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Impact of Sugarcane Production Participation on Household Food Security in Uganda

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ABSTRACT

The paper examines the impact of sugarcane production on household food security in Uganda. It is among the few studies in Uganda providing new empirical insights into household food security. Specifically, it demonstrates how cultivating sugarcane or not impacts household livelihood outcomes in communities where sugarcane is grown compared to households in the same regions that do not grow cane. The paper uses quantitative techniques (Poisson, ordered probit, PSM and IPW) on primary cross-sectional survey data from 1771 farming households conducted in 2021 across three sugarcane-growing subregions of Uganda—Bunyoro, Buganda and Busoga. The data were weighed; hence, the results are nationally representative. Findings reveal that the mean differences in Household Food Insecurity Access Scale (HFIAS) score, Household Dietary Diversity Score (HDDS) and Months of Adequate Household Food Provisions (MAHFP) were −1.70, 0.63 and 1.21, respectively, between cane growers and non-cane growers, all statistically significant at the 1% level. Poisson marginal estimates showed that HFIAS significantly decreased (−1.219) among cane growers relative to non-cane growers. Analysis using the ordered Poisson indicates that the age of the household head, maximum adult female education, location, wages/salaries, shocks (such as death of a household member and crop pests and diseases), household asset values and the number of food crops all had positive and significant effects on food security, depending on the proxy measure. The PSM and IPW analyses reveal that the average treatment effect on the treated (ATT) of cane production on HDDS is statistically significant and negative (−0.33), suggesting a reduction in HDDS for cane growers. The PSM (1:1) (Average Treatment Effect) indicates that if a non-cane grower chose to cultivate cane, their food insecurity would decrease by approximately 0.836 (HFIAS). Their months of food provision would increase by nearly half a month. Therefore, policies related to sugarcane should ensure that farmers receive timely payments from selling cane to the mill and offer stable prices to help smooth food consumption beyond their own production.

JEL Classification: C35, D13, I31, O13, Q12

1 | Introduction

Despite sufficient global food production, food insecurity continues. An estimated 2.3 billion people worldwide were moderately or severely food insecure in 2024 (FAO et al. 2025). Food insecurity is increasing in Africa, where approximately 63.3% of the sub-Saharan population experienced moderate or severe food insecurity and about 23.8% suffered from severe food insecurity (FAO et al. 2025). While context-specific, rising food prices, climate shocks, conflict and the lingering effects of COVID-19 were cited as the major drivers of food insecurity. Despite its agricultural potential and significant exports, Uganda was ranked 105th out of 127 countries with a Global Hunger Index (GHI) score of 27.3, hence classified as 'serious' by the 2024 GHI (FAO et al. 2025). This poses further challenges to the country's ability to achieve Sustainable

Development Goal 2, which aims to end hunger. Food insecurity in Uganda is a multifaceted issue, often caused by a combination of factors, including poverty, gender inequality, the effects of climate change and conflict (Uganda Bureau of Statistics (UBOS) 2024). Using the Food Insecurity Experience Scale (FIES), approximately 30.7% of the population (14.1 million people) as of May 2024 experienced severe food insecurity, particularly in Karamoja, where 62.9% of the population was severely food insecure (UBOS 2024).

Alongside small-scale food crop production, many African governments are promoting large-scale agricultural investments, particularly in cash crops such as sugarcane, oil palm and coffee, as a strategy to enhance household incomes and thereby ensure food security (Edafe et al. 2023). The rationale is that households can ensure food security through self-provision from their own food crop production and/or food market purchases, facilitated by farm income (Gebeyehu and Abbink 2022; Edafe et al. 2023). In addition, large-scale agricultural production investments increase demand for land, affecting livelihoods and food security as smallholder farmers convert their land from food crops to cash crops (Bahati et al. 2022; Gebeyehu and Abbink 2022). Food security is compromised when cash-crop incomes are unstable and insufficient (Moreda 2017).

Uganda has joined the effort to promote large-scale agricultural investments in sugarcane and palm oil. While palm oil began commercial production in 2005, sugarcane started in 1920. This paper focuses on sugarcane, given its history and the ongoing debate in the country regarding its impact on food security in the sugarcane-growing subregions. Specifically, the government has proceeded to offer land for large-scale sugarcane investments, with the number of mills increasing over time, from three mills in the 1930s to more than 33 mills licensed in 2021, with 14 operational (Mbowa et al. 2023). This has led to an increase in land conversion from food and forest cover to expand cane production by households, millers and the government. The initiative mainly aims to increase cane production to meet both the rising demand from mills (old and new) as an input and to create a niche to satisfy both domestic and export demand for sugar and other sugarcane-related by-products such as biofuels, electricity, alcohol, fertiliser and sweets (Mbowa et al. 2023). Land under cane expanded from about 20,000 ha in 2005 to over 81,000 ha in 2020, leading to a rise in total sugar production from 1 million metric tonnes in 2000 to over 6 million metric tonnes in 2020 (FAO Stat 2022). Households rushing to convert land for cane were driven by lucrative market prices and observations of earlier outgrowers becoming wealthy from the activity (Mbowa et al. 2023). These households believed that sugarcane could improve growers' food security and wellbeing as a relatively high-return crop, generating increased farm income and more farm and non-farm employment (Hess et al. 2016). However, despite the Sugar Act 2010, the absence of regulation and competition among mills has influenced the age at which sugarcane is harvested and, consequently, a farmer's cash flow, which impacts their food security.

Having more mills does not necessarily mean having more jobs and, consequently, higher incomes for farmers. Farmers' gross income/ha has not increased proportionately despite an increase in land under cane and cane price due to a reduction in mean yield tc/ha (Mbowa et al. 2023). Specifically, a drop in mean yields of approximately 30 tonnes per hectare was registered in recent years, affecting overall production due to the cyclical nature of sugarcane production (Mbowa et al. 2023). This affected farmers' incomes and their ability to smooth consumption (Tesfaye and Tirivayi 2020). In the sugarcane-growing subregions, the severity of food insecurity was 33.7%, 23.9% and 20.3% in Busoga, Bunyoro and Buganda, respectively (UBOS 2024). However, the lingering question was whether sugarcane production, based on anecdotal claims, was the leading cause of food insecurity in the sugarcane-growing subregions.

Despite this interest, there are few empirical studies on the effects and impacts of sugarcane production on household food security. Where it exists, the evidence is mixed, driven mainly by the study area's geographical focus, methodological approach and sample size. For example, in Nigeria, Edafe et al. (2023) use logistic regression and find that households in communities without large-scale agricultural land investments have a 0.2 percentage-point higher likelihood of being more food-secure than households with land investments. Using descriptive statistics, findings indicate that crop diversification enhances food security and dietary diversity, particularly when production diversity is low (Appiah-Twumasi and Asale 2022; Mengistu et al. 2021; Douyon et al. 2022). In Zambia, a higher share of cane growers was food secure (79%) compared to non-cane growers (47%), and cane growers had better access to water facilities and electricity and higher incomes (Bubala et al. 2018). Martiniello and Azambuja (2019) find that sugarcane contract farming schemes are associated with increased food insecurity among rural households in Eastern Africa. However, Herrmann et al. (2018) find that sugarcane outgrowers earned significantly higher incomes and allocated more land to food crops compared to non-outgrowers in Malawi.

In Uganda, studies such as Mwavu et al. (2018) have found that sugarcane growing increases farm household income, which, in turn, could enhance food security through an income pathway. However, the authors also find that the commercialisation of sugarcane has had negative impacts on farmland for other food crops and on natural vegetation, thereby compromising household food security among smallholder sugarcane-growing households in the Jinja and Mayuge districts of the Busoga region. Relatedly, Lubaale (2022)'s study in Kamuli district, eastern Uganda, indicated a decrease in food crop production, leading to increased famine and poverty, due to the commercialisation of sugarcane and the cultivation of other non-food crops gaining greater attention in rural households. In Masindi District, mid-western Uganda, sugarcane-growing households cultivated more acreage of food, owned more assets and earned more income than non-sugarcane-growing households, resulting in better food security outcomes (Kaahwa et al. 2023; Nsimiire and Owoyesigyire 2023). Waibi (2019) finds that a Ugandan sugarcane farmer with less than 10 acres of land is more vulnerable to food insecurity. While Adams et al. (2019) reveal that contract farming in sugarcane production exacerbates gender inequality in access to land, household labour relations and participation in production and marketing decisions, ultimately impacting household food security, given women's important roles in agricultural production and domestic decisions around food sourcing and preparation.

The review here suggests that findings from prior studies are mixed, with no consensus. All the studies conducted regionally and in Uganda focus on a single measure of food security, with a scope limited to the local or sub-national level. Generalised evidence on the national-level impact of sugarcane on food security is scarce, and none exists in Uganda. Finally, the level of rigour is often limited to descriptive statistics and estimates of significance; some studies lack comparison groups and have small sample sizes (Lubaale 2022), making these findings less impactful for policy. This paper, therefore, fills this critical gap.

