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EXAMINING THE NEXUS BETWEEN DRY SEASON VEGETABLE PRODUCTION AND HOUSEHOLD FOOD SECURITY IN THE UPPER EAST REGION OF GHANA

James Anaba Akolgo
Bolgatanga Technical University, Department of Ecological Agriculture, Ghana,
ORCID: 0000-0002-4241-2906

Yaw B. Osei-Asare
University of Ghana, Department of Agricultural Economics and Agribusiness,
Ghana. ORCID: 0009-0000-3635-8061

Daniel Bruce Sarpong
University of Ghana, Department of Agricultural Economics and Agribusiness,
Ghana, ORCID: 0000-0001-8288-2999

Freda Elikplim Asem
University of Ghana, Department of Agricultural Economics and Agribusiness,
Ghana, ORCID: 0000-0003-0331-2256

Wilhemina Quaye
CSIR-Science and Technology Policy Research Institute, Ghana.
ORCID: 0000-0002-4009-2320

Abstract

Rates of food insecurity in Ghana have been rising before the onset of COVID-19 and have remained unchanged since then despite the economy's expansion in the 1990s to date. Dry-season commercial vegetable production is one of the people's key activities for survival in the Upper East Region. This study sought to examine the extent and determinants of food insecurity through an econometric estimation with household data from 322 dry-season vegetable farmers in the region. The study revealed that close to half (45.7%) of the sampled farm households are food insecure (FI) while food secure (FS) is 54.3%. FI households have a head count index of 33.33%, a food insecurity gap of 31.20 and a severity of food insecurity of 12.97%. Vegetable income, non-farm employment and own food production have positive marginal effects on households' calorie availability in the region. The Ministry of Food and Agriculture (MOFA) should provide logistics and capacity-building workshops for the Agricultural Extension Officers (AEOs) to improve their knowledge and skills and ensure their accessibility to dry season vegetable farmers to improve the productivity, increase output and income of farmers to enhance food security in the region.

Keywords: *Food Insecurity, Dry Season Vegetables, Upper East Region, Calorie Availability.*
JEL Codes: *C67, I32, D13, D12.*

1. Introduction

One important topic in the food policy discourse has been the role of cash crops in sustainable food security in developing countries (Kuma, Dereje, Hirvonen, & Minten, 2019). Some scholars argue that cash crop contributes to a reduction of poverty and food insecurity. To them specializing in cash crop production builds households' resilience against food insecurity via market purchases (Eshetie, Matafwali, Mwalupaso, Li, & Liu, 2022). Cash crop production also increases farmers' purchasing power for food and non-food consumption goods and services thereby helping to improve households' overall welfare (Assefa Wendimu, Henningsen, & Gibbon, 2015). Although the production of food cash crops like vegetables, is labour-intensive, it benefits non-cash producers through employment creation and the inputs can be utilized for the production of other crops (Joosten, Dijkxhoorn, Sertse, & Ruben, 2015).

To other scholars, however, cash cropping may not necessarily enhance household welfare, especially when the food system of the household is linked to consumption habits, frequency and amount of income, spousal control over resources, the local market and vulnerability to changes in food prices (Von Braun, 1995). Specializing in cash crop production predisposes farmers to more risk-related losses in production, markets and prices than those who diversify their choice of crops (Birhanu, Tsehay, & Bimerew, 2021). Therefore, rather than specializing in a single cash crop which increases the risk exposure of farmers, diversification spreads the risk portfolios and smoothens household consumption (Birhanu et al., 2021). Manickam et al. (2023) again point out that diversification of vegetable crop production improved farmers' income in East Indian Plateau.

The debate on the contribution of cash crop production to income and food security has been inconclusive. For instance, the findings of Belsky and Siebert (2003) revealed that the cultivation of cacao in the Central Sulawesi region of Indonesia adversely affected long-term agricultural productivity, sustainability and livelihood security including food self-sufficiency. Additionally, a finding of Mintz-Habib (2013) reveals a negative correlation between Jatropha production, income and food insecurity in Sarawak, Malaysia. On the contrary, Kuma et al. (2019) in Ethiopia found that coffee income relaxes the seasonal liquidity challenges and reduces households' food insecurity. Similarly, there was a positive correlation between castor oil production and food availability in Ethiopia (Negash & Swinnen, 2013), peanuts cultivation and diet diversity in Mali and rice production in Gambia (Pierre-Louis, Sanjur, Nesheim, Bowman, & Mohammed, 2007). These outcomes all agreed with earlier research findings by Von Braun (1995) on maize production in Zambia as well as potato cultivation in Rwanda. Also, a recent study by Egbadzor, Akuaku, and Aidoo (2023) concluded that the baobab tree can be a perfect substitute for cocoa to raise income and reduce poverty and food insecurity not only in Ghana but also in other countries in Africa.

Interestingly, however, some empirical studies linking cash crop production and food security in other jurisdictions produced mixed outcomes. For example, Lam, Boafo, Degefa, Gasparatos, and Saito (2017) study on the effect of industrial crop expansion and food security outcomes on cotton production in Northern Ghana and sugarcane production in Central Ethiopia revealed a mixed outcome. In their study, lack of government support among others stagnated cotton production, increased poverty, and lowered food security in cotton-growing households in Ghana while sugarcane contributed as much as 51% of the total household income and food security in Ethiopia. Similarly, Kanyamurwa, Wamala, Baryamutuma, Kabwama, and Loewenson (2013), found equally mixed outcomes among women farmers engaged in coffee production in Uganda. Additionally, the study by Jemal, Callo-Concha, and van Noordwijk (2022) in Ethiopia revealed that income from cash crop production did not remove household food insecurity.

This research revisits the food security discourse in the context of dry-season vegetable production and its effect on food security in the Upper East Region of Ghana. Dry-season vegetable production is a practice whereby farmers produce vegetables during the dry season using water from various sources (eg, dams, rivers, boreholes, wells, dug-outs etc) rather than rainfall to raise income to improve the livelihood of their households. Producing vegetables in the dry season using irrigation is an important activity to obtain cash and food not only in Ghana but also in other countries in sub-Saharan Africa (Keatinge, Yang, Hughes, Easdown, & Holmer, 2011). In Ghana, vegetables represent approximately 32% of total crop sales for farm households and are said to be an important source of income for the livelihood of about 30% of all crop-producing households (GSS, 2014). Additionally, the suitability of the climatic conditions for vegetable production combined with Ghana's proximity to markets in the European Union (EU) place it in an advantageous position for vegetable exports within the sub-region. Despite the central role dry-season vegetable production plays in the Ghanaian economy (a key driver for foreign exchange and income for small-scale farmers), food production and availability continue to lag behind the rate of population growth (CFSVA, 2020). Food insecurity is particularly higher in the Upper East Region with the gradient of severity increasing from harvest and peaking during the lean season (Kansanga et al., 2022).

