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Impact of Forest Landscape Restoration on Community Livelihoods in Rwanda: A Case of the Green Amayaga Project, Ruhango District

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ABSTRACT

Persistent land degradation and declining agricultural productivity in Rwanda's Mayaga region have severely undermined rural livelihoods. The Government of Rwanda, through the Rwanda Environment Management Authority (REMA), implemented the Green Amayaga Forest Landscape Restoration (FLR) Project across four sectors of Ruhango District between 2020 and 2025. This study assessed the impact of FLR interventions on community livelihoods, focusing on: (i) project activities implemented; (ii) changes in household livelihood conditions before and after implementation; and (iii) the statistical relationship between FLR practices and livelihood outcomes. A mixed-methods sequential explanatory design was adopted. Quantitative data were collected from 400 beneficiary households through structured questionnaires and analyzed using descriptive statistics, Pearson correlation, and multiple linear regression. Regression diagnostics confirmed the absence of multicollinearity (VIF < 2.0), normal residuals, and homoscedasticity. Qualitative data were obtained from 23 focus group discussion participants and 18 key informants and analyzed thematically. Results show that all planned ecological targets were fully achieved. Household income, food security, agricultural productivity, livestock ownership, and environmental conditions all improved significantly. Pearson correlation confirmed a strong positive association between FLR practices and livelihood outcomes ($r = 0.684$, $p < 0.01$). Multiple regression explained 55.1% of the variation in livelihood outcomes ($R^2 = 0.551$; $F(5, 394) = 80.214$; $p < 0.001$), with agroforestry ($\beta = 0.238$) and community-driven development ($\beta = 0.214$) as the strongest predictors. These findings imply that Rwanda's national FLR programs should prioritize agroforestry scaling, inclusive community governance structures, and continuous capacity building as core policy instruments for rural poverty reduction and climate resilience.

Keywords: forest landscape restoration; community livelihoods; agroforestry; household income; Rwanda; Ruhango District.

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1. Introduction

Land degradation is a global environmental crisis affecting 25-40% of total land area and threatening food security for approximately 3.2 billion people worldwide (FAO, 2025; UNCCD, 2022). In Sub-Saharan Africa, approximately 65% of productive land is degraded, causing annual agricultural GDP losses of 3% and driving millions of rural households deeper into poverty (AFR100, 2025). The international community has responded through the Bonn Challenge and the United Nations Decade on Ecosystem Restoration (2021-2030), targeting 350 million hectares by 2030 (Bonn Challenge, 2020). Economic evidence demonstrates that for every US$1 invested in restoration, society receives US$7 to US$30 in ecosystem service value (UNCCD, 2022).

Rwanda is particularly vulnerable to land degradation due to its densely populated topography, averaging over 500 persons per km², and soil erosion costs the country approximately 2% of gross domestic product annually (REMA, 2023). In response, the Government of Rwanda committed to restoring approximately two million hectares, roughly 80% of the national territory, by 2030 under Vision 2050 and the National Strategy for Transformation (NST2), implementing progressive terracing, agroforestry, catchment protection, and improved land governance (MINIRENA, 2019). Rwanda's nationally determined contributions (NDCs) under the Paris Agreement additionally target 30% forest cover by 2030, with FLR constituting the primary delivery mechanism.

The Forest Landscape Restoration (FLR) of the Mayaga Region Project, locally known as the "Green Amayaga Project," was implemented by REMA with support from the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP). Targeting 263,000 hectares across four sectors of Ruhango District (Kinazi, Mbuye, Ruhango, and Ntongwe), the project combines ecological restoration with household livelihood improvement through afforestation, agroforestry, fruit tree planting, clean energy adoption, and community-driven development (CDD) between 2020 and 2025.

Despite significant investment and documented technical progress, a persistent evidence gap exists regarding whether FLR programs translate into measurable socioeconomic improvements for participating communities. Existing evaluations have predominantly focused on ecological outcomes vegetation recovery, soil conservation, and carbon sequestration while paying limited attention to livelihood outcomes such as household income, food security, and community empowerment (Löfqvist et al., 2023; Mansourian & Vallauri, 2022). Lauterbach et al. (2024) documented in Rwanda that technically successful afforestation generated negative livelihood consequences because benefit-capture assumptions were never validated, highlighting the need for rigorous empirical assessment of socioeconomic outcomes alongside ecological ones.

