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ANALYSIS OF SUSTAINABLE AGRICULTURAL PRACTICES AND FOOD SECURITY IN NYAGATARE DISTRICT OF RWANDA

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Abstract: **This study examined the relationship between sustainable agricultural practices and food security in Nyagatare District of Rwanda, focusing on organic farming, agroforestry, conservation tillage, and irrigation. Aiming to empower farmers with climate-resilient practices and aid policymakers in developing eco-friendly policies, it also aimed to inform efforts against soil erosion and deforestation. Targeting 7,085 farmers, with 379 respondents selected through stratified and convenience sampling. Data were collected through a questionnaire and analyzed using descriptive and inferential statistics, including correlation coefficient and multiple linear regression analysis with SPSS IBM version 23.0. The findings revealed high adoption of organic farming practices, such as crop rotation and composting, which positively correlated with food security (Spearman's rho = 0.614, $p < 0.01$). Agroforestry practices, including fruit tree planting and alley cropping, also showed a positive correlation with food security (Spearman's rho = 0.486, $p < 0.01$) despite moderate engagement levels. Conservation tillage practices, such as no tillage and cover cropping, strongly correlated with food security (Spearman's rho = 0.569, $p < 0.01$). Similarly, irrigation practices, like drip and sprinkler irrigation, positively affected food security (Spearman's rho = 0.418, $p < 0.01$). Overall, sustainable agricultural practices exhibited a strong positive correlation with food security (Spearman's rho = 0.586, $p < 0.01$). The study emphasized the need for thorough research to understand specific challenges faced by farmers, such as financial limitations and lack of information, to design targeted interventions. Suggested efforts included microcredit schemes, expanding agricultural extension services, and promoting community engagement programs.**

Keywords: **Food security, agriculture practices, Organic Farming, Agroforestry, Conservation Tillage, Irrigation Practices.**

1. INTRODUCTION

1.1. Background of the Study

Agriculture has a significant contribution to Rwanda's economy. The industry employs 64.5% of the working population and accounts for around 25% of the national GDP. The role of research in agricultural production is critical, particularly in addressing concerns such as agricultural productivity, climate change, pest and disease management, soil depletion, and so on. In Rwanda, agricultural research is the driving force behind agricultural expansion, resulting in food security, combatting hunger, and reducing severe poverty. (Ministry of Agriculture and Animal Resources, Annual Report 2023).

To offset these effects, sustainable measures such as climate-smart agriculture are critical. Such measures help to mitigate the consequences of climate change while also ensuring constant food supply (FAO,2013). Water scarcity in Rwanda dramatically reduces agricultural productivity, emphasising the crucial importance of proper water management and irrigation systems, especially in light of changing climatic conditions.

There are recurring floods and landslides in many parts of the country resulting from climate change and extreme hydrological events. The causes are closely related to the steepness of terrain (hilly topography) and intense rainfall leading to increased soil erosion and reduced land availability for agriculture that affects food security and export earnings (Rwanda Water Resources Board Strategic Plan 201-2030).

Furthermore, the International Water Management Institute (IWMI) highlights the importance of developing resilient irrigation infrastructure to mitigate the effects of climate change on agricultural productivity (IWMI 2020). Despite economic progress, environmental challenges like soil erosion, deforestation, and environmental degradation persist, threatening agricultural sustainability (UNEP, 2021). Nyagatare District exemplifies these challenges with its distinct climatic profile characterized by prolonged dry seasons and limited precipitation, heightening vulnerability to climate variability (NISR, 2023).

1.2. Problem Statement

Nyagatare District faces significant climate change challenges, including minimal rainfall and high temperatures, with a dry season lasting three to five months and annual temperatures ranging from 25.3°C to 27.7°C. Rainfall is erratic and insufficient, averaging 827 mm annually, which is inadequate for crops and livestock needs (NISR, 2022). Unsustainable agricultural practices, including excessive pesticide use, deforestation, and soil erosion, further degrade land quality and harm local ecosystems and biodiversity (UNEP, 2021). Previous research on climate change impacts on food security and sustainable agriculture in Rwanda often overlooks the specific challenges faced by Nyagatare. National or regional studies lack the focused analysis needed for local-level issues. Addressing these challenges requires evidence-based policies and strategies tailored to Nyagatare's unique circumstances. There is a significant gap in translating research findings into actionable policies to enhance agricultural sustainability, reduce climate-related risks, and protect the environment in Nyagatare. This study aims to fill this gap by analyzing sustainable agriculture methods and their impact on food availability in Nyagatare District, crucial for long-term agricultural sustainability, food security, and the welfare of the local population.

