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Contribution of farmer managed natural regeneration on maize productivity among farmers in Nalweyo Sub County, Kakumiro District – Uganda

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Abstract

The study examined the concept of farmer managed natural regeneration (FMNR) of tree species richness and species evenness, farmer perceptions on maize yield, quality and stimulated growth. A sample size of 291 maize farmers was used in the study. Quantitative and qualitative methods were used in the study. The study used purposive sampling during the survey and identification of the study sites. Tree parameters (species name, height and DBH) were used on the eight study plots during the study. Field tools like tape measure, range finder, diameter tape and GPS were used. The most common tree species on the farms among the farmers of Nalweyo Sub County were *Markhamia lutea* that made 97.3%, *Albizia* species at 26.3% and *Maesopsis eminii* at 20.6%. Analysis of the coefficients of Farmer Managed Natural Regeneration (FMNR) tree species richness and maize productivity was statistically insignificant and positively influence Maize productivity with $\beta = 0.179$, $P=0.483>0.05$. Coefficients of Tree species evenness and maize productivity was statistically insignificant and negatively influence Maize productivity with $\beta = -0.312$, $P=0.360>0.05$. Coefficients Farmer Perceptions and maize productivity was statistically significant and positively influence Maize productivity with $\beta = 0.643$, $P=0.047<0.05$. The study recommended proper selection of the right tree species that grow together with maize, enrichment planting for diversified eco systems and adoption of tree management practices like pruning. There is also need for future research on *Markhamia lutea* especially on its ecological uses at farm level. Continuous Mindset change through sensitization of farmers about the importance s of trees on farm.

Keywords: Species Richness; Species Evenness; Diversity; Diameter at Breast Height; Shannon Index

1. Introduction

In many developing countries, large areas of farmland and forests have become unproductive to the extent that they cannot produce anymore. Forest ecosystems provide a number of important ecosystem services [1] such as carbon sequestration, biodiversity protection, soil and water conservation. Plantations generally fall short of providing the same ecosystem services as original natural forests and the impact of plantation management practices on these services can vary significantly [2]. Consequently, the primary goal of plantation management is to enhance ecosystem services to their fullest potential [3].

Deforestation remains a critical issue especially in Africa's arid regions where 74 percent of rangelands and 61 percent of rain-fed maize lands suffer from moderate to serve dry spells. In several African nations, the rate of deforestation surpasses reforestation efforts by a staggering 300:1 rate. This imbalance has profound consequences for subsistence farmers whose food security and livelihoods hinge on these degraded lands.

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The loss of forests not only disrupts local ecosystems but also exacerbates soil erosion, reduces water retention capacity and diminishes biodiversity. In many African nations, subsistence farmers constitute 70-80 percent of the population. They are consistently facing hunger, malnutrition and famine highlighting the severe challenges the communities face as they depend on rain fed agriculture for basic survival [4].

In Africa's Sahel region, extensive removal of forest cover from productive farmland has led to desertification. This deforestation has transformed once fertile land into arid desert highlighting the critical need for sustainable land management practices to prevent further environmental degradation [4]. Severe famines in the Sahel during the 1970s and 80s spurred a global response making desertification control a key priority. This focus aimed to address the environmental and humanitarian crises tackling the root causes of land degradation and food insecurity in the region.

In Uganda context, Farmer Managed Natural Regeneration (FMNR) was first introduced in Uganda by Tony Rinaudo in Arua district on the invitation of World Vision in 2012. A group of about 30 farmers and government officials who were trained by Tony soon became champions in promoting the model. By the year 2014, FMNR had spread across to 15 districts [5]. World Vision Uganda in collaboration with the Australia introduced FMNR approach as a pilot in the district of Nakasongola, Abim, Kotido and Kibaale [5]. The practice has then so far spread to over 40 districts in Uganda.

Kakumiro simultaneously experiences among Uganda's high population growth rates of 6% and deforestation rates losing 52,834 hectares since 1990 [6]. The district receives a steady influx of immigrants and refugees from Rwanda and Congo who arrive to plunder natural resources, clear farmland and establish farms. It also suffers from significant pressure from the growing plantation industry owned by private interests that can displace indigenous trees in favor of growing exotic woodlots. Private forests and reserves are also being created for tourism purposes placing additional pressure on existing community land.