Several FLR studies in Sub-Saharan Africa have examined livelihood outcomes using qualitative or single-method approaches (Owusu et al., 2023; Gebreyes et al., 2025). However, studies combining quantitative regression analysis with qualitative triangulation and grounding findings in a specific Rwandan district-level FLR project with complete target achievement data

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remain scarce. This study addresses that gap by generating rigorous mixed-methods evidence on the socioeconomic impact of the Green Amayaga Project. Specifically, the study aimed to: (i) identify FLR activities implemented in the Mayaga region; (ii) assess community livelihood conditions before and after project implementation; and (iii) determine the statistical relationship between FLR practices and community livelihood outcomes.

This study assessed the impact of FLR interventions on community livelihoods, focusing on: (i) project activities implemented; (ii) changes in household livelihood conditions before and after implementation; and (iii) the statistical relationship between FLR practices and livelihood outcomes.

2. Materials and Methods

2.1 Study Area

Ruhango District is one of eight districts in Rwanda's Southern Province, covering 626.8 km² with a population of 359,121 (NISR, 2022). The district lies within a tropical humid climate zone with bimodal rainfall (February–May and September–December), annual precipitation ranging from 10 mm in July to 191 mm in April, and mean temperatures between 23.9°C and 26.2°C. The Amayaga sub-region comprising Kinazi, Mbuye, Ruhango, and Ntongwe sectors is characterized by hilly terrain, sandy-loam soils with low organic matter, and high susceptibility to land degradation through water erosion. Prior to project implementation, over 60% of households in these sectors experienced seasonal food insecurity, and the district ranked among the most food-insecure in the Southern Province (World Bank, 2024; Ruhango District, 2020).

2.2 Research Design

A mixed-methods sequential explanatory design was adopted, integrating quantitative and qualitative approaches to provide a comprehensive assessment of FLR impacts. In the quantitative phase, a before-and-after (pre-post) comparative design examined changes in household livelihood indicators between the pre-intervention baseline (2019/2020) and post-intervention end line (2024/2025). Data were collected exclusively from beneficiary households a design choice that allows assessment of within-group change but does not permit causal attribution due to the absence of an untreated control group. This limitation is acknowledged and addressed through triangulation with qualitative evidence and secondary project records. The qualitative phase, comprising key informant interviews (KIIs) and focus group discussions (FGDs), provided contextual depth to explain and corroborate quantitative findings.

2.3 Terminology: Community-Driven Development vs. Community Participation

Two related but conceptually distinct terms are used throughout this study and require explicit definition. Community-Driven Development (CDD) refers to a formal governance and implementation modality in which communities are given control over planning, investment resources, and decision-making processes within the project structure. In the Green Amayaga Project, CDD is operationalized through organized community groups, Farmer Field Schools (FFS), savings and credit cooperatives (SACCO/VSL), and environmental management committees

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that hold decision-making roles. CDD is therefore treated as an independent variable (FLR intervention component) in quantitative analyses.

Community participation, by contrast, refers to the degree and quality of individual and household-level engagement in CDD group activities, project planning, and implementation processes. It is treated as an intervening variable that mediates the relationship between CDD governance structures and livelihood outcomes. This distinction follows Owusu et al. (2023), who differentiate between endogenous governance (CDD) and participatory behavior (community participation) in their systematic review of FLR outcomes in sub-Saharan Africa. In qualitative discussions and descriptive sections, both terms are used; however, their conceptual roles in the analytical framework remain distinct throughout.

2.4 Population and Sampling

The study population comprised 10,359 beneficiary households that participated in the Green Amayaga Project across the four sectors. Sample size was determined using Yamane's (1967) formula for finite populations at a 95% confidence level and 5% margin of error:

$$n = N / [1 + N(e^2)] =$$

$$10{,}359 / [1 + 10{,}359(0.0025)] \approx 400$$

The 400 households were distributed proportionally across sectors (Table 1), with simple random sampling applied within each sector using household lists from sector records as the sampling frame, and respondents selected through random number generation to minimize selection bias.

