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Who profits from agroecology to secure food and nutrition? On access of women to markets and assets

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In contrast to a large body of literature linking agroecology to food security through sustainable agronomic practices, research on how agroecology enhances smallholder farmers' access to productive resources, yet necessary for food security and nutrition, is sparse in Africa. Literature does not consider the fact that agroecology practices are often adopted *via* entering a group that provides corresponding knowledge, network and possibly markets. We investigate the case of an agroecology group operating parallel to the dominant agri-industrial food system in Southeast Nigeria. We ask: who are the agroecology farmers? Do they improve their food status in comparison to conventional smallholders operating in the commodity oriented agro-industrial system? Who appears to benefit most among agroecology farmers? To provide answers to these questions, we collected data from 334 smallholder farmers (comprising 111 agroecology farmers and 223 non-agroecology farmers) through a stratified cluster sampling process. Descriptive statistics of our data showed that women make up 89% of the agroecology farmers in the group. We found that in both the agroecology and the conventional groups, women farmers had little access to land, even lower ownership of land, little exposure to extension services, and no access to financial credits. Thus, the sample of female farmers we addressed consists of marginal persons who operate at the margins of the capital and input-based networks and agricultural production. In contrast to the expectation of conventional hypotheses, we show that on average, agroecology farmers had lower food insecurity experiences and higher observed dietary diversity scores. Exploring more detail within the agroecology group via a quantile semi-parametric propensity score matching, we further show that women left out of conventional extension services benefit more from being in the agroecology group. Similarly, the increase in food security and nutrition was highest among those farmers who balance self-provisioning and market as food sources compared to strategies pursued mainly by one of these two sources. To these farmers, mostly women, the agroecology group provides alternative to access important resources and knowledge that they ordinarily would not have accessed being in the capitalistic food system, and which enables them to reach their nutrition goals. Our study supports a conceptualization of agroecology as an interdependency between agroecological agronomic practices, reciprocity and autonomy-fostering social innovations.

KEYWORDS

agroecology, food security, agency, sustainability, social reproduction

1. Introduction

Agroecology (AE) has been portrayed as a practice and as a farm-social movement aimed at promoting sustainability, human well-being, and social cohesion among agrarian communities (Wezel and Jauneau, 2011). In contrast to the large body of literature linking agroecology to food security and nutrition through sustainable agronomic practices (Altieri et al., 2012; Kangmennaang et al., 2017; Khadse and Rosset, 2017), research on how agroecology enhances smallholder farmers' access to productive resources necessary for food security and nutrition is sparse in Africa. In this paper, we estimate the effect of agroecology (as a farm-social group) on the food security and nutrition of smallholder farmers. We argue that agroecological agronomic practices, just like any sustainable farming practices, on its own, might not be sufficient in "feeding the world," but that social and political structures matter. They include self-help activities organized in agroecology groups and which are coupled with agroecological practices. These are critical in achieving food security among the rural population who are marginalized from the dominant corporate food system. Our conceptualization of agroecology differs from other work in which sustainable farming practices are the dominant concept. We take a socio-ecological and political science perspective (De Schutter, 2010).

1.1. Agroecology and Food Security and Nutrition (FSN)

In many rural and agrarian communities in developing nations, households depend on farming as their main source of livelihood (Onyenekwe et al., 2023). Also, it is usually the women who are in charge of ensuring that the family is fed (Opata et al., 2020a). They are the major land managers, farmers, and food producers (Okpara et al., 2019), though access to land and titles are largely held by men. Recent studies, therefore, point to the fact that efforts in mainstreaming sustainable farming practices will provide food and nutrition benefits based on institutional change (Kassie et al., 2020). Such efforts need to provide empowerment, especially for women who are often marginalized in terms of lack of access to markets and other production assets. For example, Kassie et al. (2020) investigated how women's empowerment boosts the gains in nutrition from push-and-pull technology adoption among women farmers in rural Kenya. Their result showed that technology adoption and empowerment interventions are more impactful together if, for instance, aspects such as access to land are included in technology diffusion policies. This position suggests that social relations of production and structural transformation need to be taken into cognizance when analyzing the effect of sustainable farm-social movements practicing agroecology. This is necessary because such sustainable farm-social movements provide additional far-reaching social and economic benefits beyond the environmental benefits derived from the adoption of agroecological practices, especially to farmers who might not easily access land.

Several studies attempt to investigate the relationship between agroecology as a sustainable farming method and food security and nutrition looking for causes. However, these studies have produced mixed results, which may be influenced by the definition of agroecology adopted (as a practice or a social innovation) (Wezel et al., 2014; Nyantakyi-Frimpong et al., 2017; Bezner Kerr et al., 2019c; Guzmán Luna et al., 2022; Sintim et al., 2022). For example, a study conducted by Pretty et al. (2003) investigated 200 farm projects comprising 8 million farmers cultivating 28 million ha of land. They concluded that agroecology farming practices have a positive impact on the nutrition and food security of the farmers involved. Conversely, study by Rogé et al. (2017) showed that there was no difference between agroecology and non-agroecology farmers in terms of farm productivity. Mugwanya (2019) on the other hand concluded that there is a danger that agroecology can lock farmers into a poverty trap and non-productive traditional agriculture if social aspects are neglected. In contrast to the large literature linking agroecological practice to food security and nutrition through sustainable production practices (Altieri et al., 2012; Kangmennaang et al., 2017; Khadse and Rosset, 2017) associated with agroecology, research on how agroecology boost economic and political agency for food security and nutrition among smallholder farmers is sparse in Africa (Ume et al., 2022). The majority of literature on agroecology in Africa associates agroecology with agronomic practices at the farm level. A literature review (Ume et al., 2022) found only two studies highlighting the role of agroecology in strengthening the political and social agency of farmers (Nyantakyi-Frimpong et al., 2017; Bezner Kerr et al., 2019a). Specifically, Bezner Kerr et al. (2019a) investigated a 17 years group of smallholder farm households that practice agroecology (as practice and social formation) in northern Malawi and showed that agroecology as a tool in enhancing food security among smallholder farmers. Similarly, Nyantakyi-Frimpong et al. (2017) investigated the role of agroecology in improving food security among vulnerable farming households (households with women living with HIV and AIDS) in Malawi and reported that by forming a participatory agroecology group, these vulnerable women were able to engage in self-help activities which were instrumental in promoting their food and nutrition security status.

1.2. Objectives of the study

Using the case of an agroecology group which was initiated by a team from the Nigerian Agricultural Extension and Research Liaison Services (NAERLS) (Emeana et al., 2018) the study asks: who are the agroecology farmers? Do they improve their food status in comparison to conventional smallholders operating in the market-based agro-industrial system? Who appears to benefit most among agroecology farmers? Is agroecology a trap or a safety net?

This study adds to the current knowledge in three main ways. While the link between agroecology and improved food security and nutrition has been explored empirically as a social innovation, results do not permit to conclude on the benefits of agroecology. Often, agroecological practices have been assessed independently from the social context (often agroecological networks or groups) in which they are implemented (or not) (Ume et al., 2022). In this paper, we adopt the position that agroecological practices are adopted in a group of farmers and are inextricable to this social reality. Thus, their impact must be analyzed within that of the belonging to the agroecology group. We address this complex dimension of agricultural practices in social systems in this paper.

Second, previous studies did not take into account the potential confounding biases arising from the fact that inherent factors, not related to adopting agroecology (such as the age of the farmer, gender, off-farm activities, and income, etc.) might also influence the food and nutrition security of farmers. A reference group or counterfactual would strengthen the findings (Jalan and Ravallion, 2003). We address these concerns by using the Propensity Score Matching (PSM) technique (Benedetto et al., 2018). The technique works as a quasi-experimental methodology by constructing an artificial control group of identical non-agroecology farmers, hence reducing the confounding biases. In our case, we compare an agroecological farmers group and neighboring conventional farmers as the reference.

Third, little has been done to empirically uncover the nature of the activities of the group that constitute the social group. These activities are important for food security and nutrition if we look at group-level and as well as individual variables. The necessary mechanisms through which the adoption of agroecological practices enhances food security remain unknown. Motivations and actions of being in a participatory agroecology group might lead to improved food security and nutrition only in a certain environment. For instance, agroecological knowledge has to be injected in the food system (Emeana et al., 2018). We claim that these mechanisms may lie precisely in the coupling between agroecological agronomic practices and reciprocity and autonomy-driven social structures.

