INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

IFPRI

IFPRI Discussion Paper 01716

March 2018

Farmers' Crop Choice Decisions: Trends and Determinants in Nigeria and Uganda

Mulubrhan Amare

George Mavrotas

Hyacinth Edeh

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

AUTHORS

Mulubrhan Amare (m.amare@cgiar.org) is an associate research fellow with IFPRI's Nigeria Strategy Support Program, based in Washington, DC.

George Mavrotas (g.mavrotas@cgiar.org) is a senior research fellow in the Development Strategy and Governance Division of the International Food Policy Research Institute (IFPRI) and Leader of the Nigeria Strategy Support Program, based in Abuja, Nigeria.

Hyacinth Edeh (h.edeh@cgiar.org) is a research analyst with IFPRI's Nigeria Strategy Support Program, based in Abuja, Nigeria.

Notices

Contents

Tables

ABSTRACT

This study investigates how farmers allocate their available farm land under various drivers of crop choice. We also investigate the determinants and trends of crop area and income diversification. We use panel data from nationally representative household-level surveys for Nigeria and Uganda that contain rich socioeconomic and demographic information, merging the survey data with detailed weather shocks and land cover change. We use both the shares of land and income of the major crop categories to measure farmers' crop choice decisions. Our main results using seemingly unrelated and fixed-effects regression models for crop choice decision and crop diversification are summarized as follows. We find that weather shocks affect farmers' crop choice decisions, but effects differ across major crop categories. For example, we find that rainfall shocks increase the land share of pulses in both countries. However, rainfall shocks have a negative effect on the land share of tuber crops in Nigeria and cash crops in Uganda. We also find that increased land cover decreases the land share of pulses and tuber crops, whereas it increases the land share of cereal crops in Nigeria. For Uganda, increased land cover increases the land share of tuber crops and cash crops, whereas it decreases the land share of cereal crops. The analysis also highlights the importance of household characteristics, plot characteristics, and road accessibility in explaining farmers' crop choice decisions, measured using land and income shares of major crops. We also examine the determinants of crop diversification using both crop area and income diversification. The results show that significant variables are heterogeneous in sign and magnitude across the two countries. Similarly, we find that socioeconomic variables and plot characteristics play a significant role in explaining crop area and income diversification in both countries. To elucidate appropriate policymaking in response to rural transformation, the use of in-depth country-specific analysis of crop diversification and farmers' crop choice decision-making processes seems to be very timely and relevant.

Keywords: Crop choice decisions, weather shocks, crop diversification, Nigeria, Uganda

ACKNOWLEDGMENTS

The authors would like to thank Mekamu Kedir Jemal for excellent research support regarding GIS data for this paper. The research presented here was conducted as part of the CGIAR Research Program on Policies, Institutions, and Markets (PIM), which is led by IFPRI. Any opinions expressed here belong to the authors and do not reflect those of IFPRI, PIM, or CGIAR.

1. INTRODUCTION

Households in developing countries are exposed to a variety of uninsured risks due to insurance and credit market imperfections and because they are often highly dependent on subsistence agriculture for their livelihoods (Dercon and Christiaensen 2011; Barrett and Carter 2013). High levels of risk caused by climate variability threaten many rural households in developing countries. These risks have strong implications for the economy because a large share of the population lives in rural areas, and agriculture continues to account for approximately three-fourths of total household incomes in sub-Saharan African countries.

Engaging in activities that are less susceptible to disruption from climate impacts is one way for rural households to manage uncertainty surrounding the future effects of weather variability on agricultural production (Newsham and Thomas 2009). One of the strategies adopted by farmers of developing countries to mitigate the effects of weather variability is to diversify their crop portfolios (Barrett and Carter 2013; Mitter, Heumesser, and Schmid 2015). However, the extent of crop diversification as a risk-coping strategy crucially depends on the risk-bearing capacities of households that rely on the household level of assets and the perception of weather variability (Dercon and Christiaensen 2011; Stuart, Schewe, and McDermott 2014). For poor farmers, who have the lowest capacity to effectively manage risk, crop diversification may be a response to constraints imposed upon them by increasing climate risk (Howden et al. 2007). In this sense, they are pushed into diversification by a lack of alternatives for risk coping. In contrast, wealthier households may be pulled into crop diversification by the existence of welfare-increasing diversification options as well as their own capacity to access them (Ellis 2000). Besides spatial considerations and access to public services, heterogeneities such as topography and land cover change also play a significant role in farmers' crop choice decisions (Jalan and Ravallion 2002).

