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Iyakaremye Ernest[1] & Dr. Richard Kabanda[2]
[1] Master of science in Economics, University of Kigali, Rwanda
[2] School of Graduate Studies, Senior Lecturer, University of Kigali, Rwanda

Abstract

The study was conducted to investigate the factors affecting household food security in rural districts of Rwanda. Specifically, the study aimed to assess the current state of household food security, analyze the influence of socioeconomic and sociodemographic factors on it, and evaluate gender-specific aspects of food security. The researchers used secondary data collected by the National Institute of Statistics of Rwanda in 2021 from 7,513 rural households for their analysis. They employed food security index estimation, logistic regression, and descriptive statistics to analyze the data. Within Rwanda's rural regions, the research discovered that family food security was greatly affected by variables such as the head of the household's age, education, farm size, gender, income, and access to credit, as well as the size of the home and money. Age and household size were negatively correlated with food security, in contrast to education, farm size, gender, income, and credit availability, which were positively correlated. Furthermore, compared to families headed by women, those headed by men were more likely to have food security, according to the research. In the rural areas of Rwanda, 60.83% of the families that were sampled had food security, while 39.13% had food insecurity. Improving food security in rural districts of Rwanda requires policies that target the unique difficulties experienced by individual families, as well as an emphasis on education and self-sufficiency, according to the study's results.

1. Introduction

Food insecurity is a major concern, particularly for individuals with lower socio-economic status, as it has been linked to a range of negative outcomes such as decreased productivity and academic performance, as well as behavioral, emotional, and health problems (Weerasekara *et al.*, 2020; Szabo *et al.*, 2022; Buscail *et al.*, 2019). It is a significant issue that should be continuously monitored. More than two billion people throughout the world face food insecurity, with developing nations bearing the brunt of this problem, according to the FAO (Marcantonio *et al.*, 2020). Household food security is closely related to children's nutritional status, which is influenced by socio-economic factors and local contexts (Chakona & Shackleton, 2018). Food insecurity is a global issue that contributes to poor health and nutritional deficiencies, particularly among marginalized populations (Weerasekara *et al.*, 2020).

The problem of migration and remittances affecting food security is a complex one, with mixed evidence available on the topic (Szabo et al., 2022). Food insecurity is a widespread problem that affects over 2 billion people, particularly those living in developing countries where it is a major issue (Mota *et al*., 2019). Even in industrialized nations, it's a problem; in 2017, 11.8% of American families were food insecure. Numerous factors, including household income, farm size, and socio-economic characteristics, are among the many determinants of food security (Alim *et al*., 2022). Having access to food, both financially and physically, and being able to put that food to good use are all parts of the larger picture that is food security (Amrullah *et al*., 2019). The well-being of households is significantly impacted by food security, as evidenced by its association with metabolic syndrome and its influence on sustainable land management technologies (Park & Strauss, 2020; Salau, 2020).

Multiple intricate social, agronomic, and nutritional aspects drive research on household food security determinants in rural Rwanda. This study is set against the backdrop of numerous challenges related to food security, malnutrition, and agricultural productivity, which have a profound impact on the welfare of households in rural Rwanda (Sly, *et al*., 2023).

The presence of food insecurity and malnutrition in Rwanda is a pressing concern, affecting 20.6% of the population and 33% of children under five years of age. Furthermore, a large number of people make their living in the agricultural sector, and a considerable number of households own farmland. However, reliance on markets for food procurement is also notable, indicating the importance of both agricultural production and market access to ensure food security (WFP, 2023).

The Rwandan government's National Strategy for Transformation (NST1) is geared towards modernising and boosting agricultural and livestock production, with the objective of increasing food production, consumption, and exports. This initiative includes extensive reforms and innovations such as collaboration with the private sector to promote agricultural mechanisation, irrigation, and improved seed varieties(MINECOFIN, 20017).

This research evaluates the food security disparities between rural and urban areas of Rwanda, revealing that rural regions experience more severe food insecurity and stunting. Furthermore, the study examines the impact of gender, education, land ownership, and livestock possession on food security outcomes in rural households.

The purpose of this research is to add to what is already known about the specific elements that affect food security in rural districts of Rwanda. The purpose of this study is to shed light on the factors that contribute to food insecurity, as well as its policy and practical consequences, by performing an exhaustive review of relevant empirical literature and using a rigorous research approach.

What follows is the outline of the rest of the document: Section 2 presents a comprehensive review of the relevant literature, including both theoretical and empirical perspectives. The technique and data sources used to evaluate food insecurity are described in Section 3. The analytical results and a thorough explanation of the findings are presented in Section 4. An overview of the main points and suggestions for food policy are provided at the conclusion of the article.