The paper thus makes a substantial methodological contribution when centering the analysis on agroecology as a complex socio-ecological system constituted of an interdependency of agronomic practices and social reciprocal and co-creation activities by employing a quantile PSM that reflects the variations of impact across different variables of interest (peer-to-peer activities, gain in time use, self-provisioning, and production diversity). This approach shall ensure that we show a within-group effect, even if we do not generalize findings without reference to factors and reasons. We hypothesize that the adoption of agroecology practices is contingent on group formation and that the combination of both leads to higher food and nutrition benefits (as compared to the isolated promotion of agricultural practices). We aim to quantify the food security and nutrition benefits of agroecology as a social farm organization and to investigate how the benefits differ among farmers with varying socioeconomic statuses. Our focus in this study is smallholder farmers, who are often victims of food system marginalization and exclusion (Ume, 2023).

2. Methodology

2.1. Study area and characterization of smallholder farming in Southeast Nigeria

The study area is located in the Okigwe agricultural zone in the Southeastern geopolitical region of Nigeria (Figure 1). This study uses data collected in 2021 from a sample of rural farmers in southeastern Nigeria to assess the impact of agroecology on food security and dietary diversity. The group consists of farmers from villages targeted under the Research Extension Farmer Input Linkage Systems (REFILS), which is a research component of the regional agricultural extension service (Emeana et al., 2018). This program offered training to farmers in the use of agroecological farming practices. In this study, the definition of a smallholder farmer follows from Food and Agriculture Organization of the United Nations (2020).

Over 80% of farmers in Nigeria farm less than five hectares (Mgbenka and Mbah, 2016) and thus can be referred to as smallholder farmers (Food and Agriculture Organization of the United Nations, 2020). Smallholders produce over 98% of the food crops consumed in Nigeria - apart from wheat and contribute to about 99% of the total crop output (Mgbenka and Mbah, 2016). They thus play a dominant role in the agricultural sector of the economy. A typical farming community in Nigeria consists of smallholder farmers producing food (crop and animal), not just for family consumption but for commercial purposes as well. According to Adewumi and Omoresho (2002), it is the development of these farming communities that will, to a large extent, determine the progress of the agricultural sector.

Currently, Nigeria is the highest producer of cassava globally followed by Brazil (FAO, 2018), the highest producer of rice in Africa (FAO, 2019). All cassava and most of the rice are produced by small-scale farmers (Olawepo, 2010). This difference suggests low profitability of rice production for smallholders. Yet, national policies encourage strongly rice production among smallholders: inland rice production and availability are key elements of Nigeria's food security and stability strategies, especially for urban Nigeria. In addition to the lack of profit for state-demanded crops, farmers face environmental pressures. The impact of climate change on food and nutritional security and environmental sustainability is continuously gaining attention across Nigeria. The Southeast region also faces difficulties related to soil erosion and water pollution.

Most farmers engage in the production of food crops such as maize, vegetables, yam, cassava, and also poultry. Farmers also keep a few animals within their homes and around the farms. Fields may be located around the houses, but in most cases, are at distant locations, where farmers have to travel on foot. The National Agricultural Extension and Research Liaison Services (NAERLS) and the Agricultural Development Programme (ADP), through their local extension agents, are the prime source of knowledge and information on farming in the study area. The bulk of farmers consists of "conventional" farmers. Conventional farmers employ so-called conventional farming practices, such as significant external inputs in the form of fertilizers and insecticides, improved seeds and they produce cash crops. Most conventional farmers are members of the FADAMA project, a government project that seeks to increase agricultural productivity and the production of commodities such as rice and maize by supplying external inputs and seeds to the farmers at subsidized prices. In addition, to access markets, government-owned land, and other production assets, farmers must engage in rice production. This specialization in rice production goes hand in hand with the adoption of market-oriented strategies, whereby most of the rice is sold to rice companies, intermediaries, and bulk purchases from the urban areas. This usually takes place at the much large commodity markets.

Recently, several agroecology groups have emerged in the Southeast region. The agroecology farmers organize to share knowledge and resources and have adopted agroecological farming practices. While agroecology farmers remain a minority, in this study we try to understand which smallholders contribute to this recent burgeoning and why. Agroecology became popularized in the region of study in 2016 after an agroecology training was implemented in several villages through the Information Resource Centers (IRCs), under the Research Extension Farmer Input Linkage Systems (REFILS) in Nigeria (Emeana et al., 2018). Smallholder farmers were trained in sustainable and agroecological farming practices. Participation was voluntary and farmers who participated in this training formed an informal agroecology group. The

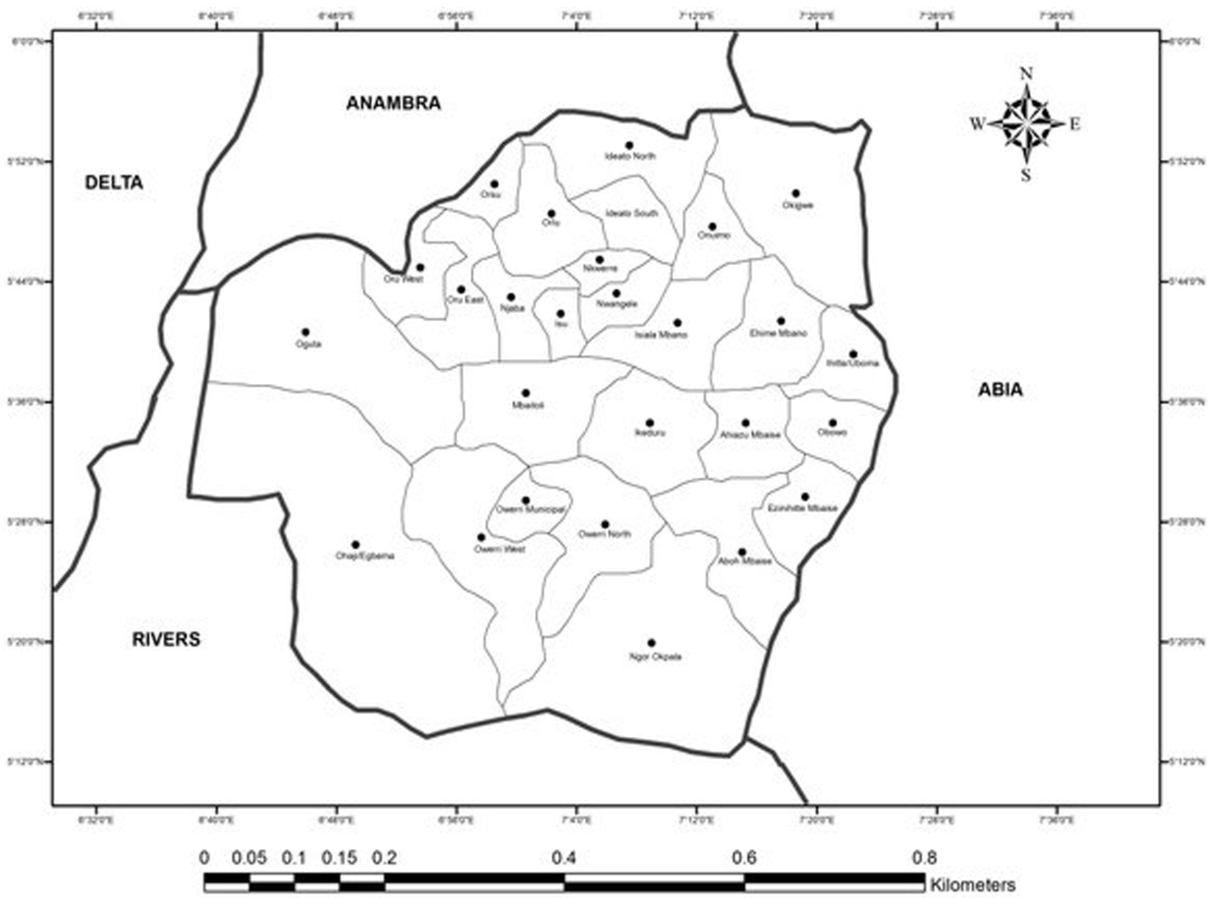

FIGURE 1
Map of the study area Source: (Uluocha et al., 2016).

team established a peer-to-peer network among the participating members (only small-scale farmers) through a registered smartphone application. Through this application and other peer-to-peer meetings and training, a stable group was formed. The group fostered knowledge-sharing and collective activities to produce food more sustainably. Agroecological practices in the group include crop choice for own food, bio-fertilizers, organic fertilization, biological pest control, natural pesticides, seed exchange, and other agroecological techniques and technologies. According to Emeana et al. (2018), the implementation of the agroecology project not only led to the adoption of sustainable farming techniques but also to social and economic changes in the production system. Apart from knowledge sharing, the farmers of the group pool their resources and share land and labor. They also support one another to be able to participate in the local "Ifewa" market (Market name changed for discretion) for consumers where they sell surpluses, and organize an internal crop exchange through a barter trading system.