Consequently, weather variability and land cover change can affect how individuals use or manage available land, particularly for agricultural purposes that serves as a major source of livelihood in most African countries. Of concern, however, is the fact that sub-Saharan Africa will continue to face these two challenges in addition to other socioeconomic issues in an intricate web of relationships. These dynamic relationships are expected to influence future crop choice decisions both at local and national levels in the region. However, empirical evidence of how the relationships of these factors shape different nodes of crop choice decision at national levels remains scarce. For instance, while the relationship between weather shocks and land use at subnational and national levels is well documented using spatiotemporal data (You et al. 2011; Hegazy and Kaloop 2015; Zoungrana et al. 2015), such documentations are scarce for other drivers of land use (Marcos-Martinez et al. 2017), which limits the usefulness of any outcome. Although spatiotemporal variations in ecological factors are useful for a proper understanding of crop choice decisions at higher levels, controlling socioeconomic and demographic variables at the micro level can yield a better understanding of how individual land users, particularly farmers, make crop choice decisions.

Against this background, this paper investigates how farmers allocate their available farm land under various drivers of crop choice by integrating especially those related to agroecological, socioeconomic, and demographic factors at the micro level. We use panel data from nationally representative household-level surveys for Nigeria and Uganda that contain rich socioeconomic and demographic information, merging the survey data with detailed weather variability and land cover information. We address the following three questions: (1) What is the nature of crop choice and diversification trends in the two countries? (2) Is there a spatiotemporal sequence in crop choice decisions vis-à-vis crop diversification practices? (3) What are the roles of land cover, weather, and socioeconomic indicators in explaining farmers' crop choice decisions? We use both the shares of land and income of the major crop categories to measure farmers' crop choice decisions.

Our main results using seemingly unrelated and fixed-effects regression models for crop choice decision and crop diversification are summarized as follows. We find that weather shocks affect farmers' crop choice decisions, but effects differ across major crop categories. For example, we find that rainfall shocks increase the land share of pulses in both countries. However, rainfall shocks have a negative effect on the land share of tuber crops in Nigeria and cash crops in Uganda. We also find that increased land cover decreases the land share of pulses and tuber crops, whereas it increases the land share of cereal crops in Nigeria. For Uganda, increased land cover increases the land share of tuber crops and cash crops, whereas it decreases the land share of cereal crops. The analysis also highlights the importance of household characteristics, plot characteristics, and road associability in explaining farmers’ crop choice decisions. We also examine the determinants of crop diversification using both crop area and income diversification. The results show that significant variables are heterogeneous in sign and magnitude across the two countries. Similarly, we find that socioeconomic variables and plot characteristics play a significant role in explaining crop area and income diversification in both countries.

The contribution of this paper to the literature is twofold: First, it contributes to the scarce empirical evidence that shows the influence of diverse factors at various scales of crop choice, especially in sub-Saharan Africa. For instance, global remote sensing products including land cover changes and weather variability were combined with plot-level biophysical factors. This combination can provide useful location-specific information for the promotion of sustainable food production practices and the fight against poverty across households. It would also shed light on designing rural development programs tailored to farmers to improve their livelihoods under these changing factors. Second, this study is the first crop choice study in Nigeria and Uganda (to the best of our knowledge) that employs nationally representative panel data, which allows us to estimate the determinants of farmers' crop choice decisions nationwide.

The rest of the paper is organized as follows: Section 2 presents the conceptual framework, and section 3 presents the empirical model and the identification strategy. The empirical results are presented in section 4, before we conclude in the final section, highlighting the main findings and policy implications of the study.

2. CONCEPTUAL FRAMEWORK

This section presents the literature on the determinants of crop choice decisions in developing countries. We use this framework to investigate the nature of crop choice decisions and the effect of weather shocks, land cover changes, and socioeconomic indicators.

