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Impacts of Crop Production and Value Chains on Household Food Insecurity in Kwazulu-Natal: An Ordered Probit Analysis

Thobani Cele * and Maxwell Mudhara

School of Agricultural, Earth, and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg 3201, South Africa
* Correspondence: thobanivpa@gmail.com

Abstract: Household food insecurity persists in the KwaZulu-Natal Province, South Africa, despite the significant contribution of agriculture to the country's economy. The role that the combination of crop production systems and value chains can play in improving household food security has yet to be addressed. This paper examines the combined effects of crop production systems and value chains on household food insecurity. A Principal Component Analysis (PCA) transformed the correlated variables into three distinct domains, namely, modern agro-production practices, sustainable market integration, and traditional knowledge. An Ordered Probit Analysis was used to determine the factors that influence household food insecurity. Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS) using 300 randomly selected smallholder farmers. The results showed that sustainable market integration, traditional knowledge focus, education, and livestock ownership significantly and negatively impact a household's food insecurity. A household's size, food expenditure, and cash credit, as well as floods, significantly and positively affect its food insecurity. Policymakers and stakeholders should prioritise the integration of a sustainable market and the preservation of traditional knowledge, while reducing the food costs, in order to combat household food insecurity.

Keywords: household food security; crop production systems; value chains; ordered probit model; principal component analysis

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1. Introduction

Agriculture plays a significant role in many nations, by driving both economic growth and employment opportunities, especially in sub-Saharan Africa, where the issue of food insecurity continues to be a significant challenge [1]. The KwaZulu-Natal Province in South Africa has a diverse agricultural sector, which contributes significantly to national food production [2]. However, household food insecurity remains a pressing issue, with a substantial part of the population experiencing inadequate access to safe and nutritious food [3].

Recent impactful events, including the COVID-19 pandemic, Russia's war in Ukraine, and the devastating KZN floods, have significantly compromised food security in South Africa. While the nation is deemed food secure at the national level, according to Stats S.A., the scenario shifts at the household level, with nearly 20% of households grappling with food insecurity. In 2023, approximately 20% (1 in 5) of South Africans faced food insecurity [4].

Within the realms of moderate and severe food insecurity, the female and black population groups emerged as the most affected. A multitude of factors contribute to this predicament, including poverty, unemployment, income inequality, climate change, the cost of living, unstable food production, past spatial imbalances, and the capacity to produce food [5]. A study by the Integrated Food Security Phase Classification (IFSPC) body underscores the COVID-19 pandemic mitigation measures, escalating food prices, drought, and the country's economic decline as primary causes of food insecurity in South Africa.

To address the persistent issue of food insecurity, studies like [6–9] have been conducted to examine the relationship between agricultural practices and food security. However, according to the authors' knowledge, no studies have focused specifically on the interaction between crop production systems and value chains and their relationship with household food insecurity in South Africa. Refs. [10–13] focused on crop production systems and their impact on household food security, but they overlooked the role of value chains. Similarly, Refs. [14–17] explored the impact of value chains on household food security, but they neglected the role played by specific crop production systems. The research conducted to date demonstrates the need to understand the combined impact of crop production systems and value chains on household food security.

This study recognises that the impact of production systems cannot be viewed in isolation from the broader value chains within which they operate [18]. The value chain describes the full range of activities that are required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use [17]. According to [19], both crop production systems and value chains can allow for a comprehensive understanding of the factors that influence household food security.

2. Materials and Methods

2.1. Study Site and Sampling Procedure

Two rural areas (Swayimana and Umbumbulu) in the KwaZulu-Natal Province were selected for this study as shown in Figure 1. These two rural areas were chosen because they represent the typical socio-economic, biological, and demographic characteristics of KwaZulu-Natal. Swayimana is in the uMgungundlovu District Municipality (UDM), under the Mshwati Local Municipality, and Umbumbulu is in the eThekwini Metropolitan Municipality.

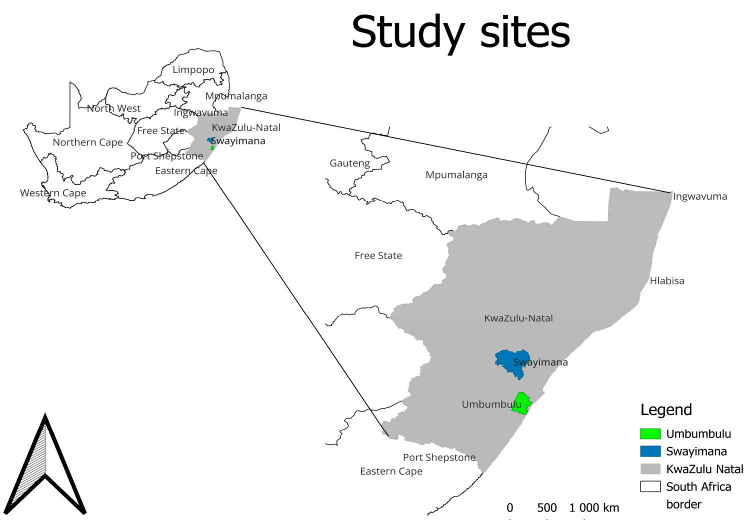

Figure 1. Location of study sites in the KwaZulu-Natal Province of South Africa.

