Food-tree cash crop diversification and farm household welfare in the Forest-Savannah Transition Zone of Ghana

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Abstract

A growing body of literature underscores the importance of diversified cropping systems in resolving the age-old controversy on the income and food security implications of cash crop production. Significant knowledge gaps, however, exist in terms of the precursors and actual impacts of diversified food-cash crop systems. This paper therefore assesses the determinants of food-tree cash crop diversification, and its impacts on the income and food security of farmers. The paper uses survey data collected from 408 randomly selected households in the Forest-Savannah Transition Zone of Ghana. Findings indicate that cash-food crop diversification impacts positively on household annual crop income and food security, and these positive impacts further increase as the diversity of tree cash crops (cocoa and/or cashew) increases. The paper emphasises the importance of income from tree cash crops, and complementarities between cash crops and food crop production in explaining the food security merits of diversified food-cash crop systems. Overall, food crop farmers' decision to diversify into cocoa and or cashew was significantly predicted by farming experience of the household head, farm characteristics of the household (fallow land availability, land ownership and livestock ownership), as well as economic (annual crop income and access to off-farm income) and institutional (access to extension) factors. These results imply that promoting livestock farming and enhancing farmers' access to financial and technical support services could encourage adoption of diversified cropping systems. However, considering that land ownership rights in sub-Saharan Africa are oftentimes unclear, contested or poorly enforced, pro-poor and equitable land tenure reforms would be indispensable in promoting diversification into tree cash crops by subsistence farm households.

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1.0 Introduction

In affirmation of the global importance of food security, the second Sustainable Development Goal (SDG) seeks to end hunger by ensuring access by all people, particularly, the poor and vulnerable to safe, nutritious and sufficient food all year round by 2030 (United Nations, 2015). Food security has become a major development concern across the globe because the world's population is fast increasing (UNICEF, 2014; FAO, 2016). Africa's population, for instance, is projected to double in the next 35 years (UNICEF, 2014). Within the West-African sub region, population explosion coupled with urbanisation, are expected to tremendously increase the demand for food, leading to higher food prices (Wessel and Quist-Wessel, 2015). To satisfy the growing demand for food driven by population growth, FAO (2016) estimates that food production will have to increase by at least 60 percent in the next decades. The use of arable lands to cultivate cash crops in the global south has therefore raised food security concerns, but empirical evidence on the link between cash crop farming and food security remains debatable and inconclusive (Anderman *et al*., 2014; Kumba *et al*., 2015; Rubhara *et al*., 2020; Jarzebski *et al*., 2020). There is a lack of a clear understanding of the food security impacts of cash crops due to the large diversity of cash crops, and variations in their production systems, production areas, and impact mechanisms (Jarzebski *et al*., 2020).

Generally, the debate in the literature has been centred on whether cash cropping undermines or enhances food security at the household level. Several authors have argued that cash crop production undermines food security by displacing food crops and rendering households more vulnerable to market conditions for food. For instance, Cushion *et al*. (2010), Gamborg *et al.* (2012) and Brinkman *et al.* (2020) have reported increased food insecurity due to land conversion for biofuels. According to the authors, biofuel crops displace food crops, and could compromise the food security of local farmers by resulting in decreased food availability and higher food prices. Similarly, findings from Kenya show that sugarcane production compromised the food security of farmers by diminishing land allocation to subsistence vegetable production (Maithya *et al.,* 2015). From the perspective of Anderman *et al*. (2014), cash cropping households are likely to be food insecure because income from cash crops is usually not high enough to match increasing food prices. The authors further argue that cash cropping shifts income distribution from a continuous flow to a lump sum. Immink and Alarcon (1993) also concur that household consumption of staple foods from own production is reduced as cash crops displace food crop production, thereby increasing farmers' market dependency for food.

In contrast, a growing body of literature rather shows that cash crop production improves food security by enhancing incomes. For instance, findings from Ethiopia show that increased returns from coffee enhanced household food security, even after controlling for total income (Kuma *et al*., 2019). Similarly, higher income from cash crops has been shown to enhance household dietary diversity score in Zimbabwe (Rubhara *et al.,* 2020). Several other authors (e.g. Achterbosch *et al*., 2014; Wiggins et al., 2015) corroborate that cash cropping is likely to enhance food security, not only by enhancing incomes, but also by complementing food crop production. This is consistent with a more recent finding from Ghana where farmers used additional income from Cocoa to expand staple food production (Hashmiu *et al*., 2022a). Likewise, farmers in Malawi used income from tobacco to pay for additional labour for maize production (Orr, 2000). Similar observations were made by German et al. (2011) in Zambia where jatropha farmers maintained staple food production by expanding their cropping areas. Schneider and Gugerty (2010) harmonise that cash crop farming is generally characterised by higher returns to land and labour. This, according to the authors, can allow cash cropping households to increase their income and use the income generated to purchase goods for consumption.

The above findings suggest that there may be potential synergies between cash crops and food crops in determining household food security, but according to Govereh and Jayne (2003), these synergies have generally been neglected by research and extension programmes. This underscores the need for future research to ascertain optimum combinations of cash and food crops required to enhance the food security of cash cropping households (Rubhara *et al*., 2020).

Food and nutritional security are closely linked to both the production of cash and food crops, as the former boosts household income to meet consumption needs while the latter ensures a consistent supply of food, especially for the majority of farm households that are exposed to significant market risk. According to Hashmiu et al. (2022a), a semi-subsistence system of producing both cash and food crops impacts positively on household food and nutritional security because it generates income and produces staple foods, which enhances household food availability and consumption, and ultimately meets household food and nutritional security. Although the potential benefits of food-cash crop diversification systems have been acknowledged in the literature, there are few to no empirical research on the topic in Africa, particularly Ghana. There is additional knowledge gap on the determinants of farmers' decision to adopt food-cash crop diversification as a strategy for enhancing household food security. The aim of this paper, therefore, is to contribute towards bridging this knowledge gap by examining the influence of a diversified stock of cocoa, cashew and food crops on household income and the likelihood impact on food security in Ghana. Another objective is to assess the determinants of farm households' decision to participate in food-cash crop diversification in Ghana.

The study makes significant contributions to literature. First, the majority of prior research on how farming systems affect household food security focuses solely on cash crop systems (Kuma et al., 2019; Achterbosch et al., 2014; Wiggins et al., 2015) or staple food systems (see, Grote et al. 2020; Mensah et al. 2020; Manda et al., 2018;). Very few studies have examined the impact of diversified food-cash crop systems (Hashmiu et al., 2022a). The failure to take into consideration potential complementarities in the diversified food-cash crop systems is a major flaw in the single crop food security impact assessment. In order to fill this information gap, we assess how an integrated food-cash crop system influences household food security using the Inverse Probability Weighted Average technique (IPWA). Unlike other impact assessment frameworks (such as propensity score matching, endogenous switching regression, and inverse probability weights, among several others), the IPWA estimate has a double-robust feature to correct for mis-specification in the outcome or treatment models in order to produce consistent and efficient coefficients (Woodridge, 2010). Further, the use of the IPWA helps to check sample selection bias from observed and unobserved heterogeneity. Findings have significant implications for policies and programmes aimed at promoting diversified food-tree cash crop systems in smallholder contexts. The rest of the paper is organised as follows: Literature and research method are presented in section II and III, respectively before results and discussions in section IV. Conclusions and recommendation of the study are also outlined in section V.

2.0 Food Security Measurement

Despite the fact that food security measurement has seen a major expansion in recent years, there is still no single way to quantify food security because the concept is elusive in itself (Kennedy 2002; Bickel et al., 2000). Widely used classes of food security indicators include dietary recall and experienced-based indicators (Kirkland et al., 2013). These indicators are much preferred because of their nutritional relevance and ability to be implemented at the individual level (Headey and Ecker, 2012).

Dietary recall indicators generally consist of recall questions about the consumption of particular food items or food groups over a period, usually from one day up to a week (Ruel, 2003). This class of indicators are meant to demonstrate a household's financial capacity to acquire a variety of foods (Kennedy et al., 2007). The difficulty in measuring diversity across regions with considerable differences in diet is the fundamental barrier to dietary diversity indicators. Pulses, for example, are a vital source of nutrients in some regions, such as South Asia, but they are not a significant part of diets in other countries (Headey and Ecker, 2012). Again, there is no robust approach for defining how cut-off points should be selected in order to determine adequate or inadequate diversity (Ruel, 2003). Consequently, comparing food security results across studies become difficult (Kirkland et al., 2013). Despite these limitations, dietary variety indicators are highly effective food security indicators, particularly when it comes to nutritional significance (Kirkland et al., 2013; Headey and Ecker, 2012). Some common dietary recall indicators include household dietary diversity score (HDDS), food frequency score (FFS), and food consumption score (FCS).

Experiential indicators, on the other hand, entail questions about food insecurity experience and the degree of frequency of food insecurity. Unlike dietary diversity indicators, these indicators can capture both physical and psychological dimensions of food insecurity (Headey and Ecker, 2012; Perez-Escamilla and Segall-Correa, 2008). Additionally, experiential indicators can be implemented over more extended recall periods spanning from a month to 12months (Headey and Ecker, 2012). Thus, they are even more helpful when program benefits need to be assessed over long recall periods. In this study, for example, where the element of interest is cash crop households, using dietary diversity indicators would be inappropriate because farmers' income is mostly lump sums rather than continuous flows, and the maximum reference period for these indicators ranges from 1 to 3 days (Kennedy et al., 2007). Although more than 15-day recall durations have been used in past studies (Drewnowski et al., 1997), they are mostly inconvenient for respondents and may result in response bias (Kennedy et al., 2011; Swindale and Bilinsky, 2006).

