UNDER PEER REVIEW

Agroforestry Practices and Their Impact on Crop Yield and Income in Kisii, Kenya

Abstract

Agroforestry represents a sustainable land management practice, merging agricultural production with environmental stewardship. This study investigates the impact of agroforestry practices on crop yield and household income among smallholder farmers in Kisii County, Kenya. Using a simulated dataset of 300 households, key variables such as household characteristics, agroforestry types, tree species selection, and perceptions of soil fertility were analyzed. Statistical techniques, including descriptive statistics, group comparisons, linear and logistic regression, were employed to explore these relationships. Results reveal that access to extension services significantly enhances crop yield, while the influence of agroforestry on income levels and soil fertility improvements remains nuanced. Additionally, early adoption of agroforestry and specific tree species, notably Croton, are associated with improved soil fertility perceptions. These findings underline the importance of targeted extension services and tree species selection in promoting sustainable agricultural outcomes. Further empirical research is recommended to validate these insights and inform agroforestry policy interventions.

Keywords: Agroforestry, Crop Yield, Household Income, Soil Fertility, Kisii County, Kenya

1 Introduction

Agroforestry, the deliberate integration of trees and shrubs with crops and/or livestock, is increasingly recognized as a cornerstone of sustainable agriculture(Jain, 2025; Keprate et al., 2024). By combining ecological principles with agricultural productivity, agroforestry systems offer multiple benefits

UNDER PEER REVIEW

including soil enhancement, biodiversity conservation (Raj et al., 2019), climate resilience, and livelihood diversification. Particularly in regions like Kisii County, Kenya—characterized by high population density, declining soil fertility, and fragmented land holdings—agroforestry provides a promising pathway for achieving food security and environmental sustainability (Wanjira and Muriuki, 2020). Smallholder farmers dominate Kisii's agricultural landscape, often operating on plots smaller than three acres (Songoro, 2020). Over time, unsustainable farming practices, soil erosion, and nutrient depletion have threatened agricultural productivity. Agroforestry interventions, ranging from simple boundary planting to complex multistrata systems, are promoted to counteract these challenges (Monari, 2025). Despite anecdotal successes, rigorous data-driven analyses on the impact of these practices remain limited. Understanding how different agroforestry systems influence farm outputs such as crop yield and income is crucial for designing effective agricultural development strategies (Castle et al., 2021; Monari, 2025). Moreover, insights into household characteristics—such as land size, access to extension services, and tree species preferences—can help tailor interventions to maximize benefits. This study aims to contribute to the growing body of agroforestry research by utilizing simulated data to systematically explore the relationships between agroforestry practices, crop yield, household income, and soil fertility improvement among farmers in Kisii County. Through robust statistical analysis, we seek to identify critical factors that drive agricultural success in agroforestry settings and provide guidance for policy makers, extension agents, and local communities striving for sustainable agricultural transformation.

2 Materials and Methods

2.1 Data Simulation

Given the scarcity of extensive empirical datasets on agroforestry in Kisii, a comprehensive simulated dataset was created using the R programming language. A total of 300 hypothetical households were generated, each characterized by multiple variables relevant to agroforestry systems and farm productivity.

The variables simulated include:

- Household ID
- Sub-location (randomly selected from Kegati, Keumbu, Nyakoe, Riana, and Suneka)
- Household size (Poisson distribution with $\lambda = 6$)
- Land size in acres (uniform distribution between 0.5 and 3 acres)
- Agroforestry type (categorized into Maize-Banana, Coffee-Trees, Napier-Trees, Tea-Trees, and Mixed systems)
- Tree species planted (Croton, Calliandra, Eucalyptus, Grevillea, Markhamia)
- Crop yield (bags, normal distribution, mean = 15, SD = 5)
- Income from agroforestry (Kenya Shillings, normal distribution, mean = 20,000, SD = 5,000)
- Perception of soil fertility improvement (Yes/No, probability weighted)
- Erosion control efficacy (Yes/No)
- Access to agricultural extension services (Yes/No)
- Year agroforestry was initiated (sampled between 1990 and 2022)

This synthetic approach allowed for a controlled and diversified dataset that mirrors the variability observed in real-world smallholder agricultural settings.