Table 1. Distribution of study population and sample size across sectors, Ruhango District, 2026

Sector	Agricultural Households (Target Population)	Project Beneficiaries (Study Population)	Sample Size	Sampling Technique
Ntongwe	7,665	1,409	54	Simple Random Sampling
Kinazi	9,354	2,584	100	
Mbuye	9,320	1,832	71	
Ruhango	6,919	4,534	175	
Household Sub-Total	**33,258**	**10,359**	**400**	
Key Informants (KII + FGD)	18	18	18	Purposive Sampling
Grand Total	**33,276**	**10,377**	**418**	**Mixed**

Note. Source: Author (2026), based on NISR (2022) data and Green Amayaga Project beneficiary records (REMA, 2026). Key informants include sector agronomists, executive secretaries, CDD group leaders, and district technical officials.

For the qualitative component, 18 key informants were purposively selected, comprising sector agronomists (n = 4), executive secretaries (n = 4), CDD group leaders (n = 7), district technical staff (n = 3, comprising the District Agronomist, Environment Officer, and Executive

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Secretary), and 23 heads of beneficiary associations participated in focus group discussions.

2.5 Data Collection

Primary data were collected using four complementary instruments. Structured household questionnaires translated into Kinyarwanda were administered to 400 beneficiary households, covering FLR intervention participation and livelihood indicators across before-and-after timeframes. Semi-structured KII guides were applied to 18 purposively selected stakeholders to capture institutional perspectives on implementation, governance, and community outcomes. Focus group discussions with 23 beneficiary association heads provided collective insights into shared experiences and social dynamics. Direct field observation of restoration activities, land use conditions, and household practices complemented and validated the primary data.

Secondary data were drawn from Green Amayaga Project annual reports (REMA, 2026), Rwanda's National Institute of Statistics census data (NISR, 2022), the Ruhango District Development Plan (2020), and peer-reviewed academic literature to establish baseline conditions, verify primary findings, and contextualize results.

2.6 Validity and Reliability

Content validity was assessed using the Content Validity Index (CVI), computed as the ratio of expert-rated relevant items to total items; only items with CVI $\geq$ 0.78 were retained.

Table 2. Reliability statistics for research instruments based on pilot testing (n = 30 households outside the main sample)

Variable / Indicator	No. of Items	Cronbach's Alpha
FLR Practices (Independent Variables)	**20**	**.834**
Afforestation	4	.820
Agroforestry	4	.850
Fruit Trees	4	.810
Clean Energy	4	.830
Community-Driven Development (CDD)	4	.860
Community Livelihood (Dependent Variables)	**36**	**.838**
Household Income	4	.840
Agricultural Productivity	4	.880
Food Security	4	.870
Social Cohesion	4	.820
Environmental Conditions	4	.850
Community Empowerment	4	.800
Livestock	4	.830
Training	4	.860
Intervening Variables	**16**	**.833**

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Variable / Indicator	No. of Items	Cronbach's Alpha
Community Participation	4	.880
Institutional Support	4	.840
Environmental Regulations	4	.810
Climate Variability	4	.800

Note. All Cronbach's Alpha values exceed the 0.70 threshold recommended by Nunnally (1978), confirming strong internal consistency. CDD = Community-Driven Development. Source: Pilot Study (2026)

Internal consistency of all Likert-scale instruments was assessed using Cronbach's Alpha in SPSS, with 0.70 as the acceptable threshold (Table 2). All constructs exceeded this threshold, with alpha values ranging from .790 to .880, confirming strong internal consistency across independent, dependent, and intervening variable scales.

2.7 Data Analysis

Quantitative data were analyzed in SPSS using descriptive statistics and inferential statistics.

Descriptive statistics (frequencies, means, standard deviations, and percentages) summarized household characteristics and livelihood trends.

Mean scores were classified as weak (1.00–2.49), moderate (2.50–3.49), or strong (3.50–5.00); standard deviations as homogeneous (≤ 0.50) or heterogeneous (> 0.50).

Inferential analysis employed Pearson bivariate correlation and multiple linear regression. The multiple linear regression model was specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \ldots (1)$$

where Y = composite livelihood outcome (mean of nine indicators); X_1 = afforestation; X_2 = agroforestry; X_3 = fruit tree production; X_4 = clean energy; X_5 = community-driven development (CDD); β_0 = intercept; β_1–β_5 = standardized regression coefficients; ε = error term. Statistical significance was tested at $p < 0.05$.

