

Effects of Agrochemical Usage on Food Security in the Sissala East Municipality, Ghana

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Abstract

Globally, to meet the growing food demands of a burgeoning population, especially in Africa, agrochemicals intensification—fertilisers, herbicides, fungicides, and pesticides—is key in modern agricultural practices. However, agrochemical use and farmer household food security are understudied. Therefore, this study seeks to: (1) identify the agrochemical types farmers use, (2) examine agrochemical use and farmer households' food security, and (3) identify the key socio-economic factors influencing this relationship. From a quantitative viewpoint, a cross-sectional survey of 382 farmer households was adopted using a structured questionnaire. Logistic regression from the R software was performed to identify the key predictors of food security. From the study, farmer household-level predictors of food security and agrochemicals use are income, household size, and education. Households with lower income levels were more vulnerable to food shortages, larger households faced a higher probability of food insecurity due to increased consumption demands, and households led by individuals with formal education were less likely to experience food shortages, mainly due to better knowledge of farm management, agrochemical application, and income diversification. In conclusion, income, household size, and education significantly influence agrochemical use and household food security. The Ministry of Food and Agriculture policies should promote farmer education, income diversification, and targeted support for low-income and large households. Strengthening extension services and capacity building can improve agrochemical management, enhance productivity, and reduce food insecurity among vulnerable farming households.

Keywords: Agrochemicals application, Smallholder Farmers, Food Security, Sissala East Municipality, Upper West Region, Ghana

1. Introduction

Globally, the increasing reliance on agrochemicals comprising fertilisers, herbicides, fungicides, and pesticides has become a defining characteristic of modern agricultural practices aimed at enhancing food production to meet the growing demands of a burgeoning global population (Merotto, et al. 2022). With the global population projected to reach 9.7 billion by 2050 (United Nations World Population Prospects, 2019), ensuring food security has emerged as a critical challenge (Mengistu, 2024). Agrochemicals are instrumental in boosting crop yields, reducing post-harvest losses, and mitigating pest-related damages. Agrochemicals use reached approximately 4.19 million tons in 2021, with Asia accounting for nearly 50% of this usage (FAO. 2023a). However, their extensive and often indiscriminate use has triggered a complex web of consequences that compromise the long-term sustainability of food systems, public health, and environmental integrity (Adedoyin et al., 2021). Agrochemical overuse and improper application have raised significant concerns regarding soil degradation, biodiversity loss, water contamination, and human health hazards (Rehman et al., 2024). Food security, as defined by the FAO, exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO., 2006). The FAO (2008) stipulated that food security is a multifaceted concept that encompasses four key dimensions. These are availability, thus the physical presence of food in a given area through

domestic production, imports, or food aid, and access—individuals' ability to obtain food for a nutritious diet, which is largely determined by household income, food prices, and distribution systems. Food security also hinges on utilization—the proper biological use of food by individuals, requiring not only adequate intake of nutrients but also access to clean water, sanitation, and healthcare—and stability—the consistency of the other three dimensions over time (FAO, 2008). On one hand, agrochemicals contribute to increased food availability through higher crop productivity (Adedoyin et al. 2021) in the short term. On the other hand, their harmful effects on soil fertility, ecological balance, and food safety can threaten the sustainability of food production systems, thereby undermining food security in the long term (Urías-García et al., 2025).

Historically, agricultural productivity in Africa has lagged behind other regions of the world due to factors such as poor soil fertility, inadequate infrastructure, and limited access to inputs (Wakweya, 2023). In response, various African governments and development partners have supported agrochemical subsidy programmes, including the widespread promotion of inorganic fertilisers and pesticides under initiatives such as the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) (Gosling et al., 2022). A recent example in Ghana is the ongoing government's fertiliser subsidy programme labelled Planting for Food and Jobs (PfJ). These interventions have contributed to yield improvements, particularly in staple crops like maize and rice (Jayne et al., 2018). Nonetheless, the benefits of agrochemicals have been uneven, and concerns are mounting about their long-term ecological and socio-economic effects, including food insecurity.

Food security remains a pressing developmental concern in Africa, where more than 280 million people are undernourished as of 2023, representing over 20% of the continent's population (FAO, 2023c; Alliance for a Green Revolution in Africa, 2023). With the African population projected to double by 2050 (Grinin and Korotayev, 2023), increasing agricultural productivity is essential to meet food demand. To this end, agrochemicals—including fertilisers, herbicides, and pesticides—have been widely promoted across the continent to improve crop yields and reduce losses from pests and diseases (Adjei, 2025). However, the intensification of agrochemical use also presents significant risks to environmental sustainability, human health, and long-term food security. Examples are fertilisers, used to supply essential nutrients (e.g., nitrogen, phosphorus, potassium) to plants to promote growth and increase yield; pesticides—chemicals that kill or control pests, including insecticides targeting insects; herbicides—control unwanted plants (weeds); and fungicides—treat fungal infections.

Food security remains a critical development priority in Ghana, particularly in agrarian regions such as the Sissala East Municipality in the Upper West Region, where agriculture constitutes the backbone of household livelihoods. In these predominantly rural communities, smallholder farmers rely heavily on rain-fed agriculture and the cultivation of staple crops such as maize, millet, sorghum, and groundnuts. In recent years, the increased adoption of agrochemicals—particularly synthetic fertilizers, herbicides, and pesticides—has been promoted as a means of enhancing crop productivity and ensuring food availability in the face of declining soil fertility and climate variability and change. However, while agrochemicals have played a role in improving short-term yields, their improper use is increasingly raising concerns about long-term food security, environmental sustainability, and public health in the municipality.

The Sissala East Municipality is one of the major grain-producing areas, thus, one of the food baskets in Ghana, benefiting from its relatively fertile land and high agricultural activity (Ghana Statistical Service, 2021). It was added that the region has seen a noticeable rise in the use of agrochemical inputs, largely driven by government fertiliser subsidy programmes and increased market demand for higher crop output. Despite the productivity gains associated with agrochemical use, local studies and field reports have highlighted a growing pattern of misuse and over-application among farmers, often due to limited extension services, lack of training, and poor regulatory enforcement (Amoabeng et al., 2014; Demi and Sicchia, 2021). This trend has resulted in several negative externalities, including soil nutrient imbalance, pesticide resistance, contamination of water bodies, and the presence of chemical residues in food crops, all of which threaten the quality, safety, and sustainability of food systems (Donko et al., 2026; Kelvin, 2024). Food security encompasses food availability, access, utilisation, and stability (FAO, 2006). There are several studies on food security in the Sissala East Municipality. For instance, Derbile et al. (2025) looked at how funeral rites affect food security in rural Ghana, and Nath et al. (2024) argued about herbicides among farmers. Dakurah et al. (2024) drew readers' attention to the effect of climate change and variability on food security, while Derbile et al. (2025) emphasised the social vulnerability to food security. Notwithstanding, there are limited studies establishing the relationship between the use of agrochemicals and food security among farmer households, especially in the Sissala East Municipality despite the increasing use of agrochemicals.

While agrochemical application has the potential to enhance farm productivity and stabilise food supply in the municipality, growing concerns exist regarding its socio-economic and food security implications at the household level. Existing studies largely emphasise productivity outcomes or environmental and health risks, with limited empirical evidence examining how specific agrochemical practices influence the multidimensional aspects of food security, particularly food availability, access, and utilisation. However, there is insufficient localised evidence linking the types and intensity of agrochemical use to household food security outcomes and the socio-economic factors shaping this relationship. This knowledge gap limits the development of context-specific agricultural and food security policies.

Therefore, this study seeks to explore the effects of agrochemical usage on food security in the Sissala East Municipality, with a focus on: (1) the agrochemical types farmers use, (2) to examine the effect of agrochemical usage on farmer households' food security, and (3) identify the key socio-economic factors influencing this relationship. Based on the examination of local practices, perceptions, and outcomes, the research aims to provide evidence-based recommendations for enhancing food system resilience in the region while contributing to the attainment of Sustainable Development Goals (SDGs)—2 (zero hunger) and 3 (good health and well-being). The remaining sections of the study consist of the conceptual framework, materials and methods, results, discussions, conclusions and recommendations, and list of references.