The best FMNR tree species are those that provide a positive relationship with crops [7]. Farmers can ensure that they choose for regeneration those tree stumps that have ample space for crops between them [7]. Farmer Managed Natural Regeneration enhances crop yields and food security for small-scale rural farmers. This sustainable agricultural practice restores degraded lands leading to improved productivity and livelihoods [8].

Increasing tree density and biomass has positive benefits for soil fertility, water availability, biodiversity and other ecosystem functions performed by a healthy environment [9;10]. Farmers in Mali began practicing FMNR because it increased crop production and studies conducted found a positive impact of FMNR on crop yields in areas with tree densities of 15 to 40 trees per hectare [10]. [11] Further urged that the benefits of trees on crop yields diminish when there are more than 40 tree species per hectare.

Field testing in Mali indicated that plots with over 10% tree cover increased soil organic matter by 25 tons per hectare boosting maize yields from 54% to 76% compared to plots of maize without trees [12]. However, farmers recognize that tree species with extensive lateral growth can compete with crops for nutrients and sunlight potentially impacting agricultural productivity [10]. Despite these concerns, the benefits of tree cover such as improved soil health and increased yields underscore the importance of balancing tree and crop interactions in sustainable farming practices.

According to [13] indigenous legume trees are recommended for their ability to fix nitrogen to the soil and hence boosting fertility and crop performance. They excel in controlling soil erosion by holding soil particles more effectively than exotic trees. Leguminous trees species in particular add nitrogen to the soil improving overall fertility and supporting crop growth [14]

The existence of different dominant tree species in an area represent an efficient resilience system among small scale farmers [15]. The abundance of tree in an ecological system is determined by the perceived benefits derived by the communities [16]. Mixing useful trees with crops enhances improved livelihoods and diversification among small holder farming communities [17] and improved productivity [18].

It's crucial to comprehend the connection between evenness and productivity to understand relationships with in the ecosystem functioning by farming communities [19]. [20]recommended for adoption of new modern agriculture that enhances both food security and conservation given the positive correlations between human population density needs and biodiversity.

Education significantly impacts farmer's attitude towards conserving naturally growing indigenous trees. [21] Found out that higher education levels positively influence farmer's perception to adopt Farmer Managed Natural Regeneration (FMNR). This attributed to the role of education in enhancing environmental awareness and the appreciation of the ecological and economic value of indigenous trees on farms. Consequently, educated farmers are more motivated to adopt sustainable practices that protect these resources. [22] Supports this by highlighting that education contributes to marginal yet meaningful increase in the willingness to conserve indigenous trees.

The traditional wisdom passed down through generations encompasses a deep understanding of local ecosystems and soil conditions favorable for crop growth. Farmers use this knowledge to integrate trees with crops in ways that enhance soil fertility, conserve water and promote biodiversity [23]. [24] Emphasized that the practice of FMNR necessitates changing beliefs, attitudes and tree management practices of farmers to facilitate social change and promotion of environmental values.

Some farmers regenerate a wide variety of tree species while others allow only a few based on their conservation goals. It is however recommended to conserve as many tree species as possible while reducing other tree species per the interests of the farmer. Some species might not be with apparent direct economic benefit but it may be critical for provision of ecosystem services such as habitat for beneficial insects [25]. Farmers maximize crop production with FMNR through pruning, weeding and thinning.