2. Literature Review

Theoretical Framework

Amartya Sen's theoretical framework, particularly his entitlement theory, provides a comprehensive understanding of the challenges surrounding hunger and food security. Sen's perspective emphasizes the importance of control over food, which can be achieved through direct production or converting wages into food. He argues that famine is primarily class-dependent, affecting those at the bottom of the economy, such as landless rural laborers. Sen's theory shifts the focus from food supply to accessibility and entitlement, considering factors such as political regimes, natural disasters, governance, and global issues. The significance of considering food security in relation to endowment and trade entitlement should be highlighted, since this shift in viewpoint is strongly associated with entitlement limits (Hossain, 2021; Rubin, 2018; Zhao *et al*., 2019; Barreda *et al*., 2019).

In contrast, modernization theory, stemming from Max Weber's ideas, posits that advancements in education, home investments, and industrialization result in cultural transformation and economic growth, ultimately improving food security. Furthermore, the ecological evolution theory proposed by Gerhard Lenski emphasizes the role of traditional plough agriculture and high agricultural density in accelerating industrialization and reducing economic inequality, thus contributing to food security. Additionally, the neo-Malthusian theory, based on Thomas Malthus's work, focuses on the disparity between population growth and food supply, highlighting the potential challenges to food security arising from rapid population growth (Hossain, 2021; Rubin, 2018; Zhao *et al*., 2019; Barreda *et al*., 2019).

The sources cited above provide extensive insights into various aspects of food security and related theories. For instance, Lenaerts et al.'s (2019) discussion of the challenges faced by global food security, including increasing demand, decreasing supply, and the need for resilient and sustainable production, offers valuable information. Arya et al.'s (2023) exploration of the entitlement approach proposed by Amartya Sen sheds light on the genesis of famine, emphasizing that famine can occur even when there is sufficient food available. It is crucial to understand the ranges of ecological security, as He *et al.* (2023) points out in their review of research evaluating the biodiversity of cultivated land. Research on the brittle structure model and set pair theory by Zhu *et al.* (2021) on obstacle diagnosis of ecosystem security adds to our knowledge of food security from several angles, including the social, economic, and ecological ones.

Li and Song (2022) reviewed the evolution of food security using bibliometrics, emphasizing the transition from focusing on the total amount of food to the quality and safety of food, as well as the balance between food supply and demand. By illuminating the origins of food entitlement, Muzerengi *et al.* (2021) investigated the potential synergy between systems theory and Amartya Sen's entitlement theory in order to develop a paradigm for achieving food security. Classical economic thinkers including A. Smith, D. Ricardo, M. Porter, and A. Maslow were acknowledged by Khuzhekova *et al.* (2022) as they outlined the evolution of the idea of food security. The research summarized here provide a thorough grounding in the theory and practice of food security.

In summary, the theoretical frameworks of food economy and entitlement, modernization theory, ecological-evolution theory, and neo-Malthusian theory offer valuable insights into the complex

issues surrounding food security. The referenced sources contribute to the understanding of these theories and their implications for addressing global food security challenges.

Empirical Review

Food insecurity among rural farming households is a pressing issue in various regions, such as Ethiopia, Gambia, and Rwanda. In a study conducted by Agidew and Singh (2018) in Ethiopia's Teleyayen sub-watershed, 79.1% of households faced food insecurity, with factors such as insufficient rainfall, poverty, recurring droughts, and land degradation significantly impacting food security (Nkomoki *et al*., 2019). Similarly, Sawaneh & Badjie (2019) conducted a study in rural Gambia, revealing that factors such as the age of the household head, income levels, assets, engagement in economic activities, support mechanisms, remittances, and land ownership significantly affect food security status (Otekunrin *et al*., 2021).

Researchers from the National Institute of Statistics and Statistics Rwanda (NISR) and the World Food Programme (WFP) found that low buying power, rising market prices, and seasonal resource scarcity are some of the factors that put Rwandan families at risk of food insecurity (2018). Furthermore, the research found that families led by women are more likely to experience food insecurity due to factors such as marital status and educational level. Nkomoki et al. (2019) found that households with more cattle had a lower likelihood of food insecurity, and our results are in line with that (Ajao *et al*., 2023).

Otekunrin *et al.* (2021) found that among Nigerian agricultural families, food insecurity is more common when non-farm income is high. Ajao *et al.* (2023) also found that food insecurity is best measured by how easy it is to get enough food, therefore our results are in line with theirs (Mundowa & Mumbengegwi, 2020).

Additionally, Mundowa and Mumbengegwi's (2020) study in Zimbabwe emphasized the need to recognize the factors that affect smallholder farmers' participation in non-farm employment activities in order to identify vulnerable households and design targeted policy interventions (as cited in Gebre & Rahut, 2021). Similarly, Gebre and Rahut (2021) stressed the connection between food access and climate vulnerability in East Africa, highlighting the need for targeted interventions to address food insecurity (as cited in Sezirahiga & Mukamazimpaka, 2021).

