Gendered Effects of Crop Diversification and Climate Shocks on Household Food Security Status in Nigeria.

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Abstract

This paper studies the impact of climate shocks and crop diversification on household food security in Nigeria by focusing on gender-disaggregated effects. We combine historical rainfall and temperature datasets with the World Bank's Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria. Furthermore, we use an adapted version of the crop diversification Weighted Shannon index (WSI) to measure crop diversification. The food security indicators adopted are the Household Dietary Diversity Score (HDDS), the reduced Coping Strategy Index (rCSI), and the per capita food expenditures. We use a set of panel and dynamic panel models for our analysis, and our results show that climate shocks have negative effects on food security, especially in households with men plot managers. However, we find that crop diversification is positively linked to food security. Our results show the need to target policies to encourage crop diversification in households and promote crop diversification components in women empowerment programs.

Keywords: Climate change, Gender, Diversification, Food security, Nigeria.

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1 Introduction

Climate shocks represent a major constraint for households' food security status as they disrupt crop production, and in turn food availability and accessibility (De Pinto et al. (2020), Amare et al. (2018a)). Quisumbing et al. (2018) and Asfaw and Maggio (2018) note that climate shocks have different effects on men and women depending on household characteristics. Although evidence suggests that crop diversification is a climate shock adaptation strategy that helps improve household food security (Birthal and Hazrana (2019), Tesfaye and Tirivayi (2020)), households' crop diversification capability varies, especially across gender groups (De Pinto et al. (2019), anf Wapulumuka Mulwafu (2018)). Thus, this work provides evidence of the nexus between climate shocks, crop diversification and household food security while exploring the gender perspective.

A large proportion of households in Sub-Saharan Africa (SSA) are reliant on agriculture, producing food for home consumption and selling off surplus for income (Bjornlund et al. (2019)). However, most agriculture in the region, around 97% of total cropland, is rainfed, which exposes agricultural production to highly variable seasonal rainfall (Calzadilla et al. (2008)). Moreover, there are few irrigation systems in SSA - less than 4% of the cropland in the region is irrigated, compared to 39% in South Asia and 29% in East Asia (Sheahan and Barrett (2017)). Hence, a sudden change in rainfall patterns (and temperature) threatens households' food production capacity and food security status and disproportionately affects vulnerable households and individuals, like woman-headed households and women population, respectively (Asfaw and Maggio (2018)). However, households employ various mitigation and adaptation strategies to counter the effects of climate shocks. Strategies vary over time and by region but may include farm and non-farm diversification (Porter (2012), Reardon (1997), Dercon (2002)), insurance (McIntosh et al. (2013), Morduch (1995)), and borrowing (Frankenberg et al. (2003)).

Recent studies suggest that crop diversification is important to promote household food security by increasing agricultural production and diet diversity while conserving the soil (Tesfaye and Tirivayi (2020), Snapp and Fisher (2015), Asfaw et al. (2015)). In addition, it can improve farmers' livelihoods, increase productivity, and help the ecosystem (Di Falco and Chavas (2009), Rahman and Chima (2016), Beillouin et al. (2021)).

However, households' and individuals' crop diversification capability is limited by their access to land, inputs, and information, and women in SSA often have limited access to these three factors. Hence, it is important to assess the gendered effects of crop diversification on households (De Pinto et al. (2019), Birthal and Hazrana (2019)). Moreover, since women's dietary diversity reflects their household's economic access to food (Doss et al. (2018), McDermott et al. (2015), Kassie et al. (2020)), women have an important role to play in mitigating the effects of climate change on households' food security status.

In view of the abovementioned empirical works, our study fills gaps in the literature by providing empirical evidence of the gendered effects of climate shocks and crop diversification on the food security status of households in Nigeria. Our focus on Nigeria is relevant given Nigeria's broad influence in SSA. The country's population is continuously growing, but its capacity to satisfy the demand for food represents a critical issue linked to malnutrition, death, and conflict (Bruck and d'Errico (2019), Ikelegbe and Edokpa (2013)). For example, FAO (2020) and Ecker and Hatzenbuehler (2022) note that about 44.1% of Nigeria's population was moderately or severely food-insecure from 2017 to 2019. Moreover, understanding how climate shocks affect the food security status of vulnerable groups like women is useful for identifying effective empowerment policies in Nigeria.

Thus, this study answers the following question: What are the gendered effects of crop diversification on household food security in the context of climate shocks? More specifically, we answer the following research questions:

1. What are the differential impacts of climate shocks on the food security status of households based on the gender of the plot manager?
2. Is crop diversification linked to improved food security status, and does its impact differ based on the gender of the plot manager?

We combine a comprehensive recent household panel survey with a historical rainfall and temperature dataset to answer these questions. We perform gender disaggregated analyses. We focus on two climate shocks – drought and flood – and observe these variables over 38 years. We use the Household Dietary Diversity Score (HDDS) as our major measure of household food security and explore other measures like food per capita consumption (food PCE) and the reduced Coping Strategy Index (rCSI). We focus on a relevant indicator of crop diversification in line with recent literature – the Weighted Shannon Index (WSI). We then employ a fixed-effect panel regression method and correct for reverse causality and endogeneity bias using lagged variables, instrumental variables, and a dynamic panel model framework. This rigorous analysis is mostly absent in the existing literature. We also test for and correct for attrition across survey waves using inverse probability weighting (IPW) and use percentile weight regression to study the heterogeneity of impacts according to a set of other factors, such as land size.

Our results show that climate shocks negatively impact households' food security status in Nigeria. More specifically, we find that the impact of climate shocks is significant for households with men plot managers but not for women plot managers. However, we note that crop diversification is positively linked to households' food security status and helps mute the effects of climate shocks on households. In addition, the additional agricultural income generated by crop diversification is better spent by women plot managers than by men plot managers to improve food security. Thus, we reinforce the need for policies that better target and allocate resources to women.

The rest of this study is organized as follows. The next section reviews the relevant literature. The theoretical framework is explained in Section 3. Section 4 describes the data employed, Section 5 discusses the descriptive statistics, and Section 6 introduces the econometric models. Section 7 presents the results from the empirical analysis, and Section 8 concludes this paper.

2 Literature review

The body of literature on the link between crop diversification, climate shocks, and households' food security status has grown and developed in recent years. The economics literature on climatic shocks indicates that droughts due to weather variability have deteriorated the living conditions of smallholder farmers who mainly cultivate rainfed crops. Therefore, an unexpected increase in the intensity and frequency of these climates shocks may either affect the choice of crops households cultivate or threaten their food security status. However, most studies use cross-section data and conclude that the relationship between climatic shocks and food security status is negative, especially for smallholder farming households in SSA.

Agamile et al. (2021) employ the seemingly unrelated regression (SUR) method to study the gendered effects of exogenous weather shocks – droughts – on farmers' crops in rural Uganda. The authors focus on subsistence crops (banana, beans, cassava, groundnuts, sweet potato), food crops (pineapple, vegetables), and cash or commercial crops (coffee). They use the 2009-2014 Uganda National Panel Survey (UNPS), and split their sample into three groups: (*i*) men-headed households, (*ii*) women-headed households, and (*iii*) women in men-headed households. To quantify the poverty gap index, the authors construct a shock exposure and intensity index for two- and three-period-long shocks. The results show that in the absence of shocks, women and women household heads allocate less land to subsistence crops (maize and sorghum) and more land to commercial crops (banana) than men and men household heads.

Amare et al. (2018a) also show that rainfall shocks are linked to decreased agricultural productivity and a 37% drop in household consumption. Nwaka and Akadiri (2022) explore the link between drought shocks and household food security status, comparing results from Nigeria and Ethiopia. The authors find significant differences in the determinants of food security between men- and women-headed households, and note that women-headed households are about two times more food insecure in Nigeria than in Ethiopia. In addition, Nigeria was ranked 133rd in the 2018 Global Gender Index report (WEF (2018)), has a Global Hunger Index of 25.5 (severe hunger prevalence), and ranks 84^{th} out of the 118 countries taken into account by the World Health Organization (von Grebmer et al. (2016)). Thus, the combined effects of population growth, climate shocks, and household socioeconomic factors further intensify food insecurity in that country, especially among the most vulnerable groups, like women-headed households and women plot managers (Nwaka and Akadiri (2022), Ajefu (2018)).

Peterman et al. (2010) contribute to the literature by investigating gendered differences in agricultural productivity in Uganda and Nigeria and explicitly addressing the issue of crop choice, the sensitivity of productivity estimates to the choice of stratifying variable, and the possible heterogeneity of agricultural productivity differences within different agro-ecological zones. The authors also demonstrate that the variability in the results is dependent on the choice and implementation of gendered indicators. They use cross-sectional data collected in 2003 and 2005 for Uganda and Nigeria, respectively, and the following three indicator dummy variables to capture gender: (*i*) gender of the farm manager, (*ii*) gender of the household head, or (*iii*) joint ownership in case of more than two ownerships. Quisumbing et al. (2018) use panel data from Bangladesh and Uganda to assess whether shocks affect men's and women's assets differently. The authors note that covariate and idiosyncratic shocks have different effects on men's, women's and jointly owned assets. Similarly, Asfaw and Maggio (2018) note that temperature shocks have negative effects on households and they affect households whose land is managed solely by women more severely.

Women's limited access to land and improved seed varieties increase the risks of malnutrition as most women household heads in developing countries are engaged primarily in agricultural activities. Unobserved factors affecting all regions and plots play key roles in gender differences (Araar and Abossolo (2021)). Evidence shows that climate variability in recent decades is one of the gendered constraints that have affected the food security status of households. These constraints might be more pronounced among households headed by women, women plot managers, and households in which the household head's spouse is the main decision-maker when it comes to household consumption behaviours.

Teklewold et al. (2019) examine the determinants of the adoption of various combinations of climate-smart agricultural innovations and their impact on different nutrition outcomes. The authors find that the food diversity index of women household heads is significantly higher than that of men household heads – 15, 9, and 14% higher when households adopt crop diversification, soil & water conservation, or modern inputs in isolation. They use the Simpson Index (SI) of food diversity as their household dietary diversity index and two household nutrition indicators: (*i*) per adult equivalent nutrient intake (calories and protein) and (*ii*) diet diversity.

However, Agnes Andersson Djurfeldt and Isinika (2018) present divergent results. They examine eight African countries[1] and do not find substantial gendered differences in seed and fertilizer technology adoption rates in maize cultivation (45% for women and 49% for men). The authors further use break down the choice of seed and fertilizer to adopt to measure agricultural diversification and use the household head as a proxy for the farm manager. However, the gendered indicator authors employed may confound their results and understate or overstate the gender gap (or effects). Using the gender of the household head rather than that of the plot manager to capture gendered effects tends to decrease the estimates (Peterman et al. (2010)). In addition, Berman et al. (2021) test how variations in input prices affect household income inequality and conflicts, thus presenting possible mechanisms through which diversification can contribute to women's empowerment and coping with food insecurity.

Nonetheless, the works of Teklewold et al. (2019) and Agnes Andersson Djurfeldt and Isinika (2018) are not nationally representative. For example, Teklewold et al. (2019) focus on cereal-based farming systems in Ethiopia, which represent 40% of the country's agricultural products cultivated with 45% of its surface water. This raises the issue of external validity. Moreover, as the literature on the gendered effect of climate shocks on crop and food security behaviours is limited, understanding crop diversification becomes increasingly important. The availability of nationally representative data for Nigeria thus gives us an opportunity to close the literature gap and provide evidence to governments of developing countries to tackle the negative impact of climate shocks on food security. Birthal and Hazrana (2019) use a dynamic panel approach and find climate shocks negatively affect agricultural productivity. They also determine that crop diversification is an important shock mitigation measure.

