



International Journal of Life Science Research Archive

ISSN: 0799-6640 (Online)

Journal homepage: <https://sciresjournals.com/ijlsra/>



(RESEARCH ARTICLE)



EVALUATING THE SOCIO-ECONOMIC AND NUTRITIONAL IMPACTS OF HOUSEHOLD FRUIT TREE ADOPTION IN WESTERN PROVINCE OF RWANDA

Tuyizere Donatha*, Pauline Niyomugabo and Mupenzi Christophe

Faculty of Environmental Studies, University of Lay Adventists of Kigali, Rwanda.

* Corresponding Author

International Journal of Life Science Research Archive, 2026, 11(01), 061–076

Publication history: Received on 27 July 2026; revised on 02 September 2026; accepted on 04 September 2026

Article DOI: <https://doi.org/10.53771/ijlsra.2026.11.1.0064>

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

This study examines how household fruit tree adoption contributes to improving rural livelihoods and nutrition in a region where agriculture remains the main source of income. Despite national efforts promoting fruit tree planting as a strategy to enhance food security, improve dietary diversity, and increase household incomes, many rural households in Western Province continue to experience moderate food insecurity, uneven income generation, and limited nutritional adequacy. The study assessed the extent of household fruit tree adoption, its socio-economic and nutritional outcomes, and the relationship between adoption practices and household wellbeing. A descriptive cross-sectional design with a mixed-methods approach was applied. The target population was 503,463, including household farmers, district agriculture staff, and sector agronomists. A sample of 288 households was selected using Slovin's formula, complemented by 7 district agriculture staff and 96 sector agronomists, giving a total of 391 respondents (all Districts in Western Province). Data were collected using structured questionnaires, key informant interviews, focus group discussions, field observations, and secondary documents. Quantitative data were analyzed using descriptive statistics, correlation, and multiple regression analysis, while qualitative data were analyzed thematically. Findings reveal that household fruit tree adoption is relatively positive associated with improved socio-economic outcomes, including increased income, employment opportunities, asset accumulation, and livelihood diversification. Regression results confirm that adoption variables explain a substantial proportion of socio-economic variation ($R^2 = 0.427$). Nutritional outcomes show a positive but weaker relationship with fruit tree adoption ($R^2 = 0.149$), mainly through dietary diversity and seasonal fruit consumption rather than full-year nutritional adequacy. Institutional support and extension services were found to enhance adoption but had limited direct nutritional influence. The study concludes that fruit tree adoption is a strong driver of socio-economic improvement and a moderate contributor to nutrition in Western Province. The findings provide important evidence for strengthening nutrition-sensitive agricultural policies and scaling up fruit tree-based interventions in Rwanda.

Keywords: Agroforestry, Household Fruit Trees, Nutritional Outcomes, Socio-Economic Impacts, Western Province of Rwanda

1 INTRODUCTION

Across the globe, the integration of fruit and nut trees into agroforestry systems has emerged as a vital strategy for promoting sustainable land use, enhancing food security, and supporting rural livelihoods. This practice, deeply rooted in traditional farming systems, plays a crucial role in diversifying income sources, restoring ecological functions, and increasing resilience to environmental and socio-economic challenges faced by communities worldwide. In parts of Asia, particularly within smallholder farms and home gardens, the cultivation of fruit and nut trees has historically contributed significantly to household food consumption and income. Studies in Central Asian countries illustrate how diverse fruit and nut tree species serve not only as sources of nutrition but also as buffers against economic uncertainties. For instance, research by Vinceti (2022) highlights how these diverse tree species support food availability and livelihood security, while simultaneously enabling farmers to engage more actively with market opportunities. These agroforestry practices foster community resilience by reducing dependence on monoculture crops and promoting biodiversity, which is crucial amid climate variability.

Moreover, agroforestry systems that incorporate fruit trees are increasingly recognized for their socio-economic benefits. Mehta (2025) emphasizes how fruit-based agroforestry diversifies income streams for smallholders and enhances their capacity to withstand climate-related shocks, such as droughts and floods in south and southeast Asia. By integrating trees into existing farming systems, farmers can improve soil health, conserve water, and create microclimates that mitigate extreme weather impacts. Beyond immediate economic gains, these systems foster social cohesion and contribute to rural stability, aligning with broader goals of sustainable development. Previous research in the Peruvian Amazon, for instance, demonstrates how integrating undervalued fruit species into agro-ecological systems can bolster local economies and strengthen food sovereignty. Zaca (2025) indicated that such practices not only enhance biodiversity and ecological resilience but also provide new market opportunities for farmers, supporting rural livelihoods and reducing external dependency.

In addition, in Europe, the trend towards integrating trees within agricultural landscapes is driven by a growing awareness of environmental sustainability and economic diversification. Recent research, as summarized by Sabiiti (2024), identifies suitable regions for agroforestry adoption, emphasizing its potential to improve environmental resilience and socio-economic outcomes. Tree crops, including fruit and nut trees, are increasingly viewed as valuable components for enhancing farm income, promoting biodiversity, and addressing regional socio-economic pressures. This shift reflects a broader recognition of agroforestry's potential to balance productivity with environmental conservation.

Across Africa, fruit trees have been shown to reduce food and nutrition insecurity among rural households by increasing access to diverse diets and enhancing food system resilience. A recent study in KwaZulu-Natal, South Africa, found that growing fruit trees was correlated with improved food security and dietary diversity, suggesting significant nutritional and economic benefits for rural communities (Zaca, 2025). Similarly, agroforestry practices including fruit trees contribute to household food security and consumption scores in Rwanda, indicating potential socio-economic gains from tree adoption (Agroforestry, Southern Rwanda, 2024). In the East African context, regional initiatives show that fruit tree planting can be part of climate adaptation strategies and household livelihood improvement. Projects in Kenya and Rwanda have promoted fruit tree expansion to enhance food security, nutrition, and local income while also building capacity among smallholder farmers (Mehta, 2025).

Despite growing interest in promoting fruit tree planting as part of sustainable agriculture, many smallholder households in rural regions continue to struggle with persistent food insecurity, low incomes, and poor nutritional outcomes. In Rwanda and other East African contexts, diversified farming practices such as agroforestry have been highlighted as having positive effects on food consumption and overall livelihoods, yet the extent of these benefits remains unclear at the household level (Karuaiehe, 2025). Research from Eastern Rwanda shows that while some agroforestry practices correlate with improved food consumption scores, the contribution of tree products like fruit to actual household income and nutrition is uneven and often under-quantified (Karuaiehe, 2025). Similarly, studies in sub-Saharan Africa report that fruit tree adoption can improve access to food and dietary diversity, but constraints such as weak market linkages and limited technical support can restrict socio-economic gains for rural households (Zaca, 2025).