Despite available research and knowledge about how dry-season vegetable production shapes the food security systems of smallholder farming households, improving the understanding of the citizens on their food security status and factors influencing it is still germane. Besides, the impact of dry-season vegetable production in the context of income and food security has not been adequately assessed across the vegetable-producing districts in the Region. Although a large number of the existing research have examined the contribution of various economic activities to household food security, only a very few exist on the contribution of dry-season vegetable production (Ma, Abdul-Rahaman, & Issahaku, 2022). Van Asselt, Masias, and Kolavalli (2018) focused extensively on the competitiveness of vegetable production while Balana et al. (2019) dealt with the contribution of vegetables to the reduction of rural poverty and food insecurity in Ghana. To the best of our knowledge, no research has yet been conducted on the extent of food insecurity among dry-season vegetable farm households and the determinants for addressing the challenge in the Upper East Region of Ghana.

To achieve the objective of the study, the following specific questions were asked: What is the extent of food insecurity among dry-season vegetable farm households in the Upper East Region? How does the income from dry-season vegetable production affect farm households' food security status in the Upper East Region? What factors affect the security of food among dry-season vegetable farm households in the study area? This paper achieved its objective by determining the extent and factors of food insecurity across the dry season vegetable farming households in the Upper East Region. This study may provide the baseline information on food security in the region. Besides, it may also contribute to the existing literature on how to overcome the vulnerability of food-insecure households in the region. Additionally, the analysis can provide information for further study as well as add knowledge to other researchers interested in the subject.

The rest of the paper continues with a review of the literature on the nexus between vegetable production and food security and the conceptual framework of the study. This is followed by a methodology that includes a brief description of the study area, examining the extent of food insecurity status, econometric model specifications and a summary of the literature on the determinants of household food security. The next was the presentation of the results and discussion while the last part comprised the conclusions and recommendations of the study.

1.1. The Nexus between Vegetable Production and Food Security

In Ghana, vegetable production has been one important strategy for poverty reduction through income and foreign exchange earnings for households and by extension the governments (Amfo & Baba Ali, 2021). Vegetable production is considered more beneficial to farmers than traditional staple crop farming in terms of employment, cash income and food security opportunities. Several empirical studies have revealed the positive effects of the vegetable sector on income and food security in many countries (Gebru, Leung, Rammelt, Zoomers, & van Westen, 2019; Hunde, 2017). Vegetable production also encourages export, develops the rural labour market and improves wage earnings. There are also some multiplier effects via the marketability and profitability of vegetables. Furthermore, the intensive demand for labour in vegetable production and processing industries contributes to high employment (Hunde, 2017). Research by McCulloch and Ota (2002) showed that the income from vegetable farming is estimated to be four times higher than from non-vegetable farming in Nairobi, Kenya. Their study further concluded that the poverty rates of workers, mostly women employed in the vegetable sub-sector were less than workers employed in non-vegetable sectors.

In terms of consumption, vegetable helps countries to have healthier populations, who may work to contribute to the growth and development of the economy. Fan, Dang, Tong, and Li (2019) state that the consumption of vegetables by people of different age groups including children, women, the working class and the aged significantly reduced the health budget in China. Vegetables are rich in biochemical, phytochemical compounds, fibre and antioxidants such as vitamins A, C and E, hence are important in neutralizing free radicals known to cause a wide range of non-communicable diseases like diabetes, ischaemic cardiovascular diseases, cerebrovascular diseases, lung and gastrointestinal cancers, and hypertension, stroke, and cataracts among others. Vegetable reduces non-communicable diseases which account for about 63% of deaths globally (Mishra, Neupane, Shakya, Adhikari, & Kallestrup, 2015). Therefore, consuming vegetables is a major source of preventive health care system, particularly among elderly people (Ridberg et al., 2019).

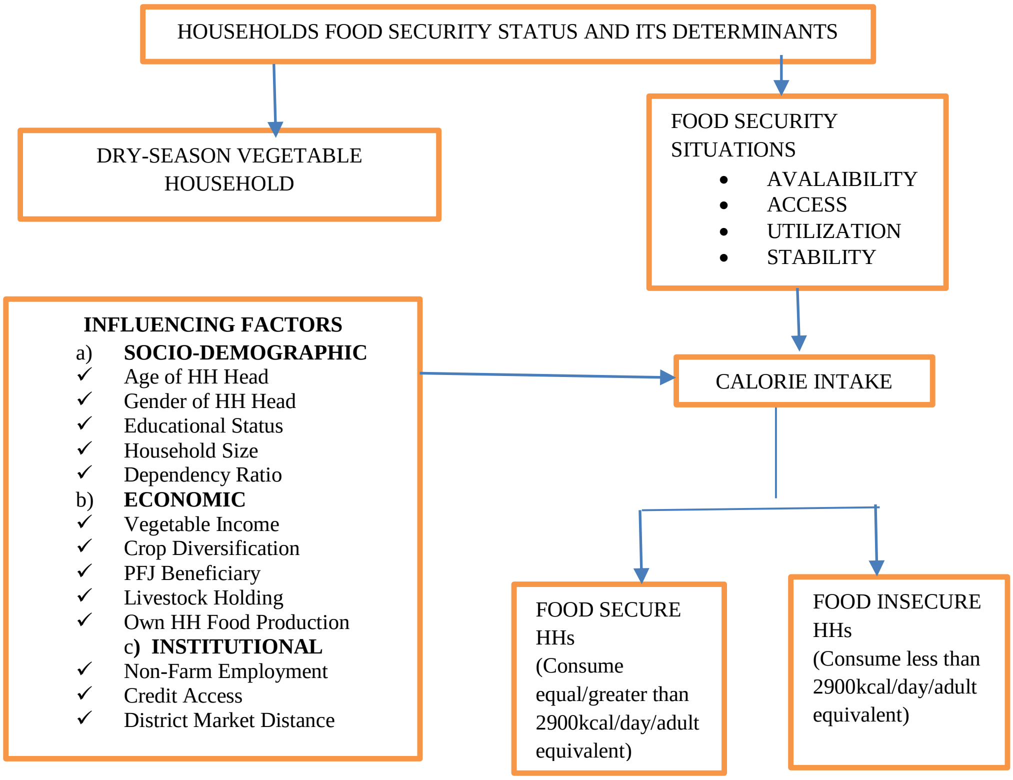
A high level of poverty particularly in rural areas is a major contributing factor to low consumption of vegetables in developing countries (Keatinge et al., 2011). According to Van Asselt et al. (2018), vegetable consumption constitutes about 12.8% of the annual budget expenditure of Ghanaians yet it still falls short of the WHO's recommended quantity per person per day (Joosten et al., 2015). The ability to produce high quantities of vegetables influences households' consumption, raises income, improves food access and enhances the socio-economic status of the majority of people both in rural and urban communities across the country (Amoah, Debrah, & Abubakari, 2014). Therefore, it is expected that when all challenges including abiotic (erratic rainfall, poor soils, etc) and biotic (arthropod pests, fungal, bacterial and viral diseases) factors are overcome, yields levels of vegetables would improve, which may translate to increases in vegetables' consumption as well as raise more income for the farming households in Ghana (Joosten et al., 2015; Van Asselt et al., 2018).