The nexus between climate shocks, crop diversification, and household food security remains under-investigated, especially in the context of SSA (Tesfaye and Tirivayi (2020)). Previous studies on the welfare impacts of diversifying ones livelihood to include non-farm sectors do not account for the risk of reduced agricultural labour and food, or consider how it varies by gender. Moreover, in the studies related to crop diversification, climate shocks, or food security status in low- and middle-income countries, the variables used to measure the relevant outcomes are questionable. Data constraints prevent authors from capturing the right level of crop diversification and climate shocks or food security status. Our study thus makes at least three contributions to the literature.

First, we combine three topics in a single study and explore their gender dimensions. We focus on the role of women plot managers versus men plot managers in improving household food security status. Second, we employ new proxies for our relevant variables in line with the recent literature in economics and other relevant fields. For example, we focus on droughts and floods as measures of climate shocks, and we use the adapted version of the crop diversification measure, WSI as a proxy for crop diversification. We also focus on three indicators of household food security status – the HDDS, food PCE, and the rCSI. Third, we employ dynamic panel models to correct for potential reverse causality bias, and we correct for attrition across survey waves using IPW. We also use rich and recent datasets and combine the historical rainfall and temper-

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[1] Ethiopia, Ghana, Kenya, Malawi, Mozambique, Nigeria, Tanzania, and Zambia.

ature dataset with the World Bank Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria.

3 Theoretical model

The works of Strauss (1986), Strauss and Thomas (1998), Strauss and Thomas (1995), the functional form of food security production (F) is as follows:

$$F = F(A, D, N, \mu) \tag{1}$$

Where A represents household socio-demographic characteristics including gender, D represents health-related environmental factors, N is the food security input, and μ represents unobserved household characteristics. Thus, we model household food security status based on the agricultural household models for consumer demand and production analysis (Singh et al. (1986)). In these models, an agricultural household is both a consumer and a producer. Thus, the specification adopted for the household utility function is:

$$U = U(C, L, A, \mu) \tag{2}$$

where C represents commodity consumption and production, L is labour supply, A represents household socio-demographic characteristics, and μ represents household unobserved characteristics.Since agricultural households are both consumers and producers, we assume they maximize their utility function subject to the following income constraint:

$$P^m C^m = P^a(q - C^a) - W^L(x^L - f^L) \tag{3}$$

where C^m and C^a correspond to market-purchased and household-produced commodities, P^m and P^a are the vectors of the market and farm gate prices, respectively, q is the vector of household production, which is equal to crop production in the context of this study, W^L is the wage rate, x^L is the total labour input, and f^L is the family labour input. Thus, the food security production function becomes:

$$F = F(A, D, P, W, q, \mu) \tag{4}$$

In this new function, P is the vector of price (P^m and P^a), W is total income including labour and non-labour wage, and q (crop production) replaces N (food security input). Thus, the first hypothesis of the study (H1) is that crop diversification (a component of q) has a positive effect on production, and thus, on household food security status. In this context of the study, the effect on household food security status can be greater for the households of women plot managers than those of men plot managers. Moreover, we consider following the approach of Breman and de Ridder (1991), which considers the crop production (q) to be a function of a vector of soil characteristics (s), climate change (rainfall and temperature levels and shocks) (ρ), the technology (τ), and crop diversification level (d), which is positively related to the amount of yield produced, as follows:

$$q = q(s, \rho, \tau, d) \tag{5}$$

Indeed, there is a high risk that production be low with a low value of δ in the case of climate shocks, and the positive relationship between crop diversification and productivity is driven by changes in soil microbial composition and frontiers in microbiology (Stefan et al. (2021)). From equations (1) to (5), of the food security demand function can be reduced to:

$$\gamma = \gamma(A, D, P, W, s, \rho, \tau, \delta, \varepsilon) \tag{6}$$

Each food security demand function varies with the price vector (P), household socio-demographic characteristics including gender (A), health-related environmental factors (D), total income (W), crop production function factors such as s, ρ, τ and δ, and ε is household unobserved characteristics including the measurement errors of covariates and innate food and nutrition security.

4 Data and key variable measurement

We combine household panel survey data and historical rainfall and temperature data to estimate the gendered effects of crop diversification and climate shocks on household food security status in Nigeria.

4.1 Climate data

The climate data used in this study was obtained from the Centre for Environmental Data Analysis in the United Kingdom. We extracted monthly total rainfall and average temperature data for all the coordinates within the country for the period 1981 to 2019.[2] To construct the climate shock variables, we modify the measure employed by Amare et al. (2018a) and Tione and Holden (2021).

In our study, we consider two important climate shocks: drought, which can persist for an extended period, and flooding, which occurs for a short period (a high level of precipitation in a few hours). We use monthly climate data such as monthly total precipitation in millimetres (mm). Our flood indicator is the number of months during the year when total precipitation is more than 450 mm. For instance, if 460 mm of precipitation fell in January, 500 mm in April, and less than 450 mm fell in each of the other months in the year, the flood indicator for that year is 2. The choice of the 450 mm threshold is based on the distribution of monthly perception. It is close to the 99th percentile of the distribution. Most rigorous studies show that flood events depend mainly on the topology of the local area, and the frequency, intensity, and total quantity of precipitation in a given period (see also Breinl et al. (2021)). Furthermore, they show that the probability of flood events starts to be high at the highest (that is, the 99th) percentile of the historical precipitations. Hence, we focus on the 99th percentile of the distribution in defining our flood events.

Contrary to flooding, a short but intense phenomenon, drought is generally characterized by two climate events and time duration. The first event is the low level of precipitation, and the second is registered high temperatures. To better capture the drought shock, we therefore assume that the drought period is when we observe both a positive temperature shock and a negative rainfall shock. For agricultural purposes, we focus on Nigeria's average planting period, which is generally between April and October. Thus, the shocks are given by

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[2] From the gridded Climate Research Unit Time Serires (CRU TS) dataset produced by the University of East Anglia's Climate Research Unit are month-by-month variations in climate over the period 1901-2012, on a high-resolution (0.5x0.5 degrees) grids.

$$
\begin{aligned}
\text{Positive Rainfall Shock} \quad (PR_{h,t}) &= 1\ if \left(\frac{R_{h,t} - \bar{R_h}}{R_h^{SD}}\right) > 0.25 & (7)\\
\text{Negative Temperature Shock}\ (NT_{h,t}) &= 1\ if \left(\frac{\bar{T_h} - T_{h,t}}{T_h^{SD}}\right) < 0.25 & (8)
\end{aligned}
$$

$$
\begin{aligned}
\text{Drought}_{h,t} &= PR_{h,t} * NT_{h,t} & (9)\\
\text{Flood}_{h,t} &= \sum_{m=1}^{12} I\left[R_{h,m,t} > 450mm\right] & (10)
\end{aligned}
$$

where $I\left[Condition\right] = 1$ if the condition is met and 0 otherwise, $R_{h,t}$ is the monthly average rainfall during the planting period in year t for household h. $\overline{R}_h$ is the average of $R_{h,t}$ over the period in question (38 years in this study), and $R_{h,m,t}$ is the total precipitation in month m of year t at household h's location. $T_{h,t}$ is the monthly average temperature during the planting period in year t at household h's location. $\overline{T}_h$ is the average of $T_{h,t}$ over the period in question (1981 to 2019).

There exist other drought indicators, such as the Standardized Precipitation Evapotranspiration Index (SPEI). Similar to our drought indicator, defined in Equation (9), the SPEI uses temperature information in addition to precipitation information. We focus on both drought and flooding to understand the distinct effects of each of these types of climate shockers.

Our method of measuring climate shocks is consistent with the existing literature in this field (Dillon et al. (2011), Tione and Holden (2021) and Amare et al. (2018a)). As for the SPEI, it can suffer from a set of disadvantages of the SPI index. As Angelidis et al. (2012) point out, due to its standardized nature, the SPI is not able to identify regions that may be more drought-prone than others and cases in which an equal index value in two different regions does not necessarily imply an equal water deficit. Additionally, misleading positive or negative SPI values may result in regions with low seasonal rainfall when short time periods (1, 2, or 3 months) iare considered.

4.2 Household survey data

We used four waves of the World Bank's Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria for this study. The LSMS-ISA is a nationally representative comprehensive panel survey conducted by the World Bank and Nigeria's National Bureau of Statistics (NBS). The first wave was collected in 2010/2011; the second, in 2012/2013; the third, in 2015/2016; and the fourth, in 2018/2019. Two visits were conducted for each of the survey; one in the post-planting period between August and October, and the other in the post harvest period between February and April.

The baseline survey was administered to 5,000 households in both rural and urban areas of the six geopolitical zones in the country, and gathers information on household, agricultural, and community-level characteristics in separate questionnaires. The household questionnaire captures data on the individual members of the household. The agricultural questionnaire captures plot-lvel information including details about on-farm activities; crop production, sales and storage; input use; landholding; livestock holdings; and technology use. The community questionnaire captures details about the facilities present in the communities, social networks, retail prices, and governance. The dataset can account for time variations, which increases the precision of our estimates.

Although the LSMS-ISA tracks individuals over time and across waves, we test for attrition across waves using the IPW methods recommended by Foster and Bickman (1996) and Verbeek and Nijman (1992).

4.3 Measuring relevant household variables

This section explains how we constructed and measured our variables such as crop diversification and household food security status.

4.3.1 Crop diversification

To measure the degree of diversification, we employ a multidimensional measure of diversity by adapting the Shannon index (SI) following Shiyani and Pandya (1998),Biswas (2016) and Araar (2021). Araar (2021) develops two subclasses of the index: unconstrained and constrained.

$$UCDS_f = \begin{cases} -\sum_{i=1}^{N} \frac{q_{f,i}}{Q_f log(N)} log\left(\frac{q_{f,i}}{Q_f}\right) & if \quad Q_f > 0 \\ 0 & \text{otherwise.} \end{cases} \tag{11}$$

where $Q_f = \sum_{i=1}^{N} q_{f,\, i}$, the sum of quantity produced for N number of crops. Araar (2021) notes that the weights can be presented as the quantities produced, the value of the crops, or the area per hectare planted with each crop.

The constrained crop diversification Shannon (CCDS) index, on the other hand, considers the agro-ecological zones in which crops are cultivated. Some crops cannot be planted due to climate and soil constraints (Araar (2021)). Thus, the CCDS index is given

$$CCDS_f = \begin{cases} -\sum_{i=1}^{N_{f,z}} \frac{q_{f,i}}{Q_f log(N_{f,z})} log\left(\frac{q_{f,i}}{Q_f}\right) & if \quad Q_f > 0 \\ 0 & if \quad Q_f = 0 \end{cases} \tag{12}$$

where $N_{f,z}$ is the maximum number of crops cultivated in zone z by farmer f.

4.3.2 Household food security status

We also focus on three different measures of food security status in this study: HDDS, rCSI and food PCE. The first two measures are commonly used as indicators of household food security, and get interpreted in opposite directions.

The HDDS is a measure of food access, and we follow the steps listed in the International Dietary Data Expansion (INDDEX) project to construct our HDDS (Swindale and Bilinsky (2006)). The HDDS is the number of food groups consumed by the households in question over a given period; we used seven days for this study. We consider 12 main food groups, which are pulses, legumes, and nuts; roots and tubers; cereals; fruits; vegetables; eggs; meat, poultry, and offal; sugar and honey; fish and seafood; oil and fat; milk and milk products; and miscellaneous. Households in which all the food groups are consumed in the seven-day reference period are assigned a score of 12. Higher scores are linked to greater diversity and associated with improved food security, better access to food, and access to higher=quality, while low scores are linked to food insecurity (Amolegbe et al. (2021)).