2. Methodology

2.1. Area of Study

The study was conducted in Nalweyo Sub County, Kakumiro district located in western Uganda with latitude of 1° 7' 0" N and longitude is 31° 16' 0" E respectively. Kakumiro district is situated in the mid-western part of Uganda bordering Kibaale and Kagadi district in the west, Kikuube district in the north, Kyankwanzi district in the east and Mubende district in the south. The district covers a total land area of 1,699.4 square kilometers. The district has a conducive climate characterized by two rainfall seasons from March to May and September to December

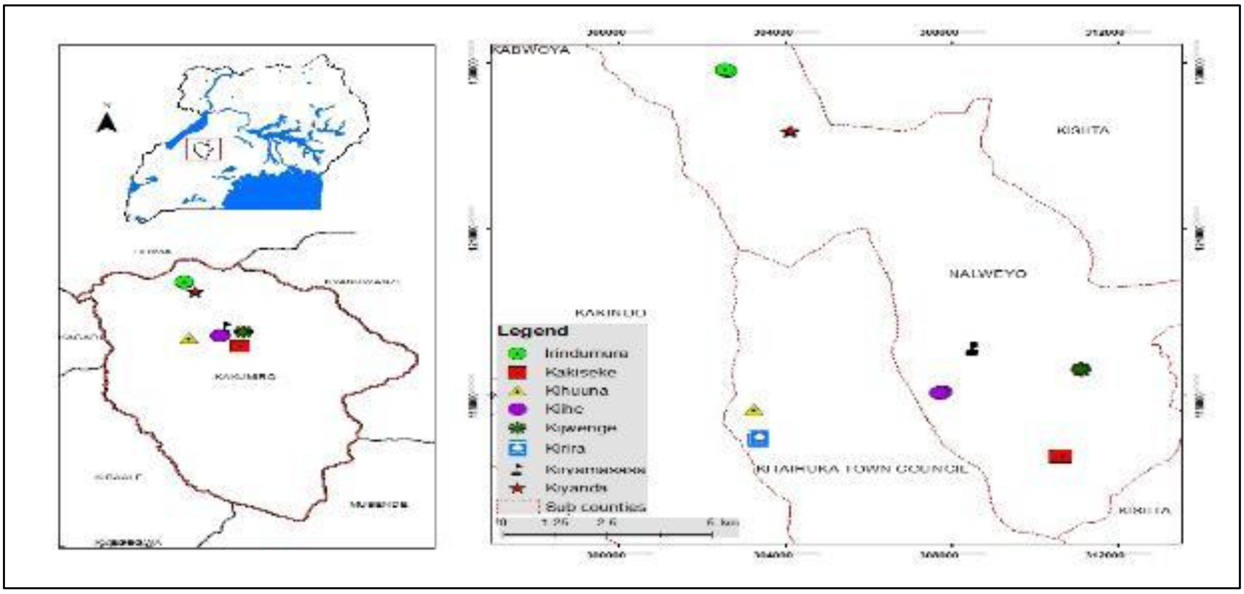

Figure 1 Map of the study area

2.2. Sampling Procedure

The study employed purposive sampling while selecting the study sites and household survey pertaining farmer's perceptions on integrating Framer Managed Natural regeneration with maize. The selected farmers for the survey were practicing FMNR and growing maize on one acre and above. Two sites per parish each measuring one acre was selected for a study from where tree species richness and evenness was measured. The two sites were representative per parish and with presence of trees naturally regenerating and growing with maize. Total of 8 study sites for selected farmer's gardens were selected for the study in Nalweyo sub county.

2.3. Research design

A correlational research design was employed to explore the relationships between variables. A mixed-methods approach combining both quantitative and qualitative methods was utilized. This allowed for both numerical and non-numerical analyses to discover patterns and trends while providing deeper insights into the experiences, perceptions and motivations of individuals.

2.4. Data collection

A questionnaire was used and was administered only to respondents selected for the study. Key informants like Natural Resources Officers, Production Officers, Forestry Officers and Extension workers provided technical experience on Farmer Managed Natural Regeneration and maize productivity. The researcher used semi-structured interview guide from where the key informants provided their sights of integrating indigenous trees with maize.

3. Results and discussions

3.1. Response rate

The study used 291 respondents practicing FMNR, whose response rate was 100%. This is assumed to be appropriate as proposed by [26] who suggested a response rate above 80% and above is considered reliable.