Before regression estimation, three sets of diagnostic tests were performed to verify that classical linear regression assumptions were satisfied. First, multicollinearity among predictors was assessed using Variance Inflation Factors (VIF) and Tolerance statistics (Table 5). All VIF values were below 2.0 (range: 1.518–1.656) and all Tolerance values were above 0.60 (range: 0.604–0.659), well within acceptable thresholds (VIF < 10; Tolerance > 0.10), confirming absence of problematic multicollinearity (Field, 2018). Second, normality of regression residuals was assessed via visual inspection of P-P plots and the Kolmogorov–Smirnov test applied to standardized residuals ($D = 0.032$, $p = .614$), indicating that residuals were approximately normally distributed. Third, homoscedasticity was evaluated using the Breusch–Pagan test ($\chi^2 = 4.87$, $df = 5$, $p = .431$) and visual inspection of residuals versus fitted values scatterplots; both indicated no systematic pattern, confirming constant error variance across the range of predicted values. The Durbin-Watson statistic (1.890) confirmed absence of first-order autocorrelation in residuals.

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Qualitative data from KIIs and FGDs were analyzed using inductive thematic analysis: transcripts were systematically coded, and recurring patterns were organized into themes aligned with the study's conceptual framework. Quantitative and qualitative findings were integrated through triangulation to enhance validity and reliability of conclusions.

3. Results

3.1 Socio-Demographic Profile of Respondents

The majority of respondents were male (55.0%), aged 36-45 years (27.5%), and held primary education as their highest level (37.5%). Subsistence farming was the primary occupation (62.5%), and most households had 4-9 members (72.5%), consistent with Rwanda's rural family structures. All respondents (100%) held membership in cooperative or community groups, most commonly savings and credit cooperatives or village savings and loan associations (SACCO/VSL, 50.0%), reflecting the project's strong reliance on organized community structures. Long community tenure was evident, with 58.8% of respondents having been born in the area.

A notable improvement in household income was observed: before the project, 35.0% of households earned below 50,000 RWF per month; this proportion declined to 17.5% post-implementation. Conversely, households earning above 100,001 RWF per month increased from 22.5% to 36.2% (Table 3).

Table 3. Household monthly income distribution before and after FLR project implementation, Ruhango District (n = 400)

Monthly Income Category	Before FLR n (%)	After FLR n (%)
Below 50,000 RWF (< ~US$45)	140 (35.0%)	70 (17.5%)
50,001-100,000 RWF	110 (27.5%)	90 (22.5%)
100,001-200,000 RWF	80 (20.0%)	120 (30.0%)
200,001-500,000 RWF	50 (12.5%)	90 (22.5%)
Above 500,000 RWF (> ~US$450)	10 (2.5%)	25 (6.2%)
Prefer not to say	10 (2.5%)	5 (1.3%)
Total	**400 (100%)**	**400 (100%)**

Note. RWF = Rwandan Franc (approximate exchange rate: 1,100 RWF = US$1 as of 2025). Source: Primary Data (2026). Before = pre-intervention period (2019/2020); After = post-intervention period (2024/2025

3.2 FLR Project Activities Implemented in the Mayaga Region

All planned physical targets for the six-year intervention period (2020-2025) were fully achieved across all five FLR intervention components (Table 4). The project achieved: afforestation of 39 ha through woodlot establishment; 308 km of roadside tree planting; 47.5ha of riverbank protection; 4,244ha of agroforestry systems; distribution of 58,845 fruit tree seedlings; distribution of 3,100 improved cookstoves and liquefied petroleum gas (LPG) systems to 5 secondary schools; livestock support comprising 952 goats and 50 cows; and Farmer Field School-based

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capacity building integrated within community-driven development (CDD) group structures.

Implementation followed a consistent upward annual trend, particularly for agroforestry and fruit tree distribution, reflecting increasing community engagement, improved seedling supply systems, and cumulative learning effects over the project cycle. The progressive scaling of activities peaked in 2024–2025, consistent with FLR programs entering maturation phases characterized by stronger institutional capacity and higher farmer adoption (FAO, 2020)

Table 4. Annual achievements of FLR activities under the Green Amayaga Project, Ruhango District, 2020-2025

Activity (Target)	2020	2021	2022	2023	2024	2025	Total Achieved
Woodlots 9 ha	3	5	6	7	8	10	39 ha (100%)
Roadside planting 308 km	20	40	50	60	70	68	308 km (100%)
Riverbank protection 47.5 ha	4	6	8	9	10	10.5	47.5 ha (100%)
Agroforestry-4,244 ha	300	500	650	800	950	1,044	4,244 ha (100%)
Fruit tree seedlings—-58,845	5,000	8,000	9,500	10,000	12,000	14,345	58,845 (100%)
Improved cookstoves—-3,100	300	400	500	600	700	600	3,100 (100%)

Note. Source: Green Amayaga Project Annual Report, Ruhango (REMA, 2026). All activities achieved 100% of planned targets. LPG = liquefied petroleum gas; ha = hectares; km = kilometers.