If these challenges are not adequately addressed, households may continue to experience high levels of food insecurity, nutritional deficiencies, and income instability despite policy efforts promoting fruit tree adoption. Without clear evidence on whether and how fruit tree planting translates into tangible socio-economic and nutritional benefits, interventions risk misallocation of resources and missed opportunities for meaningful impact. Continued inadequacies in income and nutrition can contribute to intergenerational cycles of poverty and malnutrition, which impede Rwanda's progress toward national development goals related to food security and health. Moreover, the lack of localized

evidence may discourage farmers from maintaining fruit tree practices over time, undermining long-term sustainability and resilience in farming communities.

The current study aimed to fill these knowledge gaps by systematically evaluating the socio-economic and nutritional impacts of household fruit tree adoption in Western Province of Rwanda. By generating empirical evidence on income changes, food security status, and dietary diversity associated with fruit tree practices, the research supported policymakers, extension services, and development partners in designing more effective interventions. The findings highlighted barriers and opportunities for maximizing the benefits of fruit tree integration, ultimately contributing to improved household wellbeing and sustainable agricultural development in the study area.

2 RESEARCH METHODOLOGY

2.1 Description of the Study Area

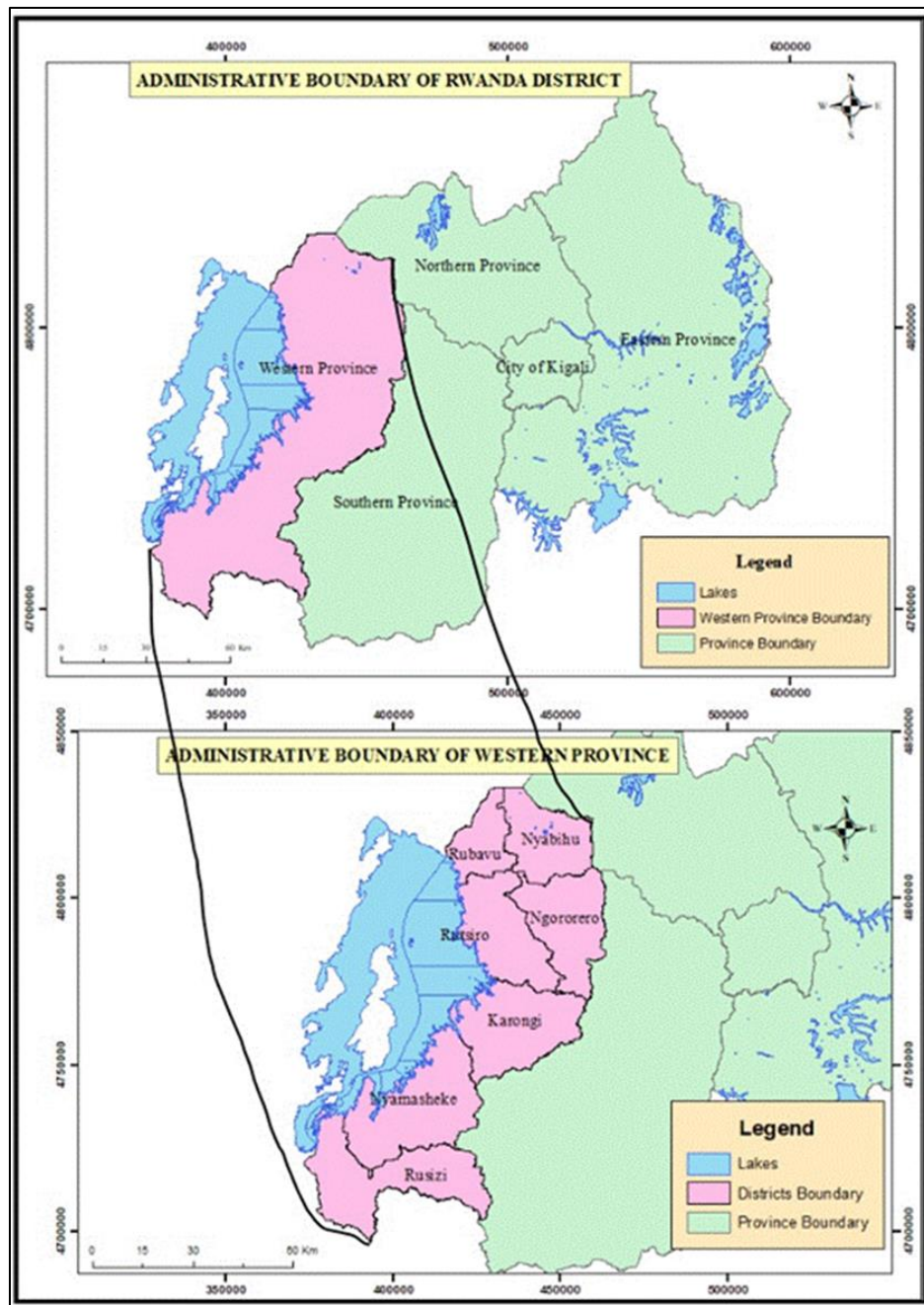


Figure 1: Map of Rwanda Showing Selected Study Province (Western)

Western Province is one of the five administrative provinces of Rwanda, created in 2006 as part of the country's decentralization efforts. It comprises seven districts: Karongi, Ngororero, Nyabihu, Nyamasheke, Rubavu, Rusizi, and

Rutsiro, with Kibuye as its provincial capital. According to the 2022 Population and Housing Census, the province has a population of about 2,896,484 people, with the majority (77.9%) residing in rural areas and 22.1% living in urban centers. This demography reflects a predominantly agrarian society where household farming remains the mainstay of livelihoods and economic activity (NISR, 2022).

Population density in Western Province averages around 693 inhabitants per square kilometer, although this varies significantly among districts, with Rubavu exhibiting the highest density (1,614/km²) and Karongi the lowest (482/km²) (NISR, 2022). Agriculture plays a central role in the province's socio-economic profile. Like much of rural Rwanda, a high proportion of households engage in farming, with crops, livestock, and fruit cultivation being integral to both food security and income generation. National surveys show that Western Province has a higher prevalence of agricultural employment than urbanized regions, reflecting its rural character (World Bank, 2022).

Despite progress in infrastructure and access to basic services such as electricity and clean water, Western Province still faces notable socio-economic challenges, including relatively higher poverty rates compared to national averages. According to the Integrated Household Living Conditions Survey (EICV7), approximately 37.4% of the population in Western Province lives below the poverty line, with variations across districts; for instance, Rusizi and Nyamasheke report poverty rates above 40%.

High youth unemployment and limited secondary and tertiary education completion also characterize the province's socio-economic landscape (NISR, 2024). Western Province's demographic structure, predominantly rural settlement, and strong reliance on agriculture emphasize the importance of considering localized agricultural interventions such as household fruit tree adoption to enhance livelihoods, food security, and nutrition outcomes. Its mixed progress in socio-economic indicators highlights the need for targeted research and development strategies tailored to regional conditions (NISR, 2024).

2.2 Research Design

This study employed a descriptive cross-sectional research design, combining quantitative and qualitative approaches.