We also test for robustness by exploring two other measures of food security – food PCE and rCSI. Food PCE is the total amount of household expenditures on food relative to the number members in the household. Although food PCE is not commonly used in the literature as a proxy for household food security status, it is an important measure of household welfare (Lele et al. (2016)). The rCSI is a simple assessment of the strategies employed by households to cope with shocks and a weighted measure of the negative strategies used to acquire food. Vaitla et al. (2017) note that the rCSI is best used with other food security measures to clearly illustrate household food security status. We follow the methods proposed by Daniel G. Maxwell (2008) to construct our rCSI. One limitation of the rCSI measure is that middle-class and welathy households may have low reduced coping strategy scores since they have less need to employ adverse coping strategies. However, this index can be informative and a good proxy for food security for poor households.

4.3.3 Gender dimension

We focus on plot managers rather than household heads to explore the gender dimension in this study. A large number of studies in the economics literature use the household head to explore gender the dimension; however, studies such as those by Udry (1996) and Peterman et al. (2011) in Uganda and Nigeria, Oseni et al. (2015) in Nigeria, and Theriault et al. (2017) in Burkina Faso find significant gendered differences in productivity at the plot level, as compared to the household head level. Hence, we analyze the gender dimension in this study by comparing households with predominantly men plot managers (more adult males than females managing farm plots) and those with predominantly women plot managers (more adult females, than males managing farm plots). However, since some households have more than one plot or plot manager and our level of analysis is at the household level in line with other food security studies, we propose to consider another measure of gender – the ratio of the number of women plot manager to the total number of plot managers in the household.

5 Descriptive statistics

This section presents the descriptive characteristics of our relevant variables such as crop diversification, gender, and our climate shock and food security measures. We also show the relationship between these variables.

More than one in five households (21.9 percent) include at least one woman who is a plot manager (see Table 1, line 1). Of those households, 18.36 percent have only women plot managers (see Table 1, line 8). For 3.11 percent of households, the share of women plot managers is 0.5, which means they include an equal proportion of men and women plot managers (see Table 1, line 5). Only 0.05 percent of households have a 0.75 share of women plot managers, the highest proportion, which Nigerian farming households are dominated by men plot managers (see Table 1, line 7).

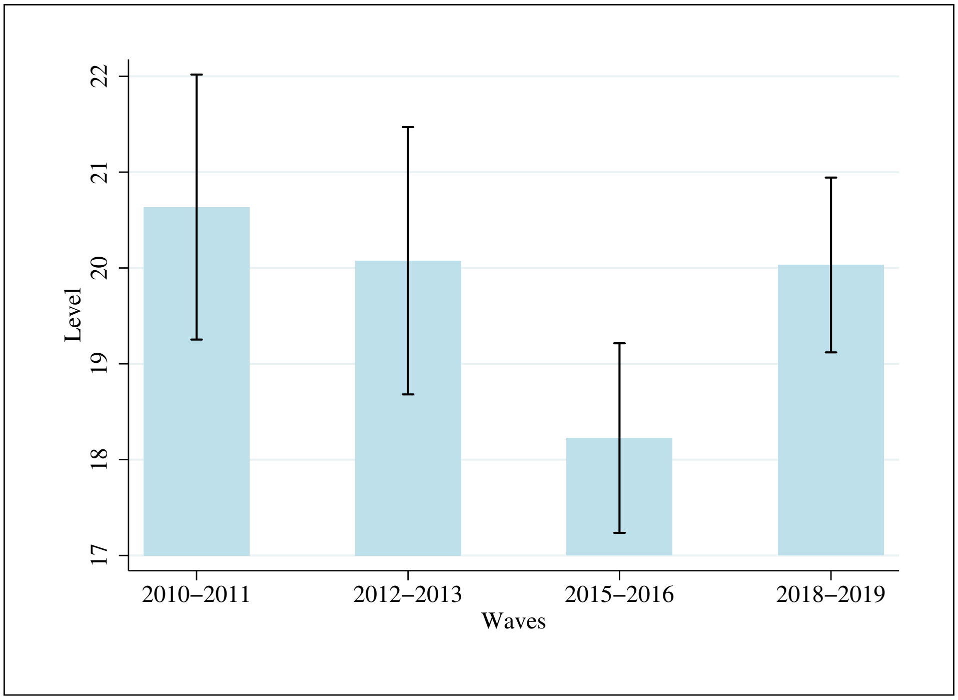
From 2010 to 2019, the share of women plot managers within a household remained almost the same, at 20 percent on average over the four waves (see Figure 1). In households with four men plot managers and one woman plot manager, the share of women plot managers is equal to 0.2. The highest share of women plot managers (21 percent) is found in 2010-2011, while the lowest share (18 percent) is reported

Table 1: Ratio of women to men plot managers in a household

Category	Share of women plot managers in the household	Proportion of households at the population level
(1)	0.00	78.10
(2)	0.25	0.01
(3)	0.33	0.12
(4	0.40	0.01
(5)	0.50	3.11
(6)	0.67	0.24
(7)	0.75	0.05
(8)	1.00	18.36

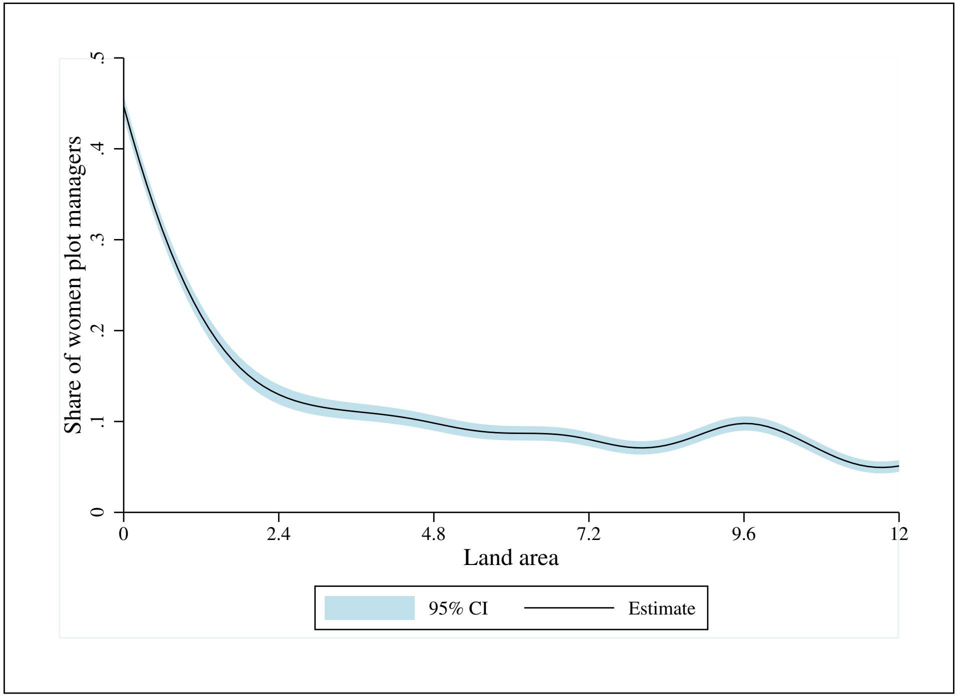
Source: Produced by the authors using LSMS-ISA data.

Figure 1: Share of women plot managers between 2010 and 2019



Source: Authors' calculations using LSMS-ISA data

Figure 2: Land area and share of women plot managers



<u>Source</u>: Authors' calculations using LSMS-ISA data

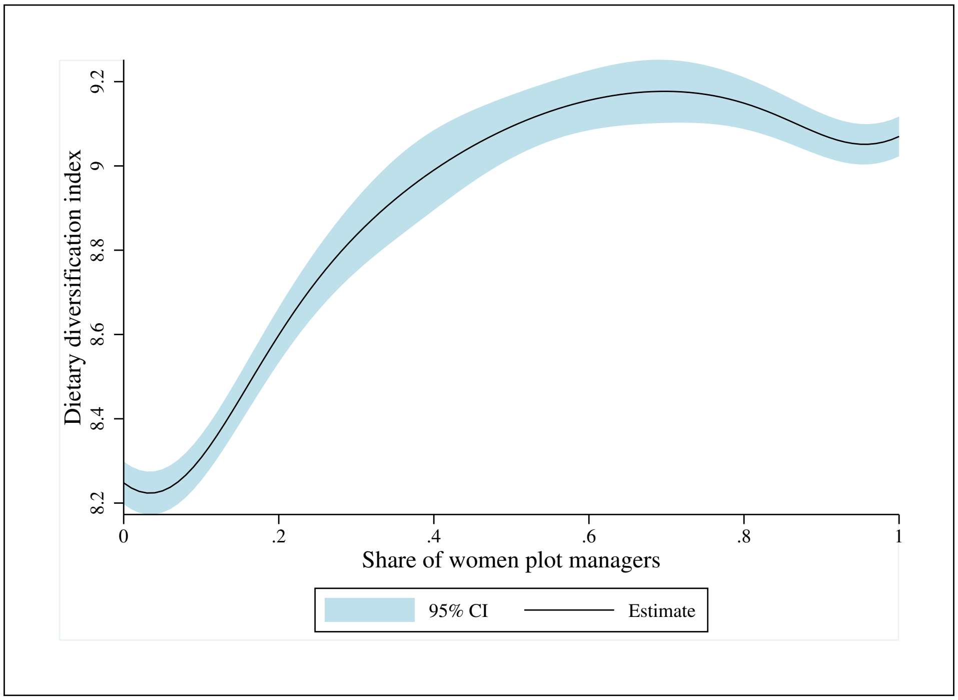
in 2015-2016. However, different trends are observed when the share of women plot managers is crossed with indicators of crop diversification and the total land area cultivated. We further explore the gender composition of the household in relation to plot management and off-farm income-generating activities. We explore whether the male members of households in which plot management is mainly a female activity are employed in non-farm (often better paid) activity.

With respect to the total land area cultivated, the nonparametric regression finding in Figure B.1 shows that the share of women plot managers decreases as the size of the land increases. The larger the size of the land, the lower the share of women plot managers in a given household. The share of women plot managers is between 10 and 40 percent when the size of the land is 2.4 hectares or less, while it represents less than 10 percent when the land is greater than 4 hectares on average. This means that the share of men plot managers increases with the land size, and it represents almost 0.9 (that is, 90 percent) when the total land area cultivated is above 4 hectares. Hence, an inverse relationship is found between the dietary diversity index and the share of women plot managers in a household.

A positive relationship exists between the dietary diversity index and the share of women plot managers in a household (see Figure 3). The higher the share of women plot managers, the higher the dietary diversity index value – the number of food groups consumed by the household. For example, the highest dietary diversity index value is 9.2, which corresponds to the share of women plot managers in a household being percent. Although the dietary index decreases, albeit only a little, when an equal share of women and men are plot managers within the same household, the score remains above 9 out of the 12 main crops cultivated.