1.2. Conceptual Framework of the Study

Food security exists when people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, IFAD, UNICEF, WFP, & WHO., 2020). Drawing from available literature and personal observation, several factors affect household food security. The framework for this study was conceived based on factors affecting the availability and access to food at the household level in Ghana. Food may be available only through the production, distribution and exchange of food while access indicates the capacity to acquire sufficient quantities of food via purchase. The study particularly focused on the important contributions of vegetable production to food security in the study area. In this study, the concept therefore reflects the linkage between household food security and some demographic, socioeconomic and institutional factors as shown in Fig. 1.

Enhancing dry-season vegetable farming will increase the productivity of the farms and income (cash earnings). According to Owusu, Abdulai, and Abdul-Rahman (2011), the major challenge affecting food security in most agriculture-dependent households is not just food production but low income and poverty. In light of this, there are two pathways through which income from dry-season vegetable production may influence food security in farm households. That is the income effect via the market pathway and the food production effect via its own (subsistence) food production pathway. Studies have shown that market purchases have a great contribution to smallholder diets in SSA including Ghana (Scott, 2017).

The income effect, on the other hand, is achieved when both the food and the output markets are not interrupted at any stage. When the food and output markets are not completely functional, dry-season vegetable income would affect food security via the food (crops and animals) production effect. That is if a vegetable farm household is not able to purchase food due to a missing market as a result of transaction costs among other challenges, the household's ability to achieve food security would depend primarily on the ability to invest the vegetable income on producing households' crops and rearing livestock. Off-farm and non-farm employment and transfers also play major roles in household food security purchases via the market channel. This study focuses on the income effect pathway.



Source: Authors construct, (2023)

Figure 1 Conceptual Framework of the Household Food Security Study

2. Methodology

2.1 Description of Study Area

The study area is the Upper East Region of Ghana. The Upper East region is among the 16 regions, located in the northeastern corner between latitudes $10^0$15 and 10^0 00 north and longitudes 0^0 and 1^0 4 west of Ghana. It is bordered to the north by Burkina Faso, to the east by the Republic of Togo, to the west by the Sissala district in the Upper West Region and south by the North East Region of Ghana. The region has 3 municipalities and 12 districts where agriculture constitutes about 83% of the livelihood of the people (GSS, 2019). The entire Northern Ghana including the Upper East Region experiences unimodal rainfall season with annual rainfall ranging between 700mm and 1010 mm, with peak rainfall occurring in late August and ending in September. The annual evapotranspiration is higher than precipitation, making water storage reservoirs a critical source for agricultural activities during the dry season. The long spell of dry season from October to mid-May is accompanied by dry cold and dusty "harmattan" winds from November to February. The months of March to April are, however, characterized by dry hot temperatures, sometimes above 40^oc. The natural vegetation is the savannah woodland with scattered drought-resistant trees and grasses (Mdemu, Rodgers, Vlek, & Borgadi, 2009).

The staple crops grown in the region include millet, guinea corn, maize, groundnut, beans, and sorghum. Rice is, however, grown in both rainy and dry seasons, though on a small scale during the dry season along with vegetables like tomatoes, pepper, onions, garden eggs, cabbage, "leafu" and "bito" leaves on irrigation sites.

2.2 Sampling Procedure

The study employed data from a comprehensive survey of dry-season irrigated vegetable farm households in the Upper East Region. A household is considered a dry-season vegetable farm household if it has at least one member (either a spouse or any breadwinner) who cultivates vegetables during the dry season using a conventional or any of the emerging irrigation systems to generate income to support the household's livelihood including food provision. The survey was conducted between May - November 2019. The Upper East Region was chosen because dry season vegetable farming constitutes one of the main economic activities of people in the area.

The households for the study were selected using a multi-stage sampling approach. In the first stage, three (3) municipalities and four (4) districts were selected based on their dry-season vegetable production potentials. These seven vegetable-growing districts were clustered into three to constitute the Primary Sampling Unit (PSU). They comprised the Central zone (Bolga municipal, Talensi and Bongo districts), Eastern zone (Bawku Municipal, Binduri and Zebilla districts) and Western zone (Navrongo Municipal).

In the second stage, eight (8) communities per farming zone were selected using simple random sampling from the three (3) zones making up 24 communities. A complete list of vegetable farm households from the sampled communities constituted the Secondary Sampling Unit (SSU) or the sample frame. The district agricultural officers provided the list of the farmers to the research team to identify the households for the study. Finally, using a simple random sampling procedure and probability proportional to size, 322 households were selected from a total of 1998 dry-season vegetable farm households from the 24 communities. The households for the research were selected using the Kothari (2004) sample size formula as soon below:

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq} \tag{1}$$

$$n = \frac{(1.96)^2 0.5*0.5*1998}{(0.05)^2\ (1998-1)+(1.96)^2*0.5*0.5} = 322$$

Where: n = sample size; N = total population; Z= 95% confidence interval under the normal curve (1.96); e = acceptable error term (0.05) and p and q are estimates of the proportion of the population to be sampled (p = 0.5 and p + q = 1).