1.3. Objectives of Study

1.3.1 General Objective

The overarching goal of this study was to undertake a thorough analysis and evaluation of the link between sustainable farming practices and food security in the specific geographical setting of Nyagatare District, in Rwanda.

1.3.2. Specific Objectives

(i) To assess the influence of organic farming on food security in Nyagatare district.

(ii) To investigate effect of agroforestry on food security in Nyagatare district.

(iii) To examine the impact of conservation tillage on food security in Nyagatare district.

(iv) To evaluate the influence of irrigation practices on food security in Nyagatare district.

1.4. Research Hypotheses

The hypotheses listed below are designed to guide the study toward a better understanding of the issues at hand. These hypotheses are intended to elicit comprehensive and nuanced responses:

Ho1: Organic farming has no statistically meaningful influence on food security in the Nyagatare District.

Ho2: There is no statistically significant effect of agroforestry on food security in Nyagatare district.

Ho3: Conservation tillage has no statistically meaningful influence on food security in the Nyagatare District.

Ho4: There is no statistically significant impact of irrigation methods on food security in the Nyagatare district.

2. REVIEW OF RELATED LITERATURE

Unsustainable agricultural methods compound these problems, including land degradation and biodiversity loss (UNEP, 2021). Despite larger study on the effects of climate change on Rwandan food security, specific dynamics in Nyagatare remain little understood. This study intends to close these gaps by examining sustainable approaches in Nyagatare such as organic farming, agroforestry, conservation tillage, and irrigation systems. It aims to inform strategies that promote long-term agricultural sustainability and food security in the district. The study offers stakeholders concrete ideas for promoting sustainable agriculture practices, including resolving adoption hurdles, providing targeted support and training, and developing supporting regulations. Increased involvement can help to create more sustainable and resilient agricultural systems, hence boosting food security and livelihoods.

Sustainable agricultural strategies are crucial for ensuring food security and environmental sustainability. Crop rotation, agroforestry, conservation tillage, and integrated pest control all contribute to increased soil fertility, reduced erosion, and increased biodiversity. Sustainable agriculture ensures long-term productivity and resilience to climate change impacts such as variable rainfall and rising temperatures (Smith et al. 2010). Crop rotation and cover cropping enhance soil structure and nutrient content, resulting in increased yields and more robust crops. Agroforestry, which combines trees with crops and livestock, improves biodiversity while also providing farmers with extra revenue streams. Conservation tillage decreases soil disturbance while retaining soil organic matter and moisture, which is critical for agricultural output in the face of climate change (FAO, 2014).

In response to these challenges, the Rwandan government and various development organizations have promoted several sustainable agricultural practices. Organic farming, for example, involves methods like crop rotation, composting, and natural pest control, which aim to improve soil health and reduce dependency on chemical inputs (Reganold & Wachter, 2016). Agroforestry practices integrate trees into agricultural landscapes, promoting biodiversity and providing additional income sources for farmers (Garrity, 2004; Nair, 2007). Conservation tillage techniques, such as no-till farming and cover cropping, help improve soil structure, reduce erosion, and enhance water retention (Derpsch et al., 2010; Hobbs & Gupta, 2020). Efficient irrigation methods, like drip and sprinkler systems, are also introduced to optimize water use efficiency in farming practices (Burney et al., 2010; Hussain & Hanjra, 2004).