Generally, all experiential food security indicators are similar and pose nearly identical questions. Widely used among them is the United States Department of Agriculture (USDA) core food security module, from which almost all experiential indicators share their root (Maitra, 2017). Unlike other experiential indicators like the Food Insecurity Experience Scale (FIES) and Household Food Insecurity Access Scale (HFIAS), this indicator addresses the differences between households with children and those without children (Bickel *et al*., 2000). Consequently, the USDA-core food security module has gained popularity as a tool for measuring food security (Nkegbe et al., 2017).

Although arguments have been made that the dietary implications of food insecurity are much more critical in food security measurement among developing countries (Ruel, 2003), Headey and Ecker (2012) suggest that psychological aspects are also often of inherent interest. Moreover, these indicators share several desired qualities with dietary recall indicators, such as the capacity to focus on people and households, as well as usefulness in detecting shocks and investigating seasonality concerns (Headey and Ecker, 2012).

3.0 Methodology

3.1 Study area description

The study was conducted in the Mampong Municipal (7.05° N, 1.40° W), Offinso North District (7.39° N, 1.95° W), Wenchi Municipal (7.74° N, 2.10° W), and Techiman North District (7.63° N, 1.91° W) in the Forest-Savannah Transition Zone (FSTZ) of Ghana. Mampong and Offinso North are in the Ashanti Region, whereas Techiman North and Wenchi are in the Bono East Region (Figure 1). The study took place in 12 communities where subsistence farmers were actively reviving cocoa farming. Three communities were selected from each administrative district/municipality. These were Atonsuagya, Adidwan and Abuontem in the Mampong Municipal; Seseko, Sraneso No.2 and Tanokwaem in the Offinso North District; Tromeso, Ayigbe and Mallamkrom in the Wenchi Municipal; and Asueyi, Aworowa and Krobo in the Techiman North district.

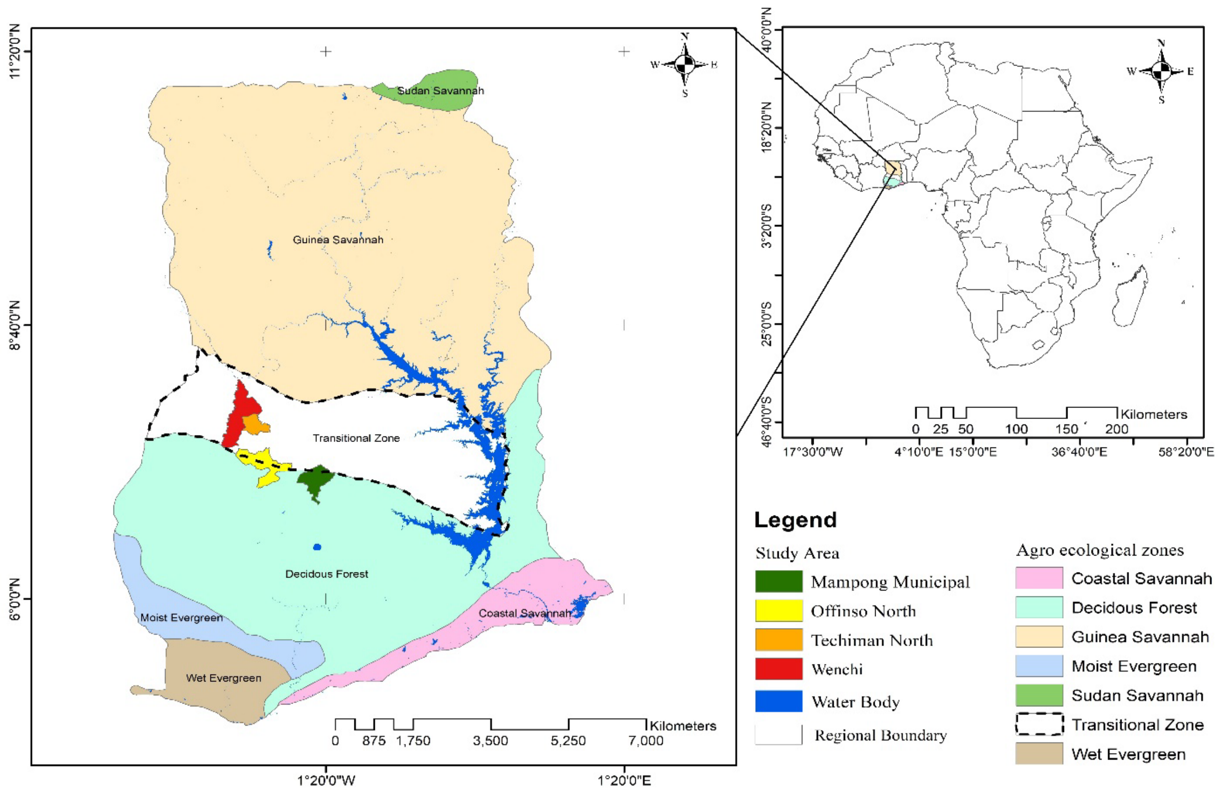

Figure 1 Regional map of Ghana showing agroecological zones

The vegetation of the study area is derived savannah between the Guinea Savannah Zone (GSZ) to the north and the High Forest Zone (HFZ) to the south, hence the name Forest-Savannah Transition Zone. It is an expanding zone along the forest fringes where grassland is progressively replacing forest (FAO, undated). Thus, the boundaries are not fixed and have been variously drawn (USAID, 2011). FAO (undated) placed the zone between about latitude 7 and 8° north. Minia (2008), however, delineated the FSTZ as being farther north (latitude 7.5-8.5° North). Total annual rainfall and average temperature in the zone are 1300 mm 27 ºC respectively (Asare-Nuamah and Botchway, 2019). Crop farming is the main source of livelihood in the area because the climate and soil are suitable for crops grown in both the forest and savannah zones.

The FSTZ used to exhibit good climate suitability for large scale cocoa production but became marginal for cocoa following the 1983 wildfires (World Bank, 2013). Subsequently, farmers in the zone shifted from cocoa to maize as the dominant crop (Adjei-Nsiah and Kermah, 2012; Hashmiu, 2015). Despite the high production risk of cocoa, many farmers in the zone have been reverting to cocoa farming (Asante *et al*., 2017) following price hikes for cocoa by the Ghana Cocoa Board in the early 2000s (Vigneri and Kolavalli, 2018). The shift to cocoa farming in the zone has raised food security concerns (Asante *et al*., 2017), but there is lack of research evidence needed to substantiate such concerns. Cashew is also gaining considerable climate suitability in the zone (Läderach *et al*., 2011). Cashew is generally perceived by farmers in the area to be more resilient to harsh temperature, drought, poor soils, and wildfire, and was therefore becoming popular as a low-risk alternative for cocoa (Hashmiu *et al*., 2022b). Some authors (e.g. Schroth *et al*., 2017; Abdulai *et al.,* 2018) have even projected that cashew could potentially replace cocoa in the zone.

3.2 Sampling technique

Three administrative regions, four districts, 12 communities, and 408 households were selected for the study using a multi-stage sampling technique. The first stage was purposive selection of the Bono/Bono East and Ashanti regions. These administrative regions were selected due to considerable efforts being made by farmers therein to revive cocoa farming in the forest-savannah transitional areas. The second stage involved the random selection of two administrative districts from each region. The Wenchi Municipal and the Techiman North District were selected from the Bono/Bono East regions; and the Mampong Municipal and the Offinso North District from the Ashanti Region (Figure 1). At the third stage, a list of communities in the aforementioned districts where farmers were actively reviving cocoa farming was obtained from the Cocoa Health and Extension Division (CHED) of the Ghana Cocoa Board. Three communities were randomly selected from each administrative district, thus bringing the total number of communities to twelve.

The final stage entailed random selection of farming households in the selected communities. A list of compounds in the selected communities was obtained from community leaders, comprising traditional authorities, assemblymen, unit committee members, executives of local farmers' association, and chief farmers. Thirty-four compounds were randomly selected from each community. In compounds which had more than one farming household, only one household was randomly selected. But in the case of compounds which had only one farming household, that household was automatically selected. This brought the total number of households to 408, which was above a minimum of 384 households derived from Cochran's (1977) sample size formula for a large population. The rationale for using the household as the unit of analyses was because risk management strategies begin with decisions at the farm and household levels (OECD, 2009). Following Yaro (2006), a household in this study is defined as 'a group of people who own the same productive resources, live together and feed from the same pot', which occasionally comprised of only one person.