2.2. Conceptual framework and hypotheses

For this study, agroecology farmers are those farmers who are a member of and identify with the established agroecology group. In other words, the term refers to the group, that is the social organization aimed at promoting a set of sustainable farming practices as well as exchanging knowledge and inputs among one another.

There is no single comprehensive economic theory on the behavior of agroecology households. We embed this research in theories on household reproduction which in our opinion frames best the ecological and social processes we observe in the agroecology group. We define household reproduction activities as investments in activities that ensure that household members are nourished. There are two ways through which the household reproduction goals can be achieved; first, by producing enough food for all household members, or, second, by purchasing this food (Fanzo, 2019). When markets are inefficient - by inefficiency we mean the inability of markets to incorporate social and environmental externalities, it becomes difficult for the agroecology farmers to reproduce or maintain their households by solely depending on productive or market activities that orient towards cash alone. The farmers are therefore constrained to ensure food security by depending on what they produce on their farms. The orientation towards self-provisioning, therefore, presents an alternative food security strategy for farmers who might not be able to benefit from commodity-oriented markets.

Similarly, in most rural households, women are in charge of food provisioning and the overall care of the household (Opata et al., 2020a). Domestic workloads make them time-poor with regard to production or income-generating activities (Kassie et al., 2020). Ajao et al. (2010) assessed the impact of reproductive activities such as family management and childcare practices on the food and nutritional status of rural households and found that children with less childcare were significantly more likely to be stunted and food insecure. Li et al. (2009) showed that reproductive activities such as childcare and family management reduce diseases and health challenges in households.

Social reproduction is also central for agroecology farmers groups. Social reproduction as defined by Paltasingh and Lingam (2014) consists in "those practices that preserve and cultivate the ecological conditions necessary for the generational continuance (reproduction) of cultural practices that enable livelihoods that are meaningful, dignified, and economically adequate relative to the norms of the community" (Menser, 2018: p. 4). According to Menser (2018), the ecological conditions improve through the reproduction process, and the ecological and biological functions of soil fertility maintenance are achieved through physical reproduction which encompasses the knowledge accumulated over many generations which makes these sustainable modes of production possible. Most of the organic and agroecology markets and relationships exist because of the common production systems adopted by farmers of like-minds (Gliessman, 2016; De Schutter, 2019). The agroecological and other sustainable production models are therefore territorially rooted in social reproduction (O'Kane and Wijaya, 2015; Nasser et al., 2020).

2.3. Data collection

Both agroecology and conventional farmers constitute our sample: all agroecology farmers of the group were in the sample. The counterfactual sample of conventional farmers was chosen so as to be comparable in terms of the size of the land farmed. Only farms below 5 ha were included in the sample.

We employed cluster sampling, as the population for the study comprises mutually homogeneous, yet internally heterogeneous groups of agroecology and conventional farmers. We obtained a list of conventional farmers from the regional headquarters of the Agricultural Development Program (ADP) and a list of agroecology farmers from the agroecology group facilitator. For the agroecology group, we surveyed 111 farmers. For the conventional farmers, sampled 223 smallholder farm households. In total, we surveyed 334 respondents (comprising 111 agroecology farmers and 223 non-agroecology farmers). We administered a structured questionnaire to the farmers. We employed trained enumerators who understood and spoke the local language of the study area to administer the questionnaires in person.

We used a detailed participant information sheet containing participants' consent forms to obtain consent from each of the respondents. We limited identifying information obtained to the questionnaire number and the name of the village. We used the household questionnaire to elicit information on the demographic characteristics of the farmers such as their asses, off-farm income generating activities, access to services such as markets, extension agents, and credit, as well as social capital in terms of networking activities.

A second section of questions was used to collect data on food insecurity. Food insecurity is conceptualized in this study as a situation that exists when people do not have adequate physical or economic access to food (World Food Summit, 1996). The Food Insecurity Experience Scale (FIES) and Dietary Diversity Score (DDS). We measured the variable 'Agroecology membership' by employing the dummy of 0 and 1, where 1 represents farmers belonging to an agroecology group, and 0 otherwise. Food Insecurity Experience Scale has been proposed by the Food and Agricultural Organization for measuring food security at the individual and household level (Food and Agriculture Organization of the United Nations, 2020). A score or scale based on the experience and perception of the affected individuals has become the fundamental measure of household food security over the past decade. Due to the following advantages, the FIES measurement scale was used: (i) As the only method that directly measures our variable of interest which is food insecurity, as experienced by the farmers, it is the only method with scientific validity. (ii) The methods described above can be used to map and understand hunger and food insecurity's causes and consequences. (iii) The FIES can be employed for both individual and household analysis. Hence, making it appropriate for the measure of food insecurity among farmers. (iv) The process of data collection and analyzing the data is comparatively straightforward and inexpensive. (v) The FIES reflects both psychosocial and physical dimensions of food security. There are eight questions in the FIES so each of the farmers' answers was scored based on the total number of question items the farmers answers in affirmation.

To include the nutrition component in the FSN measure, we included the Dietary Diversity Scale (DDS: Kissoly et al., 2020). The DDS has been validated as an indicator of nutrient adequacy and malnutrition (Moursi et al., 2008; McDonald et al., 2015; Zhao et al., 2017) and socio-economic status (Vhurumuku, 2014). DDS consists of 12 questions representing 12 food groups consumed by members of the household of which values "0" or "1" are assigned when individuals in the family did not consume or did consume the food groups, respectively. A raw score is assigned by calculating the arithmetic sum of all the questions answered in affirmation by the respondents in both the food security experience scale and dietary diversity components. In Table 1, we provide the definition and descriptive statistics of the variables used in the study.

2.4. Econometric approach

We employed the propensity-score matching technique (Benedetto et al., 2018; Tang et al., 2019) to determine the causal effects of belonging to the agroecology group on food security and nutrition in a cross-sectional sample of smallholder farmers. The propensity-score matching has the advantage of balancing the distributions of observed control variables between a control group and a treatment group according to the similarity in their probability values (propensity scores) of belonging to the group. The approach allows estimating the mean impacts as it does not require a parametric model linking the propensity scores to outcome variables, hence, does not require the usual arbitrary assumptions about error distributions and functional forms (Jalan and Ravallion, 2001). We leverage this flexibility to further test for more potentially complex interaction effects as stipulated in the research questions.

We identified two groups: those farmers who are members of the agroecology group (given as Ai = 1, for farmer *i*) and those who are not members of the group ($A_i = 0$). The treated group (farmers who

TABLE 1 Definition and descriptive statistics of exogenous, outcomes, and control variables.

Variables	Description	Mean	Std dev.
Exogenous variable			
Agroecology	Farmer belong to agroecology group (1 = agroecology; 0 = Other)	0.33	-
Outcome variables			
Food security experience scale	Number of food insecurity experienced by households in the last 1 month	3.28	3.12
Dietary diversity	Number of food groups consumed by a farmer's household in the last 24 h out of 12 food groups	7.51	1.22
Socioeconomic characteristics			
Gender	Male = 1; female = 0	0.21	-
Age of the respondents	Main occupation of the farmer (1 = Farming; 0 = Other occupations)	38	20.12
Education status	Number of years spent in formal education	9	3.0.1
Marital Status	Single = 1, otherwise = 0		
Family size	Number of individuals in a household eating from the same pot	0.71	-
Farm size	Size of land under cultivation	2.21	2.52
Land ownership	Ownership = 1, Rented = 2, Communal = 3, Borrowed = 4	-	-
Farming experience	Number of years in farming	17.54	22.6
Tropical Livestock Unit	livestock from various species converted to a common unit	3.25	1.02
Off-farm income	Money gotten from non-farm undertakings, gifts, or cash transfers ('000 Naira)	110	51.01
Extension visits	Number of extension visits in the last farming season	3	4
No. of relatives	Number of close families the farmer can depend on at difficult times in a community	5.81	12,425
Access to development services			
Distance to market	Time taken to reach preferred selling point	50.2	9.22
County fixed effects			
Umuduru-Egbeaguru		0.29	-
Umuna		0.35	-
Okwe		0.14	-
Okwelle		0.20	-

Source: Authors.

belong to the agroecology group) are matched to the control group (farmers who are not members) based on the propensity scores given in Equation (1):

$$P(xi) = Prob(Ai = 1|xi)(0 < P(xi) < 1) \qquad (1)$$

where, x_i = vector of the covariates. If Ai is independent over all farmers i, and the outcomes are not dependent on belonging, given x_i, then the outcomes are not also dependent on belonging given $P(x_i)$, meaning that it is exactly as it would have been if the assignment of who will belong or not belong to the group was done randomly. This is referred to as conditional independence (Benedetto et al., 2018). The propensity score matching uses a monotone function of $P(x)$ to select covariates for each of the observations that are treated. The implication will be that in estimated treatment effects, any observable heterogeneity will be addressed, as the exact matching on $P(x)$ will yield treated and control groups having the same distribution of the covariates.