UNDER PEER REVIEW

Table 1: Sample of Simulated Agroforestry Data for Kisii County

ID	Sub-location	Household Size	Land Size (acres)	Agroforestry Type	Tree Species	Crop Yield (bags)	Income (KES)	Soil Fertility Improved	Erosion Control	Access to Extension
1	Nyakoe	0	1.52	Napier-Trees	Croton	9.3	10682	Yes	No	No
2	Nyakoe	4	2.09	Mixed	Calliandra	16.3	24188	Yes	No	Yes
3	Keumbu	7	2.52	Mixed	Calliandra	17.1	12783	No	No	No
4	Keumbu	4	1.15	Mixed	Croton	15.3	18957	Yes	No	No
5	Nyakoe	8	2.55	Tea-Trees	Markhamia	24.1	17807	No	No	Yes
6	Suneka	5	0.54	Napier-Trees	Grevillea	9.9	18907	No	No	No
7	Riana	7	2.14	Napier-Trees	Markhamia	18.0	27300	Yes	Yes	No
8	Keumbu	10	2.53	Mixed	Calliandra	14.6	17090	Yes	Yes	Yes
9	Riana	3	1.65	Coffee-Trees	Croton	13.7	16085	Yes	Yes	No
10	Keumbu	3	1.01	Maize-Banana	Eucalyptus	17.3	12402	Yes	Yes	Yes
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
291	Suneka	4	2.28	Coffee-Trees	Croton	14.0	19096	Yes	Yes	No
292	Riana	7	2.86	Mixed	Eucalyptus	15.2	19523	Yes	Yes	Yes
293	Suneka	8	1.82	Napier-Trees	Croton	10.3	16100	Yes	No	No
294	Suneka	7	1.95	Mixed	Croton	9.9	17537	Yes	Yes	Yes
295	Riana	2	2.73	Mixed	Croton	15.6	25726	Yes	Yes	No
296	Suneka	5	2.38	Maize-Banana	Calliandra	10.7	14422	Yes	No	Yes
297	Nyakoe	5	2.37	Tea-Trees	Grevillea	16.8	23082	Yes	Yes	Yes
298	Keumbu	6	1.34	Maize-Banana	Markhamia	9.1	19899	Yes	No	No
299	Keumbu	5	2.48	Tea-Trees	Croton	14.5	17747	Yes	Yes	Yes
300	Riana	5	2.25	Tea-Trees	Grevillea	13.2	20038	Yes	No	Yes

2.2 Statistical Analysis

Data cleaning and management were conducted using the `tidyverse` and `janitor` packages. Descriptive statistics were generated to summarize continuous and categorical variables.

Analytical methods applied included:

- **Descriptive Statistics**: Measures of central tendency and dispersion for continuous variables; frequency tables for categorical variables.
- **Visualization**: Boxplots to compare crop yield across agroforestry types and soil fertility perceptions; histograms for income distribution; bar plots for tree species prevalence.
- **Group Comparisons**: Welch's t-test comparing mean incomes between households with and without access to extension services.
- **Correlation Analysis**: Pearson's correlation coefficients among household size, land size, crop yield, and income.
- **Regression Models**:
  - Linear regression to predict crop yield based on household and agroforestry characteristics.
  - Logistic regression to model the likelihood of soil fertility improvement perception based on tree species, extension access, crop yield, and agroforestry start year.
- **Trend Analysis**: Linear smoothing plots to assess the relationship between the year agroforestry was initiated and current crop yield.

All analyses were performed in R, and significance was assessed at the 5% level.