2. Conceptual Framework

Figure 1 (the conceptual framework) illustrates the causal relationship between the types and intensity of agrochemical use (independent variables) and household food security (dependent variable), using the Food Consumption Score (FCS) as the primary food security measurement

tool. The framework also integrates moderating and mediating factors such as environmental health, income, and knowledge of safe agrochemical use.

Figure 1 Here

Agrochemical Use—farmers use different types of agrochemicals in farming—fertilisers to boost soil fertility and increase crop yield (FAO, 2022), pesticides to protect crops from pests, weeds, and diseases—but these can also pose health and ecological hazards when misused (Stathers et al., 2020)—and weedicides for controlling weeds. Understanding the type of agrochemical is crucial, as different types have varying effects on productivity, input costs, and food safety (Kumah et al., 2023).

Demographic Characteristics—the farmer household heads' socioeconomic characteristics influence agrochemical use. Farmers' demographic characteristics, such as age, income, marital status, educational background, experience, and belonging to Farmer-Based Associations (FBAs), influence the ability of farmers to use agrochemicals of different categories. This is manifested in farmers' willingness to use or not, and when use, the type of chemical a farmer prefers. The demographic features of farmers also condition their affordability of agrochemicals.

Intermediate Effects—the use of agrochemicals has two effects: positive and negative. The positive effects are that agrochemicals such as fertilisers (nitrogen, phosphorus, potassium) significantly improve soil fertility, promoting faster and healthier plant growth, which leads to higher crop productivity (FAO, 203b). For instance, the use of nitrogen-based fertilisers has contributed to over 40% of the global food supply (Osabohien, 2024). In addition, pesticides (insecticides, fungicides, herbicides) help protect crops from pests, weeds, and diseases, reducing crop losses and improving both yield and quality. For example, in tropical countries, pesticide use has reduced post-harvest losses by up to 30% in some staple crops (Sheikomar et al., 2021). Higher yields from agrochemical use translate into higher farm incomes, improving farmers' purchasing power and livelihoods. For instance, a study in Ghana found that farmers using agrochemicals earned 15–25% more per acre than those who did not. Growth regulators and fertilisers can promote faster growth and synchronised maturation, enabling timely harvests and better seasonal planning. Herbicides reduce manual weeding requirements, saving labour and enabling farmers to manage larger plots of land with fewer workers (Mitra et al., 2022).

Household Food Security—this can be measured using the Food Consumption Score (FCS) developed by WFP in 2008. The FCS is a composite score based on dietary diversity, frequency of food group consumption, and nutritional value over the past 7 days (WFP, 2008). Higher FCS values suggest better food security, while lower scores indicate vulnerability. Agrochemical practices affect food security directly (through yield and access) and indirectly (through health and income impacts). Therefore, appropriate and informed use of agrochemicals contributes positively to food availability. For instance, fertiliser application helped Sub-Saharan Africa increase maize yields by 18% between 2005 and 2015 (Shrestha et al., 2021). Furthermore, the misuse or overuse of agrochemicals negatively influences soil health and food safety, thereby affecting FCS and household food security. As such, demographic and environmental factors moderate the strength of these relationships.

3. Materials and Methods

3.1 Study area selection and profile

The Sissala East Municipality is located in the Upper West Region of Ghana, sharing its northern boundary with Burkina Faso, to the south with the Daffiama-Bussie-Issa District, to the east with the Sissala West District, and to the west with the Lambussie-Karni District. The Municipal capital is Tumu, which serves as the administrative and commercial centre. The Municipality lies between latitude 10°00'N and 11°00'N and longitude 1°00'W and 1°40'W, and covers a land area of approximately 5,375km², making it one of the largest districts in the Upper West Region. The location of the study area is important in this study as it makes it easier for referencing purposes. The selection of the Sissala East Municipality as the study area for assessing the use of agrochemicals and its implications for food security among farmer households is based on the GSS (2021) report of the Municipality, indicating dominance of agrochemical usage patterns, ecological vulnerability, and socio-economic characteristics. Agriculture is the primary livelihood source for over 70% of the economically active population, making it an ideal setting to investigate the dynamics between farming practices, agrochemical use, and food security outcomes.

According to the 2021 Population and Housing Census (PHC) by the Ghana Statistical Service (GSS), the Sissala East Municipality has a total population of 80,619. Of this number, over 70% of the economically active population are engaged in agriculture, primarily as smallholder or subsistence farmers. Key crops grown include maize, sorghum, millet, groundnuts, cowpeas, and vegetables (such as okra and tomatoes), often for both subsistence and local markets. In addition to farming, the households also engage in petty trading. Knowledge of the type of economic activities in the area helps in understanding farmers' coping strategies aside from farming. The Sissala East Municipality falls within the Guinea Savannah zone, characterised by tall grasses interspersed with scattered trees such as baobab, acacia, and shea trees. This type of vegetation supports both crop cultivation and livestock rearing. The soil fertility is defined by the ecological zone, and this has tendencies in the use of agrochemicals—soil fertility level and outbreak of pests and diseases on crops. This is crucial in determining the soil fertility level that necessitates the use of agrochemicals like fertilisers.

3.2 Study approach, sampling and sample size determination

This study adopts a quantitative research approach to examine the relationship between the use of agrochemicals and food security among farmer households in the Sissala East Municipality of Ghana. The quantitative approach is suitable for this study as it allows for the collection of measurable and numerical data for statistical analysis to identify patterns, relationships, and trends among variables related to agrochemical usage and food security dimensions (Creswell and Clark (2017)). The study adopted an explanatory quantitative research design based on cross-sectional survey data to investigate the relationship between agrochemical use and household food security outcomes among farmer households. The design was selected to enable empirical testing of measurable associations and to explain how variations in agrochemical adoption predict differences in food security status. Using structured survey data, agrochemical use was modelled as an explanatory variable while controlling for socio-demographic and farm-level characteristics. The use of standardised household questionnaires ensures consistency in data collection and

facilitates comparative analysis across households and demographic sub-groups (Díaz-Oreiro et al., 2019).

Figure 2 Here

The Sissala East Municipality was purposively selected as it serves as the food basket of the Upper West Region, Ghana. The study population comprises all farmer households within the Sissala East Municipality. A stratified random sampling technique was used to ensure that different farming communities and agroecological conditions within the Municipality are proportionally represented. The strata were based on key characteristics such as farming type (crop or mixed farming) and the Ministry of Food and Agriculture (MoFA) extension services zonation—that resulted in Tumu, Wellembelle, Bujan, Sakai, and Nabulo (Figure 2). In these zones, communities were randomly selected from each zone depending on their respective sizes and density of farming activities. The households in each community were also listed and selected randomly (Table 1). In all, there were eight thousand and thirty-eight farmer households (8,038) from which the sample size was drawn.

Table 1: Farming Households' Sample Distribution

Zone	Community	No. households	No. selected
Tumu	Chinchang	108	5
	Dimajan	179	9
	Kusinjan	1009	48
	Total	1296	62
Sakai	Sentie	303	14
	Lilixi	581	28
	Jijen	569	27
	Dangi	80	4
	Kong	487	23
	Total	2020	96
Nabulo	Bawiesibelle	248	15
	Guosi	287	17
	Santijan	97	6
	Gbena- Kajia	315	19
	Total	1195	57
Wellembelle	Bichemboi	200	9
	Bugubelle	483	23
	Nwanduonu	1435	68
	Kuroboi	327	16
	Total	2445	116
Bujan	Dolibizon	355	17
	Yigantu	182	8
	Pina	141	7
	Tanla	92	4
	Challu Upper	312	15
	Total	1082	51
Overall total		8038	382

Source: Sissala East Municipal Health Directorate (2024)

The sample size was determined using Yamane's (1967) sample size determination formula, which is calculated statistically based on the formula:

$$n = N/(1 + N(e)^2) \dots\dots\dots[1]$$

Where:

n = the sample size for the study

N = the sample population of the study

1 = constant

e = margin of error for the sample mean

Therefore, in this study:

N = 8038

e = 95% or an error margin of 0.05 confidence level.

$$n = 8038/(1 + 8038(0.05)^2)$$

$$n = 8038/(1 + 8038(0.0025))$$

$$n = 8038/21 = \mathbf{382}$$

This sample was distributed proportionally across all the zones—Tumu, Wellembelle, Bujan, Sakai, and Nabulo. The primary data were collected using a structured questionnaire administered through face-to-face interviews from farmer household heads to solicit the type of agrochemicals used and their food security situation. Although 20 questionnaires were not initially responded to due to farmers' unavailability, there was a mop-up exercise to replace all the 20 to make up the 382.