The research conducted by Sezirahiga and Mukamazimpaka (2021) in Rwanda revealed the impact of climate variability on crop production and rural farmers' livelihoods, as well as the positive correlation between crop projects and improved diet and food security (as cited in Fikre, 2020). Furthermore, Fikre (2020) research in Ethiopia highlighted the significance of agricultural pursuits in guaranteeing food security for households. Although the existing literature on food insecurity among rural farming households offers a comprehensive understanding of the contributing factors, there are still several gaps that need further investigation.

One of these gaps is the need for a more in-depth examination of the specific mechanisms by which non-farm income affects food security. Studies such as Gebre and Rahut (2021) and Otekunrin *et al.* (2021) have shown the influence of non-farm income on food insecurity, however, it is critical to recognize the many forms of non-farm income and how they affect food security. These forms include remittances, off-farm jobs, and small-scale businesses. This information would be valuable for policymakers and practitioners in developing effective strategies to address food insecurity among rural farming households.

The influence of household size on food security has been emphasized by research, as demonstrated by Nkomoki *et al.* (2019) and Jih *et al.* (2018), but the specific mechanisms through which this influence occurs remain unclear. To address this gap, future research could investigate intra-household dynamics, resource allocation, and coping strategies related to food insecurity in larger households compared to smaller ones.

In addition, some research have investigated the link between food insecurity and demographic characteristics. For example, Parekh et al. (2021) and Miguel et al. (2020) looked at this correlation, there is a need for more nuanced investigations into the intersectionality of these factors. A deeper understanding of how factors such as gender, age, education, and income interact to exacerbate or mitigate food insecurity would provide a more comprehensive understanding of this issue.

Additionally, the literature has highlighted the impact of external factors, such as climate change, land degradation, and market access, on food insecurity, as shown by Sime (2020). However, there is a need for research that explores the differential effects of these external factors across diverse geographical and socioeconomic contexts, taking into account the unique vulnerabilities and adaptive capacities of rural farming households in various regions.

Furthermore, although some studies have explored the factors contributing to food insecurity among specific demographic groups, such as university students or older adults, there is a lack of comprehensive comparative analyses across different demographic segments within rural farming households. Conducting research on how food insecurity manifests differently among men, women, children, and the elderly in these households would yield valuable insights for implementing targeted interventions.

Finally, there has been less effort to assess the efficacy of policies and programs designed to alleviate food insecurity; instead, the current research has concentrated on determining the causes and frequency of food insecurity. Future research should prioritise rigorous evaluations of food security interventions, including agricultural support programs, income generation initiatives, and social safety nets, to identify best practices and inform evidence-based policy recommendations.

In conclusion, additional study is required to fill in certain gaps in our understanding of the causes of food insecurity among rural agricultural families, even if the current literature has offered valuable insights in this area. Future research may help fill in these blanks, leading to a more complex understanding of food insecurity and the development of more precise interventions to improve the food security of rural farming families, particularly in rural Africa.

3. Methodology

The proposed research strategy to explore food insecurity in rural farming households involves a multidisciplinary approach that incorporates theories from economics, sociology, geography, and political science. The research provided a thorough knowledge of the variables influencing food security by using a mixed-method methodology, which combines quantitative and qualitative methodologies. The research guided by Sen's entitlement theory, focusing on individuals' control over essential goods like food within established norms and customs. The study will analyze fair distribution, economic equity, and capability deprivation, as highlighted by Bouton et al. (2020), Sferrazzo & Ruffini (2019), and Arya et al. (2023.The study will apply Sen's capability approach, which examines individuals' capacity to attain desired outcomes and lead a fulfilling life, as a framework for evaluating the well-being and quality of life of rural farming households, with a

focus on food security and economic engagement (Assad-Uz-Zaman et al., 2020; Hart, 2018; Zhao et al., 2019).

This study examines the ecological evolution theory, which highlights the influence of traditional plough agriculture and high agricultural density on driving industrialization and reducing economic disparities, ultimately contributing to food security (Neglo *et al.* 2021). Additionally, the research investigates the impact of the non-farm sector and urban planning on food security, focusing on the connections between economic activities, welfare, and public interest. The study evaluates the influence of non-farm employment, a circular economy, and sustainable development on household food security, as outlined by Stoica and Stoian (2022) and Bajmócy et *al.* (2020).

Furthermore, the research examines the political economy of debt and entitlements, analyzing power dynamics and obligations linked to entitlements in the context of food security. This provides insights into the political and economic aspects of food access and entitlements, particularly in relation to accumulating debt and total obligations, as outlined in Bouton et al. (2020). The study investigates food insecurity by examining economic policy, income distribution, and capability deprivation in marginalized communities, as outlined in Marlina *et al.* (2019), "Justice in the Philosophy of Amartya Sen" (2019), and Arponen (2018). The works of Amartya Sen are used to provide a comprehensive understanding of the socioeconomic factors that contribute to food insecurity. The study employs multiple linear regression and Bayesian techniques to identify factors such as household size, income, agricultural productivity, and food resource availability that contribute to food insecurity (Sime, 2020). Additionally, grounded theory methodology is used to analyze qualitative data and gain insight into the experiences and coping mechanisms of households dealing with food insecurity (Brand, 2023).