Uncertainty in weather conditions poses a serious challenge to food production, farming households' capacity to plan, and rural livelihoods (Akanda 2011; Hochman et al. 2017). Weather variability, particularly rainfall, constitutes a major environmental input for production activities in rainfed agriculture. Like other production inputs, the consideration of weather variability in farm production remains part of farmers' crop choice decision making processes (Bert et al. 2006; Lehmann, Briner, and Finger 2013; Robert et al. 2016), particularly in Africa, where most of the farmers are smallholders and agricultural production is climate dependent. For example, studies (e.g., Chalise and Naranpanawa 2016; Asante et al. 2017) find that farmers tend to allocate land to crops that are comparatively less impacted by climate change. Similarly, farmers adapt to the incidence of drought by abandoning farming, reducing the land area cultivated, and changing of current crop types to maintain agricultural production (Akanda 2011; Yang et al. 2016). Crop choice decision is based on farmers' level of agricultural income and dependence on agriculture as a livelihood source, such that households that have higher crop and livestock income are less likely to either abandon farming or change crop types, preferring rather to reduce their crop areas (Mertz et al. 2009; Akanda 2011; Makate et al. 2016; Yang et al. 2016).

Crop diversification, a practice of cultivating more than one variety of crops belonging to the same or different species in a given area in the form of rotations, intercropping, or both, has been identified as a response to climate change impacts (Mertz et al. 2009; Makate et al. 2016). Smallholder farmers adopt crop diversification to protect them against total crop failure or the effects of reduced crop yields. Therefore, the decision to employ this strategy is an indication of the influence of the threat of climate change on various facets of their household food security. Farmers in sub-Saharan Africa respond to climate change by adopting the multiple cropping system, which allows for intensification by growing two or more crops on the same field either at the same time or after each other in a sequence (Waha et al. 2013).

Furthermore, the decision to put a parcel of farmland under any sustainable agricultural practices is determined by plot, household and village characteristics, including rainfall (Teklewold et al. 2013). The weather-related information, especially on the amount, timing, and distribution of rainfall, can have a significant effect on the farmers' decision to adopt and use sustainable agricultural technologies on farmland (Teklewold and Mekonnen 2017). Farmers adopt different tillage intensity according to the prevailing weather conditions in their location. This implies that farmers can take advantage of reduced rainfall variability to put their farmland into more than one cropping season, particularly for crops with a shorter growing period, to improve their farm income earnings (Howden et al. 2007; Barrett and Carter 2013).

The choice of crop to be grown also depends on the extent and degree of capability and suitability of the land resources in any location. The normalized difference vegetation index (NDVI) is one of the indicators usually employed in the literature to assess the capability and suitability of the land resources. It empirically measures vegetation change through satellite imagery based on visible and near-infrared bands of the electromagnetic spectrum (Walsh et al. 2001). It uses the multispectral remote sensing data technique to monitor spatiotemporal variation in such features as urban area, agricultural land, water bodies, and forest type, among others (Dong et al. 2016). It also provides an indication of the vegetation density, differentiating between vegetated and barren land areas, agricultural land, and forest cover (Samal and Gedam 2015). Consequently, it has the potential to be used as a parameter for land cover condition (Ghandhi et al. 2015; Dahigamuwa, Yu, and Gunaratne 2016), agricultural production (Yin et al. 2012), and climate change risks, particularly drought (Zoungrana et al. 2015).

NDVI, therefore, has implications for the crops grown in a geographical area. The NDVI techniques are used to study crop patterns and crop suitability (Bharathkumar and Mohammed-Aslam 2015). Some studies (Onţel and Moroşanu 2014) also use NDVI values as indicators for drought and vegetation density, and they observe that very low NDVI values of between -0.2 and 0.1 reflect low vegetation density corresponding with dry years in the study area (Onţel and Moroşanu 2014). This observation has a potential influence on crop choice if farmers are to maintain or increase yield. A major option will therefore be for farmers to switch to other crops that are more drought resistant. The NDVI metric as an indicator of land cover condition has also been used to capture changes in land cover conditions (Tadesse et al. 2017) and as an indicator for long-term change in soil fertility, which can help farmers decide on inputs and input uses, including those related to fertilizer and crops (Fabiyi, Ige-Olumide, and Fabiyi 2013). Since farmers would make land allocation and crop selection decisions based on soil biophysical and management attributes, which can be derived using the NDVI, it is implied that NDVI has the potential to influence crop choice decisions.