3.3 Data collection methods and analytical strategies

Primary data were collected through face-to-face interviews using a structured questionnaire comprising sections on socio-demographic characteristics, farm management practices, agrochemical use patterns, and household food consumption behaviour. The questionnaire underwent expert review by specialists in agricultural economics and public health to ensure content validity and alignment with study objectives. A pilot survey was conducted in a community with similar characteristics to the study area but excluded from the final sample. Feedback from the pilot test informed revisions to improve clarity, question sequencing, and contextual relevance. Reliability of multi-item measures was assessed using Cronbach's alpha, with coefficients exceeding the acceptable threshold of 0.70, indicating satisfactory internal consistency.

The study seeks to examine the effect of agrochemical usage on farmer households' food security and the socio-economic determinants. In this study, the data were screened and analysed using R software version 4.4.x [R Core Team, 2024]. The R software is one of the most profound and useful computer programmes for quantitative data analysis (Gardener, 2017). This analytical procedure aids researchers in summarizing and illuminating observations. Furthermore, researchers use this statistical method since it aids in the development of quantification-related justification (Dakurah, 2024). In addition, descriptive statistics such as frequencies and percentages were used. The results

were presented in the form of tables. Stock and Watson's (2017) logit regression model is given as:

$$\Pr(Y = 1|X_1, X_2, \dots, X_k) = F(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k) \dots\dots\dots[2]$$

Where: **Pr** denotes the probability of occurrence; **Y** denotes the outcome of interest; **Y = 1** when the outcome of interest occurs; **X₁, X₂, ..., X_k** denote the independent variables included in the model; and **F** denotes a cumulative standard logistic distribution function. This is rewritten as:

$$\Pr(Y = 1|X_1, X_2, \dots, X_k) = \frac{1}{1+e^{-(\beta_0+\beta_1 X_1+\beta_2 X_2+\dots+\beta_k X_k)}} \dots\dots\dots[3]$$

One useful and easy way to interpret non-linear regression analysis is to use the marginal effect. This is because, in non-linear regression analysis, the interest is in understanding the effect of independent variables (**X_i**) on the probability of the dependent variable occurring. The marginal effect, measured by the probability scale, is a mean of summarizing how a change in the dependent variable is related to a change in the independent variables. To calculate the marginal effect of **X_i**, we take the derivatives as shown in the equation below:

$$\frac{dy}{dx_i} = \lim_{\Delta} \left[\frac{\Pr(Y = 1|X, X_i + \Delta) - \Pr(Y = 1|X, X_i)}{\Delta} \right] \dots\dots\dots[4]$$

Because **X_i** (independent variables) are categorical variables, we calculate the incremental changes rather than taking the derivatives. Thus, we take the difference between the predicted probabilities in one category and the reference category. The marginal effect for categorical variables (**X_i**) becomes:

$$\Pr(Y = 1|X, X_i = 1) - \Pr(Y = 1|X, X_0 = 0) \dots\dots\dots[5]$$

Where; **X₀** is the reference category and **i = 1, 2, ..., k**

Household food security status was assessed using the Food Consumption Score (FCS), a standardized indicator developed by the World Food Programme (2008). Respondents reported the frequency of consumption of major food groups over a seven-day recall period. Each food group was assigned a nutritional weight reflecting dietary importance, and the FCS was computed as:

$$FCS = \Sigma(\text{frequency} \times \text{food group weight})$$

The weighted scores were aggregated to produce a composite index used to classify households into food consumption categories (poor, borderline, and acceptable food consumption). This approach captures both dietary diversity and food frequency, providing a proxy indicator of household food access and nutritional adequacy. Household food insecurity manifests not only through dietary diversity deficits but also through behavioural adjustments, including meal skipping, portion reduction, and temporary fasting. These coping strategies reflect household responses to resource constraints and therefore serve as valid indicators of food insecurity severity.

As such, the following were used in assessing the duration of how long the household food lasts and whether they have money to buy more, and the affordability of the household to eat a balanced diet: (i) Often true, (ii) Sometimes true, and (iii) Never true. In addition, (i) Almost every month, (ii) Some months, and (iii) Only one or two months were used to assess the frequency in which

households skip/cut meal sizes. Because these categorical variables have a natural ordering, an ordered logit regression stated in equation was used to determine their effects.

$$\log\left(\frac{y_j x_i}{1 - y_j x_i}\right) = \alpha_j - (\beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_k x_{ki}) \dots \dots \dots [6]$$

Where; $i = 1, 2, \dots, n$; $j = 1, 2, \dots, k$; $(\beta_j) = \beta_1, \beta_2, \dots, \beta_k$ are the parameters of the model and x_i are the independent variables.

The independent component of the model is:

$$\beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_k x_{ki} \dots \dots \dots [7]$$

The cumulative probability of y_i as:

$$y_j x_i = y(\alpha_j - \beta' x_i) = \Pr(y_i \leq j | x_i) \dots \dots \dots [8]$$

From the expression of the cumulative probability, the ordered logit regression model estimates a household ' i ' likelihood of at ' j ' or less ($1, \dots, j - 1$)

The probability of estimating y_i at ' i ' is:

$$\Pr(y_i = j) = \Pr(y_i \geq \alpha_j) = \Pr(\varepsilon_i \geq \alpha_{j-1} - \beta' x_i) \dots \dots \dots [9]$$

Since y_i is discrete, the relationship between the estimated y_i^* and the observed y_i is:

$$y_1 = 1, \text{ if } (-\infty \leq y_i^* < \alpha_1), \quad i = 1, 2, \dots, n \dots \dots \dots [10]$$

$$y_2 = 2, \text{ if } (\alpha_1 \leq y_i^* < \alpha_2), \quad i = 1, 2, \dots, n \dots \dots \dots [11]$$

$$y_n = 1, \text{ if } (\alpha_{j-1} \leq y_i^* < +\infty), \quad i = 1, 2, \dots, n \dots \dots \dots [12]$$

Where; ' n ' is the sample size

In the first case, it would be;

$$y_1 = 1, \text{ if } (-\infty \leq y_i^* < \text{often true}), \quad i = 1, 2, \dots, n \dots \dots \dots [13]$$

$$y_2 = 2, \text{ if } (\text{often true} \leq y_i^* < \text{sometimes true}), \quad i = 1, 2, \dots, n \dots \dots \dots [14]$$

$$y_n = 1, \text{ if } (\text{sometimes true} \leq y_i^* < \text{never true}), \quad i = 1, 2, \dots, n \dots \dots \dots [15]$$

In the second case;

$$y_1 = 1, \text{ if } (-\infty \leq y_i^* < \text{almost every month}), \quad i = 1, 2, \dots, n \dots \dots \dots [16]$$

$$y_2 = 2, \text{ if } (\text{almost every month} \leq y_i^* < \text{some months}), \quad i = 1, 2, \dots, n \dots \dots \dots [17]$$

$$y_n = 1, \text{ if } (\text{some months} \leq y_i^* < \text{only one or two month}), \quad i = 1, 2, \dots, n \dots \dots \dots [18]$$

3.4 Ethical approval

This study obtained an ethical clearance certificate (No. UBIDS/RERB/002/2025/08/09) from the Research Ethics Review Board (RERB), University of Business and Integrated Development Studies (SDD-UBIDS), Ghana—West Africa. Therefore, the authors affirm that all necessary steps were taken to ensure the ethical conduct of this research and confirm that there are no conflicts of interest related to the ethical handling of the study. The next section of this study presents the results of the study.

4. Results

This section presents the results of the study. These are in the form of the demographic features of the farmer household heads, the type of agrochemicals used, and the food security conditions among the farming households. It specifically covers the demographic features of the farmers, the type of agrochemicals used, and the food security analysis.