3.3 Methods of data collection

Data was collected from July 2017 to September 2017, using a structured questionnaire which was administered to 408 household heads. Household heads were chosen as the primary respondents because they were traditionally the key decision makers at the household level in the study area. Data was collected on the socio-demographic characteristics of household heads, households' crop portfolio, gross annual crop income, food security status, and livelihood assets. The questionnaire consisted of both close and open-ended questions. Open-ended questions were included to allow respondents to provide additional information. In estimating gross annual crop income (GINC), the quantities of cocoa, cashew and other crops sold in the last 12 months (2016/17) were first obtained from respondents. Subsequently, income from each crop was estimated using the average price per unit. Household food security was estimated using the United States Department of Agriculture (USDA) Food Security Core Module (Bickel *et al*., 2000). The USDA module estimates food security on a numeric scale of 0.0 to 9.3, on which lower scores represent higher food security, i.e. lower food insecurity. As shown in Table 1, the numeric scores also indicate various categories of food security: 0.0-2.2 categorically represents 'food secure', while scores greater than 2.2 represent various classes of food insecurity. In appendix 3 are the questions captured on USDA food security core modules.

Table 1 Categories of food security based on the USDA food security core module

Numeric Score	**Categorical Food Security Status**
0.0-2.2	Food Secure
2.4-4.4	Food Insecure Without Hunger
4.7-6.4	Food Insecure with Hunger, Moderate
6.6-9.3	Food Insecure with Hunger, Severe

3.4 Analytical approach and multinomial logit regression

Cash crop – food crop diversification choice of farmers was investigated on the basis of the random utility theory. The theory suggests that each economic agent, *t*, has a utility function *Ut(.),* and when faced with a finite choice set, *Ct* chooses an alternative that maximises their utility (McFadden, 2001). Thus, by assigning a value to each potentially available cropping system choice (food crops and cocoa-FCC-; food crops and cashew-FCCa; food crops, cocoa and cashew -FCCCa; food crops only-FC), where each option is nominally available to every farmer, if a farmer chooses some alternative $i \in C_t$, then it holds that the utility derived from alternative *i* is greater and hence the option that maximises their income and food security. Mathematically this is expressed as;

$$P(i) = P[t; U_t(i) \geq U_t(j), all\ j \in C_t] \qquad (1)$$

Where *p(i)* represents the probability of a farmer choosing alternative *i,* $U_t(i)$ and $U_t(j)$ represents the utility derived from alternative *i* and alternative *j* respectively. The utilities of farmers are not directly observed but the choices they make are observed through the actions they undertake. For instance, if U_j and U_k represents a farmer's utility for two options, the random utility model is represented as:

$$U_j = \beta'_j X_i + \varepsilon_j \text{ and } U_k = \beta'_k X_i + \varepsilon_k \qquad (2)$$

where U_j and U_k are the perceived utilities associated with choosing options (j) and (k); X_i denotes the vector of covariates that influences the choice of the options; β_j and β_k are the coefficients to be estimated and ε_j and ε_k are the error terms (or unobserved effects) which are independently and identically distributed (Maddala, 2001).

Choice models including logit, and probit classified as dichotomous dependent variables and multinomial logit or probit, multivariate probit, among others termed polychotomous dependent variables are employed to examine individuals' choice behavior depending on the measurement of the response variable and distribution of residuals (Maddala, 2001). Therefore, in this paper the multinomial logit model (MNL) is adopted to investigate farmers' food–cash crop diversification choice, a dependent variable with more than two options. The model is formulated under the condition that the choice of an agent is dependent upon the characteristics of the agent rather than characteristics of the various options available (Makate et al., 2018). Unlike other choice models, the multinomial logistic regression is often regarded as a flexible and attractive analysis since it does not assume normality, linearity, or homoscedasticity (Starkweather and Moske, 2011). However, the robust estimations of the model requires that the probability of a farmer choosing a particular cash crop – food crop combination, is independent of the probability of choosing another combination. Thus, there is assumption of independence from irrelevant alternatives (IIA), which can be tested using the Hausman test (McFadden, 1973).

The empirical MNL is of the form;

$$\log \frac{\Pr(Y=i)}{\Pr(Y=i^{*})} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \ldots \ldots \ldots \ldots \beta_n x_n + \mu \quad (2)$$

Where *i* represents a given category, i.e. food crops only (FC), food crops and cocoa (FCC); food crops and cashew (FCCa); food crops, cocoa and cashew (FCCCa), and i* is the reference category (food crops, cocoa and cashew). β0 is the intercept, $\beta_1 - \beta_n$ are parameters to be estimated and μ is the error term. The estimated parameters depict the effect and direction of independent variables (Maddala, 2001). Therefore, the marginal probabilities that explain the magnitude of change in the response variable (diversification of crops) with respect to a unit change in the independent variables are frequently used. Equation (2) is differentiated as below:

$$\frac{\partial P_1 (log \frac{P_j}{1-P_j})}{\partial X_{ij}} = \beta_j \quad (3)$$

Each explanatory variable and consequent effects on the choice of cropping system captured in the MNL are summarised in Table 2.

Table 2 Description of explanatory variables in the MNL regression model

Explanatory variables	Description	Expected signs	References
Personal characteristics			
Gender	Gender of household head, measured as a dummy variable (1=male, 0=otherwise)	+/-	Kemboi et al. (2020); Rehima et al. (2013)
Age	Age of respondent, measured as a continuous variable (in years)	+/-	Dembele et. al. (2018); Kemboi et. al. (2020); Rehima et al. (2013)

Years in education	Years of formal education, measured as a continuous variable (years)	+	Dembele et. al. (2018); Douyon et al. (2022); Kemboi et. al. (2020)
Household size	Household size, measured as a continuous variable (number of persons in the household)	+	Dembele et. al. (2018); Douyon et. al. (2022)
Farming experience	Years of farming experience, measured as a continuous variable (years)	+	
(a) Farm characteristics			
Fallow land availability	Availability of fallow land, measured as a dummy variable (1 = if household has a fallow land for more than 5 years, 0= otherwise)	+	Rehima et al. (2013)
Labour in household	Number of active household members above 18 years but less than 60 years, measured as a continuous variable	+	Baba and Abdulai, (2020); Rehima et al. (2013)
Land ownership	Type of land ownership, measured as a dummy variable (1= private ownership, 0=otherwise)	+	Dembele et. al. (2018)
Own Livestock	Livestock ownership, measured as a dummy variable (1= if farmer owns any livestock, 0= otherwise)	+	Rehima et al. (2013); Dembele et. al. (2018)
(a) Institutional characteristics			
Access to credit	Credit access, measured as a dummy variable (1= if household applied and received formal credit, 0= otherwise)	+	Kemboi et. al. (2020); Rehima et al. (2013)
Extension access	Extension access, measured as a dummy variable (1= Contact with extension officer, 0= otherwise)	+	Dembele et. al. (2018)
Income	Income from farming activities, measured as a continuous variable (in Ghana cedis-Gh¢)	+	Rehima et al. (2013); Dembele et. al. (2018)
Non-farm income	Engagement in non-farm income, measured as a dummy variable (1= if farming participates in non-farm income, 0= otherwise)	-	Baba and Abdulai (2020); Rehima et al. (2013)
Response variable: choice of cropping system			
FC only	1= produce FC only		
FCC	2= produce food crops and cocoa		
FCCa	3= produce food crops and cashew		
FCCCa	4[a] = produce food crops, cocoa and cashew		

[a]Base category

3.5 Impact assessment tool

Given that farmers' food – cash crop combination choice is not randomly assigned, members of each combination group may differ systematically which will result in biased average treatment effect (ATE) estimates if self-selection is not corrected for (Zheng and Ma, 2021). Various techniques have been used by previous studies to estimate robust and unbiased ATE's (Tefera and Bijman, 2021; Manda et al., 2020; Rubhara et al., 2020; Wossen et al., 2017; Linden et al., 2015). Some of these include the propensity score matching (PSM) method, inverse probability weights (IPW) estimator, regression adjustment (RA) estimator, endogenous switching regression (ESR) model, and inverse probability weighted regression adjustment (IPWRA) estimator.

To attain unbiased ATE estimations, the PSM and IPW approaches depend solely on the accurate specification of the treatment equation, disregarding the outcome equation specification (Zheng and Ma, 2021). Similarly, the RA model also relies on the right specification of the outcome equation (Linden et al., 2015). Thus, when either the selection equation or the outcome equation is mis-specified, ATE estimates are inconsistent and unreliable in these approaches.

By combining the IPW and RA estimators, the IPWRA ensures unbiased estimates by requiring only the correct specification of either the treatment equation (IPW) or the outcome equation (RA) (StataCorp, 2017). As a result, the IPWRA estimator has a double-robust characteristic that accounts for mis-specification in either the outcome and treatment models, ensuring consistent results (Wooldridge, 2010).

Although the ESR approach also ensures robust ATE estimates by estimating the selection and outcome equations concurrently (Ma and Abdulai, 2016), it is strictly reliant on the availability of an instrument satisfying several econometric requirements, yet identifying an instrument with these properties in practice is difficult (Imbens and Wooldridge, 2009; Manda et al., 2021). To this end, we employ the IPWRA estimator to assess the impact of food crop – cash crop combination choice on income and food security.

The IPWRA model estimates the ATT in three (3) phases (Zheng and Ma, 2021; Linden et al., 2015). The propensity scores, which represent the likelihood of receiving a treatment based on pre-treatment characteristics, are estimated using multinomial logit regression, and the inverse probability weights (IPW) for each treatment level are generated in the second stage.