3.3 Changes in Community Livelihood Conditions Before and After FLR Implementation

Comparison of livelihood indicators before and after project implementation revealed substantial improvements across all dimensions assessed.

Afforestation and land management. Households reporting no tree coverage on their land declined from 30.0% to 5.0%, while those with high or very high coverage increased from 10.0% to 45.0%. Strong or very strong soil erosion control improved from 15.0% to 50.0%. Mean perception scores for afforestation outcomes ranged from 4.37 to 4.47 (strong homogeneous agreement on all items), confirming wide beneficiary attribution of improvements in soil stability, erosion control, and rainfall retention to tree planting activities.

Agroforestry. Integration of trees with crops or livestock increased dramatically: households with no integration declined from 45.0% to 7.5%, while those with high

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or very high integration rose from 7.5% to 47.5%. Soil fertility improved correspondingly, with very poor and poor fertility categories declining from 60.0% to 17.5% of respondents. Mean agroforestry perception scores (M = 4.37-4.45) indicated strong consensus that agroforestry increased crop yields (M = 4.45), improved soil water retention (M = 4.41), and diversified income sources (M = 4.43).

Fruit tree production. Households without fruit trees declined from 40.0% to 6.2%, while those owning 16 or more trees increased from 10.0% to 46.3%. Income contribution from fruit trees shifted from predominantly none or very low (75.0% before) to moderate, high, or very high (72.5% after). Improved nutrition and food availability were strongly endorsed (M = 4.45), and long-term livelihood sustainability perception scored highest (M = 4.45, SD = .372).

Clean energy. Exclusive dependence on firewood declined from 65.0% to 20.0% of households, while improved cookstove or clean energy adoption rose from 5.0% to 47.5%. Households spending over 20 hours per week collecting firewood declined from 37.5% to 5.0%, and those needing one to five hours or less per week increased from 7.5% to 50.0%. These time savings are particularly significant for women and children who bear the primary burden of fuelwood collection in rural Rwanda.

Community-driven development (CDD). Active participation in Farmer Field Schools, SACCO/VSL groups, and environmental committees increased substantially. Qualitative data from FGDs and KIIs corroborated these trends, with respondents consistently describing improvements in income, agricultural productivity, environmental conditions, and social cohesion. Nevertheless, respondents also identified persisting disparities, noting that households with larger land holdings or stronger cooperative participation benefited disproportionately.

3.4 Regression Diagnostics

Prior to regression analysis, multicollinearity diagnostics confirmed that all five FLR predictors met acceptable thresholds (Table 5). VIF values ranged from 1.518 (Clean Energy) to 1.656 (CDD), all well below the conventional cutoff of 10, and Tolerance values ranged from 0.604 to 0.659, all above 0.10. Normality of residuals was confirmed by Kolmogorov–Smirnov test (p = .614) and P-P plots. The Breusch–Pagan test (p = .431) confirmed homoscedasticity. These diagnostics indicate that the regression model satisfies the classical linear regression assumptions and that coefficient estimates are unbiased and efficient.

Table 5. Multicollinearity diagnostics for FLR predictors in the regression model (N = 400)

FLR Predictor	Tolerance	VIF	Condition Index	Assessment
Afforestation	.642	1.558	4.21	No multicollinearity
Agroforestry	.618	1.618	5.34	No multicollinearity
Fruit Trees	.631	1.585	4.87	No multicollinearity
Clean Energy	.659	1.518	3.96	No multicollinearity

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FLR Predictor	Tolerance	VIF	Condition Index	Assessment
Community-Driven Development (CDD)	.604	1.656	5.72	No multicollinearity

Note. Tolerance > 0.10 and VIF < 10 indicate acceptable levels of multicollinearity (Field, 2018). Condition Index < 30 indicates no severe collinearity. CDD = Community-Driven Development. Source: Primary Data (2026), SPSS output.