4.1 Demographic characteristics of respondent-farmers

From Table 2, the results indicate that in terms of sex, there were more male household heads than females. This is represented by the majority of the respondents (68.1%) as against 31.9% females. In terms of age, many of the household heads (78.5%) who make decisions on agrochemical use and farming practices were within the age bracket of 31 and 50 years at the time of the fieldwork. This is followed by 20.2% who were between 18 and 30 years of age, and only 1.3% were above 50 years. The study further revealed that the majority of the household heads (92.4%) were married, followed by those who were single (7.1%), with widows being less than 1% at the time of the fieldwork. In addition, the employment status showed that the majority of the household heads were full-time farmers, representing 78.5%, followed by those who took farming as a temporary economic activity (21.5%).

Table 2: Demographic Characteristics of Farming Households (N = 382)

Demographic Characteristics	Frequency	Percent
Sex		
Male	260	68.1
Female	122	31.9
Age		
18-30	77	20.2
31-50	300	78.5
Above 50	5	1.3
Marital Status		
Single	27	7.1
Married	353	92.4
Widowed	2	.5
Employment Status as a Farmer		
Full time	300	78.5
Temporary	82	21.5

Educational Level		
No formal education	185	48.4
Basic education	112	29.3
Secondary	44	11.5
Tertiary	41	10.7
Household Monthly Income		
Less than GHS 1000.00	95	24.9
GHS 1000.00-2000.00	158	41.4
Above GHS 2000.00	129	33.8
Farmer Experience		
Less than 5 years	68	17.8
5 - 10 years	143	37.4
More than 10 years	171	44.8
Farmers' Association Membership		
Yes	70	18.3
No	312	81.7

Source: Field Work, January 2024

Regarding educational levels, farming household heads with no formal education stood at 48.4%, while 29.3%, 11.5%, and 10.7% attained basic, secondary, and tertiary level education, respectively (Table 2). Furthermore, the results showed that 41.4% of the farming households' monthly income was between GHS 1000.00 and GHS 2000.00 (US\$1=GHS 16.10) per month. This is followed by 33.8% of the household heads who said their monthly income was above GHS 2000.00 (US\$1=GHS 16.10), while 24.9% said their monthly income was less than GHS 1000.00 (US\$1= GHS 16.10) at the time of the fieldwork. In terms of respondents' years of farming experience, the results showed that 44.8% had more than 10 years of farming experience, followed by 37.4% with 5 to 10 years of experience as farmers, while less than 5 years constituted 17.8%. These farmers indicated that the majority (81.7%) did not belong to any farmers' associations, while 18.3% belonged to farmers' associations.

4.2 Types of agrochemicals used by farmers

The study revealed that 99.5% of the farmers used fertilisers in their agricultural production. Herbicide and insecticide users were about 95.0% each. Farmers who are not into the use of fungicides in farming were 63.4%, while 36.6% used fungicides (Figure 3). There are different types of agrochemicals that farmers use on their farms. These included fertilisers (NPK, nitrogen, phosphate, and potash), herbicides (Glyphosate, amitrole, picloram, and 2,4-D), insecticides (Metaldehyde, Glyphosate, Deet, Propoxur, Diazinon, DDT, Malathion, Dursban), and fungicides (benzimidazoles, dithiocarbamates, imidazoles, and triazoles).

Figure 3 Here

4.3 Agrochemical use and food security implications

This was done using logit regression model by Stock and Watson (2019). According to Stock and Watson (2019), logit regression model is given as:

$$\Pr(Y = 1|X_1, X_2, \dots, X_k) = F(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k) \dots \dots \dots [19]$$

Where: **Pr** denotes the probability of occurrence; **Y** denotes the outcome of interest; **Y = 1** when the outcome of interest occurs; **X₁, X₂, ..., X_k** denotes the independent variables included in the model; and **F** denotes a cumulative standard logistic distribution function.

This can be rewritten as:

$$\Pr(Y = 1|X_1, X_2, \dots, X_k) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k)}} \dots \dots \dots [20]$$

One useful and easy way to interpret non-linear regression analysis is to use the marginal effect. This is because, in non-linear regression analysis, the interest is in understanding the effect of independent variables (**X_i**) on the probability of the dependent variable. The marginal effect, measured on the probability scale, is a means of summarising how a change in the dependent variable is related to a change in the independent variables. To calculate the marginal effect of **X_i**, we take the derivatives as shown in the equation below:

$$\frac{dY}{dX_i} = \text{limit} \left[\frac{\Pr(Y = 1|X, X_i + \Delta) - \Pr(Y = 1|X, X_i)}{\Delta} \right] \dots \dots \dots [21]$$

Because **X_i** (independent variables) are categorical variables, we calculate the incremental changes rather than taking the derivatives. Thus, we take the difference between the predicted probabilities in one category and the reference category. The marginal effect for categorical variables (**X_i**) become:

$$\Pr(Y = 1|X, X_i = 1) - \Pr(Y = 1|X, X_0 = 0) \dots \dots \dots [22]$$

Where; **X₀** is the reference category and **i = 1, 2, ..., k**

Because these categorical variables have a natural ordering, an ordered logit regression model was used, as stated below.

4.3.1 Estimates of the Logistic Equation Model

Table 3 shows the likelihood of: (i) any adult within the household cutting meal size or skipping meals; (ii) Household eating less than they felt they should; (iii) Were ever hungry but didn't eat, within the last 12 months, because they did not have enough money. From the results of the logit regression model, household heads within the ages of 31–50 years, the household's average monthly income, and their farming experience (in terms of the years of farming) have nonlinear and significant effects on (i), (ii), and (iii). In addition to these, the coefficient of basic education of the household head significantly affects (ii). Also from Table 3, other variables, including the gender of the household head, marital status, whether permanently or temporarily engaged in farming, educational levels of the household heads, whether the household owns the land, or belongs to an association or not, were all not significant even though they showed a positive or negative correlation. From the results, the probabilities of an adult within the household cutting meals size or skipping meals; the household eating less than they felt they should; were ever hungry but didn't eat, increased by 27.1%, 33.4%, and 31.3% respectively for household heads within the 31–50 age bracket (at $P < 0.05$) compared to households within the ages of 18–30 years. However, there is no significant difference between household heads within the ages of 18–30 and those above 50 years.

Table 3: Estimates of the Logistic Equation Model

	Adults cutting meals size or skipping meals			Household eating less than they felt they should			Were ever hungry but couldn't eat		
	Coefficient	P-value	Marginal effect	Coefficient	P-value	Marginal effect	Coefficient	P-value	Marginal effect
Household head demographic characteristics									
Female	-0.266	0.377	-0.063	-0.370	0.207	-0.092	-0.388	0.210	-0.090
31 - 50 years	1.113***	0.003	0.271	1.391***	0.001	0.334	1.299***	0.001	0.313
Above 50 years	-0.701	0.570	-0.173	-0.557	0.667	-0.137	-0.524	0.678	-0.128
Married	0.907	0.103	0.223	0.414	0.493	0.100	0.284	0.622	0.069
Widowed	-0.170	0.926	-0.042	-1.045	0.611	-0.255	-0.962	0.614	-0.236
Divorced	11.103	0.983	0.409	10.907	0.990	0.384	9.947	0.985	0.383
Farming as a permanent employment	0.441	0.220	0.108	0.601	0.120	0.145	0.451	0.225	0.108
Basic education	0.330	0.250	0.078	0.600**	0.046	0.136	0.451	0.124	0.103
Secondary education	-0.122	0.758	-0.030	0.117	0.780	0.027	0.181	0.658	0.042
Tertiary education	-0.561	0.195	-0.138	-0.398	0.376	-0.096	-0.223	0.608	-0.053
Household average monthly income									
Income: GHS1000 to GHS2000	-1.984***	0.000	-0.456	-2.646***	0.000	-0.575	-2.358***	0.000	-0.524
Income: Above GHS2000	-1.439***	0.000	-0.343	-2.073***	0.000	-0.474	-1.831***	0.000	-0.425
Farm characteristics and experience									
Own farmland	-0.121	0.731	-0.029	-0.315	0.374	-0.072	-0.396	0.281	-0.090
5 - 10 years of farming	-1.487***	0.001	-0.352	-1.563***	0.001	-0.365	-1.707***	0.000	-0.397
More than 10 years of farming	-1.668***	0.001	-0.388	-1.623***	0.002	-0.373	-1.702***	0.001	-0.390
Belong to a farmer's association	-0.356	0.299	-0.087	-0.536	0.148	-0.130	0.552	0.125	-0.134
Constant	1.141*	0.051	-	1.985***	0.005	-	2.266***	0.002	-
Log-likelihood	-229.577			-213.586			-221.088		
Number of observation	415			413			415		

Significant at 90% (*), 95% (**), 99% (***) confidence.