The objective of this paper is therefore to contribute to the evidence base by quantifying the generalised impacts of sugarcane cultivation on household food security, both in general and in Uganda in particular, using a nationally representative survey that covers the major sugarcane-growing subregions. The empirical strategy combines estimates from both the causal and impact models applied to count data. This implies that the impacts of sugarcane production on food security should not be underestimated, hence the need to contribute to this debate using multiple globally accepted food security indicators. The study is anchored on answering the following questions: (1) Is participation in sugarcane production associated with better food security outcomes? (2) How often were households experiencing food insecurity? (3) What is the impact of sugarcane growing on food security and the likely drivers?

In answering these questions, the study contributes to the limited body of empirical knowledge on sugarcane and food security. Hence, the study is crucial for devising national-level strategic and area-specific policies and interventions for sugarcane- and non-sugarcane-growing households within the same communities in Uganda.

2 | Methodology

This paper utilises primary data from Uganda's sugarcane-growing subregions, collected by the Economic Policy Research Centre (EPRC) as part of the Innovations Lab for Food Security Policy, Research, Capacity and Influence (PRCI) project.

2.1 | Description of the Study Areas

Uganda is located in Eastern Africa, crossing the Equator, with approximate coordinates from 4°12′N to 1°29′S latitude and from 29°34′E to 35°00′E longitude. Sugarcane in Uganda thrives in the fertile, loamy soils along the shores of Lake Victoria and in other regions with sufficient rainfall. It requires warm temperatures (16°C–32°C), adequate sunlight and high rainfall for optimal growth, and it flourishes within the tropical zone. It grows best in fertile, deep, well-drained and aerated soils, such as alluvial or black soils, with an ideal pH range of 6.5–8.5; however, it can tolerate a variety of soil types and pH levels. These conditions have led to sugarcane production in Uganda being dominated by three subregions—Buganda, Bunyoro and Busoga. These areas host the three historic mills with large nucleus farms. Newly established mills are beginning to set up their own farms but still rely heavily on outgrowers for inputs. This has resulted in significant land acquisitions, as mills aim to achieve self-sufficiency with less dependence on outgrowers. In all three subregions, sugarcane remains the primary cash crop cultivated by many smallholder farmers. The study focused on these regions for several reasons. First, they are the historic districts where sugarcane farming began and where the three largest nucleus farm estates are located. Secondly, these regions feature well-established large mills, recognised through various organised outgrower-miller arrangements and plans for major expansion. Third, these regions include households experiencing food insecurity, raising questions about whether sugarcane cultivation contributes to this situation. Figure 1 shows the distribution of sugarcane mills across Uganda, with a high concentration in Busoga (eastern region) and Buganda (central region), followed by Bunyoro (western region) (Ministry of Trade, Industry and cooperatives 2013).

While we did not ask farmers who are non-cane growers about their willingness to adopt alternative cash crops to sugarcane, anecdotal data shows that the three subregions had historic cash crops being grown, such as cotton in Busoga, coffee in Buganda and tea in Bunyoro, which farmers, over time, substituted for sugarcane in their gardens due to much quicker returns over a shorter period of time. Amid sugarcane woes, some farmers were returning to growing these cash crops, but even more so to cash-driven food crops, which vary across the three subregions. Maize, sweet potatoes and groundnuts are the main food crops cultivated in Busoga; maize and cooking bananas in Buganda and maize, beans, cassava and nuts in Bunyoro (UBOS 2021), whose choices are partly driven by tribal or cultural affiliations, beyond soil-suitability tests, which this study did not conduct. Regarding cropping patterns, all three subregions examined have bimodal rainfall; hence, two cropping seasons for non-cane-growing households, given their agro-ecological zones. This implies that they also have two crop harvesting seasons for their agricultural produce.

2.2 | Sample Selection and Data Collection

The study used a three-stage sampling design. In the first stage, 12 sub-counties were randomly selected from the 16 major sugarcane-growing districts of Buganda, Busoga,[1] and Bunyoro[2] subregions. From the selected sub-counties, 120 villages were randomly selected using probabilities proportional to size. In the second stage, a listing of farming households was conducted for all selected villages. During that time, information on a household's cane-growing status (cane and non-cane growers) and production arrangements (registered and aided, registered and unaided and unregistered and unaided growers) was collected. In the third stage, the listing and stratification were followed by the random selection of 20 households (15 sugarcane growers and 5 non-sugarcane growers) from each selected village. The survey used the latest 2014 Uganda Population and Housing Census sampling frame to select a representative sample of cane and non-cane-growing households from these subregions.

A cross-sectional survey was conducted, collecting data through face-to-face interviews using a semi-structured questionnaire developed in a CAPI-enabled data collection tool at the parcel, household and community levels. Within each subregion, data were gathered from households with access to at least one

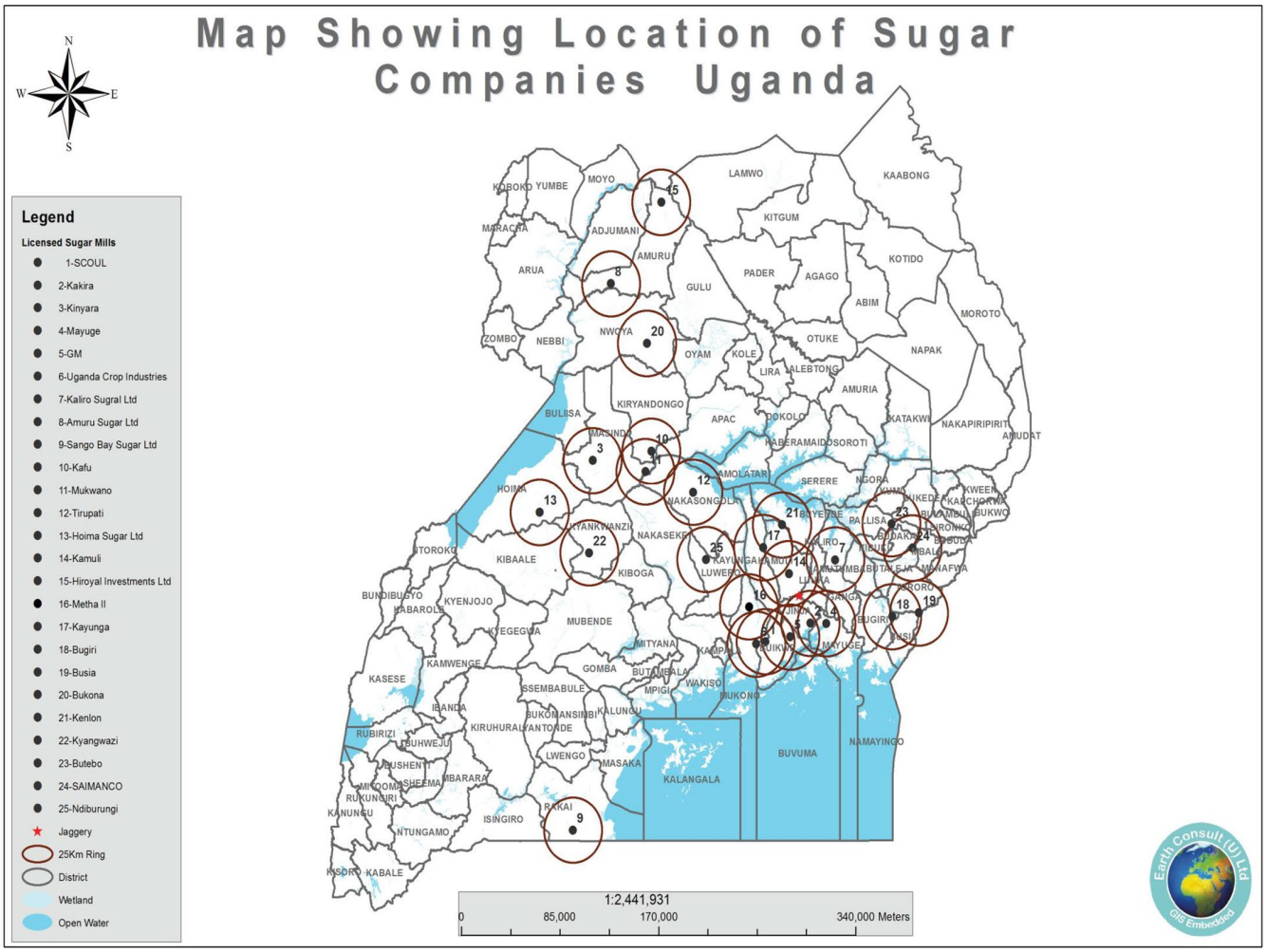

FIGURE 1 | Location of sugarcane mills in Uganda. The majority of the sugarcane mills are in the Buganda (central) and Busoga (eastern) subregions, followed by the Bunyoro (western) subregion. *Source:* Ministry of Trade, Industry and Cooperatives (2022). [Colour figure can be viewed at wileyonlinelibrary.com]

milling factory, as cane-growing farmers are almost always located near these mills because harvested sugarcane is highly perishable and has a low value-to-weight ratio. The information modules included household demographics, food security, land management, household assets, other crops cultivated, market access, shocks, community characteristics and food security indicators across three dimensions: Household Food Insecurity Access (HFIA), Months of Adequate Household Food Provisions (MAHFP) and Household Dietary Diversity Score (HDDS), which were collected from both cane and non-cane growers. A household was considered a sugarcane grower if any member had ever cultivated crystal cane and was still growing it at the time of the survey (November/December 2021). Conversely, a household was categorised as a non-cane grower if, at the time of the survey, they had ceased entirely growing cane or had never grown it. Questionnaires were administered to household heads or their spouses, as well as to adults aged 18 years and above.