2.2.1 Population of the study

The target population consisted of 503,463 respondents from two categories. The first category comprised 503,360 household farmers across 96 sectors in the Western Province of Rwanda (NISR, 2024). From this population, three households per sector were purposively selected, focusing on the best-performing farmers with the highest number of fruit trees, as identified by the sector agronomists. These respondents provided information on fruit tree adoption, management practices, and the associated socio-economic and nutritional outcomes.

The second category consisted of 103 institutional stakeholders, including 7 district agriculture staff and 96 sector agronomists, who provided insights into policy support, extension services, institutional coordination, and challenges affecting fruit tree adoption. The study did not use a census approach; instead, it employed survey sampling to select representative respondents, enabling the collection of relevant and in-depth data while ensuring the study remained feasible.

2.2.2 Sample Size Determination

To determine an appropriate sample size for household farmers, the study applies Slovin's formula using a margin of error of 0.0589 (5.89%), which is suitable for social science research where large populations are involved, and resource constraints must be considered. The formula is expressed as

$$n = \frac{N}{1 + N(e^2)},$$

where $N = 503,360$ (total number of household farmers) and $e = 0.0589$ or 5.89% means 94.11% level of significance.

Substituting these values gives:

$$n = \frac{503,360}{1 + 503,360(0.0589^2)} = \frac{503,360}{1 + 503,360(0.0589)} = \frac{503,360}{5,034.6} \approx 288$$

Therefore, the study included a sample of 288 household farmers, selected from across the 96 sectors of Western Province (Fanzo, 2020). This sample size is considered adequate to provide reliable and generalizable insights into household fruit tree adoption and its socio-economic and nutritional impacts while ensuring feasibility in terms of time

and resources. This was also added to District agriculture staff (from 7 districts of Western Province) 7 and Sector agronomists (Counted from 96 total sectors of Western Province) 96 giving 391 total sample size.

2.2.3 Sampling technique

Since the study aims to cover the entire target population, all identified households and institutional stakeholders were included, eliminating the need for sample size calculations. The “best farmer” in each sector ensures representation of successful adoption cases, while district staff and sector agronomists are selected purposively due to their direct involvement in promoting and supporting fruit tree adoption. Table 1 below provides details on the sampling technique:

Table 1: Target Population in Western Province

Population Group	Target Population	Sample Size	Data Collection Tool	Sampling Technique
Household farmers(3 per sector among 96 sectors of Western Province)	503,360	288	Closed-ended Questions: Questionnaire	Purposive Sampling: 3 Best Farmer in a Sector
District agriculture staff (from 7 districts of Western Province)	7	7	Open-Questions: Focus Group Discussions (FGDs)	Purposive sampling/ Census
Sector agronomists (Counted from 96 total sectors of Western Province)	96	96		Purposive sampling/ Census
Total	503,463	391	Questionnaire/ FGD	Mixed-methods, full coverage

2.2.4 Data Collection Methods and Instruments

The study used structured questionnaires, semi-structured interview guides, field observation checklists, and document review frameworks to collect comprehensive data. Household questionnaires gathered information on demographic characteristics, fruit tree adoption and management practices, access to extension services, and socio-economic and nutritional outcomes. Semi-structured interviews with district agriculture staff and sector agronomists explored institutional support, extension service effectiveness, and challenges affecting fruit tree adoption. Field observation checklists verified tree species diversity, planting arrangements, tree survival, and environmental conditions, while document reviews examined relevant policies, reports, and literature to provide evidence on institutional roles, historical trends, and fruit tree adoption outcomes.

2.2.5 Data Analysis Methods

The study examined the relationship between household fruit tree adoption (independent variables, X) and socio-economic and nutritional outcomes (dependent variable, Y), while considering government support programmes and agricultural extension services (intervening variables, Z). The dependent variable included household income, employment, livelihood diversification, dietary diversity, fruit consumption, food security, and micronutrient adequacy. Independent variables comprised the number of fruit trees, species diversity, tree age and productivity, management practices, and land allocated to fruit trees. The regression model is structured as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 Z_1 + \beta_7 Z_2 + \epsilon$$

Where:

Dependent Variable (Y) was based on socio-economic and nutritional outcomes, including household income, employment, livelihood diversification, dietary diversity, and food security. Independent Variables (X) focused on the household fruit tree adoption indicators such as number of trees, species diversity, tree age/productivity, management practices, land allocation. While Intervening Variables (Z) was government support program. Mean scores were interpreted as weak (1.00–2.49), moderate (2.50–3.49), or strong (3.50–5.00), while standard deviations below 0.5 indicated homogeneity and those above 0.5 indicated variability in responses.

2.2.6 Qualitative Data Analysis

Qualitative data from interviews and field observations were analyzed using thematic content analysis. Interview transcripts and observation notes were reviewed to identify recurring themes related to fruit tree adoption practices, barriers and facilitators, socio-economic and nutritional outcomes, and institutional support. The qualitative findings

were triangulated with the quantitative results to provide a comprehensive understanding of the impacts of household fruit tree adoption in the Western Province of Rwanda.

2.3 Ethical Considerations

All participants were informed about the purpose of the study, its objectives, and the procedures involved in data collection. Information provided by participants was treated as strictly confidential. Prior to data collection, authorization was sought from relevant local authorities in the Western Province of Rwanda. The study also complied with institutional ethical guidelines for research involving human subjects.

3 FINDINGS

Table 2: Household Perceptions on the Number of Fruit Trees and Their Socio-Economic Benefits

Household Fruit Tree Quantity Perceptions (n=288)	D	A	SA	Mean	Stdv.	Comment
1. My household has planted enough fruit trees to meet both consumption and sale needs.	8 (2.8%)	140 (48.4%)	141 (48.8%)	4.46	0.492	Strong Homogeneity
2. The number of fruit trees in our household has increased steadily over the past few years.	12 (4.2%)	151 (52.2%)	126 (43.6%)	4.39	0.661	Strong Heterogeneity
3. Having more fruit trees in the household has positively influenced our ability to generate additional income.	6 (2.1%)	135 (46.7%)	148 (51.2%)	4.49	0.448	Strong Homogeneity
Average	8.7 (3.0%)	142.0 (49.1%)	138.3 (47.9%)	4.45	0.53	Strong Heterogeneity

Table 2 results indicate a strong level of agreement among respondents regarding the adequacy and benefits of the number of fruit trees owned. A large proportion of respondents either agreed (49.1%) or strongly agreed (47.9%) that they have planted enough fruit trees to meet both consumption and sale needs, with a high score of 4.46, suggesting strong perceived sufficiency. Similarly, the perception that the number of fruit trees has increased over time recorded a mean of 4.39, indicating continued expansion in adoption, although with slightly higher variability (SD= 0.661). Furthermore, the statement that having more fruit trees improves income generation recorded the highest mean (4.49) with strong agreement and low dispersion, implying that respondents clearly associate increased tree numbers with better economic outcomes. Overall, the average mean of 4.45 confirms a high level of adoption intensity and positive perception of its benefits.