Source: Field Work, January 2024

This implies that adults within households whose heads aged between 31–50 were more likely to cut a meal size or skip a meal, eat less than they felt they should, and could not find food to eat even when hungry. Even though the likelihood of an adult skipping a meal or cutting meal sizes is real, the household eating less than they felt they should, and were ever hungry but could not eat, decreases as the level of education of the household head increases. These coefficients are not significantly different from those who have not been to school at all. Farming on one's own land and belonging to a farmers' association reduces the probabilities of the above-mentioned outcomes, but are equally not significantly different from those who cultivated their crops on rented land and also do not belong to a farmers' association.

Also from the results above, households with average monthly income above GHS 1000.00 (at the time US\$1 = GHS 16.10) decreased the likelihood of an adult cutting meal size or skipping meals, the household eating less than they should, or being ever hungry within the past 12 months, but could not get food to eat. Income of households between GHS 1000.00 and GHS 2000.00 (at the time US\$1 = GHS 16.10) reduces the likelihood of an adult cutting meals size or skipping meals by 45.6% (at $p < 0.01$) and also by 34.3% (at $p < 0.01$) for those with monthly income above GHS 2000.00 compared to households with monthly income less than GHS 1000.00 (at the time US\$1 = GHS 16.10).

The probability of a household eating less significantly decreases by 57.5% for households with a monthly income of GHS 1000.00 to GHS 2000.00 (at the time US\$1 = GHS 16.10) and by 47.4% for households with income above GHS 2000.00 (at the time US\$1 = GHS 16.10) compared to households with a monthly income of less than GHS 1000.00 (at the time US\$1 = GHS 16.10). When compared with households whose average monthly income is below GHS 1000.00 (at the time US\$1 = GHS 16.10), the probability of a household ever being hungry, but couldn't get food to eat, reduced significantly by 52.4% and 42.5% for households with average monthly income of GHS 1000.00 to GHS 2000.00 (at the time US\$1 = GHS 16.10) and above GHS 2000.00 (at the time US\$1 = GHS 16.10) respectively (Table 4).

Table 4: Estimates of Ordinal Logistic Regression of Household Characteristics on Food Security

	Coefficient	P-value	Marginal effects		
			Often true	Sometimes true	Never true
Household head demographic characteristics					
Female	-0.166	0.573	0.014	0.005	-0.020
31 - 50 years	-0.340	0.310	0.028	0.015	-0.042
Above 50 years	-0.331	0.779	0.033	0.001	-0.034
Married	-0.126	0.799	0.011	0.005	-0.015
Widowed	1.283	0.404	-0.069	-0.154	0.224
Divorced	-				
	18.299***	0.000	0.906	-0.766	-0.139
Temporary employment as a farmer	0.430	0.202	-0.042	-0.005	0.046
Basic education	-0.055	0.847	0.005	0.001	-0.006
Secondary education	0.438	0.267	-0.034	-0.023	0.057
Tertiary education	0.224	0.604	-0.018	-0.009	0.028

Household average annual income					
Income between GHS 1000 and GHS 2000	-0.906***	0.007	0.088	0.011	-0.099
Income above GHS 2000	-1.263***	0.002	0.136	-0.008	-0.128
Farm characteristics and experience					
Renting land	0.309	0.371	-0.030	-0.004	0.033
5 - 10 years of farming	-0.035	0.920	0.003	0.001	-0.004
More than 10 years of farming	-0.027	0.951	0.002	0.001	-0.003
Belong to a farmer's association	-0.274	0.401	0.026	0.004	-0.030
Often true Sometimes true	-2.963***	0.000			
Sometimes true Never true	1.121	0.057			
Number of observations	415				

Significant at 90% (*), 95% (**), 99% (***) confidence.

Source: Field Work, January 2024

Similarly, households with 5 or more years of farming are less likely to have an adult cutting the size or skipping meals, eating less than they felt they should, or being ever hungry but could not get food to eat because they do not have it within the last 12 months than households with fewer than 5 years of farming. Those with 5–10 years of farming are 35.2% less likely to cut meal size or skip meals, 36.5% less likely to eat less than they felt they should, and 39.7% less likely to ever go hungry without eating compared to households with fewer than 5 years of farming. Also, the probability of households with more than 10 years of farming cutting their meal size or skipping meals, eating less than they felt they should, and ever going hungry without eating decreased by 38.8%, 37.3%, and 39.0%, respectively (Table 4).

4.4 Farmer households' coping strategies

The results in Table 5 show that variables of farmer household heads, such as household head marital status, basic level of education, and household income level in the regression model, are not statistically significant in terms of the household's inability to afford a balanced diet in their meals. The results point to the fact that the likelihood of the household being unable to eat a balanced diet increases when comparing household heads with or without education, and married and not married. However, a household income level above GHS 1000.00 (at the time US\$1 = GHS 16.10) reduces the likelihood of the household being unable to afford to eat a balanced diet. Again, for married household heads compared to singles, the likelihood of eating a balanced diet decreased by 14.5%, and the likelihood of their inability to eat a balanced diet increased by 8.4%. Compared to a household with no formal education, the likelihood of eating a balanced diet decreases by 4.0% for a household head with a basic education level. However, the likelihood that the household is often unable to eat a balanced diet increases by 6.7% (Table 5).

Table 5: Estimates of Ordinal Logistic Regression of Household Characteristics on their ability to afford to eat balanced meals

Characteristics	Coefficient	P-value	Marginal effects		
			Often true	Sometimes true	Never true

Household head demographic characteristics

Female	-0.107	0.727	0.007	0.003	-0.011
31 - 50 years	0.257	0.466	-0.019	-0.004	0.024
Above 50 years	-1.211	0.294	0.139	-0.064	-0.075
Married	1.308	0.011	-0.145	0.061	0.084
Widowed	2.626	0.114	-0.071	-0.447	0.518
Divorced	-0.395	0.876	0.033	0.000	-0.033
Temporary employment as a farmer	0.373	0.276	-0.028	-0.005	0.034
Basic education	0.627**	0.037	-0.040	-0.027	0.067
Secondary education	-0.549	0.198	0.046	-0.001	-0.045
Tertiary education	0.536	0.246	-0.032	-0.030	0.061
Household average annual income					
Income between GHS 1000 to GHS 2000	-1.055***	0.003	0.084	0.011	-0.095
Income above GHS 2000	-1.416***	0.001	0.126	-0.008	-0.118
Farm characteristics and experience					
Renting land	-0.026	0.942	0.002	0.001	-0.003
5 - 10 years of farming	-0.100	0.781	0.007	0.003	-0.010
More than 10 years of farming	-0.288	0.523	0.021	0.007	-0.028
Belong to a farmer's association	-0.497	0.137	0.040	0.003	-0.043
Often true Sometimes true	-1.839***	0.003			
Sometimes true Never true	2.764***	0.000			
Number of observations	414				

Significant at 90% (*), 95% (**), 99% (***) confidence.

Source: Field Work, January 2024

Both income levels, GHS 1000 to GHS 2000 (at the time US\$1 = GHS 16.10) and above GHS 2000.00 (at the time US\$1 = GHS 16.10), increased the household ability to afford a balanced diet by 8.4% and 12.6% respectively and also decreased the household inability to afford a balanced diet by 9.5% and 11.8% respectively. Among the households (182) that skip or cut meals sizes because they do not have enough money for food, household heads aged from 31–50 years, household heads being a widow, household heads with permanent employment as farmers, and household income level of GHS 1000 to GHS 2000 (at the time US\$1 = GHS 16.10) positively affects the frequency at which they skip or cut meals sizes. Meanwhile, household heads belonging to a farmers' association negatively affects the frequency at which they skip or cut meal sizes.