The study conducted in Gambia by (Sawaneh & Badjie,2019) employed a logit model methodology to investigate the factors affecting food security status among rural farmers. The results showed that various factors such as the age of the family head, income levels, assets, engagement in economic activities, support mechanisms, remittances, and land ownership significantly influenced the food security of households.

The research study conducted by (Agidew & Singh, 2018) aimed to identify the factors contributing to food insecurity in rural farming households within Ethiopia's Teleyayen sub-watershed. Various statistical methods, including the logit regression model, chi-square, percentage, mean were employed to analyze the collected data.

The study employed a binary logistic regression model to identify the factors influencing home food security in the Bajo community within the Napano Kusambi Sub District. The findings demonstrated that the variables that substantially affected the food security of households were Household earnings, the age of the household leader, and the age of the female head of the household (Limi, Zani, & Selvi, 2021).

The functional form of the logistic model is described as follows

$$P_i\left(Y = \frac{1}{z}\right) = \frac{e^{z_i}}{1+e^{z_i}} \quad (1)$$

$$P_i(Y = 0/z) = 1 - P_i(Y = 1/z) = 1 - \frac{e^{z_i}}{1+e^{z_i}} = \frac{1}{1+e^{z_i}} \, (2)$$

The Probability that a given household is secure is expressed by (1),and the Probability that a given household is insecure is given by (2)

Therefore, we can write as

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \quad (3)$$

Where $\frac{P_i}{1-P_i}$ is the Odds ratio in Favor of food is secure.

The ratio of Probability that household was food secure to the probability of that it was food insecure ,Final take the natural log of equation (3) we get

$$Li = ln\left(\frac{P_i}{1-P_i}\right) = Z_i = B_0 + B_i X_{1i} + B_2 X_{2i} + \cdots B_n X_n \quad (4)$$

Where P_i : The probability that a household is secure.

$1 - P_i$: The probability that a household is insecure.

Z_i : is a function of n explanatory variables (x) and is expressed as:
$Z_i = B_0 + B_i X_{1i} + B_2 X_{2i} + \cdots B_n X_n \quad (5)$
B_0 is Intercept, B_1, B_2 ………….…....B_n are the slope of equation in the model
Li: is log of odds ratio
X_i :is a vector of relevant household characteristics, if Error term (U_i) is introduced ,the logit model becames:

$L_i = B_0 + B_i X_{1i} + B_2 X_{2i} + \cdots B_n X_n + U_i \quad (6)$
In this research, eight explanatory variables were used for achieving the Objectives of this study,

therefore (6) becomes:

$$Li = ln\left(\frac{P_i}{1-P_i}\right) = B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5 + B_6 X_6 + B_7 X_7 + B_8 X_8 + U_i \quad (7)$$

The probability prediction equation can be deduced and the logit equation for p can be solved by deriving it from the given equation (7).

$$, P_i = \frac{e^{B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5 + B_6 X_6 + B_7 X_7 + B_8 X_8}}{1 + e^{B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5 + B_6 X_6 + B_7 X_7 + B_8 X_8}}$$

X_1: Age of head of household
X_2 : Education of head of household
X_3 : Farm size
X_4: Gender of head of household
X_5: Household size
X_6 : Income of head of household

X_7 : livestock
X_8 : Access to Credit.
U_i : Error term
Based on this study, the factors affecting household food security in rural district of Rwanda indicate that the dependent variable in this study is food security and it is dichotomous dependent variable in the model, since it can take value of 1 if a household is food secure and 0 otherwise.

Due to the binary or dichotomous nature of the dependent variable, the binary logistic regression model is appropriate for this research.

According to (Stoltzfus, 2011)logistic regression serves as a potent and effective method for examining the impact of a set of independent variables on a binary outcome. It quantifies the

distinct contribution of each independent variable by utilizing elements from linear regression, expressed in the logit scale. Through an iterative process, logistic regression identifies the most influential linear combination of variables that maximizes the probability of observing the given outcome.

Logistic regression is employed to assess the association between one or multiple independent variables and a binary (dichotomous) outcome variable (Schober& Vetter ,2021; Breen,Bernt &Anders,2018)

Basic assumption of logistic regression

Logistic regression differs significantly from linear regression as it departs from several critical assumptions upheld by linear models, general linear models, and other models based on ordinary least squares algorithms. Unlike linear regression, logistic regression does not necessitate a linear association between the dependent and independent variables. Additionally, it does not mandate the normal distribution of error terms (residuals), homoscedasticity, or the measurement of the dependent variable on an interval or ratio scale. Despite these distinctions, logistic regression does retain some assumptions from linear regression while introducing its own set of considerations (Schreiber-Gregory, Jackson & Bader, 2018).

