Crop diversification and farm household food and nutrition security in Northern Ghana

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Abstract
Farm households in Africa adopt resource allocation tools such as crop diversification to minimize risk exposure and safeguard their food and nutrition security. This study uses primary data and an ordered probit model to examine how crop diversification impacts the food security outcomes of rural farmers in northern Ghana. The findings revealed that along with other factors like access to extension services and use of soil fertility management practices, crop diversification increased food access and reduced the food insecurity experience of households. As a result, policies targeted at improving the food and nutrition security of peasant households should promote adoption of diversified crop production and use of sustainable soil management practices like composting.

Keywords Crop diversification · Food and nutrition security · Food insecurity experience scale · Food consumption score · Ordered probit

1 Introduction

In 2018, the Food and Agriculture Organization (FAO) of the United Nations estimated that despite achievements in global efforts towards resolving hunger and poverty, about 821 million people were vulnerable to food and nutrition security shocks. Unsurprisingly, majority of these people live and work in south-east Asia and sub-Saharan Africa (SSA) (FAO et al., 2018). In the latter region, the issues of poverty and food insecurity represent a perplexing paradox since majority of the labour force are engaged in agriculture and produce their own food, and even non-farm urban dwellers have ready access to agricultural markets that assemble and supply farm surpluses to boost food availability. Admittedly, this may be an overgeneralization of a complex issue: one that is country- and context-specific and requires focused attention to analyse and address. Specifically, although most countries in SSA ratified the African Union’s Malabo Declaration and the United Nations Sustainable Development Goals (SDGs) Goal 2 which call for ending hunger, food insecurity and malnutrition, and promoting sustainable food systems by 2025 and 2030, respectively, each
country has developed and implemented unique national agricultural policies to guide its efforts.

To this end, this study focuses on the food insecurity and malnutrition situation in Ghana’s most vulnerable region with the aim of assessing the effect of measures farm households adopt to offset these undesirable outcomes.

Ghana is a lower middle-income country with estimated 2016 average GDP per capita of US$1,513.46, total population of 30,832,019 and total land area of 23,884,245 hectares (GSS, 2021; Steiner-Asiedu et al., 2017). The country has 16 administrative regions and 7 agroecological zones ranging from the south-west to north-eastern tip as: the Wet Evergreen, Moist Evergreen, Coastal Savannah, Deciduous Forest, Transitional Zone, Guinea Savannah and Sudan Savannah. Generally, distribution of annual rainfall and allocation of national resources follow these lines, decreasing as one travels northwards (Tsiboe et al., 2022; MoFA, 2019). Compared to other countries in the sub-region, Ghana has more natural resource endowments and has performed better in reducing hunger and poverty. For example, Ghana was the first African country to achieve the Millennium Development Goal (MDG) 1 of halving poverty and hunger by 2015. However, poverty and hunger remain problems in Ghana especially in the northern regions: Savannah, Northern, North-East, Upper West and Upper East Regions. Regions in this area are in the Guinea Savannah and Sudan Savannah agroecological zones where smallholder farming is the main employer of the local labour force, soils are poor and face increasing desertification, and the prevalence of one rainfall peak means most farm households are unemployed or underemployed for large portions of the year (Alhassan, 2020). Specifically, GSS (2020) estimated the highest intensity of multidimensional and monetary poverty in Ghana in these northern regions while the area also recorded the lowest attainments in formal education and highest incidence of unemployment. These factors, along with the impacts of climate change and the ongoing coronavirus pandemic, have contributed to widening rural–urban, north–south and gender inequality gaps.

These stark conditions foster future uncertainty. Farm households in northern Ghana are buffeted by uncertainties in planning their resource allocation to ensure food security and minimize income variability. The concept of resource diversification has long been touted as a decision-making tool for preventing undesirable outcomes in smallholder agricultural enterprises. Heady (1952) asserts that “a farm manager with imperfect knowledge of future yield outcomes and prices may attempt to maximise profit or minimise exposure by… selecting a combination of enterprises in a manner that ensures that income does not drop below levels required to meet family living expenses, farm costs and principal payments”.

Heady (1952) identifies two systems through which farmers can accomplish resource diversification: by increasing their capital at hand to invest in an alternative enterprise or in the more likely event that capital resources are limited, shifting some of the available capital towards other enterprise. It is noteworthy that although both systems are possible, the former is not feasible as it rests on the availability of bank credits at affordable rates for farm investment: the literature attests this is hardly ever the case for rural farmers in Ghana (Appiah-Twumasi et al., 2020; Asare-Nuamah et al., 2021).

Hence, the head of a farm household must decide on when and how much of the limited resources to allocate to crop and livestock farming, off-farm employment and even facilitating the migration to urban centres of some household members to generate remittances all in a bid to maintain household welfare (Alhassan et al., 2019). As noted by Ellis and Freeman (2005), rural households’ attempts to move out of poverty employ a mix of diversity strategies consisting of agricultural, home processing, marketing and off-farm labour activities as well as reciprocity relation with other households.
However, this broad scope of rural livelihood diversity has as much potential to resolve food insecurity and vulnerability to extraneous shocks as it does to entrench poverty: diversified coping strategies to food insecurity and other undesirable outcomes means poor households cannot specialize their production, processing and marketing. This forecloses their ability to realize the benefits accruing from increased household productivity and efficiency. Given the need for sustainable policy efforts to guide Ghana’s achievement of the five pillars of SDG 2, this study explores the effect of households’ crop diversification strategies on their attainment of food security. We elect to study crop diversification for two main reasons: (1) its practice is ubiquitous to the farming systems of Ghana irrespective of tribe, clan or agroecological zone, and (2) it is relevant to the national agricultural strategy – it has been promoted, in some form, by almost all post-independence national agricultural policies and programmes. We also examine the heterogenous effects of crop diversification on two indicators of household food security: Food Consumption Score (FCS) and Food Insecurity Experience Scale (FIES). We further analyse the matching power of these food security indicators taking cognizance of their measurement approach. By this, we contribute to the discourse by examining the effect of households’ ex ante coping strategies on the state of food security in northern Ghana. Answers to this inquiry have widespread applications for local-level policy formulations as we plan the post-pandemic future.

The remainder of this study is organized as follows. Section 2 discusses the study context. Section 3 presents the conceptual models and empirical approaches adopted. Section 4 outlines the results, whose informed conclusions and policy recommendations we discuss in Sect. 5.

2 Study context

This study was carried out in northern Ghana which is made of five administrative regions namely Upper East, Northern, Savannah, Upper West and North-East regions. Northern Ghana is partly covered with the Guinea Savannah zone and partly by the Sudan Savannah. Regions such as Upper East and West who share boundaries with Burkina Faso fall under the Sudan Savannah. Northern Ghana has low population density, per capita income and less resource endowment as compared to the south (WFP, 2012). The northern zone of Ghana has two major seasons: the dry season runs from November – April and the rainy season from May – October. This affects the main source of livelihood in the north—agriculture. Farming is sometimes the only occupation in rural communities in the north (Adzawla et al., 2016). WFP (2012) revealed that about 88 per cent of households in northern Ghana survive by cultivating multiple crops such as millet, maize, yam, rice, corn, soyabean and groundnut and producing livestock on subsistence basis. Taken together, the effects of poor climate, soils, institutions and absence of diversified employment opportunities inform rural farmers’ ex ante decisions to spread risks by producing multiple crops (Asravor, 2018). However, it is not clear whether and how these attempts contribute to household welfare.

For instance, diversifying the crop production portfolio may enable households in northern Ghana to escape the effects of erratic rainfall. If the rains cease earlier than expected, early maturing cereals and legumes may still yield, and the farm family can survive on these. On the one hand, in the event of late rains, starchy staples like yam, cassava and potatoes may survive the initial lean periods and take advantage of the excess soil moisture needed during the tuber bulking stage. Thus, a household can hedge its food security bets
by cultivating both cereals and tubers. Our study focuses on what Di Falco and Chavas (2009) refer to as on-farm diversification strategies. The rationale behind this diversification strategy is to enhance total farm household productivity and reduce the risk of crop failure.