Table 1 Demographics characteristics of respondents

Characteristic	Categories	Practiced the integration of maize Cultivation with FMNR	
		Frequency	Percentage
Sex of respondent	Male	169	58.1
	Female	122	41.9
	Total	291	100.0

Source: Primary data 2024

Table 1 indicates the sex of the respondent, 58.1% (169) of the males and 41.9% (122) of females had practiced the integration of maize Cultivation with FMNR

3.1.1. Tree species and evenness

Table 2 Tree diversity indices in the eight FMNR plots

FMNR Sites	Diversity Indices			
	Abundance	Margalef Diversity	Evenness	Shannon-Weiner
Kijwenge	10	3.11	0.67	2.14
Kirira	10	2.57	0.58	1.84
Kakiseke	8	2.53	0.59	1.89
Kiyanda	8	1.95	0.52	1.64
Kihuuna	6	2.17	0.53	1.70
Irindumura	6	1.60	0.51	1.61
Kiihe	6	1.30	0.33	1.06
Kiryamasasa	4	0.86	0.18	0.57

From the results above, (Table 2) Kijwenge had the highest abundance of trees (10) while Kiryamasasa has the lowest (4). In terms of richness, Kijwenge has the highest richness (3.11) while Kiryamasasa has the lowest richness (0.86). For evenness, Kijwenge site was the highest with 0.67 while Kiryamasasa site was the lowest with 0.18 In terms of diversity (Shannon), Kijwenge site was more diverse (2.14) than all sites. Kiryamasasa site recorded the lowest diversity of 0.57. Conclusion: Kijwenge site was more diverse hence having several different tree species being retained on the farm (Plot).