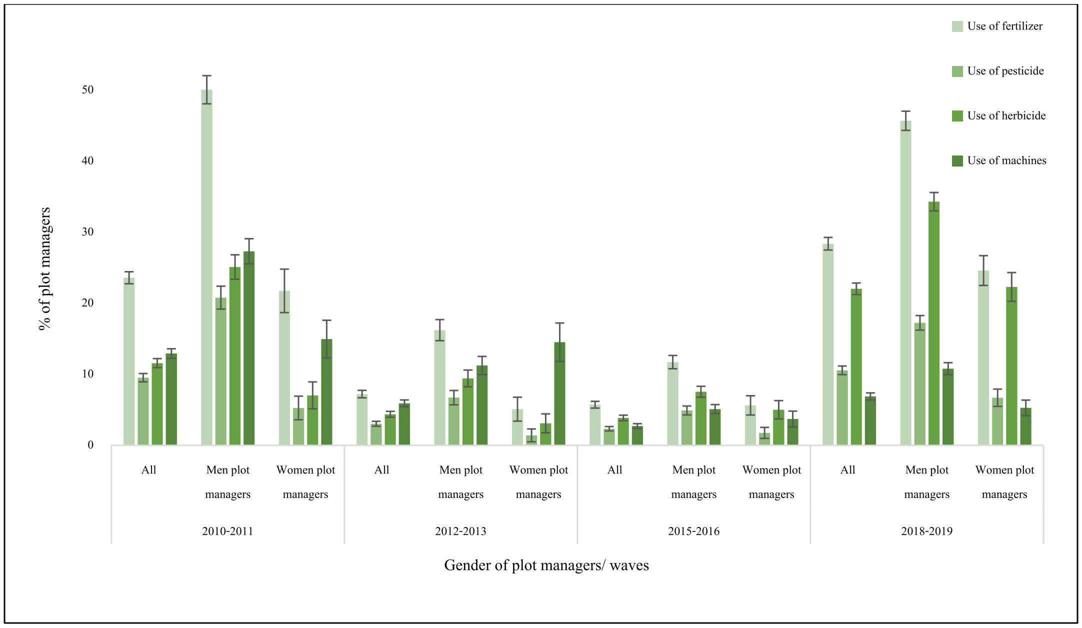
Figure 4 shows that the main inputs plot managers use on their plots are fertilizers and machines. A synoptic analysis of the use of fertilizers, pesticides, herbicides, and machines by waves and gender of the plot manager shows that more men plot managers than women plot managers use more fertilizers, pesticides, herbicides, and machines on their plots. The use of fertilizers peaked in 2010-2011 and 2018-

Figure 3: Dietary diversity index and share of women plot managers



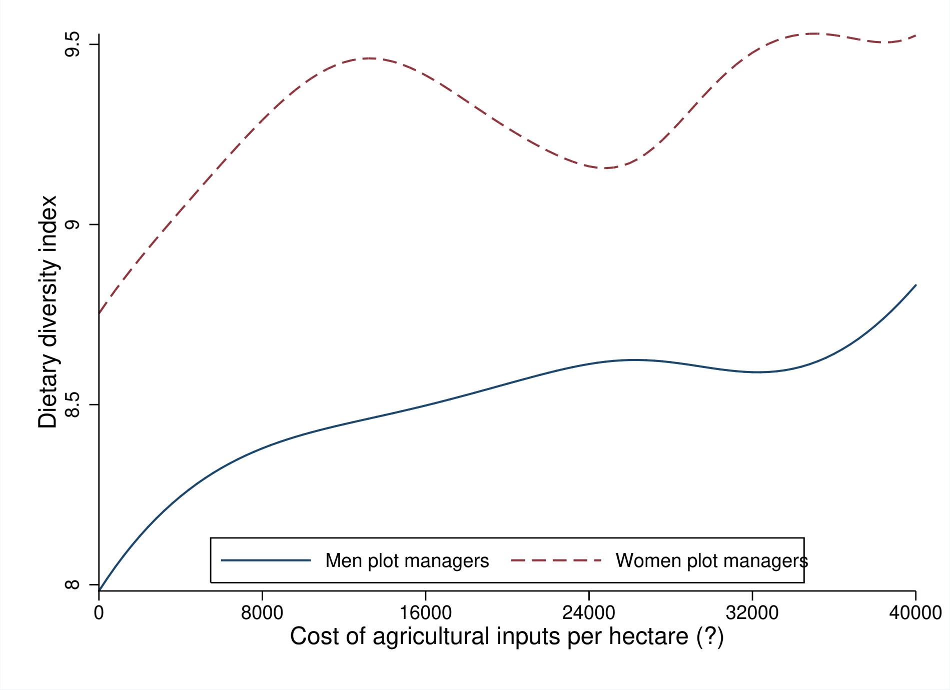
<u>Source</u>: Authors' calculations using LSMS-ISA data

Figure 4: Gender of plot managers by wave and agricultural inputs used



<u>Source</u>: Authors' calculations using LSMS-ISA data

Figure 5: Dietary diversity index and cost of agricultural inputs per hectare



Source: Authors' calculations using LSMS-ISA data

2019, when almost one in two men plot managers used this input, compared to about one in five women plot managers.

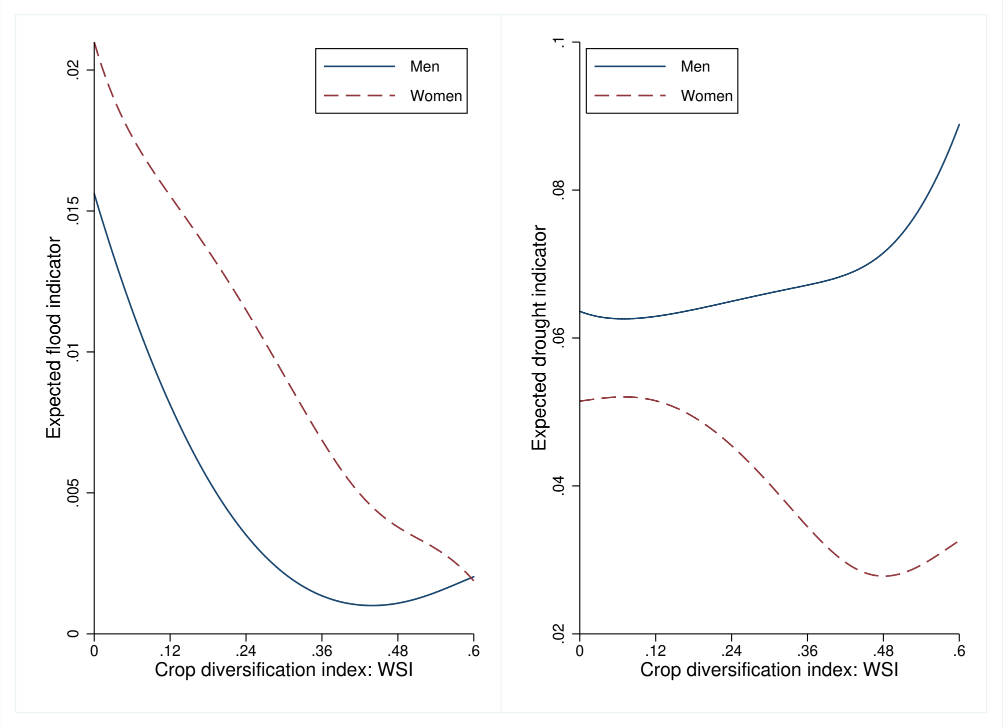
The nonparametric regressions in Figure 5 show that the cost of agricultural inputs per hectare positively increases with the dietary diversity index. This implies that households that invest in agricultural production will mostly cultivate diverse food crops and are more food secure compared to households with limited investment. A positive gender gap is observed between women and men plot managers, with women plot managers almost 0.1 percentage points more likely than men plot managers to diversify their diet. The gender gap is largest at an evaluated agricultural inputs cost of ₦12,000 (₦=Nigerian Naira) on average, and is smallest when inputs cost about ₦25,000.

Women and men plot managers exhibit differentiated crop diversification behaviours depending on the type of climate shocks they are exposed to (see Figure 6). For households exposed to flood shocks (the vertical axis on the left in Figure 6), the higher the flood indicator, the lower the crop diversification index, especially for women plot managers. Similarly, when households are exposed to drought shocks (the vertical axis on the right in Figure 6), the higher the drought indicator, the lower the crop diversification index for women plot managers. Men plot managers, on the other hand, practice more crop diversification during droughts than women plot managers do.

6 Empirical strategy

In this section, we present the econometric specifications used to study the nexus between crop diversification, gender, climate shocks and household food security status. We then explain the identification strategy we employed to help disentangle the possible causal relationships between our relevant variables.

Figure 6: Crop diversification index and climate exposure of men and women plot managers



Source: Authors' calculations using LSMS-ISA data

6.1 Econometric specifications

The main interest of this study was to examine the effects of crop diversification and climate shocks on household food security status, and focus on the gender dimension in doing so. Thus, we hypothesize that (1) climate shocks have negative effects on the food security status of households in Nigeria, (2) climate shocks have a stronger negative impact on the food security status of households with predominantly women plot managers than those with predominantly men plot managers, (3) crop diversification has positive effects on household food security status, and (4) crop diversification impacts the food security status of households with predominantly women than those with predominantly men plot managers.

Given that we seek to establish the causal links between household food status, crop diversification and climate shocks, we define our model as follows:

$$P_{ht} = C + eP_{h,t-1} + sCD_{h,t} + \beta Climate_{h,t} + dX_{h,t} + zH_t + \varepsilon_{h,t} \tag{13}$$

where P_{ht} is a household food security measure – HDDS, food PCE, or rCSI, $Climate_{h,t}$ is a vector of variables for the climate shock question – drought and flooding.$X_{h,t}$ is a vector of plot characteristics such as the logarithm value of the cost of agricultural inputs (fertilizer, pesticide, seeds) per hectare, H_t, is a vector of household characteristics such as the dependency ratio and the age of household head, and ε_{ht} is the error term. The coefficient of interest is β, which indicates the climate shock's effects on the food security status of households. We expect the effects to be negative for both drought and flooding. $CD_{h,t}$ is the crop diversification measure (WSI). We expect crop diversification to have a positive effect on household food security status.

We employ different panel and dynamic panel models to estimate equation (13) and benefit from the strength of each of the models. Considering our data is panel data, we start by estimating the popular fixed effects (FE) panel model as well as the random effects (RE) and between effects (BE) panel models. Note that, the BE and RE models require that the unit-specific error term ($\vartheta_h, \ \ where \ \ \varepsilon_{h,t} = \vartheta_h + \omega_{h,t}$) and the unit-specific average of covariates ($\overline{x}_h$) not be correlated. The RE model's results will be more reliable than the BE model's will because the BE fails to estimate the constant time factor. This may represent a serious limitation if this time factor is the variable of utmost interest in the model. While the FE model is the most popular to control for omitted variable bias due to constant heterogeneity over time, it can have serious limitations of its own if the variable of interest is almost constant over time, such as being a woman plot manager. One way to validate the adoption of the RE or BE model is to perform the Hausman test, for which estimated coefficients will not vary significantly if ϑ_h and $\overline{x}_h$ are uncorrelated.

Our use of the dynamic panel model is mainly explained by the potential presence of reverse causality between crop diversification and food security status. Not only can these models tackle the endogeneity bias of constant heterogeneity, some of these models – the first difference (FD) model, the lagged dependent variable (LDV) model, or a system model. These econometrics specifications were estimated using the generalized method of moments (GMM) proposed by Arellano and Bond (1991) and Arellano and Bover (1995), which has a clear advantage. The FD model is defined as follows:

$$\Delta P_{ht} = e^{'}\Delta P_{h,t-1} + s^{'}\Delta CD_{h,t} + \beta^{'}\Delta Climate_{h,t} + d^{'}\Delta X_{h,t} + z^{'}\Delta H_t + \xi^{'}_{h,t} \tag{14}$$

As we can remark, equation (14) is the outcome of transforming the reference equation (13) into first differences and thus eliminating the household-specific effect. However, it raises a new problem since the lagged dependent variable is by construction correlated with the error term. To solve this problem, we make two assumptions: error terms are not correlated and the explanatory variables have low exogeneity (the explanatory variables must be uncorrelated with the future realizations of the error terms). Therefore, Arellano and Bond (1991) propose the moments condition, which emphasizes the absence of correlation between the lagged explanatory variables or the lagged endogenous variables and the variations of the error term.

Thus, using dynamic panel modelling without including lagged variables and instrument variables leads to an endogeneity problem. This problem generally results from the omission of relevant explanatory variables in the model specifications, from the simultaneity that arises when the dependent variable and some explanatory variables are determined at "the same time", or independent or dependent variables measurement errors. In the case of our study, the problem of simultaneity, i.e., reverse causality between household food security status and crop diversification variables, arises.