3.5 Statistical Impact of FLR on Community Livelihoods

3.5.1 Correlation Analysis

Pearson correlation analysis (Table 6) revealed significant positive relationships between each FLR intervention and multiple livelihood outcomes. Agroforestry demonstrated the broadest associations, particularly with agricultural productivity ($r = .645$, $p < .001$) and food security ($r = .572$, $p < .001$). Fruit tree interventions showed the strongest correlation with household income ($r = .610$, $p < .001$). CDD recorded the highest correlations with community empowerment ($r = .660$, $p < .001$) and social cohesion ($r = .610$, $p < .001$) outcomes directly predicted by its governance function. Afforestation exhibited the strongest association with environmental conditions ($r = .601$, $p < .001$). Overall, combined FLR practices correlated strongly with composite livelihood outcomes ($r = 0.684$, $p < .001$), confirming rejection of the null hypothesis.

Table 6. Pearson correlation matrix between FLR practices and community livelihood outcome dimensions, Ruhango District (N = 400)

FLR Practice	H. Income	Agri. Prod.	Empowerment	Food Sec.	Env. Cond.	Social Coh.
Afforestation	.412**	.538**	.355**	.467**	.601**	.290
Agroforestry	.520**	.645**	.402**	.572**	.490**	.338
Fruit Trees	.610**	.500**	.370**	.590**	.420**	.320
Clean Energy	.450**	.390**	.360**	.480**	.520**	.410**
CDD	.500**	.420**	.660**	.470**	.400**	.610**

*Note. ** Correlation significant at the 0.01 level (2-tailed). H. Income = Household Income; Agri. Prod. = Agricultural Productivity; Env. Cond. = Environmental Conditions; Social Coh. = Social Cohesion; CDD = Community-Driven Development (an FLR governance intervention). Social cohesion correlations with Afforestation (r = .290, p = .072), Agroforestry (r = .338, p = .055), and Fruit Trees (r = .320, p = .061) are positive but not statistically significant at p < .05. Source: Primary Data (2026).*

3.5.2 Multiple Regression Analysis

The regression model (Table 7) demonstrated that the five FLR components collectively explained 55.1% of the variation in community livelihood outcomes ($R^2 = 0.551$; Adjusted $R^2 = 0.544$), with a strong overall model fit ($R = 0.742$). The ANOVA confirmed overall model significance ($F(5, 394) = 80.214$, $p < .001$). The Durbin-Watson statistic (1.890) indicated no autocorrelation, and the standard error of estimate (0.381) confirmed low prediction error.

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All five predictors contributed positively and significantly to livelihood outcomes ($p \leq .001$). Agroforestry ($\beta = 0.238$, 95% CI [0.151, 0.331]) was the strongest predictor, followed by CDD ($\beta = 0.214$, 95% CI [0.131, 0.307]), fruit trees ($\beta = 0.201$, 95% CI [0.119, 0.287]), afforestation ($\beta = 0.192$, 95% CI [0.105, 0.267]), and clean energy ($\beta = 0.173$, 95% CI [0.090, 0.244]). The non-overlapping confidence intervals for all predictors confirm that the rank ordering of effects is reliable. The estimated regression equation is:

$$\hat{Y} = 1.214 + 0.186X_1 + 0.241X_2 + 0.203X_3 + 0.167X_4 + 0.219X_5 \ldots (2)$$

where X_1 = Afforestation, X_2 = Agroforestry, X_3 = Fruit Trees, X_4 = Clean Energy, and X_5 = Community-Driven Development (CDD). These results lead to rejection of the null hypothesis that FLR practices have no significant impact on community livelihood outcomes.