2.1 Conceptual Framework

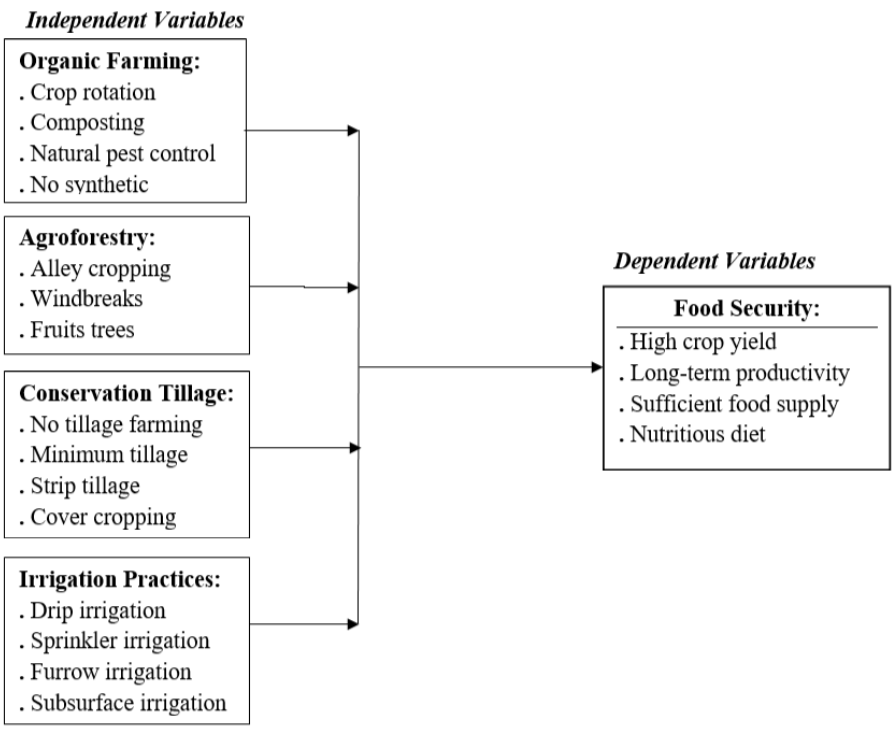

Figure 1: Conceptual Framework

Source: Researcher (2024)

3. RESEARCH METHODOLOGY

3.1. Research Design

Research design is a structured plan guiding data collection, measurement, and analysis. Creswell and Creswell (2018) state that a well-constructed research design helps achieve study objectives. This study used descriptive methods to depict the current state in Nyagatare and a cross-sectional approach to capture data at a specific time, aiming to quantify agricultural productivity and gather contextual insights.

3.2. Study Area Description

Nyagatare District, located in Rwanda's Eastern Province, has a rural agrarian economy with crop cultivation and livestock farming. It faces climate challenges like erratic rainfall, rising temperatures, and droughts, affecting agriculture and food security (NISR, 2022). The district spans 1,919 square kilometers, with a 2022 population of 653,861, making it the most populous in the province (NISR, 2022).

3.3. Target Population

The research targeted 7,085 farmers in cooperatives growing cereals, pulses, and vegetables. These farmers' perspectives are crucial for understanding sustainable farming methods and their impact on food security. Nyagatare's agricultural activities include a high percentage of households engaged in farming, with significant crop diversity across sectors (Source: Nyagatare administration).

3.4. Sample Design

A stratified sampling approach was used, categorizing farmers into three groups: cereal, pulse, and vegetable farmers. The sample size of 379 was calculated using Yamane's formula, ensuring proportional representation from each stratum.

3.5. Sampling Technique

Convenience sampling was employed, selecting participants based on accessibility and availability, regarded as purposive in this context (Neuman, 2014).

3.6. Data Collection Methods

A self-administered questionnaire was the primary data collection tool. It included structured and unstructured questions to gather comprehensive responses. Data collection was supported by introductory letters from Mount Kenya University and Nyagatare District, ensuring participant confidentiality and ethical compliance.

3.7. Reliability and Validity of Instruments

To ensure validity, instruments were evaluated by experts. Construct validity ensured accurate measurement of variables. Reliability was assessed using Cronbach's Alpha, with a coefficient above 0.70 indicating high internal consistency.