Moreover, dynamic panel specifications require that the dependent variable lagged by at least one period be included in the explanatory variables. Having this variable present on the right-hand side of our equation automatically leads to endogeneity bias. Consequently, traditional methods, particularly the FE, RE and BE methods, are no longer adequate. They give biased and non-convergent estimators because of the correlation between the lagged endogenous variable and the error term when residuals are autoregressive. We must therefore resort to more efficient estimation methods, in this case, the abovementioned generalized method of moments (GMM) developed by Holtz-Eakin et al. (1988) and Arellano and Bond (1991).

Although this method provides more accurate results than the usual techniques, it has some limitations because lagged level variables used as instruments are not always adequate. Blundell and Bond (1998) have shown that, the coefficients can be seriously biased in small samples explanatory level variables are highly correlated. Thus, the approach preferred in this study is the systems GMM in Arellano and Bover (1995) and Blundell and Bond (1998) to take into account the endogeneity problems we face in this study. It consists of combining the FD equation with the level equation for each period. The variables in FD equation are then instrumented by their level values lagged by at least one period. In the level equation, the variables are instrumented by their FDs (Jeanneney and Kpodar (2006)).

We performed teo tests to check the robustness of our model. The first is the Sargan/Hansen overidentification test, which enables us to test the lagged variables' validity as instruments. It is conclusive if we cannot reject the null hypothesis (absence of autocorrelation of the error terms in the first difference at order 2) at the 10% threshold. We prefer the Hansen test to the Sargan test because it is robust to heteroscedasticity in the residuals. The second is Arellano and Bond's second-order autocorrelation test. Again, it is conclusive if the null hypothesis cannot be rejected at the 10% threshold.

7 Estimation results and discussion

In this section, we first analyze the impact of climate shocks and crop diversification on the food security status of households in Nigeria using panel data models. Second, we employ GMM to understand the relationship between the three variables of interest. Third, we compare households with predominantly men plot managers and those with predominantly women plot managers. Finally, we explore the heterogeneity of the effects of crop diversification and climate shocks based on a set of household characteristics.

7.1 Impact of climate shocks and crop diversification on the food security status of households in Nigeria

Table 2 shows the results of the estimations for FE, RE, and BE models of the relationship between gender, climate shocks, crop diversification, and household food security status[3]. Indeed, for the fixed effects and random effect models, crop diversification is statistically significant and linked to an increase in HDDS. Similarly, crop diversification increases the rCSI for the three models and is statistically significant. However, the relationship between crop diversification and food PCE is significant for the BE model, and this relationship is negative.

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[3] The estimated coefficients of the lagged food security measures (not presented) are within their possible range. We note that according to Roodman (2009), the coefficient of the lagged variable from the GMM model must be between that of the FE model (downward bias) and the Ordinary Least Squares (upward bias).

Table 2: Fixed, random, and between effects models of the impacts of gender, climate shocks, and crops diversification on household food security status

	Fixed Effect			**Random Effect**			**Between Effect**		
	Dietary diversity	rCSI	Log of food PCE	Dietary diversity	rCSI	Log of food PCE	Dietary diversity	rCSI	Log of food PCE
Crop diversification index (WSI)	0.9347***	3.2822***	0.1038	0.5872***	2.4164***	-0.0974	0.0955	1.8785**	-0.3862***
	(0.1335)	(0.5135)	(0.0885)	(0.1036)	(0.3972)	(0.0660)	(0.1615)	(0.6408)	(0.0975)
Climate shocks:									
Drought	-0.2828***	-0.1614	-0.4881***	-0.4405***	-1.0044***	-0.5137***	-0.3149*	-4.4699***	0.1243
	(0.0629)	(0.2340)	(0.0417)	(0.0587)	(0.2158)	(0.0385)	(0.1565)	(0.5163)	(0.0947)
Flooding	0.1246	2.7122*	-0.0261	0.5526**	4.5862***	0.1152	1.5264***	9.9521***	0.3894*
	(0.2010)	(1.1998)	(0.1333)	(0.1748)	(1.0385)	(0.1135)	(0.3274)	(1.8576)	(0.1976)
Plot characteristics:									
Share of omen plot managers share	-0.0729	0.1669	-0.1673*	0.3724***	2.4554***	0.0409	0.5106***	3.3676***	0.1321
	(0.1235)	(0.4875)	(0.0819)	(0.0882)	(0.3434)	(0.0560)	(0.1288)	(0.4995)	(0.0777)
Agric. input cost (log per hectare)	-0.0393***	-0.0531**	-0.1127***	0.0136**	-0.0165	-0.0524***	0.0818***	0.1169**	0.0071
	(0.0056)	(0.0200)	(0.0037)	(0.0041)	(0.0180)	(0.0026)	(0.0060)	(0.0413)	(0.0036)
Household characteristics:									
Dependency ratio	0.0709	0.1100	-0.0544*	0.0799**	0.1293	-0.1192***	0.0384	-0.0382	-0.1904***
	(0.0399)	(0.1651)	(0.0264)	(0.0258)	(0.0962)	(0.0162)	(0.0337)	(0.1192)	(0.0203)
Age of household head	0.0145***	-0.0214	-0.0107***	0.0063***	0.0142**	0.0001	0.0031*	0.0189***	0.0024*
	(0.0029)	(0.0117)	(0.0019)	(0.0014)	(0.0050)	(0.0008)	(0.0016)	(0.0057)	(0.0009)
SHare of women plot mgr * WSI	0.0027	-0.2088	0.4553*	0.3991	0.0662	0.6964***	1.2352**	0.2904	1.1085***
	(0.3056)	(1.1976)	(0.2025)	(0.2430)	(0.9386)	(0.1556)	(0.3863)	(1.4646)	(0.2331)
Constant	7.3120***	3.9068***	10.6524***	7.6451***	1.9071***	10.1329***	7.7268***	2.0629***	9.9922***
	(0.1786)	(0.7205)	(0.1180)	(0.0933)	(0.3453)	(0.0577)	(0.1122)	(0.4119)	(0.0677)
Observations	17,673	11,264	17,699	17,673	11,264	17,699	17,673	11,264	17,699
Within r-squared	0.0168	0.0080	0.0914	0.0039	0.0031	0.0747	0.0016	0.0007	0.0057
Between r-squared	0.0015	0.0003	0.0007	0.0404	0.0899	0.0040	0.0692	0.1059	0.0347
Overall r-squared	0.0007	0.0025	0.0087	0.0304	0.0405	0.0243	0.0303	0.0352	0.0089

*Standard errors are in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Source: Produced by the authors using LSMS-ISA data.

The climate shocks variable, drought, has a negative impact on the number of food groups consumed by households for the three models. On the other hand, flood shock has a positive impact on the number of food groups consumed by households and the coping strategy index for the RE and BE models.

The gendered variable "share of women plot manager" contributes to increasing the dietary diversity score and the rCSI for the RE and BE models but has a negative effect on food PCE for the FE model. The effect is also found to be positive and significant for food PCE with all three models and positive for the dietary diversity score with the BE model. These effects results can be explained by the fact that the share of women plot managers changes mainly within the household rather than at the state level.

The results from the Hausman tests confirm the explanation of the the robustness of the BE model for the dietary diversity score against the FE model for the rCSI and the food PCE. Nevertheless, there are non-significant differences both in rCSI and food PCE for the FE and BE models for crop diversification, climate shocks, and the gendered variables. Thus, the FE model is not as robust in the context of this study as the BE model (see Tables C.2 to C.4 in Appendix C).

Furthermore, to deal with the spatially robust standard error of climate shocks between states, we used the Conley (1999) standard errors robust that are spatially robust to autocorrelation and heteroskedasticity. Following Hirvonen (2016), we based the Conley (1999) standard errors on the cut-points: 10, 50, and 500 km. Therefore, the spatially robust Conley (1999) standard errors from the estimation can be different from usual standard errors (that do not consider the spatial correlation). Table C.1 in Appendix C shows that the extent of correction in standard errors is very low for plausible distances of spatial correlation (50 km and less). Thus, we can conclude that correlation bias will not have a significant effect on our estimation of standard errors.

Table 3 shows the results for a more appropriate specification, the dynamic panel model. We also show the results for the other two measures of household food security status (rCSI and food PCE) but focus on HDDS in subsequent tables. Again, our results are in line with a priori expectations. As predicted by the literature, climate shocks have a negative impact on households' food security status.

In other words, climate shocks (drought and flooding) are negatively linked to the logarithm value of food PCE. An increase in extreme dryness, that is, drought, is linked to a 14.1% decrease in household expenditures on food, while an increase in excess water, which can indicate a flood shock, is linked to a 66.9% decrease. These results could be explained by the crop production risks associated with climate shocks, which represent an increasing threat to the adoption of crop diversification strategies. More specifically, it reduces productivity, food availability, and accessibility in rainfed constraints (Barrios et al. (2010), Dercon and Christiaensen (2011), De Pinto et al. (2020), Amare et al. (2018a)).

These results confirm those of Thompson et al. (2010) and Pickson and Boateng (2022) on SSA households, on the one hand, and those of Demeke et al. (2011) and Wossen and Berger (2015) on Ghanaian households, McLaughlin (2021) on Malawian households and Mwesigye (2021) on Ugandan households, on the other hand. They found climate variation had a negative effect on welfare and there was a negative relationship between climate shocks and dietary diversity. Similarly, we find that crop diversification is linked to an increase in the number of food groups consumed by households and the extreme measures employed by households. These results align with those of Tesfaye and Tirivayi (2020), who note that crop diversification is positively associated with improved diet and food security. It is important to note, however, that we do not explore the precise mechanisms through which drought affects households.

Crop diversification increases agricultural production, enhances nutrition security, and supports sustainable agricultural transformation by retaining farming household labour in the agricultural sector (Asfaw et al. (2015), Ecker (2018), Amare et al. (2018b)). Also, the adoption of sustainable agricultural practices by households is linked to farming productivity and household food security (Teklewold et al. (2013)).

Like Rahman and Kazal (2015), we also note that the crop diversification status of a household is linked

Table 3: Crop diversification, climate shocks, and food security using the dynamic panel model

	Dietary diversity	rCSI	Log of food PCE
Lag of dietary diversity score	-0.4499***		
	(0.0132)		
Crop diversification index	0.6851**	2.6437**	0.1550
	(0.2295)	(0.9635)	(0.1599)
Lag of crop diversification index	0.2798***	1.0102*	-0.1089*
	(0.0837)	(0.5143)	(0.0531)
Climate shocks:			
Drought	-0.0971	-0.3077	-0.1410***
	(0.0843)	(0.4023)	(0.0399)
Flooding	-0.3745	5.9961*	-0.6692***
	(0.3314)	(2.7443)	(0.1592)
Plot characteristics:			
Share of women plot managers	0.0483	-0.2068	0.1388
	(0.1307)	(0.6175)	(0.0953)
Agric. input cost (log per hectare)	0.0408*	0.0019	-0.1287***
	(0.0204)	(0.1031)	(0.0156)
Household characteristics:			
Dependency ratio	-0.0792	0.6589	-0.0333
	(0.0848)	(0.5326)	(0.0554)
Age of household head	0.0121	0.0065	0.0024
	(0.0085)	(0.0595)	(0.0058)
Lag of rCSI		-0.4835***	
		(0.0365)	
Lag of logarithm value of food PCE			-0.1145***
			(0.0100)
Constant	11.3724***	3.9279	11.0675***
	(0.4827)	(3.3082)	(0.3779)
Observations	4,832	1,637	4,832
Chi-squared	1.2e+03	206.8063	316.4091
Number of groups	2.8e+03	1.3e+03	2.8e+03
Model degrees of freedom	9.0000	9.0000	9.0000

*Standard errors are in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*
Source: Produced by the authors using LSMS-ISA data.

to fluctuation in food prices. We show this relationship in Appendix A. Janssen and van Ittersum (2007), Feola et al. (2015), and Lee et al. (2016) note that farming households also face the risk of food price fluctuation as a result of climate shocks. However, crop diversification can compensate for the welfare loss caused by a drop in the price of a particular crop. Lee et al. (2016) used agroeconomic time series data to assess crop selection subject to price and yield fluctuation in South Korea and found that the price variability among different crops is linked to a farming household's crop selection and the crop composition of their land and therefore directly impacts the food security status of the household. Rahman and Kazal (2015) used a panel of 19 regions in Bangladesh and explored the determinants of crop diversity. They also found significant relationships between food prices and crop diversification, with the direction of the effect depending on the food class. For example, they found that increasing the price of vegetables increases crop diversity, while increasing that of pulses and sugarcane reduces crop diversity.