From the results in Table 6, household heads aged from 31 to 50 years decrease the likelihood of skipping/cutting meal sizes almost every month by 9.4% and increase the likelihood of skipping/cutting meal sizes only in one/two months in the past 12 months by 36.1% compared to household heads aged below 31. There is no significant difference between household heads aged above 50 and those aged below 31. For widows, their likelihood of skipping/cutting meal sizes almost every month decreases by 4.7% and the likelihood of skipping/cutting meal sizes only in one/two months in the past 12 months increases by 45.2%. The likelihood of a household head whose permanent employment is farming skipping/cutting meal sizes almost every month goes down by 23.1%. The likelihood of temporary and permanent farming household heads

skipping/cutting meal sizes one month or two months in the last 12 months increased by 56.2%. Only households with income levels of GHS 1000.00–GHS 2000.00 (at the time US\$1 = GHS 16.10) were statistically different from households with incomes below GHS 1000.00 (at the time US\$1 = GHS 16.10). The likelihood of households with income levels between GHS 1000.00 and GHS 2000.00 (at the time US\$1 = GHS 16.10) skipping/cutting meal sizes almost every month reduces by 7.3% and goes up by 36.7% for the likelihood of skipping/cutting meal sizes only one or two months. When the household head belongs to a farmer association, the likelihood of skipping/cutting meal sizes almost every month goes up by 14.7%. The likelihood of skipping/cutting meal sizes only one or two months in the past twelve months goes down by 43.0% compared to household heads who do not belong to any farmer's association.

Table 6: Estimates of Ordinal Logistic Regression of Household frequency of skipping meals

	Coefficient	P-value	Marginal effects		
			Almost monthly	Some month	1 or 2 months
Household head demographic characteristics					
Male	-0.139	0.747	0.006	0.028	-0.034
31 - 50 years	1.515***	0.001	-0.094	-0.267	0.361
Above 50 years	-0.056	0.959	0.002	0.011	-0.014
Married	-0.698	0.252	0.023	0.138	-0.161
Widowed	14.179***	0.000	-0.047	-0.406	0.452
Divorced	-	-	-	-	-
Permanent employment as a farmer	2.645***	0.000	-0.231	-0.330	0.562
Basic education	0.035	0.941	-0.001	-0.007	0.009
Secondary education	0.081	0.892	-0.003	-0.017	0.020
Tertiary education	-0.103	0.862	0.004	0.004	-0.025
Household average annual income					
Income: GHc1000 to GHc2000	1.559**	0.018	-0.073	-0.294	0.367
Income: GHc2000	0.529	0.449	-0.021	-0.107	0.128
Farm characteristics and experience					
Renting land	0.436	0.385	-0.21	-0.087	0.108
5 - 10 years of farming	-0.858	0.238	0.04	0.170	-0.210
More than 10 years of farming	-0.578	0.465	0.024	0.117	-0.141
Belong to a farmer's association	-1.893***	0.000	0.147	0.282	-0.430
Often true Sometimes true	-0.138	0.878			
Sometimes true Never true	2.685**	0.004			
Number of observations	182				

Significant at 90% (*), 95% (**), 99% (***) confidence.

Source: Field Work, 2024

5. Discussion

5.1 Types of agrochemicals used by farmers in relation to food security

The findings that 99.5% of farmers used fertilisers, and about 95% used herbicides and insecticides, highlight a growing reliance on agrochemicals in modern smallholder farming systems. This trend is consistent with recent studies across Sub-Saharan Africa and other developing regions where increased agricultural intensification and the pursuit of higher yields have encouraged widespread chemical input usage (Asante et al., 2024). The relatively low use of fungicides (36.6%), compared to other agrochemicals, suggests that fungal-related crop diseases may either be less prevalent or less recognized among the surveyed farmers. However, it may also reflect limited access to fungicides or inadequate extension services that fail to diagnose or educate smallholder farmers on fungal threats (Mandal et al., 2023; He et al., 2024). The high non-use rate (63.4%) of fungicides could potentially expose farmers to unmitigated crop losses in cases of fungal outbreaks, particularly in increasingly humid conditions due to climate variability (George et al., 2025). The diversity of agrochemicals reported—ranging from fertilizers such as NPK, nitrogen, phosphate, and potash, to herbicides like Glyphosate and 2,4-D, and insecticides such as DDT, Malathion, and Diazinon—reflects both the complexity of modern pest and nutrient management and a concerning trend of persistent organic pollutant (POP) usage, especially substances like DDT and Diazinon, which are banned or restricted in many countries due to their toxicity and environmental persistence (Zhou et al., 2025; Zhang et al. 2025).

5.2 Farmer household food insecurity and socioeconomic determinants

The study's findings reveal a significant association between the age of household heads and household food insecurity experiences, particularly among those within the 31–50 age bracket. Specifically, households led by individuals aged 31–50 were more likely to cut meal sizes, skip meals, eat less than they felt they should, or experience hunger without eating, compared to those led by younger individuals aged 18–30. This aligns with recent evidence that household vulnerability to food insecurity is not uniformly distributed across age groups, with middle-aged household heads often facing greater economic pressures due to larger household sizes and greater dependency burdens (Adams et al., 2020). Interestingly, no significant difference was observed between the youngest (18–30) and the oldest (above 50) household heads, which could reflect that older households either have better coping mechanisms or smaller household sizes, thus reducing food insecurity exposures—a pattern noted by Doss (2025). Older household heads may also have diversified livelihoods, social capital, or accumulated assets that buffer them against food shortages (Wossen et al., 2028). The study further shows that higher education levels among household heads are associated with a reduced likelihood of experiencing food insecurity, although the coefficients were not statistically different from those with no formal education. This is not in line with Guyalo's (2025) assertion that education alone, without corresponding income or structural support, may not offer enough protection against food insecurity, especially in rural and informal economies.

Additionally, farming on one's own land and belonging to a farmers' association appears to reduce food insecurity risks, but these factors were also not statistically significant. This is consistent with findings that land ownership and social capital through group membership are important, but their effects are often moderated by market access, productivity, and climatic shocks [38, 4]. The strongest protective factor identified was adequate household income. Households with monthly incomes above GHS 1000.00 significantly reduced their likelihood of cutting meal sizes or skipping meals, with even greater reductions among those earning above GHS 2000.00. This

finding directly supports well-established evidence that income is the most critical determinant of food security because it enhances purchasing power and dietary diversity (World Bank, 2017; Akosikumah et al., 2025).

The results indicate that higher household income significantly reduces the probability of food insecurity. Specifically, households earning between GHS 1000.00 and GHS 2000.00 (approximately US\$62–US\$124) per month were 57.5% less likely to eat less than they felt they should, while those earning above GHS 2000.00 (US\$124+) had a 47.4% reduction in this likelihood, compared to households earning less than GHS 1000.00. Similarly, the probability of a household being hungry but unable to find food dropped by 52.4% and 42.5% for the two higher income brackets, respectively. These findings reinforce the strong and consistent evidence that income is a primary determinant of household food security. Households with higher incomes generally have better access to adequate and nutritious food, are more resilient to price shocks, and can diversify their diets more easily (Atuoye et al., 2019). In low-income rural settings, small increases in income can yield substantial improvements in food consumption patterns.

5.3 Household head characteristics in relation to having a balanced diet and coping strategies

The findings from Table 6 highlight how socioeconomic and demographic factors shape households' coping strategies in response to food insecurity conditions, particularly with regard to skipping meals and the inability to afford a balanced diet. The analysis shows that marital status and basic education of the household heads are not statistically significant predictors of a household's ability to afford a balanced diet. Interestingly, compared to single or uneducated household heads, married and having basic education had a slightly higher likelihood of being able to eat a balanced diet. This could reflect the fact that in Africa, higher household dependency burdens, especially in married households, strain limited food budgets (Quak, 2025). The findings support the assertion that, in Asia—Nepal and Vietnam—formal education correlates with improved dietary diversity and food security, as educated individuals are more likely to engage in non-farm employment and access market information (Phuong et al., 2025; Rahman et al., 2025). Household composition and size, rather than just education or marital status, often determine dietary adequacy in low-income settings. For instance, studies in Kenya, Tanzania, and Ghana report that larger households often experience lower per capita food access and dietary diversity, especially when resources are limited (Kansiime et al., 2021).