3.8. Data Analysis Methods

Data analysis utilized SPSS and Excel. Descriptive statistics analyzed frequencies, percentages, means, and standard deviations. Inferential statistics, including correlation coefficient and multiple linear regression analysis, were used to establish relationships between sustainable farming practices (independent variables) and food security (dependent variable). The multiple linear regression analysis test used the econometric model equation as stated below: X represents Sustainable Agricultural Practices (SAP), which was an independent variable consisting of four sub-variables.:

X1: Organic Farming

X2: Agroforestry

X3: Conservation Tillage

X4: Irrigation Practices

While Y is Food Security (FS) as dependent variable.

Then, Y=F(X), which provides, $\mathbf{Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \varepsilon}$

β0= constant number; **β1, β2, β3**, and **β4**: are coefficients of **X** while **ε**: is a standard error.

3.9. Ethical Considerations

Ethical considerations included obtaining informed consent, ensuring confidentiality, and anonymizing personal identifiers. Data storage was secured to maintain integrity and confidentiality during and after the study.

4. RESEARCH FINDINGS AND DISCUSSION

The study analysed the relationship between sustainable farming practices and food availability in Nyagatare District, Rwanda. It specifically investigated the impacts of organic farming, agroforestry, conservation tillage, and irrigation practices on food security in the region.

4.1. Findings on the influence of organic farming on food security in Nyagatare district.

The study on organic farming's impact on food security in Nyagatare district reveals widespread adoption of key organic practices among respondents. Data from 379 participants highlight significant use of methods like crop rotation, composting, natural pest control, and avoidance of synthetic pesticides (Table 1). Overall, respondents strongly agree on the effectiveness of these practices, reflected in a high average mean score of 4.4281. Low standard deviations indicate consistent responses, with negative skewness indicating widespread high ratings. Varying kurtosis values suggest differing frequencies of extreme responses across practices. These findings emphasize organic farming's crucial role in enhancing food security in Nyagatare. Practices such as crop rotation, composting, and natural pest management foster sustainable agriculture, ensuring reliable food production in the region.

Table 1: The influence of organic farming on food security in Nyagatare district

Organic Farming Practices	N	Mean	Std. Deviation	Skewness	Kurtosis
I practice Crop Rotation	379	4.314	0.81914	-0.898	-0.168
I implement Composting	379	4.5092	0.67596	-1.041	-0.152
I utilize Natural Pest Control	379	4.4195	0.81047	-1.596	2.889
I avoid Synthetic Chemicals	379	4.4697	0.8489	-1.9	3.964
Overall Average	**379**	**4.4281**	**0.7886175**	**-1.35875**	**1.63325**

Source: Primary data (2024)

Table 1 reveals insights into respondents' perceptions of organic farming's impact on food security in Nyagatare district. The mean score of 4.314 for crop rotation indicates widespread adoption among respondents, with a low standard deviation suggesting consistent implementation. Negative skewness (-0.898) indicates high ratings for crop rotation, while slight negative kurtosis (-0.168) suggests a moderately even distribution.

Composting, with a mean of 4.5092, also shows high adoption, supported by a low standard deviation and negative skewness (-1.041), indicating strong agreement among respondents. Slight negative kurtosis (-0.152) suggests a relatively uniform distribution. Natural pest control, mean score 4.4195, exhibits moderate spread (standard deviation = 0.81047) and strong inclination towards higher ratings (skewness = -1.596), with more respondents clustering around the mean (kurtosis = 2.889). Avoidance of synthetic chemicals, mean 4.4697, is highly rated (skewness = -1.900), with responses clustered at the high end (kurtosis = 3.964).

Overall, organic farming practices (mean= 4.4281) are widely implemented, with respondents showing strong agreement (average skewness = -1.359) and responses clustered around high mean values (average kurtosis = 1.633). These findings underscore organic farming's critical role in enhancing food security in Nyagatare district. High mean values and low standard deviations indicate strong commitment to organic farming in Nyagatare, crucial for enhancing food security through sustainable practices. Negative skewness and kurtosis values further affirm widespread adoption and concentrated high ratings, highlighting organic farming's pivotal role in district food security.

Findings on the effect of agroforestry on food security in Nyagatare district. This section explores how agroforestry practices impact food security in Nyagatare district using primary 2024 data. It analyzes alley cropping, windbreak use, and fruit tree planting to assess their role in improving regional food security, detailed in Table 2.