To estimate the propensity scores for each observation in the agroecology group and the non-agroecology group samples, we employed the standard logit model. With the estimated propensity scores generated for each observation, $\hat{p}(x)$, we constructed matched-pairs based on how close the propensity scores are between the two groups. This is known as the nearest neighbor matching (Stuart, 2010). According to Jalan and Ravallion (2001), the nearest neighbor to the *ith* observation in the treatment group is defined as the non-group member that minimizes.

$[p(x_i) - p(x_j)]^2$ overall j among all the non-group members. $P(x_z)$ will be the predicted odds ratio for observation z, i.e., $p(xz) = \frac{\hat{P}(Xk)}{1 - \hat{p}(xk)}$.

Using the caliper values of 0.001, we accepted matches only if $[p(x_i) - p(x_j)]^2$ were less than the caliper value of 0.001. Therefore, if the gain in food security or nutrition *for* j_{th} farmer as a result of belonging to the group is given as ΔF_j, the mean impact will be estimated as:

$$\Delta Fj = \sum_{j=1}^{T} \omega j \left(fj1 - \sum_{i=1}^{c} Wijfij0 \right) \quad (2)$$

$f\,j1$ = post-intervention food security indicator. $fij0$ = outcome indicator of the jth treated matched to the ith non-treated. T is the total number of treatments. C = total number of non-treated farmers. $\omega\,j$ = sampling weights used to construct the mean impact estimator. Wij = weights applied in calculating the mean of the "any testable variable such as extension visits, own food production ..." of the matched non-participants.

Based on kernel functions of the differences in scores, we use the nearest four neighbors estimator, meaning that we took into account the mean outcome measure of the closest four matched non-members as the counterfactual for each member.

The Logistic Regression Analysis (Logistic regression assumes categorical outcome variables, such as dichotomous outcomes, but logit does not directly model them) was used to generate the propensity scores, hence indicating variables that significantly motivate farmers to join the agroecology group. The LRA is an extension of the multiple regression and is employed when the dependent variable is a binary outcome assuming the form of 0 and 1. Therefore, for the Propensity Score Matching model, three (3) groups of variables were included. The first category of variables is the matching variables that will be used for the logit model. According to Tang et al. (2019), in the selection of variables for PSM, variables that are unrelated to the treatment variable but related to the outcome should always be included in a PSM model. These variables should be similar for both treatment and control groups to ensure matching. The inclusion of these variables will increase the precision of the estimated exposure effect without increasing bias. More recent studies also follow similar guidelines.

In an agricultural evaluation program, for instance, one can make predictions for a binary outcome as regards treatment and control groups (Pufahl and Weiss, 2009). Logistic regression assumes categorical outcome variables, such as dichotomous outcomes, but logit does not directly model the Y outcome. Due to simplicity and because it is the case most frequently encountered in practice, it relies on the probability associated with the values of Y, however, it is assumed that Y is dichotomous, meaning that it's the values of 1 for success or positive outcome, and 0, otherwise.

Conversely, in the context of regression analysis, we assume that $X_1,\ldots,Xn$, is set of predictors related to the outcome variable, Y and which provides information on Y. For mathematical and theoretical reasons, the model was based on natural logarithm whereby the logit function will be defined as the logarithm (ln) of the possibility (1) of being in the agroecology group. i.e.,

$$A_i = F\left(Y_i\right) = F\left\{\alpha + \Sigma_{i=}^{n}\beta_i X_i\right\} = \frac{1}{1 + e^{-(\propto + \Sigma\beta_i X_i)}} \quad (3)$$

In terms of the log of the odds ratio we rewrite the model as the likelihood that a farmer will be in the agroecology group (A_i) with respect to the likelihood that the farmer is not in the agroecology group (1 - A_i) as expounded (Otum Ume et al., 2020). The likelihood that a farmer is non-agroecology group member (1 - A_i) we define as:

$$\left(1 - A\right) = \frac{1}{1 + e^{Z_i}} \quad (4)$$

By means of Equations (3) and (4) the generate the odd ratio as:

$$\left(\frac{A_i}{1 - A_i}\right) = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i} \quad (5)$$

We take the natural log of the odd ratio from Equation (5) we get an expanded probability (Y) as:

$$Y_i = \ln\left(\frac{A_i}{1 - A_i}\right) = \ln e^{(\propto + \Sigma\beta_i X_i)} = \propto + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \ldots\ldots\ldots \beta_n X_n + U \quad (6)$$

By introducing the error term is into the model we have Equation (7) as:

$$Y_i = \propto \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots.\beta_n X_n + \mu_i \quad (7)$$

The linearization of the logit model Equation (7) will give:

$$Y_i = \propto + \; b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 \ldots b_n x_n + U \quad (8)$$

where, A_i is the likelihood that i^{th} farmer will be in the agroecology group X_i, and X_i is the explanatory variable for the i^{th} farmer's, i = 1, 2, 3...n; e is the base of exponentials; β_i is the regression parameter estimates of the explanatory variables or the slope coefficient of the equation, α is the constant and, U is the error term.

3. Results

The result of the study emanates from the application of both descriptive and inferential analysis. The descriptive results are presented first, highlighting the socioeconomic characteristics of the agroecology farmers, and how that might enlighten our understanding of the make-up of the group and motivation for joining the group. The descriptive results also provided descriptive results showing the distribution of the agroecology farmers' food and nutrition status compared to the non-agroecology farmers. The descriptive statistics were followed by the econometric results that further reinforced the descriptive results, as well as providing information on which kinds of agroecology members that appears to benefit most among agroecology farmers.

3.1. Descriptive statistics

This section compares the socioeconomic characteristics of the agroecology farmers (STATA 15). The results generated (in this section) are used as input for further analysis in the propensity score matching analysis. The percentage distribution is based on the sample size of 111 agroecology farmers, and 223 non-agroecology farmers. Our survey showed that the agroecology group is quite gendered as 83% of the 111 agroecology group members are women (Table 2). Almost half of the agroecology farmers (47%) earn less than 200 dollars from their farming activities in one planting season. In addition, 70% of agroecology farmers have farming as their major occupation. This point to the fact that farming is their major source of livelihood and food security. Table 2 showed that the majority of agroecology farmers access their land through free lending or borrowing. Further, the number of times extension agents visit the agroecology farmers was found to be very low (less than 2 times in a planting season) compared to the non-agroecology farmers (between 2 to 3 times in a planting season). The low level of extension visits indicated by the agroecology farmers might be a reflection of the fact that most of the extension agents prefer vising the large-scale farmers.

Finally, the descriptive statistics also suggest a negative relationship between being in the agroecology group and food insecurity experience (Figure 2): on average, the dietary diversity score of a farmer belonging to the agroecology group is higher (7.59) than for the farmer that is not a member of the agroecology group (5.70).

Figure 3 suggests a positive association between being in the agroecology group and cultivating more food crops. The figure shows that on average, an agroecology farmer produces approximately five different food groups while an average group member cultivates approximately three food groups. In terms of farm meetings, an agroecology group member attends an average of about 14 group meetings in a farming season (Figure 3B). These include activities such as field days and training on nutrition and dietetics. Figure 3C shows that non-agroecology group members are more market-oriented. An average group member consumed 86% of the food he or she produces while a non-agroecology group member consumes 48% of the crops produced. Finally, Figure 3D suggests a positive association between being in the agroecology group and the balance of time between paid and unpaid work. 81% of the agroecology group members against only 26% of non-agroecology members spent less than or equal to 12 h on paid and unpaid work in the last 24 h before recall.

TABLE 2 Socioeconomic characteristics of the agroecology farmers.

