and insects.

Furthermore; the emphasis on mixed cropping with trees supporting ecological balance demonstrates an understanding of the interconnectedness of farming practices and environmental health. The finding that higher biodiversity improves farm resilience to pests and diseases reflects a collective awareness that agroforestry practices incorporated agricultural stability and productivity. Therefore; these results reveal that the adoption of agroforestry in Nyanza district is viewed as a critical strategy for promoting ecological sustainability and resilience, which directly contributes to the general improvement of livelihoods in the area.

3.1.2. Analysis of the means of livelihood of smallholder households in Nyanza District

Table 6: Household Resilience

	N	Mean	Standard Deviation
Agroforestry provides households with multiple income sources, reducing risk.	396	4.53	.557
Tree products like fruits and firewood act as safety nets during crises.	396	4.53	.557
Agroforestry helps families recover faster from droughts or crop failures.	396	4.51	.622
Diversified farms improve long-term stability and food security.	396	4.54	.514
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 6 highlights the significant role of agroforestry in enhancing household resilience among smallholder families in Nyanza district. With a mean score of 4.53; respondents strongly agree that agroforestry provides multiple income sources, which effectively reduces economic risk. This diversification is crucial for families, as it allows them to mitigate the impacts of financial shocks or adverse agricultural conditions. The consistent mean score of 4.53 for the statement that tree products such as fruits and firewood, serve as safety nets during crises underscores the importance of these resources in sustaining livelihoods during challenging times.

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Additionally; a mean score of 4.51 related to the ability of agroforestry to aid families in recovering more swiftly from droughts or crop failures further reinforces its role in building resilience against climate variability. The slightly lower mean of 4.54 regarding the contribution of diversified farms to long-term stability and food security indicates a strong recognition of the link between agroforestry and sustainable agricultural practices. Hence; these findings illustrate that agroforestry is not only a means of income diversification but also a fundamental strategy for enhancing the resilience and food security of smallholder households in the region.

Table 7: Employment Opportunities

	N	Mean	Standard Deviation
Agroforestry creates jobs in tree planting, maintenance, and harvesting	396	4.54	.514
It supports small-scale businesses such as charcoal production and beekeeping	396	4.54	.514
Seasonal labour demand increases, offering work for rural youth and women	396	4.54	.514
Value addition of tree products boosts entrepreneurship and local income	396	4.56	.647
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 7 underscores the significant impact of agroforestry on employment opportunities for smallholder households in Nyanza district. With a mean score of 4.54; respondents uniformly recognize that agroforestry creates various jobs related to tree planting, maintenance and harvesting. This consistent score reflects a shared understanding of how agroforestry not only contributes to environmental sustainability but also generates significant employment opportunities for local communities.

Furthermore; the data indicates that agroforestry supports small-scale businesses such as charcoal production and beekeeping, reinforcing the economic benefits derived from diversified agricultural practices. The mean score for seasonal labor demand increasing providing opportunities for rural youth and women highlights the social impact of these practices on community livelihood. The highest mean score of 4.56 concerning the value addition of tree products further emphasizes how agroforestry enhances entrepreneurship and local income. Collectively; these findings illustrate that agroforestry diversification is fundamental to improving job creation, empowering marginalized groups, and strengthening the economy of the community in Nyanza district.

Table 8: Social Capital

	N	Mean	Standard Deviation
Agroforestry promotes collaboration among farmers through shared resources and knowledge.	396	4.55	.682
It strengthens community networks by encouraging group tree planting initiatives.	396	4.56	.647
Trust and cooperation grow as farmers work together on land management.	396	4.56	.671
Social ties help in collective problem-solving and accessing external support.	396	4.55	.682
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 8 highlights the significant impact of agroforestry on social capital among smallholder households in Nyanza district. The results demonstrate a strong consensus, with mean scores of 4.55 and 4.56, indicating that agroforestry promotes collaboration among farmers and strengthens community networks through shared resources and group tree planting initiatives. This collaborative environment fosters mutual support, allowing farmers to apply collective knowledge and experiences to improve their agricultural practices.

Additionally; a mean score of 4.56 related to the development of trust and cooperation as farmers work together on land management underscores the importance of social bonds in effective resource management. The consistent score of 4.55 for social ties facilitating collective problem-solving and access to external support illustrates how agroforestry not only builds individual resilience but also enhances the social structure of the community. Therefore; these findings indicate that agroforestry serves as a catalyst for social cohesion and collaborative action, reinforcing community bonds that are critical for addressing challenges and enhancing livelihoods in the district.