Out of 2400 farmer households listed, 1800 were surveyed, and 1771 had complete household information from 72 communities, from which analysis was done. Note that analysis is at the household level unless otherwise stated. In addition, weights were applied to ensure that the data is nationally representative.

2.3 | Measuring Household Food Security

According to the endorsed definition by FAO, food security is defined as 'the state in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences, ensuring an active and healthy life'. This comprehensive definition encompasses four key dimensions: availability (ensuring an adequate food supply), accessibility (ensuring adequate resources and means to obtain food), utilisation (promoting nutritious and safe diets and access to clean water) and stability (maintaining consistent food security over time) (Shaw 2007). Given its multiconceptual nature, there is no consensus on indicators or variables that best represent food security. This paper employs three proxy indicators of food security: HFIAS, HDDS and MAHFP. These internationally recognised indicators and their recall period are summarised in Table 1.

2.4 | Conceptual and Analytical Frameworks

In the binary case, as shown in Figure 2, the programme/intervention is 1 if the household is a sugarcane grower and 0

TABLE 1 | Summary of food security indicators used in this study.

Indicator	Recall period	Description	Source
Household Food Insecurity Access Scale (HFIAS)	30 days/4 weeks/1 month	The HFIAS score is a continuous measure of the degree of food insecurity (access) in the household over the past 30 days. It also reflects the three universal domains of household food insecurity: insufficient quantity and insufficient quality of food supplies. This indicator captures the household's perception of their diet regardless of its nutritional composition. The HFIAS score ranges from 0 to 27 for the nine food insecurity-related conditions. At the household level, a high HFIAS score indicates that a household is highly food insecure, while a low score indicates that a household is less food insecure. HFIAS is also measured on a scale of 1–4. Where 1 = *Food secure*, 2 = *Mildly food insecure*, 3 = *Moderately food insecure* and 4 = *Severely food insecure*. The four food security categories were created sequentially, in the same order shown below, to ensure that households are classified according to their most severe response, as determined by the nine questions. HFIAS = *1* if [(Q1a = 0 or Q1a = 1) and Q2 = 0 and Q3 = 0 and Q4 = 0 and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0] HFIAS = 2 if [(Q1a = 2 or Q1a = 3 or Q2a = 1 or Q2a = 2 or Q2a = 3 or Q3a = 1 or Q4a = 1) and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0] HFIAS = 3 if [(Q3a = 2 or Q3a = 3 or Q4a = 2 or Q4a = 3 or Q5a = 1 or Q5a = 2 or Q6a = 1 or Q6a = 2) and Q7 = 0 and Q8 = 0 and Q9 = 0] HFIAS = 4 if [Q5a = 3 or Q6a = 3 or Q7a = 1 or Q7a = 2 or Q7a = 3 or Q8a = 1 or Q8a = 2 or Q8a = 3 or Q9a = 1 or Q9a = 2 or Q9a = 3]	Coates et al. (2007)
Household Dietary Diversity Score (HDDS)	24-h	HDDS is a measure of diet quality and quantity, capturing the number of food groups consumed in the last 24 h at either the household or individual level. It is calculated by summing the number of unique food groups consumed during the last 7 days. The value ranges from 0 to 12, where the lowest HDDS value indicates a higher level of food insecurity and vice versa. The HDDS denotes 12 food groups. These are: cereals, roots and tubers, vegetables with tubers, leafy vegetables, fruits, meat, poultry, eggs, fish, legumes/nuts/seeds, milk and milk products, oils and fats, sweets (sugar/honey), spices, condiments and beverages.	Swindale and Bilinsky (2006)
Months of Adequate Household Food Provisioning (MAHFP)	12 months	The MAHFP measures household food access and availability above the minimal level of the year. The indicator is the sum of the months of adequate provision.	Bilinsky and Swindale (2010)

otherwise. Other variables range from household institutional and locational factors such as the age of the household head, gender of the household head, marital status of the household head, education of the household head and spouse, household size, farm size, access to extension services, access to markets, wealth status, crop diversification, allocation of crop harvest proceeds, household non-farm income (wages and salaries), among others. The interactions of individual/household and community/institutional characteristics affect the household's food security status.

Analytically, various tools and techniques were employed to analyse the collected quantitative data. The first two questions were addressed through descriptive statistics with significance levels estimated, as is common in studies conducted in Uganda (Kaahwa et al. 2023; Waibi 2019; Nabalegwa et al. 2022). The

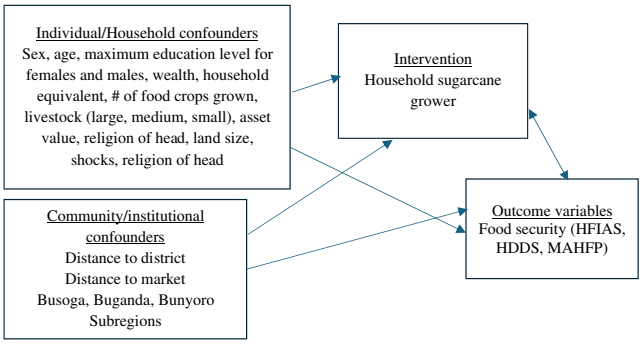

FIGURE 2 | Conceptual framework through which sugarcane growing affects food security. *Source:* Authors' own conceptualisation (2023). [Colour figure can be viewed at wileyonlinelibrary.com]

impact was assessed using different methods depending on whether the dependent variable, food security, was a count or categorical variable.

2.4.1 | Poisson Regression Model

In analysing the effect of sugarcane production on household food security, the study employed a Poisson regression model specification, given that the three food security outcome indicators—HFIAS, HDDS and MAHFP—are count variables. The model estimates the impact of these predictors on the expected count or rate of the event of interest. The Poisson regression model assumes equidispersion—that the mean and variance of the count variable are equal. However, if this assumption is violated and overdispersion occurs, Poisson estimates can be biased; however, alternative models, such as negative binomial regression, can be used. The Poisson model was selected based on the econometric validity of the results obtained with the negative binomial regression model, with an alpha of 0.971 and robust clustered standard errors of 0.1465, indicating that the specification was not significantly different from zero. This implies that a Poisson model produced a better fit for the data.

The Poisson model estimated is:

$$y_i = \beta_0 + \beta_1 Canegrow_1 + \beta_i X_i + u_i, \quad (1)$$

where y_i is the food security indicator, a count-dependent variable; β_0 is the intercept; β_1 coefficient for 1 if a household grows cane and 0 otherwise; β_i is a vector of unknown parameters to be estimated for the household i, X_i is a vector of other explanatory variables of the household i; u_i is a robust standard error term. Given that the results in Equation (1) may be subject to selection bias due to endogeneity in the treatment variable (sugarcane growing) and food security, we estimate an alternative Poisson model that accounts for endogeneity.

2.4.2 | Endogenous Treatment Effect Model for a Count Outcome—Poisson

For the count food security outcome indicator, following studies such as Hlatshwayo et al. (2023) for South Africa and Olutumise (2023) for Nigeria, we employ an endogenous treatment Poisson regression (ETPR) model (Greene 2002). The choice of ETPR over the endogenous switching regression model was made because the outcome is a count and the treatment (sugarcane growing or not) is binary, with the selection potentially correlated with unobserved factors that affect food security. Thus, distance to a mill (distmill) was used as an instrumental variable (Equation 2). This was first excluded in the estimation of Equation (1). The instrumental variable, distmill, is valid only if it influences the household's sugarcane-growing status but does not directly influence the state of household food security (the outcome variable).

$$canegrow_i^* = \gamma_i T_i + \omega_i distmill_i + \vartheta_i \text{ with } canegrow_i = \begin{cases} 1, if\ canegrow_i^* > 0 \\ 0\ otherwise \end{cases} \quad (2)$$

where $canegrow_i^*$ represents the household's sugarcane growing status, which is determined by the observed variable cane growing. That is $canegrow_i = 1$ if a farmer is growing sugarcane and $canegrow_i = 0$ otherwise. γ_i and ω_i are the parameters to be estimated for the exogenous explanatory variable T_i and instrumental variable $distmill_i$, respectively. T_i is a vector of explanatory variables that might influence the latent variable $canegrow_i^*$. ϑ_i is a random robust standard error term. For identification purposes, variable $distmill_i$ was included in the model because it is expected to affect the sugarcane-growing status of a farming household, but not its food security. Following Greene (2002), a Pearson correlation test was used to validate the instrument variable, $distmill_i$.