2.3 Data Collection and Analysis

Under the direct supervision of the lead researcher, the data was collected by a team of enumerators recruited and trained on the use of smartphone technology before the survey for the data collection. Both quantitative and qualitative primary data were collected via face-to-face interviews with individuals who prepare food in farm households using tablets. Semi-structured survey questionnaires were used for the data collection. The questionnaire was first pre-tested on a randomly selected 10 households before deploying for the survey. The Open Data Kit (ODK) platform was used and data was uploaded daily to a central point. The study used cross-sectional data recognizing that it may not account for endogeneity biases. This notwithstanding, the researchers made efforts including quality data collection and close supervision to reduce the problem.

The study applied descriptive and inferential statistics as well as an econometric model to analyze the data. Descriptive statistics (percentage and means) were used to present summary statistics of quantitative data about the socio-demographic, institutional and economic characteristics of the sampled households. For econometrics analysis, the study employed the Foster-Greer-Thorbecke (FGT) and the Food Security Index (FSI) approaches to determine the food security status of households in the study area. Inferential statistics such as T-tests were used to assess the existence of statistically significant differences in the data between food-secure households and food-insecure households. Additionally, a binary probit model was applied to analyze the effects of vegetable income and other variables on households' calorie intake in the study area.

2.4 The Extent of Food Insecurity Status

There are many methods available to researchers for analyzing food security data. Calorie intake is one direct measure for physically estimating food consumed by individuals (Jemal et al., 2022). A structured questionnaire was given to respondents to report food items consumed in kind and the amount purchased or otherwise by the households within the week preceding the survey. Then, several processes were adopted to transform the data into calories while adjusting for age and gender composition. The physical quantity of food consumed by the sampled households was synthesized and assessed to determine the level of food security status of household members. The common approaches usually employed to establish the extent of food insecurity status at the household level include: the Foster-Greer-Thorbecke (FGT) approach (Zereyesus, Embaye, Tsiboe, & Amanor-Boadu, 2017) and the Food Security Index (FSI) approach (Kuwornu, Demi, & PK, 2013).

The FGT and FSI are proxies for household food security status. Both approaches employ the Recommended Daily Allowance (RDA) of calories per male adult, which is constructed based on the household food security line. The construction of a household's calorie intake is done according to the age, sex and activity level of household members as recommended by FAO and WHO (1985).

2.5 Estimating Household Calorie Intake (HCI)

Generally, the household calorie intake was estimated by determining the absolute quantity of food the household consumed within a seven-day recall period before the survey. This went through a series of steps. Firstly, each food item in local measurement units consumed was converted into standard metric units. Secondly, each food item (in kilogram) consumed was converted into standard calorie values (kcal) using the calorie conversion factor for each food item. That is, the total quantity of each food item consumed was multiplied by the food energy (calorie) content and edible portion. The total consumption (kcal) equals the total quantity of food items (kg) multiplied by the energy conversion factor and the edible portion (Ibok, Osbahr, & Srinivasan, 2019).

Finally, the net weekly calorie intake per household was divided by seven (7) to obtain the daily calorie intake. The members in each household were converted into adult equivalent (AE) household sizes with consideration for the age, sex, and activity level of each member. The daily calorie intake per adult equivalent of a household is obtained by dividing the net calorie consumption of the household by the adult equivalent household size. The calories per AE is preferred to the calories per capita since it allows for a comparison of calorie intake across households with different demographic compositions. One thing worth noting in this analysis is that more than two-thirds of diets of developing countries, particularly from Africa including Ghana come from cereals and starchy roots, few animal products, and may be high in fats, and sugars (Conceição, Levine, Lipton, & Warren-Rodríguez, 2016).

2.6 Estimation of the Recommended Daily Household Calorie Requirement

To be able to estimate each household's calorie requirement, all household members were first classified based on age and sex since people of different ages and sexes require different thresholds of food energy according to the World Health Organization (WHO). The daily calorie requirements of people of different ages and sexes in a household were converted into adult equivalents using the equivalent scales. This was done by multiplying the adult equivalent scales by the conversion factor of the respective age and sex of household members and converting it to the adult equivalent (AE). For example, a female of age between 11 and 14 years requires 0.76 of the adult equivalence while a male of the same age bracket requires 0.86 of the adult equivalence.

The total calorie requirement for each household is determined by multiplying the respective total adult equivalence in each household by the Recommended Daily Allowance (RDA) for an adult. The RDA is the minimum quantity of energy required to achieve about 97% -98% healthy status for every household member (Latham, 1997). In Ghana, an RDA value is 2900kcal for people aged between 19-51+ years old, as used by IFPRI (2000). The energy requirements for all ages and sexes for each household were then aggregated to give the total energy requirement of the household.

2.7 Measuring the Extent of Households' Food Insecurity

The estimation of the Food Security Index (FSI_i) for the ith household was determined based on the formula given:

$$FSI_i = \frac{Y_i}{R_i} \tag{2}$$

Where Y_i is the absolute daily calorie intake (or consumption) of the ith household and R is the recommended daily calorie (or energy) requirement per adult equivalent in the ith household. Households with FSI less than 1 are food insecure while households with FSI equal or greater than 1 are food secure. Based on the absolute daily calorie indicator, the study further estimated the household-specific food energy deficiency. A household's consumption below the daily AE consumption of 2900 kcal (the national food poverty line) per person in Ghana is considered undernourished (Fisher & Lewin, 2013). To this end, the study employed the Foster-Greer-Thorbecke approach (Foster, Greer, & Thorbecke, 1984) to determine the extent of food insecurity based on headcount ratio, food insecurity gap and severity of food security

Food insecurity headcount refers to the percentage of households whose per capita calorie consumption falls below the predetermined food poverty line. Similarly, the food poverty gap, also referred to as the food poverty depth, measures the extent to which those classified as food-poor or insecure, fall below the food poverty line. Likewise, the severity of food poverty (insecurity) measures the level of inequality among food-insecure households by assigning a higher weight. The specification of FGT is given by:

$$FGT_\alpha = (1/m)\sum_{i=1}^{n}\left(\frac{p - y_i}{p}\right)^\alpha \tag{3}$$

Where p is the cut-off line between food security and food insecurity (2900 calories per AE per day); y_i is the individual household's calorie intake per AE per day; m is number of households in the sample; n is the number of food insecure households and α reflects the weight, example $\alpha = 0,1,2 — attached$ to the severity of food insecurity. Following this formula, an expression within the summation is employed to evaluate a given household food insecurity status by setting α at 0, 1, or 2 to determine the extent of severity in that order. For instance, setting α at zero (0) in equation 3 is reduced to $FGT(\alpha = 0) = n/m$ to obtain the headcount ratio (or the percentage) of food insecure households. In other words, substituting $\alpha = 0$, classifies a household as food insecure. However, if $p - y_i \geq 0$, that household is considered food secure (Hoddinott, 2001).