The uMgungundlovu District Municipality is in KwaZulu-Natal and is comprised of seven local municipalities that are connected to different towns [20]. This study focused on Swayimana based on its bioresources, socio-economic, and demographic categories. The region receives an average of 600 to 1200 mm of rain annually, with Swayimana specifically receiving 600 to 1100 mm [21]. Swayimana is part of the humid Midlands in the mist belt. The average temperature ranges from 11.8 °C to 24.0 °C, with Swayimana having an average temperature of 17 °C. The Midlands have dry winters and warm, wet, and cold summers [21]. The soil is a productive type of clay loam.

The Umbumbulu region is part of the eThekwini Metropolitan Municipality in the coastal area of KwaZulu-Natal. The annual rainfall in Umbumbulu is 956 mm [22], which is abundant for agriculture, with most rain falling between November and March. Smallholder farming in the region starts in September or October before the start of the rainy season. The maximum and minimum temperatures in Umbumbulu are 24.0 °C and 13.4 °C, respectively [22]. According to [23], 15% of the Umbumbulu region has good potential for annual agriculture, while 9% is fertile, but less suitable. Its climate is ideal for a wide range of crops, including taro roots and sweet potatoes, and farming can be conducted all year round, with most smallholder relying on rainfall.

2.2. Data Collection and Sampling

In the survey conducted from July to September 2022, a comprehensive effort was made to gather data from a diverse group of smallholder farmers in Umbumbulu and Swayimana, South Africa. A total of 300 farmers were randomly selected to ensure a representative sample. The demographic characteristics of these farmers were considered, including age and gender. This approach aimed to capture a holistic understanding of the agricultural landscape, recognising the potential influence of demographic factors on farming practices and food security outcomes. The survey employed a questionnaire that had undergone meticulous pre-testing among 30 smallholder farmers in June 2022. Expert enumerators, proficient in Zulu, were instrumental in the pre-test and the subsequent survey, ensuring effective communication and comprehension of the questionnaire among the farmers.

The pre-testing phase played a crucial role in refining the questionnaire, not only to verify the farmers' understanding but also to ensure that it comprehensively captured all necessary information. This iterative process improved the translation of the questionnaire into Zulu, enhancing its cultural and linguistic appropriateness. By incorporating demographic considerations and employing rigorous pre-testing procedures, this study aimed to provide a nuanced and accurate portrayal of the experiences and practices of smallholder farmers in the Umbumbulu and Swayimana regions. The ethical considerations, such as informed consent and confidentiality, were diligently observed throughout the data collection process.

2.3. Analytical Framework

This study used an Ordered Probit Model and the STATA Version 15 statistical analysis software to address the limitations associated with the binary choice models that were used in previous food security studies. In this case, the Ordered Probit Regression Model is preferred to multinomial logit or binary choice models, in view of its discrete variables, the values of which are ordinal [24]. This study effectively unveils crucial insights into the genuine condition of household food security, by using the Ordered Probit Model.

The dependent variable that is used in this study is ordered, with respect to the categories of household food security. Ref. [25] stated that the selected model is helpful for determining the multiple determinants of household food security. Underlying the indexing in such models is a latent, but continuous, descriptor of the response, i.e.,

$$Y_i{*} = \beta' X_i + \varepsilon_i \tag{1}$$

where Y_i^* is the latent and continuous measure, X_i is a vector of the explanatory variables describing the independent descriptors, β is a vector of the parameters to be estimated, and ε_i is a random error term.

The observed and coded discrete Y_i is determined from the model as follows:

$$\begin{aligned} Y_i = 0 \text{ if } & -\infty \leq Y_i^* \leq \mu_1 \\ 1 \text{ if } & \mu_1 < Y^* \leq \mu_2 \\ 2 \text{ if } & \mu_2 < Y^* \leq \mu_3 \\ 3 \text{ if } & \mu_3 < Y^* \leq \infty \end{aligned} \tag{2}$$

The μ_1 represents the thresholds to be estimated (along with the parameter vector β).

2.4. Data Analytical Methods

This study employs several data analytical methods, i.e., the Household Food Insecurity Access Scale (HFIAS) for food security measurement, Principal Component Analysis (PCA) for reducing the directionality in the permutations of combinations in the relationship between crop production systems and value chains, and an Ordered Probit Regression model for determining the factors that influence household food security. Collectively, these methods allow for a comprehensive analysis of the intricate dynamics between crop production systems, value chains, and household food security.