A weighted regression is then used to fit the outcome models (income and food security) for each treatment level using the calculated weights, and the estimated coefficients from this weighted regression are used to derive treatment-specific predicted outcomes for each individual. Finally, the mean outcomes for each treatment level are calculated and the ATTs are estimated using the difference between these averages. The following is how the ATT was calculated:

$$ATT = \frac{1}{A_t}\sum_{1}^{N_t}\{(\emptyset 1 - \emptyset 2) - (\delta 1 - \delta 2)X_i\} \qquad (4)$$

In which (Φ1 and δ1) are estimated inverse probability weighted parameters for adopters, while (Φ2 and δ2) are estimated inverse probability weighted parameters for non-adopters, and A_t indicates the total number of adopters. A key weakness of the IPWRA is that it fails to account for unobserved heterogeneity in the variables of interest (Sseguya et al. 2021). To offset this, two robustness checks are conducted. First, we test the overlap assumption underlying the IPWRA model by using an overlap graph. The overlap assumption states that each farmer has a strictly positive probability of conditioning on a rich set of covariates. The graph indicated that all the estimated densities had most of their respective masses in regions where they overlap each other. Second, we estimate the PSM a key robustness check for the IPWRA results and further assess the impact of food-tree crop diversification on farm household welfare.

In this study we adopt the PSM's average treatment effect on the treated (ATT) which is consistent with IPWRA estimation as one of the robustness checks. The ATT measures the average differences on the outcome variables with and without farm households who engaged in multiple cropping systems. Shaikh et al. (2009) claim that the PSM eliminates all unpaired units by matching the treatment and control units based on similar propensity score values and perhaps additional factors. The PSM contains two steps: first, probit model estimation; second, average treatment effect computation (ATT). Following Rosunbaum (1983), the ATT is computed as:

$$\boldsymbol{ATT = E\left\{\delta_1 - \delta_0 \mid A = 1\right\}} \qquad (5)$$

$$\boldsymbol{ATT = E[E\left\{\delta_1 - \delta_0 \mid A = 1, p(X)\right\}} \qquad (6)$$

$$ATT = E[E\{\delta_1 \mid A = 1, p(X)\} - \boldsymbol{E}\left\{\delta_0 \mid A = 0, p(X)\right\} \mid \boldsymbol{A = 1}] \qquad (7)$$

Due to its capacity to provide precise empirical data on impact studies, the PSM's closest neighbour matching (NNM), kernel-based matching (KBM), and radius matching (RM) approaches were utilized in this study (Donkor et al., 2019; Ma and Abdulai, 2016; 2019).

4.0 Results and Discussion

4.1 Food security status of farmers based on crop categories

Farm households generally reported to be food insecure regardless of the category of crops cultivated (Figure 2). According to the data, 63.97% of farm households reported various categories of food insecurity, compared to 36.03% who reported being food secure. This figure is slightly above the food insecurity prevalence rate of 48% reported by Atiglo et al. (2022) from farm households across three agro-ecological zones of Ghana. Across the food insecure category, more than a quarter (29.5%) were found to be severely food insecure with hunger. Such households exhibited the following peculiarities: (i) did not have food to eat the whole day in the past 4 weeks preceding the survey and that occurred most often, (ii) often reduced or cut down the size of family member's food and that and (iii) had family members who often skipped meals.. Other categories of food insecurity reported were moderately food insecure with hunger (43.3%) and food insecure without hunger (27.2%).

The results imply that food insecurity accompanied by hunger was widespread in the study area, which necessitates immediate intervention to remedy the situation. Although a sizable number of selected households indicated mild and hunger-free food insecurity, previous studies have argued that any type of food insecurity in the community is unacceptable, (Kuwornu et al. 2013; Mustapha et al. 2016; Nkegbe et al. 2017). For instance, Nkegbe (2017) found 36% and 63% of households in northern Ghana to be food insecure with moderate and little or no hunger respectively, and regarded that to be problematic and outside the acceptable food insecurity rate.

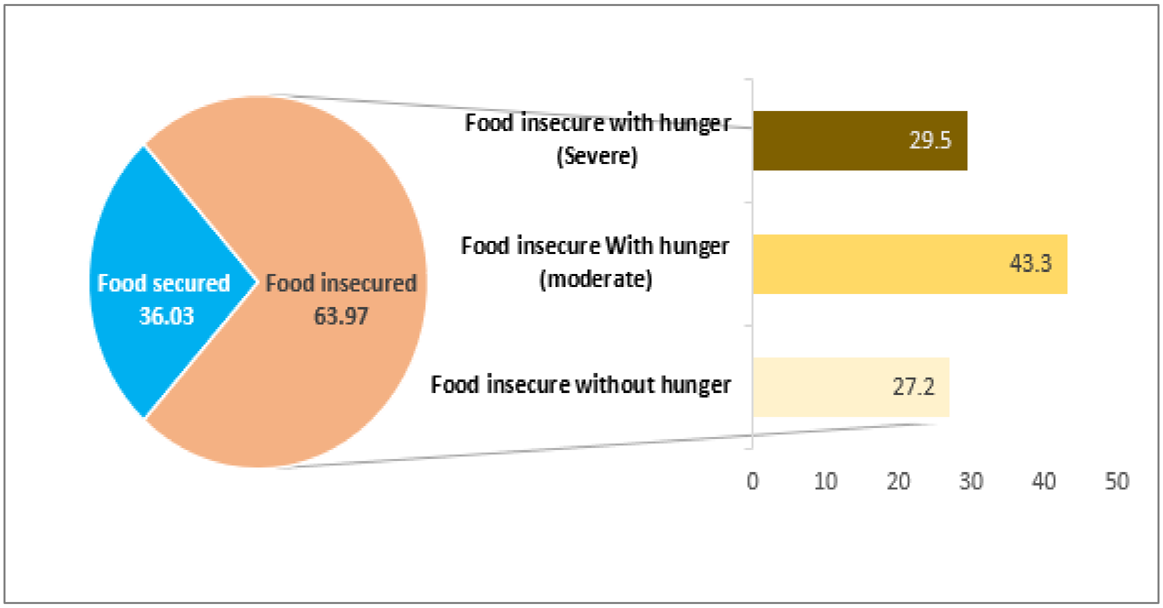

Figure 2 Food security status of the farm households

The food security status of households was also analysed in relation to the category of crops cultivated (Figure 3). The data indicates that food security was associated with higher crop diversity. A higher proportion of farm households that had diversified into all the three categories of crops (specify %) () were food secure compared to those that engaged in two (specify the %) or mono-cropping (food crop) systems (specify the %). A plausible explanation to this finding could be the direct impact of multiple cropping systems on food availability and accessibility at the farm household level as observed by Appiah-Tumasi and Asale (2022). Crop diversification systems that include tree cash crops particularly have the potential to provide additional money to enhance farmers' access to food items that cannot be obtained through own farm production and also to purchase home non-food items. Further evidence from the data points to a higher likelihood of food security for farmers who grow cocoa with other crops compared to those cultivate only food crops. This finding might be influenced by Ghana Cocoa Board's market stabilisation policy which provides higher and stable prices for cocoa farmers.

In terms of all the hunger categories, households that produced only food crops reported higher prevalence of severe food insecurity with hunger (40%) and moderate food insecurity with hunger (45%) compared to their counterparts who cultivated multiple crops with tree cash crops inclusive. The finding is in line with Mustapha et al. (2016) who observed that households who cultivate different crop types tend to be less vulnerable to food insecurity in northern Ghana.