Similarly, the food security gap is obtained when equal weight is attached to the severity of food insecurity among all food insecure, which means $FGT(\alpha = 1)$. Hence, summing $p - y_i$ gives the food insecurity gap, and further dividing by p is the index of food insecurity. This is given as:

$$\left(\frac{p-y_i}{p}\right)^\alpha \tag{4}$$

Where p and y_i and α remain as previously defined and setting α at one and two, respectively.

The food insecurity gap/depth measures the quantity of resources that will be required to bring all the food insecure households to subsistence level. Also, as commonly applied to estimate the poverty index, increasing the weight to the severity of food insecurity means that $\alpha > 1$. In this case, applying, for example, $FGT(\alpha = 2)$, yields severely food insecure households among all food insecure groups. Thus, those households that are farther away from the subsistence level. Based on equation 4 and applying the weights in each case, the incidence, depth and severity of food insecurity among vegetable farm households in the study area were identified and classified.

2.8 Econometric Model Specification

Three models: the linear probability, logit, and probit models are usually employed for estimating a binary response variable. Though similar, the dichotomous nature of the outcome variable of the logit and probit models distinguish them from the linear regression model (Alexopoulos, 2010), Again, the cumulative normal probability function of the probit model and the cumulative normal probability distribution of the logit model make them similar except at the tail. In this case, the outcome from using either the logit or the probit model is not likely to be different. Therefore, the choice between the logit and probit models may just be due to practical concerns such as the skill, availability and flexibility of the computer program, own preferences, and experience, because the substantive results may generally be undistinguishable (Gujarati, Porter, & Gunasekar, 2012).

Therefore, given the similarity between the two models, this study applied the binary probit model as it perfectly fits the objective of the study. A household calorie intake per capita was used as a proxy to measure household food security status in the study area. The dependent variable has categorical outcomes, which is either a household is food secure (coded 1) or insecure (coded 0). A household calorie intake was estimated based on 2900 kcal per adult per day in Ghana (IFPRI, 2000). This standard provides the basis for the categorization of farm households' food security status into a categorical variable. Hence, households whose consumption was equal to or greater than the threshold of 2900kcal were classified as food secure (coded 1) and otherwise as food insecure, (coded 0) based on the following.

$$food\ secure = 1\ if\ HCI \geq 2900kcal;\ otherwise\ 0 \quad (5)$$

Following Long (1997), a dichotomous dependent variable was constructed to represent households' daily calorie intake per capita. Several studies such as the work of Cele and Mudhara (2022) and Adjei-Mantey, Kwakwa, and Adusah-Poku (2022) have used binary probit to identify determinants of household food security. The probit model may be econometrically stated as:

$$P_i = F(Z_i) = \frac{1}{1+e-(\alpha+\sum(\beta_i X_i)} \quad (6)$$

Where P_i is the probability that a respondent household is food secure; X_i represents the ith explanatory variables; $\propto$ and β_i are regression parameters to be estimated, and e is the base of the natural logarithm. Using the observed socio-economic variables, the probability of a food-insecure household was estimated by solving Equation (7) as:

$$y^* = \beta_1 + \beta_2 x_2 + \cdots \beta_z x_z + \in \quad (7)$$

Where y =1 measures the observed variable a household's inability to meet food requirements, and 0 otherwise. Y^* is a continuous latent dependent variable that is bounded between 0 and 1. Practically, the probability that a household is food secure is rarely observed; instead, the actual outcome of whether a household can be food insecure or not can only be observed. Then, x is a vector of observed demographic and socioeconomic explanatory variables determining household's calorie intake; β are vector of unknown parameters to be determined; $i = 1,2, \ldots 322$ households; and ε is the unobserved part of the latent variable which is assumed to be normally distributed across observations. The probit model assumes that ∈ follows a standard normal distribution.

3. Results and Discussion

3.1 Food Security Status of Vegetable Farm Households

The food security status of dry-season vegetable farm-households is indicated in Table 1. The results show that food security remains a challenge for most households in the region (MOFA, GSS, WFP, & FAO, 2020). When the household average daily calorie intake per capita was compared with the recommended minimum calorie requirement of 2900cal per adult equivalent per day in Ghana (GSS, 2014; IFPRI, 2000), it revealed that 175 (54.3%) households out of the total sampled households of 322 were food secure whereas 147 (45.7%) were food insecure. The average kilo calorie (kcal) intake for the food-secured households was 2,958 per capita whereas for the food-insecure households was 1,670 per capita which is far below the average daily per capita calorie requirement of 2,423kcal. However, since the food security data was taken soon after the main harvest season, these interpretations are done cautiously, because it might be severe or otherwise than estimated.

Besides, the study also sought evidence on the food security status of vegetable farm households using the Food Security Index (FSI) in the study area. As indicated, the mean food security indices of 1.2 for the food-secure households and 0.69 for the food-insecure households concurred with the findings of Kuwornu et al. (2013) who obtained 1.42 for food-secure households and 0.69 for food-insecure households in the forest communities in the central region of Ghana. A similar outcome was also obtained by Abu and Soom (2016) in rural and urban areas of Benue State in Nigeria.