Figure 2: Fruits Trees Seedling, Growing and Production in Western province (Field Photo)

3.1 Diversity of fruit tree species

Table 3: Household Perceptions on Fruit Tree Species Diversity and Its Role in Resilience and Nutrition

Fruit Tree Species Diversity Perceptions(n=288)	D	A	SA	Mean	Stdv.	Comment
1. Our household cultivates multiple types of fruit tree species to enhance both nutrition and income opportunities.	8 (2.8%)	149 (51.6%)	132 (45.8%)	4.43	0.519	Strong Heterogeneity
2. Growing a variety of fruit trees helps protect our household against seasonal crop failures or pest infestations.	13 (4.5%)	158 (54.7%)	118 (40.9%)	4.36	0.683	Strong Heterogeneity
3. We intentionally select different fruit tree species to ensure year-round fruit availability for consumption and sale.	6 (2.1%)	141 (48.8%)	145 (50.2%)	4.48	0.412	Strong Homogeneity
Average	9.0 (2.7%)	149.3 (51.7%)	131.7 (45.6%)	4.42	0.54	Strong Heterogeneity

The Table 3 findings reveal a high level of agreement among respondents regarding the importance of fruit tree species diversity. Most respondents agreed (51.7%) or strongly agreed (45.6%) that cultivating multiple fruit tree species enhances both nutrition and income opportunities, reflected in a high score of 4.43. Similarly, the perception that species diversity protects households against seasonal crop failures and pest infestations recorded a mean of 4.36, although with relatively higher variability (SD = 0.683), suggesting differences in experience across households. The strongest agreement was observed in the intentional selection of different fruit tree species to ensure year-round fruit

availability, with a mean of 4.48 and low standard deviation, indicating strong consensus. Overall, the average mean of 4.42 confirms that households widely recognize the value of diversification in fruit tree systems.

Table 4: Household Perceptions on Fruit Tree Age, Productivity, and Livelihood Outcomes

Fruit Tree Maturity and Productivity (n=288)	D	A	SA	Mean	Stdv.	Comment
1. The fruit trees in our household are mature and produce fruit consistently every season.	8 (2.8%)	125 (43.3%)	156 (54.0%)	4.51	0.397	Strong Homogeneity
2. Older and well-established fruit trees provide more economic and nutritional benefits to our family.	7 (2.4%)	144 (49.8%)	138 (47.8%)	4.47	0.441	Strong Homogeneity
3. The productivity of our fruit trees determines the level of household income and dietary diversity.	8 (2.8%)	129 (44.6%)	152 (52.6%)	4.49	0.409	Strong Homogeneity
Average	7.7 (2.6%)	132.7 (45.9%)	148.7 (51.5%)	4.49	0.42	Strong Homogeneity

Qualitative data further supports these results by highlighting the practical benefits of species diversity. One key informant explained that *"farmers are encouraged to plant different fruit species so that when one is not producing, another one is available."* Another participant noted that *"diversifying fruit trees helps households avoid total loss when pests or diseases affect one type of crop. Additionally, respondents emphasized the nutritional benefits of fruit tree adoption. One respondent stated that "having different fruits improves the diet of families, especially for children." However, some challenges were also highlighted, including the fact that "access to diverse seedlings is still limited in some areas," which may partly explain the observed variability in responses.*

The results presented in Table 4 indicate a very high level of agreement among respondents regarding the importance of fruit tree age and productivity in influencing household outcomes. Most respondents strongly agreed that their fruit trees were mature and produced fruits consistently (54.0%), with a high mean score ($M = 4.51$) and a low standard deviation ($SD = 0.397$), indicating strong consensus. Similarly, respondents agreed that older trees provide greater economic and nutritional benefits ($M = 4.47$, $SD = 0.441$) and that productivity determines both income and dietary diversity ($M = 4.49$, $SD = 0.409$). The overall average ($M = 4.49$, $SD = 0.42$) reflects a highly homogeneous perception that mature and productive trees are central to household welfare.

Qualitative findings reinforce these results. Key informants emphasized that *"older fruit trees are more reliable because they produce consistently and require less replanting effort"*.

Table 5: Household Perceptions on Land Allocation to Fruit Trees and Associated Economic Benefits

Land Allocation for Fruit Trees (n=288)	D	A	SA	Mean	Stdv.	Comment
1. A significant portion of our farm is dedicated to fruit tree cultivation.	8 (2.8%)	165 (57.1%)	116 (40.1%)	4.38	0.652	Strong Heterogeneity
2. Expanding the land area dedicated to fruit trees has improved both food availability and income potential.	9 (3.1%)	171 (59.2%)	109 (37.7%)	4.35	0.668	Strong Heterogeneity
3. The area allocated to fruit trees reflects the priority our household places on fruit production for both economic and dietary purposes.	8 (2.8%)	160 (55.4%)	121 (41.9%)	4.41	0.635	Strong Heterogeneity
Average	8.3 (2.9%)	165.3 (57.2%)	115.3 (39.9%)	4.38	0.65	Strong Heterogeneity

The Table 4.6 results show that households generally agree that a notable portion of land is allocated to fruit trees ($M = 4.38$), but with relatively higher variability ($SD = 0.65$), indicating differences in land availability and competing farming priorities. Most respondents also agreed that expanding fruit tree land improves food availability and income ($M = 4.35$), while land allocation reflects household priorities ($M = 4.41$). The overall pattern suggests that although fruit tree adoption is widely accepted, its scale is constrained by land scarcity and livelihood trade-offs.

Table 6: Perceived Contribution of Fruit Tree Income to Household Earnings

Household Income from Fruit Sales Perceptions (n=288)	D	A	SA	Mean	Stdv.	Comment
1. Income from selling fruit from our household trees contributes significantly to our family's total earnings.	12 (4%)	128 (44%)	151 (52%)	4.48	0.461	Strong Homogeneity
2. Fruit sales help us meet household expenses such as school fees, healthcare, and other necessities.	15 (4%)	121 (42%)	155 (54%)	4.47	0.489	Strong Homogeneity
3. Revenue generated from fruit sales has improved the financial stability of our household.	13 (4%)	130 (45%)	148 (51%)	4.46	0.457	Strong Homogeneity
Average	13 (4%)	126 (44%)	151 (52%)	4.47	0.469	Strong Homogeneity

Qualitative responses confirmed this, with farmers noting that *“land is not enough to fully dedicate to fruit trees”* and that *“food crops still take priority for household survival”*. This aligns with Hall et al. (2025), who observed that land constraints often limit agroforestry expansion in smallholder systems, and Umuhoza et al. (2024), who found that farmers prioritize food crops despite recognizing the benefits of fruit trees. Similarly, ACIAR (2024) reported that land availability remains a key barrier to scaling fruit tree adoption in mixed farming systems.