Conversely, given the limited scale of crop production in Ghana (MoFA [2019] estimates average land holdings at less than 2 ha), households may have limited areas to grow enough crop to meet subsistence needs and supply to markets. In such cases, it might be more productive to specialize in producing a couple of staples with sufficient potential to meet domestic food needs and market preferences. Specialization has the added benefit of improving farmers’ experience in managing the agronomic needs and market architecture of the chosen crops. This can then lead to improved household incomes and food security. Hence, crop diversification may improve or limit rural households’ ability to meet their basic needs and assure their food security. We explore the extant literature on this subject in the next section.

2.1 Crop diversification and food security in the literature

Food security, as declared at the World Food Summit in 1996, is a situation where all people at all times have access to adequate, nutritious and safe food that meets their dietary needs and preference for a healthy life. Food insecurity remains a global problem. About 3 billion people in the world are unable to afford healthy diets (FAO et al., 2021). The number of people who are undernourished in the world was estimated as 768 million in 2020, an increase of 117.7 million from 2019 (FAO et al., 2021). Of the 768 million undernourished people in the world, 410 million live in Asia and 281.6 million in Africa out of which 264.2 million live sub-Saharan Africa (FAO et al., 2021). The report further noted that, about 928 million people are severely food insecure with about 471 million and 347 million of them living in Asia and Africa, respectively. These figures clearly show that food insecurity is more prevalent in developing countries. Sub-Saharan Africa’s inability to meet the food needs of its increasing population is principally ascribed to food price hikes, conflicts, civil strife, widespread epidemics, poor technology, political instability, unsustainable agricultural practices and swift population growth (Abi & Tolossa, 2015).

Over 45% of Ghanaians are employed in agricultural sector and majority of these workers live in rural areas and are involved in smallholder, traditional or rain-fed farming (Wasunna & Ngumi, 2019). Smallholder farmers who rely mainly on farming for their livelihoods represent 62% of households in the northern belt of Ghana; almost half (49%) of these are poor and face various challenges like high costs of agricultural inputs which restrain their capability to increase production and put them in food insecure states (WFP, 2012). Particularly, WFP (2012) indicated that 21% of these smallholders were either severely or moderately food insecure.

Crop diversification has been identified as one viable option in tackling food insecurity. Studies over the years on crop diversification and its effect on food and nutrition security in Africa have found mixed effects (Jones et al., 2014). For example, Mango et al. (2018) in their study among smallholder farming households in central Malawi found a positively significant relation between crop diversification and smallholder farm household food security. They concluded that crop diversification is one viable option for establishing resilient agricultural systems that can enhance farm household food security.

Adjimoti and Kwadzo (2018) noted in their study in the Collines Region of Benin that crop diversification contributes positively and significantly to rural household food
security. The study further indicated that farmer-specific and institutional variables like level of education, credit, herd size, availability of produce storage facilities and access to extension service also affected household’s food security status. Similarly, Goshu et al. (2012) in their study conducted in Eastern and Central Ethiopia revealed that crop diversification is a positive determinant of household food security. Finally, Herforth (2010) in his study found a positive association between number of crops grown and farm household food security in Kenya and Tanzania. Other empirical studies that found a positive association between crop diversification and food security include Chinnadurai et al. (2016), Deb and Bayes (2018), Pellegrini and Tasciotti (2014), Kumar et al. (2015), Mulmi et al. (2017), Taruvinga et al. (2013), Mahbub et al. (2016), Pandey et al. (2016) and Mulwa and Visser (2020).

Like its continental neighbours, smallholder farm households in Ghana rely mainly on their own production to meet their food consumption needs. This makes production decisions such as those on crop diversification crucial to households’ welfare outcomes, especially in the climate- and resource-challenged areas of northern Ghana. According to Asravor (2018), crop diversification is rampant in northern Ghana because of government policies like the Fertilizer Subsidy Programme and its successor, the Planting for Food and Jobs (PFJ) programme. These policies provided opportunities for the youth in northern Ghana to enter the business of farming and for existing farm households to intensify their production by planting new improved crop varieties and apply different farm management strategies (Tanko et al., 2019; Tsiboe et al., 2021; Zakaria et al., 2021). Recent studies like Baba and Abdulai’s (2021) enquiry into the determinants of crop diversification and its effect on household food security in northern Ghana revealed significantly positive associations between crop diversification and household food security.

A related study by Danso-Abbeam et al. (2021) on the implications of crop–livestock diversification in the mixed farming system on food security in northern Ghana also found positive and statistically significant effects of crop–livestock diversification on household food security.

Contrary to these studies, Sibhatu and Qaim’s (2018) meta-analysis of 45 empirical studies in less developed countries concluded that there is little evidence to substantiate the assertion that increasing farm production diversity is a highly effective strategy to meeting smallholder diet and nutrition needs in most or all situations. The study revealed that more than half of the studies showed positive association between production diversity and food security, but the rest found no significant association at all. Congruent to the latter, Nkegbe et al. (2017) noted that farm households that cultivate multiple crops were more likely to experience severe and moderate food insecurity while households with less production diversity were more likely to experience little or no hunger. Thus, the study concluded that households with multiple crops do not have the capability to manage multiple enterprises and may be less productive, whereas households who produce specific crops find it easier to manage their farms efficiently to enhance productivity. This conclusion buttresses the notion that crop diversification has as much potential to resolve food and nutrition insecurity as it does to entrench poverty.

Another enigma from our review of the literature concerns the measurement of food security indicators. Studies like Chinnadurai et al. (2016), Deb and Bayes (2018), Pellegrini and Tasciotti (2014), Kumar et al. (2015), Mulmi et al. (2017), Taruvinga et al. (2013), Mahbub et al. (2016), Goshu et al. (2012), Mulwa and Visser (2020), Danso-Abbeam et al. (2021) and Baba and Abdulai (2021) measure food security by the dietary diversity indicator. Few studies like Mongo et al. (2018) applied the Food Consumption Score (FCS) and
Household Food Insecurity Access Scale while Adjimoti and Kwadzo (2018) used a multi-dimensional food security index constructed from Principal Component Analysis.

In these studies that link crop diversification and food security, food security was either measured as a continuous variable or a binary variable using linear regression, logit, probit and Tobit models. The binary measure is problematic because it assumes that farm households are either food insecure or secure. The challenge with this assertion is that it overlooks relevant information on households who fall in between the lowest and highest food security indices.

Given the nuanced nature of household food security situations, it is more likely to expect three levels of food security outcomes: low, moderate and high. According to Nkegbe et al. (2017), this provides basis for ordering households’ food security indices.

Our study differs from the others by its application of the Food Insecurity Experience Scale (FIES) together with FCS. The FIES also contains Household Food Insecurity Access Scale (HFIAS), Household Hunger Scale (HHS) and the Latin American and Caribbean Food Security scale (ELCSA). It was developed by FAO through the Voices of the hungry (VoH) project, building on the pioneering work of HFIAS and ELCSA. The FIES was derived from the adult-referenced questions of ELCSA to create a shortened, standardized experience-based measure for use across sociocultural contexts (Ballard et al., 2013).

Though the FCS and the HDDS provide very similar results and can be used interchangeably, the FCS was favoured in this study as it captures information about usual household diet through the incorporation of consumption frequency over a seven-day period as against HDDS which only gathers information about the previous day’s consumption (Kennedy et al., 2010). Thus, the two food security indicators chosen for this study—FIES and FCS—show marked robustness and superiority to other tools available for this purpose.

By adopting these indicators, our study also makes methodological contributions to the literature on food security and crop diversification. Specifically, we deviate from the norm of inefficient operationalization and estimation of food security status using binary models, Tobit and linear regression estimators and opt for an ordered model estimator that provides a more holistic picture of how crop diversification influences household food security. This serves more useful evidence for formulating agricultural and socioeconomic policies.

2.2 Data

The data for this study are derived from a cross-sectional field survey of smallholder farmers in northern Ghana. A multi-stage sampling technique was used to obtain the respondents for the study. First, purposive sampling was used to select the Upper East Region. The region was predefined because of the high levels of crop diversification among farm households in the region (households cultivated more than three crops, on average). Also, the region has the highest number of households who are food insecure in Ghana. In the second stage, two districts were selected for the data collection, with four communities randomly selected from both districts. Finally, 30 households were randomly selected from each community making a total of 240 households.