Table 1. Food Security Status of Vegetable Farming Households

Indicator	**FS (n =175)**		**FI (n =147)**		**t-value**	**Total (n =322)**	
Food Security Indicator	Mean	SD	Mean	SD		Mean	SD
Food Availability (kcal)	2958	675.65	1670	474.32	18.61***	2421	949.28
Calorie allowance (kcal)	-	-	-	-	-	2423	256.40
Food Security Index (FSI)	1.215	0.241	0.690	0.186	20.58***	1.001	0.376

Source: Model results (2023). Note: Food secure (FS), Food insecure (FI), *** is significant at 1% prob.

Usually, the gradient of severity of food insecurity increases in households during the dry season in the study region, which starts just before the onset of rains for the main cropping season (lean season) (Kansanga et al., 2022). This normally coincides with the period during which farmers cultivate vegetables to raise income. The implications are that food-insecure vegetable farm households will continue to experience challenges of food security unless issues relating to the enhancement of farm-level efficiency, productivity and income of vegetables are addressed in the study area. Overcoming the challenges of farm productivity would ultimately increase the output of vegetables for the farmers to generate enough income to improve livelihood including the provision of food.

3.2 The Level and Severity of Food Insecurity

The extent of food insecurity among vegetable farm households in the study region is shown in Table 2. The FGT measures three stages: headcount ratio, food insecurity gap and severity of food insecurity to reflect the incidence, depth/gap and severity of food insecurity among vegetable farm households, respectively. The mean headcount ratio or incidence of food insecurity of 0.3333 implies that about 33% of the sampled farmers' households do not meet their daily recommended calorie intake. The findings also revealed that the incidence of food insecurity in the region is, however greater among households in the Bawku East, Bawku West (Zebilla) and Binduri (51%), followed by the Navrongo (28%) and the Bolga, Talensi and Bongo (21%), in that order. The implication is that any intervention intended to address food insecurity among dry season farm households in the Upper East Region must target more vegetable farm households in the Eastern zone (Bawku Municipal, Bawku West and Binduri Districts).

Table 2 Measures: Level and Severity of Food Insecurity by Vegetable Farming Zones

	Headcount (p = 0)		**FI Gap/Depth (p = 1)**		**Severity of FI (p = 2)**	
Zone	Per cent	Rank	Per cent	Rank	Per cent	Rank
Central (Bolga, Talensi, Bongo)	21	3	31.0	2	13.0	2
Eastern (Bawku, Zebilla, Binduri)	51	1	32.0	1	14.0	1
Western (Navrongo)	28	2	30.6	3	11.9	3
Total	**33.33**		**31.20**		**12.97**	

Source: Models results (2023)

The food insecurity gap, otherwise termed the food poverty gap estimates the extent to which food-insecure households fall below the recommended daily caloric requirement. This indicator provides a clue on how to estimate the resources necessary to eliminate food insecurity through appropriate targeting. The study revealed a mean food insecurity gap of 31.20% across the three vegetable farming zones. This implied that if resources for dry season vegetable farming (including irrigation water, agrochemicals, and fertilizer) could be mobilized to increase farm income to achieve 31.20% of calorie intake requirement level among food insecure vegetable farm households, then theoretically, food insecurity could be eliminated among vegetable farm households in the study region.

The study also revealed the extent of inequality among the food-insecure households in the study area. The findings showed a mean severity of food insecurity of 12.97% across the three zones in the study. These results were in line with the findings of Kuwornu et al. (2013) who studied food security among farming households in the forest belt in the central region of Ghana. Similar findings were also obtained by Mitiku, Fufa, and Tadese (2012) in southern Ethiopia. The severity of food insecurity was however higher in the Eastern zone, followed by the Central and Western zones, in that order.

3.3 Description of Socio-economic Factors Influencing Households Food Security

The description of the socio-economic variables employed to estimate the determinants of food security (calorie availability) in the study area is shown in Table 3. The data reveals that average, dry-season vegetable farmers in the region had 9 years of experience in vegetable farming, implying that the experience acquired over the years in vegetable farming could positively influence the ability to raise more income from vegetable farming which may be used to improve household food security. The dependency ratio was an average of 1:2½ household members in an average household size of 7 members. This implied that an average working person in the household fed averagely more than two people. This certainly would be a burden for low-income working people and, as such might lower the food security status of household members who depend on such persons in the study area. On average, a vegetable farmer cultivates 0.6ha and receives about 2 extension agent visits during the farming process.

The cultivation of crops and the rearing of animals constitute the main economic activities of most farmers who intend to meet their households' food and other needs in the study area. A similar report was obtained by GSS (2019), where it was stated that grains and flour constitute 84.3% of the food consumed by households in the study area. The data of the study confirmed that households accumulate an average of 1373kg of grains and rear animals valued at about 2.6 Tropical Livestock Units (TLUs) in the area. These findings corroborate the comprehensive food security and vulnerability survey which found that poor households in northern Ghana keep farm animals valued at about 2.5 TLUs in their homes. The common livestock kept by farmers in the area includes cattle, sheep, goats, pigs, and poultry among others. Each tropical livestock unit is equivalent to one head of cattle of 250kg of live weight (Yikii, Turyahabwe, & Bashaasha, 2017).

The data also reveal that dry-season vegetable farmers spend an average of 49% of their gross profit (income) to purchase food for their households' consumption. Indeed, the food consumption expenditure from vegetable production could be higher if the analysis was limited to net profit instead. This agrees with similar findings by the GSS (2019) which stated that food expenditure accounts for 44.8% of the total expenditure of households in the Upper East Region.

Table 3. Descriptive Statistics of Determinants of Household Food Security Status

Continuous Var.	**Measurement**		**Mean**	**Std.**	**Min.**	**Max.**
Vegetable income	Ratio		0.488	0.295	0.027	0.996
Experience	Years in farming		9	7.8	1	45
Household size	No. of members		7	4.2	1	35
Dependency ratio	Working to non-working		2.5	2.0	0	10
Extension visits	Number		2.3	1.8	0	7
Hh. food production	Kilogramme		1,373	4,764	0	80,000
Livestock value	TLUs		2.6	4.9	0	48.6
Veg. farm size	Hectare		0.61	0.51	0.04	6.9
Farm to mkt. dist.	Kilometre		4.5	3.9	0.1	20
Crop diversification	1 crop = 0. 2 crops =1. 3 crops =2. 4 crops =3.		0.3	0.5	0	3
Dichotomous var.	**Measurement**		**% With 1**		**% With 0**	
Non-farm emplymt	Yes = 1	No = 0	59.90		40.10	
Credit access	Yes = 1	No = 0	5.59		94.41	
PFJs prog.	Yes = 1	No = 0	41.00		59.00	
Gender	Male =1	Female = 0	90.00		10.00	
Level of education						
No. formal edu	Yes = 1	No = 0	37.60		62.40	
Pri/JHS edu	Yes = 1	No = 0	41.30		58.70	
SHS/Tech/Voc.edu	Yes = 1	No = 0	14.00		86.00	
Tertiary edu.	Yes = 1	No = 0	7.10		92.90	