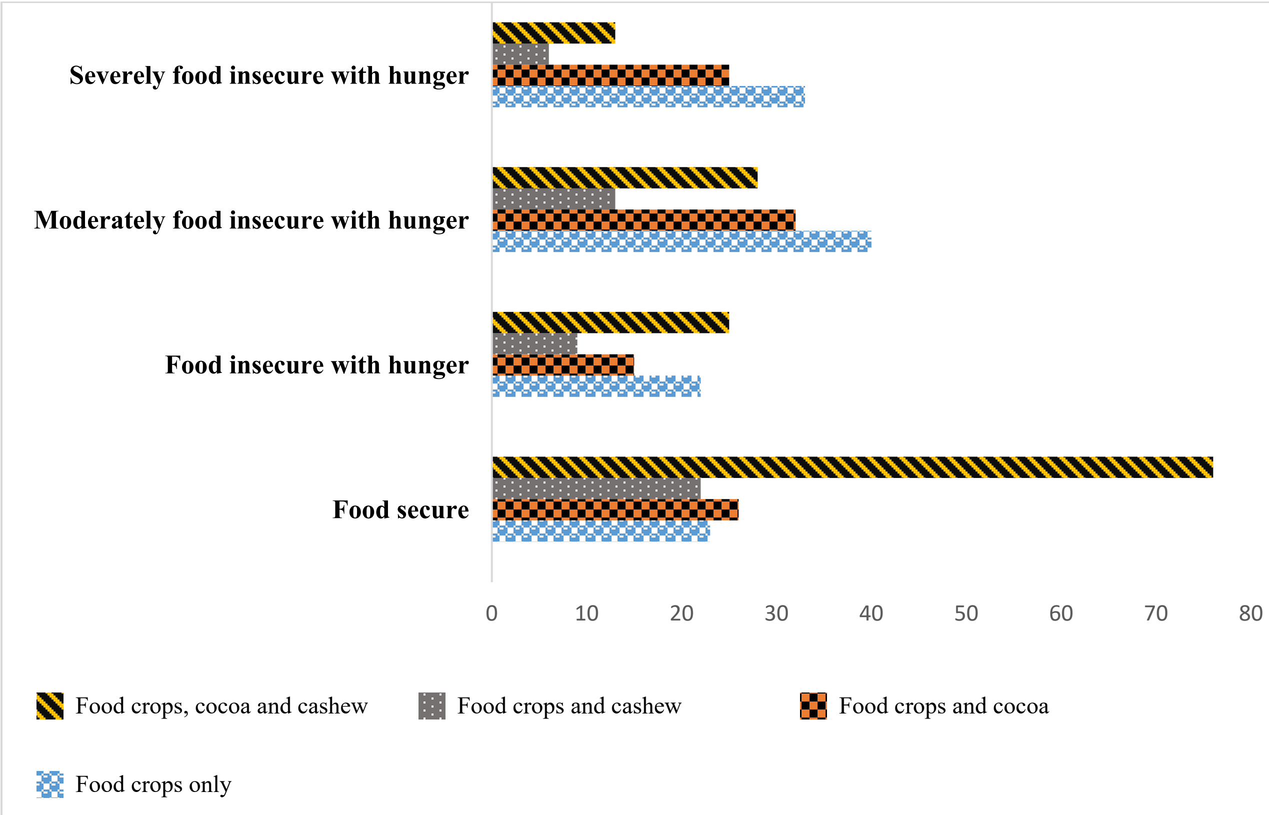

Figure 3 Food security status based on cropping system of farm households

4.2 Socio-economic characteristics of farmers

The socioeconomic characteristics of the farmers are illustrated in Table 2. The survey depicts that majority of the respondents were males (84.56%), which is marginally higher than 73% reported by Valino et al. (2019) in the transition zone of Ghana. However, a higher proportion of female farmers was observed in households that cultivated food crops only (18.64%) compared to those who produced cashew and cocoa (11.97%). The low involvement of female farmers in tree cash crop cultivation may partly be due to economic and socio-cultural constraints that limit women capacity to access high-value cash crops including cocoa, cashew, coffee, among others across developing economies (Zakaria, 2017). There was high access to extension, especially among food crop and cocoa farmers (67.35%), and those who produced food crops, cocoa and cashew (79.58%). This could have a positive implication for technology adoption since agricultural extension offices are the main conduit to technology dissemination and provision of technical knowledge among smallholder farmers. The extension data is however, at variance with the Adams et al. (2021) who reported that less than 20% of smallholder farmers in the forest zone of Ghana had access to extension services. In terms of education, more than 60% were literate, i.e. had completed a minimum primary formal education, hence could write and read simple instructions on the use of technologies. This finding contradicts Nordjo and Adjasi (2020) who reported high illiteracy among smallholder farmers in northern Ghana. Less than 20% of the respondents had access to credit while 50% were engaged in off-farm income generating activities. The low access to credit may limit farmers' opportunity to adopt improved technologies to increase crop productivity. The average age was 52.48 years, which implies an aging farmer population in the study area. The statistic is slightly higher than the 43.82 years reported by Villano et al. (2019) but is consistent with Asravor (2018) who observed a relatively older farmers in the semi-arid region of Ghana. The overall family size of 7 persons is significantly higher than the national average of 4 persons per household across the country (Ghana Statistics Services, 2021). The high household size may imply extra labour to undertake the laborious production-related activities on the farm. However, Obi and Tafa (2016) argued that higher family size could contribute to food insecurity by increasing the demand for food for home consumption.

Table 3 Socioeconomic characteristics of farmers based on crop categories (n=408)

Variable	Total sample (408)	Food crops only (118)	Food crops and cocoa (98)	Food crops and cashew (50)	Food crops, cocoa and cashew (142)	(p-value)
(a) Categorical						
Gender						
Male	345 (84.56)	96 (81.36)	84 (85.71)	40 (80)	125 (88.03)	0.7473 ^{ns}
Female	63 (15.44)	22 (18.64)	14 (14.29)	10 (20)	17 (11.97)	
Off farm income						
Yes	204 (50)	51 (43.22)	38 (38.78)	24 (48)	91 (64.08)	0.0032***
No	204 (50)	67 (56.78)	60 (61.22)	26 (52)	51 (35.92)	
Extension access						
Yes	256 (62.75)	57 (48.31)	66 (67.35)	20 (40)	113 (79.58)	0.0001***
No	152 (37.25)	61 (51.69)	32 (32.65)	30 (60)	29 (20.42)	
Access to credit						
Yes	70 (17.16)	18 (15.25)	18 (18.37)	9 (18)	25 (17.61)	0.989^{ns}
No	338 (82.84)	100 (84.75)	80 (81.63)	41 (82)	117 (82.39)	

Education						
None	159 (38.97)	70 (59.32)	26 (26.53)	21 (42)	42 (29.58)	0.0001***
Primary	59 14.46)	17 14.41)	19 19.39)	8 (16)	15 (10.56)	
JHS/Middle	159 (38.97)	28 23.73)	44 (44.9)	17 (34)	70 (49.30)	
SHS/O&A	23 (5.64)	2 (1.69)	6 (6.12)	4 (8)	11 (7.75)	
Tertiary	8 (1.96)	1 (0.85)	3 (3.06)	0 (0)	4 (2.82)	
Livestock Ownership						
Yes	282 (69.12)	77 (65.25)	67 (68.37)	34 (68.00)	104 (73.24)	0.7329^{ns}
No	126 (30.88)	41 (34.75)	31 (31.63)	16 (32.00)	38 (26.76)	
(b) Continuous						
Age	52.48	50.86)	53.86	49.52	53.90	0.0646**
Household Size	6.94	7.05	6.99	6.38	7.01	0.179^{ns}
Farming experience	24.57	24.64	23.89	21.86	25.93	0.2279^{ns}
Labor size	3.29	3.52	3.38	3.3	3.06	0.2116^{ns}
Annual crop income	7436.95	3642.10	9358.77	6231.92	9688.41	0.0001***
Years in education	7.41	5.58	4.58	8.96	8.02	0.0001***

Note(s): ***Indicates significance at the 1% level. **Indicates significance at the 5% level and ^{ns} indicates non-significance.

The study indicates that the average farmer was highly skilled and had been engaged in farming for more than 24 years. In contrast to this finding, Nordjo and Adjasi (2020) reported that on average, farmers in northern Ghana have 15.15 years of practicing farming which is much lower than the figure observed in this study. The farmers' annual crop income was Gh₵7,436.95 (US$676.07)[1], which is just a little above the US$693.5 globally accepted poverty threshold (Kenton, 2020). The data across all crop categories, however, shows that farmers who cultivated cocoa, cashew and food crops had a much higher annual income of Gh₵9688.41 compared to their counterparts who produced less than three crop categories. The farmers who produced food crops only reported the least annual crop income. This finding could be attributed to market instability and poor pricing for food crops as observed by Hashmiu et al. (2022b). The relatively low income of food crop farmers could have detrimental effects on their access to food and nutrition by restricting their capacity to afford a wider variety of food for consumption.

4.3 Econometric results

4.3.1 Determinants of farm household's decision to participate in food-cash cropping systems

The assumption of independence of the multinomial logit (MNL) regression model from irrelevant alternatives (IIA) was assessed after estimation of the model (Cheng and Long, 2007). The IIA assumes that if a farm household is confronted to choose between two cropping options such as FC only versus FCC, such choice should not be affected by the availability of a third choice such as FFCa or FCCCa production. In this scenario, the IIA demands that if a farmer decided to

[1] 2020 Official exchange rate at US$1 = Gh₵11.0

produce FCCa or FCCCa, the likelihood of the decision to either cultivate FC only or FCCa must adjust in equal proportion to preserve their original odds. The IIA assumption was assessed usingthe Hausman-McFadden test. The test yielded an insignificant chi-square value of 0.52 at 10% significance level. We, therefore, rejected the null hypothesis which states that the difference in coefficients is not systematic, and concluded that the IIA assumption was not violated. Thus, it was justifiable to apply MNL to the data. Likewise, we used the pairwise correlation matrix to examine the presence of multicollinearity among the covariates. The highest pairwise correlation matrix was less than 0.50 which suggests the absence of cross-correlations among the explanatory variables (Gujarati, 2004). The determinants of multiple cropping systems as assessed using MNL are presented in Table 4. The coefficients do not show the magnitude of change in the response variable; hence the significant explanatory variables are discussed in the light of marginal effects based on the sign and category. The MNL model shows that four variables-landownership, livestock ownership, extension access and household income- strongly influenced farm household decision to produce food crops only when compared with the base category of choosing food crops, cashew and cocoa. However, compared to the control category, the production of food crops and cocoa was significantly influenced by three predictor variables (farming experience, household annual crop income and access to off-farm income). Thus, five out of the 13 variables were significant predictors of farmers' decisions to cultivate food crops and cocoa only as opposed to cultivating food crops, cashew, and cocoa. These are availability of fallow land, land ownership, access to extension services, annual crop income, and off-farm income.