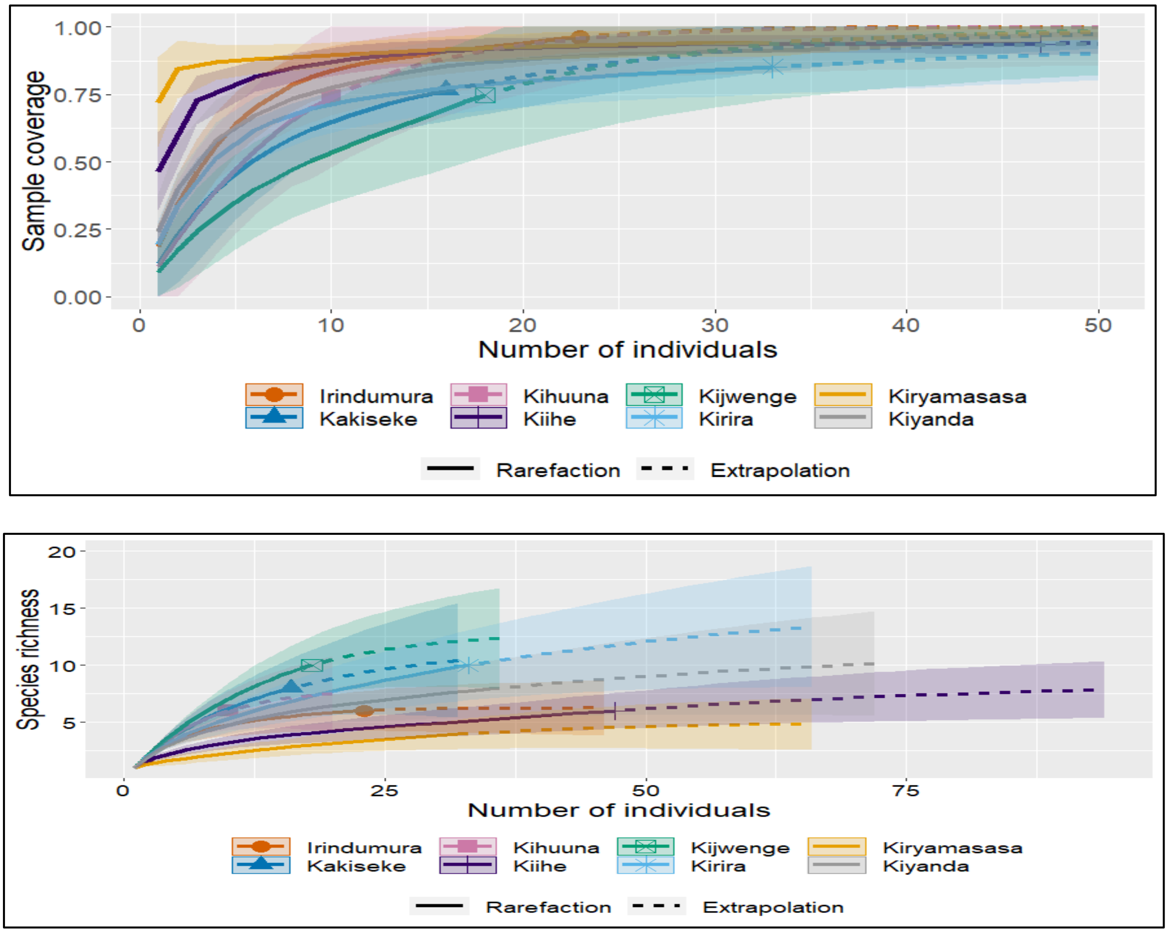

Figure 2 Species accumulation curves/Sample coverage curves

Species accumulation curves, (Fig 2) based on number of individuals and FMNR sites. Solid lines represent observed total species richness and dashed lines show species richness extrapolated to 50 and 75 individuals under species richness. Sample based showed that the sample coverage was adequate for the eight FMNR sites as shown by the flattening of the curves.

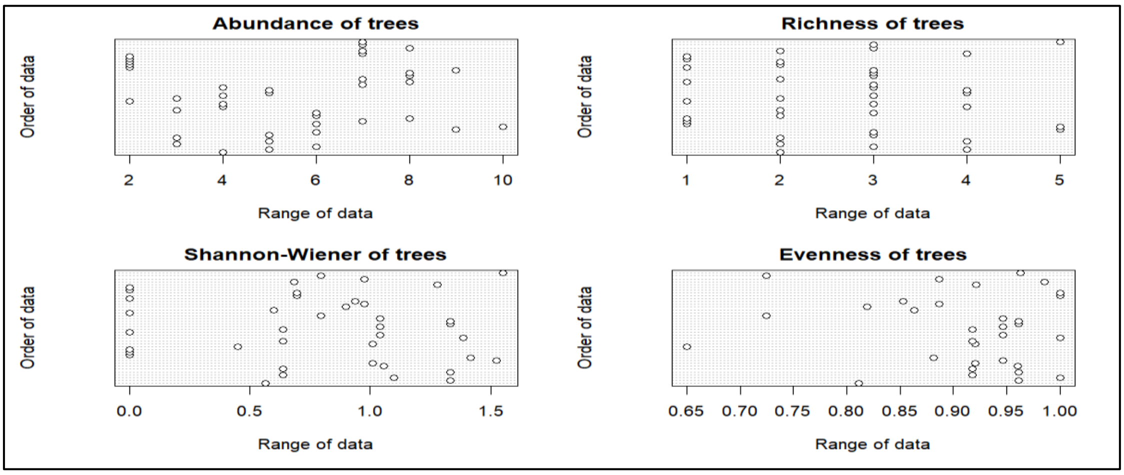

Figure 3 Scatter plots elucidating spread of data

Abundance of trees represents how different tree species were distributed across the scatter plots. In terms of evenness, most of the tree species were similar with some few unique tree species which were different. Basing on the results from Shannon – Wiener, the scatter plots indicate diversity across the different tree species.