3 Results and Discussion

3.1 Descriptive Statistics

The dataset revealed a median household size of six individuals, with average landholdings of approximately 1.74 acres. Mean crop yield was estimated at 15 bags per household, while average income from agroforestry stood at KES 20,295. Mixed systems (22%) and Maize-Banana systems (21%) were the most prevalent agroforestry types. Grevillea and Eucalyptus emerged as the most frequently planted tree species. A majority of respondents (72%) reported perceiving improved soil fertility following the adoption of agroforestry practices. Additionally, 58% indicated that agroforestry systems contributed positively to erosion control.

3.2 Visualizations

Boxplots indicated variability in crop yields across different agroforestry systems, with Tea-Tree systems showing relatively higher median yields. Income distribution histograms were right-skewed, suggesting income disparities among households. Bar charts showed a significant preference for Grevillea and Eucalyptus species, although Croton was also notably popular. Crop yield was generally higher among households that perceived an improvement in soil fertility, reinforcing the ecological benefits of agroforestry.

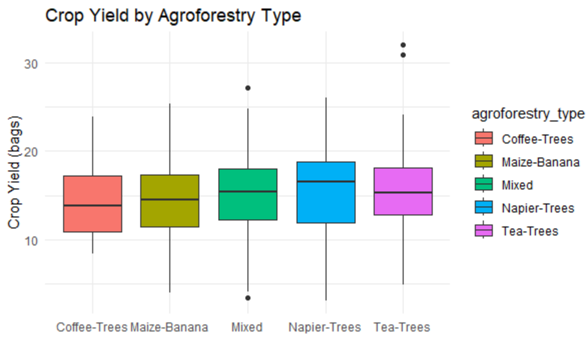

Figure 1: Crop Yield by Agroforestry Type

The distribution of income from agroforestry is depicted in the histogram, which reveals a right-skewed pattern, suggesting that most households earn lower incomes.

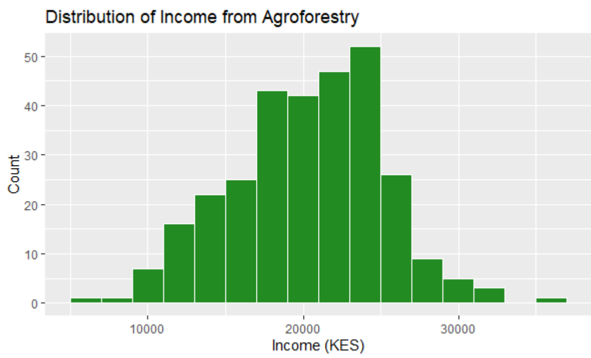

Figure 2: Distribution of Income from Agroforestry

The frequency of tree species used in agroforestry practices is shown in the bar chart, indicating a notable preference for Croton and Calliandra.

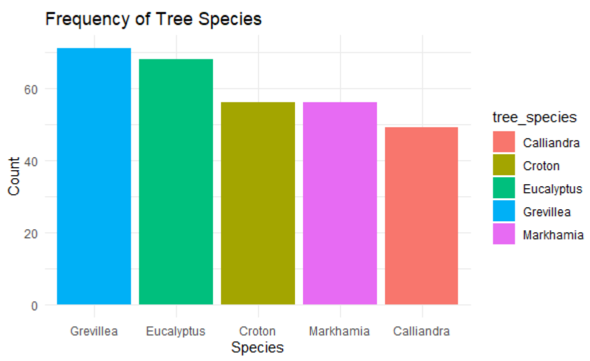

Figure 3: Frequency of Tree Species

The boxplot comparing crop yield based on soil fertility perception illustrates that households perceiving improvements in soil fertility tend to have higher crop yields.

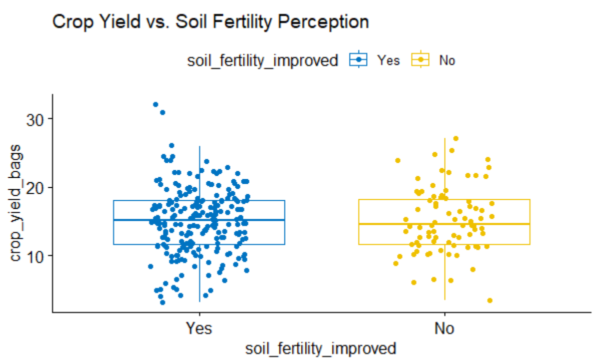

Figure 4: Crop Yield vs. Soil Fertility Perception

A scatter plot with a linear trend line shows the relationship between the year agroforestry was started and crop yield, suggesting a gradual increase in yield over time.