2.4.1. Food Security Measurement

This study used the HFIAS to assess the food insecurity situation in smallholder farmers' households. The HFIAS has nine questions (Table 1) on the occurrence of food insecurity, each representing its increasing severity, followed by questions on the frequency of its occurrence. These frequency questions are aimed at determining how often the specific food security condition occurred over the previous 30 days. The HFIAS Indicator Guide v3 [26] provides detailed instructions on how to use this questionnaire. It categorises the household food security status into four categories, as follows:

- A household categorised as HFIA category 1 rarely encounters food access issues and typically experiences worries (Household Food Insecurity Access Scale (HFIAS) [26].
- For HFIA category 2, a mildly food-insecure household occasionally or frequently expresses concerns about insufficient food, leading to a less varied diet.
- HFIA category 3 represents a moderately food-insecure household that often sacrifices food quality, occasionally reducing meal quantity [26].
- In HFIA category 4, a severely food-insecure household takes more extreme measures, cutting down on meal size or facing severe conditions like running out of food [26].

2.4.2. Principal Component Analysis

The relationship between the crop production systems and value chains was explored by using a Principal Component Analysis (PCA). This study preferred a Principal Component Analysis (PCA) over a Factor Analysis (FA), as the former is primarily a dimensionality-reduction technique, which aims to capture the maximum variance in the data without making strong assumptions about the underlying structure [27]. In contrast, a Factor Analysis assumes the existence of latent constructs that drive the observed variable [28]. A PCA was chosen because of its ability to reduce dimensionality, capture maximum variance, provide uncorrelated components, and offer an objective criterion for component selection, all of which contribute to a more robust and interpretable analysis.

A PCA was performed on the dataset, transforming the original variables into a set of uncorrelated Principal Components (PCs). Table 2 lists the variables that were used in the PCA. The Kaiser criterion was used to decide how many PC domains to retain. According to this criterion, any component with eigenvalues below 1 (after standardising the data) is discarded. Eigenvalues greater than 1 indicate that the corresponding component explains more variance than a single variable [29].

Table 1. Household Food Insecurity Access Scale (HFIAS).

No	Question (Q)	Response Options 0 = No 1 = Yes	If Yes, How Often Did This Happen? 1 = Rarely 2 = Sometimes 3 = Often
1.	In the past four (4) weeks, did you worry that your household would not have enough food?		
2.	In the past four (4) weeks, were you, or any household member, not able to eat the kind of food you preferred because of a lack of resources?		
3.	In the past four (4) weeks, did you, or any household member, have to eat a limited variety of foods due to a lack of resources?		
4.	In the past four (4) weeks, did you, or any household member, have to eat some foods that you really did not want to eat, because of a lack of resources to obtain other types of food?		
5.	In the past four (4) weeks, did you, or any household member, have to eat a smaller meal than you felt you needed because there was not enough food?		
6.	In the past four (4) weeks, did you, or any household member, have to eat fewer meals in a day, because of a lack of resources to obtain food?		
7.	In the past four (4) weeks, was there ever no food of any kind to eat in your household, because of a lack of resources to obtain food?		
8.	In the past four (4) weeks, did you, or any household member, go to sleep hungry at night because there was not enough food?		
9.	In the past four (4) weeks, did you, or any household member, go a whole day and night without eating anything, because there was not enough food?		

Table 2. Variables used in Principal Component Analysis.

Value Chain Variables	Production System Variables
Reliance on traditional knowledge and practices	Crop yield per unit area
Traceability and labelling practices	Use of synthetic fertilisers
Direct marketing channels	Use of chemical pesticides
Organic certification	Use of traditional seed varieties
Post-harvest handling practices	Reliance on traditional knowledge and practices
Wholesale market	Use of natural pest control methods
Local market integration (local markets)	Use of organic fertilisers
Traditional value-added products	Agrobiodiversity

2.5. *Empirical Model: Ordered Probit Model*

The household food security status depends on certain measurable factors (Xi) and unobservable factors (εi). The Ordered Probit Model was computed for a polychotomous dependent variable with four categories. In accordance with [24], the Ordered Probit Model for Y, conditioned on explanatory variables Xi, can be deduced from a latent variable model in a subsequent manner:

$$Yi^* = \beta' Xi + \varepsilon i, \quad (3)$$

where Yi* is the latent and continuous measure of food insecurity severity faced by smallholder farmers i in a rural area, Xi is a vector of the explanatory variables describing the socio-economic characteristics of farmers (as in Table 3), β is a vector of the parameters to be estimated, and εi is a random error term.

Table 3. Variables used in the Ordered Probit Analysis.