Farming experience had a negative relationship with the probability of producing FCC against FCCCa at 5% significance level. The data implies that as farmers' experience in crop production increases by a year, the likelihood of cultivating FCC only decreases by 0.33%, all things being equal. This result is reasonable in the sense that cashew cultivation provides households with additional income that serves as insurance against the risks associated with cocoa production and sale of staple foods in the study area (Adjei and Boafo, 2019). Besides, cashew nuts are gathered and sold between January and May, when the cocoa season is over and income from cocoa is practically depleted (Hashmiu et al. 2022a). This finding further conforms to that of Makate et al. (2016) in Ethiopia.

The MNL further indicates that farm households that had access to fallow land were less likely to produce FCCa than FCCCa. The marginal effects of -0.097 indicate that, when all other factors are equal, the likelihood of cultivating food crops and cashew decreases by 9.7% for every unit increase in the ownership of fallow land. In other words, farm households that grew FCCa and owned fallow fields were more inclined to further diversify into cocoa production. This result is in line with Sabas et al. (2019) who posit that farm households are encouraged to start cocoa farms on fallow lands since such lands have the capacity to generate the nutrients demanded for establishment of cocoa plantations.

Table 4 Multinomial logit regression results

Portfolio	Food Crops Only	Food Crops and Cocoa	Food crops and cashew

Variables	dy/dx	Std. Err	dy/dx	Std. Err	Dydx	Std. Err
(a) Personal characteristics						
Gender (Male)	-0.0502	0.051	-0.0058	0.060	0.042	0.042
Age	-0.0012	0.002	0.0029	0.002	-0.002	0.002
Years in education	-0.0035	0.003	0.0013	0.003	-0.0041	0.002
Household size	0.0055	0.007	-0.0017	0.007	-0.004	0.006
Farming experience	0.0029	0.002	-0.0033*	0.002	-0.0002	0.002
(b) Farm characteristics						
Fallow land availability	0.1089	0.095	0.0719	0.062	-0.0997**	0.05
Labour in household	0.0058	0.012	0.0025	0.012	0.0113	0.01
Land ownership	-0.2125***	0.036	0.0301	0.02	-0.0673***	0.016
Livestock ownership	-0.0716*	0.042	-0.0024	0.047	0.05	0.038
(c) Institutional and economic factors						
Access to credit	-0.0234	0.048	0.0285	0.053	-0.0021	0.042
Extension access	-0.0891**	0.035	0.0333	0.042	-0.0987***	0.031
Annual crop income	-0.0461***	0.015	0.0692***	0.019	-0.0387***	0.014
Off-farm income	0.0299	0.036	-0.1291***	0.041	0.0012	0.032
_cons						
(base outcome)	***Food crops, Cocoa and cashew***					
Number of observations	408					
LRchi2 (39)	294.66					
Prob > chi2	0.000					
Likelihood	-393.67					
Pseudo R^2	0.2723					

(***) Indicates significance at the 1% level. (**) Indicates significance at the 5% level. (*) indicates significance at the 10% level

In terms of land ownership, the MNL shows a significant negative relationship with the probability of choosing FC only and FCCa at 1% significance level. This finding makes sense in the context of this study because individual land ownership plays significant role in crop diversification and adoption of improved technologies among smallholder farmers (Appiah-Tumasi and Asale, 2022; Makate et al. 2016; Amfo, 2019). For instance, Amfo et al. (2021) observed in Ghana that cocoa farmers with own farmlands were more likely to adopt perennial cropping systems including cocoa production, which in turn, influenced their decisions to adopt soil water conservation practices compared to farmers who lacked landownership. Positive correlations between land ownership and expansion of farm holdings to include more tree crops have also been reported by Jansen et al. (2006) and Fraser (2004).

Findings further show a significant negative relationship between access to extension and the likelihood of producing FC and FCCa at 5% and 1% significance level. This result probably suggests that farm households with better extension service contact are more likely to diversify into cashew, cocoa and food crops. Belay et al. (2013) concur that the extension service department helps to disseminate information on new technologies and output markets which are relevant for crop diversification decisions among farmers. The finding also corroborates with observations made in Ethiopia by Makate et al. (2016).

The income effect on the likelihood of food-tree crop diversification decision of farm households is conflicting. The data show that income had a significant negative association with the likelihood of producing FC only and FCCa, but established a positive relationship with FCC at 1% significance level. The finding on farmers' decision to produce FCC at the expense of FCCCa is counter-intuitive which explains why smallholder farmers are risk averse towards new farm enterprises, even when such ventures show promising economic prospects. The cashew plant is a relatively new plantation crop that was just recently introduced to farmers in the study area (Adjei-Nsiah and Kermah, 2012). This may explain why farmers may prefer to produce food crops and cocoa instead of the combination of the three crops. Most smallholder farmers, particularly cocoa farmers, may still be sceptical about the potential market and business prospect of cashew cultivation. On the other hand, the data evidences that farm households who have access to off-farm income generating activities are more likely to engage in the production of food crops, cocoa and cashew plantations. This evidence conforms to prior expectations since several studies have established positive correlations between off-income source and diversification into tree cash crops (Appiah-Tumasi and Asale, 2022; Nkegbe et al. 2017). Households who engaged in off-farm income activities probably generated additional income to acquire additional lands or buy productive inputs to expand or diversify farm operations.

4.3.2 Quantifying the ***impact of food-tree cash crop diversification on household income and food security***

The average treatments of the treated (ATT) estimates of the IPWRA on income and food security are shown in Table 5. Stage 1 (treatment model) and 2 (outcome model) of the IPWRA that shows the casual effects of food security status and income levels of the different categories of smallholder farmers are presented in Appendix 1 and 2. Therefore, in this section, we discuss the post-estimates of the causal effects since several studies including Anderman *et al*., 2014; Kumba *et al*., 2015; Rubhara *et al*., 2020 have extensively examined the factors influencing food security among food crop and cash-crop producers in Africa. However, the multinomial logit in Table 4 is the same as that captured in the first stage of the IPWRA model. Before the causal effects were estimated, the overlap assumption that explains that each surveyed respondent has fair chance of getting any treatment was examined. Figure 4 shows an overlap graph with substantial overlap distribution of the treated propensity scores of the control and treated groups. The graph shows no violation of the assumption after the propensity score reweighting.

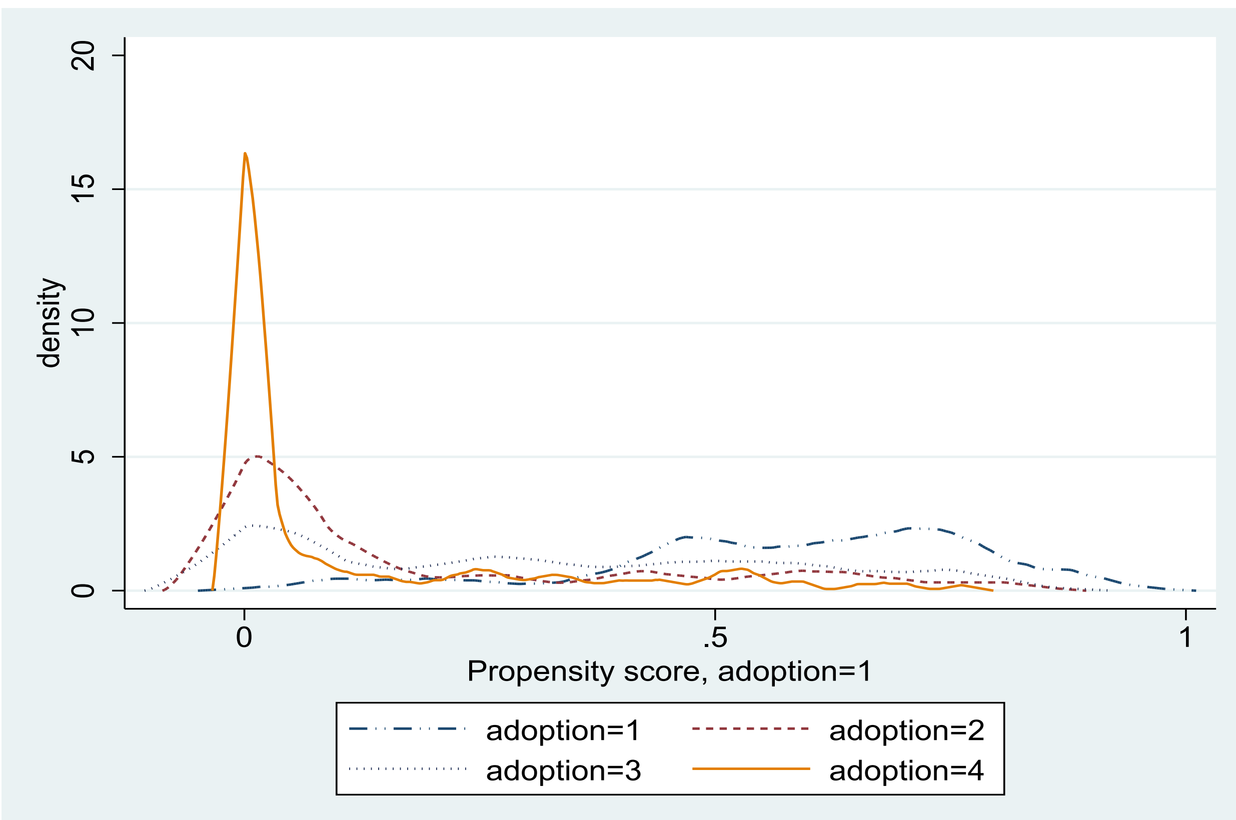

Figure 4 Test of overlap assumption

The results in Table 5 show significant impact of cash-crop diversification on farm household food security and income levels. The data depicts that households that diversify into food and cash crops realise significant positive impacts on food security and annual crop income at least at 10% significance level. It must be noted that based on the USDA food insecurity scale, negative ATTs will denote better food security scores for farm families practising food-cash crop systems. Thus, compared to exclusively food crop households (FC), farm families who had diversified their farm portfolios to include food crops and cocoa (FCC), food crops and cashew (FCCa), and food crops, cocoa, and cashew (FCCCa) tend to be more food secure. The results further indicate that diversifying into more than one cash crop (cocoa and cashew) had greater impact (47.24%) in reducing food insecurity among farming households than only one cash crop. However, significant food security difference existed in favor of farmers who cultivated FCCa, with 14.71 percentage points more than farmers who engaged in FCC production. This result is counterintuitive given the fact that cocoa production and marketing in Ghana are well structured with more financial and technical support for farmers to increase production, productivity and income. Perhaps, a plausible explanation to this finding could be attributed to the timing of this study which coincides with harvesting time of cashew nuts among farmers for marketing.