We interviewed one respondent in each household—this was usually the household head, or someone directly involved in making production and/or food preparation decisions. The interviews were conducted using a semi-structured questionnaire to collect data on farm- and farmer-specific characteristics such as demographic characteristics of household members, crop production and diversification, food consumption and food insecurity.
Coping strategies. However, we dropped some responses during the data cleaning process due to insufficient data. Thus, the analysis is based on useful observations for 217 households.

2.3 Variables used

We present and describe the variables used for the analysis in Table 1. Precisely, we indicate the a priori expectation of each variable based on a review of the literature. The variables in Table 1 cover farmer characteristics like sex, age, education level, household size and livelihood practices like whether respondents undertake off-farm employment or households receive remittances from migrated members.

Table 1 further presents farm characteristics like crop farm size, herd size, level of crop diversification and practice of good agronomic practices like composting, fallowing and legume intercropping. The final portions of Table 1 describe institutional variables like access to extension services, motorable roads, markets and credit. These latter factors depict the state of social amenities available to the farm household and have the potential to generate synergistic welfare gains or losses when combined with the farm and farmer characteristics. We return exposition on the a priori expectations of these variables in Sect. 3.

3 Conceptual models and empirical approach

Figure 1 illustrates the conceptual framework of the study. In theory, crop diversification and household food security are determined by institutional, farm and farmer-specific characteristics. Institutional factors such as access to credit, access to motorable roads, markets and extension services influence crop diversification and farm households’ food security. Similarly, farmer-specific characteristic such as farmer’s age, gender, household size, educational level, consumption–expenditure ratio, farming experience and social integration through participation in farmer- or community-based organizations (FBO/CBO) determine the extent to which households diversify their crop production. The effects of these on food security is channelled through farm characteristics like crop and herd sizes as well as livelihood options like receipt of remittance and off-farm work/engagement. Food security is also determined by dimensional components such as food availability, access and utilization.

How will these factors influence food security? Fundamentally, farm households who have access to credit for production are more likely to engage in the production of many crops including cash crops and by implication, enhancing their food availability and access through the income from cash crops sales.

Alternatively, access to credit may cause a household to focus on cash crops to the detriment of food crops. This can negatively affect food security in two ways. The first and most obvious means is the fact that focus on cash crop production may result in farm households becoming net buyers of food. The second is like this and is exacerbated by failings of the agricultural credit market. Most agricultural lenders require that borrowers repay in full shortly after harvest. (This assures the lender of repayment, but exposes the farmer to low prices due to high produce availability.) Minten and Barrett (2008) revealed that most farm households sell off large quantities of their freshly harvested produce to raise cash for credit repayment and to meet household needs. This significant early divestment means households usually lack food in the latter stages of the dry season and must borrow
| Variable                        | Description of measurement                                      | Empirical studies that use the variables                                                               | A priori expectation |
|--------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------|
| Male                           | Sex of household head (1 = male, 0 = otherwise)                 | Dube et al. (2018), Mulwa and Visser (2020), Alhassan et al. (2019)                                  | +                    |
| Age                            | Age of the household head in years                              | Negash and Alemu (2013), Asravor (2018), Alhassan et al. (2019)                                      | + / −                |
| Education                      | Years of completed formal education                             | Nkegbe et al (2017), Mulwa and Visser (2020)                                                         | +                    |
| Education squared              | Years of completed formal education squared                     |                                                                                                      | +                    |
| HHI                            | Herfindahl–Hirschman Index of Crop Diversification              | Makate et al. (2016), Mango et al. (2018), Herforth (2010)                                           | +                    |
| Farm size                      | Total cultivated crop area                                      | Di Falco and Chavas (2009), Alhassan (2020)                                                          | +                    |
| Household size                 | Adult Equivalent household size                                 | Aidoo et al. (2013), Asravor (2018)                                                                  | + / −                |
| Group position                 | Farmer holds a position in a CBO or FBO                        | Adzawla et al. (2016)                                                                                | +                    |
| Extension contacts             | = 1 if farmer received advise from an extension agent           | Asravor, 2018, Alhassan (2020)                                                                      | +                    |
| Off-farm work                  | = 1 if farmer engages in off-farm employment                    | Adamuala et al. (2016)                                                                               | +                    |
| No credit                      | Access to production/consumption credit (1 = did not receive)  | Kuwornu et al. (2013) and Sani and Kemaw (2019)                                                      | + / −                |
| Motorable road                 | = 1 if road to farmer’s field is motorable                      | Asravor (2018), Minten and Barrett (2008)                                                            | +                    |
| Herd size (TLU)                | Total household livestock in tropical livestock units           | Tetteh et al. (2020), Mulwa and Visser (2020)                                                        | +                    |
| Expenditure ratio              | = 1 if food to non-food expenditure ratio is greater than unitary| Duflo and Banerjee (2011), Negash and Alemu (2013)                                                   | + / −                |
| Remittance                     | Total monthly remittance received in GHS                        | Husein Duale (2020), Mulwa and Visser (2020)                                                         | +                    |
| Market access                  | = 1 if farmer gets ready market for produce                     | Minten and Barrett (2008)                                                                           | +                    |
| Fallow                         | = 1 if household fallowed at least one plot in the past 5 years  |                                                                                                      | +                    |
| Legume intercrop               | = 1 if farmer intercrops cereals with legumes                   |                                                                                                      | +                    |
| Compost                        | = 1 if farmer amended soil with compost                         |                                                                                                      | +                    |
| **Outcome variables**          |                                                                  |                                                                                                      |                      |
| HFCS                           | Categorized household food consumption score                    |                                                                                                      |                      |
| FIES                           | Categorized food insecurity experience scale                    |                                                                                                      |                      |
| Observations                   | 217                                                             |                                                                                                      |                      |
to offset hunger. This results in a vicious cycle of poverty and food insecurity. In contrast, Kuwornu et al. (2013) found that productive credit gives households the ability to access farm inputs that increase production and improve household food security. Similarly, Sani and Kemaw (2019) pointed out that access to credit gives farm households the chance to engage in income-generating activities; as a result, the income generated from these activities strengthens farm households’ financial capabilities and purchasing power, which, in turn, increases the food security of farm households. Thus, access to credit may arm or harm households in their fight against food insecurity.

Access to motorable road to farm and ready market for farm produce enhance farm access in terms of carting inputs to farm and output from the farm. These increase the likelihood of high productivity and reduce the transaction costs of participating in markets. Again, these factors reduce the likelihood of post-harvest losses and thus positively influence household food security and crop diversification. Minten and Barrett (2008) reported that quality of road networks is crucial to food security as it impacts the prices received by both consumers and producers.

Holding a position in an FBO/CBO and having access to extension services, all else constant, are expected to positively affect household food security and crop diversification (Adzawla et al. 2016). Leaders of FBO/CBOs are exposed to modern agricultural practices and technologies which boost production. This exposure also equips farmers to better manage diversified crop enterprises to attain high yields. Extension agents play crucial roles in disseminating new production technologies to rural farmers. In northern Ghana, they usually do this through farmer groups (Damba et al., 2020). Knowledge on new technologies and adoption of strategic farm practices like crop diversification enable farmers to cope with climatic shocks and poor yield of specific crops and achieve food security.

Farmer and farm characteristics like level of education, age, gender, off-farm work, consumption–expenditure ratio, household size, receipt of remittances and farm size can affect household food security in many ways. Basically, education has long-run effects on food security as educated household heads are more likely to be exposed to information about food security, have strong livelihood and income diversification choices, and engaged in
decent and well-paid jobs. These are expected to culminate in improved access to and utilization of food (Mulwa & Visser, 2020; Nkegbe et al., 2017).

Age and household size are expected to have multidimensional impacts on food security. Older farmers may lack the strength or zeal to diversify their crop production, but possess sufficient experience to achieve high yields to attain food security. Large household sizes may ensure available labour to produce multiple crops. However, this labour force is more costly to feed particularly in the lean season (Alhassan et al., 2019; Asravor, 2018).

Participation in off-farm work, farm size and receipts of remittances are expected to directly improve household food security through the incomes generated from these sources (Adzawla et al., 2016). Households must constantly make decisions on how to allocate these funds: to either food or non-food expenditure. To this end, this study assessed the expenditure ratio of households in the sample (measured as a binary variable = 1 if households incur more food than non-food expenditure). We expect households that spend more on food to have better food security than those that allocate more expenses to non-food sources. However, the literature shows that more expenses on food may not necessarily translate to better nutrition. For example, Duflo and Banerjee (2011) found that poor people in India tend to spend their extra income on “better-tasting, more expensive calories” which do not necessarily improve household nutrition. Thus, we assign inconclusive a priori expectations to this variable.