Furthermore, since the ETPR model is nested within a possible-outcomes model, we also estimate the average treatment effect (ATE) and the ATE on the treated (ATT). The prospective outcome model describes what each farm household might receive at each treatment level (sugarcane growing).

2.4.3 | Ordered Probit Regression Model

Specifically, for the HFIAS scale, we use the ordered probit model (Hyodo and Hasegawa 2021) to obtain the drivers of HFIAS. The ordered probit is the most widely used model for ordered response data (Muche and Tolossa 2022) and assumes a normally distributed error term.

Therefore, the empirical model for the analysis is specified as follows:

$$FS_{ij} = \alpha + \phi Canegrow_i + \beta W_i + \delta Z_i + \varepsilon_i \quad (3)$$

The dependent variable, FS is the household's food security indicator for household i with jth HFIAS scale, where ($j = 1, 2, 3$ and 4) represents the four categories of the dependent variable, that is, if the household falls within food *secure* = 1, *mildly food insecure* = 2, *moderately food insecure* = 3 and *severely food insecure* = 4 categories, $\alpha, \beta, \emptyset$ and δ are estimated parameters, W and Z are socioeconomic characteristics and institutional and location characteristics of the respective household expected to influence their food security status. ε_i is the robust standard error term.

TABLE 2 | Variable names, description and expected signs.

Variable	Description	Expected sign
HFIAS	Household Food Insecurity Access Scale	
HDDS	Household Dietary Diversity Score	
MAHFP	Months of Adequate Household Food Provisions	
Age of household head	Age of the respondent (years)	−
Sex of household head	Is the sex of the household head male = 1, 0 for female	+
Household adult equivalence	Family size of the household	+
Annual household non-agric income ('000)	Total non-agricultural income from wages, salaries and non-farm business in Uganda Shillings	+
HH total land size	Household total land size (acres)	+
HH total land under sugarcane land	Household sugarcane land size (acres)	+/−
Max female education level in the HH	Maximum education level of adult females in a household (years)	−
Max male education level in the HH	Maximum education level of adult males in a household (years)	−
Catholic	If household head is catholic, coded 1, 0 otherwise	+
Anglican	If household head is Anglican, coded 1, 0 otherwise	+
Other Christian	If household head is other Christian, coded 1, 0 otherwise	+
Muslim	If household head is Muslim, coded 1, 0 otherwise	+
Others (specify)	If household head is others (specify), coded 1, 0 otherwise	−
# of household assets	Total number of household assets	−
HH # large livestock	Total number of large livestock	−
HH # medium livestock	Total number of medium livestock	−
HH # small livestock	Total number of small livestock	−
# of household food crops	Number of diversified food crops grown	−
Buganda subregion	If household is Buganda coded 1, 0 otherwise	+/−
Busoga subregion	If household is Busoga coded 1, 0 otherwise	+/−
Bunyoro subregion	If household is Bunyoro coded 1, 0 otherwise	+/−
Distance from house to mill (km)	Distance of household from mill (km)	+/−
Distance to district (miles)	Distance of household from the district (km)	+/−
Distance to market (miles)	Distance of household from the market (km)	+/−
Household shock experiences		
Experienced at least one shock	If household has experienced at least one shock coded 1, 0 otherwise	+
Natural calamities (floods, droughts, landslides, hailstorms)	If household experienced natural calamities (floods, droughts, landslides, hailstorms), coded 1, 0 otherwise	+
Diseases and pests	If household experienced diseases and pests, coded 1, 0 otherwise	+
Income related	If household experienced income-related shocks, coded 1, 0 otherwise	+
Death	If household experienced a death coded 1, 0 otherwise	+
Other shocks	If household experienced other shocks, coded 1, 0 otherwise	+

Source: Author's construction based on theory 2025.

TABLE 3 | Descriptive statistics of the sample (means).

Select indicators	All (1)	Cane producers (2)	Non-cane Producers (3)	Mean diff, Columns (2–3) (4)	Diff (*p*) (5)
Panel (a): Food security indicators					
HDDS	6.22	6.60	5.97	0.63***	0.022
MAHFP	9.59	10.31	9.10	1.21***	0.000
HFIAS score	7.15	6.14	7.84	−1.70***	0.000
HFIAS scale					
Food secure	0.25	0.27	0.24	0.03	0.451
Mildly food insecure	0.10	0.09	0.10	−0.01	0.734
Moderately food insecure	0.39	0.43	0.36	0.07	0.384
Severely food insecure	0.26	0.21	0.30	−0.09***	0.000
Panel (b): Other select indicators					
Age of household head	48.23	48.63	47.96	0.67	0.244
Sex of head	0.79	0.86	0.75	0.11**	0.048
Household adult equivalence	4.99	5.40	4.70	0.70***	0.009
Annual household non-agric income ('000)	1045.14	1111.22	999.87	111.34	0.468
HH total land size in acres	7.68	14.83	2.77	12.06***	0.000
HH total sugarcane land in acres	6.89	7.42	1.98	5.44***	0.000
Max female education level in the HH	7.55	8.30	7.02	1.28***	0.000
Max male education level in the HH	8.56	8.90	8.30	0.60***	0.007
Religion of household head					
Catholic	0.25	0.21	0.27	−0.06**	0.042
Anglican	0.39	0.40	0.38	0.02	0.643
Other Christian	0.10	0.09	0.10	−0.01	0.682
Muslim	0.25	0.28	0.23	0.05**	0.040
Others (specify)	0.01	0.01	0.00	0.01	0.253
# of household assets	7.55	8.37	6.99	1.38***	0.000
HH # large livestock	0.34	0.36	0.33	0.03	0.345
HH # medium livestock	0.97	1.08	0.89	0.19*	0.051
HH # small livestock	0.81	0.88	0.76	0.12	0.238
# of household food crops	3.38	3.35	3.40	−0.05	0.668
Location-subregion of household					
Buganda	0.15	0.15	0.15	0.00	0.694
Busoga	0.74	0.71	0.76	−0.05	0.144
Bunyoro	0.11	0.13	0.09	0.04	0.114
Distance from house to mill (km)	22.96	23.51	19.64	3.87	0.162

(Continues)

TABLE 3 | (Continued)

Select indicators	All (1)	Cane producers (2)	Non-cane Producers (3)	Mean diff, Columns (2–3) (4)	Diff (p) (5)
Distance to district (miles)	11.03	10.78	11.21	−0.43	0.722
Distance to market (miles)	2.17	2.54	1.92	0.62	0.146
Experienced at least one shock	0.94	0.92	0.95	−0.03*	0.051
Experienced natural calamities (floods, droughts, landslides, hailstorms)	0.56	0.53	0.57	−0.04	0.129
Experienced diseases and pests	0.31	0.34	0.29	0.05*	0.06
Experienced income-related shocks	0.35	0.32	0.37	−0.05*	0.074
Experienced death	0.05	0.06	0.04	0.02	0.123
Experienced other shocks	0.25	0.29	0.21	0.08***	0.002
Observations (N)	1771	983	788		

Note: Annual household non-agric income = annual salary income + wage income. The non-cane grower households (Column 3) combine past-cane growers and never-grown-cane households.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.
Source: Author's own computations.

2.4.4 | Propensity Score Matching (PSM) and Inverse Probability Weighting (IPW) Models

Matching methods, such as PSM, offer more accurate and robust treatment effect estimates in observational studies where relevant pre-treatment information is scarce (Dehejia and Wahba 2002; Kebede et al. 2023). We follow similar studies; hence, PSM and the IPW average techniques were used to quantify the impact of sugarcane-growing intervention on household food security status. Evaluating a programme or intervention is always challenging when there is no baseline survey and when subjects receiving the treatment are assigned non-randomly. To reduce bias in the estimation of treatment effects, the technique of matching subjects who received the treatment (sugarcane growers) with those who did not (non-sugarcane growers) based on observable covariates was developed (Rosenbaum and Rubin 1983; Imbens and Wooldridge 2009).

During data transformation, the observable covariates in Table 1 were presented for both sugarcane- and non-sugarcane-growing households to estimate propensity scores and their inverse probabilities. Specifically, matching on propensity scores is a mechanism used to control bias in estimating treatment effects (impact) arising from confounding factors. Once propensity scores are established, the ATE on the affected households (ATT/impact) can be estimated for the large-scale farm. In this study, we employ various matching methods that utilise distinct techniques to match the two groups based on their propensity scores. We use the nearest neighbour matching (NN), radius matching (RR), kernel matching (KK) and mahalanobis matching methods. Measuring observable covariates for the pre-treatment period after the affected households experienced the effects of the interventions could be argued to increase bias. While this is generally a limitation of the PSM technique, in this study, some covariates, such as age, sex of the household head and subregions, are not easily changed by the intervention. The use of such covariates helps reduce the magnitude of the bias.

2.4.5 | Variable Definition

Table 2 presents the variable names, descriptions and the expected signs. The selected variables were first checked for multicollinearity and for their ability to provide the best fit. The models were then assessed for convergence after estimation.