In terms of income effect of food-cash crop diversification, the positive ATT estimates indicate positive impact of cash crop production on household income (Table 5). The data shows improved farm household earnings when the farm portfolio was diversified to include either food crops and cocoa, food crops and cashew, or food crops, cocoa and cashew compared to traditional food crop production. Even though the impact of the food-cash crop diversification was marginal, farmers who cultivated FCCCa realised income gains of 7.86% compared to FCC (5.76%) and FCCa (6.65%) producers. The data further shows modest income improvement for farm families that had diversified into cashew and food crops compared to cocoa and food crop production. These findings are in line with Achterbosch et al. (2014) and Wiggins et al. (2015) who maintain that cash cropping increase income available to farming households, and that farmers use income from cash crops to purchase food and complement crop food production. This suggests that, by diversifying into cash and food crops, farmers may gain access to food not only by self-production but also by purchasing. Thus, diversified food-cash crop systems could potentially address two fundamental dimensions of food security – availability and accessibility. This finding is also reiterated by Hashmiu et al. (2022a) who suggest that Ghanaian farmers use additional income from cocoa to venture into staple food crop production. It is without doubt that positive synergies exist between cash – food crop diversification.

Table 5 Impact of diversification on food security

Food security					
	ATT	**std. err**	**Z**	**P>|z|**	**%Impact**
FCC vs FC	-1.653***	0.573	-2.88	0.004	31.26%
FCCa vs FC	-2.431***	0.655	-3.71	0.000	45.97%
FCCCa vs FC	-2.498***	0.547	-4.57	0.000	47.24%
Baseline potential outcome (PO means)					
Food crops only	5.288***	0.485	10.89	0.000	

Income					
	ATT	**std. err**	**z**	**P>|z|**	**%Impact**
FCC vs FC	0.468*	0.274	1.71	0.088	5.76%
FCCa vs FC	0.540**	0.273	1.98	0.048	6.65%
FCCCa vs FC	0.638**	0.304	2.10	0.036	7.86%
Baseline potential outcome (PO means)					
Food crops only	8.117***	0.277	29.35	0.00	

Robustness check: Impact of diversification on income and food security

Before estimating the treatment effects of cash– food crop diversification, we first checked whether the common support and covariate balancing assumptions were met. The covariate balancing test conducted showed low pseudoR^2 reduced mean bias and insignificant log-likelihood values after matching for all matching techniques. These are all indications of good matching quality (Sianesi ,2004) and confirm that the assumptions underlying the PSM model were not violated.

Table 6 displays the results of the Kernel matching and Caliper matching estimators of the impact of diversification on income and food security. Our results were mostly consistent, with the same signs, significance levels and comparable ATT estimates across the two estimation techniques. Similar to the IPWRA estimator, the results from the PSM estimator show significant and positive ATT values associated with cash – food crop diversification. This confirms the results of the IPWRA model, implying that cash – food crop diversification leads to higher income. Similarly, the negative and consistent ATT values also confirm the findings, that cash – food crop diversification reduces food insecurity among farming households.

Table 6 PSM estimates on Impact of diversification on income and food security

	Income	
	Kernel matching	**Caliper matching**
(Food crops and cocoa vs Food crops only)	0.657 (0.30) **	1.33 (0.155) **
(Food crops and cashew vs Food crops only)	0.968 (0.27) ***	0.820 (0.27) ***
(Food crops, cocoa and cashew vs Food crops only)	1.172 (0.27) ***	1.181 (0.34) ***

	Food security	
	Kernel matching	**Caliper matching**
(Food crops and cocoa vs Food crops only)	-1.93 (0.52) ***	-1.54 (0.60) ***
(Food crops and cashew vs Food crops only)	-2.627 (0.66) ***	-2.78 (0.79) ***
(Food crops, cocoa and cashew vs Food crops only)	-2.408 (0.48) ***	-2.128 (0.69) ***

5.0 Conclusion and Recommendations

The main purpose of the study was to assess the determinants of food-tree cash crop diversification, and its impacts on the income and food security of smallholder households in the Forest-Savannah Transition Zone of Ghana. Findings indicate that cash-food crop diversification impacts positively on household annual crop income and food security, and these positive impacts further increase as the diversity of tree cash crops increases. The food security advantage of diversified cropping systems could be due to the income effect of tree cash crops and complementarities between cash crops and food crop production at the household level. The multinomial logit regression demonstrates personal factors (farming experience), farm characteristics (fallow land availability, land ownership and livestock ownership), economic (annual crop income and access to off-farm income) and institutional factors (access to extension) as the significant predictors of farmers' decision to adopt a diversified system of food and tree cash crops.

The results could be used to promote adoption the of integrated food-tree cash production in the Forest-Savannah Transition Zone of Ghana. For instance, the significant effect of annual crop income, off-farm income and extension on adoption of food-tree crop integration underscores the importance of financial capital and technical support in promoting sustainable farming systems and achieving the second Sustainable Development Goal of eradicating hunger by 2030. In addition, it would be pragmatic for food security interventions to mainstream livestock production into the livelihood portfolios of smallholder households. While income from livestock may indirectly enhance the financial ability of farmers to diversify their cropping system, direct consumption of livestock products such as meat and milk could improve dietary diversity and nutritional outcomes at the household level. However, considering that land ownership rights in sub-Saharan Africa are oftentimes unclear, contested or poorly enforced, pro-poor and equitable land tenure reforms would be indispensable in promoting diversification into tree cash crops by subsistence farm households.

APPENDICES

Appendix 1 First and second stage of IPWRA casual effects of diversification on food security

	Food crops only		**Food crops and Cocoa**		**Food crops and cashew**		**Food crops, Cocoa and csahew**	
Variable	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Outcome Model								
Gender (Male)	-2.635***	0.811	1.238*	0.693	0.679	1.609	-0.168	0.993
Farming experience	-0.019	0.024	0.019	0.025	0.083**	0.034	0.033	0.025
Age	0.035	0.026	-0.016	0.021	-0.124***	0.026	-0.05	0.031
Years in education	0.104***	0.039	-0.027	0.039	0.005	0.062	0.067	0.045
Bear land available	-0.782**	0.377	0.313	0.221	-0.172	0.365	-0.315*	0.176
Own fallow land	1.93	1.176	0.024	0.631	-0.969	0.81	-0.16	0.65
Household size	-0.218*	0.121	0.201**	0.092	0.075	0.098	-0.143**	0.066
Household labor	0.023	0.212	0.288**	0.137	-0.592*	0.333	-0.014	0.169
Extension (Yes)	0.97**	0.458	-0.547	0.51	-1.591	1.032	0.057	0.554
Credit access (Yes)	-0.37	0.45	-0.874	0.752	2.654***	0.826	-0.159	0.607
Own livestock(Yes)	-0.043	0.549	-0.476	0.603	-0.134	0.712	-0.292	0.775
Log income	-0.092	0.188	-0.81***	0.23	1.035***	0.263	-0.074	0.255
Off farm income	-0.627	0.479	-0.551	0.535	-0.462	0.503	0.055	0.482
_cons	7.812***	1.778	8.15***	2.023	1.249	2.964	6.773***	2.439
Treatment Model								
Gender (Male)			0.355	0.458	0.265	0.467	0.64	0.488
Farming experience			-0.034**	0.017	-0.017	0.021	-0.019	0.018
Age			0.023	0.018	-0.01	0.022	0.012	0.018
Years in education			0.038	0.028	-0.012	0.028	0.06**	0.028
Bear land available			1.547***	0.408	1.757***	0.404	1.97***	0.4
Own fallow land			-0.334	0.927	-1.447	0.936	-1.009	0.898
Household size			-0.039	0.061	-0.063	0.089	-0.033	0.069
Household labor			-0.055	0.105	0.053	0.117	-0.146	0.119