Finally, crop diversification, which involves the cultivation of more than one crop including both food and cash crops, will also positively affect food security. Farmers who engage in crop diversification will improve their income through the sales of cash crops and food security through own consumption and purchased food crops using the income generated from the cash crop sales.

3.1 Measures of crop diversification and food security

3.1.1 Overview of the Herfindahl–Hirschman index of crop diversification

The level of crop diversification can be quantified using different statistical methods including Index of Maximum Proportions, Simpson Diversity Index, Ogive Index, Composite Entropy, Entropy Index and Herfindahl–Hirschman Index. These methods differ in the level of sophistication and computation, advantages and limitations, but their results are similar.

To obtain crop diversification index, this study employed the Herfindahl–Hirschman Index (HHI). HHI is the summation of the square of the proportion of individual crop area in the gross crop area. HHI is an inverse measure of diversification as the index decreases with increase in diversification. HHI value of one means complete diversification, and zero means complete specialization.

\[
p_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \quad (1)
\]

\[
HHI = \sum_{i=1}^{n} p_i^2 \quad (2)
\]
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$$\text{CDI} = 1 - \sum_{i=1}^{N} p_i^2 = 1 - \text{HHI}$$

Table 2  Food categories and their respective weights

| Food groups                                      | Food types                   | Weights |
|-------------------------------------------------|------------------------------|---------|
| Cereals, root and tubers                        | Primary staples              | 2       |
| Beans, groundnuts, peas and cashew nuts         | Pulses                       | 3       |
| Beef, goat, poultry, pork, fish, egg, etc.      | Meat and fish                | 4       |
| Milk yoghurt                                    | Milk                         | 4       |
| Vegetables, leaves                              | Vegetables                   | 1       |
| Fruits                                          | Fruits                       | 1       |
| Sugar and sugar products, honey                 | Sugar                        | 0.5     |
| Fats, oil, butter                               | Oil                          | 0.5     |
| Spices, tea, coffee, salt, fish power, small amount of milk in tea | Condiments | 0       |

Source: Maxwell (2008)

Table 3  Food security threshold

| HFCS   | Food security threshold |
|--------|-------------------------|
| 0–21   | Food poor               |
| 21.5–35| Borderline              |
| > 35   | Acceptable              |

Source: Maxwell (2008)

$$p_i$$ denotes the proportionate area of the $$i$$th crop in the total cropped area, and $$n$$ denotes the total number of crops grown by the household.

3.1.2 Overview of the FCS and FIES

3.1.2.1 Food Consumption Score  The World Food Programme (WFP) developed the food consumption score indicator for measuring aggregate household-level dietary diversity and frequency of food groups eaten by household over a 7-day period, weighted based on their specific nutritional value. It is calculated using the frequency of consumption of eight food groups consumed by a household in a seven days period before a survey (IFPRI, 2008). Food groups with higher nutritional values are assigned higher weights and vice versa as given in Table 2.

In constructing the FCS, respondents are asked about the number of times their household consumed each of the eight different food groups over the last 7 days. It adds the weighted food group scores and recodes the household food consumption score from a continuous variable into a categorical variable for the consumption group using appropriate thresholds: 0–21 as food poor, 21.5–35 as borderline and > 35 as acceptable (IFPRI, 2008). When the FCS is calculated, the cutoff for the food consumption gap is set depending on the study location and food consumption behaviour. The cutoff set for northern Ghana is presented in Table 3.
3.1.2.2 Food insecurity experience scale  The food insecurity experience scale was developed by the food and agricultural organization (FAO). The FIES is an experience-based measure of the access pillar of food security, and it has been confirmed for cross-cultural use (Ballard et al., 2013). It is one of the globally accepted indicators for measuring progress towards the attainment of the Sustainable Development Goal 2 of ending hunger and attaining food security and better nutrition. FIES is a measure of food insecurity at the individual or household level based on yes/no responses to eight basic questions about adequate food access. The FIES is based on three areas of food insecurity including anxiety, compromising of food quality and quantity (Ballard et al., 2013).

FAO-VoH began including FIES as a client module in the GWP survey in 2014. Over a one-month period, FIES elicits self-reported experiences and behaviours linked to food access owing to a lack of money or other resources, regardless of frequency of occurrence. FIES is made up of eight questions that range in severity of FI measured, from mild FI (question 1) to SFI (question 8). Respondents answer yes/no to the eight questions with 12 months reference period to capture the seasonality of the phenomenon, and their answers are aggregated to get raw scores ranging from 0 to 8. FI was divided into three categories: (1) food secure (FS), with raw scores ranging from 0 to 3; (2) moderate FI (MFI), with raw values ranging from 4 to 6; and (3) SFI, with raw scores ranging from 7 to 8. The eight set of questions are presented on the table below.

3.2 Theoretical framework

This study is underpinned by the theory of diversification which has its origin from the utility maximization theory (Rahm and Huffman, 1984). Farmers’ decision to diversify is grounded in the utility (gains or net benefit) they stand to get for diversifying. Therefore, the latent utility of the \( i \) th farmer for the \( g \) th diversification is represented by \( U_{gi} \) [in Eq. (4)], where \( g \) assumes the values of 0 and 1 for no diversification and complete diversification, respectively. The basic assumption of this theory is that the net benefit farmer gain for diversifying is subject to a vector of socioeconomic factors, and a vector of factors related to diversification, for the \( i \) th farmer.

Notwithstanding the latent nature of utility, we postulate that it is a linear function of institutional, farmer-specific, farm-level and diversification-related factors with zero mean random error as expressed in Eq. (4):

\[
U_{gi} = X_i\alpha_i + e_{gi} \quad \text{where } g = 0, 1; \text{ and } i = 1, 2, 3, 4, \ldots, n
\]

(4)

where \( X_i \) is a \((1 \times k)\) vector of values of important factors to explain the utility for the \( i^{th} \) farmer. Farmers will diversify their crop cultivation if the gains/utility of the existing farm operation \( (U_0) \) is less than the utility for adding an extra crop \( (U_i) \). Thus, a farmer \( i \) will only diversify if the utility obtained from crop diversification is higher than non-diversification: if \( U_{i1} > U_{0i} \) or if the latent variable \( CDI = U_{i1} - U_{0i} > 0 \). The probability that \( i \) th farmer will diversify, represented by \( CDI_i = 1 \), is a function of the explanatory variables and is specified as:

\[
P_i = (CDI_i = 1) = P(U_{i1} > U_{0i})
\]

(5)

\[
P_i = X_i\alpha_i + e_{i1} > X_i\alpha_0 + e_{0i}) = P(\mu_{i1} < X_i\beta)
\]

(5.1)
where $\mu_{ij} = e_{ij} - e_{0i}$, $\beta = (\alpha - \alpha_0)$ and the $F(.)$ denotes the distribution function for $\mu_i$.

### 3.3 Empirical formulation of the ordered probit model

The measurement of food security in this study goes beyond the application of the binary choice model. Given the multiple categorical measures of food security, the literature recommends a choice between multinomial and ordered logit or probit models. According to Greene (2002), the multinomial logit or probit models fail to explain the dependent variable’s direction even though their outcome is discrete.

Because the food security measures in this study are categorical and ordinal, the ordered logit or probit models will yield better results for the analysis. Apart from the difference in the error term distribution where the probit assumes a normal distribution and the logit a logistic distribution of the error term, they practically give similar results (Greene, 2002). The ordered probit has gained a broader usage for ordered response data in econometric work (Davidson & MacKinnon, 2004). Thus, this study used the ordered probit. McKelvey and Zavoina (1975) developed the ordered probit, which is constructed on a latent (unobservable) random variable which can be expressed as:

$$ Y_{i}^* = X_i' \beta + e_i, \quad i = 1, 2, ..., N $$

where $E(e_i|X_i) = 0$ and $\text{Var}(e_i|X_i) = 1$ given $Y_i$, the observed variable, as a categorical variable with $J$ response groups and as a proxy for the theoretical unobserved or random variable $Y_i^*$ and outlining $\mu = \mu - 1, \mu_0, \mu_1, \ldots, \mu_{j-1}, \mu_j$ is a vector of unobservable cut point parameters. The nexus between the observed and the latent variable can be written as:

$$ Y_i = j \text{ if } \mu J - 1 < Y_i^* \leq \mu J, \quad j = 0, 1, 2, ..., J $$

where $\mu - 1 = \infty$, $\mu 0 = 0$, $\mu J = \infty$, and $\mu - 1 < \mu 0 < \mu 1 < \cdots < \mu J$. The probabilities therefore are given as

$$ \Pr[Y_i = j] = \Pr[\mu J - 1 < Y_i^* \leq \mu J] $$

$$ = \Pr[\mu J - 1 - x_i' \beta < e_i \leq \mu J - x_i' \beta] $$

$$ = \Phi(\mu J - x_i' \beta) - \Phi(\mu J - 1 - x_i' \beta) $$

where $\Phi(.)$ is the standard normal cumulative distribution function and $J$ is the response groups; in this situation, they are 0, 1 and 2 since there are three groups for food security.