When using binary logistic regression, a binary dependent variable is needed, whereas ordinal logistic regression requires an ordinal dependent variable, logistic regression presupposes that the instances within the dataset are independent of one another, logistic regression relies on the assumption that there is not a significant presence of multicollinearity among the predictor variables. Finally, for logistic regression, a large sample size is frequently required. A general rule is that you need at least ten cases with the least frequent outcome for each independent variable in your model (Schreiber-Gregory, Jackson, & Bader,2018).

Testing the significance of Model

Three often used tests for evaluating the overall significance of the logit regression model are the Score, Likelihood ratio, and Wald tests. The most used measure of goodness of fit in ML estimations is the likelihood ratio. The likelihood ratio is the difference between the unconstrained model and the constrained model .The null hypothesis H0 is that the model brings no significant information as follows:

$$LR = 2(lnL_{Unc} - lnL_C)$$

With degrees of freedom equal to the difference in the number of parameters estimated in the two models, LR is asymptotically distributed as a Chi-square.

High LR values will lead the observer to reject hypothesis H0 and accept the alternative hypothesis H1 that the set of explanatory variables does significantly explain the outcome (Park & Hyeoun-Ae, 2013).

Variable definition and Measurement

The definition and Measurement of the variables used in this study were presented in table 1 below.

Table 1: Definition and measurements of variables

Variable	Definition and measurements
Dependent variable:	
Household food security	1= if household is food secure and 0 otherwise
Independent variable:	
Age	Age of head of the household in years
Education of head of household schools	Number of years head of household spent in
Farm size	Farm size in hectare
Gender of head of the household	1=if head of the household is male and 0 otherwise
Household size	Number of member of household
Income	Monthly income of head of household in (rwf)
Livestock	1= if household possesses livestock and 0 otherwise
Access to credit	1=if household access to credit and 0 otherwise

Data Sources

In this study, we used the secondary data from Comprehensive Food Security and Vulnerability Analysis survey (CFSVA), the data was collected in 2021 by the National Institute of Statistics of Rwanda in collaboration with World Food Program (WFP).

4. Data Analysis & Interpretation,

The use of logit regression model is aimed at presenting the econometric outcomes of the proposed variables. In order to determine what variables may affect food security in the home, we choose to employ maximum likelihood (ML) estimations. It was critical to check for multicollinearity among the regressor variables before running the analysis.

Table 2: Variance Inflation Factors test

Variable	VIF	1/VIF
AGE	1.30	0.767005
EDUCATION	1.21	0.828784
FARMSIZE	1.15	0.870608
GENDER	1.35	0.739806
HOUSEHOLDSIZE	1.25	0.800480
INCOME	1.09	0.919562
LIVESTOCK	1.09	0.914161
ACCESSTOCREDIT	1.06	0.941997

Source: Author's calculations

Finding out how much multicollinearity there was among the predictor variables was the goal of calculating the variance inflation factor. No signs of multicollinearity between the variables were found throughout our analysis. Given that no predictor variable has a variance inflation factor (VIF) greater than 10, it may be concluded that multicollinearity is not a significant concern.

Table 3: Summary of dependent variable

Food security	Freq.	Percent	Cum.
0	2,943	39.17	39.17
1	4,570	60.83	100.00
Total	7,513	100.00	

Source: Author's calculations

Table 3, shows the statistical descriptions of dependent variable and indicate that the dependent variable in this study is dichotomous dependent variable, since it can take value of 1 if a household is food secure and 0 otherwise. Due to the binary or dichotomous nature of the dependent variable, the binary logistic regression model is appropriate for this research.

Table 4: Correlation Analysis

Variable	food security of households	Significant
AGE	-0.0539	0.0000
EUCATION	0.1316	0.0000
FARMSIZE	0.0480	0.0000
GENDER	0.0124	0.0001
HOUSEHOLDSIZE	-0.2135	0.0000
INCOME	0.1427	0.0000
LIVESTOCK	-0.0466	0.2728
ACCESSTOCREDIT	0.0857	0.0000

Source: Author's calculations

This research aimed to determine whether variables, such as head of household age, education level, household size, farm size, head of household gender, income, and access to credit, were associated with food security in households. Researchers evaluated the linear relationship strength between the dependent and independent variables by using correlation analysis. Food security decreases as the age of the household head grows, according to the results, which show a strong negative correlation between household food security and the head's age ($r = -0.0539$, $p < 0.0000$). On the other hand, there was a strong correlation between household food security and the education level of the head of the family ($r = 0.1316$, $p < 0.000$), indicating that education significantly impacts food security. Reincke *et al.* (2018) found a positive association between farm size and household food security, indicating that bigger farms tend to provide more food options for households. Additionally, the research found that there was a negative association between household food security and the age of the head of the family, suggesting that as the head of the household becomes older, food security tends to decline (Mulugeta *et al.*, 2018). Education and farm size are two of the most important factors in improving food security for households, according to the study's findings.