3 | Results and Discussion

3.1 | Descriptive Analysis

Table 3 presents the summary descriptive statistics of households' food security status and the explanatory variables used in this study. The table displays the mean values for all variables, including those for households involved in sugarcane cultivation and those not, as well as the mean differences between the two groups and the corresponding p values (significance tests) indicating the significance of these differences. The results show that out of the 1771 households surveyed with complete information, 983 were sugarcane growers and 788 were non-sugarcane growers (Table 3). Other explanatory variables highlighted in Table 3, Panel (b) reveal that distribution across the three subregions (Buganda, Bunyoro and Busoga) showed no statistically significant difference between sugarcane and non-sugarcane households, suggesting their selection was random. The average age

of household heads was 48 years. About 9 out of 10 households among cane growers were male-headed compared to 7 out of 10 among non-cane growers, a difference significant at 5% ($p < 0.05$). The average household size was approximately five persons, with an average of four children per household. Significant mean differences indicate that cane-growing households had larger families compared to non-cane growers. Cane-growing households possessed significantly more land—nearly five times more than non-cane growers (Waibi 2019). Cane grower households (adult males and females) had higher levels of education; notably, the maximum education level for adult females (18 years and above) was 8.3 years among cane growers, versus 7.02 years for non-cane growers. Regarding household wealth, significant differences were observed in asset values and ownership of medium livestock units, favouring cane-growing households. Kaahwa et al. (2023) reported similar findings. Cane growers also experienced more crop pests, diseases and other shocks, but fewer income-related shocks, compared to non-cane growers; these differences were statistically significant at the 10% and 1% levels.

3.1.1 | Participation in Cane Production and Food Security Outcomes

Table 3, Panel (a), which presents food security indicators, shows that, overall, statistically significant differences (at 1%) are observed in favour of cane growers across all indicators. Specifically, the HDDS mean score for cane and non-cane growers is 6.6 and 5.97, respectively, on a scale of 0–12 food groups, with a mean difference of 0.63 ($p < 0.01$), indicating that households of cane growers had a more diversified diet than non-cane growers. The MAHFP indicates that cane grower households had, on average, 10.3 months of adequate food, while non-cane-grower households had 9.1 months, with a mean difference of 1.21 ($p < 0.01$). The HFIAS scores were 6.14 for cane and 7.84 for non-cane grower households, with a mean difference of −1.70 ($p < 0.01$), implying that food insecurity was statistically lower among cane growers. Using the HFIAS scale, about 27% of sampled cane-grower households were food secure. Similarly, the sampled households classified as mildly, moderately and severely food insecure represented about 9%, 43% and 21%, respectively, as measured by the HFIAS scale. In non-cane grower households, 24% were food secure, while 10%, 36% and 30% were mildly, moderately and severely food insecure, respectively. Nonetheless, there were no statistically significant mean differences between cane and non-cane growers in all food security status categories except for the severely food insecure group, where cane-grower households were less severely food insecure, and this difference was significant at 1%. These findings align with Kaahwa et al. (2023), who found that sugarcane growers were more food secure (32.3%) than non-sugarcane growers ($p < 0.05$), with corresponding mean HFIAS scores of 6.62 and 8.41, respectively, demonstrating that sugarcane households in the Masindi district in mid-western Uganda had better food security than their counterparts.

3.1.2 | Frequency of Household Food Insecurity Experiences

We use the HFIAS to assess self-reported food security experiences, which covers nine questions. Households were asked if any of the food security indicators occurred (*yes* = 1; *no* = 0) and if yes, 'how often the condition happened in the last 30 days?' where 1 = *Rarely* (1–2 times in the past 4 weeks), 2 = *Sometimes* (3–10 times in the past 4 weeks) and 3 = *Often* (more than 10 times in the past 4 weeks). Table 4 summarises the descriptive statistics for the surveyed households across the nine questions used to estimate the HFIAS indicator. The mean comparison test provided an overview of food insecurity occurrences and experiences between cane growers and non-cane growers. The mean occurrence values were higher for six of the nine food insecurity experiences in non-cane-growing households than in cane-growing households. Occurrences such as worrying about not having enough, members eating fewer meals, and a household member going to sleep at night because they did not have enough to eat were higher and statistically significant among non-cane growers than among cane growers (Table 4). Most households' responses to the frequency of these occurrences indicated that they occurred sometimes (3–10 times) in the 30 days preceding the survey. While Appiah-Twumasi and Asale (2022) employed a different food security indicator, the Food Insecurity Experiences Score (FIES), the findings of this study align with theirs, showing that crop diversity ensured household food security.

3.1.3 | Effect of Sugarcane Growing on Food Security and the Likely Drivers

While results are available upon request for other food security indicators (HDDS and MAHFP), here we present only the HFIAS score along with selected explanatory variables, including the treatment (sugarcane growing). Table 5 presents the marginal effects of the Poisson regression model estimates for Model 1, including interaction terms. The results show that participation in cane production is associated with a 1.219 reduction in household food insecurity, which is statistically significant ($p < 0.1$) (Table 5, Column 1). When interacting the binary cane production variable with selected variables (Columns 2–8), food insecurity significantly decreases upon including subregional interaction terms with cane-growing households and interaction with the sex of the household head at various levels. Other explanatory variables included are the sex of the household head; age of the head; log of the annual income earned from a salary; maximum adult female and male education; number of live small, medium and large animals; household asset value; subregion; primary source of household income from wages and salaries; religion; shocks such as crop pests and diseases, death of a household member, natural shocks and others; distance to districts and food markets and the number of food crops (Appiah-Twumasi and Asale 2022; Nabalegwa et al. 2022). The sex and age of the household head have statistically significant effects in reducing the HFIAS, even when interaction terms are included.

3.1.4 | Addressing Selection Bias Using the ETPR Model

In estimating model 2 (ETPR), the diagnostic tests show that the Log pseudolikelihood is −1700.6141 and Wald $\chi^2(21)$ is 411.99, with Prob > χ^2 = 0.0000, indicating that the ETPR regression provides a good model fit. Moreover, comparison tests reveal that

TABLE 4 | Descriptive statistics of HFIAS occurrence and frequency of related conditions (%).

		Occurrence 1, if yes				Frequency of occurrence in the last 30 days (%)					
		Canegrower	Non-cane grower		Mean diff	Cane grower			Non-cane grower		
Q1	Questions	Mean	Mean	Diff.	*t*-test	Rarely (1–2 times)	Sometimes (3–10 times)	Often (more than 10 times)	Rarely (1–2 times)	Sometimes (3–10 times)	Often (more than 10 times)
1	Did you worry that your household would not have enough food?	42.9	51.4	−8.5**	−2.71	24.0	42.26	33.8	29.1	55	15.9
2	Were you or any household member not able to eat the kind of foods you preferred because of a lack of resources?	62.7	68.8	−6.1	−1.45	21.4	38.5	40.1	23.7	56.3	20.1
3	Did you or any household member have to eat a limited variety of foods due to a lack of resources?	59.2	65.0	−5.8	−1.62	22.1	37.9	40	24.1	54.1	20.8
4	Did you or any household member have to eat some food that you really did not want to eat because of a lack of resources to obtain other types of food?	62.2	65.9	−3.7	−0.4	22.8	41.8	35.4	22.8	58.4	18.8
5	Did you or any other household member have to eat a smaller meal than you felt you needed because there was not enough food?	37.8	41.0	−3.3	−0.98	21.8	46.5	31.8	31.7	51.6	16.7
6	Did you or any household member have to eat fewer meals in a day because there was not enough food?	30.2	37.6	−7.4*	−1.86	19.3	46.4	34.3	24.9	55.9	19.1
7	Was there ever no food to eat of any kind in your household because of a lack of resources to get food?	13.2	20.1	−6.8	1.151	25.2	61.0	13.8	34.9	57.5	7.6

(Continues)

TABLE 4 | (Continued)

Q1	Questions	Occurrence 1, if yes			Mean diff	Frequency of occurrence in the last 30 days (%)					
		Canegrower	Non-cane grower			Cane grower			Non-cane grower		
		Mean	Mean	Diff.	*t*-test	Rarely (1–2 times)	Sometimes (3–10 times)	Often (more than 10 times)	Rarely (1–2 times)	Sometimes (3–10 times)	Often (more than 10 times)
8	Did you or any household member go to sleep at night hungry because there was not enough food?	10.8	16.0	−5.2***	−3.43	22.3	59.6	18.1	53.3	41.5	5.2
9	Did you or any household member go a whole day and night without eating anything because there was not enough food to eat?	4.4	3.9	0.5	−0.42	33.8	52.7	13.5	63.7	33.3	3.0

*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.
Source: Authors computations using EPRC-PRCI Sugarcane survey dataset 2021.

the Wald test of independence of equations indicates the equality of parameters between the treatment status (Wald test of independence of equations ($\rho = 0$): $\chi^2(1) = 0.40$, Prob > $\chi^2 = 0.5276$) with estimated a*thrho* (ρ) = 0.1061 is not statistically significant. The results, therefore, suggest that there is no sample selection bias and that the standard Poisson model specification would produce unbiased estimates. The estimation results of the treatment effects were:

	Coefficient	SE	*z*	$p > \|z\|$
ATE	−2.3272	2.3145	−1.0055	
ATET/ATT	−2.3053	2.3677	−0.97	0.33

*, ** and *** denote statistical significance at the 1%, 5% and 10% levels, respectively.