Dependent Variable	Measurements	Expected Sign	Rationale
HFIAS	1 = Food secure, 2 = Mildly food insecure, 3 = Moderately food insecure, and 4 = Severely food insecure		Household food security status, measured by using HFIAS.
	Independent variables		
Hsize	Continuous variable measuring the number of people in the household	+	Larger households may have higher food requirements and face challenges in meeting those needs [30].
Age	Number of years of the household head	−	Older household heads have more farming experience and are less likely to be food insecure [31].
Education	0 = No school, 1 = Primary, 2 = Secondary, 3 = Tertiary	−	Higher education levels are often associated with better income potential and resource access, which can negatively affect food insecurity [31].
Livestock	Number of livestock owned by a household	−	Households with more livestock may be better equipped to ensure their food security [32].
Household food expenditure	0 = Low (≤60% total expenditure), 1 = High (>60% total expenditure)	−	Higher food expenditure may show better food security, which suggests that a larger amount of income is allocated to food [32].
Occupation	0 = non-Farmer 1 = Farmer	−	Farmers may have more direct control over food production and better access to nutritious food than non-farmers [33].
Remittances	Receives remittances 0 = No, 1 = Yes	−	Remittances, i.e., money sent by family members working in other locations, can contribute to household income and improve food security by increasing its purchasing power [31].
Floods	Affected by floods 0 = No, 1 = Yes	+	Floods can have a significantly negative impact on agricultural production and food security [34].
Cash credit	Access to cash credit 0 = No, 1 = Yes	−	Households with access to cash credit may manage unexpected expenses and ensure food availability [35].
Modern agro-production practices (PC1)	Factor score	−/+	Modern agro-production practices, such as the use of synthetic fertilisers and chemical pesticides, are known to influence crop yields and agricultural productivity. Including a PC1 allows us to investigate how modern farming techniques may affect food insecurity levels.

Table 3. *Cont.*

Dependent Variable	Measurements	Expected Sign	Rationale
Sustainable market integration (PC2)	Factor score	−/+	Sustainable market integration can enhance market access, income diversification, and supply chain efficiency, which potentially affects food availability and accessibility. Including PC2 enables us to explore the role of market-oriented approaches in mitigating food insecurity.
Traditional knowledge (PC3)	Factor score	−/+	Traditional knowledge encompasses time-tested farming practices and local ability, which potentially contributes to agricultural resilience and sustainable resource management. Including PC3 allows us to assess the influence of traditional knowledge on food security outcomes.

The odds associated with the coded responses of an Ordered Probit Model are as follows:

$$\begin{aligned} Pn(0) &= \Pr(Y_n = 0) = \Pr(Y_n^* \leq \mu_1) = \Pr(\beta' \mathrm{Xi} + \varepsilon \mathrm{i} \leq \mu_1) \\ &= \Pr(\varepsilon \mathrm{i} \leq \mu_1 - \beta' \mathrm{Xi} = \varnothing(\mu_1 - \beta' \mathrm{Xi}) \\ Pn(1) &= \Pr(Y_n = 1) = \Pr(\mu_1 \leq Y_n^* \leq \mu_2) \\ &= \Pr(\varepsilon \mathrm{i} \leq \mu_2 - \beta' \mathrm{Xi}) - \Pr(\varepsilon \mathrm{i} \leq \mu_1 - \beta' \mathrm{Xi}) \\ &= \varnothing(\mu_2 - \beta' \mathrm{Xi}) - \varnothing(\mu_1 - \beta' \mathrm{Xi}) \\ Pn(k) &= \Pr(Y_n = k) = \Pr(\mu_k < Y_n^* \leq \mu_k + 1) \\ &= \varnothing(\mu_{k+1} - \beta' \mathrm{Xi}) - \varnothing(\mu_k - \beta' \mathrm{Xi}) \\ Pn(K) &= \Pr(Y_n = K) = \Pr(\mu_k < Y_n^*) \\ &= 1 - \varnothing(\mu_k - \beta' \mathrm{Xi}) \end{aligned} \tag{4}$$

where n is an individual, k is a response alternative, $\mathrm{P}(Y_n = k)$ is the probability that individual n responds in a manner k, and $\varnothing$ is the standard normal cumulative distribution function. In the increasing nature of the ordered classes, the interpretation of this model's primary parameter is set β.

The smallholder farmer food security determinants were identified by means of a literature review. Table 3 describes the explanatory variables used in the model and the expected signs (hypothesised outcome) of the potential explanatory variables.

3. Results and Discussion

This section presents the results of various statistical analyses of the data received from 300 participants. These analyses include chi-square tests, one-way ANOVA, a multi-collinearity test, a Principal Component Analysis (PCA), and an Ordered Probit Model. The analytical tools facilitated a thorough investigation of the intricate relationship between food security levels, socio-economic parameters, crop production systems, value chains, and their interactions.

3.1. Descriptive Analysis Results

Table 4 shows that 36% of the farmers were food secure, 33% were mildly food insecure, 22% were moderately food secure, and 9% were severely food insecure. The chi-square test was employed to check the association between the food security status, which is measured as the HFIAS and independent variables.

Table 4. Association between food security and socio-economic parameters.