3. HOUSEHOLD CROP CHOICE DECISION DETERMINANTS

A farmer's crop choice decision-making process is thought to be implicit and internal, cyclical and recurrent, leading to a better understanding and evaluation of production terrains over time (Aubry, Papy, and Capillon 1998). As the basic farm decision-making unit, the farmer makes critical decisions in agricultural production, particularly on land use and farm resource allocation. The nature and extent of such decisions are usually motivated by the goals, objectives, and values of the farming households (Wallace and Moss 2002). They are also guided by prevailing socioeconomic and environmental constraints including those outside the farmers' control. The determinants of crop choice decision-making processes, particularly among smallholder farmers, have been examined in various empirical studies and can be broadly classified into economic, biophysical, psychological, technological, policy and institutional (Willock et al. 1999; Wallace and Moss 2002; Verburg et al. 2004; Sakane et al. 2014; Wang et al. 2017), and sociocultural factors such as demographics, endowment, and credit constraints (Mottet et al. 2006; Nguyen et al. 2017).

Crop choice decisions are made by utility-maximizing individuals (Verburg et al. 2004), implying that economic factors that influence crop choice decisions are rooted in neoclassical economic theory of profit maximization. As such, factors that encourage increasing returns to farm investment will guide decisions of farming families, such that resource allocation is made toward achieving pecuniary goals. Farmers choose uses to maximize the present discounted value of the stream of expected net benefits from the land and base their expectations of future land-use profits on current and historic values of relevant variables, such as costs of land conversion (Lubowski, Plantinga, and Stavins 2008). Therefore, a farmer decides how to use a parcel of land after estimating, either implicitly or explicitly, the costs and benefits of the proposed actions.

Furthermore, the combination of crop portfolios follows the differential input (land and labor) productivity and risk status of farmers (Lubowski, Plantinga, and Stavins 2008). For instance, farmers would combine less risk, high labor, and a low land productivity crop portfolio (oil palm) with higher risk, low labor, and high land productivity crop portfolio (rubber). Economic factors such as poverty, imperfect capital markets, and insecure land tenure play a significant role in rural household decisions to shift land use from short-term to long-term investment production (Barbier 1997). Nonpoor households take advantage of their market power to have access to better farming environments and investment opportunities to affect crop choice decisions (Howden et al. 2007; Barrett and Carter 2013). The plot's biophysical conditions (slope and elevation), farm structure, and technological change (introduction of tractors), also play a significant role in explaining crop choice decisions (Mottet et al. 2006). Furthermore, the farmers' demographic characteristics play a substantial role in crop choice decision-making at the household level (Briassoulis 2009; Hettig, Lay, and Sipangule 2016; Mwaura and Adong 2016). Demographic characteristics and input supply play a remarkable role in whether landowners would switch between various crop choice options available to them. Again, the shift from cash crops to cereals, pulses, and tuber production underlie the effect of political instability in crop choice decision-making. The geographical location (distance and accessibility) of output markets influences shifts in the share of land allocated to crops (Briassoulis 2009; Ebanyat et al. 2010; Jiang, Deng, and Seto 2013; Mwaura and Adong 2016).

4. DATA SOURCES AND VARIABLE DESCRIPTION

Data Sources

The study uses three wave panel data sets from the Living Standards Measurement Study—Integrated Surveys on Agriculture (LSMS-ISA) from Nigeria and Uganda. The LSMS-ISA data sets are nationally representative and the significant degree of uniformity in the survey instruments used across countries offers a unique opportunity for cross-country comparison. These nationally representative data sets include detailed information on demographic and household characteristics, assets, agricultural production, nonfarm income and other sources of income, allocation of family labor, hiring of labor, and access to services. The agriculture module, among others, contains information on agricultural and livestock production, farm technology, use of modern inputs, and productivity of crops and livestock. The community-level instrument contains information on local level infrastructure, basic public goods, nature of agricultural land, precipitation, and other factors that could affect the farmers' crop choice decisions.

Since we have geolocalized households, we merge the Nigeria and Uganda LSMS-ISA data with weather shock variables and land cover condition data. Weather shock and the NDVI measure for land cover condition change come from the daily African Rainfall Climatology Version 2 (ARC2) of the National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA-CPC) and advanced very high-resolution radiometer.