According to Greene (2006), there is no meaningful qualified mean function, and the marginal effects in the ordered probability models are not upfront. The influences of changes in the independent variables on cell probabilities usually are measured as given below.

$$ b \delta \Pr \frac{\partial P_{ij}}{\partial X_i} = [\varphi(\mu J - 1 - x_i' \beta) - \varphi(\mu J - x_i' \beta)] \times \beta $$

The empirical model for the study is given as:

$$ FS_{ij} = \alpha + \beta W_i + \gamma X_i + \delta CDI_i + \epsilon $$
where \( FS_{ij} \) is the food security measured via FIES and HFCS, and subscripts \( i \) and \( j \) represent a household and the three categories of food security: \( j = 0, 1, 2 \) denote (i) food secure household (acceptable food security households), (ii) moderately food insecure household (borderline food security households) and (iii) severe food insecure household (poor food households). \( W \) and \( X \) are variables hypothesized to affect food security while \( CDI \) is the crop diversity index. \( \alpha, \beta, \gamma \) and \( \delta \) are parameters to be estimated, and \( \varepsilon \sim NID(0, 1) \) (Table 4).

### 4 Empirical results

#### 4.1 Demographic and socioeconomic characteristics of respondents

The summary statistics of the variables captured in the model are given in Table 5. The results revealed that about 69% of respondents are males. The average age in the sample is 47 years with a standard deviation of 9.11; this shows that most respondents are in the economically active age range. This bodes well for the capacity of respondents to cultivate multiple crops to safeguard the food security of their households. This is further highlighted by the average adult equivalent household size of 5.4 and 4 years of completed formal education. Thus, a randomly selected household contains about 5 members capable of participating in the household farm enterprise. These members would have attained basic proficiency in literacy and arithmancy to guide their farm management decisions. We explore the long-term effects of educational attainment on household food security in the ordered probit model.

Alternatively, household members could contribute labour to off-farm engagements: this scenario is true for about 51% of respondents. This latter finding shows that farm households in Ghana’s Upper East Region employ substantial levels of livelihood diversification strategies. For some households, these strategies include receipt of remittances from

| Table 4 | Measures of the Food Insecurity Experience Scale |
|---------|-----------------------------------------------|
| Food insecurity experience scale |
| Household Referenced Now I would like to ask you some questions about food. During the last 12 MONTHS, was there a time when: |
| Q1. You or others in your household worried about not having enough food to eat because of a lack of money or other resources? |
| Q2. Still thinking about the last 12 MONTHS, was there a time when you or others in your household were unable to eat healthy and nutritious food because of a lack of money or other resources? |
| Q3. Was there a time when you or others in your household ate only a few kinds of foods because of a lack of money or other resources? |
| Q4. Was there a time when you or others in your household had to skip a meal because there was not enough money or r resources to get food? |
| Q5. Still thinking about the last 12 MONTHS, was there a time when you or others in your household ate less than you thought you should because of a lack of money or other resources? |
| Q6. Was there a time when your household ran out of food because of a lack of money or other resources? |
| Q7. Was there a time when you or others in your household were hungry but did not eat because there was not enough money or other resources for food? |
| Q8. Was there a time when you or others in your household went without eating for a whole day because of a lack of money or other resources? |
migrated household members. The results show that remittances contribute about GHS39 per month to households’ livelihoods; the actual average amount for the 56% of households that regularly receive remittances is about GHS68 and ranges from GHS20 to GHS400. Hence, repatriated earnings constitute significant portions of households’ livelihoods in the study area. Together, these factors determine the food consumption and expenditure patterns of rural farmers in Ghana. We find that only about 9% of households in the sample incur more food than non-food expenses while about 1.4% of respondents hold positions in CBOs/FBOs.

Concerning the farm characteristics, households hold about 3.6 acres of crop land per capita and own an average herd size of 1.5 tropical livestock units—this is equivalent to about 150 chickens. These figures are significant for crop diversification and household food security. The estimated landholding means households can cultivate more than one crop assuming the major staple (maize or millet, in most cases) is allocated to about 2 acres and the remaining allotted to secondary crops. Also, livestock holdings such as goats, sheep and pigs are a store of wealth for most households and serve as a bulwark against utter desolation in the event of crop failure. For smallholder farmers in northern Ghana, Tetteh et al. (2020) find that producing small ruminants increases household welfare.

Again, Appiah-Twumasi et al. (2020) revealed that smallholder farmers time their livestock sales to raise funds for purchasing fertilizer at the beginning of the season. Of course,

| Variable                  | Description                                                                 | Mean  | SD   |
|----------------------------|-----------------------------------------------------------------------------|-------|------|
| Male                       | Gender of household head (1 = Male, 0 = otherwise)                          | 0.6866| 0.4649|
| Age                        | Age of the household head in years                                         | 47.1198| 9.1127|
| Education                  | Years of completed formal education                                        | 4.0369| 4.7482|
| HHI                        | Herfindahl–Hirschman Index of Crop Diversification                         | 0.9209| 0.2109|
| Farm size                  | Total cultivated crop area                                                  | 3.5728| 2.2692|
| Household size             | Adult Equivalent household size                                             | 5.3674| 2.5263|
| Group position             | Farmer holds a position in a CBO or FBO                                     | 0.0138| 0.1170|
| Extension contacts         | = 1 if farmer received advise from an extension agent                       | 0.5023| 0.5012|
| Off-farm work              | = 1 if farmer engages in off-farm employment                                | 0.5115| 0.5010|
| No credit                  | Access to production/consumption credit (1 = did not receive)               | 0.7604| 0.4278|
| Compost                    | = 1 if farmer amended soil with compost                                     | 0.1613| 0.3686|
| Market access              | = 1 if farmer gets ready market for produce                                 | 0.9862| 0.1170|
| Motorable road             | = 1 if road to farmer’s field is motorable                                  | 0.5576| 0.4978|
| Herd size                  | Total household livestock in tropical livestock units                       | 1.5386| 2.0459|
| Expenditure ratio          | = 1 if food to non-food expenditure ratio is greater than unitary           | 0.0922| 0.2899|
| Education squared          | Years of completed formal education squared                                | 38.7558| 62.3981|
| Remittance                 | Total monthly remittance received in GHS                                   | 38.9355| 47.7389|
| Fallow                     | = 1 if household fallowed at least one plot in the past 5 years             | 0.0461| 0.2101|
| Legume intercrop           | = 1 if farmer intercrops cereals with legumes                              | 0.6221| 0.486 |

**Outcome variables**

| Variable                  | Description                                                                 | Mean  | SD   |
|----------------------------|-----------------------------------------------------------------------------|-------|------|
| HFCS                       | Categorized household food consumption score                               | 1.4194| 0.5964|
| FIES                       | Categorized food insecurity experience scale                               | 1.3594| 0.8606|
| Observations               |                                                                             | 217   |      |
livestock and poultry also contribute to household food consumption by providing meat, milk and fish.

The main independent variable in this study concerns the level of crop diversification. The Herfindahl–Hirschman Index revealed average crop diversification of 0.92 among farmers in the sample. This shows a high level of crop diversification in the study area. Specifically, we found that farmers in the sample cultivate multiple crops including maize, rice, cowpea, millet, groundnut and sorghum as well as microplots of fruit and leafy vegetables. The final tranche of farm characteristics concerns farmers’ use of sustainable land management practices. Here, we focused on composting, fallowing and cereal–legume intercrop and found that about 16%, 5% and 62% of farmers, respectively, implemented these practices.