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Table 9: Food security and Nutrition

	N	Mean	Standard Deviation
Agroforestry increases food availability by diversifying crop production.	396	4.55	.682
Trees provide fruits and nuts that improve household nutrition.	396	4.57	.627
Shade from trees supports livestock health, contributing to milk and meat production.	396	4.57	.622
Sustainable practices reduce hunger risks during droughts or poor harvest seasons.	396	4.56	.647
Valid N (listwise)	**396**		

Source: Primary data; 2026

Table 9 illustrates the significant role of agroforestry in enhancing food security and nutrition among smallholder households in Nyanza district. The findings show a strong consensus with mean scores ranging from 4.55 to 4.57, indicating that agroforestry effectively increases food availability through diversified crop production. This diversification is crucial for improving household nutrition, as indicated by the high score for the contribution of trees in providing fruits and nuts.

Moreover; the mean score of 4.57 regarding the positive impact of tree shade on livestock health underscores the multifaceted benefits of agroforestry; healthier livestock contribute to increased milk and meat production, further strengthening food security. Additionally; the score of 4.56 for sustainable practices reducing hunger risks during droughts or poor harvests highlights the adaptive capacity of agroforestry systems to withstand climatic challenges. Collectively; these results illustrate that agroforestry diversification not only enhances food security but also improves nutritional outcomes, playing a vital role in the resilience of smallholder livelihoods in Nyanza district.

3.1.3. Relationship between agroforestry diversification and livelihood among smallholder households

Table 10: Correlation between Agroforestry diversification and livelihood

		Agroforestry Diversification	Livelihood
Agroforestry Diversification	Pearson Correlation	1	.819
	Sig. (1-tailed)		.000
	N	396	396
Livelihood	Pearson Correlation	.819	1
	Sig. (1-tailed)	.000	
	N	396	396
Correlation is significant at the 0.01 level (1-tailed).			

Source: Primary data; 2026

Table 10 demonstrates a strong positive correlation between agroforestry diversification and livelihood among smallholder households in Nyanza district. The Pearson correlation coefficient of 0.819 indicates a strong relationship, revealing that as agroforestry practices become more diversified, households experience significant improvements in their livelihood strategies. This high correlation implies that investments in agroforestry not only enhance agricultural productivity but also foster multiple income streams which are essential for sustaining household resilience.

The statistical significance of this correlation indicated by a p-value of 0.000, reinforces the reliability of the findings, confirming that the relationship is highly significant at the 0.01 level. Such strong evidence positions agroforestry diversification as a key driver of livelihood improvement, demonstrating that enhancing agroforestry practices could lead to substantial benefits for smallholder households in terms of economic stability and resilience. Therefore; these results highlight the critical role of agroforestry in transforming livelihoods and promoting sustainable development in Nyanza district.

3.2 Data Analysis and Discussion

3.2.1 Assessment of the Influence of Agroforestry Diversification in Nyanza District

The descriptive findings indicate that respondents reported high levels of agreement regarding the contribution of agroforestry diversification to environmental sustainability and livelihood resilience in Nyanza District. Across Tables 2–

5, all mean scores exceeded 3.98 on a five-point Likert scale (N = 396), indicating generally positive perceptions of agroforestry practices. Water management indicators recorded the highest levels of agreement (Mean = 4.41–4.69; SD = 0.521–0.602), suggesting that respondents perceived agroforestry as contributing to improved water infiltration, reduced surface runoff, and enhanced dry-season water availability. The relatively low standard deviations indicate limited variation in respondents' views. These findings are consistent with those of Mochesane (2024), who reported that agroforestry improves soil structure, minimizes erosion, and enhances hydrological functions in smallholder farming systems. Similarly, Kehinde et al. (2024) found that tree-based farming systems increase soil organic matter and water retention, thereby strengthening ecosystem services.

Regarding land tenure security (Table 3), respondents expressed the strongest agreement with the statement that clear land ownership encourages investment in agroforestry (Mean = 4.55; SD = 0.556). Other tenure-related indicators recorded slightly lower but still positive mean scores (Mean = 3.98–3.99; SD = 0.201–0.275), indicating moderate agreement concerning the role of tenure security in conflict reduction and long-term land-use planning. The smaller standard deviations suggest substantial consistency among respondents. These findings support the property rights perspective presented by Abab et al. (2023), which argues that secure land tenure encourages long-term investments such as tree planting. Similarly, Mochesane (2024) reported that secure land rights reduce uncertainty and promote investments in sustainable agricultural practices.