Description and Choice of Variables

Building on the literature, we investigate determinants and trends of crop choice decisions using two sets of measurements. First, we measure crop choice decision using land shares to land use alternatives and income shares of major crop categories to total crop income. To do so, we divide the total farm land area and crop income of a household into five categories of crops, including cereal crops, pulses, tubers, cash crops, and other uses. Cereal crops include maize, sorghum, millet, and rice, while pulse crops include bean, cowpeas, and chickpeas. Tubers include cassava and yam, while cash crops include fruits, coffee, tea, oil palm, and rubber. Other uses include fish ponds or self-employed businesses. The shares of these five land use types (in percentage) are the dependent variables of the first set of regression models. The classification of these five land use types demonstrates the farming activities of farmers of the study areas. Income shares are also used to understand the extent of dependence or reliance on major crop categories as the major source of crop income and the key determinants. Therefore, the income share measurement mainly focuses on one metric of the extent of dependence on major crop categories (Barrett et al. 2005).

Second, we use different indices to determine factors affecting crop diversification, which is measured via the crop diversification index. Both the cropland area share index and the crop income share index are employed. The Herfindahl-Simpson concentration index is used to examine the extent to which households diversify income across various sources (Barrett et al. 2005). The index is computed as equal to the sum of the shares across each possible income source. A value of one indicates complete dependence on a single income source, while a value of 1/*k* represents perfectly equal earnings across income sources, where there are *k* different income source categories analyzed. The literature employs the Simpson Index of Diversification (SID) (Minot 2006; Baird and Gray 2014) to construct the diversification indexes, and the extent of income from major crops and total cropped area to represent the diversification. Thus, the indexes are calculated as follows:

$$\mathrm{SID}_{it} = 1 - \sum_{k=1}^{n} SL_{kit}^{2} \tag{1}$$

where SID_{it} is the Herfindahl-Simpson concentration of household i in year t; SL_{kit}^{2} is either the land share or the income share of crop k in total farm land or total net crop income of household i in year t. In the case of land share, it is the cropland share diversification index, and in the case of income share, it is the crop income share diversification index. The value of each SID_{it} index can vary between zero and one. If household i grows only one crop in year *t*, then $SL_{kit} = 1$, and thus $\mathrm{SID}_{it} = 0$. As the number of cultivated crops increases, the shares (SL_{kit}) decline, as does the sum of squared shares, and SID_{it} approaches the value of one. The larger the value of SID_{it}, the more diversified is the crop portfolio of household i in year t. These two indices are dependent variables in the second set of regression models.

To measure the impact of weather shock variables on the farmers' crop choice decisions, we follow the previous literature (Macinni and Yang 2009; Björkman-Nyqvist 2013; Rocha and Soares 2015). First, we adopt the conventional measure of rainfall shocks as a deviation of a given year's rainfall during the growing season (monsoon season) from the historical averages (for 30 years) during the crop growing season for the same locality. We measure the rainfall shocks variable as log-deviation from historical average as follows:

$$\text{rainfall shock } (RS)_{it} = \ln(R_{it}) - \ln(\bar{R}_{it}) , \tag{2}$$

where R_{it} indicates the rainfall during the growing season at the location of household i for year t, and $\bar{R}$ is the historical average rainfall (for 30 years) during the growing season at the location of household i. The rainfall deviation implies a percentage deviation from mean rainfall (Macinni and Yang 2009). Second, we also measure rainfall shocks using a dummy variable designed to capture extreme events as follows:

$$\text{negative rainfall shock } (NRS)_{it} = 1 \text{ if } R_{it} < \left(\bar{R}_{it} - R_i^{SD}\right) , \tag{3}$$

where $\bar{R}_{it}$ is historical average rainfall during the growing season; R_i^{SD} is the standard deviation of rainfall during the growing season at the location of household i (calculated over the 30-year period). Therefore, $NRS = 1$ as the indicator of the weather shock indicates that the rainfall during the growing season for a given year was more than one standard deviation below the historical average rainfall during the growing season at the location of household i.

5. EMPIRICAL MODEL

Building on the previous section, we investigate the factors that drive the farmers' crop choice decision-making process, mainly the impact of rainfall shocks and land cover change on a household's crop choice decision. We first estimate land share to total land available and income share of major crop categories to total crop income using the following model:

$$SL_{itk} = \gamma_c \mathrm{RS}_{it} + \gamma_c L_{it} + \beta_x X_{it} + \nu_{ik} + \varepsilon_{itk} , \qquad (4)$$

where SL_{itk} is the share of land use and income share of major crop categories to total crop income type k by household i in year t. RS_{it} is rainfall shocks, and L_{it} is land cover change at household level i in year t. Similarly, X is a vector of household and community characteristics, including education, household size, age, gender of the household head, household assets, and input use. The variable ν_{ik} is a household specific fixed effect, and ε_{itk} is the variant representing unobserved characteristics of household i in year t for land use type k. It is assumed to be a zero mean identically and independently distributed random error, which is assumed to be uncorrelated to all the explanatory variables.