Variables	Measure	Food Secure (n = 107) 36%	Mildly Food Insecure (n = 99) 33%	Moderately Food Insecure (n = 66) 22%	Severely Food Insecure (n = 28) 9%	X^2
Education	1 = No School	53.27	41.41	46.97	28.57	**
	2 = Primary	23.36	24.24	13.64	14.29	
	3 = Secondary	18.82	30.30	31.82	50	
	4 = Tertiary	6.54	4.04	7.58	7.14	
Household food expenditure	0 = Low	56.60	61.62	57.58	64.29	n.s
	1 = High	43.40	38.38	42.42	35.71	
Occupation	0 = non-farmer	57.94	57.58	53.03	75	n.s
	1 = Farmer	42.06	42.42	46.97	25	
Remittances	0 = No	52.34	41.41	51.52	67.86	*
	1 = Yes	47.66	58.59	48.48	32.14	
Floods	0 = No	53.27	60.61	62.12	64.29	n.s
	1 = Yes	46.73	39.39	37.88	35.71	
Cash credit	0 = No	93.46	93.94	96.97	100	n.s
	1 = Yes	6.54	6.06	3.03	0	

Note: * and ** means statistically significant at a 10% and 5% level, respectively; n.s means not significant.

Table 4 shows a statistically significant relationship between education and the food security status ($p < 0.05$). The results show that 53.27% of households that did not go to school were food secure, and in households that had a primary education, about 23.36% were classified as food secure. About 18.82% had a secondary education, and 6.54% had a tertiary education and were classified as food secure. In the mildly food-insecure category, about 41.41% had no schooling, 24.24% had a primary education, 30.30% had a secondary education, and 4.04% had a tertiary education. The results further showed that, at the moderate food-insecurity level, about 46.97% of households had no schooling, 13.64% had a primary education, 31.82% had a secondary education, and 7.58% had a tertiary education. In the fourth food insecurity category, namely, severe food insecurity, the results showed that 28.57% of all household heads had no schooling, 14.29% had a primary education, 50% had a secondary education, and 7.14% had a tertiary education.

The results also showed a statistical significance between receiving remittances and household food security ($p < 0.1$). For households with "No" remittances, approximately 52.34% of households were classified as food secure, 41.41% of households were mildly food insecure, 51.52% of households were moderately food insecure, and 67.86% of households were severely food insecure. For households with "Yes" remittances, about 47.66% of households were food secure, 58.59% were mildly food insecure, 48.48% were moderately food insecure, and 32.14% were severely food insecure.

Table 5 shows the relationship between the household food security level and continuous variables, which was measured by using one-way ANOVA. The statistical analysis in this table revealed a significant difference in livestock-owned means across the different levels of food security ($p < 0.01$). Livestock ownership varied significantly among households with different levels of food security. The mean value of livestock owned by food-secure households was 22. In comparison, households with mild food insecurity had a mean livestock ownership of 18, while moderately food-insecure households had a mean livestock ownership of 11. The lowest mean livestock-owned value was among severely food-insecure households. These findings indicate that livestock ownership tends to decrease with an increase in food insecurity.

Table 5. One-way ANOVA results for household food security determinants.

Variables	Food Secure		Mildly Food Insecurity		Moderately Food Insecurity		Severe Food Insecurity		F Significance
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Household size	8	4.29	7	4.42	8	4.11	8	3.22	n.s
Age	53	13.28	51	13.26	54	14.85	49	14.43	n.s
Livestock owned	22	0.88	18	1.85	11	1.98	3	2.56	***

Note: *** means statistically significant at a 1% level, respectively; n.s means not significant.

3.2. Multicollinearity Test of Variables

The multicollinearity among the independent variables was assessed by using the Variance Inflation Factor (VIF), which is considered to be acceptable if the values are below 10. The findings in Table 6 indicate no multicollinearity issues since all the VIF values were below this threshold [36].

Table 6. Multicollinearity assessment: Variance Inflation Factor (VIF).

Variable	VIF	1/VIF
Modern agro-productivity practices	3.66	0.27
Floods	3.02	0.33
Household food expenditure	1.44	0.69
Age	1.39	0.72
Education	1.26	0.79
Livestock owned	1.21	0.82
Occupation	1.15	0.87
Remittances	1.12	0.89
Traditional knowledge focus	1.09	0.92
Sustainable market integration	1.09	0.92
Household size	1.03	0.97
Cash credit	1.01	0.99
Mean VIF	1.54	

3.3. Principal Component Analysis Results

A Principal Component Analysis (PCA) was conducted to reduce the dimensionality of the interactive relationship between crop production systems and value chains. When conducting a PCA, a set of three Principal Components (PCs) were derived, as shown in Table 7. The three PCs met the Kaiser criterion, as they had eigenvalues exceeding one, and they collectively explained 36.31% of the total variance in the utilised variables. Specifically, the three components accounted for 15.06%, 11.79%, and 9.46% of the variance, respectively, as specified in Table 7. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy assesses the suitability of the data for the PCA. The value of 0.615 indicates that the sample size, as well as the intercorrelations among the variables, is suitable for it.