The Table 6 findings indicate a strong consensus that income from fruit sales contributes significantly to household earnings ($M = 4.48$), supports essential expenditures ($M = 4.47$), and improves financial stability ($M = 4.46$), with low variation across responses. This shows that fruit trees are an important supplementary income source for rural households. Qualitative insights support this, with respondents stating that *“fruit sales help during school fee seasons”* and *“they provide small but reliable cash income throughout the year”*.

Table 7: Perceived Employment and Labor Utilization from Fruit Tree Activities

Employment and Labor Use Perceptions(n=288)	D	A	SA	Mean	Stdv.	Comment
1. Household fruit tree cultivation creates employment opportunities for family members or hired labor.	12 (4%)	132 (46%)	144 (50%)	4.45	0.501	Strong Heterogeneity
2. Managing fruit trees requires skills and labor that contribute to household economic activities.	12 (4%)	137 (48%)	139 (48%)	4.44	0.488	Strong Homogeneity
3. Fruit tree farming has enabled our household to utilize labor more effectively and productively.	13 (4%)	125 (44%)	150 (52%)	4.47	0.495	Strong Homogeneity
Average	12 (4%)	131 (46%)	144 (50%)	4.45	0.495	Strong Homogeneity

The Table 7 results show that respondents strongly agree that fruit tree cultivation contributes to employment and effective labor utilization within households. The mean scores across all items ($M = 4.44$ – 4.47) indicate a high perception that fruit tree activities create job opportunities for family members and occasionally hired labor, while also improving labor productivity. The overall average ($M = 4.45$, $SD = 0.495$) suggests a generally homogeneous perception, although slight variation exists in responses regarding employment creation. This indicates that fruit trees are not only income-generating but also labor-demanding activities that enhance household productivity. Qualitative findings support this pattern. Respondents indicated that *“fruit trees keep family members engaged throughout the year”* and that

“during harvesting seasons, additional workers are sometimes hired for picking and transportation”. Extension officers also noted that fruit tree farming *“helps utilize otherwise idle household labor, especially among youth and women”.*

Table 8: Perceived Asset Accumulation from Fruit Tree Income

Asset Accumulation Perceptions (n=288)	D	A	SA	Mean	Stdv.	Comment
1. Income from fruit trees has allowed our household to acquire new assets, such as livestock, tools, or equipment.	12 (4%)	140 (48%)	137 (48%)	4.43	0.512	Strong Heterogeneity
2. Growing fruit trees has strengthened our household's ability to invest in productive resources.	12 (4%)	128 (44%)	149 (52%)	4.47	0.476	Strong Homogeneity
3. Fruit tree adoption has contributed to long-term wealth accumulation in our household.	12 (4%)	137 (47%)	140 (49%)	4.44	0.503	Strong Heterogeneity
Average	12 (4%)	135 (46%)	142 (49%)	4.45	0.497	Strong Homogeneity

The Table 8 findings indicate strong agreement that fruit tree income contributes to asset accumulation and long-term household wealth building. The mean scores ($M = 4.43$ – 4.47) show that households perceive fruit trees as an important source of investment capacity, enabling acquisition of livestock, tools, and other productive assets. The overall average ($M = 4.45$, $SD = 0.497$) reflects a consistent perception that fruit tree adoption supports gradual wealth accumulation, although slight variability suggests differences in income levels and investment capacity across households. Qualitative responses reinforce these findings. Participants explained that *“fruit income helps us buy livestock and improve our farming tools”* and that *“over time, fruit trees have become part of our savings strategy”*. Others emphasized that *“asset growth is slow but steady compared to seasonal crops”*.

Table9: Perceived Improvement in Household Dietary Diversity

Household Dietary Diversity Perceptions (n=288)	D	A	SA	Mean	Stdv.	Comment
1. The fruits harvested from our trees contribute to a variety of foods in our family meals.	8 (3%)	129 (45%)	151 (52%)	4.49	0.441	Strong Homogeneity
2. Having fruit trees increases the range of nutrients available in our daily diet.	9 (3%)	133 (46%)	146 (51%)	4.47	0.467	Strong Homogeneity
3. Fruit tree adoption has encouraged our household to include more diverse foods in meals.	7 (2%)	132 (46%)	149 (52%)	4.49	0.439	Strong Homogeneity
Average	8 (3%)	131 (46%)	149 (52%)	4.48	0.449	Strong Homogeneity

The Table 9 findings indicate that fruit tree adoption has a strong positive effect on household dietary diversity. High mean scores ($M = 4.47$ – 4.49) show that respondents widely agree that fruit consumption contributes to more varied meals, increases nutrient availability, and encourages diversified diets. The overall average ($M = 4.48$, $SD = 0.449$) suggests strong agreement with very low variation, indicating that dietary improvements are consistently experienced across households. Qualitative responses reinforce these findings, with participants stating that *“fruits from our trees make our meals more balanced”* and that *“children now eat fruits regularly, which was not common before”*. Others noted that *“having fruits at home reduces monotony in meals and improves health”*.

Table 10: Perceived Effectiveness of Government Support Programs in Fruit Tree Adoption

Government Support Programs Perceptions (n=288)	SD	D	NS	A	SA	Mean	Stdv.	Comment
1. Government initiatives, such as provision of seedlings or financial support, have facilitated our household's fruit tree adoption.	5 (2%)	8 (3%)	9 (3%)	118 (41%)	148 (51%)	4.38	0.77	Strong Heterogeneity
2. Policies and programs from local authorities encourage households to plant and maintain fruit trees effectively.	5 (2%)	9 (3%)	10 (3%)	122 (42%)	142 (49%)	4.35	0.79	Strong Heterogeneity
3. Access to government support has influenced the success and productivity of our household fruit trees.	6 (2%)	9 (3%)	8 (3%)	115 (40%)	150 (52%)	4.38	0.81	Strong Heterogeneity
Average	5 (2%)	9 (3%)	9 (3%)	118 (41%)	147 (51%)	4.37	0.79	Strong Heterogeneity

The Table 10 results indicate that respondents moderately to strongly agree that government support programs influence fruit tree adoption, though with relatively higher variation in responses. Mean scores (4.35–4.38) show strong agreement, while higher standard deviations (0.77–0.81) indicate noticeable diversity in perceptions across households. This suggests that while institutional support exists, its reach and effectiveness may not be uniform.

Qualitative findings reveal mixed experiences regarding access to government support services. Some respondents reported that *"seedling distribution programs helped us start fruit farming,"* while others noted that *"support is not always enough or reaches everyone equally."* These findings suggest that although government support programs have contributed to the adoption of fruit tree farming, access to such services remains uneven among households.