3.2. Tree species on the farm

Table 3 Tree species Importance Value Index in the eight FMNR sites

Specie name	dbh (m)	Ht (m)	Fi	Ra	RFi	BAi (m2)	RD_0 (%)	IVI
Markhamia lutea	12.2	897.0	101	319.6	46.8	464.9	82.9	449.3
Antiaris toxicaria	3.3	113.9	19	60.1	8.8	33.8	6.0	75.0
Blighia unijugata	2.1	73.4	18	57.0	8.3	13.3	2.4	67.7
Spathodea campanulata	2.1	92.2	12	38.0	5.6	13.8	2.5	46.0
Albizia zygia	1.7	69.0	8	25.3	3.7	9.1	1.6	30.6
Phoenix reclinata	1.6	61.0	8	25.3	3.7	8.4	1.5	30.5
Trichilia dregeana	0.9	39.0	6	19.0	2.8	2.6	0.5	22.2
Bauhinia variegata	1.0	33.0	5	15.8	2.3	2.9	0.5	18.7
Artocarpus heterophyllus	0.8	28.0	5	15.8	2.3	2.1	0.4	18.5
Erythrina abyssinica	0.9	22.0	4	12.7	1.9	2.4	0.4	14.9
Albizia coriaria	0.6	21.0	4	12.7	1.9	0.9	0.2	14.7
Senna spectabilis	0.5	16.4	4	12.7	1.9	0.9	0.2	14.7
Funtumia elastica	0.6	33.0	3	9.5	1.4	1.3	0.2	11.1
Moringa oleifera	0.5	15.9	3	9.5	1.4	0.7	0.1	11.0
Mangifera indica	0.2	11.0	3	9.5	1.4	0.2	0.0	10.9
Vernonia amygdalina	0.2	9.8	3	9.5	1.4	0.1	0.0	10.9
Acacia gerrardii	0.8	36.0	2	6.3	0.9	2.0	0.4	7.6
Olinia rochetiana	0.2	5.8	2	6.3	0.9	0.1	0.0	7.3
Lannea barteri	0.3	6.0	1	3.2	0.5	0.3	0.1	3.7
Acacia hockii	0.3	7.0	1	3.2	0.5	0.3	0.1	3.7
Ficus exasperata	0.3	8.0	1	3.2	0.5	0.3	0.1	3.7
Ficus mucuso	0.2	6.0	1	3.2	0.5	0.1	0.0	3.6
Tabebuia pentaphylla	0.2	5.0	1	3.2	0.5	0.1	0.0	3.6
Shirakiopsis elliptica	0.2	2.0	1	3.2	0.5	0.1	0.0	3.6
Total	31.6	1611.4	216.0	683.5	100.0	560.8	100.0	883.6

Source: primary data 2024

F_i is the Frequency of the species i encountered. R_a is Relative abundance of species i encountered. RF_i is the Relative Frequency. BA_i is the Basal Area of all individual trees belonging to a particular species i(m^2). RD_0 is the Relative Dominance (%). IVI is the Important Value Index.

In terms of IVI, *Markhamia lutea* was the most preferred trees across all the sites comprising of 449.3%, followed by *Antiaris toxicaria with* 75.0%, *Blighia unijugata with 67.7%*, *Spathodea campanulata* with 46% and *Albizia zygia* with 30.6% respectively. *Shirakiopsis elliptica, Tabebuia pentaphylla, Ficus mucuso* were the least preferred trees across all sites with 3.6%. Across the eight study plots, 24 tree species with frequency of 216 were recorded. According to the study *Markhamia lutea* was the most preferred trees across all the sites comprising of 449.3% and this implies that it is important to grow with maize by fertilizing soil through shading leaves and flowers (14). The same results conceded with results from key informant interviews as extension worker Nalweyo Sub County had this to say "*Farmers like Markhamia tree in their gardens because its less competitive and has a light high canopy that allows other crops to grow*". This was further emphasized by production officer Kakumiro who said, "*Markhamia tree regenerates very fast than any other indigenous tree and is resistant to pests and diseases, more so it's the most source of fire wood for farmers"*

3.3. Tree management on Farmland.

Table 4 Tree management on farmland with crops

Question	Technique	Frequency	Percent
Management of trees as they grow with maize on the form the farm	Pruning	270	92.8
	Thinning	190	65.3
	Pollarding	44	15.1
	Coppicing	90	30.9
	Replanting	2	0.7
	Total	523	100.0

Source: primary data 2024

Regarding the management of trees growing with maize on the farm, majority 92.8% of the farmers reported to have been practicing pruning, 65.3% reported to be practicing thinning, 30.9% were using coppicing while 15.1% used pollarding to manage trees on the farm (Table 4)

[14] revealed that pruning can be one of the best things a farmer can do to improve crop production. The same results were in agreement with the Forest Officer Kakumiro who said *"Farmers are aware of the advantages of pruning so as to create a positive relationship between the tree and crops*"