Table 7. Principal Component Analysis.

Variable	PC1—Modern Agro-Productivity Practices	PC2—Sustainable Market Integration	PC3—Traditional Knowledge Focus
Crop yield per unit area	0.571	0.036	0.336
Use of synthetic fertilisers	0.738	0.143	−0.017
Use of chemical pesticides	0.118	−0.090	0.110
Use of traditional seed varieties	0.134	0.284	0.228
Reliance on traditional knowledge and practices	−0.227	0.462	0.526
Traceability and labelling practices	−0.104	0.474	−0.379
Direct marketing channels	−0.089	0.023	0.432
Use of natural pest control methods	0.034	0.562	0.254
Use of organic fertilisers	−0.179	0.416	0.182
Organic certification	−0.004	0.470	−0.517
Post-harvest handling practices	−0.018	0.455	−0.142
Market integration (wholesale market)	−0.246	0.479	−0.430
Agrobiodiversity	0.826	0.207	0.066
Local market integration (local markets)	0.712	0.175	0.210
Traditional value-added products	−0.055	0.035	−0.135
Eigenvalue	2.258	1.769	1.419
Proportion	15.06%	11.79%	9.46%
Cumulative	15.06%	26.85%	36.31%
KMO	0.615		
Alpha	0.386		

LR test: independent vs. saturated: chi^2 (105) = 502.30; Prob > chi^2 = 0.0000.

The PC1 domain represents a pattern that is related to modern agro-productivity practices. The positive loading values for the 'crop yield per unit area', 'use of synthetic fertilisers', 'agrobiodiversity', and 'local market integration' suggest that these variables are positively correlated with each other and contribute to modern agro-productivity practices. This positive correlation implies that systems exhibiting higher crop yields, the increased use of synthetic fertilisers, and a greater agrobiodiversity tend to integrate better into the local markets. This alignment of variables is consistent with the notion that modern agro-productivity practices often go hand in hand with increased market participation [15].

The PC2 domain represents a pattern that is related to sustainable market integration. The positive loading values for the reliance on traditional knowledge and practices, traceability and labelling practices, the use of natural pest control methods, the use of organic fertilisers, organic certification, post-harvest handling practices, and market integration (the wholesale market) indicate that these variables are positively correlated and contribute to sustainable market integration. High values in PC2 suggest an agricultural system that emphasises the markets, traditional knowledge, and traceability in the supply chain.

The PC3 domain represents a pattern that focuses on traditional knowledge and practices. The positive loading values for 'direct marketing channels' and 'reliance on traditional knowledge and practices' indicate that these variables are associated with a focus on traditional agricultural methods.

3.4. Impact of the Interaction between Crop Production Systems and Value Chains on Household Food Security

The Ordered Probit Model was utilised to identify the household characteristics that influence the food security status of smallholder farmers' households (as shown in Table 8).

The results demonstrated that, collectively, the estimated coefficients statistically and significantly determined food security, as indicated by the LR statistic ($p < 0.01$). The coefficients of the Ordered Probit Model do not directly indicate the size of the effects of the explanatory variables. Instead, the marginal effects are presented and discussed. In this context, a positive value of the coefficient suggests an increase in the HFIAS score, which indicates the higher likelihood of a household being food insecure. Conversely, a negative coefficient implies a higher probability of a household being food secure.

Table 8. Factors influencing household food insecurity status.

Variables	Coef.	Std. Err.	*p*-Value	Marginal Effects			
				Food Secure	Mildly Food Insecure	Moderately Food Insecure	Severely Food Insecure
Modern agro-productivity practices	0.051	0.055	0.349	0.018	−0.001	−0.008	−0.008
Sustainable market integration	−0.228	0.078	0.003 ***	−0.078 *	0.005	0.037 **	0.037 ***
Traditional knowledge focus	−0.113	0.067	0.094 *	−0.039 **	0.002	0.018 *	0.018 *
Household size	0.026	0.009	0.004 ***	0.009 ***	−0.001	−0.004 ***	−0.004 ***
Age	0.004	0.005	0.438	0.001	−0.000	−0.001	−0.001
Education	−0.202	0.073	0.006 ***	−0.069 *	0.004	0.033 ***	0.032 ***
Livestock owned	−0.022	0.007	0.001 ***	−0.008 ***	0.000	0.004 ***	0.004 ***
Occupation	0.067	0.140	0.634	0.023	−0.001	−0.011	−0.011
Household food expenditure	0.454	0.170	0.008 ***	0.156 ***	−0.010	−0.073 ***	−0.073 **
Remittances	0.165	0.133	0.214	0.057	−0.004	−0.027	−0.026
Floods	0.260	0.152	0.088 *	0.089 *	0.006	0.042 **	0.042 *
Cash Credit	0.562	0.307	0.067 *	0.193 *	−0.012	−0.091 *	−0.090 *

The number of obs = 300 LR Chi^2 (12) = 42.60 Prob > Chi^2 = 0.001 Pseudo R^2 = 0.055 Log likelihood = −364.19357.
Note: *, ** and *** means coefficient and dy/dx are statistically significant at the 10%, 5% and 1% levels, respectively.