Table 11: Perceived Role of Agricultural Extension Services in Fruit Tree Management and Productivity

Agricultural Extension Services Perceptions (n=288)	SD	D	NS	A	SA	Mean	Stdv.	Comment
1. Extension officers provide guidance that has improved the management and productivity of our household fruit trees.	4 (1%)	7 (2%)	7 (2%)	110 (38%)	160 (56%)	4.45	0.71	Strong Heterogeneity
2. Regular advice and training from agricultural extension services have helped our household adopt better fruit tree management practices.	3 (1%)	7 (2%)	8 (3%)	115 (40%)	155 (54%)	4.43	0.72	Strong Heterogeneity
3. The support from extension services has strengthened our household's capacity to maximize the benefits of fruit trees.	4 (1%)	8 (3%)	6 (2%)	108 (38%)	162 (56%)	4.46	0.7	Strong Heterogeneity
Average	4 (1%)	7 (2%)	7 (2%)	111 (39%)	159 (55%)	4.45	0.71	Strong Heterogeneity

The Table 11 findings reveal strong agreement that agricultural extension services positively influence fruit tree management and productivity. Mean values (4.43–4.46) indicate high agreement, while standard deviations (0.70–0.72) suggest moderate variability in perceptions. Overall, respondents acknowledge that extension services improve knowledge, practices, and productivity of fruit trees.

Qualitative responses support this, with participants stating that “extension officers taught us how to care for fruit trees properly” and that “training helped us improve fruit production and reduce losses.” This indicates the practical value of advisory services in strengthening household farming practices.

Table 12: Model Summary for the Correlation Between Household Fruit Tree Adoption and Nutritional Outcomes

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.387 ^a	0.149	0.128	0.1734771

Predictors: (Constant), 2. Agricultural extension services, Age and productivity of fruit trees, Diversity of fruit tree species, 1. Government support programs, Land area allocated to fruit trees, Management practices, Number of fruit trees per household

The Table 12 model summary indicates a weak-to-moderate relationship between household fruit tree adoption variables and nutritional outcomes. The correlation coefficient ($R = 0.387$) suggests a low positive association between the combined predictors and nutritional outcomes. The coefficient of determination ($R^2 = 0.149$) shows that only 14.9% of the variation in nutritional outcomes is explained by the model, while the adjusted R^2 (0.128) confirms that the explanatory power remains low even after adjustment for the number of predictors. The standard error of 0.1735 indicates relatively small prediction error, but overall, the model has limited explanatory strength compared to the socio-economic model.

Qualitative findings suggest that nutritional improvements are perceived but not uniformly experienced across households. Some respondents indicated that “*we eat more fruits when trees are available in season*”, while others noted that “*fruit availability alone is not enough; we still depend on other foods*”.

Table 13: ANOVA Table for the Correlation Between Household Fruit Tree Adoption and Nutritional Outcomes

		ANOVA ^a			
Model		Sum of Squares	df	Mean Square	F
1	Regression	1.480	7	0.211	7.026
	Residual	8.426	280	0.030	
	Total	9.907	287		

Dependent Variable: Nutritional Outcomes

Predictors: (Constant), 2. Agricultural extension services, Age and productivity of fruit trees, Diversity of fruit tree species, 1. Government support programs, Land area allocated to fruit trees, Management practices, Number of fruit trees per household

The Table of ANOVA results show that the regression model is statistically significant ($F = 7.026$, $p < 0.001$), indicating that the independent variables jointly explain variations in nutritional outcomes, although the overall explanatory strength is limited. The regression sum of squares (1.480) is relatively small compared to the residual sum of squares (8.426), confirming that most variation in nutritional outcomes is explained by factors outside the model. Qualitative responses support this limited but meaningful influence. Participants mentioned that “*fruit trees help, but nutrition also depends on other foods we buy or grow*”, showing that fruit trees are one component of a broader dietary system. Another respondent stated that “*during harvest season we eat better, but not all year round*”, emphasizing seasonal constraints.

The regression coefficients show mixed and generally weaker effects compared to socio-economic outcomes. The model indicates that: Number of fruit trees per household ($B = 0.115$, $p = 0.047$) has a weak but significant positive effect on nutritional outcomes. Diversity of fruit tree species ($B = 0.080$, $p = 0.016$) also has a significant positive influence, suggesting that variety improves dietary quality. Land area allocated to fruit trees ($B = 0.104$, $p < 0.001$) is the strongest significant predictor of nutritional outcomes in the model.

However, age and productivity ($p = 0.237$), management practices ($p = 0.456$), government support programs ($p = 0.275$), and agricultural extension services ($p = 0.773$) are not statistically significant predictors of nutritional outcomes in this model.

Qualitative evidence helps explain these results. Respondents noted that “*having many trees helps, but what matters most is the variety of fruits available*”, supporting the significance of diversity. Others indicated that “*nutrition depends on how much land we use for food production overall*”, explaining the strong effect of land allocation. Meanwhile, several

participants stated that “*training and support are helpful, but they do not directly change what we eat*”, which explains the non-significance of institutional variables in this model.

Table 14: Coefficients Table for the Correlation Between Household Fruit Tree Adoption and Nutritional Outcomes

		Coefficients ^a				
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.378	.201		16.829	0.000
	Number of Fruit Trees per Household	0.115	0.058	0.172	1.997	0.047
	Diversity of Fruit Tree Species	0.080	0.033	0.194	2.433	0.016
	Age and Productivity of Fruit Trees	0.028	0.023	0.071	1.184	0.237
	Fruit Tree Management Practices	0.023	0.031	0.059	.746	0.456
	Land Area Allocated to Fruit Trees	0.104	0.028	0.257	3.667	0.000
	1. Government support programs	0.025	0.023	0.069	1.094	0.275
	2. Agricultural extension services	0.007	0.025	0.019	.289	0.773

a. Dependent Variable: Nutritional Outcomes

4 DISCUSSION OF FINDINGS

The findings of this study provide strong empirical evidence that household fruit tree adoption significantly improves socio-economic outcomes while having a comparatively moderate effect on nutritional outcomes among rural households in Western Province of Rwanda. Descriptive results show high levels of agreement among respondents, with mean scores ranging from 4.43 to 4.49 across key socio-economic indicators. These findings suggest that fruit tree adoption makes a substantial contribution to household income generation, employment creation, asset accumulation, and livelihood diversification. Specifically, income from fruit sales recorded a high mean ($M = 4.47$, $SD = 0.469$), indicating strong consensus that fruit trees provide a reliable supplementary income source. This is further supported by correlation results, where the number of fruit trees per household has a strong positive and statistically significant relationship with income ($r = 0.591$, $p < 0.01$), and management practices also show a similarly strong association ($r = 0.588$, $p < 0.01$). These findings are consistent with Zaca et al. (2025), who reported that fruit tree adoption significantly increases rural household income, and Hall et al. (2025), who found that tree-based systems enhance economic stability through sustained production. In Rwanda, Kabano (2024) similarly observed that fruit tree expansion improves household income and resilience.