7.2 Gender disaggregated effects of climate shocks and crop diversification

Table 4 shows the gender-disaggregated effects of crop diversification and climate shocks on HDDS. Tables D.1 and D.2 in Appendix D show the effects on the other food security measures – rCSI and the logarithm value of food PCE, respectively. Since men and women plot managersbehave differently in terms of climate change adaptation to maintain food security, it is very important to explore the gender-disaggregated effects using the share of women and men plots managers

Table 4 shows that climate shocks have a significant negative impact on the food security status of households with men and women plot managers. However, an increase in extreme dryness, that is, drought, is linked to a five-unit reduction in the number of food groups consumed by households with men plot managers. However, the effect on households with women plot managers is small and not statistically significant. The result is the same for the rCSI. However, we also find that excess water, that is, flood shocks are linked to a significant large drop0 in women plot managers' household expenditures on food. The hypothesis is that food insecurity can be perceived as poverty status. Those who are practically poor are the ones who are more vulnerable to food insecurity. Recall here that households with men plot managers spend less on food per capita than households with women plot managers. However, we further explore the dataset (see Table E.1 and Figures E.1 and E.2 in Appendix E) and find that households without women plot managers are in highly drought-prone areas. We note that the fact that climate shock is lecc severe for women, combined with the high crop diversification, makes households with women plot managers more food secure.

We also find that the lag of crop diversification index and flooding contribute to increased dietary diversity in households with men plot managers, while drought has a negative effect on these households. We note that women plot managers tend to diversify crops as well as dietary (food) items. Moreover, crop diversification is assumed to reduce the risk associated with focusing on specific agricultural products and thus contribute to household food security. Our results are in line with those of Nwaka and Akadiri (2022), who find significant differences in the determinants of food security between men and women-headed households in Nigeria and in Ethiopia. These authors, however, note that women-headed households are about two times more food insecure in Nigeria than in Ethiopia. However, our study focuses on the gender of the plot manager rather than that of the household head. We further note that there is an inverse relationship between the share of men migrants and the number of women plot managers in a household. That is to say that the migration of male household members does not preclude the emergence of women household members as plot managers (see Figure E.3 in Appendix E).

Our results also align with the minor impact Quisumbing et al. (2018) found that droughts have on wives' assets compared to husbands' assets. They also confirm the rainfall-gendered inequality found among Ugandan households (Björkman-Nyqvist (2013)) and Tanzanian households (Beegle et al. (2006)). Finally, we note that compared to men, women can often grow very nutritious and energy-rich food crops to ensure an adequate supply of essential nutrients for their household (Doss et al. (2018), anf Wapulumuka Mulwafu (2018), De Pinto et al. (2019)).

Table 4: Crop diversification, climate shocks, and dietary diversity using the system GMM model

	Dietary diversity	Dietary diversity, women	Dietary diversity, men
Lag of dietary diversity score	0.0801*	0.1170*	0.0999**
	(0.0333)	(0.0592)	(0.0326)
Crop diversification index	2.7918***	0.5081	2.9655***
	(0.8383)	(0.4484)	(0.9001)
Lag of crop diversification index	1.1778*	0.3809	1.2565*
	(0.5007)	(0.4540)	(0.5072)
Climate shocks:			
Drought	-4.9062**	0.0264	-5.3568**
	(1.6416)	(1.3402)	(1.6530)
Flooding	12.1352*	0.9639	19.1395*
	(5.6074)	(2.5252)	(8.4763)
Plot characteristics:			
Agric. input cost (in log per hectare)	-0.3837*	-0.1089	-0.3709*
	(0.1773)	(0.1651)	(0.1802)
Household characteristics:			
Dependency ratio	-0.2610	0.1210	0.0189
	(1.7648)	(0.5708)	(1.6913)
Age of household head	-0.2021**	-0.1007*	-0.2079**
	(0.0646)	(0.0413)	(0.0692)
Constant	18.5592***	13.5046***	17.7308***
	(4.2466)	(3.0104)	(4.4528)
Observations	12,555	2,288	10,267
Sargan statistic	51.0322	43.3084	76.5096
Hansen J statistic	36.2620	27.0211	35.0846
p value of AR(1) statistic	0.0000	0.0000	0.0000
p value of AR(2) statistic	0.0745	0.6058	0.1553

Standard errors are in parentheses * p <0.05, ** p <0.01, *** p <0.001. and AR means Auto-regressive process
Source: Produced by the authors using LSMS-ISA data

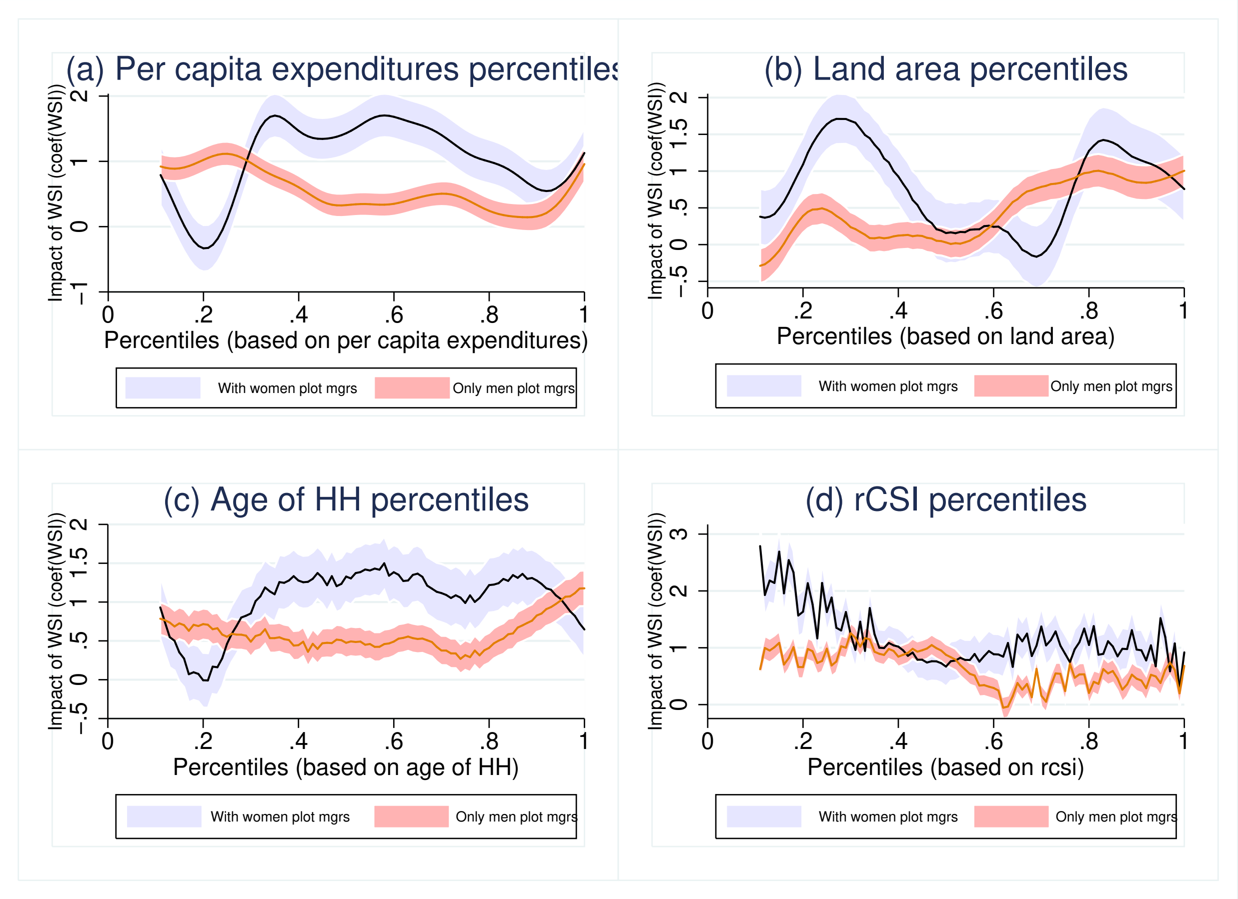
7.3 Heterogeneous effects of climate shocks and crop diversification

The weighed percentile regression method (Araar (2016)) is a non-parametric regression method that we used for complementary analysis to highlight the heterogeneity effects between crop diversification and household food security based on per capita expenditures, land area, age of the household head, and rCSI.

This method assigns high weights to the households close to the quantile or percentile of interest and low weights to those far away from it. Weights are generated using Kernel's Gaussian normal distribution estimation around the percentile of interest. The precision of the estimation coefficients is obtained by applying an optimal level of bandwidth, which corresponds to that suggested by Silverman (1998) divided by three.

The estimation is done in three steps: (1) generate of the percentile of the household food security

Figure 7: Gendered impact of crop diversification on HDDS based on household subgroups (percentiles)



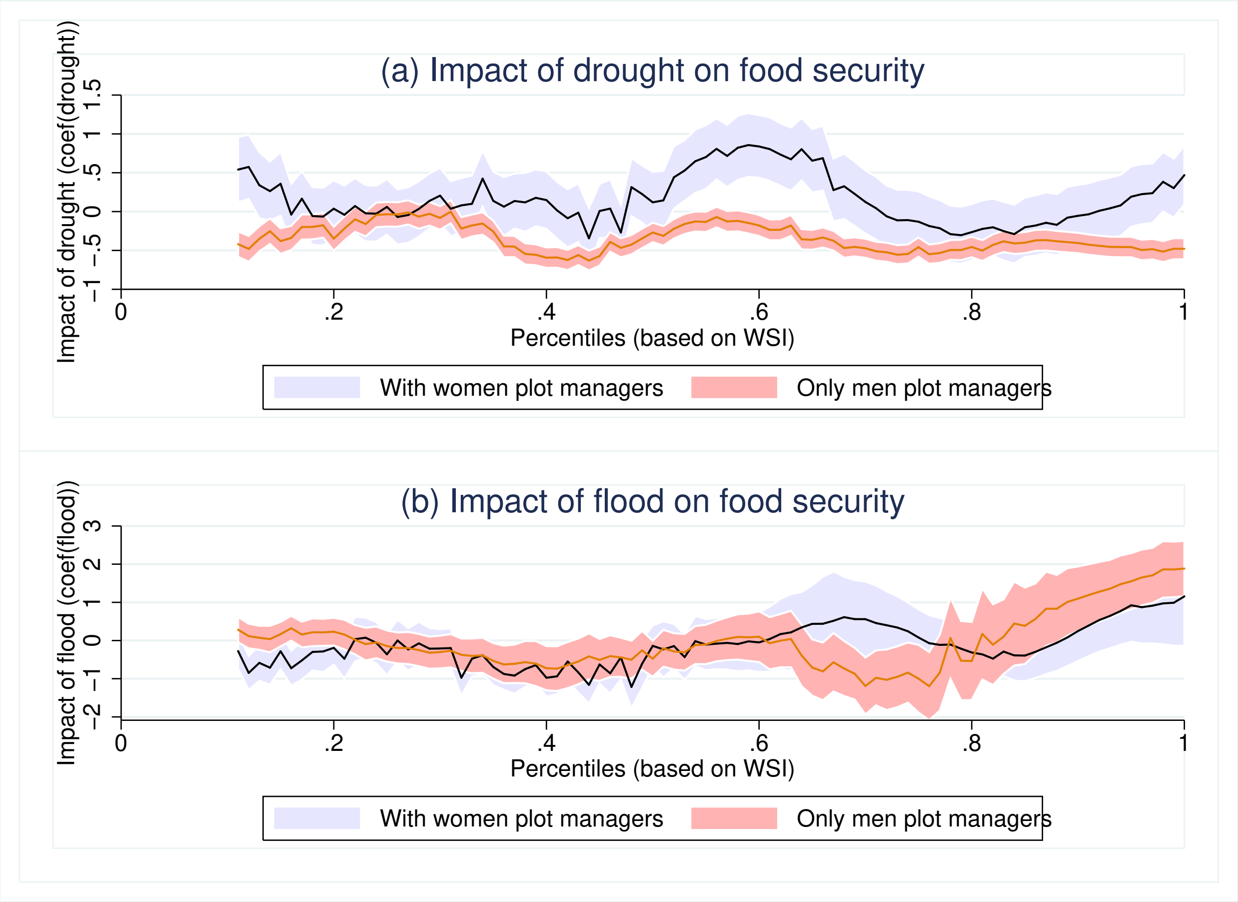
Source: Authors' calculations using LSMS-ISA data

variables, (2) estimate of the Gaussian density (the percentile weights) around the percentile of interest, and (3) run the regression with the percentile weights.