The cultural and biodiversity dimensions (Tables 4 and 5) also received high levels of agreement, with mean scores ranging from 4.52 to 4.53. Respondents acknowledged the contribution of agroforestry to cultural identity, biodiversity conservation, and ecological balance. The very low standard deviation for the statement that trees hold traditional significance (SD = 0.195) indicates strong consensus among respondents. These findings are consistent with Matiku et al. (2021), who emphasized that sustainable livelihoods encompass social and natural capital alongside economic benefits.

Likewise, Dissanayaka et al. (2024) reported that biodiversity-rich farming systems enhance resilience to pests and climate variability while supporting sustainable agricultural productivity. Overall, the descriptive findings suggest that respondents perceive agroforestry diversification as contributing to environmental conservation, secure land management, biodiversity preservation, and cultural continuity.

3.2.2 Analysis of the Livelihoods of Smallholder Households in Nyanza District

The findings presented in Tables 6–9 indicate positive perceptions of the contribution of agroforestry diversification to household livelihoods. Household resilience indicators recorded mean scores ranging from 4.51 to 4.54 (SD = 0.514–0.622), suggesting that respondents generally agreed that agroforestry provides multiple income sources, enhances household stability, and serves as a buffer during periods of economic or climatic stress. The relatively low standard deviations indicate consistency in responses across the study population. These findings are consistent with the Sustainable Livelihoods Framework and with Mannepalli et al. (2025), who reported that livelihood resilience is strengthened through diversification of natural and financial assets. Similarly, Areef and Sekhar (2025) found that diversified livelihood strategies reduce household vulnerability to market and climatic shocks.

Employment opportunities and social capital indicators (Tables 7 and 8) also recorded high levels of agreement, with mean scores ranging from 4.54 to 4.56. Respondents indicated that agroforestry contributes to employment creation, entrepreneurship, and community collaboration. The highest mean score was recorded for value addition to tree products (Mean = 4.56; SD = 0.647), suggesting recognition of agroforestry's contribution to income-generating activities such as beekeeping and wood-based enterprises.

These findings are consistent with Ghimire et al. (2024), who reported that agroforestry enhances rural employment through integrated production systems. They also support the social network perspective advanced by Noll and Rivera (2023), which emphasizes the importance of trust and cooperation in strengthening community resilience and collective action.

Food security and nutrition indicators (Table 9) recorded the highest mean scores (Mean = 4.55–4.57), indicating strong agreement that agroforestry contributes to improved food availability, dietary diversity, livestock productivity, and reduced food shortages during adverse seasons. These findings are consistent with Manono and Gichana (2025), who found that integrated tree-crop-livestock systems improve ecosystem services, agricultural productivity, and household food security. Their study further demonstrated that agroforestry enhances climate adaptation through improved soil fertility and sustained crop production. Collectively, the descriptive findings indicate that respondents perceive agroforestry diversification as contributing positively to household resilience, employment generation, social capital, and food and nutrition security.

3.2.3 Relationship Between Agroforestry Diversification and Livelihoods Among Smallholder Households

The Pearson correlation analysis presented in Table 10 shows a strong positive and statistically significant relationship between agroforestry diversification and household livelihoods ($r = 0.819$, $p < 0.01$, $N = 396$). The correlation coefficient indicates that higher levels of agroforestry diversification are associated with improved livelihood outcomes among the sampled households. The statistical significance ($p < 0.01$) indicates that the observed relationship is unlikely to have occurred by chance.

The coefficient of determination ($r^2 = 0.67$) indicates that approximately 67% of the variation in livelihood outcomes is associated with variation in agroforestry diversification. However, this result should be interpreted as indicating the strength of association rather than causation, since correlation analysis does not establish causal relationships.

The findings are consistent with Getahun et al. (2023), who reported that livelihood diversification through integrated agricultural practices enhances household resilience and adaptive capacity. Similarly, Bashir (2025) found that agroforestry systems simultaneously improve agricultural productivity, generate ecosystem services, and create additional income opportunities for rural households. Comparable evidence was reported by Abebaw et al. (2025), who demonstrated that agroforestry contributes to improved food security, income generation, and resilience to climate-related shocks across sub-Saharan Africa.