In addition, as expected, income level is a strong and significant determinant of food security. Households earning between GHS 1000–2000 and those earning above GHS 2000 were more likely to afford a balanced diet and less likely to frequently skip meals. Specifically, these income levels increased the ability to afford a balanced diet by 8.4% and 12.6%, and reduced the inability to do so by 9.5% and 11.8%, respectively. Household income emerged as a strong predictor of food security, consistent with global empirical evidence demonstrating that higher income improves access to diverse and nutritionally adequate diets. In Africa, studies in Ethiopia, Ghana, and Nigeria show that households with higher agricultural and off-farm incomes have significantly greater food consumption scores and reduced risk of food insecurity (Dakurah et al., 2024; Jumpah et al., 2024). These findings align with the notion that income enhances both food purchasing power and investments in productive assets that support sustained food access. Within the Asian continent, evidence from India and Bangladesh also supports the fact that rural households with

diversified income sources often experience better food security outcomes (Ferdous et al., 2021; Panda and Parashari, 2024; Cruz-Sánchez et al., 2024). However, some studies report weaker or non-linear relationships. In parts of Europe, where social safety nets moderate income impacts, food insecurity persists even among moderate-income households facing high living costs and market food price volatility (Loopstra et al., 2018; Hollinrake et al., 2025).

Skipping or reducing meal sizes is one of the most common coping mechanisms during food shortages. Our findings revealed that household heads aged 31–50 are less likely to skip meals frequently (monthly) but more likely to do so occasionally (1–2 months/year). This indicates a moderate vulnerability, where coping strategies are used strategically rather than chronically. Widowed household heads are less likely to skip meals monthly but more likely to skip occasionally. This may be due to social safety nets or kin support mitigating extreme food shortages (Mitra et al., 2022). Permanently employed farmers show a 23.1% reduction in monthly meal skipping, suggesting that stable agricultural livelihoods buffer against chronic food insecurity. However, the 56.2% increase in occasional meal skipping among both temporary and permanent farmers may reflect seasonal income gaps, consistent with the literature on agricultural seasonality and food access (Shrestha et al., 2024). Belonging to a farmer association reduces the likelihood of meal skipping in one or two months (by 43.0%) but surprisingly increases monthly skipping by 14.7%. This duality could reflect uneven benefits from associations—some provide access to inputs and markets, while others may involve financial obligations or collective shocks that increase vulnerability (Kehinde et al., 2021).

6. Conclusions and Recommendations

This study examined the relationship between agrochemical use and household food security in the Sissala East Municipality of Ghana using an explanatory quantitative cross-sectional design. The findings indicate that agrochemical use is positively associated with improved household food security, likely through enhanced agricultural productivity. However, the results also demonstrate that socio-demographic factors significantly moderate this relationship. Higher household income and educational attainment strengthen the likelihood that productivity gains translate into improved food security, while larger household size increases vulnerability where resources are constrained. These findings contribute localised empirical evidence to the growing literature on agricultural intensification and food security in sub-Saharan Africa. Importantly, the study highlights that technological inputs alone are insufficient to guarantee improved welfare outcomes. Rather, household characteristics and economic capacity determine how effectively production gains convert into dietary adequacy. The results, therefore, support integrated agricultural policies that combine access to agro-inputs with farmer education, income diversification strategies, and strengthened extension services promoting safe and efficient agrochemical use.

This study is limited in terms of the cross-sectional design restricts causal interpretation of observed associations; we can only infer correlations, not causal relationships. In addition, reliance on self-reported data may introduce recall bias in food consumption and agrochemical use reporting, particularly regarding the 7-day recall period for FCS. Future research should adopt longitudinal and multi-site designs to enhance causal inference and external validity, incorporate objective measures of agrochemical use, and assess the trade-offs between agricultural productivity gains and long-term human and ecological well-being.

Data Availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request. Therefore, the dataset, and study instruments are attached as supplementary files for only evaluation not for public use.

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Figure Legend:

Figure 1: Farmers' Agrochemical Use and Household Food Security Relationship

Figure 2: Map of the Study Area

Figure 3: Type of Agrochemicals Farmers Used

Ethical Statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki (1964) and its subsequent amendments governing research involving human participants. Ethical approval (No. UBIDS/RERB/002/2025/08/09) for the study was obtained from the Research Ethics Review Board (RERB), University of Business and Integrated Development Studies (SDD-UBIDS), Ghana—West Africa. Permission to conduct the research was also sought from the Sissala West Municipal Assembly and relevant community authorities. The study ensured respect for participants' autonomy, privacy, dignity, and confidentiality throughout the research process. Participation was entirely voluntary, and respondents were informed of their right to decline participation or withdraw from the study at any stage without any consequences. No physical, psychological, social, or economic harm was anticipated or inflicted on participants during the study. Personal identifiers were not collected, and all data were anonymized, securely stored, and used solely for academic and research purposes. The findings are presented in aggregate form to ensure that individual participants cannot be identified.

Informed Consent Statement

Written informed consent was obtained from all participants prior to their inclusion in the study. Before administering the questionnaire, the objectives, procedures, potential benefits, and minimal risks associated with the research were clearly explained to each participant in a language they understood. Participants were assured that their participation was voluntary, that they could refuse to answer any question or withdraw from the study at any time without penalty, and that all information provided would be treated with strict confidentiality and used exclusively for research purposes. For participants who could not read or write, the consent information was read and explained in the local language, and informed consent was obtained through a thumbprint in the presence of an impartial witness.

Competing Interest: The author(s) declare no competing interests.

AI Statement: During the preparation of this work, the author(s) used ChatGPT to assist in the drawing of the conceptual framework for the study. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Authors Contributions: All authors contributed equally to the study. Initially, S.M. and G.K.N. and J.B.B.S. conceptualized the study idea. G.K.N. and S.M. assisted by J.B.B.S. made the data collection instrument. G.K.N. did the data analysis. All the authors did the manuscript drafting and approval. While J.B.B.S. reviewed the manuscript, G.K.N. and S.M. coordinated the feedback.

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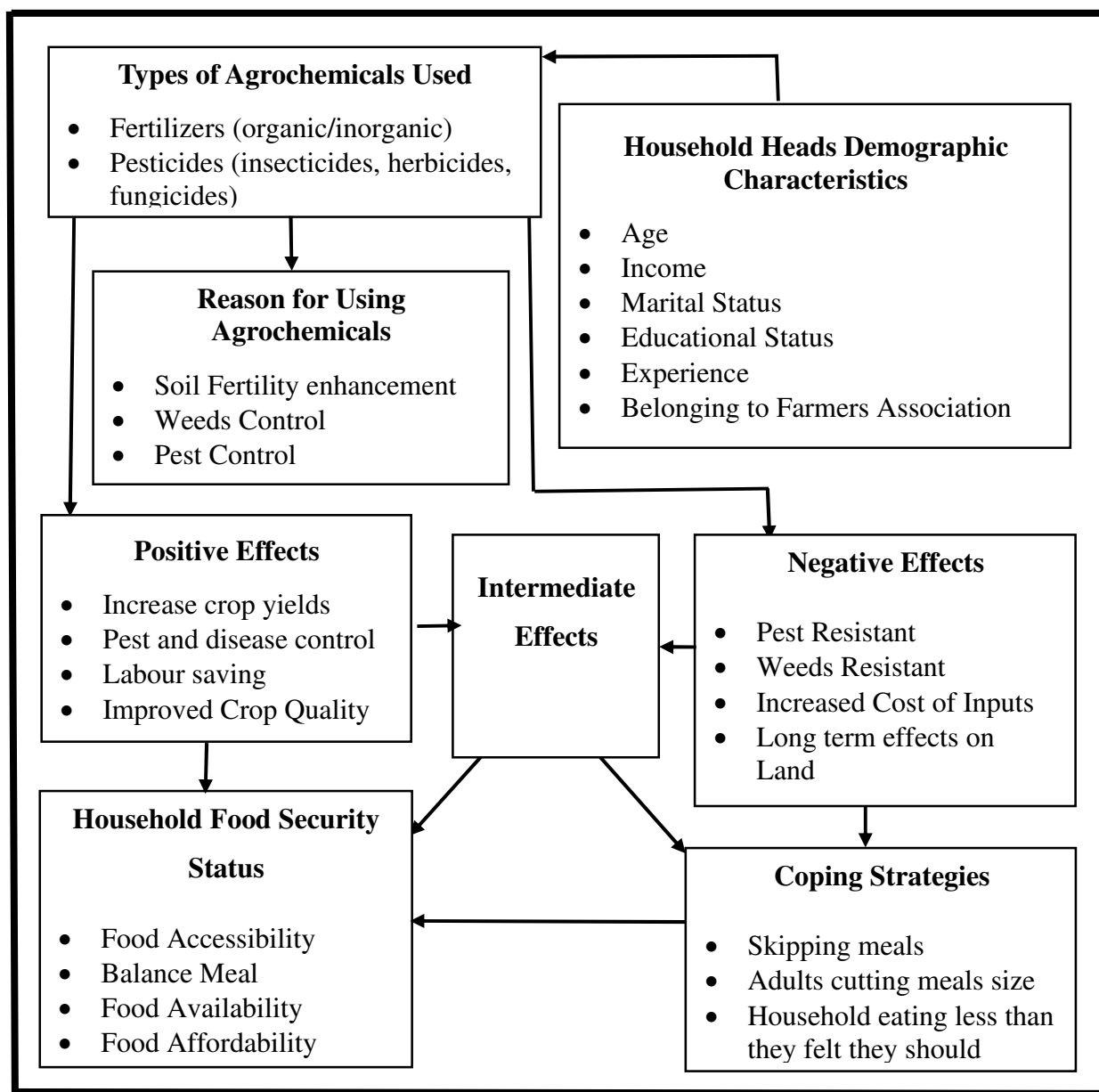