As the total farm land area and income share of major crop categories to total crop income of a household in a particular year is fixed, the factors affecting the intensity of a specific crop choice type for a farm land area could also affect the intensity of other land use types (Kokoye et al. 2013). Since most rural households in this analysis allocated the same crop land to different major crop categories, cross-equation error terms will likely be correlated for the same household (Wooldridge 2010). This unique characteristic requires the application of the seemingly unrelated regression (SURE) model (Zellner 1962). The SURE model was developed to include joint estimates from several regression models, where the error terms associated with the dependent variables are assumed to be correlated across the following equations. Therefore, the empirical model of crop choice decision as "share of area allocated and share of income on major crops" is a set of five simultaneous equations as specified below:

$$\begin{cases} SL_{it1} = \gamma_{c1}RS_{it} + \gamma_{c1}R_{it} + \beta_1 X_{it} + \nu_{i1} + \varepsilon_{it1} \\ SL_{it2} = \gamma_{c2}RS_{it} + \gamma_{c1}R_{it} + \beta_2 X_{it} + \nu_{i2} + \varepsilon_{it2} \\ SL_{it3} = \gamma_{c3}RS_{it} + \gamma_{c1}R_{it} + \beta_3 X_{it} + \nu_{i3} + \varepsilon_{it3} \\ SL_{it4} = \gamma_{c4}RS_{it} + \gamma_{c1}R_{it} + \beta_4 X_{it} + \nu_{i4} + \varepsilon_{it4} \\ SL_{it5} = \gamma c_5 RS_{it} + \gamma_{c1}R_{it} + \beta_5 X_{it} + \nu_{i5} + \varepsilon_{it5} \end{cases} \tag{5}$$

where SL_{it1}, SL_{it2}, SL_{it3}, SL_{it4}, and SL_{it5} are the shares of farm land and income of major crop categories to total crop income of cereal crops, pulses, tubers, cash crops, and other uses, respectively, of household i in year t. As the sum of all land and income shares of household i is 100 percent, SL_{it5} is dropped during the estimation procedure.

Second, we estimate the determinants of crop area and income diversification indices and the effect of weather shocks and land cover change using fixed effects as follows:

$$SID_{it} = \gamma_c R_{it} + \gamma_c L_{it} + \gamma_x X_{it} + \lambda_{ik} + \vartheta_{itk} \ , \tag{6}$$

where SID_{it} is the Herfindahl-Simpson concentration of household i in year t as defined in Equation (1). The other variables are as defined above.[1]

[1] To collaborate our main results, we estimate the impact of extreme rainfall shocks on farmers' crop choice decisions using a dummy designed to capture extreme events. Our measure of the negative rainfall shock (extreme events) dummy indicates that the yearly seasonal rainfall was more than one standard deviation below seasonal rainfall historical averages.

6. RESULTS AND DISCUSSION

Descriptive Results

The results of the descriptive analyses of the sample households are presented in Table 6.1. The area shares of the major crop activity sectors indicate that crop priorities among farming households in Nigeria and Uganda are similar. However, the share of area cultivated to each crop category differs between the two countries. In Nigeria, for instance, 35 percent of the total area cultivated by households is allocated to cereals, compared with a 21 percent share of cereals in Uganda. Similarly, tubers, pulses, and cash crops share 28, 21, and 9 percent, respectively, of the total farm area of the Nigerian households. In Uganda, the corresponding figures are 21, 20, and 9 percent. The contribution of tubers, cereals, pulses, and cash crops to farming households' income are 35, 32, 16, and 7 percent in Nigeria, respectively. For Uganda, the corresponding contribution of these crops are 17, 19, 20, and 6 percent.