Extension (Yes)	0.972***	0.374	-0.261	0.372	1.482***	0.382
Credit access (Yes)	0.285	0.466	0.108	0.493	0.162	0.485
Own livestock(Yes)	0.42	0.415	0.81*	0.445	0.558	0.426
Log income	0.678***	0.17	-0.062	0.168	0.466***	0.165
Off farm income	-0.714**	0.339	-0.109	0.374	0.21	0.358
_cons	-7.70***	1.569	-0.677	1.372	-7.09***	1.497

Appendix 2 First and second stage of IPWRA casual effects of diversification on income

	Food crops only		**Food crops and Cocoa**		**Food crops and cashew**		**Food crops, Cocoa and csahew**	
Variable	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Outcome Model								
Gender (Male)	0.719**	0.342	0.925***	0.302	0.467	0.337	0.701***	0.227
Age	0.001	0.017	0	0.009	0.009	0.008	0.001	0.01
Years in education	0.022	0.019	-0.026	0.016	0.045**	0.02	0.022	0.016
Household size	0.083	0.051	0.027	0.033	-0.035	0.021	0.062**	0.03
Farming experience	-0.012	0.016	0.002	0.01	0.014	0.009	0.015	0.01
Own fallow land	-2.138***	0.728	-0.58***	0.211	0.888***	0.244	-0.117	0.208
Household labor	-0.1	0.096	0.106**	0.049	0.016	0.074	0.064	0.045
Bear land available	0.995***	0.179	0.414***	0.086	-0.036	0.075	0.144***	0.054
Own livestock(Yes)	0.769***	0.254	0.174	0.221	0.355	0.231	0.481***	0.182
Credit access (Yes)	-0.197	0.292	0.075	0.249	0.206	0.242	-0.36*	0.205
Extension (Yes)	0.008	0.303	0.133	0.223	0.254	0.298	0.193	0.218
Off farm income	0.48	0.343	0.016	0.229	-0.296	0.205	0.2	0.199
_cons	5.758***	0.786	6.527***	0.599	6.727***	0.526	5.688***	0.567
Treatment Model								
Gender (Male)			0.75*	0.438	0.244	0.46	0.903*	0.481
Age			0.017	0.016	-0.013	0.022	0.006	0.017
Years in education			0.042	0.027	-0.012	0.028	0.061**	0.028
Household size			0.002	0.054	-0.053	0.093	-0.001	0.063
Farming experience			-0.033**	0.017	-0.016	0.021	-0.017	0.018
Own fallow land			-0.728	0.943	-1.549	0.958	-1.309	0.917
Household labor			-0.013	0.098	0.02	0.123	-0.124	0.116
Bear land available			1.763***	0.41	1.81***	0.409	2.132***	0.402
Own livestock(Yes)			0.662*	0.397	0.817*	0.444	0.767*	0.419
Credit access (Yes)			0.132	0.423	0.054	0.497	0.027	0.456
Extension (Yes)			0.959***	0.353	-0.274	0.377	1.45***	0.37

Off farm income	-0.611*	0.325	-0.1	0.38	0.284	0.35
_cons	-3.04***	0.84	-0.935	0.972	-3.90***	0.871

Appendix 3

The USDA food security core module contains 18 items for households with children and 10 items for households without children, so a complete response requires either 18 or 10 valid answers.

THE USDA FOOD SECURITY CORE MODULE

The next set of questions are about the food eaten in your household in the last 12 months, since (current month) of last year, and whether you were able to afford the food you need.

To Enumerator: In the case of single adult households, use "I" instead of "We"; and "My" instead of "Our". In case the respondent doesn't know or refuses to answer a particular question, select "**DK or R**".

Stage 1: Questions 1-5 --ask all households:
Now I'm going to read to you several statements that people have made about their food situation. For these statements, please tell me whether the statement was **often true, sometimes true, or never true** for your household **in the last 12 months**, that is, since last (name of current month).

1) "We worried whether our food would run out before we got money to buy more." Was that often true, sometimes true, or never true for your household **in the last 12 months**?
   1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

2) "The food that we bought just didn't last, and we didn't have money to get more." Was that often, sometimes, or never true for your household **in the last 12 months**?
   1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

3) "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for your household **in the last 12 months**?
   1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

To Enumerator: If this household has at least one child, ask Questions 4 and 5; otherwise skip to the next section (1st Level Screen).

4) "We relied on only a few kinds of low-cost food to feed our child/children because we were running out of money to buy food". Was that often, sometimes, or never true for your household **in the last 12 months**?
   1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

5) “We couldn’t feed our child/children a balanced meal, because we couldn’t afford that.” Was that often, sometimes, or never true for your household **in the last 12 months?**
1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

1st –Level Screen

To Enumerator: IF AFFIRMATIVE RESPONSE (i.e., "often true" or "sometimes true") to ANY ONE of Questions 1-5, then continue to the next stage (i.e. Stage 2); otherwise, skip to Question 16.

Stage 2: Questions 6-10 --ask households passing the 1st -Level Screen

To Enumerator: If this household has at least one child, ask Question 6; otherwise skip to Question 7.

6) "Our child was/children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for your household **in the last 12 months?**
1. Often true [ ] 2. Sometimes true [ ] 3. Never true [ ] 4. DK or R [ ]

7) **In the last 12 months**, since last (name of current month), did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?
1. Yes [ ] 2. No [ ] 3. DK or R [ ]

7a) [IF YES ABOVE, ASK] How often did this happen---almost every month, some months but not every month, or in only 1 or 2 months?

1. Almost every month [ ] 2. Some months but not every month [ ]
3.Only 1 or 2 months [ ] 4.DK or R [ ]

8) **In the last 12 months**, did you ever eat less than you felt you should because there wasn't enough money to buy food?
1. Yes [ ] 2. No [ ] 3. DK or R [ ]

9) **In the last 12 months** were you ever hungry but didn't eat because you couldn't afford enough food?
1. Yes [ ] 2. No [ ] 3. DK or R [ ]

10) **In the last 12 months**, did you lose weight because you didn't have enough money for food?
1. Yes [ ] 2. No [ ] 3. DK or R [ ]

2nd-Level Screen

To Enumerator: IF AFFIRMATIVE RESPONSE (i.e., "yes' or "often true" or "sometimes true") to **ANY ONE of Questions 6 through 10, then continue to Stage 3; otherwise,** end the module.

Stage 3: Questions 11-15 --ask households passing the 2nd -Level Screen

11) **In the last 12 months** did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?
    1. Yes [ ]   2. No [ ]   3. DK or R [ ]

    11a) [IF YES ABOVE, ASK] How often did this happen---almost every month, some months but not every month, or in only 1 or 2 months?
    1. Almost every month [ ]   2. Some months but not every month [ ]
    3.Only 1 or 2 months [ ]   4.DK or R [ ]

To Enumerator: If this household has at least one child, ask Questions 12-15; **otherwise**, end the module.

12) **In the last 12 months**, since (current month) of last year, did you ever cut the size of your child's/any of the children's meals because there wasn't enough money for food?
    1. Yes [ ]   2. No [ ]   3. DK or R [ ]

13) **In the last 12 months** did your child/any of your children ever skip meals because there wasn't enough money for food?   1. Yes [ ]   2. No [ ]   3. DK or R [ ]

    13a) [IF YES ABOVE ASK] How often did this happen---almost every month, some months but not every month, or in only 1 or 2 months?

    1. Almost every month [ ]   2. Some months but not every month [ ]
    3.Only 1 or 2 months [ ]   4.DK or R [ ]

14) **In the last 12 months** was your child/were the children ever hungry but you just couldn't afford more food?
    1. Yes [ ]   2. No [ ]   3. DK or R [ ]

15) **In the last 12 months** did your child/any of the children ever not eat for a whole day because there wasn't enough money for food?   1. Yes [ ]   2. No [ ]   3. DK or R [ ]

CODING SURVEY RESPONSES

Negative responses (never true, no, and only 1 or 2 months) are coded as 0, while affirmative responses (often true, sometimes true, yes, almost every month, some months but not every month) are coded as 1. Missing data (Refused or Don't Know) are coded with dots.

DETERMINING FOOD SECURITY VALUES AND STATUS LEVELS

The number of affirmative responses for each household is counted and used to determine the food security values, codes, and status levels (classes) as illustrated in the table below:

Table 1. Food Security Scale Values and Status Levels Corresponding to Number of Affirmative Responses[2]

[2] Source: Bickel, G, Nord, M., Price, C., Hamilton, W. and Cook, J. (2000). *Guide to Measuring Household Food Security, Revised 2000*. U.S. Department of Agriculture, Food and Nutrition Service, Alexandria VA.

Number of Affirmative Responses:		1998 Food Security Scale Values [a]	Food Security Status Level	
(Out of 18) Households With Children	(Out of 10) Households Without Children		Code	Category
0	0	0.0	0	Food Secure
1		1.0		
	1	1.2		
2		1.8		
	2	2.2		
3		2.4	1	Food Insecure Without Hunger
4		3.0		
	3	3.0		
5		3.4		
	4	3.7		
6		3.9		
7		4.3		
	5	4.4		
8		4.7	2	Food Insecure With Hunger, Moderate
	6	5.0		
9		5.1		
10		5.5		
	7	5.7		
11		5.9		
12		6.3		
	8	6.4		
13		6.6	3	Food Insecure With Hunger, Severe
14		7.0		
	9	7.2		
15		7.4		
	10	7.9		
16		8.0		
17		8.7		
18		9.3		

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