The correlation analysis provides empirical evidence of a strong positive association between agroforestry diversification and livelihood outcomes among smallholder households in Nyanza District, supporting the descriptive findings presented in the preceding sections.

4. CONCLUSION

The study concludes that agroforestry diversification significantly enhances the livelihoods of smallholder households in Nyanza District by improving water management, diversifying income sources, strengthening social capital, and promoting food security and environmental sustainability. These findings demonstrate that agroforestry is an effective strategy for improving rural livelihoods while supporting climate resilience and sustainable agricultural development. Therefore, strengthening policies and investments that promote agroforestry adoption is essential for achieving sustainable rural development in Rwanda.

REFERENCES

[1] Abebaw, S. E., Yeshiwas, E. M., & Feleke, T. G. (2025). A systematic review on the role of agroforestry practices in climate change mitigation and adaptation. *Climate Resilience and Sustainability*, *4*(2), e70018.

[2] Alix, A., Bylemans, D., Dauber, J., Dohmen, P., Knauer, K., Maltby, L., Mayer, C. J., & Pepiette, Z. Thünen Report 98.

[3] Ansah, I. G. K. (2021). *Household resilience to food security shocks* Wageningen University and Research].

[4] Arakwiye, B. (2020). *Forest Cover Change in Western Rwanda During Periods of Wars and Policy Shifts: Dynamics, Drivers, and Ecological Outcomes*. Clark University.

[5] Areef, M., & Sekhar, C. (2025). *Is Income Diversification Welfare-enhancing?: Empirical Evidence on Smallholder Resilience to Climate Shocks in India*. Institute of Economic Growth, University of Delhi.

[6] Atkinson, R. (2023). *Short-Rotation Coppice Willow: Soil Carbon Sequestration and Financial Incentives for Farmers* University of Liverpool].

[7] Awazi, N. P., Njamnjubo, N. A., & Ambebe, T. F. (2024). Agroforestry for ecosystem services: assessing the role of agroforestry for water regulation. *Forestist*.

[8] Ballón Ossio, A. (2020). *Unravelling the challenges of turning words into action Reflections on Buen Vivir ('good living') in Bolivia* Dissertation, Universität Freiburg, 2020].

[9] Bashir, M. (2025). Enhancing Food Productivity through Intensive Agroforestry Cropping for Sustainable Soil Practices–A Review. *International Congresses of Turkish Science and Technology Publishing*, 797-807.

[10] Byiringiro, B., Akshay, U., Kayijuka, C., & Bharti, B. (2024). The effectiveness of agroforestry on agricultural productivity and erosion control in Rwanda. *Reforesta*(17), 1-9.

[11] Chavan, S., Uthappa, A., Chichaghare, A., Kumar, D., Sirohi, C., & Kakade, V. D. (2024). Agroforestry Systems for Ecosystem Services in India. *Sustainable Management and Conservation of Environmental Resources in India*, 105-147.

[12] Chukwuere, J. E. (2021). Theoretical and conceptual framework: A critical part of information systems research process and writing. *Rigeo*, *11*(9).

[13] Dinh, H. H., Basnet, S., & Wesseler, J. (2023). Impact of land tenure security perception on tree planting investment in Vietnam. *Land*, *12*(2), 503.

[14] Dissanayaka, D., Udumann, S., & Atapattu, A. J. (2024). Synergies between tree crops and ecosystems in tropical agroforestry. *Agroforestry*, 49-87.

[15] Falkowski, T. B., & Diemont, S. A. (2021). Cultural ecosystem services in agroforests. In *Agroforestry and Ecosystem Services* (pp. 361-387). Springer.

[16] Getahun, W., Haji, J., Mehare, A., & Zemedu, L. (2023). Drivers of income diversification among rural households in the Ethiopian central highlands. *Food and Energy Security*, *12*(3), e443.

[17] Ghimire, M., Khanal, A., Bhatt, D., Dahal, D., & Giri, S. (2024). Agroforestry systems in Nepal: Enhancing food security and rural livelihoods–a comprehensive review. *Food and Energy Security*, *13*(1), e524.