Table 2: Findings on the effect of agroforestry on food security in Nyagatare district

Agroforestry Practices	N	Mean	Std. Deviation	Skewness	Kurtosis
I engage in Alley Cropping	379	4.5092	0.79801	-1.93	4.096
I utilize Windbreaks	379	4.4063	0.90476	-2.078	4.868
I plant Fruit trees	379	4.5594	0.73717	-1.959	4.707
Overall Average	**284**	**3.3687**	**0.609985**	**-1.49175**	**3.41775**

Source: Primary data (2024)

In Table 2, you can see how the respondents evaluated the impact of agroforestry on food security in Nyagatare district. Alley cropping received a mean score of 4.5092 with a standard deviation of 0.79801, indicating widespread adoption. The negative skewness (-1.93) and high kurtosis (4.096) suggest that the distribution is skewed and peaked around the mean, reflecting strong engagement. Windbreaks scored a mean of 4.4063, with a standard deviation of 0.90476, showing slightly lower adoption than alley cropping.

Negative skewness (-2.078) and high kurtosis (4.868) indicate a skewed distribution with a peak, although less pronounced than alley cropping. The planting of fruit trees received the highest mean score of 4.5594 and had a standard deviation of 0.73717, indicating strong adoption. It exhibited a negative skewness (-1.959) and high kurtosis (4.707), suggesting a distribution skewed and peaked around the mean, similar to other practices.

Overall, agroforestry practices in Nyagatare district scored a a mean of 3.3687 with a standard deviation of 0.609985, indicating moderate engagement. They displayed a negative skewness of (-1.49175) and a kurtosis of (3.41775), indicating a distribution that is skewed and moderately peaked around the mean and suggesting varying levels of adoption across practices. The results indicate that fruit tree planting is the most prevalent agroforestry technique in Nyagatare district, followed by alley cropping and windbreak utilization. The consistently high mean scores across these practices reflect a positive reception and active participation in agroforestry, suggesting its beneficial impact on food security in the region.

4.2. Findings on the impact of conservation tillage on food security in Nyagatare district.

In this section, we will analyse the impact of conservation tillage practices on food security in Nyagatare district. Based on primary data collected in 2024, the analysis will focus on different conservation tillage techniques such as no tillage, minimum tillage, strip tillage, and cover cropping. The findings will offer a comprehensive understanding of how these practices influence food security, emphasizing the extent of involvement and the statistical distribution of responses among the surveyed population.

Table 3: Findings on the impact of conservation tillage on food security in Nyagatare district

Conservation Tillage Practices	N	Mean	Std. Deviation	Skewness	Kurtosis
I practice No Tillage	379	4.3826	0.98605	-1.892	3.413
I practice Minimum tillage	379	4.343	0.91346	-1.402	1.468
I practice Strip tillage	379	4.3536	0.89179	-1.386	1.529
I utilize Cover cropping	379	4.2876	1.03337	-1.668	2.398
Overall Average	**379**	**4.3417**	**0.9561675**	**-1.587**	**2.202**

Source: Primary data (2024)

The findings from Table 3 illustrate the perspectives of respondents regarding the impact of conservation tillage on food security in Nyagatare district. Participants practicing no tillage reported a mean score of 4.3826 with a standard deviation of 0.98605, indicating robust engagement in this practice. The negative skewness (-1.892) suggests a left-skewed distribution, with most respondents rating their adoption of no tillage above the mean, and a leptokurtic kurtosis (3.413) indicates a concentrated distribution around the mean.

Similarly, those using minimum tillage showed a mean score of 4.343 with a standard deviation of 0.91346, demonstrating strong involvement with less skewness (-1.402) and a more normal kurtosis (1.468). Strip tillage practitioners reported a mean of 4.3536 and a standard deviation of 0.89179, with skewness (-1.386) and kurtosis (1.529) values indicating a slightly skewed distribution. Participants employing cover cropping had a mean score of 4.2876 and a standard deviation of 1.03337, with skewness (-1.668) and a leptokurtic kurtosis (2.398) suggesting a concentration of higher scores.