Ogunniyi *et al.* (2021) found a strong positive correlation between farm size and family food security, with bigger farms leading to better food security for households. Ogunniyi *et al.* (2021) also found that families led by men had better food security than households headed by females, and this connection was statistically significant. However, according to Ogunniyi *et al.* (2021), there was a strong negative relationship between household food security and household size ($r =$

-0.2135, p < 0.0001). This suggests that as household size increases, food security also decreases. A larger family is likely to have less food security, according to Kleve *et al.* (2018), who also discovered a statistically significant negative correlation between the two variables. In addition, Chowdhury *et al.* (2018) found a positive association between family head income and household food security, suggesting that higher incomes are associated with better food security. In a similar vein, Ikudayisi *et al.* (2019) found that having access to credit correlates positively and significantly with food security in the home.

Ogunniyi *et al.* (2021) found that household income positively affects food security, implying that higher incomes lead to better food security. Furthermore, Ogunniyi *et al.* (2021) found a strong positive correlation between having access to credit and food security. On the other hand, there is a negative association between food security and family size, suggesting that bigger households are associated with worse food security (Kleve *et al.*, 2018). There is a positive correlation between household income and food security, suggesting that a higher income leads to greater food security (Chowdhury *et al.*, 2018).

In addition, having access to credit correlates positively and significantly with food security, according to Ikudayisi *et al.* (2019). Keep in mind that although correlation analysis does show a connection between variables, it does not tell you which way the two variables are influencing each other. Therefore, more studies like logistic regression are needed to identify the determinants that impact food security status in households (Guiné *et al.*, 2021). These results show how several demographic and socioeconomic variables influence family food security.

Table 5: Maximum likelihood estimated of logit model

Variable	Coefficient	OR	Std. Error	z-Statistic	Prob.
C	1.215902	3.373335	0.131054	9.277868	0.0000
AGE	-0.006320	0.9936997	0.001840	-3.435744	0.0006
EDUCATION	0.336207	1.399629	0.046623	7.211116	0.0000
FARMSIZE	0.115254	1.122158	0.023483	4.907965	0.0000
GENDER	0.295494	1.343791	0.065850	4.487408	0.0000
HOUSEHOLDSIZE	-0.329303	0.7194249	0.014578	-22.58946	0.0000
INCOME	1.76E-05	1.000018	1.43E-06	12.28505	0.0000
LIVESTOCK	-0.067147	0 .9350575	0.061233	-1.096585	0.2728
ACCESSTOCREDIT	0.422122	1.525194	0.062489	6.755172	0.0000
Log likelihood = -4554.8342					
Number of obs = 7,513					
LR chi2(8) = 950.41					
Prob > chi2 = 0.0000					

Source: Author's calculations

In their research on household food security in rural districts of Rwanda, Pakravan-Charvadeh *et al.* (2021) found that seven of the eight explanatory factors they looked at significantly affected food security. At the 5% level of significance, the study found that food security was influenced by the following factors: the age and education level of the household head, the size of the home and farm, the gender of the head of the household, the income of the household, and access to credit.

The logit model analysis revealed a negative and statistically significant coefficient for the age of the family head. This suggests that food security declines with increasing household head age. According to previous studies, the likelihood of food insecurity in families decreases as the head of the family becomes older (Pakravan-Charvadeh *et al.*, 2021). This result is in keeping with those findings.

There was a positive and strong relationship between the educational attainment of the household head and providing food security, according to the research. This suggests that in rural homes, the chance of attaining food security improves as the head's degree of education rises. Nkomoki *et al.* (2019) found that higher levels of education among household heads were positively associated with food security, and our results are in line with that. An additional finding from the study was a negative association between the number of people living in a family and their likelihood of being food secure. According to Weatherspoon *et al.* (2019), there is a strong negative correlation between the number of people living in a family and their ability to afford food.

The study found a positive and statistically significant relationship between the size of a farm and the food security of households. This data demonstrates that the probability of attaining food security is enhanced as farm size grows. Previous research has shown a favorable correlation between larger farms and greater food security, which is in line with our current findings (Movahed *et al.*, 2022). Furthermore, the research discovered that there is a positive correlation between the gender of the household head and the chance of food security for the home. Consistent with previous study that has found a positive association between the gender of the household head and food security, male-headed families are more likely to achieve food security than female-headed households (Yazdanpanah *et al.*, 2021). A higher household income was also associated with a higher likelihood of food security, according to the study's significant coefficient of household income. Consistent with other research, this finding indicates that higher family income is associated with better food security (Haque *et al.*, 2022).