[18] Hagger, M. S., Cheung, M. W.-L., Ajzen, I., & Hamilton, K. (2022). Perceived behavioral control moderating effects in the theory of planned behavior: A meta-analysis. *Health Psychology*, *41*(2), 155.

[19] He, Y., & Ahmed, T. (2022). Farmers' livelihood capital and its impact on sustainable livelihood strategies: evidence from the poverty-stricken areas of Southwest China. *Sustainability*, *14*(9), 4955.

[20] Hetemäki, L., Tegegne, Y. T., & Ochieng, R. M. (2023). Outlook for sustainable forest bioeconomy in Gabon, Kenya, Nigeria, South Africa and Tanzania. *Outlook for sustainable forest bioeconomy in Gabon, Kenya, Nigeria, South Africa and Tanzania*.

[21] Kaushal, G. S., & Umrao, R. (2023). Agroforestry. In *Vegetation Dynamics, Changing Ecosystems and Human Responsibility*. IntechOpen.

[22] Kehinde, O. C., Ujah, G., Ogunsola, M. O., & James, A. B. (2024). Integrating trees into agricultural landscapes: benefits and challenges of agroforestry systems. *Int J Agric Environ Sci*, *10*(7), 94-121.

[23] Keprate, A., Sharma, V., Bhatnagar, S., Thakur, R., Abbas, G., Bhardwaj, D., & Sharma, P. (2024). Economic studies in agroforestry for livelihood security. *Agroforestry*, 443-479.

[24] Kresna, R., Winara, A., Widiyanto, A., Achmad, B., Sanudin, Siarudin, M., Widyaningsih, T. S., Gartika, D., Diniyati, D., & Ruswandi, A. (2024). Out of the woods: social capital and smallholder dairy farmers' access to state-owned agroforestry lands in West Java, Indonesia. *Agroforestry Systems*, *98*(3), 637-652.

[25] Kuyah, S., Öborn, I., Jonsson, M., Dahlin, A. S., Barrios, E., Muthuri, C., Malmer, A., Nyaga, J., Magaju, C., & Namirembe, S. (2016). Trees in agricultural landscapes enhance provision of ecosystem services in Sub-Saharan Africa. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *12*(4), 255-273.

[26] Lal, P., Masozera, M., Kayitare, A., Banerjee, O., Cicowiez, M., Wolde, B., Ranjan, A., Alavalapati, J., Lyttek, E., & Nguyen, H. (2020). Achieving green growth through terrestrial natural capital restoration in Rwanda. In: A Case Study for the Economics of Land Degradation (ELD) Initiative and ….

[27] Leal, P. H., & Marques, A. C. (2022). The evolution of the environmental Kuznets curve hypothesis assessment: A literature review under a critical analysis perspective. *Heliyon*, *8*(11).

[28] Maduka, S. M. (2007). *Role of agroforestry products in household income and poverty reduction in semi-arid areas of Misungwi district, Mwanza, Tanzania* Sokoine University of Agriculture (SUA)].

[29] Majoro, F., Bagaragaza, R., Mukamwambali, C., Nsengiyumva, P., Mutabaruka, J. D. D., Buregeya, E. M., Uwamahoro, A., Nikuze, J., & Twangirimana, A. (2024). Evaluating the Effectiveness and Adoptability of Mulching Technology to Control Soil Erosion: Case Study of the Nyabugogo Catchment in Rwanda. *Ghana Journal of Geography*, *16*(2), 52-63.

[30] Mannepalli, B. K., Kushwaha, S., Kamalvanshi, V., Parida, P. K., Kemboi, E., Yadav, A., Deep, P., & Mukherjee, R. (2025). The adaptation triangle: a multivariate analysis of vulnerability, resilience and livelihood strategies in semi-arid regions of India. *Frontiers in Climate*, *7*, 1674565.

[31] Manono, B. O., & Gichana, Z. (2025). Agriculture-livestock-forestry nexus: pathways to enhanced incomes, soil health, food security and climate change mitigation in sub-Saharan Africa. *Earth*, *6*(3), 74.

[32] Matiku, S. M., Zuwarimwe, J., & Tshipala, N. (2021). *A Tourism Framework for Community-Driven Sustainable Livelihood: A Comparative Study* Doctoral dissertation]. South Africa: University of Venda].

[33] Mbatha, B. (2024). Diffusion of innovations: How adoption of new technology spreads in society. In *Information, Knowledge, and Technology for Teaching and Research in Africa: Human Machine Interaction and User Interfaces* (pp. 1-18). Springer.