The results of the heterogeneous analysis (see Figure 7) show that crop diversification has a positive effect on all households but has the largest effects poorer households, those in the lower percentiles (panels (a) and (b)). In addition, households with women plot managers are better off that households with men plot managers when it comes to crop diversification, especially those with women plot managers of childbearing age (panel (c)). We also note that the effect of crop diversification is relatively low for men plot managers with small plots of land. An increase in rCSI, which may inform the different strategies of poor groups, is also tied to the small effect of crop diversification (panel (d)).

We further show, in Figure 8, the heterogeneous effects of drought and flooding by using the crop diversification index to classify households into subgroups. We find that climate shocks have negative effects, especially drought, on the "only men plot managers" group. However, those households with high crop diversification index will be spared from the negative effects of flood shocks.

Figure 8: Gendered impact of climate shocks on HDDS by WSI subgroup (percentiles)



Source: Authors' calculations using LSMS-ISA data

8 Conclusion and policy implications

Climate shocks represent a major constraint for households' food security status and have varying effects on households with men and women plot managers depending on household characteristics. Thus, crop diversification, which also varies across gender groups, is an important climate shock adaptation strategy that helps improve household food security. Therefore, understanding the nexus between climate shocks, crop diversification, and household food security while exploring the gender perspective within and between households is an important policy issue in Nigeria and other Sub-Saharan African countries.

This paper answers the question – What is the gendered effect of crop diversification on household food security in the context of climate shocks? We combine household survey data with historical rainfall and temperature datasets covering the four waves of the World Bank's Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria. We address four hypotheses. We define climate shocks as drought and flooding. We focus on the Household Dietary Diversity Score (HDDS), the reduced Coping Strategy Index (rCSI), and food PCE as our food security measures. We use the adapted version of the crop diversification Weighted Shannon index (WSI). We then employ a system GMM regression method to answer our research questions, and correct for attrition across survey waves using inverse probability weighting (IPW). We identify an opportunity to extend this research to further understand and thoroughly explore factors (such as agency issues) that may aggravate the effects of climate shocks on women and hinder women's resilience to climate shocks.

Our results corroborate those found in other empirical works and confirm that climate shocks negatively impact households' food security status. We also find that the impact of climate shocks is significant for households with men plot managers but not for those with women plot managers. We note that crop diversification is linked to improved food security status with varying effects across gender groups. Another expected result is that crop diversification is constrained by different factors, such as limited access to large areas of land, poverty status and education level. Furthermore, these constraints are more pronounced for households with women plot managers, and this may induce the need for more gender targeting in agricultural policies. Due to data limitations, we unable to further explore the constraints that limit crop diversification among households but suggest these variables need to be explored in future studies.

Our results have important implications for Nigeria's food security and development policy and offer valuable avenue for agricultural transformation in Sub-Saharan Africa. First, government and non-government organizations should address the problem of climate shocks impacting households, and focus plausible solutions such as, crop diversification policy options, on households with predominantly women plot managers. Second, households should be encouraged to take up crop diversification strategies to mitigate the effect of climate shocks. This could be done by educating households about crop diversification strategies and providing cash transfers and subsidies to help households diversify more easily. Households should also be provided with access to inputs such as land, fertilizer, and seeds encourage diversification. Finally, women empowerment program should include components to help women more easily diversify.

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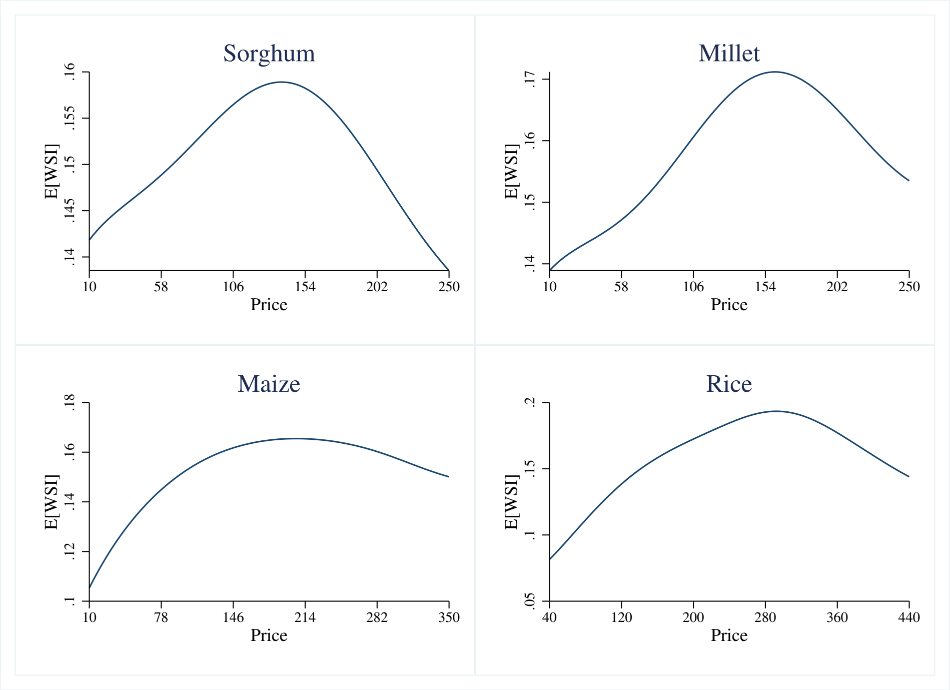
Appendices

A The link between prices and crop diversification

What link might exist between prices and crop diversification?
Assume that a farmer cultivates four crop items (sorghum, millet, maize, and rice) on equal areas of land. An increase in the price of only one crop will trigger him/her to increase the amount of land allocated to that crop and thus reduce his/her crop diversification. Also, a large decrease in the price of only one crop will trigger him/her to decrease the amount of land dedicated to that crop and thus reduce his/her crop diversification.

Of course, as one can deduce, the nature of a change in diversification also depends on the initial state of the farmer's crop diversification before price changes. The following figure shows the link between prices and the diversification index using the LSMS-ISA dataset for Nigeria.

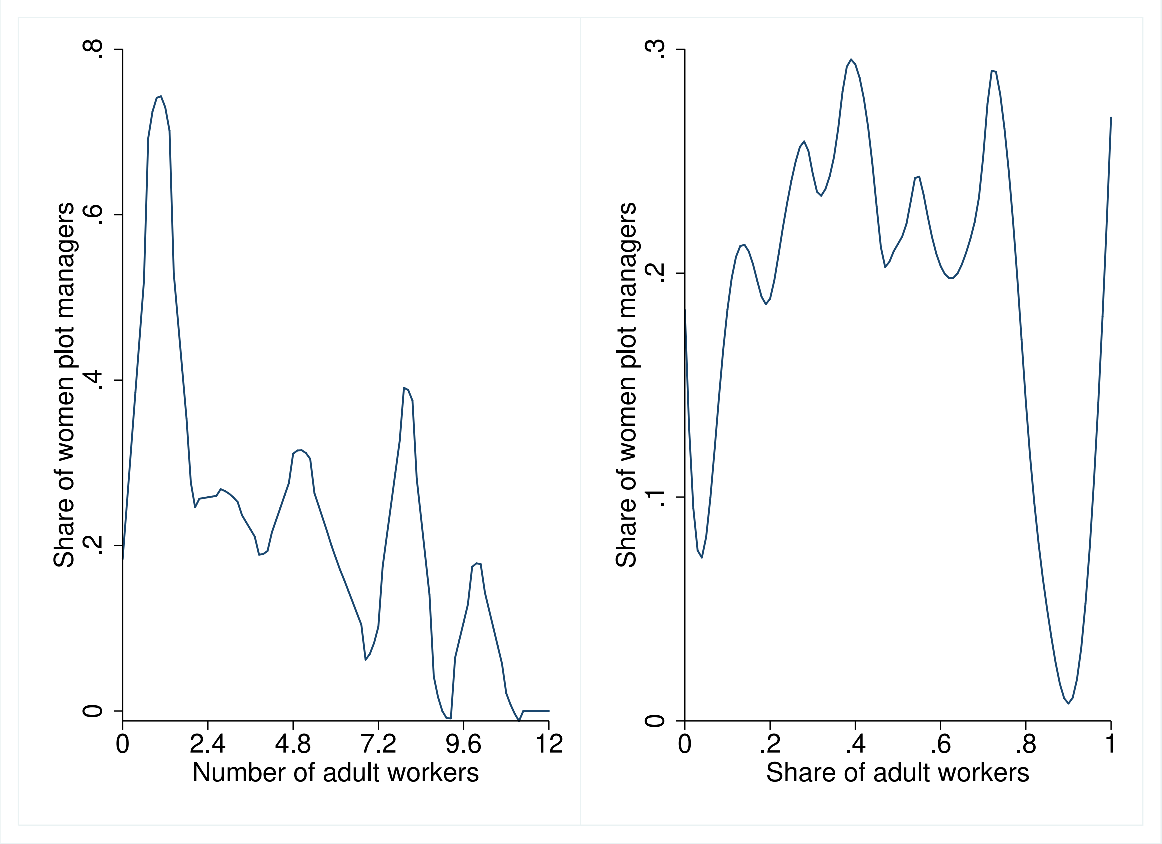
Figure A.1: Relationship between the Consumer Price Index of Food (CPI) and weighted Shannon index (WSI)



<u>Source</u>: *Authors' calculations using LSMS-ISA data*

B Labour market participation and plot management

Figure B.1: Adult workers and share of women plot managers



Source: Authors' calculations using LSMS-ISA data

C Results of spatial correction with the fixed effect model

Table C.1: Crop diversification, climate shocks, and food security

	Dietary diversity fixed effect	Dietary diversity	Dietary diversity	Dietary diversity
		(dis 10)	(dis 50)	(dis 500)
Crop diversification index (WSI)	0.9076***	0.9076***	0.9076***	0.9076***
	(0.1666)	(0.1666)	(0.1666)	-0.2501
Climate shocks:				
Drought	-0.2898***	-0.2898***	-0.2898***	-0.2898
	(0.0810)	(0.0810)	(0.0810)	-0.154
Flooding	0.1145	0.1145	0.1145	0.1145
	(0.2409)	(0.2409)	(0.2409)	-0.2445
Plot characteristics:				
Share of women plot managers	-0.0401	-0.0401	-0.0401	-0.0401
	(0.1369)	(0.1369)	(0.1369)	-0.1428
Agric. input cost (in log // per hectare)	-0.0390***	-0.0390***	-0.0390***	-0.0390*
	(0.0084)	(0.0084)	(0.0084)	-0.0152
Household characteristics:				
Dependency ratio	0.0691	0.0691	0.0691	0.0691
	(0.0490)	(0.0490)	(0.0490)	-0.0434
Age of household head	0.0143***	0.0143***	0.0143***	0.0143***
	(0.0037)	(0.0037)	(0.0037)	-0.0033
Share of women plot mgrs*WSI	-0.0652	-0.0652	-0.0652	-0.0652
	(0.3256)	(0.3256)	(0.3256)	-0.3063
Constant	0.0000	0.0000	0.0000	0
	(0.0163)	(0.0163)	(0.0163)	-0.0733
Observations	17,730	17,730	17,730	17,730
Residual sum of squares		3.1e+04	3.1e+04	3.10E+04
Centered R2 (1-rss/tss)		0.0163	0.0163	0.0163
Uncentered R2		0.0163	0.0163	0.0163
R-squared	0.016			
p	0			
F	21.52			

*Standard errors in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001*
Source: Produced by the authors using LSMS-ISA data.