The results show that sustainable market integration has a significant and negative association ($p < 0.01$) with the food insecurity levels (Table 8). The marginal effect shows that the effects are twofold, i.e., there are further increases in food security when at the food-secure level, and increased food insecurity at high levels of food insecurity. The results of the marginal effects show that a unit increment in sustainable market integration at a food-secure level yields a statistically significant 7.8% decrease in food insecurity. Refs. [37,38] have emphasised the positive role of market access and integration in enhancing the food security of households that already meet their basic needs. Refs. [39,40] suggest that market access improves food availability, diversity, and stability. Households with surplus production sell their products at the markets, which generates an income so that they can purchase a wider variety of foods, which reduces the risk of food shortages [41]. Conversely, the results also entail a 3.7% probability of transitioning from moderately to severely food insecure, i.e., becoming more food insecure. The results reflect the complex and context-dependent nature of the food security outcomes. This finding is consistent with the concept of vulnerability to food insecurity. Households at higher food insecurity levels often need more resources and face various constraints, which prevent them from benefiting fully from market integration. Ref. [42] underscore the vulnerability of moderately food-insecure households to external shocks and stresses, which can exacerbate their food insecurity.

The result suggests that a focus on traditional knowledge has a statistically significant and negative impact ($p < 0.1$) on household food security. It indicates that an increase in the focus on traditional knowledge is associated with a statistically significant 3.9% decrease in food insecurity. These results are consistent with the findings of [43] on the role of traditional knowledge systems in promoting food security. Traditional knowledge encompasses an indigenous and local knowledge of agriculture, of natural resource management, and of food production [44]. Ref. [45] highlighted the value of integrating traditional knowledge practices into modern agricultural systems. For instance, [46] emphasised the contribution of traditional ecological knowledge to sustainable resource management and food production. Traditional knowledge often includes valuable practices for crop cultivation, pest control, and water management, which can enhance agricultural productivity and food security.

The results also show that the same increase in the focus on traditional knowledge results in a 1.8% probability of households transitioning from being moderately food insecure to becoming severely food insecure. The finding aligns with the recognition that traditional knowledge alone may not be a panacea for addressing food security, especially for households that are already facing moderate-to-severe food insecurity. The vulnerability of moderately food-insecure households to external shocks limits their capacity to fully leverage the traditional knowledge systems to improve their food security status [47].

Consistent with a priori expectations, larger households were more food insecure than smaller households (ceteris paribus). Overall, the household size positively, statistically, and significantly impacted household food insecurity ($p < 0.01$). The results of the marginal effects showed that an increase in the household size resulted in a 0.9% increase in the likelihood of becoming food insecure, as well as a 0.4% chance of sliding from being severely food insecure to becoming moderately food insecure, i.e., becoming more food secure. The finding that a larger family size leads to food insecurity, at the food security level, aligns with the notion that the household size adversely impacts food security. Ref. [23] stressed that larger families strain the resources, including food, in already food-secure households. In such cases, an increased family size leads to a higher demand for food, which potentially stretches the available resources and increases the risk of food insecurity [23].

Conversely, the observation is that, at higher levels of food insecurity, larger families benefit from the extra labour and sharing of tasks, which leads to improved food security outcomes. This finding is consistent with that of [48], who emphasised the role of household labour in food production and security. In resource-constrained settings that are dependent on labour-intensive practices, additional family members can contribute to the agricultural activities, such as farming and livestock management, which enhances food production and self-sufficiency [48]. The concept of labour sharing and cooperation within larger households has been explored in subsistence agriculture, where the division of labour among family members can improve food security outcomes [49].

The negative and statistically significant ($p < 0.01$) relationship between the level of education and the food insecurity status suggests that a higher educational level of the household head is associated with a higher likelihood of the household being food secure. The results of the marginal effects suggest that, at a food-secure level, a higher level of education is likely to lead to improved food security outcomes. A higher level of education leads to a 6.9% decrease in the chance of becoming food insecure. Ref. [50] obtained similar findings and stated that higher levels of education are often associated with increased knowledge and skills. Education equips individuals with a broader understanding of nutrition, agriculture, and economic concepts, which can positively influence food-related decision-making within the household [51]. Ref. [51] also noted that household heads with a higher educational level possess better agricultural and financial management skills, which enable them to make informed choices regarding crop production, income generation, and resource allocation, all of which can contribute to improved food security outcomes. However, the results of the marginal effects also show that there is a 3.3% increase in the chance of an educated household head sliding from moderately food insecure to severely food insecure. These findings align with those of [50], namely, that highly educated individuals allocate and invest a significant portion of their income in their education and career development, leaving less disposable income for immediate needs like food.