[34] Mochesane, L. E. (2024). *Effect of land tenure security on agricultural productivity among small scale maize farmers in Leribe and Maseru districts of Lesotho* National University of Lesotho].

[35] Mohamud, M. (2024). *Exploring the Adaptation of Rwanda's Green Growth Climate Resilience Strategy (GGCRS) Model in East Africa. A Comparative Analysis of its Effectiveness and Best Practice to Learn for Northeastern Kenya* Webster University].

[36] Muthee, K., Duguma, L., Majale, C., Mucheru-Muna, M., Wainaina, P., & Minang, P. (2022). A quantitative appraisal of selected agroforestry studies in the Sub-Saharan Africa. *Heliyon*, *8*(9).

[37] Ngure, M. W. (2021). *Enhancing Food Security through crop and livelihood diversification among Kimandi-Wanyaga community in Murang'a County, Kenya* University of Nairobi].

[38] Noll, D., & Rivera, M. (2023). *Enhancing sustainable rural development through social capital*. Imprensa Universidade de Évora.

[39] Nuwarapaksha, T., Udumann, S., & Atapattu, A. J. (2024). Fostering food and nutritional security through agroforestry practices. *Agroforestry*, 285-318.

[40] Nyambo, D. G., Luhanga, E. T., Yonah, Z. O., Mujibi, F. D., & Clemen, T. (2022). Leveraging peer-to-peer farmer learning to facilitate better strategies in smallholder dairy husbandry. *Adaptive Behavior*, *30*(1), 51-62.

[41] Octavia, D., Murniati, Suharti, S., Hani, A., Mindawati, N., Suratman, Swestiani, D., Junaedi, A., Undaharta, N. K. E., & Santosa, P. B. (2023). Smart agroforestry for sustaining soil fertility and community livelihood. *Forest Science and Technology*, *19*(4), 315-328.

[42] Olapade, D. T., Aluko, T. B., Adisa, A. L., & Abobarin, A. A. (2023). A framework for assessment of customary land delivery institutions: instrument development, content validity and reliability testing. *Property Management*, *41*(5), 729-752.

[43] Onyancha, E. O. (2024). *Effect of Farmer's Participation and Perception of NGO Interventions on Household Food Security in Kenya* JKUAT-COHRED].

[44] Pavlidis, G., & Tsihrintzis, V. A. (2018). Environmental benefits and control of pollution to surface water and groundwater by agroforestry systems: a review. *Water Resources Management*, *32*(1), 1-29.

[45] Peri, P. L., Chará, J., Viñoles, C., Bussoni, A., & Cubbage, F. (2024). Current trends in silvopastoral systems. *Agroforestry Systems*, *98*(7), 1945-1953.

[46] Rahman, S. A., Foli, S., Al Pavel, M. A., Al Mamun, M. A., & Sunderland, T. (2015). Forest, trees and agroforestry: Better livelihoods and ecosystem services from multifunctional landscapes. *International Journal of Development and Sustainability*, *4*(4), 479-491.

[47] Roudaut, M.-B. (2023). *A Socio-Ecological Understanding of Ecosystem Services and Their Benefits to Livelihoods: Insights From Semi-Arid West Africa and Southern Arizona* The University of Arizona].

[48] Sahoo, S., & Prasad, S. (2024). Rethinking environmental restoration through climate-smart agroforestry. In *Agroforestry Solutions for Climate Change and Environmental Restoration* (pp. 393-414). Springer.

[49] Sarkar, T., Sengupta, S., Kanthal, S., & Kundu, S. (2024). Climate change mitigation through agro-forestry improves natural resource and livelihood security. In *Agroforestry to Combat Global Challenges: Current Prospects and Future Challenges* (pp. 219-246). Springer.

[50] Udawatta, R. P., Garrett, H. E., Jose, S., & Lovell, S. T. (2021). Water quality and quantity benefits of agroforestry and processes: Long-term case studies from Missouri, USA. In *Agroforestry and ecosystem services* (pp. 113-139). Springer.

[51] Uwihanganye, J., Ishimwe, J. C., Ndayambaje, J. D., & Mugunga, P. C. (2025). Assessing the agroforestry potential of selected native tree species in Rwanda. *Cogent Food & Agriculture*, *11*(1), 2555743.