Expectedly, there is a direct relationship between the crop area and income diversification indices for both countries. The crop area diversification index for Nigeria and Uganda is 0.44 and 0.64, respectively. Their respective income diversification index is 0.36 and 0.43, indicating that farming households in Uganda are more diversified than farming households in Nigeria, producing a few more crops on their land and consequently, generating more diversified income sources. The estimated normalized difference vegetation index (NDVI) in Nigeria and Uganda is 0.39 and 0.59, respectively. Following the classifications of NDVI estimates by Ayehu and Besufekad (2015) and Ghandhi et al. (2015), Nigeria has a medium (shrub and grassland) vegetation cover, while Uganda has a dense (rainforest) vegetation cover. Also, the observed values for rainfall shortages is lower in Nigeria (-0.02) than in Uganda (-0.09).

Table 6.1 Descriptive statistics by country (pooled)

Variable description	Nigeria = 9,912		Uganda = 7,161	
	Pooled mean	Standard deviation	Pooled mean	Standard deviation
Share of area by major crops				
Pulse crops (share)	0.21	0.23	0.20	0.21
Tuber crops (share)	0.28	0.33	0.21	0.23
Cash crops (share)	0.09	0.17	0.09	0.16
Cereal crops (share)	0.35	0.29	0.21	0.23
Others (share-proportion)	0.07	0.16	0.09	0.19
Share of net income by major crops				
Pulse crops (share)	0.16	0.22	0.20	0.34
Tuber crops (share)	0.35	0.39	0.17	0.33
Cash crops (share)	0.07	0.17	0.06	0.19
Cereal crops (share)	0.32	0.33	0.19	0.34
Others (share)	0.09	0.20	0.10	0.26
Diversification index				
Simpson—area (share)	0.44	0.23	0.64	0.25
Simpson—income (share)	0.36	0.22	0.43	0.41
Weather variables				
Rainfall shortfall	-0.02	0.11	-0.09	0.18
Mean NDVI (share)	0.39	0.11	0.59	0.12
Household demographics				
Household size (AEU)	3.36	1.43	4.15	2.08
Dependency ratio	1.16	1.01	1.37	1.20
Gender of head (male = 1)	0.85	0.36	0.70	0.46
Education of head (years)	6.94	6.50	2.38	4.36
Age of head (years)	51.38	14.57	46.53	15.18
Inputs access				
Access to finance (Yes = 1)	0.61	0.49	0.05	0.23
Access to extension services (Yes = 1)	0.10	0.30	0.06	0.24
Apply fertilizer (Yes = 1)	0.36	0.48	0.16	0.36
Apply pesticides/herbicides (Yes = 1)	0.29	0.45	0.12	0.33
Amount of labor use (person-days)	773.95	3,354.55	354.24	1,321.02
Wealth indicators				
Livestock ownership (TLU)	11.91	19.53	0.41	2.24
Asset value (in NGN 1000/UGX)	34.54	285.49	5,446.05	26,900.00
Real crop income (in NGN 1000/UGX)	67.98	141.79	7,580.88	11,900.00
Real self-employment (in NGN 1000/UGX)	13.06	159.86	1,008.71	2,504.34
Real wage income (in NGN 1000/UGX)	25.29	826.79	1,648.55	3,617.45
Real remittances (in NGN 1000/UGX)	1.445	59.60	239.23	583.50

Table 6.1 Continued

Variable description	Nigeria = 9,912		Uganda = 7,161	
	Pooled mean	Standard deviation	Pooled mean	Standard deviation
Market and plot characteristics				
Distance to the main road (km)	8.74	12.21	7.27	7.59
Potential wetness index	14.43	3.12	12.23	2.36
Slope of the plot (%)	2.98	3.08	7.02	6.66

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All wealth indicator variables are given in adult equivalent units (AEU); TLU = tropical livestock unit; NGN = Nigerian naira; UGX = Ugandan shilling.

The results of the respondents' demographic characteristics show that the average household size (adult equivalent) is 3.36 and 4.15, respectively, for Nigeria and Uganda, with corresponding average dependency ratios of 1.16 and 1.37. A similar dominant pattern of having a male head of household is observed in both countries, while household heads in Nigeria tend to have completed more years of schooling than those in Uganda. Again, heads of households in Nigeria tend to be a little older, with an average age of 51 years, compared with Uganda, where their average age is 47 years.