Research has shown that there is a favorable association between households having access to credit facilities and their chances of achieving food security. Issahaku *et al.* (2023) found that having access to credit improves food security, and our results are in line with that. Logit model analysis revealed that food security in Rwandan rural households is impacted by a number of socioeconomic and demographic factors. These factors include the head of the household's age, education level, household size, farm size, gender, income, and access to credit. These results highlight how these variables are very important in determining whether or not rural families have food security.

Table 6: Marginal effect of significant explanatory variable

Variable	Change in the probability of food security	z-Statistic	Prob.
AGE	-0.0013293	-3.45	0.001
EDUCATION	0.0707149	7.30	0.000
FARMSIZE	0.0242414	4.94	0.000
GENDER	0.0621517	4.51	0.000
HOUSEHOLDSIZE	-0.0692627	-26.08	0.000
INCOME	3.69e-06	12.69	0.000
ACCESSTOCREDIT	0.0887854	6.83	0.000

Source: Author's calculations

The results show that there are a lot of factors that affect the problem of family food security. In particular, the probability of having access to sufficient food decreases as the age of the head of the home decreases. Contrarily, indicators of improved food security include higher levels of education, larger farms, higher incomes, more female representation among family heads, and easier access to financing. Logit model study backs up these findings and emphasizes how these variables impact food security in households (Abdela *et al.,* 2021).

To better understand the relationships between explanatory factors and food security, marginal effects analysis thoroughly examines the influence of covariates on the chance of obtaining food security. By breaking down the outcomes of the logistic model in this way, we can see how each component affects food security in the home in a more nuanced way (Uberti, 2022). This study adds to the existing body of knowledge on the factors impacting food security in rural districts of Rwanda by providing a more nuanced understanding of the relationships between explanatory variables and the likelihood of attaining food security. It does this by incorporating the marginal effects of covariates (Abdela *et al.*, 2021). Because of the complexity of the variables that affect food security, our results highlight the need to employ marginal effects in logit models to investigate the causes of food insecurity in households.

By revealing the precise influence of each explanatory variable on food security outcomes, the study's use of the marginal effects technique provides a thorough examination of family food security. The intricate web of causes affecting food insecurity in rural Rwanda may be better understood with this method (Abdela *et al.*, 2021). In order to determine how different variables affect food security in rural Rwandan households, this research used marginal effects to compute the changes in probability in the logit model. The findings showed that the chances of attaining food security were greatly influenced by variables including the age of the family head, degree of education, size of the farm, gender, household size, income, and availability of credit. Holding all other factors constant, the chance of attaining food security decreased by 0.00132 for every one-year rise in the age of the household head, which was the only marginal change in age that negatively affected the likelihood.

In contrast, Uberti (2022) discovered that, everything else being equal, the likelihood of attaining food security increased by 0.0707 points for every degree of education, suggesting a positive relationship between education and food security. This discovery is in line with what Sen has shown, which is that entitlements and skills are crucial in guaranteeing food security. To be more specific, the study's identification of wealth and educational attainment as critical variables is in line with Sen's (Otekunrin *et al.*, 2021) focus on the significance of these elements in attaining food security. The study's findings on the impact of family income and size on food security may also be seen through the lens of the ecological-evolutionary theory, which describes the dynamic relationship between these two types of processes. The negative relationship between family size and food security may be attributable to natural constraints on resource availability, but the positive relationship between income and food security implies that families have adapted to increase their economic resources in order to enhance food security (Asrani, 2021).

A useful tool for estimating the likelihood of an occurrence given a number of parameters, the logit model was used in the research. Because of the marginal effect of gender and farm size on food security, this model determines the probability of certain variables and generates a marginal plot. with example, with every one hectare increase in farm area, the likelihood of a family

reaching food security rose by 0.0242. Households headed by men had a 0.0621 greater chance of food security than those headed by females.

But the research also showed that having more people living in a home decreased the chances of being food secure. In particular, while holding all other variables constant at their average levels, the likelihood of obtaining food security reduced by 0.0692627 for each extra family member. In contrast, the chance of obtaining food security increased by 3.69 percentage points for every unit increase in income, while holding all other factors constant at their average values, indicating that an increase in income positively impacts this probability.

Education and technical progress are key to the modernization idea, which the study's findings corroborate. According to Gomila (2021), the research found that greater farm sizes and better levels of education both contribute to food security. The neo-Malthusian hypothesis, which examines how an expanding population affects food supplies, is also relevant to the gender-related results of the research. As pointed out by Breen *et al.* (2018), the research found that gender is a key determinant. This might be a reflection of the demographic dynamics at work, which impact food security results.