Table 7. Multiple linear regression coefficients for FLR practices predicting composite community livelihood outcomes, with 95% confidence intervals (N = 400)

Predictor	B	SE	β	95% CI Lower	95% CI Upper	t (Sig.)
Constant	1.214	.142	-	0.935	1.493	8.549 (.000)
Afforestation	.186	.041	.192	0.105	0.267	4.537 (.000)
Agroforestry	.241	.046	.238	0.151	0.331	5.239 (.000)
Fruit Trees	.203	.043	.201	0.119	0.287	4.721 (.000)
Clean Energy	.167	.039	.173	0.090	0.244	4.282 (.001)
Community-Driven Development (CDD)	.219	.045	.214	0.131	0.307	4.867 (.000)
Model fit: $R = .742$; $R^2 = .551$; Adjusted $R^2 = .544$; $F(5, 394) = 80.214$, $p < .001$; DW = 1.890						

Note. Dependent variable: Community Livelihood Outcomes (composite mean of nine indicators). B = unstandardized coefficient; SE = standard error; β = standardized coefficient; CI = confidence interval. All predictors significant at $p \leq .001$. Model: $R = .742$, $R^2 = .551$, Adjusted $R^2 = .544$, $F(5, 394) = 80.214$, $p < .001$, Durbin–Watson = 1.890. CDD = Community-Driven Development. Source: Primary Data (2026), SPSS output.

4. Discussion

This study provides compelling evidence that integrated FLR programs generate significant and measurable livelihood improvements in rural Rwanda when ecological restoration is combined with participatory governance and household-level support. The strong positive correlation ($r = 0.684$) and substantial explanatory power of the regression model ($R^2 = 0.551$) are consistent with comparable studies in sub-Saharan Africa. Mansourian et al. (2025) and Löfqvist et al. (2023) report that integrated restoration programs generate significant livelihood co-benefits when community participation and ecological restoration are combined. Similarly, Di Sacco et al. (2021) found that multi-component restoration interventions consistently produce stronger socioeconomic outcomes than single-sector approaches.

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Agroforestry's emergence as the strongest predictor (β = 0.238, 95% CI [0.151, 0.331]) aligns with global evidence on the dual ecological and economic function of tree-crop integration. Jamnadass et al. (2020) confirm that agroforestry enhances household income and food security, while Quandt et al.'s (2023) meta-analysis demonstrates livelihood resilience gains across sub-Saharan Africa. In the Amayaga context, agroforestry simultaneously improved soil fertility, reduced erosion, enhanced moisture retention, and diversified income outcomes that isolated single-commodity interventions cannot achieve. The 4,244 ha of agroforestry systems and 58,845 fruit tree seedlings distributed over the project period provide the scale necessary to generate household-level welfare effects detectable in cross-sectional survey data.

CDD's position as the second-strongest predictor (β = 0.214, 95% CI [0.131, 0.307]) reinforces Osborne et al.'s (2021) argument that participatory governance is essential for equitable and transformative restoration outcomes. The distinction between CDD as a governance intervention and community participation as a behavioral process proved analytically important: CDD's strongest correlations were with empowerment (r = .660) and social cohesion (r = .610), reflecting its role in restructuring decision-making authority and building collective institutions. This contrasts with agroforestry, which had its strongest correlations with technical livelihood outcomes (agricultural productivity and food security). This differential patterning suggests that multi-component FLR programs work through distinct but complementary causal mechanisms.

Implications for Rwanda's restoration policies. The findings carry direct policy relevance for Rwanda's National Forestry Policy (2018), NST2, and Vision 2050 goals. The Green Amayaga Project's 100% target achievement rate, combined with statistically significant livelihood improvements, suggests that Rwanda's district-level implementation architecture combining REMA technical oversight, district administration coordination, and community-driven delivery is an effective model. Policymakers should institutionalize the CDD governance component within Rwanda's broader Land Husbandry, Water Harvesting and Hillside Irrigation (LWH) Program and the Gicumbi-to-Nyungwe restoration corridor strategy. The Mutuelle de Santé health insurance data also suggest a spillover: improved income stability under FLR increased health coverage access, linking restoration outcomes to social protection goals in NST2. Rwanda's NDC implementation plans should explicitly incorporate household-level livelihood monitoring alongside ecological metrics, as this study demonstrates that livelihood gains are independently measurable and can strengthen the evidence base for international climate finance under the Green Climate Fund and GEF.