Variables	Agroecology Farmers (*n*=111)		Non-Agroecology farmers (*n*=223)	
	Freq.	(%)	Freq.	(%)
Gender				
Women	92	83	169	76
Men	18	17	54	24
Farming as major occupation				
Yes	79	70	152	56
No	32	30	98	44
Method of access to land				
Ownership	8	7	103	46
Rented	25	23	51	23
Communal	27	24	56	25
Borrowed	40	36	13	6
Number of extension visits (per planting season)				
<2	104	91	29	13
2–3	5	4	25	11
3–4	4	3	116	52
>4	2	1	54	24
Farm size (Ha)				
<1	105	93	145	65
1–2	5	6	54	24
2–3	1	1	11	5
>3	-	-	13	6
Farm income ($/planting season)				
<100	52	47	16	70
100–200	35	32	27	12
200–300	-	-	18	8
>400	24	21	22	10

Source: Authors.

3.2. Propensity score analysis

3.2.1. Relationship between agroecology and food and nutrition security

The estimated mean impacts of the agroecology group on food security and nutrition are given in Table 3. The average treatment effect indicates that being in the agroecology group significantly reduces food insecurity and increases dietary diversity. The result shows that food insecurity experience points amongst those in the agroecology group would be 0.45 points higher if they were not in the agroecology group. Dietary diversity will be 2.18 points lower if they were not in the agroecology group.

Before matching, the estimated average propensity score for farmers who were members of the group was 0.6315 with a standard deviation of 0.242, while the average propensity score for farmers who did not join the group was 0.2518, and a standard deviation of 0.126. Figure 4 presents the histograms of the propensity score estimates from the two groups.

After matching, we lost only four treatment observations, as we did not find a suitable match for them. The propensity score estimates after matching showed a negligible difference in the average propensity scores of the treatments and the resulting control group. The estimated average propensity score for the treatment group was 0.5182 with a standard deviation of 0.122, while the average propensity score of the treatment group was 0.509, and a standard deviation of 0.120. Figure 5 presents the histograms of the propensity score estimates from the treatment and control groups. Thus, we are assured that the two groups are comparable and our analysis shows the effect of belonging to the agroecology group rather than differences in resource endowments among farmers.

Once stratified based on 'time load' time-poor farmers in the agroecology group have better food security than time-poor farmers who do not belong to the agroecology group. In all the quantiles, the effect of agroecology on the dietary diversity of time-poor farmers is statistically significant. In terms of food security, we found significant agroecology gains amongst the time-poorest two quintiles (first and second quantiles).

When we stratify the sample based on production diversity, our data showed a significant effect of production diversity on dietary diversity for all the quantiles, but we did not observe any significant effect of production diversity on food security. The difference in dietary diversity was pronounced for the farmers in the first quantile (highest production diversity?). Within the second, third, and fourth quantiles, we observed a statistically significant difference in dietary diversity between agroecology and non-agroecology farmers, however, in a declining magnitude. This shows that the dietary diversity impact is more pronounced among farmers producing relatively more crops than those producing fewer crops (Table 3).

Furthermore, we observed that food and nutrition security effects from belonging to the agroecology group tend to be larger and more significant in families who produce more of their own food. We found a similar pattern when we stratified instead by the strategy employed by the farmers to feed their households. However, we found an interesting case when we consider the first and third quantiles. The result shows that the impact of the agroecology group on food security tends to be larger and more significant for those in the first and third quantiles. The first quantile represents farmers whose 75% and above of their household food consumption comes from what they produce.

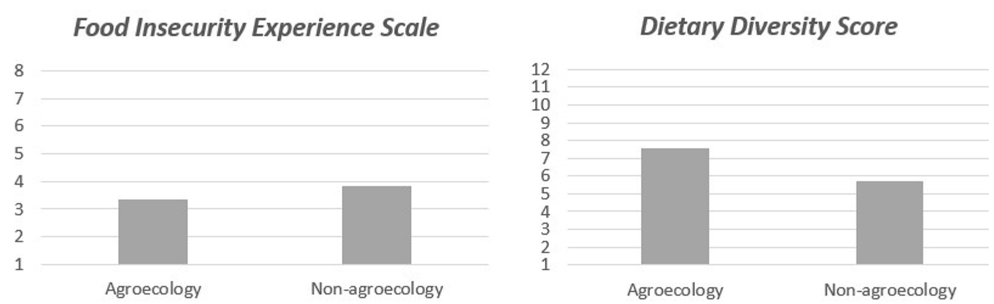

FIGURE 2
Average food security and dietary diversity among agroecology and conventional farmers. Food insecurity experience scale from 1 to 8; Dietary diversity scale from 1 to 12.
(Source: Authors).

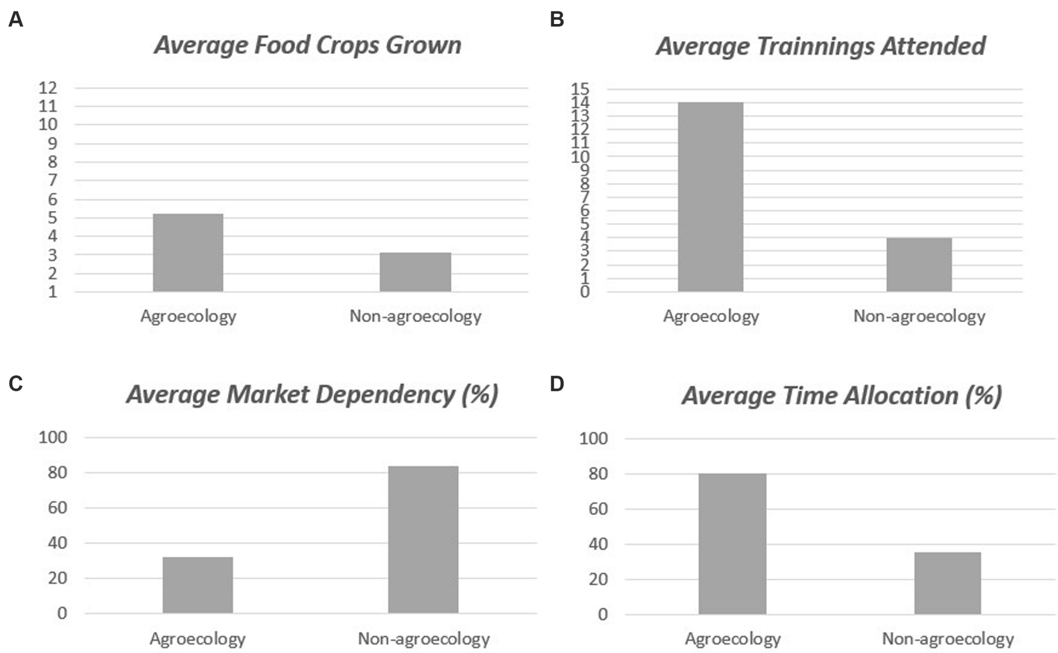

FIGURE 3
Distribution of agroecology and non-agroecology group members in terms of **(A)** the number of food crops cultivated by the farmer **(B)** the number of farming training attended **(C)** the average percentage of crops consumed that is bought from the market **(D)** Percentage of time allocated to reproductive activities.
(Source: Authors).

TABLE 3 Impact of Agroecology on Food Insecurity Experience (Scale 1 to 8) and Dietary Diversity (Scale 1–12).

	Food Security		Dietary diversity	
	Mean for agroecology farmers (Std. Dev)	Impact of agroecology (st. error)	Mean for agroecology farmers (Std. Dev)	Impact of agroecology (st. error)
Full sample	3.35 (0.12)	−0.4536* (0.22)	7.65 (1.33)	2.182* (0.28)
Stratified by Time (quantiles)				
1 (Smallest)	3.61 (0.042)	−3.025* (0.12)	7.02 (1.23)	2.813* (0.19)
2	3.37 (0.113)	−2.948* (0.04)	6.81 (1.01)	1.527 (0.11)
3	2.96 (0.231)	−2.367 (0.005)	6.33 (0.02)	1.085* (0.21)
4	2.43 (0.23)	−1.491 (0.22)	5.21 (0.11)	0.864* (0.05)
Stratified by the production diversity (quantiles)				
1 (highest)	3.51 (0.12)	−1.0457 (0.02)	8.68 (1.25)	2.2950* (0.05)
2	3.22 (0.02)	−0.1505 (0.18)	7.61 (0.52)	2.1694* (0.19)
3	2.51 (0.15)	0.5994 (0.21)	6.82 (0.91)	1.9186* (0.25)
4	2.01 (0.22)	2.1694 (0.09)	3.99 (1.32)	1.8919* (0.09)
Stratified by % of food consumed from self (quantiles)				
1 (Highest)	2.91 (0.01)	−0.8292* (0.12)	7.71 (0.21)	0.5131* (0.05)
2	3.73 (0.005)	−2.1235 (0.02)	6.52 (1.03)	0.3160* (0.09)
3	4.18 (0.21)	−1.8290* (0.15)	4.45 (1.21)	−1.6944 (0.21)
4	1.96 (0.30)	2.2076 (0.09)	5.29 (1.85)	−1.2923 (0.11)
Stratified by extension visits				
1 (Yes)	−2.2040* (0.02)	4.21 (0.21)	4.35 (1.02)	1.9894* (0.24)
2 (No)	−1.30 (0.10)	2.49 (0.11)	3.44 (0.55)	1.57 (0.32)

*Indicates significance at the 5% level or lower.
Source: Authors.