Finally, access to institutional services like extension, credit, markets and motorable roads are expected to promote farmers’ production and household food security. Except for credit, the results in Table 5 indicate relatively high access among farmers in the study area; each recorded greater than 50% access. About 99% of farmers had access to input and output markets, 56% of farm roads were motorable, and 50.2% of farmers had at least one contact with an extension agent during the production season. On the other hand, about 76% of farmers in the sample received no formal production credit; this is typical of the constrained agricultural credit market in northern Ghana (Lu et al., 2021, Martey et al., 2019, Sekyi et al., 2017, Anang et al., 2016).

In the final rows of Table 5, the estimated means for both FCS and FIES point to the mid-point categories for these food security indicators, i.e. borderline food security and moderate food insecurity. However, the magnitudes of the estimated means and their standard deviations suggest significant heterogeneity in the categorization of households’ food security status. We present an in-depth comparison of the results from these indicators in the next section.

4.2 Household food security status measured by different indicators

This section compares food security status of the sampled farming households in the study area as measured by FIES and FCS. Figure 2 presents frequencies and percentages of the food security status of the farming households in the study area.

The food (in)security status analysis using the FIES indicator established that about 61.29%, 13.36% and 25.35% of the sampled households were classified as food secure, moderately food insecure and severely food insecure, respectively. However, the Food Consumption Score indicator categorized 47.47%, 47.00% and 5.53% of households as having acceptable food consumption (food secure), borderline (moderately food insecure) and food poor (severely food insecure), respectively. Thus, there are considerable disparities in the classification of households’ food security status as measured by the two indicators. We return to the implications of this finding in Sect. 4.4 and, in the meantime, discuss the results from the ordered probit model in the next section.

4.3 Results from the ordered probit estimation

The results from the ordered probit model are presented in Table 6. We base the discussions of these variables on their estimated marginal effects. The signs and coefficients represent the magnitude and direction of change in a respondent’s food security status attributable to changes in the explanatory variables in the model. The marginal effects are reported
Crop diversification was found to have positive and statistically significant effect on farm household food security status for both FIES and FCS. This finding suggests that crop diversification has direct impact on food availability and access at the household level. Thus, an increase in the crop diversification index of a household increases its likelihood of achieving acceptable food consumption and attaining psychometric food security.

As indicated, there are several mechanisms by which crop diversification can help rural households transition from a state of food insecurity to food secure. For instance, households with higher crop diversification index are more likely to improve output, stabilize their yields and guard against total crop failure as failure of one crop is compensated by the success of others (Mugendi Njeru, 2013; Yachi & Loreau, 1999). Thus, crop diversification yields crop insurance effect for households that adopt multiple cropping and assures better food availability and access relative to households that practise monocropping. Also, farmers who engage in crop diversification may produce cash and food crops where the revenue generated through the cash crops can be used to meet food needs that cannot be met from own production and other non-food needs.

Our finding of positive food security effects of crop diversification contradicts that of Nkegbe et al. (2017) who found that farm households who engage in multiple cropping were more likely to experience severe and moderate hunger and less likely to experience little or no hunger. Their study attributed the negative effects to the inability of multiple cropping households to manage multiple enterprises which results in inefficiencies as compared to those households engaged in specialized crop production. However, our result is consistent with that of Jones et al. (2014) who argued that intense diversification of production systems could also result in household diet diversity in Malawi. Similar positive effects of crop diversification on household food security were reported by Makate et al. (2016) in Zimbabwe, Mango et al. (2018) in Malawi, Herforth (2010) in Kenya and Tanzania, and Mulwa and Visser (2020) in northern Namibia. We discuss the effects of other livelihood diversification strategies on food security in northern Ghana in the following. The results from the ordered probit estimations showed significant effects of other livelihood strategies

![Fig. 2 Food security status by FIES and HFCS](image-url)
Table 6  Ordered probit estimates of the effects of crop diversification on household food security

| Variables          | (1)                  | Marginal effects after FIES | (2)                  | Marginal effects after HFCS |
|--------------------|----------------------|----------------------------|----------------------|----------------------------|
|                    | (1a) | (1b) | (1c) | (2a) | (2b) | (2c) |
| FIES               |       |       |      |       |       |      |
|                    |       |       |      |       |       |      |
| HHI                | 1.6477** | (0.8333) | − 0.3907** | (0.1924) | 0.4539** | (0.2252) | 1.4668** | (0.6906) | − 0.1459** | (0.0722) | − 0.3691** | (0.1766) | 0.5150** | (0.2385) |
| Off-farm work      | 0.4328** | (0.1925) | − 0.1026** | (0.0454) | 0.1192** | (0.0522) | 0.1511 | (0.1898) | − 0.0057 | (0.0195) | − 0.0143 | (0.0471) | 0.0530 | (0.662) |
| Herd size          | 0.0195 | (0.0660) | − 0.0046 | (0.0157) | 0.0054 | (0.0181) | 0.0569 | (0.0474) | − 0.0191 | (0.0249) | 0.0119 | (0.0119) | 0.0200 | (0.166) |
| Remittance         | 0.0035* | (0.0021) | − 0.0008 | (0.0005) | 0.0010* | (0.0006) | 0.0013 | (0.0017) | − 0.0001 | (0.0002) | − 0.0003 | (0.0004) | 0.0004 | (0.0006) |
| Farm size          | 0.2493** | (0.0969) | − 0.0591*** | (0.0221) | 0.0687*** | (0.0259) | 0.1608** | (0.0817) | − 0.0160* | (0.0086) | − 0.0405* | (0.0207) | 0.0565** | (0.0282) |
| Household size     | − 0.0682* | (0.0410) | 0.0162* | (0.0097) | − 0.0188* | (0.0113) | − 0.0068 | (0.0388) | 0.0007 | (0.0039) | 0.0017 | (0.0097) | − 0.0024 | (0.0136) |
| Group position     | 5.6488*** | (0.3487) | − 1.3395*** | (0.1131) | 1.5561*** | (0.1092) | 0.2793 | (0.0275) | 0.1560*** | (0.0765) | − 0.2176** | (0.0997) | 0.0004 | (0.0005) |
| Education squared  | 0.0096*** | (0.0022) | − 0.0023*** | (0.0005) | 0.0026*** | (0.0005) | 0.0015 | (0.0002) | − 0.0004*** | (0.0002) | − 0.0009*** | (0.0004) | 0.0013** | (0.0005) |
| Expenditure ratio  | 0.8630** | (0.4059) | − 0.2046** | (0.0937) | 0.2377** | (0.1081) | 0.4778 | (0.3423) | − 0.0475 | (0.0364) | − 0.1202 | (0.0834) | 0.1678 | (0.1177) |
| Extension access   | 0.4990*** | (0.2315) | − 0.1183*** | (0.0535) | 0.1375** | (0.0623) | 0.2253 | (0.2068) | − 0.0224 | (0.0204) | − 0.0567 | (0.0528) | 0.0791 | (0.0724) |
| No credit          | 0.3590 | (0.2336) | − 0.0851 | (− 1.5600) | 0.0989 | (0.0637) | 0.2459 | (0.2258) | − 0.0245 | (0.0232) | − 0.0619 | (0.0563) | 0.0863 | (0.0785) |
| Market access      | − 5.6195*** | (0.3537) | 1.3325*** | (0.1226) | 0.2155*** | (0.0612) | 0.9643** | (0.4243) | − 0.0950** | (0.0440) | − 0.2426** | (0.1128) | 0.3386** | (0.1497) |
| Motorable road     | 0.4332** | (0.2172) | − 0.1027** | (0.0507) | 0.1193** | (0.0096) | 0.3105 | (0.2028) | − 0.0309 | (0.0194) | − 0.0781 | (0.0531) | 0.1090 | (0.0710) |
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Table 6 (continued)

| Variables          | (1)                          | Marginal effects after FIES | (2)                          | Marginal effects after HFCS |
|--------------------|------------------------------|-----------------------------|------------------------------|------------------------------|
|                    | FIES (1a) (1b) (1c)         | HFCS (2a) (2b) (2c)         |                              |                              |
| Compost            | 1.0076*** (0.3706)          | −0.2389*** (0.0884)         | 0.2776*** (0.0996)           | −0.1342 (0.2341)             |
| Fallow             | 4.7559*** (0.4011)          | −1.1277*** (0.1201)         | 1.3101*** (0.1332)           | 0.0498 (0.3812)              |
| Legume intercrop   | −0.2476 (0.2295)            | 0.0587 (0.0537)             | −0.0682 (0.0626)             | −0.5527*** (0.1828)          |
| /cut1              | −2.7652** (1.2143)          | 1.5183 (1.0473)             |                              |                              |
| /cut2              | −2.2559* (1.2137)           | 3.3911*** (1.0728)          |                              |                              |
| Observations       | 217                         | 1.5183 (1.0473)             |                              |                              |