Overall, the mean score for conservation tillage practices in Nyagatare district was 4.3417, with a standard deviation of 0.9561675. The negative skewness (-1.587) indicates a left-skewed distribution, emphasizing widespread engagement. The kurtosis (2.202) suggests a peaked distribution but less pronounced compared to no tillage. These findings indicate that conservation tillage practices are well-adopted and positively perceived, contributing significantly to food security. Variations in skewness and kurtosis values across different practices reflect differences in the distribution and concentration of responses among farmers in the district.

4.3. Findings on the influence of irrigation practices on food security in Nyagatare district.

This section examines the impact of different irrigation practices on food security in Nyagatare district, using 2024 primary data. It assesses techniques like drip, sprinkler, furrow, and subsurface irrigation. The study offers statistical insights into how these practices are adopted and their perceived influence on local food security.

Table 4: Findings on the influence of irrigation practices on food security in Nyagatare district

Irrigation Practices	N	Mean	Std. Deviation	Skewness	Kurtosis
I use Drip irrigation	379	4.3747	0.89205	-1.529	2.005
I use Sprinkler irrigation	379	4.3615	0.87511	-1.44	1.844
I use Furrow irrigation	379	4.3193	0.9845	-1.812	3.292
I use Subsurface irrigation	379	4.3773	0.87747	-1.475	1.901
Overall Average	**379**	**4.3582**	**0.9072825**	**-1.564**	**2.2605**

Source: Primary data (2024)

Findings in Table 4 indicate the impact of different irrigation methods on food security in Nyagatare district. In Nyagatare district, irrigation practices show robust adoption and high engagement. Drip irrigation users reported an average score of 4.3747 (SD = 0.89205), indicating strong adoption with a left-skewed distribution (skewness = -1.529) and peaked responses around the mean (kurtosis = 2.005). Sprinkler irrigation scored 4.3615 on average (SD = 0.87511), also showing strong engagement with similar distribution characteristics (skewness = -1.44, kurtosis = 1.844). Furrow irrigation users averaged 4.3193 (SD = 0.9845), displaying a left-skewed (skewness = -1.812) and leptokurtic distribution (kurtosis = 3.292). Subsurface irrigation users averaged 4.3773 (SD = 0.87747), indicating robust engagement with left-skewed (skewness = -1.475) and peaked distribution (kurtosis = 1.901).

Overall, irrigation practices in Nyagatare district scored a mean of 4.3582 (SD = 0.9072825), reflecting widespread adoption and high engagement. Negative skewness (-1.564) suggests a left-skewed distribution, with most respondents highly engaged. The kurtosis (2.2605) indicates a peaked distribution around the mean, highlighting concentrated responses with some variability. These findings indicate well-established and positively perceived irrigation practices, likely contributing significantly to food security. Variations in skewness and kurtosis values underscore differences in response distribution across different irrigation methods.

4.4. Findings on the indicators of Food Security in Nyagatare district

This section analyzes key food security indicators in Nyagatare district using 2024 primary data. It examines crop yields, sustainable farming practices, food supply stability and sufficiency, and dietary diversity and nutrition. These indicators offer a thorough assessment of food security, reflecting the district's capacity to meet food needs consistently and sustainably.

Table 5. Findings from respondents about Indicators of Food Security

Indicators of Food Security	N	Mean	Std. Deviation	Skewness	Kurtosis
1. Consistently high crop yields in Nyagatare are capable of meeting the food needs of the population;	379	4.5119	0.73228	-1.951	5.232
2. Sustainable farming practices and soil fertility indicate that the district can maintain agricultural output over time, ensuring food security;	379	4.52	0.7464	-1.641	2.358
3. A stable and sufficient food supply, with regular access to adequate food for all residents, demonstrates food security in Nyagatare District;	379	4.6016	0.68398	-1.842	3.236
4. There is a presence of a diverse and nutritious diet among the population, with access to a variety of food groups.	379	4.5594	0.67341	-1.446	1.557
Overall Average	**379**	**4.5482**	**0.7090175**	**-1.72**	**3.09575**

Source: Primary data (2024)

Table 5 presents findings on key food security indicators in Nyagatare district based on 2024 data. Respondents reported a high average score of 4.5119 (SD = 0.73228) for the belief that high crop yields meet population food needs, indicating strong confidence in crop yield adequacy. Negative skewness (-1.951) suggests widespread high ratings, while high kurtosis (5.232) indicates a sharply peaked distribution around the mean.