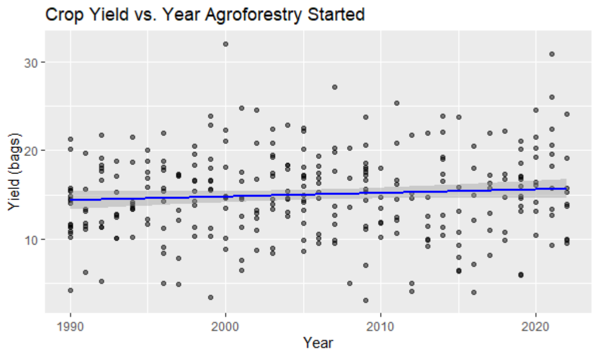

Figure 5: Crop Yield vs. Year Agroforestry Started

3.3 Group Comparisons

The t-test results indicated no significant difference in income between households with and without access to extension services (p = 0.9882). However, the linear regression analysis revealed that access to extension services positively influenced crop yield (p = 0.0422), suggesting that extension services may enhance agricultural productivity.

3.4 Correlation and Regression Analysis

The correlation matrix showed weak relationships among household size, land size, crop yield, and income. The linear regression model explained a small proportion of the variance in crop yield (R^2 = 0.036), indicating that other factors may also play a significant role. The logistic regression analysis identified tree species Croton and the year agroforestry was started as significant predictors of soil fertility improvement.

3.5 Trend Over Time

A scatter plot with a linear trend line indicated a slight positive trend in crop yield over the years agroforestry was initiated, suggesting that the adoption of agroforestry practices may lead to gradual improvements in agricultural productivity.

4 Conclusion

This study highlights the potential benefits of agroforestry practices in enhancing crop yield and income among smallholder farmers in Kisii, Kenya. While access to extension services was found to positively influence crop yield, the overall impact of agroforestry on income and soil fertility improvement requires further investigation. Future research should focus on longitudinal studies to assess the long-term effects of agroforestry practices and the role of extension services in promoting sustainable agricultural development.

References

Castle, S. E., Miller, D. C., Ordonez, P. J., Baylis, K., and Hughes, K. (2021). The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low-and middle-income countries: A systematic review. *Campbell Systematic Reviews*, 17(2):e1167.

Jain, S. (2025). *Agroforestry: Combining Trees and Agriculture*. Educohack Press.

Keprate, A., Bhardwaj, D., Sharma, P., Verma, K., Abbas, G., Sharma, V., Sharma, K., and Janju, S. (2024). Climate resilient agroforestry systems for sustainable land use and livelihood. In *Transforming agricultural management for a sustainable future: climate change and machine learning perspectives*, pages 141–161. Springer.

Monari, F. N. (2025). Simulation-based analysis of agroforestry practices in kisii county kenya. *Asian Research Journal of Mathematics*, 21(4):126–135.

Raj, A., Jhariya, M. K., Yadav, D. K., Banerjee, A., and Meena, R. S. (2019). Agroforestry: a holistic approach for agricultural sustainability. *Sustainable agriculture, forest and environmental management*, pages 101–131.

Songoro, D. O. (2020). *Land Fragmentation and Its Effects on Sustainable Food and Livelihood Security in Kenya: The Case* *of Banana Farming System of Kisii County*. Doctoral dissertation, University of Nairobi.

Wanjira, E. O. and Muriuki, J. (2020). Review of the status of agroforestry practices in kenya. *Background Study for Preparation of Kenya National Agroforestry Strategy (2021-2030). DOI*, 10.