1. Robust standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.
2. FIES Food Insecurity Experience Scale categorized as SFI Severe Food Insecurity, MFI Moderate Food Insecurity and FS Food Secure
3. HFCS Household Food Consumption Score categorized as Poor FC Poor Food Consumption Score (Score between 0 and 21), Borderline FC Borderline Food Consumption (Scores between 21.5 and > 35) and Adequate FC Adequate Food Consumption (HFCS scores > 35)
were limited to the food insecurity indicator (FIES). Thus, off-farm work, livestock rearing and receipt of remittances had no significant effects on households’ food consumption outcomes.

Particularly, we found respondents’ engagement in off-farm work significantly reduced the likelihood of experiencing moderate and severe food insecurity and increased the probability of experiencing psychometric food security. This finding makes sense because off-farm engagement is expected to enable households generate extra income to supplement farm returns. This gives households the ability to access enough and diversified food types and reduces the likelihood of positive responses to the FIES questions. We intuit similar reasons for the finding that households who received remittances were, at 10% level of significance, less likely to experience severe and moderate food insecurity and more likely to be food secure. However, livestock rearing had non-effect on either households’ food insecurity experience or food consumption score.

This is especially worrying since increased livestock productivity is one of the key thrusts in Ghana’s efforts to achieve food security. Steiner-Asiedu et al. (2017) intimate that livestock production may have contributed little to national food production due to modest breed diversification and the continued practice of extensive management systems. In northern Ghana, climate change and harsh environmental conditions contribute to shortage of forage and feedstock for rural livestock farmers. These foster the spread of disease, deflate farmers’ profits and potentially blunt the effects of livestock rearing on households’ food security outcomes (Tetteh et al., 2020).

With regard to the farm characteristics of respondents, the results revealed that an increase in farm size by one acre decreases the likelihood of a farm household experiencing severe and moderate food insecurity by 5.91% and 0.96%, respectively, while increasing their chances of being food secure by 6.87% per cent for the FIES indicator. The FCS showed similar results as an acre increase in farm size decreases the likelihood of a farm household experiencing poor and borderline food consumption by 1.6% and 4.1%, respectively, and increases the probability of the farm household having acceptable food consumption.

This finding is in line with our a priori expectation as increase in farm size will increase the area available for diversifying crop production, improve quantity of food produced and thus increase household food availability.

In line with the finding of positive effects of farm size on food security, we find that composting and fallowing decrease the likelihood of experiencing severe and moderate food insecurity for rural households in northern Ghana and increases their probability of being food secure by 27% and 131%, respectively. The ability to fallow at least one plot of arable land with the aim of replenishing soil fertility is usually the preserve of the relatively wealthy in society. Thus, the finding of positive associations between fallowing and secured food access makes sense for the study context. These results are significant at 1% level.

On the other hand, the practice of intercropping cereals with legumes was found to be more prevalent among households in the poor and borderline food consumption categories than those with adequate food consumption. This finding is not surprising as it reflects the lived experience of poor people in the study area. In northern Ghana, intercropping tends to be a risk mitigation measure practised by households with minimal landholdings, poor social status and poor access to productive resources.

The regression results showed non-trivial effects of farmer-specific characteristics on households’ food security outcomes. For instance, we observed from the FIES model that an increase in household members by one adult lowers the probability of a rural household
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experiencing food security and increases their probability of experiencing moderate and severe food insecurity. While anecdotal evidence suggests that households with more adult members have increased availability of farm labour, we postulated that the prevailing extended dry season in northern Ghana, coupled with inadequate avenues for alternative employment may increase the cost of year-round food access.

This might compel household members to resort to such food insecurity coping strategies as skipping meals, eating smaller portions or going all day without eating because the household has run out food. Indeed, Wambogo et al. (2018) revealed that larger households in SSA are more likely to be food insecure while more Ghanaian households than expected reported going the whole day without eating—the most severe measure of food insecurity. This finding is also in line with those of Aidoo et al.’s (2013) study in the Sekyere Afram Plains District of Ghana.

Active participation in farmer organizations and social group has been reported to improve household income, crop yield and production quality (Bizikova et al., 2020). In the study area, we found that respondents who hold group positions had consistently better household food security outcomes. Specifically, households with active social group members were less likely to experience severe and moderate food insecurity, but more likely to experience food security measured by the FIES indicator. Again, the FCS model showed that household heads holding group position had direct associations with adequate food consumption status and inverse relationships with poor and borderline food consumption.

Furthermore, education square which measures the long-term effect of education on food security was found decrease the probability of a farm household in northern Ghana experiencing severe and moderate food insecurity, but increases their likelihood of being food secure for the FIES indicator. The FCS model also showed that a respondent’s years of completed formal education, in the long run, decreases the probability of his household having food poor and borderline food consumption and makes them more likely to have acceptable food consumption. Usually, well-educated household heads are more likely to be employed in decent jobs with good earnings and have better access to nutritious food types and knowledge on income diversification strategies, which culminate in greater positive impact on their food security status.

This result affirms the finding of Nkegbe et al. (2017), who showed that better educated household heads have greater capacity to benefit from new agricultural technologies and are more capable of diversifying their household income to advance household food access. Also, Mulwa and Visser (2020) found that an extra year of completed formal education increased Namibia households’ consumption expenditure of in by N$11 (11 Namibian Dollars) and dietary diversity by 0.11 points.

The final farmer-specific variable, expenditure ratio, tests whether households that spend more on food than non-food have better food security outcomes. As expected, the FIES model results indicated that farm households who spent more on food than non-food were less likely to experience severe and moderate food insecurity, but more likely to be self-report being food secure. However, the FCS indicator, which classifies households according to the frequency of consuming certain food types associated with better caloric intake, found no such effects. We contend that this is one of the strengths of the FCS indicator over the FIES. Hence, merely allocating more income to food expenditure without focusing on nutritional content of the food groups may confound the welfare effects of the increased expenditure. This becomes even more pertinent if the goal is to evaluate the outcome of an intervention such as income or expenditure subsidy on the lives of the poor.

We shift our attention to the effects of institutional variables on rural farmers’ food security. The FIES model estimates that access to extension services reduces the likelihood
of farm households reporting severe and moderate food insecurity, but increases the likelihood of experiencing food security. This meets our a priori expectations because households who have access to extension services are more likely to adopt improved agronomic practices and production techniques.

These will advance their production and increase household food availability and access. This finding is also consistent with Nkegbe et al.’s (2017) argument that an increase in extension access increases farm households’ consumption expenditure on and access to quality and quantity of food.

Motorable roads was significant only in the FIES model. The estimated marginal effects reveal that access to motorable farm roads increases respondents’ probability of reporting their households as food secure. As indicated, motorable roads may increase the frequency with which farmers attend to their farms and reduce the transaction costs of transporting inputs to the farm and outputs to the homestead (Minten and Barrett, 2008).

However, the finding on market access in the same model appears to indicate that the benefits of motorable farm roads do not always translate to the output market. Here, the results suggest that access to market increases the likelihood of households’ self-classification as severely or moderately food insecure rather than food secure. The FCS model provides contrary results and indicate that households with ready access to market have a higher likelihood of achieving adequate food consumption. Although the result from the FIES model contradict our expectation, it is not implausible because households with ready market access may sell large portions of the harvest early in the season and encounter food shortages later which necessitate using some of the coping strategies the FIES questions elicit. The opposite finding from the FCS is also plausible because nearness to market centres means households have more diversified food choices for consumption (beyond what they produce) and the extent of their access is only defined by the level of household income. This inconsistency in the effects of the same variable on the food security status of a household is symptomatic of the disparity in classifying households by the two food security indicators (see Sect. 4.4). The next section assesses the extent of these disparities and discusses the implications of these on policy and future research.