3.4. Maize productivity

The dependent variable of the study was maize productivity. Maize productivity was measured by yield per acre, the quality of the maize and increase in productivity per year. Data on maize productivity is summarized in the table below

Table 5 Descriptive statistics on maize productivity

Question	Categories	Frequency	Percent
Increase of maize production after practicing FMNR	Yes	242	83.2
	No	49	16.8
	Total	291	100.0
Has the maize quality been good	Yes	249	85.6
	No	42	14.4
	Total	291	100
Quality of the maize produced under FMNR under observation	Bigger cobs	152	52.2
	Bigger seeds	162	55.7
	Strong stems (Vigor)	151	51.9
	Greener leaves	153	52.6
	Poor yields	18	6.2
	Double cobs	14	2.0

	High germination rate	20	2.2
	Total	454	100.0
Yield per acre	Less than 100Kgs	2	0.7
	100-500Kgs	23	7.9
	500-700Kgs	169	58.1
	One tone and above	97	33.3
	Total	291	100.0

Source: Primary data 2024

Table 5 shows that When farmers were asked about their yield per acre upon incorporation of FMNR majority 58.1% of the farmers reported to have got between 500-700 Kgs per acre of maize, 33.3% had yielded one tone and above. 7.9% had yields between 100-500Kgs and only 0.7% had less than 100kgs per acre after intercropping maize with trees on their farms. This was in agreement with production officer who said “Farmers lack access to improved maize seeds and have resorted to use of farmer saved seeds that yield low outputs” On further inquiry whether they had realized any increase of maize production after practicing FMNR majority 84.2% of the farmers had realized an increase of maize production after practicing FMNR. Only 15.8% of the maize farmers had not realized an increase in maize production after practicing FMNR. Analysis of the quality of the maize produced showed that 52.2% of the farmers had bigger cobs, 55.7% had bigger maize seeds, 52.6% had greener leaves while 51.9% of the famers had maize with stronger stems and vigor; all showing an improvement in quality of maize resulting from the use of FMNR on their maize farms.

3.4.1. Correlation between tree species richness and Maize quality

The correlation analysis conducted between tree species richness and Maize quality yielded the results shown below;

Table 6 Pearson Correlation between Tree Species richness and Maize Quality

		Tree species Richness	**Maize Quality**
Tree species Richness	Pearson Correlation	1	0.225
	Sig. (2-tailed)		0.592
	N	8	8
Maize Quality	Pearson Correlation	0.225	1
	Sig. (2-tailed)	0.592	
	N	8	291

Source: Primary data 2024. N is the number of study plots

Table 6 shows the weak positive relationship between Tree Species richness and Maize Quality among farmers of Nalweyo sub county ($r=0.225$, $p=0.592>0.05$). The positive relation means that two variables (Tree Species richness and Maize Quality) move in the same directions. The better the Tree Species richness the better the maize quality produced and the poorer the tree species richness, the poorer the Maize Quality among maize farmers.

3.4.2. Pearson Correlation between tree species richness and Maize quantity

The correlation analysis conducted between FMNR Tree Species Richness and Maize quantity yielded the results shown below;

Table 7 Pearson Correlation between FMNR Tree Species Richness and Maize Quantity

		FMNR Tree species Richness	Maize Quantity
FMNR Tree species Richness	Pearson Correlation	1	0.100
	Sig. (2-tailed)		0.815
	N	8	8
Maize Quantity	Pearson Correlation	0.100	1
	Sig. (2-tailed)	0.815	
	N	8	291

Source: Primary data 2024

Table 7 shows that there is a weak positive relationship between FMNR Tree Species richness and Maize Quantity among farmers of Nalweyo sub county (r=0.100, p=0.815>0.05). The positive relation means that two variables (FMNR Tree Species richness and Maize Quantity) move in the same directions. The better the FMNR Tree Species richness the better the maize Quantity produced and the poorer the tree species richness, the poorer the Maize Quantity among maize farmers.