The third quantile represents farmers whose household consumption constitutes between 25 to 50% of their own food production. In addition, farmers within this third quantile have better dietary diversity and food security compared to the farmers in the rest of the quantiles. We could infer that although the strategy of own food production provides more gain for the agroecology farmers, those who balance their own food production and purchase from the market (3rd quantile) tend to have higher dietary diversity and reduced food insecurity, than those in the first quantile. Over 70% of the farmers, in this third quantile, engage in off-farm income-generating activities and receive income from relations or husbands who either are in other businesses or are abroad. The major occupation of the farmers in the first quantile is farming; hence, agriculture is their main source of livelihood.

Finally, the fourth quantile is constituted by farmers who purchase over 75% of their food from the market (irrespective of whether it is the agroecology or conventional market). The result shows that this set of farmers has higher food insecurity experience and lower dietary diversity compared to the rest of the quantile. Our data showed that 91% of the land under cultivation for the farmers in the 4th quantile is used in the production of rice. This is usually a result of the fact that they do not have their land (no private land right) and hence would produce according to the dictate of the processors or other landlords. Although rice can be said to be a food crop, in the study area, farmers engaged in rice production are engaged in contract farming, either with the government or with processing firms. Hence, most of their products are sold out and they receive cash in return. The 1st quantile, however, represents farmers whose major part of their land was used in the cultivation of vegetables, yam, cassava, and other food crops. Interestingly, the farmers in the 1st quantile representing the farmers that are engaged in self-provisioning have far higher production diversity compared to the farmers in the 4th quantile which reflects farmers highly commercialized.

Finally, after stratifying the sample based on (no) visits by extension agents in the last planting season, we found that farmers in the agroecology group had better food security and dietary diversity in both strata. However, the gain was more pronounced among the farmers who did not receive extension services. We therefore could infer that the peer-to-peer activities engaged by members of the group to improve their practices and increase their knowledge *de facto* replace formal extension visits and services.

3.2.2. Determinants for joining the group

In Table 4, we report the logit regression estimates where the binary outcome takes the value 1 if the farmer belongs to the agroecology group, and 0 otherwise. The determinants are made up of socioeconomic and household characteristics including proxies that we believe are seemingly plausible for explaining why farmers would be driven to join the agroecology group. The variables include gender, age, educational status, marital status, and family

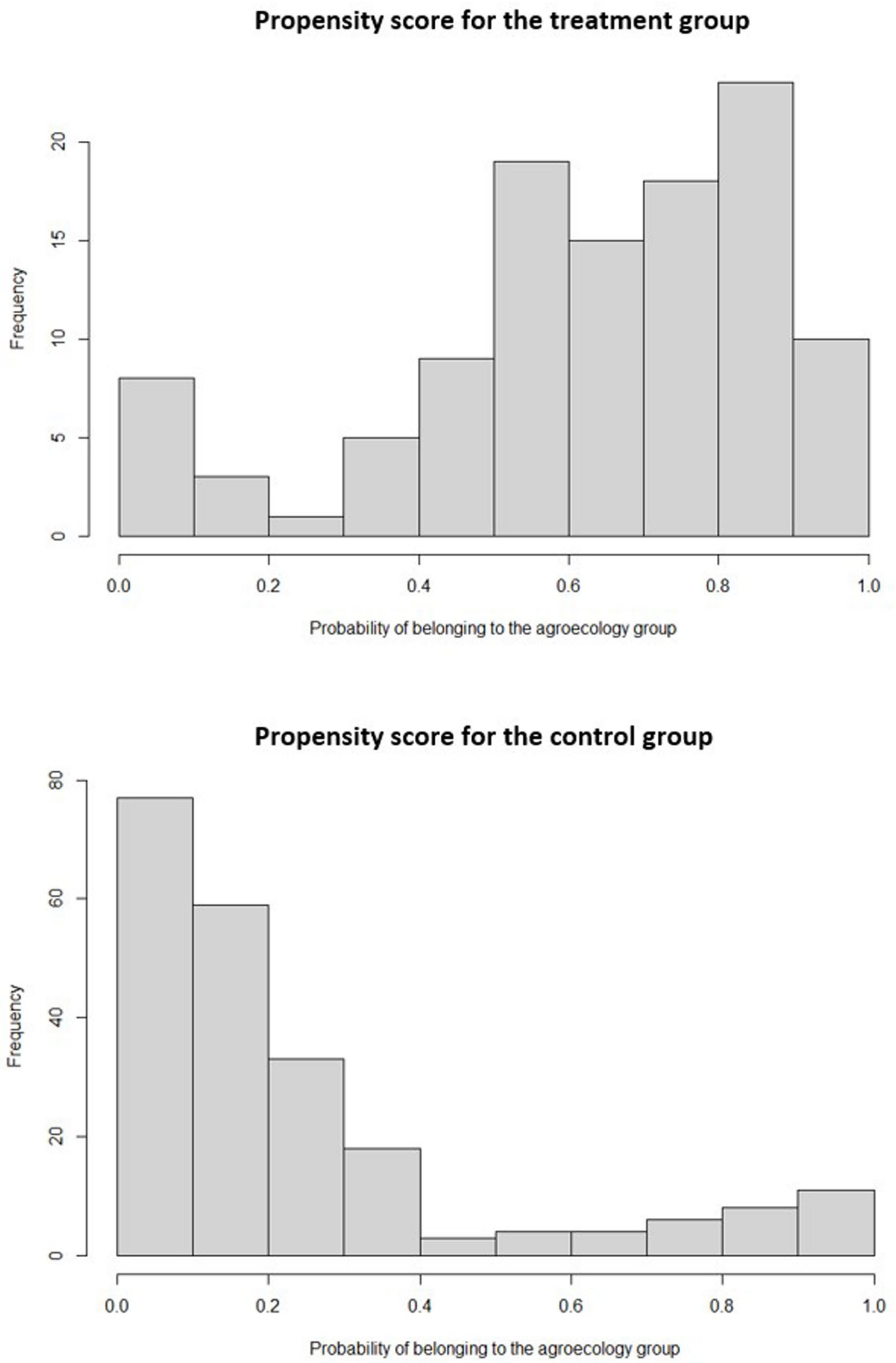

FIGURE 4
Histograms of the propensity score estimates from the two groups before matching.

size of the farmers. The variables were included as exploratory observation in the community as well as studies such as Emeana and Trenchard (2018) showed that the group mostly comprised family women with little formal educational training. Other included variables are the economic variables such as the number of relatives who are already members of the group, farm size, land ownership, and off-farm activities. Farmers who have alternative sources of income and assistance might not be motivated to join the group, compared to those who need assistance and a sense of identity. We also included extension visits, as most of the farmers who do not have access to extension agents might be more motivated to join the group. The location of the farmers within the community was also important as farmers closer to the community where meetings usually take place might be more motivated to join compared to those living far from the village center where meeting normally takes place.