The negative coefficient for the livestock that is owned suggests that an increase in the number of livestock is associated with a higher likelihood of households being food secure ($p < 0.01$). A unit increase in livestock ownership results in a 0.8% increase probability in the likelihood of a household being food secure and a 0.4% increase in the likelihood of transitioning from severely food insecure to moderately food insecure, i.e., more food secure. Ref. [52] noted that livestock ownership provides households with an indirect and direct source of food, in the form of income, milk, meat, and eggs. According to [52], having more livestock means that more animal-sourced protein and nutrients are available within the household's diet, which contributes to improved food security and nutritional outcomes. Livestock ownership represents an asset diversification strategy for households; however, to rely solely on crop production for food and income is risky, because of possible crop failures, pests, or market price fluctuations [53].

The results show that food expenditure has a positive and statistically significant impact ($p < 0.01$) on the food security status of households. The positive relationship implies that households with a higher expenditure on food are more likely to experience higher levels of food insecurity. Higher food expenditure leads to a statistically significant 15.6% increase in the chance of sliding from being food secure to being mildly food insecure and a 7.3% chance of transitioning from moderately to severely food insecure. Ref. [54] found that households that have a higher proportion of their expenditure allocated to food tend to be food insecure. The results suggest that these households have a lower purchasing power, or limited access to adequate food supplies.

Flooding was another major factor that determined the food security of farming households. A positive and statistically significant relationship ($p < 0.1$) exists between food insecurity and flood experiences. Table 8 indicates that experiencing floods leads to a statistically significant 8.9% increase in the chance of sliding from food secure to mildly food insecure, and a 4.2% chance of sliding from moderately to severely food insecure. The impact of floods on agricultural systems has various consequences, including crop damage and prolonged reduced productivity, which contribute significantly to food shortages within farming households, and ultimately lead to severe food scarcity [55]. This finding agrees with recent research that was conducted in Afghanistan [55] and Niger [34].

The relationship between access to credit and the level of household food security is positive and statistically significant ($p < 0.1$). The findings on the marginal effects suggest that having access to cash credit leads to a 19.3% probability of transitioning from a food-secure to a mildly food-insecure status, which suggests that cash credit worsens the food security of households. The findings of this study align with those of [56], which suggest that poor households turn to cash credit when they are facing financial difficulties, including unexpected expenses or income shortages. While credit provides immediate relief and helps to secure food, it often comes with interest and repayment obligations. Informal credit is accompanied by high interest rates, which results in poor households struggling to repay their loans [56]. In turn, this can lead to a cycle of debt and financial strain, which ultimately results in a shift from food security to mild food insecurity. The results of the marginal effects also show that, for households facing severe food insecurity, access to cash credit increases the probability of them transitioning from severely food insecure to moderately food insecure by 9%. For households facing severe food insecurity, access to credit provides a lifeline, by allowing them to purchase essential food items, or to cover emergency expenses.

4. Conclusions and Recommendations

This study investigated the impact of the interaction between crop production systems and value chains on household food security. The results of the Ordered Probit Model revealed that several significant factors influence the food insecurity status. Sustainable market integration (PC2) and a focus on traditional knowledge (PC3) showed a negative association with food insecurity. Furthermore, a larger household size was associated with a higher level of food insecurity, mainly due to the increased demand for food, with limited resources. The education level of the household head and the number of livestock owned negatively affected their food insecurity status. However, higher expenditure on food was associated with increased food insecurity, which indicates a limited purchasing power or access to adequate food supplies. Lastly, flooding contributed significantly to food insecurity, as it results in degraded infrastructure and production bases.

Policymakers and stakeholders should prioritise sustainable market integration initiatives that facilitate the smallholder farmers' access to markets, for example, by improving their income opportunities and promoting environmentally friendly agricultural practices. Efforts should also be directed towards preserving and incorporating traditional knowledge into farming practices, in order to enhance their productivity and resilience in the face of challenges. Strategies, such as promoting family planning and providing support to mitigate food shortages, are crucial for addressing the negative impacts that a larger household size has on food security. Investing in the education and training of farmers can lead to better agricultural and financial management practices and it can contribute to improved food security outcomes. Encouraging livestock ownership and promoting asset diversification can serve as a risk-reducing strategy for households, and it can strengthen food security.

Interventions should be explored for supporting households with a limited purchasing power, in order to improve their access to an adequate and diverse food source. Finally, proactive measures should be taken to minimise flooding and to address its effects on agricultural systems, such as implementing flood-prevention programmes through an improved rural infrastructure. By implementing these recommendations, policymakers and stakeholders can work towards enhancing the food security of households and promoting sustainable agriculture.

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