3.4.3. Pearson Correlation between Tree Species Evenness and Maize quality

The correlation analysis conducted between Tree Species Evenness and Maize quality yielded the results shown below;

Table 8 Correlation between Tree Species Evenness and Maize Quality

		Maize Quality	Tree species Evenness
Maize Quality	Pearson Correlation	1	-0.054
	Sig. (2-tailed)		0.898
	N	291	8
Tree species Evenness	Pearson Correlation	-0.054	1
	Sig. (2-tailed)	0.898	
	N	8	8

Source: Primary data 2024

Table 8 shows that there a negative relationship between FMNR tree species evenness and maize quality among farmers of Nalweyo sub county (r=-0.054, p=0.898). The negative relation means that two variables (FMNR tree species evenness and maize quality) move in the different directions. The better the FMNR tree species evenness the poorer the maize quality produced and the poorer the FMNR tree species evenness, the better the quality the maize by farmers.

3.5. Multiple Regression Analysis of FMNR practice and maize production

Multiple regressions are a general and flexible statistical method for analyzing associations between two or more independent variables and a single dependent variable. A multivariate regression model was run to determine the relative importance of each of the variables with respect to the practice of FMNR on maize productivity in Nalweyo Sub County. The variable coefficients from the regression will show the effect (whether positive or negative) of the independent variables on the dependent variable.

Table 9 Regeneration of tree species richness and species evenness on Maize productivity

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.873[a]	0.763	0.644	0.225198

Predictors: (Constant), farmer Perspectives, tree species richness, tree species evenness from the above (Table 10)

From the above table it can be concluded that all aspects of Farmer Managed Natural Regeneration of tree species richness and tree species evenness reflect an adjusted R-square of 0.644 to Maize productivity among farmers in Nalweyo sub county, Kakumiro district. This means that a positive change in FMNR tree species richness and tree species evenness aspects causes a change in Maize productivity by 0.644 (64.4%). This finding conquers with [14]. [20] who found a positive impact of FMNR on crop yields when the tree density was between 15 and 40 trees hectare.

4. Conclusion

The study concludes that Farmer Managed Natural Regeneration affects Maize productivity among farmers in Nalweyo Sub County, Kakumiro district. Farmer Managed Natural Regeneration (FMNR) of tree species richness affects maize productivity among farmers (r=0.203, p=0.629).

This signifies that FMNR of trees species insignificantly increases maize production. Therefore, there is a positive effect of tree species richness on maize productivity.

It was concluded that Farmer Managed Natural Regeneration (FMNR) of tree species evenness negatively affects maize productivity among farmers of Nalweyo sub county (r=-0.656, p=0.039). This signifies that FMNR of trees species evenness significantly reduces maize production. Therefore, there is a negative relationship effect of tree species richness on maize productivity.

Farmer Managed Natural Regeneration (FMNR) farmer perspectives affects maize productivity among farmers of Nalweyo sub county (r=0.744, p=0.000). This signifies that FMNR farmer perspectives significantly affect maize production. Therefore, there is a positive effect of tree FMNR farmer perspectives on maize productivity.

Recommendations

There should be proper selection of the right species that grow together with maize and farmers realizing the positive relationship that exist between crops and trees and farmers need more knowledge on the tree species that give better results in an integrated approach.

For increased maize production, emphasis be put on building their capacity on tree management practices especially pruning so as to reduce competition and suppression effects to crops.

Where tree species evenness occurs, there is need to encourage farmers to practice enrichment planting with different tree species so as to promote diversity of ecosystems and improved productivity. More so where tree species do not occur, assisted natural regeneration should be encouraged as a means of conserving indigenous trees on farm.

To stimulate peer to peer learning and exchange visits among farmers, creation and development of agroforestry demonstration learning sites at community level for better adoption of tree crop interventions that aim at increasing crop productivity and linkages.

For purposes of sustainability, government should reward and recognize environmental stewards (Ever green farmers) through payment for ecosystem services and carbon trade. This kind of motivation can further act as a multiplier effect of adopting ever greening practices at community level.

More scientific research on *Markhamia lutea* is needed to clearly spell out its ecological uses as opposed to being an ornamental tree.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

All participants in this study, were consulted and accepted to offer service on a voluntary basis.

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