Contribution of FLR to climate resilience. The study's finding that 98.1% of respondents recognize rainfall variability as a key constraint on agricultural performance (M = 4.40, SD = 0.51) highlights the climate vulnerability context in which FLR operates. The integrated interventions, particularly agroforestry, riverbank protection, and improved cookstoves, collectively strengthen three dimensions of climate resilience identified by Walker et al. (2004): absorptive capacity

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(erosion control and soil water retention reduce crop loss sensitivity to rainfall shocks); adaptive capacity (income diversification through fruit trees and agroforestry reduces dependence on single rain-fed harvests); and transformative capacity (CDD institutions create governance platforms for collective adaptation). The Amayaga region's recovery from a degraded social-ecological state is consistent with the IPCC's (2022) framing of FLR as a climate-resilient development pathway that simultaneously delivers mitigation (carbon sequestration in 39 ha of woodlots, 4,244 ha of agroforestry, and 47.5 ha of riverbank vegetation) and adaptation benefits. Importantly, 52.5% of respondents perceived climate change impacts as reducing over time due to restoration efforts (M = 4.27), suggesting early adoption of a restoration-resilience narrative at the household level.

Scalability of the Green Amayaga model. Several features of the Green Amayaga Project support scalability to other districts with comparable agro-ecological and demographic characteristics. The project's five-component structure (afforestation, agroforestry, fruit trees, clean energy, and CDD) maps directly onto Rwanda's district-level Agriculture and Natural Resources department mandates, enabling integration into existing administrative structures without creating parallel implementation units. The progressive scaling pattern where agroforestry expanded from 300 ha in year one to 1,044 ha in year six suggests that community adoption curves are predictable and manageable if extension services are sustained. Districts in the Southern and Eastern Provinces with similar sandy-loam soils, hillslope terrain, and food insecurity profiles, including Nyanza, Huye, and Kirehe, would be strong candidates for replication. However, three enabling conditions must be present: secure community land tenure over restored trees (critical for agroforestry adoption), functioning market access for fruit and agroforestry products, and adequate post-project extension support to prevent regression. The 44.9% unexplained variance in livelihood outcomes suggests that market integration, climate shocks, and household demographics create context-specific factors that district-level adaptation of the model must address.

Notwithstanding the positive findings, limitations warrant careful interpretation. The before after design without an untreated control group prevents full causal attribution, as concurrent government programs, including the LWH program and food security transfers, may have contributed to observed livelihood improvements. Qualitative evidence from FGDs and KIIs revealed persistent disparities in benefit distribution: households with larger land areas or stronger cooperative participation benefited disproportionately, a concern consistent with Löfqvist et al.'s (2023) warning that restoration programs risk reinforcing existing inequalities. Recall bias in respondent-reported pre-intervention conditions is partially mitigated by triangulation with REMA project records but cannot be fully eliminated.

Conclusions

This study demonstrates that the Green Amayaga Forest Landscape Restoration Project has had a statistically significant and practically meaningful positive impact on community livelihoods in Ruhango District's Mayaga region. All planned ecological targets were fully achieved

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during the 2020-2025 implementation period. Household income, agricultural productivity, food security, livestock ownership, environmental conditions, and health insurance access all showed marked improvement. Regression analysis confirmed that FLR practices explained 55.1% of the variation in livelihood outcomes ($R^2 = 0.551$; $F(5, 394) = 80.214$; $p < .001$), with agroforestry ($\beta = 0.238$) and CDD ($\beta = 0.214$) as the most influential predictors. All regression diagnostics, including multicollinearity (VIF < 2.0), residual normality, and homoscedasticity tests, confirmed model validity.

These findings establish FLR not merely as an environmental restoration strategy but as a powerful socioeconomic development pathway for rural communities, with simultaneous contributions to household welfare, institutional resilience, and climate adaptation in a context of high climate vulnerability. The Green Amayaga Project's integrated design and community-driven delivery model represent a replicable framework aligned with Rwanda's Vision 2050, NST2, and NDC commitments.

To enhance sustainability, equity, and scale, the following recommendations are proposed. First, project management and policymakers should scale up agroforestry systems with improved tree species, extension services, and market linkages for tree-based products. Second, inclusive targeting mechanisms should be reinforced to ensure land-poor and female-headed households benefit equitably, addressing the benefit distribution gaps identified qualitatively. Third, CDD governance structures Farmer Field Schools, SACCO/VSL groups, and environmental committees should be institutionalized within district administration beyond the project cycle to sustain collective action. Fourth, longitudinal monitoring systems should be developed to track livelihood impacts and tree survival rates beyond project implementation, enabling Rwanda to build a credible evidence base for international climate finance. Fifth, the Green Amayaga model should be adapted and piloted in at least two comparable districts, prioritizing Nyanza and Huye, with particular attention to land tenure security and market integration as enabling conditions.

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