Source: author's computation, (2023)

The average distance from the farmer's vegetable field to the nearest district's local market is 4.5 km. A simplified method of crop diversification was employed in the analysis. Since the study was based on 4 vegetable crops, the diversification ranged between 0 – 3, where farmers who cultivated only one crop did not diversify, coded 0, while farmers who cultivated all 4 crops were the highly diversified farmers and coded 3. Based on these classifications, the mean crop diversification was 0.3 among the vegetable farmers. The variables: gender, and educational level. Credit access, non-farm employment, planting for food and jobs remain the same as defined previously.

As earlier explained, men dominated the distribution of vegetable farmers which constituted 90% while only 10% were headed by females. About 60% of the household heads were engaged in non-farm employment to generate additional income to supplement their daily livelihood including the purchase of food for household consumption. Few (6%) of the vegetable farmers had access to credit support for farming activities. Given the challenges of accessing credit, the introduction of the government's "Planting for Food and Jobs" (PFJs) programme was a great relief to some farmers, especially those who cultivate maize, the main crop supported by the programme in 2018. Hence, about 41% of the farmers benefitted from the programme as against 59% of farmers who did not. Perhaps, those farmers do not cultivate maize as one of the staples in the main cropping seasons.

3.4 T-Tests of Socio-economic Variables Affecting Households' Food Security

Table 4 depicts the contrast between the effects of the variables on food-secure and food-insecure farm households in the study area. Note that the discussions are focused on statistically significant variables. The results showed that farmers in the food-secure households employed more intensive inputs such as fertilizer, and agrochemicals (herbicides and pesticides) than the food-insecure households. They also cultivated on larger farm sizes, adopted the use of improved seeds, and intensive use of labour to maintain their farms (Wongnaa & Awunyo-Vitor, 2018). Intensive cultivation of vegetables resulted in higher output value, and higher profit (income) for the food-secure households.

Table 4. Summary of the Effects of Production Variables on Food Secure and Insecure Farm Households

Variable definition	Measurement		Food secure Household	Food insecure Household	T-test
Continuous var.					
Age of farmer	Years		42.84	40.61	-1.810*
Household size	Number of people		7.00	8.00	1.624
Fertilizer	Kg/Ha		189.52	156.63	-2.727**
Agrochemical	Litters/Ha		4.40	3.46	-2.675**
Labour	Cost/Ha		1,326.09	925.68	-3.979***
Veg. farm size	Ha		0. 70	0.55	-1.96**
Output value	GHS/Ha		9,818.46	6,820.57	-3.330***
Vegetable profit	GHS/Ha		8,132.15	5,484.01	-3.075***
Veg. profit spent on food	GHS/Ha		3,759.82	3,489.05	-3.036***
Extension visits	Number		2.28	2.24	-0.194
Dummy var.	**Measurement**				
Gender	Male = 1	Female = 0	0.88	0.92	1.195
Non-farm income	Yes = 1	No = 0	0.66	0.60	1.003
Improved seed	Yes = 1	No = 0	0.60	0.45	-2.687***
Type of irrigation tech.					
Manual tech.	Yes = 1	No = 0	0.29	0.27	-0.374
Water pump	Yes = 1	No = 0	0.70	0.61	-1.419*

Gravity fed	Yes = 1	No = 0	0.14	0.23	2.0503**
Level of edu.					
No edu.	Yes = 1	No = 0	0.47	0.54	1.235
Basic edu.	Yes = 1	No = 0	0.57	0.48	-1.556
SHS/Tech/Voc.	Yes = 1	No = 0	0.48	0.52	0.546
Tertiary edu.	Yes = 1	No = 0	0.50	0.52	0.158

Source: Author's computations, (2023) Note: 1$ = GHS12.86

High income influences households' expenditure on food hence an improvement on food secure households than the food insecure households. Similar conclusions were drawn on studies on the effects of vegetable production on income, and food security in Kenya (Muriithi & Matz, 2015), Ethiopia (Gebru et al., 2019). Holding all other things constant, it may be deduced that effective utilization of productive factors would lead to improvement in productivity, increases income which may lead to the reduction of food insecurity among vegetable farm households in the Upper East Region (Tsiboe, Asravor, & Osei, 2019).

Again, the study found that farmers in food-secure households adopt gravity-fed and motorized water pump technologies for irrigating their farms where whereas farmers in food-insecure households rely on the manual system of irrigation. Adopting the appropriate type of irrigation technology, all things being equal may have a positive influence on the productivity and profitability of vegetable production.

Finally, the study also found that households with aged vegetable farmers were more food secure than younger farmers' households. This may be because experience gained over the years may help them to increase households' income from vegetable cultivation and thereby improve their food security status.

3.5 Determinants of Household Calorie Intake

The estimates of a binary probit model indicating the determinants of Households' Calorie Intake (HCI) among dry season vegetable farm households in the study area are indicated in Table 5. Households' calorie Intake (HCI) is used as a proxy for the quantity of households' calorie (energy) availability. The model is satisfactory given its statistical significance at a 1% level, a pseudo-$R2$ of 0.194 and a log-likelihood value of -173.283. The sensitivity and specificity test results of the data were 91% and 62%, respectively.

The results showed that among the fifteen variables hypothesized to influence food security, six were significant determinants of food security of farm households in the study area. The empirical results of the study also showed that vegetable income, land size and households' own (subsistence) food production significantly increased the probability of households' food security. In other words, those variables positively increased the probability of the households' calorie availability above 2900kcal (the food security threshold in Ghana).