The ATE and ATT estimates are not statistically significant; therefore, they are less informative than the Poisson estimate. This suggests that the distance to the mill (instrument) has weak effects on household food security for both cane and non-cane growers.

3.1.5 | Determinants of Food Security

In estimating Model 3, the ordered probit model results for the drivers of food security using the HFIAS scale are presented in Table 6. The categories were significant ($p < 0.001$) (Table 6). The threshold value indicates the food insecurity categories $\mu_1\mu_2\mu_3$ (cut1, cut2 and cut3) are ranked in an ordered manner. The predicted probabilities of $Y = 1$ or the marginal effects were estimated to measure changes in the likelihood of a food insecurity (access) outcome for a one-unit change in an explanatory variable. The marginal effects of the respective models are presented in Columns (2–5) and are discussed since the coefficients of the ordered probit model (Column 1) do not show the magnitude of the effect of the independent variables (HFIAS).[3]

According to Table 6, sugarcane-growing households were more likely to be classified as food-secure or mildly food-insecure. At the same time, they were less likely to be categorised as moderately or severely food-insecure. While the household food security scales for cane-growing households exhibit the expected signs, these signs are not statistically significant at the $p < 0.10$ level. Results further show that households headed by older adults were more likely to be in the food-secure and mildly food-insecure categories but less likely to be in the moderately and severely food-insecure categories. This is possible when the household age of the head is associated with more experience and wealth. Households in Busoga and Bunyoro were less likely to be food secure and mildly food insecure; however, they were more likely to be in the moderately and severely food insecure categories compared to those in the Buganda subregion. Household equivalent (size) indicates that an additional member makes a household more likely to fall into the severely and moderately food-insecure categories, but less likely to fall into the food-secure and mildly food-insecure categories. This is consistent with most studies, which also find that an additional member increases resource demand and caloric requirements for the

TABLE 5 | Model 1—Poisson correlations of sugarcane growing effects on food security.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***	***dy/dx***
HH cane_grower (1 if yes)	−1.219*	−1.792+	−0.796	−1.047	−1.466	−1.135+	−1.542*	−1.225+
	(0.0476)	(0.0784)	(0.509)	(0.142)	(0.133)	(0.0843)	(0.0202)	(0.0678)
Sex of household head (1 is male)	−1.489*	−1.677+	−1.491*	−1.496*	−1.502*	−1.487*	−1.476*	−1.491*
	(0.0376)	(0.0545)	(0.0376)	(0.0369)	(0.0345)	(0.0381)	(0.0396)	(0.0377)
Age of household head (years)	−0.0401+	−0.0413+	−0.0396+	−0.0398+	−0.0406+	−0.0399+	−0.0397+	−0.0401+
	(0.0852)	(0.0737)	(0.0907)	(0.0880)	(0.0860)	(0.0868)	(0.0898)	(0.0855)
Interaction terms								
hhcane × hhsex		0.730						
		(0.536)						
hhcane × landsize			−0.137					
			(0.649)					
hhcane × dist to district				−0.0751				
				(0.453)				
hhcane × dist to market					0.0227			
					(0.678)			
hhcane × Buganda subregion						−0.919		
						(0.460)		
hhcane × Busoga subregion							0.409	
							(0.644)	
hhcane × Bunyoro subregion								0.0511
								(0.955)
Other explanatory variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1769	1769	1769	1769	1769	1769	1769	1769

Note: Robust standard errors in parentheses. $p+=0.1$.
*$p<0.1$.
Source: Author's computations using EPRC-PRCI Sugarcane survey dataset 2021.

extra member relative to the already available resources in the household (Kirimi et al. 2013).

Households growing more than one variety of food crops (Tesfaye and Tirivayi 2020), owning highly valued household assets, earning a salary from a non-agricultural source (Mengistu et al. 2021), and having highly educated adult females are more likely to be food secure and moderately food secure and less likely to fall in the moderately and severely food insecure categories. Maximum adult female education attainment highlights the critical importance of educated adult females in the home, as they are also likely to work and earn income to supplement household food needs (Adams et al. 2019). The household value of assets highlights the critical importance of possessing the right assets (Table 6). The assets might be few but highly valued, and their sale fetches more resources to smooth food consumption needs for longer than those of less valued assets. households practising other non-mainstream religions (traditionalists in comparison to being a Catholic), experiencing crop pests and diseases, death of a household member and distance to the district are more likely to be categorised in the severely food insecure category and less likely to be in the food secure and mildly food insecure categories. This implies that, for example, an additional mile a household travels to the district makes them more likely to be severely food-insecure. The farther the district is from a household, the more difficult it becomes to obtain the requisite information, access food and secure better-paying jobs off the farm (Nabalegwa et al. 2022).

TABLE 6 | Determinants of HFIAS (marginal effects)—Ordered Probit Model.

	(1)		(2)		(3)		(4)		(5)	
			Food secure		Mildly food insecure		Moderately food insecure		Severely food insecure	
Variables	**Oprobit coeff.**	**SE**	***Y*=1**	**SE**	***Y*=2**	**SE**	***Y*=3**	**SE**	***Y*=4**	**SE**
HH cane grower (1 if yes)	−0.0362	(0.121)	0.0106	(0.0350)	0.00153	(0.00516)	−0.00215	(0.00696)	−0.0108	(0.0362)
Sex of household head (1 if male)	−0.280	(0.176)	0.0816	(0.0524)	0.0119	(0.00740)	−0.0163	(0.0130)	−0.0841	(0.0529)
Age of household head (yrs)	−0.0105**	(0.00456)	0.00305**	(0.00131)	0.000444**	(0.000215)	−0.000609*	(0.000358)	−0.00315**	(0.00139)
Subregion (Base = Buganda)										
Busoga	0.508***	(0.137)	−0.167***	(0.0452)	−0.0162***	(0.00600)	0.0628***	(0.0219)	0.130***	(0.0338)
Bunyoyo	0.570***	(0.160)	−0.184***	(0.0498)	−0.0193***	(0.00729)	0.0639***	(0.0217)	0.150***	(0.0445)
Household equivalent (size)	0.114***	(0.0232)	−0.0332***	(0.00741)	−0.00482***	(0.00122)	0.00662**	(0.00333)	0.0342***	(0.00705)
Log of annual income-salary	−0.0330**	(0.0136)	0.00963**	(0.00394)	0.00140**	(0.000666)	−0.00192*	(0.00115)	−0.00992**	(0.00410)
Log of annual income-wage	0.00707	(0.0111)	−0.00206	(0.00320)	−0.000299	(0.000486)	0.000411	(0.000669)	0.00212	(0.00333)
Maximum adult female education	−0.0429***	(0.0150)	0.0125***	(0.00438)	0.00182**	(0.000738)	−0.00249*	(0.00144)	−0.0129***	(0.00448)
Maximum adult male education	−0.0170	(0.0167)	0.00495	(0.00484)	0.000720	(0.000750)	−0.000987	(0.00104)	−0.00510	(0.00505)
Religion of head (base = Catholic)										
Anglican	−0.133	(0.162)	0.0394	(0.0476)	0.00559	(0.00705)	−0.00867	(0.0105)	−0.0395	(0.0488)
Other Christian	−0.0125	(0.231)	0.00352	(0.0652)	0.000562	(0.0104)	−0.000517	(0.00977)	−0.00387	(0.0715)
Muslim	−0.0163	(0.190)	0.00459	(0.0536)	0.000730	(0.00854)	−0.000685	(0.00802)	−0.00503	(0.0588)
Other	1.176**	(0.483)	−0.178***	(0.0463)	−0.0619***	(0.0233)	−0.182	(0.122)	0.441***	(0.171)

(Continues)

TABLE 6 | (Continued)