Figure 1: Farmers' Agrochemical Use and Household Food Security Relationship

Source: Adapted from World Food Programme (WFP) (2008)

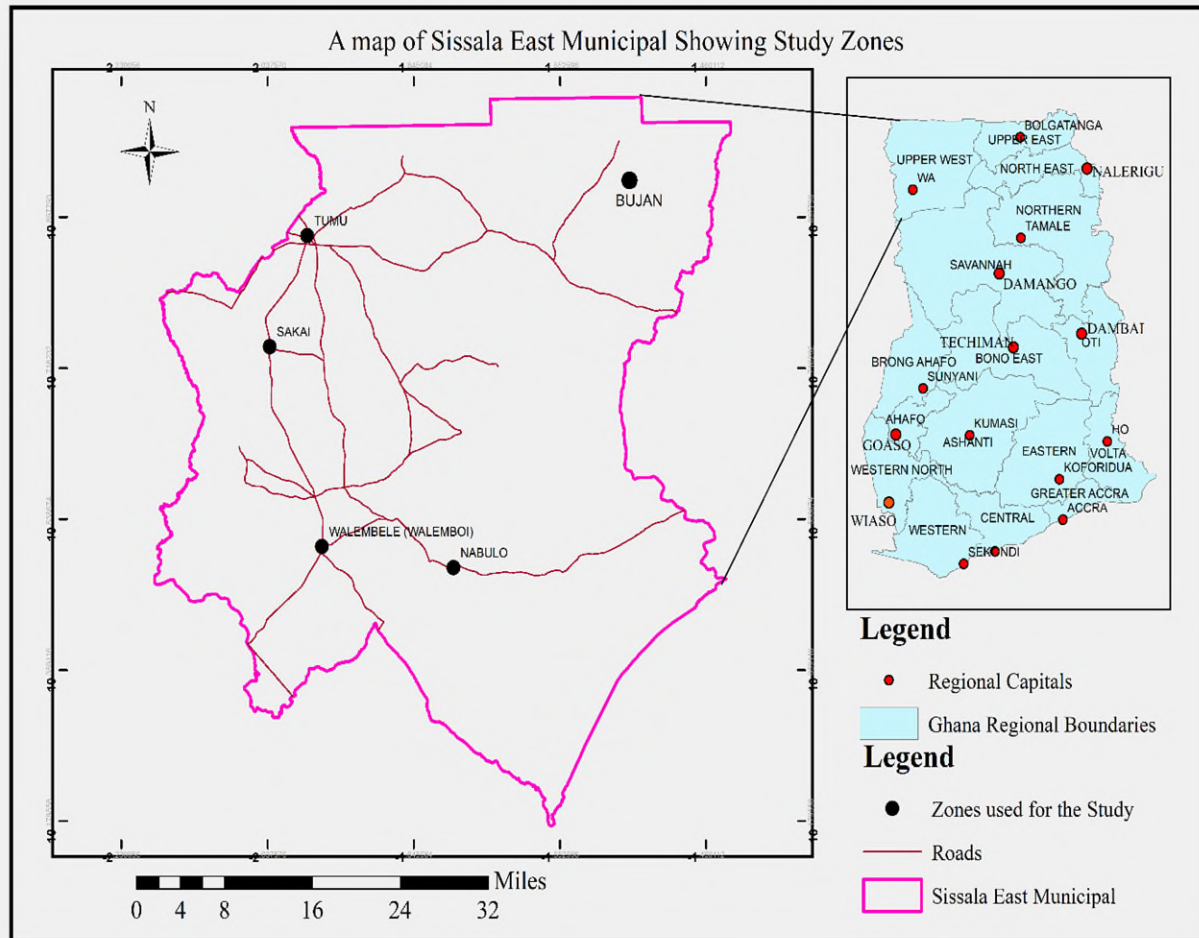


Figure 2: Map of the Study Area

Source: Authors' Construct, 2025

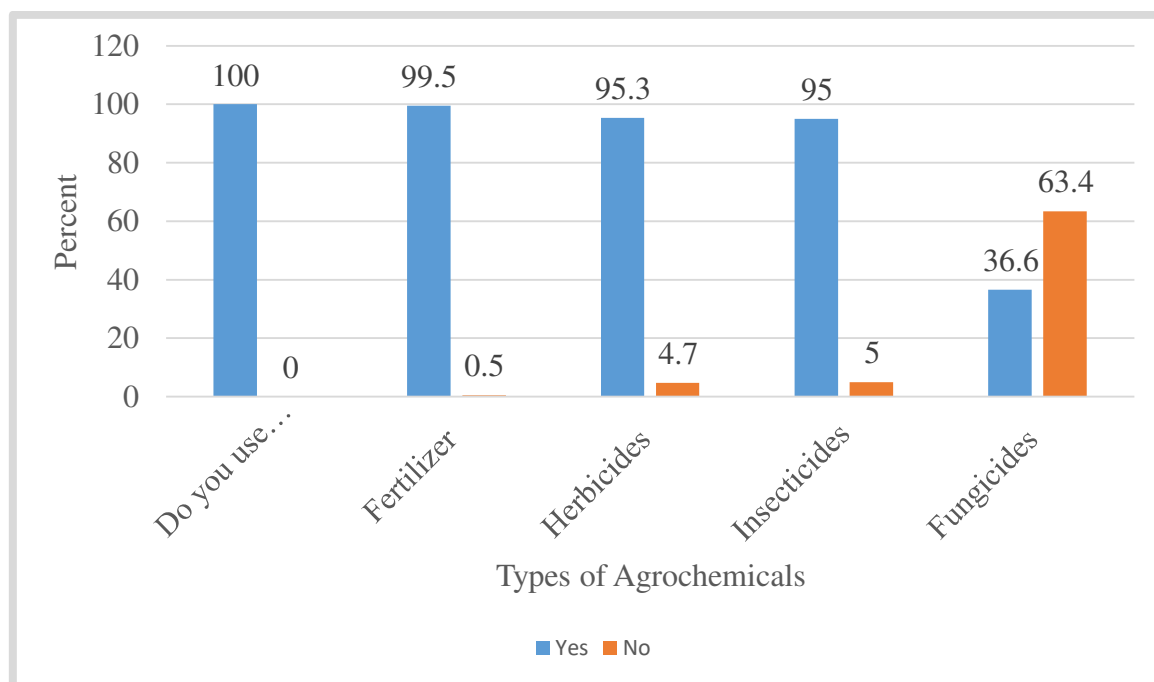


Figure 3: Type of Agrochemicals Farmers Used

Source: Field Work, January 2024