By include marginal effects in the logit model, researchers have been able to better understand how each variable affects family food security and draw more accurate conclusions. Our comprehension of the complex interaction of elements impacting food security has been enhanced as a result of this (Pham, 2019). Using marginal effects, Abdela *et al.* (2021) revealed the influence of several variables on family food security by determining changes in probability inside a logit model. In Rwanda's rural areas, factors that greatly affected the possibility of attaining food security were the head of the home's age, degree of education, farm size, gender, household size, income, and availability of credit. The impact of each variable on the probability of attaining food security in rural families was shown via marginal effects. To illustrate the point, according to Pham (2019), the probability of attaining food security decreased with each incremental change in the head of household's age but increased with each incremental change in the head's education level, farm size, gender, income, and access to borrowing.

To find out how statistically significant the collection of explanatory factors was in connection to the outcome, we ran the Likelihood Ratio Test for Goodness of Fit, which is shown in Table 5. With the alternative hypothesis stating that the collection of explanatory variables substantially explained the result and the null hypothesis stating that the model gave no meaningful information in between, we can see how these two theories interact. It was clear that the collection of explanatory factors had a substantial impact on the result since the P-value of the test strongly supported the rejection of the null hypothesis and acceptance of the alternative hypothesis. The research looked at two models' capacity to explain household food security using the log-likelihood measure, and it attempted to assess the link between the set of explanatory factors and the result using the Likelihood Ratio Test for Goodness of Fit. The findings demonstrated that the collection of explanatory factors had a major influence on the outcome, as shown by the statistically significant p-value of 0.000000. The likelihood ratio of 950.4144 indicates that the models with unconstrained parameters adequately explained the result and produced useful information (Pham, 2019).

Table 7: Likelihood ratio Test

	Value	Probability
Likelihood ratio	950.4144	0.000000

Source: Author's calculations

The Likelihood Ratio Test emphasizes the significance of the p-value in showing that logit models can capture the impact of explanatory variables on food security in rural regions of Rwandan households. This finding reinforces the validity and effectiveness of the models in explaining the variability in food security outcomes based on the selected explanatory variables. The results of the Likelihood Ratio Test provide substantial evidence that the set of explanatory variables plays a crucial role in explaining the outcome, thereby confirming the relevance and efficiency of the models in assessing household food security in rural Rwanda (Pham 2019).

Each variable's impact on food security in rural families may be better understood by looking at the marginal effects of the logit model. In addition, the models' ability to capture the influence of explanatory variables on household food security in rural parts of Rwanda is shown by the Likelihood Ratio Test for Goodness of Fit. Most often, the likelihood ratio is used in conjunction with the log-likelihood metric to assess the quality of fit. The alternative hypothesis posits that the set of explanatory factors significantly explains the outcome, while the null hypothesis argues that the model adds no meaningful information.

5. Conclusion

Examining what elements impact rural Rwandan households' food security is the primary goal of this study. The findings show that food security in rural regions is greatly affected by a number of factors, such as the age and education level of the family head, the size of the farm, the size of the household, the gender of the head of the household, income, and access to credit. Food security in rural Rwanda is positively affected by the following factors: income, gender of the family head, size of the farm, degree of education of the household head, and availability of credit. In contrast, food security is negatively affected by both the number of people living in the family and the age of the head of the household. The data showed that the majority (60.83%) of the surveyed households in rural Rwanda are food secure, indicating that a significant portion of the rural population has reliable access to nutritious and sufficient food. However, 39.17% of the sampled households in rural Rwanda face food insecurity. Although many people are food secure, it is crucial to address food insecurity as a significant issue that requires attention and targeted interventions.

The results also show that there is a gender gap when it comes to food security for household heads. To be more specific, food security is higher in families headed by men than by women. This research suggests that gender is one of the variables influencing food security outcomes in rural regions. Based on this, the researcher proposed the following recommendations to enhance food security in the rural district of Rwanda:

It is recommended to promote family planning and awareness programs to mitigate the adverse effects of household size on food security. Such efforts could involve imparting knowledge on the methods and benefits of family planning to help manage and control household size.

Considering the positive influence of access to credit on food security, financial institutions and policymakers should collaborate to develop and enhance mechanisms for rural households to access credit. This would empower families to invest in agricultural inputs, education, and other income-generating activities. Therefore, commercial banks and other lending institutions should extend affordable credit in rural areas to overcome the current limitations faced by households due to limited credit availability.

6. Recommendations

It is in this context that the researcher draws the following recommendations for improving food security in rural district of Rwanda:

Addressing the adverse effects of household size on food security, it is advisable to promote family planning and awareness programs. These efforts may involve providing education on the methods and benefits of family planning to help manage and control household sizes.

Recognizing the positive impact of access to credit on food security, financial institutions and policymakers should work towards creating and improving mechanisms for rural households to access credit. This could empower families to invest in agricultural inputs, education, and other income-generating activities therefore lending institutions such as commercial banks ought to extend affordable credit in rural areas. This will lessen the limitation that households in the research area currently face due to limited credit availability.

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