The regression analysis reinforces these findings, showing that the socio-economic model has strong explanatory power ($R = 0.653$, $R^2 = 0.427$), meaning that 42.7% of the variation in socio-economic outcomes is explained by fruit tree adoption variables. The most influential predictors include the number of fruit trees ($B = 0.372$, $p < 0.001$), management practices ($B = 0.230$, $p < 0.001$), government support programs ($B = 0.155$, $p < 0.001$), land allocation ($B = 0.140$, $p = 0.001$), and species diversity ($B = 0.127$, $p = 0.009$). These results indicate that both adoption intensity and quality of management are critical determinants of economic benefits. Similar findings are reported by ACIAR (2024), which emphasized that productivity and income gains from agroforestry depend on proper management and institutional support, while Zaca et al. (2025) highlighted that tree density and diversification are key drivers of livelihood improvements.

Employment and labor utilization results ($M = 4.45$, $SD = 0.495$) further demonstrate that fruit tree farming contributes to household labor engagement and productivity. Correlation analysis shows a significant relationship between land allocation and employment ($r = 0.449$, $p < 0.01$), as well as between tree age/productivity and labor use ($r = 0.337$, $p < 0.01$). These findings align with Kabano (2024) and ACIAR (2024), who reported that agroforestry systems increase both family labor use and seasonal employment opportunities. Similarly, asset accumulation results ($M = 4.45$, $SD = 0.497$) and its significant correlations with management practices ($r = 0.331$, p

< 0.01) confirm that fruit tree income contributes to long-term wealth building, supporting findings by Hall et al. (2025) that tree-based systems promote gradual asset accumulation and resilience.

Livelihood diversification also shows strong agreement ($M = 4.47$, $SD = 0.46$), with species diversity significantly associated with diversification ($r = 0.118$, $p < 0.05$). This suggests that fruit tree adoption reduces households' dependence on single-crop farming and enhances their resilience to economic and environmental shocks. These findings are consistent with Zaca et al. (2025), who found that agroforestry systems reduce household vulnerability by promoting income diversification and strengthening livelihood resilience and ACIAR (2024), which highlighted diversification as a key pathway to resilience in rural livelihoods.

In contrast, although nutritional outcomes show high descriptive mean scores ($M \approx 4.46$ – 4.48), indicating strong perceived benefits in dietary diversity, fruit consumption, food security, and micronutrient intake, inferential results reveal weaker statistical relationships. The regression model for nutritional outcomes has relatively low explanatory power ($R = 0.387$, $R^2 = 0.149$), meaning that only 14.9% of the variation in nutrition is explained by fruit tree adoption variables. Among predictors, only land allocation ($B = 0.104$, $p < 0.001$), species diversity ($B = 0.080$, $p = 0.016$), and number of trees ($B = 0.115$, $p = 0.047$) are statistically significant, while management practices, government support, and extension services are not significant. This indicates that nutritional improvements depend more on diversity and availability of fruits rather than management or institutional factors alone. These findings are consistent with Hall et al. (2025), who found that species diversity is a stronger determinant of dietary quality than tree quantity, and Zaca et al. (2025), who reported that nutrition outcomes are influenced by consumption behavior and food access. In Rwanda, Umuhoza et al. (2024) also emphasized that fruit trees improve nutrition mainly when integrated with broader dietary practices.

The correlation matrix further supports these conclusions, showing that household fruit tree adoption is significantly associated with socio-economic outcomes ($r = 0.372$, $p < 0.01$) and nutritional outcomes ($r = 0.743$, $p < 0.05$). Institutional support also demonstrates a strong and significant relationship with overall outcomes ($r = 0.729$, $p < 0.05$). However, the disaggregated results indicate that institutional factors are more strongly associated with economic outcomes than with nutritional outcomes. Government support programs show moderate and significant correlations with income ($r = 0.205$, $p < 0.01$), employment ($r = 0.308$, $p < 0.01$), and asset accumulation ($r = 0.303$, $p < 0.01$). Similarly, extension services are significantly associated with income ($r = 0.250$, $p < 0.01$), but show no significant relationship with most nutritional indicators. These findings align with ACIAR (2024) and Kabano (2024), who noted that institutional support enhances adoption and productivity but does not directly translate into improved nutrition without complementary interventions.

Overall, the discussion demonstrates that fruit tree adoption is a strong and statistically significant driver of socio-economic improvement, with clear evidence from both descriptive (high mean scores) and inferential (correlation and regression) analyses. However, its influence on nutritional outcomes is more indirect and limited, as reflected by weaker statistical relationships and lower model explanatory power. These findings confirm broader empirical literature, including Zaca et al. (2025), Hall et al. (2025), ACIAR (2024), Kabano (2024), and Umuhoza et al. (2024), all of which emphasize that while agroforestry systems improve livelihoods, achieving substantial nutritional gains requires integrated approaches that combine production, diversity, education, and access to diverse foods. Consequently, the study highlights the need for policy interventions that not only promote fruit tree adoption but also strengthen nutrition-sensitive agriculture, improve market access, and ensure equitable institutional support to maximize both economic and nutritional benefits.

5 CONCLUSION

The study concludes that household fruit tree adoption in Western Province of Rwanda has successfully contributed to addressing the research objectives. It confirms that fruit tree adoption is generally well established among households, with a high level of integration into farming systems through increased tree numbers, species diversity, and management practices. The findings also confirm that fruit tree adoption has a strong and statistically significant positive effect on socio-economic outcomes, particularly in improving household income, employment opportunities, asset accumulation, and livelihood diversification.

However, while nutritional outcomes are positively influenced by fruit tree adoption, the relationship is comparatively weaker and more context dependent. Fruit trees mainly enhance dietary diversity and seasonal food availability rather than fully ensuring long-term nutritional adequacy. Overall, the study confirms that the research questions have been satisfactorily addressed, demonstrating that fruit tree adoption is more strongly linked to socio-economic improvement than to direct nutritional transformation.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The principal author appreciates the guidance and support of UNILAK lecturers. She wants to express her heartfelt thanks, particularly to her supervisors, Dr. Pauline Niyomugabo and Prof. Mupenzi Christophe. She wants also to thank Nzabonimpa Oscar, the Executive Director of APEFA, as well as to everyone else who contributed to the completion and value of this work.

Disclosure of conflict of interest

This study declared no competing interests.