4.4 Matching power of the FCS and FIES

Our discussions of the analysed results so far point out that there are disparities in how farm households in the sample are assigned food security status. Mainly, we suspect that the choice of food security indicator is crucial in determining where a household is assigned on the food security scale. It is only natural that differences in the methods of measurement as well as the scope of the recall period over which respondents report their food security status influence validity of the measures. Nonetheless, we do not expect an overly wide disparity because the underlying phenomenon being measured is essentially the same. Therefore, we compare the external validity of the two food security indicators used in this study by focusing on how uniformly their respective categories align. The outcome of this test is presented in Table 7.

Table 7 presents the frequencies and percentages of the sample and their as assigned food security status based on the FIES and FCS indicators. Here, we match the three categories of food insecurity experience (severe FI, moderate FI and food secure) with their analogous food consumption score categories (poor FC, borderline FC and adequate FC, respectively) using a simple cross-tabulation exercise. After this, we code the
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For our purposes, we define two categories as a good match if they occupy the same ordinal position in their respective indicators. Thus, good matches for FIES and FCS are severe FI and poor FC, moderate FI and borderline FC, and food secure and adequate FC. Conversely, a poor match exists if two matched categories occupy the ordinal extremes of their respective indicators. Examples of such matches include those between food secure under FIES and poor FC under FCS or severe FI under FIES and adequate FC under FCS. Any other matching that straddles the mid-point between good and poor matches is deemed a close match.

From the results in Table 7, close matches dominate the validity comparison between FCS and FIES and represent about 46% of the cases in this study. This is closely followed by good matches with 43% of the cases: poor matches finish a distant third and represent a little above 11% of the cases in the sample. On the surface, the finding that only about 11% of the categorization are completely incorrect may appear mild, acceptable even. However, it belies the seriousness of the level of disparity. For instance, 20 households (out of 55) that self-reported severe food insecurity were deemed to have adequate food consumption, or 20 of the 103 households with acceptable FC reported behaviours and experiences that marked them as severely food insecure. Thus, 1 in 3 (or more conservatively, 1 in 5) households in the sample would have been completely mischaracterized if only one of FCS or FIES was used as the indicator of food security.

Finally, we test the significance of the observed differences in the matching power of FIES and FCS using two related statistics: Pearson’s Chi-square and the Fisher’s exact test. For both tests, a probability value less than 0.05 shows that the disparity is trivial and can be safely ignored. The estimated p-values of 0.050 and 0.0715 for the Fisher’s exact test and Chi-square tests suggest that divergence in measurement outcomes for the two indicators is statistically significant and warrants further attention. Thus, as similar constructs that measure food security, FIES and FCS show a level of convergent validity that is hardly acceptable. This finding is relevant considering the policy sensitivity of accurately measuring food insecurity.

| Table 7  | Matching comparison between HFCS and FIES |
|----------|------------------------------------------|
| **HFCS** | **FIES** | **Key** |
| Severe FI | Moderate FI | Food secure | Total |
| Poor FC | 4 (1.84) | 3 (1.38) | 5 (2.30) | 12 (5.53) | Good match | 93 (42.86) |
| Borderline FC | 31 (14.29) | 16 (7.37) | 55 (25.35) | 102 (47.00) | Close match | 99 (45.62) |
| Adequate FC | 20 (9.22) | 10 (4.61) | 73 (33.64) | 103 (47.47) | Poor match | 25 (11.52) |
| Total | 55 (25.35) | 29 (13.36) | 133 (61.29) | 217 (100.00) |
| Pearson Chi² = 8.61 | Fisher’s exact test = 0.050 |
| Prob > chi² = 0.0715 |

Top rows have frequencies and cell percentages are in parentheses.

uniformity of the matching using “Bold” for “Good Match”, “Italic” for “Close Match” and “Bolditalic” for “Poor Match”.

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5 Summary of findings, conclusions and policy recommendations

The main objectives of this study were twofold: to assess the effect of crop diversification on smallholder farmers’ food security outcomes and to test the validity of the FIES and FCS indicators of food security. Along the way, we also examined the socioeconomic factors affecting food security. The study applied the Herfindahl–Hirschman Index to measure crop diversification, while food security was measured by the food insecurity experience scale and food consumption score. This study attended to the first objective by estimating an ordered probit model. Again, we approached the second objective by using a cross-tabulation exercise to match the classification of households’ food security status and tested the convergent validity of the two indicators using the Fisher’s exact test and Pearson’s Chi-square tests.

The ordered probit models for both indicators showed that crop diversification is positively related to self-reports of food secure status and acceptable food consumption. Except for market access, the significant marginal effects of the other socioeconomic determinants of food security followed the same direction. Nevertheless, the discussion here follows the results from FIES ordered probit model because it reported more significant variables than the FCS model. The FIES model results revealed that off-farm work, farm size, households’ receipt of remittances, active social group participation, formal education attainments, expenditure ratio, access to extension, motorable road to farms, compost use and fallowing had significant positive effects on farm household food security status. Conversely, household size and farm households’ ready access to produce markets negatively influenced farm household food security.

The analysis of household food security using the FIES and FCS indicators showed up other issues that warranted this study’s second objective. Some of these include the already mentioned divergence in the direction of effects of market access on households’ food security. The other issues cover profound differences in the categorization of households’ food security status depending on which indicator is used.

Here, it is important to state that we agree there cannot be a universally accepted indicator of food security. That said, when two indicators with proven internal consistencies and acceptance for cross-cultural studies are applied to the same sample in the same survey, we expect a higher level of convergent validity than in the result of the present study. The outcomes of two statistical tests suggested that these differences may have non-trivial effects on policy.

We set out our conclusions based on the above findings. Crop diversification has been promoted by various national agricultural policies and programmes since, at the very least, the post-independence State Farms agenda of the early 1960s. Different reasons have been cited for backing its implementation in each of its past iterations. In recent times, the national agricultural goal of modernizing agriculture identifies three crops: maize, rice and soya, as worthy of promotion across all agroecological zones. To this end, producers of these crops have been targeted in the Planting for Food and Jobs programme to benefit from subsidized seeds, fertilizer and capability-building technical skills transfer to boost outputs for local and export consumption (Ansah et al., 2020; Tekuni et al., 2021).

Our finding that diversified crop production enhances the welfare outcomes of poor, rural households in northern Ghana corroborates the usefulness of this agenda while highlighting the breadth of possibilities that exist for government to do more. Specifically, roots and tubers such as yam and cassava as well as marginal cereals like early
and late millet are integral to the diets of poor households in the study area. However, they have received very little policy attention in recent times.

We contend that state actors can further safeguard the food security of farm households in northern Ghana by directing some of the subsidized inputs to these staples, especially for households that do not cultivate rice due to geographic incompatibility. This has the potential to improve food security by increasing the quantity and variety of households’ shock buffer stocks, as well as increasing income through the sale of crops produced from a variety of crops grown, which in turn improves household consumption patterns.

In doing this, policy makers should be guided by our finding that households attain better food security when they apply compost and/or fallow portions of their farm plots. The extension service delivery—which itself was found to improve food security—component of the ongoing Planting for Food and Jobs (PFJ) programme can be channelled towards developing programmes to train household heads on compost preparation and application.

The success of this proposed intervention will be further enhanced by properly targeting benefits to those households that are able to benefit from them. The study results suggest that formally educated respondents and household heads who actively participate in social and farmer groups have greater potential to generate food security benefits from an intervention. Thus, vulnerable farmers who are already marginalized because of poor education, social status and land access will require extra capacity building and support systems before they can benefit from crop diversification and food security interventions (Bizikova et al., 2020).

Our final recommendation concerns this study’s contributions to the methods of analysing household food security. First, by deviating from the norm of assessing individuals’ food security status using a binary measure, we have established that rural households exhibit more nuanced experiences and behaviours during periods of limited food access. Secondly, the accuracy with which these conditions are measured depends on the researcher’s choice of food security indicator and the sample size under review. Therefore, we recommend that future studies employ diverse scales and a wider scope as robustness checks to ensure the convergent validity of their food security measurements.

Data availability The data for this study will be made available on reasonable request.

Declarations

Conflict of interest No potential conflict of interest was reported by the author(s).

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