Table C.2: Hausman fixed-between tests for dietary diversity

	Fixed (b)	Between (B)	Difference (b-B)	SE. sqrt(diag(V_b-V_B))
Crop diversification index (WSI)	.9347308	.0941292	.8406015	.
Drought	-.2828474	-.3155107	.0326632	.
Flooding	.1246227	1.527958	-1.403335	.
Share of women plot managers	-.0729437	.5117711	-.5847147	.
Log of agri. input cost	-.0393364	.0820963	-.1214326	.
Dependency ratio	.0708542	.0381884	.0326658	0.0213179
Age of household head	0.0145399	0.0031431	0.0113968	0.0024768
Share of women plot mgrs*WSI	.0026643	1.235135	-1.23247	.
Chi-square test value	-3675.641			
P-value	1			

Table C.3: Hausman fixed-between tests for reduced Coping Strategy Index

	Fixed (b)	Between (B)	Difference (b-B)	SE. sqrt(diag(V_b-V_B))
Crop diversification index (WSI)	3.282211	1.868579	1.413632	.
Drought	-0.1614074	-4.469479	4.308072	.
Flooding	2.712227	9.945038	-7.232812	.
Share of women plot manager	0.1668549	3.378122	-3.211267	.
Log of agri. input cost	-0.0530507	0.1172349	-0.1702855	.
Dependency ratio	0.1099642	-0.0402422	0.1502064	0.1141799
Age of head	-0.0214491	0.0196209	-0.0410699	0.0101791
Share of women plot mgrs x WSI	-0.2088079	0.2818961	-0.490704	.
Chi-square test value	197.604			
P-value	0			

Table C.4: Hausman fixed-between tests for Log of food PCE

	Fixed (b)	Between (B)	Difference (b-B)	SE. sqrt(diag(V_b-V_B))
Crop diversification index (WSI)	0.1038319	-0.3828854	0.4867173	.
Drought	-0.4880652	0.1258882	-0.6139534	.
Flooding	-0.0261274	0.3893171	-0.4154446	.
Share of women plot manager	-0.1672842	0.1364099	-0.3036941	0.0256845
Log of input cost	-0.1126999	0.0070492	-0.1197492	0.0006784
Dependency ratio	-0.0543881	-0.1896695	0.1352814	0.0168591
Age of head	-0.0106891	0.0018099	-0.012499	0.001688
Share of women plot mgrs x WSI	0.4552999	1.109247	-0.6539469	.
Chi-square test value	24674.244			
P-value	0			

D Gender-disaggregated effects

Table D.1: Crop diversification, climate shocks, and reduced Coping Strategy Index using system GMM model

	rCSI	rCSI, women	rCSI, men
First lag - Reduced Coping Strategy Index	0.0935	0.0184	0.2456*
	(0.1242)	(0.3681)	(0.1137)
Second lag - Reduced Coping Strategy Index	-0.0494	-0.1169	0.0170
	(0.0477)	(0.1480)	(0.0488)
Crop diversification index (WSI)	11.4150*	21.6137*	5.6760
	(4.7392)	(10.0342)	(4.7915)
Lag of Crop diversification index (WSI)	13.8630***	21.6705*	9.7402**
	(4.0753)	(9.9813)	(3.5181)
Climate shocks:			
Drought	-40.5768**	-66.0641	-22.1265*
	(13.7893)	(42.0728)	(11.2164)
Flooding	-57.2754	-92.8497	-77.4098
	(58.3281)	(103.0910)	(83.2298)
Plot characteristics:			
Agric. input cost (in log per hectare)	-5.8819	-5.0840	-3.6480
	(3.6054)	(3.7657)	(4.1466)
Household characteristics:			
Dependency ratio	12.8810**	5.9812	8.9542
	(4.6346)	(10.2313)	(7.9631)
Age of household head	0.1265	0.2742	0.0130
	(0.4240)	(0.4851)	(0.4889)
Constant	-30.4391	-28.4684	-15.8147
	(22.8051)	(44.0337)	(19.8692)
Observations	4,717	1,057	3,660
Sargan statistic	12.5575	4.2876	19.8800
Hansen J statistic	13.4789	8.5565	16.2302
p value of AR(1) statistic	0.0001	0.1207	0.0000
p value of AR(2) statistic	0.7064	0.2329	0.6879

*Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Source: Produced by the authors using LSMS-ISA data.

Table D.2: Crop diversification, climate shocks, and food expenditures: *System GMM model*

	Log of food PCE	Log of food PCE, women	Log of food PCE, men
Lag of Log of food PCE	-0.1844	-0.1424	0.0312
	(0.1469)	(0.1406)	(0.2627)
Crop diversification index (WSI)	-3.3423*	-1.2689	-4.9882**
	(1.5935)	(1.5316)	(1.8885)
Lag of crop diversification index	3.4590**	2.4100	2.6478
	(1.0618)	(1.8131)	(1.3558)
Climate shocks:			
Drought	-2.7057	-4.5265	0.8524
	(2.6186)	(3.3263)	(3.0700)
Flooding	-1.8e+02***	-46.0268***	-2.2e+02***
	(26.6189)	(11.9423)	(61.9352)
Plot characteristics:			
Agric. input cost (in log // per hectare)	0.8185***	0.2719	1.1825***
	(0.2153)	(0.1553)	(0.1658)
Household characteristics:			
Dependency ratio	1.2110	-0.3532	-1.7968
	(3.3981)	(0.8054)	(1.5255)
Age of household head	0.2457	0.0152	0.5546***
	(0.1853)	(0.0836)	(0.1527)
Constant	-3.3172	11.9060**	-15.4100
	(10.6306)	(3.8080)	(8.3538)
Observations	12,561	2,289	10,272
Sargan statistic	176.0050	42.4785	384.6373
Hansen J statistic	152.8271	80.4811	311.6806
p value of AR(1) statistic	0.0060	0.3023	0.0142
p value of AR(2) statistic	0.7154	0.9083	0.4209

*Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*
Source: Produced by the authors using LSMS-ISA data.

E Extra descriptive results

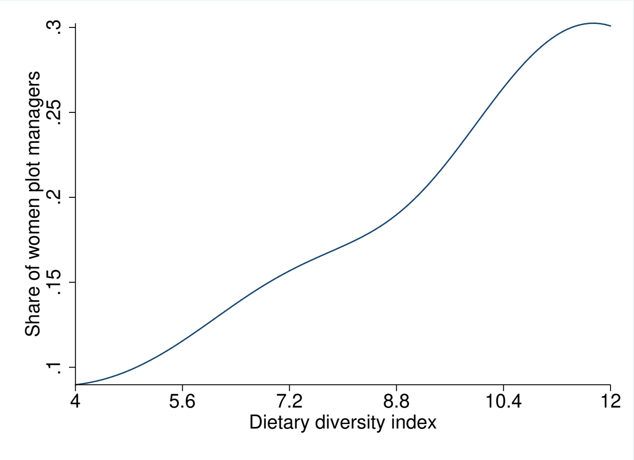
Table E.1: Summary statistics at baseline by gender of the household head at the household level

Variable	**Total**	**Women HH**	**Men HH**	**ttest difference**
Land size (ha)	28.10	17.10	31.00	13.91
Household size	6.00	4.90	6.40	1.500***
Age of head (years)	50.80	56.40	49.30	-7.077***
Woman head (1=Yes)	0.11	0.53	0.00	-0.531***
Adult equivalence	3.20	2.30	3.40	1.144***
At least one literate hh member (1=Yes)	0.67	0.78	0.64	-0.132***
Per capita expenditure	20044.40	29906.90	17444.20	-12462.8***
Share of women	0.50	0.40	0.53	0.122***
Number of women workers in any sector	0.80	1.10	0.70	-0.332***
Number of workers in any sector	1.70	1.70	1.70	-0.03
Total number	2859.00	601.00	2258.00	2859.00

** $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

Source: Produced by the authors using LSMS-ISA data.

Figure E.1: Gender and food security



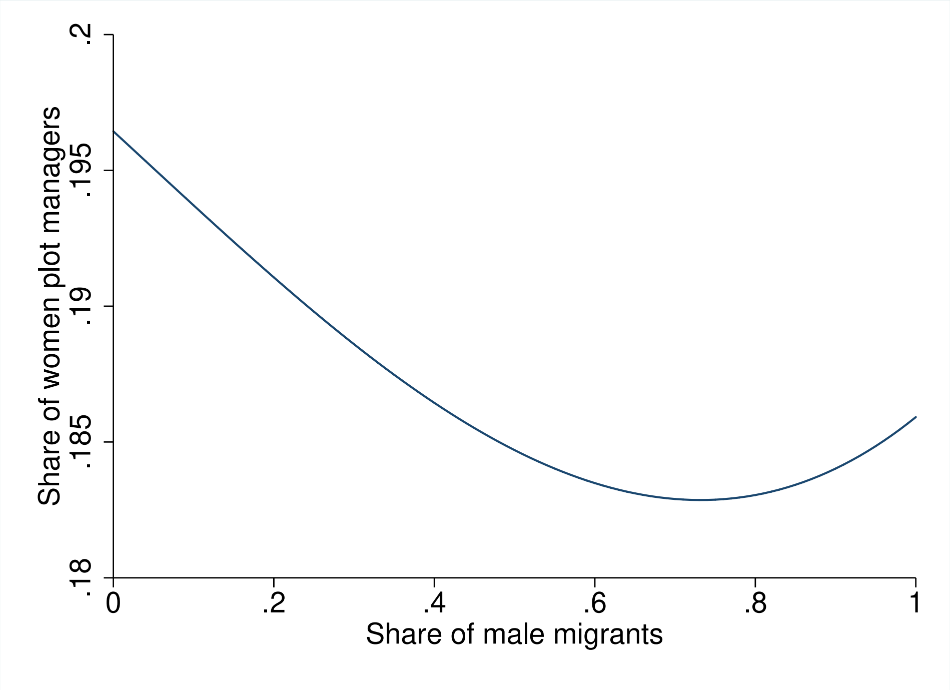
Source*: Authors' calculations using LSMS-ISA data*

Households with women plot managers are more food secure. They also cultivate highly diverse crops, which serves to buffer against climate shocks. Thus, all households, but especially households with men plot managers, are more exposed to climate shocks (drought and flooding)

Figure E.2: Gender, climate shocks, and food security

Source: Authors' calculations using LSMS-ISA data

Figure E.3: Gender, migration, and plot management



Source: Authors' calculations using LSMS-ISA data