For sustainable farming practices and soil fertility maintaining agricultural output, the mean score was 4.52 (SD = 0.7464), highlighting robust confidence in long-term food security. Skewness (-1.641) indicates a left-skewed distribution with predominantly high ratings, and kurtosis (2.358) suggests moderate concentration around the mean with variability. The highest mean score of 4.6016 (SD = 0.68398) was for a stable and sufficient food supply ensuring regular access to food, showing strong consensus on its critical role in food security. Skewness (-1.842) indicates a left-skewed distribution, and kurtosis (3.236) suggests a sharply peaked distribution

Regarding dietary diversity's importance for food security, the mean score was 4.5594 (SD = 0.67341), indicating strong belief in its significance. Skewness (-1.446) suggests a left-skewed distribution with high ratings, and kurtosis (1.557) indicates a distribution closer to normal with some concentration around the mean. Overall, the district's average score for food security indicators was 4.5482 (SD = 0.7090175), reflecting strong consensus. Negative skewness (-1.72) indicates a left-skewed distribution, and kurtosis (3.09575) suggests concentration around the mean with variability across responses.

4.5. Multiple linear regression analysis results

The multiple linear regression analysis was conducted to examine the relationship between various agricultural practices and food security in Nyagatare district. The model summary provides insights into the overall fit of the regression model, while the coefficients table offers information about the individual predictors' contributions to explaining variations in food security. Additionally, the ANOVA table assesses the significance of the regression model as a whole. These results shed light on the predictive power of irrigation practices, agroforestry, conservation tillage, and organic farming on food security outcomes, providing valuable insights for agricultural policy and practice in addressing food insecurity challenges.

Table 6: Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.482[a]	.233	.224	2.06338	1.362

Source: Primary data (2024)

a. Predictors: (Constant), Irrigation Practices, Agroforestry, Conservation Tillage, Organic Farming.

b. Dependent Variable: Food Security.

The regression model (Table 6) evaluates predictors' impact on food security. R = 0.482 indicates a moderately positive relationship. R^2 = 0.233 explains 23.3% of food security variability, while adjusted R^2 = 0.224 adjusts for predictors, explaining 22.4% variability. The model's standard error of estimate is 2.06338, estimating deviation from predicted values. Durbin-Watson = 1.362 suggests slight positive autocorrelation in residuals. The model explains a moderate portion of food security variance, highlighting predictors (irrigation practices, agroforestry, conservation tillage, and organic farming) contributing collectively. Yet, other unaccounted factors might influence food security. Integrating additional variables could enhance model accuracy, refining insights into sustainable agricultural practices' impact on food security in Nyagatare District.

Table 7: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	482.615	4	120.654	28.339	.000[b]
	Residual	1592.324	374	4.258		
	Total	2074.939	378			

Source: Primary data (2024)

a. Dependent Variable: Food Security.

b. Predictors: (Constant), Irrigation Practices, Agroforestry, Conservation Tillage, Organic Farming.

The ANOVA analysis (Table 7) assesses the impact of agricultural methods on food security in Nyagatare district. The F-statistic of 28.339 indicates significant overall model significance, explaining more variance in food security than expected by chance. The p-value of 0.000 confirms a strong statistical link between predictors (irrigation practices, agroforestry, conservation tillage, organic farming) and food security. Ho1, rejecting that organic farming lacks significant impact on food security, aligns with a statistically significant coefficient (p = 0.000). Consequently, all null hypotheses (Ho1-Ho4) are rejected, indicating significant effects of organic farming, agroforestry, conservation tillage, and irrigation practices on food security in Nyagatare. These findings underscore the crucial role of specific agricultural practices in enhancing food security, offering insights for policy and interventions in the district.

Table 8: Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10.991	0.156		12.280	.000
	Agroforestry	.194	.051	.205	3.788	.000
	Conservation Tillage	.095	.040	.078	1.188	.000
	Organic Farming	.327	.005	.509	4.831	.000
	Irrigation Practices	.184	.060	.279	3.008	.000

Source: Primary data (2024)

a. Dependent Variable: Food Security.