	(1)		(2)		(3)		(4)		(5)	
			Food secure		Mildly food insecure		Moderately food insecure		Severely food insecure	
Variables	**Oprobit coeff.**	**SE**	***Y*=1**	**SE**	***Y*=2**	**SE**	***Y*=3**	**SE**	***Y*=4**	**SE**
HH shock experiences										
Natural shocks (floods, drought, landslides)	0.144	(0.138)	−0.0421	(0.0413)	−0.00597	(0.00567)	0.00877	(0.0104)	0.0429	(0.0403)
Crop pests and diseases	0.414***	(0.132)	−0.113***	(0.0358)	−0.0192***	(0.00729)	0.0110	(0.0106)	0.131***	(0.0454)
Death of HH member	0.412**	(0.171)	−0.102***	(0.0368)	−0.0206**	(0.0100)	−0.00686	(0.0170)	0.139**	(0.0626)
Other	0.129	(0.153)	−0.0365	(0.0419)	−0.00569	(0.00724)	0.00580	(0.00597)	0.0395	(0.0480)
hh livestock ownership (#)										
# live large animals	−0.134	(0.116)	0.0391	(0.0335)	0.00569	(0.00517)	−0.00780	(0.00725)	−0.0403	(0.0350)
# live medium animals	−0.0816	(0.0646)	0.0238	(0.0190)	0.00346	(0.00277)	−0.00474	(0.00433)	−0.0245	(0.0195)
# live small animals	0.00153	(0.0551)	−0.000445	(0.0160)	−6.47e-05	(0.00233)	8.87e-05	(0.00320)	0.000459	(0.0165)
Log of household asset value	−0.137***	(0.0293)	0.0400***	(0.00925)	0.00582***	(0.00134)	−0.00798**	(0.00384)	−0.0413***	(0.00905)
Distance to district (miles)	0.0152**	(0.00746)	−0.00443**	(0.00218)	−0.000644*	(0.000339)	0.000883	(0.000557)	0.00457**	(0.00227)
Distance to market (miles)	−0.00557	(0.00987)	0.00162	(0.00284)	0.000236	(0.000428)	−0.000324	(0.000542)	−0.00167	(0.00299)
# of food crops grown	−0.109***	(0.0386)	0.0318***	(0.0112)	0.00463**	(0.00185)	−0.00635*	(0.00353)	−0.0328***	(0.0117)
/cut1	−2.816***	(0.508)								
/cut2	−2.487***	(0.514)								
/cut3	−1.270**	(0.505)								
Observations	1771		1771		1771		1771		1771	

Note: Robust standard errors in parentheses.
*$p<0.1$.
**$p<0.05$.
***$p<0.01$.
Source: Author's computations using the EPRC-PRCI Sugarcane survey dataset 2021.

3.1.6 | Impact of Sugarcane Growing on Food Security

Table 7 presents detailed results from various matching techniques used to assess the impact of sugarcane production on the three food security measures. The analysis is adjusted using all explanatory variables included in the Poisson regression model.

Using the NNMatch and IPW matching methods, the average treatment effect on the treated (ATT) of cane production on HDDS is statistically significant and unexpectedly negative. This implies that growing cane is associated with a −0.33-point reduction in HDDS for cane growers, though this is only about a 4% reduction (Table 7, Column 2). Likewise, the PSM (1:1) matching method finds a statistically significant and negative association between growing cane and HDDS for both growers and non-growers (ATE), though the magnitude is relatively small. The ATC (average treatment of the untreated) for the HFIAS of non-cane growers indicates that if they were to grow cane, their food insecurity would be reduced by −0.8, and their months of adequate food provision would increase by 0.4 months. This aligns with Nabalegwa et al. (2022), who found that sugarcane farming households were more food-secure in Uganda.

The Mahalanobis-distance kernel matching, NNMatch and PSM (1:1) estimators all find a statistically significant and positive association of cane growing with a 0.4 increase in the MAHFP. That means that if a non-cane grower were to decide to grow cane, these matching methods estimate that their food insecurity would fall (HFIAS) slightly, and their months of food provision would increase by nearly half a month. None of the impact measurements using the PSM-kernel matching approach were statistically significant. This is likely because the PSM balances confounding variables and could have revealed additional hidden effects, but it does not undermine the appropriateness of the Poisson model for estimating this.

While the latter results above suggest that cane production could benefit farmers that currently do not grow cane, the matching results need to be taken with caution, as the key assumption underlying matching methods is that after controlling for explanatory variables that are observed, there are no known factors that are unobserved—that is, not included as an explanatory variable—that are expected to affect household food security, yet may also be correlated with cane production. If that is the case, then impact estimates from matching approaches can be biased; however, this has been tested using ETPR and the result is not significant.

Graphical diagnostics assisted our observation of the distribution of propensity scores between treatment and control groups using kernel density plots, cumulative density plots, and a box-and-whisker plot. The graphical representation of some of our matching model techniques illustrates how matching successfully reduces bias between the treated and untreated groups (Figures 3 and 4). Figure 4 demonstrates that the difference in the means of the propensity scores between the two groups was small, with the means less than half a standard deviation apart. Likewise, the covariate distributions in both groups are nearly symmetric in the matched sample, and their variances are nearly equal.

TABLE 7 | Impact of sugarcane growing on HFIAS, HDDS and MAHFP.

Impact estimation methods	PSM (Mahalanobis-distance kernel)			PSM (NNMatch)			IPW			PSM (1:1)			PSM-Kernel		
	(1) hfias	(2) hdds	(3) mahfp	(1) hfias	(2) hdds	(3) mahfp	(1) hfias	(2) hdds	(3) mahfp	(1) hfias	(2) hdds	(3) mahfp	(1) hfias	(2) hdds	(3) mahfp
ATE	0.275	−0.0279	0.00437	0.914	−0.281	−0.189	−0.173	−0.206*	0.000146	−0.324	−0.268*	0.122	−0.180	−0.113	0.0355
	(0.557)	(0.177)	(0.240)	(0.725)	(0.211)	(0.277)	(0.302)	(0.117)	(0.130)	(0.501)	(0.152)	(0.181)	(0.417)	(0.133)	(0.163)
ATT	1.148	−0.198	−0.340	2.138	−0.632*	−0.659	−0.174	−0.333**	−0.173	−0.405	−0.202	−0.103	−0.291	−0.126	−0.137
	(0.875)	(0.272)	(0.392)	(1.311)	(0.341)	(0.498)	(0.351)	(0.150)	(0.139)	(0.783)	(0.222)	(0.283)	(0.634)	(0.206)	(0.197)
ATC	−0.836**	0.189	0.443***	−0.618	0.158	0.400**	−0.173	−0.0461	0.216	−0.223	−0.350*	0.402*	−0.0421	−0.0980	0.250
	(0.355)	(0.119)	(0.147)	(0.511)	(0.152)	(0.193)	(0.381)	(0.129)	(0.171)	(0.498)	(0.208)	(0.225)	(0.375)	(0.117)	(0.218)
Observations	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766	1766

Note: Standard errors in parentheses. Mahalanobis-distance kernel matching with post-matching regression adjustment, NNMatch-Mahalanobis with Nearest-Neighbour Matching (1:1) with replacement and post-matching regression adjustment.
Abbreviations: ATC, average treatment effect on the untreated; ATE, average treatment effect; ATT, average treatment effect on the treated; IPW, inverse probability weighting with regression adjustment; PSM, kernel matching with regression adjustment; PSM, nearest neighbour matching (1:1) with regression adjustment.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.
Source: Author's computations using EPRC-PRCI Sugarcane survey dataset 2021.