We found no sign of correlation between farmers who are members of the group and their location (Table 4). This suggests that the location of the farmer does not determine their motivation to join or not to join the group. We saw a number of significant

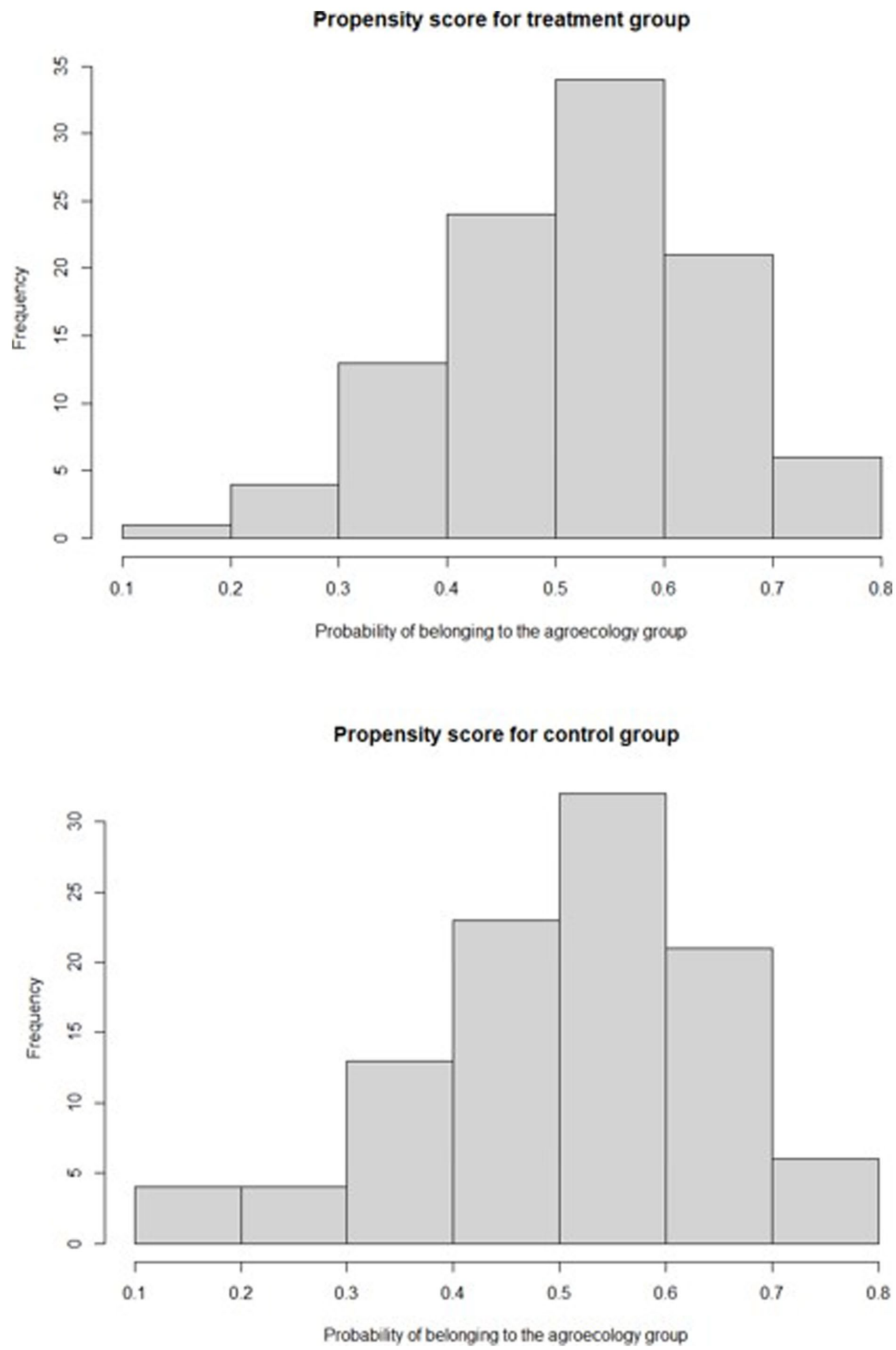

FIGURE 5
Histogram of propensity scores after matching.

variables that could explain the reasons for joining the group. Out of the ten variables tested, six were found to be significant explanatory variables. The result showed that women were more likely to join the group than their main counterparts. This confirms the idea that agroecology groups provide an empowerment platform for women and other historically marginalized stakeholders in the food system such as the caste and smallholder farmers (Oteros-Rozas et al., 2019; Zaremba et al., 2021). This is also not surprising as 83% of the group members were women. In addition, the entire leadership was women, suggesting that the group might have provided a safe origination for the women to air their views conveniently. Having more relatives made it more probable that a farmer will join the group. This is contrary to our expectation as we assumed that farmers who have relatives to rely on in times of need might be less interested in joining the group. However, our interview with the members of the group showed that most of them knew about the group through referrals from their friends and relatives. This might explain the positive correlation between being in the agroecology group and the number of relatives. Expectedly the greater the farm size, the less the probability of joining the

TABLE 4 Determinants of choosing to belong to the agroecology group.

	Coefficient	z-values	Std. Error
Gender	−0.7581**	−2.15	0.35
Age	−0.0085	−0.01	0.006
Educational status	−0.0457	10.31	0.14
Marital status	0.2412	0.66	0.36
Number of relatives	0.2778***	4.99	0.06
Family size	−0.0305**	−0.40	0.07
Farm size	−0.2097*	−1.77	0.11
Land ownership	−0.0317	−0.24	0.13
Ln (Off-farm activities)	−0.0779	−0.36	0.21
Extension visits	−0.2341***	−2.81	0.08
Location	−0.0895	−0.76	0.11

*, **, and *** denote sign. Levels of < 10%, < 5% and < 1%, respectively.
Source: Authors.

group. This finding is plausible and consistent with the *apriori* expectation that the group provides better benefits to landless farmers. By farming communally as well as sharing their lands, these farmers can attract farmers who are landless as they might be able to pull resources and benefit from economies of scale. Finally, farmers who had no access to extension agents have a higher probability of joining the group. This also justifies the hypothesis that the peer-to-peer activities and the training within the agroecology group can provide an alternative learning and knowledge acquisition platform for the agroecology farmers who might not have access to the traditional extension practices provided by the state.

4. Discussion

4.1. Agroecology as a safety net for marginalized farmers

Our findings have to be seen in the context of a discussion on strategies for combating food insecurity (Altieri et al., 2012; FAO, 2014; Nyantakyi-Frimpong et al., 2017). Several governments of developing nations address the problem of food insecurity by fostering the integration of farmers into formal value chains and the production of commodities for regional, national, or global markets. This strategy, which translates into greater support to large farms and commodity markets, also has the aim to generate revenues for the state. Since the advance of the green revolution and deployment of improved corporate-developed seeds and capitalized technology, smallholder farmers are depicted as anachronistic, backward, and inefficient (Jayne et al., 2016; Otsuka et al., 2016; Omotilewa et al., 2021). In practice, farmers with higher income generation potential are more likely to receive assistance and aid from governmental extension offices, subsidy schemes and credit opportunities than farmers with lower income generation potential. Yet, doubts upon the logic that food security in rural areas and among smallholders can be addressed by the focus on commercialization of the smallholder production are now casted (Collier, 2008).

In recent years, food sociologists have begun to realize that social organizations among small farmers have the potential to improve the food and nutrition security of smallholder farmers by enabling and nurturing reciprocal exchanges and supporting structures. The result is a welfare outcome that goes beyond financial individual benefit (Kangmennaang et al., 2017; Rahmadanih et al., 2018; Bezner Kerr et al., 2019b; Kehinde et al., 2021). The findings of the propensity score matching analysis reveal a relationship between being a member of the studied agroecology group and being food and nutrition secure as compared to the food status of conventional matched farmers in the same area. Of course, this result cannot be generalized easily, as the exact causal mechanisms are not revealed by PSM and the result could be case-dependent. Rather, in this study we use PSM as a method to test the efficacy of programs.

Nevertheless, our results suggest at least that the sum of the activities taking place within the agroecology group in the study area has been effective in improving the nutrition and food security status of its members. While the activities themselves might be case-specific, they are built on logics of reciprocity, providing access to resources without cash, co-creation, and sharing of free knowledge, that is principles of agency and empowerment (Emeana et al., 2018). Thus, our evidence strengthens the existing claims that agroecology in Sub-Saharan Africa also exists and manifests itself as a complex association of sustainable agronomic and social (organizational) innovations aimed and managing to improve food security and nutrition among smallholder farmers (Kangmennaang et al., 2017; Bezner Kerr et al., 2019a; Mdee et al., 2019; Kassie et al., 2020; Sachet et al., 2021).

Zooming onto the characteristics of the agroecology group members reveals that mostly marginalized smallholder farmers are more frequent in the agroecology group. Indeed, our logit regression model identified the following variables to be critical in predicting farmers joining the group: being a women, facing land shortage, and having no/little access to extension services. Female farmers were more likely to join the group than their male counterparts. This might be attributed to the fact that, apart from the sense of comradery in the group, the group presents a platform where women can be more empowered to make reproductive decisions, that is to achieve their aim of ensuring food security at the level of their household. This suggests that the association of agroecological practices restoring soil fertility associated with social reciprocal structures supporting the autonomy of women from the mainstream conventional farming system supports women in achieving food security. We can hypothesize further that it is through providing the farmers access to resources, ideas, support, human connection, and role models they do not get from the mainstream system that the agroecology group improves the food status of these women and their households.