Table 8 presents regression coefficients for predicting food security based on sustainable agricultural practices. The constant value of 10.991 indicates the baseline food security score when all predictors are zero. Agroforestry shows a coefficient of 0.194, indicating a 0.194-unit increase in food security for each unit increase in agroforestry practices ($t = 3.788$, $p < 0.001$). Conservation tillage contributes a coefficient of 0.095, suggesting a 0.095-unit increase in food security per unit increase in conservation tillage ($t = 1.188$, $p < 0.001$). Organic farming exhibits the most significant impact with a coefficient of 0.327, equating to a 0.327-unit rise in food security per unit improvement in organic practices ($t = 4.831$, $p < 0.001$). Similarly, irrigation practices have a coefficient of 0.184, leading to a 0.184-unit increase in food security for each unit increase in irrigation methods ($t = 3.008$, $p < 0.001$).

These findings underscore the positive influence of each sustainable agricultural practice on food security in Nyagatare District. Organic farming emerges as the most influential factor, followed by agroforestry, irrigation practices, and conservation tillage. These results emphasize the importance of promoting sustainable agricultural methods to enhance food security locally. Organic farming stands out for its substantial impact, highlighting its potential role in mitigating food insecurity in agricultural communities facing similar challenges.

The study's findings reveal that organic farming practices, widely adopted in Nyagatare District with an average score of 4.4281, significantly enhance food security (Spearman's rho = 0.614, $p < 0.01$). Organic methods like crop rotation and composting not only improve soil health and biodiversity but also reduce reliance on synthetic inputs, benefiting both agricultural sustainability and economic returns (Seufert et al., 2012; Pretty et al., 2006). Agroforestry, with a participation average of 3.3687, also shows a positive correlation with food security (Spearman's rho = 0.486, $p < 0.01$), providing diverse benefits such as soil protection and additional food sources (Garrity, 2004; Nair, 2007). Despite moderate engagement, agroforestry has been proven effective in enhancing food security and income in similar contexts (Nyaga et al., 2015).

Conservation tillage practices, scoring an average of 4.3417, contribute positively to food security by preserving soil structure and moisture, crucial for sustainable agriculture (Lal, 2004; Derpsch et al., 2010). High adoption rates underscore farmers' recognition of these benefits, though continued support is necessary to sustain and expand these practices (Baudron et al., 2012). Similarly, irrigation practices, with an average score of 4.3582, significantly correlate with food security (Spearman's rho = 0.418, $p < 0.01$), enhancing agricultural productivity and resilience against climate variability (Burney et al., 2010; Hussain and Hanjra, 2004).

The comprehensive analysis underscores that these sustainable agricultural practices collectively improve food security in Nyagatare District. Organic farming emerges as particularly influential due to its significant impact on food security, followed by agroforestry, conservation tillage, and irrigation practices. Addressing barriers to adoption through education, support programs, and policy initiatives can further enhance the benefits of these practices, promoting more sustainable and resilient agricultural systems in the region. By integrating these approaches, Nyagatare District can improve food security outcomes and support the livelihoods of its residents, aligning with global trends in sustainable agriculture.

5. CONCLUSION

Organic farming practices, including crop rotation and composting, show a significant positive relationship with food security in Nyagatare District, reflecting their role in stabilizing food production. Agroforestry practices such as fruit tree planting and alley cropping also contribute positively, though their adoption levels suggest room for improvement. Conservation tillage methods like no tillage and cover cropping are well-received and contribute to soil health and crop yield improvements. Meanwhile, irrigation practices such as drip and sprinkler systems play a crucial role in enhancing food security by stabilizing crop production in the face of variable rainfall.

Overall, sustainable agricultural practices significantly bolster food security in Nyagatare District. The study emphasizes the need for increased adoption and support for these practices to maximize their impact. Addressing barriers like knowledge gaps and initial costs is essential to enhancing the effectiveness of agroforestry and ensuring broader adoption across the district. By promoting a holistic approach, that integrates organic farming, agroforestry, conservation tillage, and efficient irrigation, Nyagatare can achieve more resilient agricultural systems, ultimately improving food security and livelihoods for its residents.

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