Author Contributions

- Conceptualization: Tuyizere Donatha
- Data curation: Tuyizere Donatha
- Formal analysis: Tuyizere Donatha
- Methodology: Tuyizere Donatha
- Writing – original draft: Tuyizere Donatha
- Writing – review & editing: Dr. Pauline Niyomugabo and Prof. Mupenzi Christophe

REFERENCES

- [1] ACIAR. (2024). *Fruit trees for climate adaptation and mitigation in East Africa* (Final Report). Australian Centre for International Agricultural Research (ACIAR).
- [2] Adjimoti, G. O. (2021). Crop diversification and household food security status: Evidence from rural Ghana. *Scientific African*, 12, e00751. <https://doi.org/10.1016/j.sciaf.2021.e00751>
- [3] Anderson, et al. (2021). Agricultural extension and advisory services: Lessons from recent research. *World Bank Research Observer*, 36(1), 1–27. <https://doi.org/10.1093/wbro/lkab002>
- [4] Baiyegunhi, L. J. (2021). Rural household food security in South Africa: Evidence from household survey data. *Agrekon*, 60(1), 1–17. <https://doi.org/10.1080/03031853.2020.1812415>
- [5] Bizimana, et al. (2023). Productivity of fruit trees and household welfare in Rwanda. *African Journal of Agricultural Economics*, 11(2), 45–59.
- [6] Chambers, R., & Conway, G. R. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century* (IDS Discussion Paper No. 296). Institute of Development Studies.
- [7] Coe, R. S. (2021). Scaling up agroforestry requires research "in" rather than "for" development. *Current Opinion in Environmental Sustainability*, 48, 31–38. <https://doi.org/10.1016/j.cosust.2020.10.002>
- [8] Dawson, et al. (2020). Trees, tree genetic resources and the resilience of agricultural systems. *Forest Ecology and Management*, 462, 117986. <https://doi.org/10.1016/j.foreco.2020.117986>
- [9] Fanzo, J. H. (2020). The role of food systems in achieving nutrition outcomes. *Global Food Security*, 26, 100425. <https://doi.org/10.1016/j.gfs.2020.100425>
- [10] FAO. (2021). *The state of food security and nutrition in the world 2021*. Food and Agriculture Organization of the United Nations. <https://www.fao.org>
- [11] Hall, et al. (2025). Growing trees on farms boosts nutrition in rural Malawi. *Conservation Letters*.
- [12] Herrero, et al. (2020). Innovation can accelerate the transition towards a sustainable food system. *Nature Food*, 1, 266–272. <https://doi.org/10.1038/s43016-020-0074-1>
- [13] HLPE. (2020). *Agroecological and other innovative approaches for sustainable agriculture and food systems*. High Level Panel of Experts on Food Security and Nutrition, FAO.
- [14] Ickowitz, A. P. (2019). Agricultural intensification, dietary diversity, and markets in the global food security narrative. *Global Food Security*, 20, 9–16. <https://doi.org/10.1016/j.gfs.2018.11.002>
- [15] Ingabire, C. M. (2023). Fruit consumption patterns and household nutrition in rural Rwanda. *Rwanda Journal of Public Health*, 5(1), 18–29.
- [16] Jamnadass, et al. (2021). *Agroforestry for food and nutritional security*. World Agroforestry (ICRAF).

- [17] Jones, A. D., et al. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi. *The Journal of Nutrition*, 144(7), 1065–1072. <https://doi.org/10.3945/jn.114.194241>
- [18] Kabano, J. C. (2024). *Scaling up fruit tree production to improve food security, nutrition, and the environment in Rwanda*. Global Alliance for Improved Nutrition.
- [19] Karuaiehe, S. T. (2025). An empirical analysis of the determinants of food insecurity among smallholder farmers in Eastern Rwanda. *Agriculture & Food Security*.
- [20] Kuyah, S. W. (2022). Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. *Agriculture, Ecosystems & Environment*, 301, 107032. <https://doi.org/10.1016/j.agee.2020.107032>
- [21] Mehta, S. N. (2025). Fruit tree based agroforestry: A scalable solution for climate change and food security. *IOSR Journal of Agriculture and Veterinary Science*.
- [22] Miller, V., et al. (2021). Availability, affordability, and consumption of fruits and vegetables worldwide. *The Lancet Global Health*, 9(10), e1413–e1421. [https://doi.org/10.1016/S2214-109X\(21\)00319-4](https://doi.org/10.1016/S2214-109X(21)00319-4)
- [23] MINAGRI. (2021). *National agriculture policy*. Ministry of Agriculture and Animal Resources, Rwanda. <https://www.minagri.gov.rw>
- [24] MINAGRI. (2022). *National food and nutrition strategy*. Ministry of Agriculture and Animal Resources, Rwanda.
- [25] Mukamana, et al. (2022). Crop and fruit tree diversification in Rwanda's smallholder systems. *African Journal of Agricultural Research*, 17(6), 812–823.
- [26] NISR. (2022). *Fifth Population and Housing Census, Rwanda: Main indicators report*. National Institute of Statistics of Rwanda (NISR). <https://www.statistics.gov.rw>
- [27] NISR. (2024). *Household Living Conditions Survey (EICV 7)*. National Institute of Statistics of Rwanda (NISR).
- [28] Nsengimana, J., & et al. (2022). Extension services and productivity of fruit trees in Rwanda. *Journal of Agricultural Extension and Rural Development*, 14(3), 96–105.
- [29] Nshimiyiryo, et al. (2022). Farm production diversity and household dietary diversity in Rwanda. *Food Security*, 14(4), 893–907.
- [30] OECD. (2021). *Making better policies for food systems*. Organisation for Economic Co-operation and Development.
- [31] Paumgarten, et al. (2021). Home gardens and livelihood security. *Sustainability Science*, 16, 217–230.
- [32] Place, F. A. (2020). Improved policies for facilitating the adoption of agroforestry. *World Development*, 134, 105041. <https://doi.org/10.1016/j.worlddev.2020.105041>
- [33] Reed, et al. (2021). Trees for livelihoods: The role of tree age and productivity. *Forest Policy and Economics*, 131, 102549.
- [34] Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- [35] Rosenstock, T. S. (2020). A planetary health perspective on agroforestry in sub-Saharan Africa. *One Earth*, 2(4), 330–344.
- [36] Sabiiti, D. (2024). *Planting a future: How Rwanda is fighting stunting with fruit trees*. KT Press.
- [37] Umuhoza, et al. (2024). Domestication of wild indigenous fruit trees in Rwanda: Perspectives from rural communities. *Trees, Forests and People*.
- [38] Uwimana, et al. (2023). Land allocation strategies among smallholder farmers in Rwanda. *Journal of Land Use Science*, 18(1), 55–70.
- [39] Van Noordwijk, et al. (2020). Agroforestry systems and sustainable development goals. *Sustainability*, 12(14), 5473. <https://doi.org/10.3390/su12145473>
- [40] Vinceti, B., et al. (2022). Home gardens of Central Asia: Reservoirs of diversity of fruit and nut tree species. *PLoS ONE*, 17(7).
- [41] Waldman, K. B. (2021). Smallholder land-use decisions and nutrition outcomes. *World Development*, 143, 105457.
- [42] WHO. (2020). *Healthy diet*. World Health Organization (WHO).
- [43] World Agroforestry. (2021). *Agroforestry and livelihoods in Africa*. ICRAF.
- [44] World Bank. (2022). *Rwanda poverty assessment: Driving forces of poverty reduction*. World Bank Group. <https://www.worldbank.org>
- [45] Zaca, F. N. (2025). The role of fruit trees in reducing food insecurity and improving nutrition security of rural households: A case study of the KwaZulu-Natal province, South Africa. *Journal of Agricultural and Food Research*.