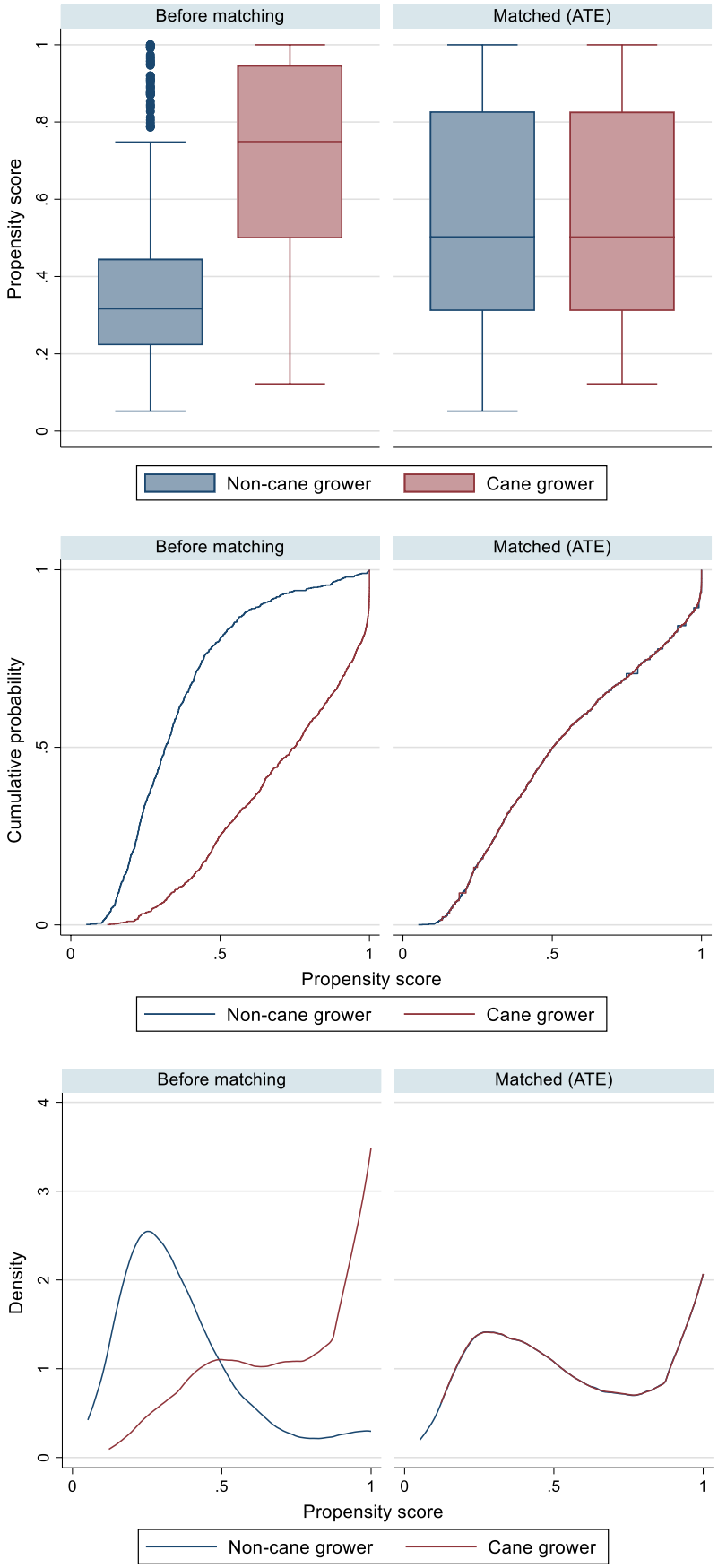

FIGURE 3 | Distance matching. [Colour figure can be viewed at wileyonlinelibrary.com]

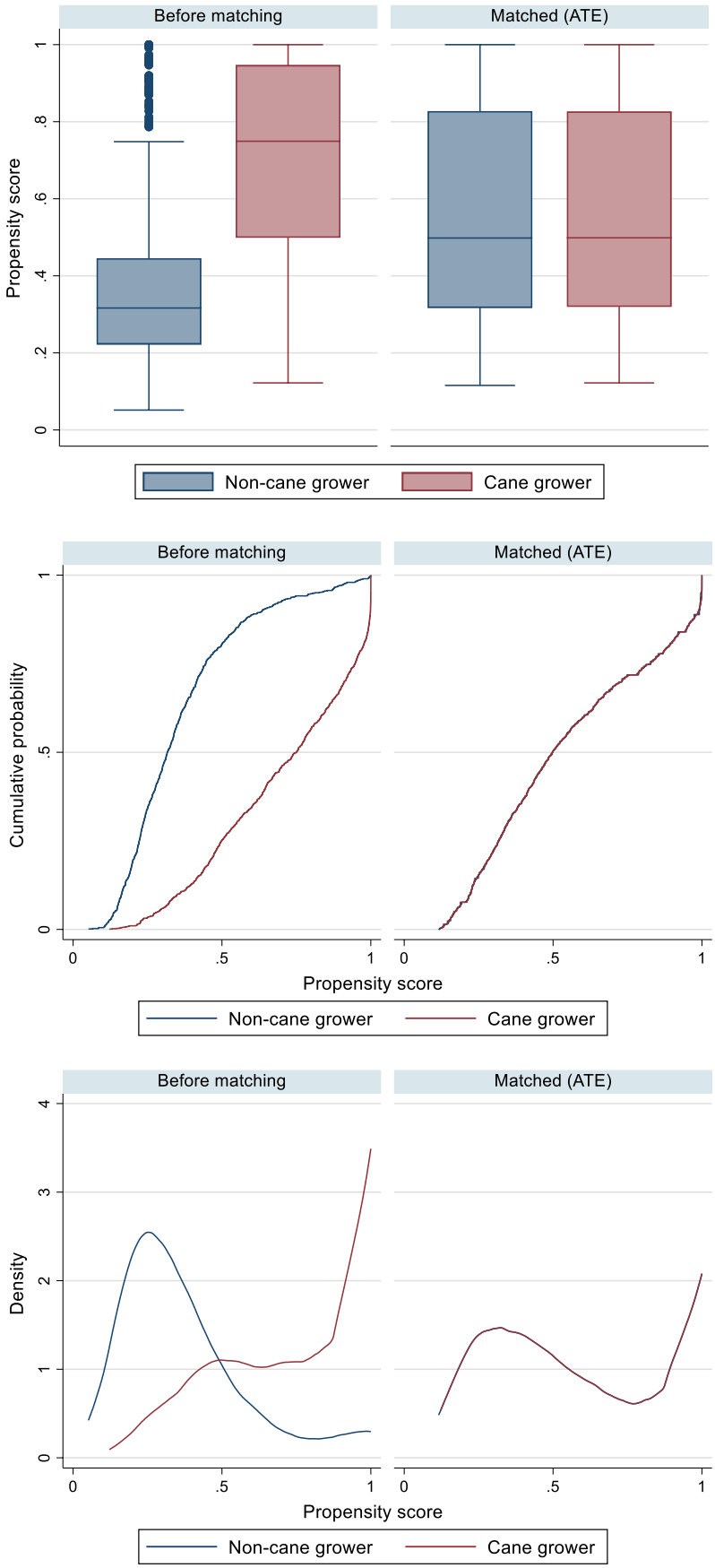

FIGURE 4 | One-to-one nearest neighbour. [Colour figure can be viewed at wileyonlinelibrary.com]

4 | Conclusions and Policy Recommendations

Ensuring food security remains a key concern in Uganda. Sugarcane growing has been central to this debate across all sugarcane-growing subregions of the country. The direct and indirect effects of sugarcane farming on food security have been studied, particularly its ability to generate employment and boost household incomes, enabling households to purchase food from the market and smooth consumption needs. This has led many smaller farm households to convert their arable land from food production to cash crops—particularly sugarcane. This study, therefore, analyses the impacts of small- and large-scale sugarcane outgrower farming households on food security in Uganda, along with their drivers, using a cross-sectional data sample of 1771 farming households. The study employs several impact estimation models to provide insights into this. First-level descriptive analysis reveals that the mean differences in all food security indicators—HFIAS, HDDS and MAHFP—were statistically significant at the 1% level. For instance, cane growers had an HFIAS score of 6.14, while non-cane growers scored 7.84; this difference was statistically significant at the 1% level, suggesting that sugarcane cultivation improved their food security status. The severity of food insecurity was also statistically more significant among non-cane growers (30%) compared to cane growers (21%) at $p < 0.000$.

Analysis shows that using different approaches adds rigour to the results. We find that households engaged in sugarcane production are more likely to be food secure than households not growing sugarcane. This is supported by positive and significant results using the Poisson model, as well as positive but not statistically significant results from the ordered probit model. Additionally, the PSM Mahalanobis matching method indicates a positive impact on the ATE. Specifically, the ATC (average treatment on the control/untreated) for the HFIAS among non-cane growers suggests that if they were to grow cane, their food insecurity would decrease by −0.8 and their MAHFP would increase by 0.4 months. As estimated by the ordered probit and Poisson models, key factors influencing some of the observed findings include the age of the household head, diversity in the number of food crops grown, land size, household size as proxied by the household adult equivalence, ownership of household assets, number of medium animals owned and the highest education level achieved by an adult female. The study, therefore, reaffirms that, when well-managed, sugarcane growing can improve a farming household's food security, as it provides additional income that can be used to purchase food from the market beyond their own production. However, it is essential to recognise that a farmer may still experience food insecurity even when growing sugarcane due to other significant confounders, such as less diversified sources of income, limited high-value household assets, increasing age, reliance on food markets and the age of the household head, among others. Therefore, policies related to sugarcane should ensure that farmers receive their income from selling cane on time and offer predictable prices, enabling better livelihood planning, especially to guarantee a sustained food supply for households. Additionally, programmes that promote female education should be encouraged, as an educated adult female has a positive impact on fostering household food security. Given that land size plays a crucial role in food security, the agricultural policy should enforce what is already in the law, that at least three-quarters of the land owned must be left under food crops.

One of the main limitations to note is that the survey was conducted between November and December 2021, a period during which millers offered some of the lowest sugar prices. Additionally, outgrower farmers had large fields of unharvested cane due to huge bumper harvests from nucleus farms; many institutional arrangements between millers and outgrowers had deteriorated. While the findings from this study can be used to make strong policy recommendations for Uganda as a whole, further research should be conducted when farmer–miller relations are amicable, following the revision of the Sugar Act 2010, in 2024, to gain additional insights into the impact of sugarcane cultivation on food security at the national level.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

[1] Busoga sub-region districts include: Bugiri, Namutumba, Buyende, Iganga, Jinja, Kaliro, Kamuli, Luuka, Mayuge, Namayingo, Bugweri and Jinja City.

[2] Bunyoro sub-region districts include: Buliisa, Hoima, Kibaale, Kiryandongo, Masindi, Kikuube, Hoima City and KItagwenda.

[3] The interpretation of the marginal effects is based solely on the sign of the food security category. A negative sign of any category would mean an increase in that variable, decreasing the probability of being in that food security category. In contrast, a category's positive coefficients mean an increase in that variable will increase the likelihood of being in that food security category.

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