In fact, women are the main actors in the agroecology group. This may not be surprising as in the study area, it is women who are in charge of food provision. They might likely tilt towards organizations that strengthen their ability to realize the non-monetary reproductive goals of family care. Our hypothesis rejoins with Peacock (2006)'s view that the non-monetary economy – in this case created by the agroecology group - has a socially or morally conscious philosophy that eliminates social exclusion. It works through the inclusion of the unemployed and poor persons and gives them economic access and opportunities to goods and services. The agroecology group appears as a structure able to empower women in their role of food providers: Opata et al. (2020b) show that empowered women contribute to production decisions, income control, and access to resources which enables them to increase the quantity and quality and improve the fair distribution of food consumed in the home.

4.2. Key variables in the agroecology-food security nexus

Our matching technique highlights further particularly significant variables (reproduction goals) in analyzing the nexus between farm social organizations and food security and nutrition among smallholder farmers: market dependency, farm group meetings, production diversity, and time balance between production and household reproduction goals as we will see in the following sections.

In terms of production diversity, our findings showed that farmers who have higher production diversity have better food security and nutrition. Planting two or more crops on the same land simultaneously is one of the core principles of agroecology and farmers within the agroecology group largely adopted the mixed cropping techniques. Studies have shown that mixed cropping is associated with dietary diversity (PNAS, 2015) and food security (Usman and Callo-Concha, 2021). Mixed farming also has the benefit of fighting against diseases and weeds, hence enhancing production (Ngapo et al., 2021).

In terms of time balance, our result showed that the adoption of agroecological practices such as pull and push technology and zero tillage substantially reduce weeding and tillage time respectively, which are the most time-consuming cultural practices. These practices, thereby free up (wo)man-hours that can be relocated to non-farm or care activities (Kassie et al., 2020; Notenbaert et al., 2021).

Farm group activities such as peer-to-peer meetings and training on sustainable practices are important as it helps the farmer put knowledge into action for better food security and nutrition (Organic Farming Research Foundation, 2022). The more meetings are attended by the agroecology group members, the higher their food and nutrition security, according to our results. The gains observed among agroecology and non-agroecology farmers who had access to extension agents suggest that the interactions within the agroecology group provide an additional or even better knowledge base for the agroecology member. One may interpret that peer-to-peer meetings strengthen the adoption and application of agroecology principles and structures and increase productivity and food security (Faysse et al., 2012; Chen et al., 2015). Indeed, farmers consider other farmers their "best sources of information" (Organic Farming Research Foundation, 2022: p. 3). Yet, the importance of meetings in increasing food security may not relate to the fact that they foster peer-to-peer learning but rather to the content of the knowledge shared and in fact also co-developed within the group. The group delivers and creates agroecological knowledge, which is knowingly complex, place-based, adapted to diverse food crops and based on agroecological principles (Rahmadanih et al., 2018), far from the teachings of rice-supporting extension schemes. In addition, a higher attendance to meetings may mean that farmers contribute financially more often in the financial reciprocal credit system and thus benefit more when they indeed need it. They may also have better chances to access inputs (seeds, lands) and to cooperate with others to sell their product to the agroecological market. The additional benefits from these social networks among rural farmers, may explain the role of the attendance of peer to peer meetings on the food security and nutrition status of farmers (De Schutter, 2010; Tilzey, 2021). The next section deals with the market dependency variable.

4.3. Commercialization, subsistence, and adequate markets

Access to food is critical for food security. We show evidence that farmers who strategize their own food security goals through self-provisioning are better-off both in experiencing more food security as well as diversifying their diets compared to comparable farmers depending more extensively on food purchased from the market. As Edmondson et al. (2019) and Galhena et al. (2013) found in the United Kingdom and Sri Lanka respectively, prioritizing the production of food for subsistence as compared to producing crops for markets is essential in the FNS among farmers excluded from the mainstream farming and cash-based economic system. At the same time, our evidence shows that agroecology farmers sourcing their foods in about equal shares from own production and purchase improved their food security and dietary diversity most. Thus, while it does not contradict the commonly assumed view that (off-farm) income is essential in achieving food security (Bazezew et al., 2013; Gebreyesus, 2016; FAO, 2019; Dsouza et al., 2020), it does temperate this statement and highlights the complementary role of purchased foods, as opposed to being a main strategy. The production of own food remains key for women, who within households do not have access to cash, land and inputs and yet are responsible for food and reproduction in their families. In fact, the high food security result of agroecology farmers who source foods from farming and markets leads to suggest that agroecology in its agricultural and social practices as in the farmers group investigated may be able to reduce the tension between consuming and commercializing, in fact maybe even create a synergy among these two apparently contradictory activities. Fanzo (2015) suggests h that a fundamental tension exists between income-based entitlements and direct production entitlements. The fact that those who are able to balance best between self-consumption and purchased food in our sample are also the best fed ones is an evidence for this tension. Yet, our results also point to a successful manner of navigating it and suggest that agroecology can support this optimal balance between subsistence and commercialization.

Indeed, the question is which kinds of markets support both the production of food and the generation of income? Certainly, commodity markets sharpen the trade-off between food and income generation as commodities are often produced in monocultures and extracted from the local food system for more distant or urban markets. In the presence of only such markets, the distinction between production decisions and consumption decisions is lost as consumption decisions ultimately become production decisions (Fischer and Qaim, 2012; Opata et al., 2020b; Anderson and Maughan, 2021; Usman and Callo-Concha, 2021). Farmers need to choose to produce for food or for cash, which affects food security differently. As opposed, the market used and co-developed by the agroecology group in southern Nigeria enables farmers to sell "real" surpluses of food (and not specific commodities) to a valuable price. Thus, production decisions that women make can be directed towards consumption first and foremost, while still enabling them to acquire cash for supplementary necessary food purchase. Ume (2023) has shown that such markets are possible when they are local markets that are organized by the farmers themselves and most times involve an exchange system that is not only driven by money. This is important as it will help to deemphasize cash crop production as the panacea to improve food security. Rather, we need to promote local rural markets and the production of food crops such that excess food crops can be produced and transacted in such markets.

5. Concluding comments

The paper empirically investigates which farmers participate in the emergence of AE in Southeastern Nigeria and how it supports them in ensuring their food security. It uses PSM to analyze the efficiency of belonging to one specific agroecology group – as a program- in improving the food security of the members. The reference population constitutes of comparable conventional farmers in the same area. Findings from the analysis show that the agroecology social group is an important farm organization that leads to the improvement of the food security status of smallholder farmers by 0.45 points and nutrition status by 2.1 points. Our findings further showed that the improvement in food security is greater if the group supports (and the farmers make use of) elements such as production diversity, peer-to-peer resource sharing, and local food markets. In terms of production diversity, our findings showed that farmers who engage in production diversity rather than monocropping will have better access and could also take advantage of the benefits of mixed cropping. In terms of time balance, our result showed that the adoption of agroecological practices such as pull and push technology and zero tillage substantially reduce weeding and tillage time respectively, which are the most time-consuming cultural practices. Farm group activities such as peer-to-peer meetings and training on sustainable practices helped the farmers put knowledge into action for better food security and nutrition. Finally, we showed that farmers who strategize their own food security goals through self-provisioning are better off both in experiencing more food security as well as diversifying their diets compared to comparable farmers depending more extensively on food purchased from the market.

Our approach shows the value of the social dimension of agroecology in addressing food security and nutrition, especially among smallholder women farmers who are responsible for food provision in the household. In this study therefore, we conceptualize agroecology as a complex socio-ecological system constituted of agronomic practices and social reciprocal and co-creation activities mobilizing local production and exchange of production factors (land, labor) and inputs (seeds, knowledge). Food security programs and academic studies that conceptualize agroecological farm organizations only from the lens of agroecology as a farming practice might disregard other innovative ways through which the farming practices associated with agroecology are embedded both at the household level and at the societal scale. Furthermore, acknowledging gendered responsibilities in achieving food security at the household level and the political, social, and economic conditions under which these household activities are conducted will improve research and the ability of programs to support and empower food careers towards this aim.

Finally, there are some limitations to the study. In studying real-life evaluations, it is difficult to investigate phenomena or interventions before during after due to the absence of time-series data. Thus, making it difficult to properly infer causality of the hypothesized mechanisms. For future studies, relevant information would be to uncover exact causal mechanisms and this could be investigated by a qualitative investigation.

Data availability statement

The datasets generated for this study can be found in the Figshare (https://figshare.com/s/d4efd3f5e3c9548752b3). DOI: 10.6084/m9.figshare.21076312.

Ethics statement

The studies involving human participants were reviewed and approved by Institute of Agricultural policy and Market research. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CU carried out fieldwork in Nigeria and data analysis. E-AN and SD were involved in the conceptualization, framing, writing, and other intellectual contributions. All authors listed have given approval and consent for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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