However, gender, household size, and the value of livestock holdings had negative effects on the food security of vegetable farm households in the study area. This is contrary to the findings of Kolog, Asem, and Mensah-Bonsu (2023) where female-headed households are more likely to consume more calories of food than male-headed households in the study area. This may be because women are more inclined to spend their earnings and resources on the upkeep of the home including food provisioning than men. Similar results were obtained by Goshu, Kassa, and Ketema (2013) in Ethiopia and Sinyolo and Mudhara (2018) in South Africa. Therefore, all strategies intended to improve the food security of dry-season vegetable farm households in the study region should target more women than men. These results, however, contradict the findings of Meludu, Ifie, Akinbile, and Adekoya (1999) in Nigeria and Lam et al. (2017) in northern Ghana who all concluded that female farmers have limited access to resources such as land, education, credit and extension, and are largely engaged in unpaid care work such as fetching water, collecting firewood, childbearing and care. These engagements limit their time to effectively manage their farms to raise enough income for household needs including food. The results also affirm the dominance of men (90%) relative to women (10%) in commercialized agriculture in northern Ghana (Lambrecht, Schuster, Asare, & Pelleriaux, 2017).

In terms of household size, an increase in household members decreases the availability of calories for the households to consume. This was expected because an increase in household members means more people are expected to be fed even though few of them may be contributing to the "bread basket". Large household size therefore tends to increase the burden on the few household members who produce food, thereby negatively affecting the availability of food for the households (Ajuruchukwu & Sanelise, 2016). A similar outcome was reported by Sinyolo (2020) in a study on the relationship between technology adoption and food security among rural households in South Africa.

Table 5. Model Estimates of Determinants of Food Security by Binary Probit

Dependent Variable: HCA		
Variables	**Parameter (Robust Standard Error)**	**Marginal effects ($\delta y/\delta x$)**
Vegetable Income	1.123 (0.175 **	0.420***
Household Size	-0.027 (0 .019) *	-0.010*
Experience	-0.004 (0.011)	-0.002
Vegetable Land Size	0.394 (0.237) *	0.147*
Gender	-0.724 (0.328) **	-0.271**
Dependency Ratio	0.066 (0.042)	0.026
Educational level	0.016 (0.014)	0.006
Non-Farm Employment	0.103 (0.168)	0.038
Planting for Food & Jobs	0.004 (0.171)	0.001
Farm Distance to Market	-0.031 (0.022)	-0.011
Value of Livestock Holding	-0.036 (0.020) *	-0.014*
Credit Access	0.199 (0.214)	0.075
Crop Diversification	-0.040 (0.146)	-0.015
Own Food Production	0.046 (0.027) *	0.017*
N	322	
Log-likelihood	-173.283	
Pseudo R^2	0.194	
P-Value	0.000	
VIF	1.190	
Sensitivity	91%	
Specificity	62%	

Source: Model results, 2020
Note: Food Secure Household (1) Food Insecure Household (0). Statistical significance is indicated by ***p < 0.01, **p < 0.05, *p < 0.10, figure in parentheses standard errors.

The size of land put to vegetable production had a positive influence on household food security status. This may be explained that households with more irrigated vegetable farmland size, all things being equal, would generate more income which they may use to improve their food security status and enhance their calorie availability than farmers with small land size. The outcome of this study confirms the findings of Balana et al. (2019) in northern Ghana. A similar conclusion was arrived at by Joshi and Joshi (2017) in the Eastern region of Nepal and Getaneh, Alemu, Ganewo, and Haile (2022) in the northeastern rift valley of Ethiopia.

Contrary to the hypothesis of the study and the findings by Getaneh et al. (2022) in Ethiopia, the study revealed a negative relationship between the value of animal holdings and food security in the Upper East Region of Ghana. Perhaps, the farm households may only be keeping the animals for prestige and a stock of wealth but the farmers may not be interested in selling the animals to raise income for the households' welfare including meeting their food security needs.

Regarding the marginal effects, for instance, a 10% increase in vegetable income, land size and own food production of farmers had a 4.20%, 1.47% and 0.017% more likely to improve the availability of calories among vegetable farm households, respectively.

In terms of the effect of gender, female-headed vegetable farm households are 7.1% more likely to have available calories than male-headed households in the study area. On the other hand, the household size and the value of animal holdings are l 0.10% and 0.14% less likely to enhance the food security of vegetable farm households, respectively. Surprisingly, the value of animal farm households is associated with a reduction in food security of households but was positive in a similar study by Getaneh et al. (2022) in Ethiopia.

Regarding the magnitude, the most important factor that increases the probability of higher calorie availability of food for consumption among respondent households in the region is vegetable income. This implies that dry season vegetable income plays a critical role in reducing households' food insecurity in the study area. Similar results were found by Gebru et al. (2019) in Ethiopia, Balana et al. (2019) and Balana et al. (2020) in northern Ghana. Therefore, improving the productivity of dry-season vegetable farmers can be an effective strategy to generate more household income, reduce poverty as well as improve households' food security in the study area.

4. Conclusion and Recommendations

This study attempted to analyze the net effect of engaging in dry-season vegetable farming on household food security in the Upper East Region of Ghana. The research gap was addressed through an econometric estimation of the determinants of food security status using household data from 322 farming households in the region. It revealed that close to half (46.7%) of the sampled farm households consume an average of 1670 kcal per capita, far below the recommended daily calorie of 2900 kcal per day per person while about 54.3% are food secure (FS). The food-secure vegetable farm households in the region consume an average of 2958kcal per capita.

Food insecure households have a head count index of 33.33%, food insecurity gap of 31.20 and severity of food insecurity of 12.97%. This implies that over 33% of farm households consume food below the recommended daily calorie of 2900kcal/day/adult equivalence in the Region. Vegetable income, non-farm employment and own food production have positive marginal effects on households' calorie availability in the region. The study recommends that the Ministry of Food and Agriculture (MOFA) should organize capacity-building workshops for the Agricultural Extension Officers (AEOs) to improve their knowledge and skills and also make them accessible to dry season vegetable farmers to improve the productivity of vegetable farmers to increase output, income and enhance food security of vegetable households in the region. Again, the government of Ghana and NGOs working on the vegetable sub-sector should promote policies and interventions that include subsidy programmes to incentivize farmers to adopt the use of modern production inputs (improved seeds, agrochemicals, fertilizer), efficient irrigation machinery (water pumps, drip irrigation system) to enhance productivity. This will increase vegetable farm yields and income and help the country achieve the SDGs of no poverty and zero hunger by 2030.

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