Farm input access, as presented in Table 6.1, shows a wide gap between the two countries, with Nigeria having a greater advantage. The proportion of households with access to financial services over the study period is estimated to be 61 percent and 5 percent for Nigeria and Uganda, respectively. Although financial inclusion is higher in Nigeria than Uganda, it remains low when compared with the inclusion level in other African countries, such as South Africa (85 percent), Kenya (83 percent), Ghana (75 percent), and Rwanda (89 percent). Generally, access to farm inputs remains very low in both countries, though with a better outlook for Nigeria. The highest proportions of household access are recorded for fertilizer in both Nigeria and Uganda at 36 percent and 16 percent, respectively. Only about 10 percent of the households have access to extension services in Nigeria, compared with 6 percent of Ugandan farming households. Access to agrochemicals (pesticides and herbicides) and labor use follow the same trend. In terms of wealth indices, the average number of livestock owned per person is higher in Nigeria than in Uganda, with respective values of 1.23 and 0.41. Livestock ownership measured as tropical livestock unit (TLU).

We summarize the trends among farmers' crop choice decisions and diversification indices in Table 6.2. The trend in the share of area cultivated to different crop categories differs between countries. In Nigeria, pulses maintain an upward trend over the study period but show a decreasing trend in Uganda. For tubers, the trend fluctuates in Nigeria, with the area share increasing from 27 to 29 percent between year two and year three, after an initial decrease between year one and year 3; but Uganda shows a reverse trend. The share of land area for other crops exhibits a similar pattern. In both countries, the area share of cash crops shows a parabolic trend, while the area share of cereals decreases over the study period. Under the net income share by crop categories, pulses exhibit steady increases in Nigeria and a relatively constant share in Uganda over the study period. The share of tubers increases in Nigeria throughout the period under investigation but fluctuates in Uganda, while the share of cereals shows a decreasing trend in Nigeria and an increasing trend in Uganda. The extent of land area diversification and income diversification among farming households in Nigeria increases progressively over the period. In Uganda, the extent of land area diversification increases over the study period, but income diversification increases between 2010 and 2012 and decreases in 2015.

Table 6.2 Descriptive statistics of key interest variables by country

Variable description	Nigeria = 3,304			Uganda = 2,387		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Share of area by major crops						
Pulse crops	0.18	0.19	0.26	0.22	0.20	0.19
	(0.23)	(0.23)	(0.23)	(0.23)	(0.21)	(0.20)
Tuber crops	0.28	0.27	0.29	0.21	0.23	0.20
	(0.37)	(0.34)	(0.28)	(0.23)	(0.23)	(0.23)
Cash crops	0.07	0.10	0.09	0.08	0.10	0.08
	(0.17)	(0.17)	(0.16)	(0.16)	(0.17)	(0.15)
Cereal crops	0.38	0.36	0.31	0.23	0.22	0.19
	(0.32)	(0.27)	(0.27)	(0.24)	(0.23)	(0.23)
Others	0.07	0.08	0.05	0.07	0.06	0.14
	(0.18)	(0.17)	(0.13)	(0.19)	(0.18)	(0.19)

Table 6.2 Continued

Variable description	Nigeria = 3,304			Uganda = 2,387		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Share of net income by major crops						
Pulse crops	0.14	0.15	0.19	0.19	0.21	0.20
	(0.22)	(0.22)	(0.22)	(0.39)	(0.33)	(0.30)
Tuber crops	0.30	0.33	0.41	0.14	0.20	0.17
	(0.39)	(0.40)	(0.36)	(0.35)	(0.33)	(0.30)
Cash crops	0.08	0.08	0.07	0.04	0.06	0.06
	(0.18)	(0.17)	(0.15)	(0.20)	(0.19)	(0.19)
Cereal crops	0.38	0.33	0.26	0.18	0.17	0.23
	(0.35)	(0.33)	(0.30)	(0.39)	(0.30)	(0.34)
Others	0.09	0.10	0.07	0.13	0.06	0.09
	(0.21)	(0.22)	(0.16)	(0.34)	(0.19)	(0.23)
Diversification index						
Simpson—area	0.38	0.45	0.49	0.62	0.64	0.66
	(0.26)	(0.22)	(0.20)	(0.26)	(0.25)	(0.25)
Simpson—income	0.33	0.34	0.41	0.31	0.51	0.48
	(0.23)	(0.22)	(0.21)	(0.46)	(0.38)	(0.36)

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.

7. ECONOMETRIC RESULTS

Determinants of Crop Choice Decisions

Table 7.1 reports the fixed-effects estimates for determinants of the share of farm land allocated to major crop categories for both countries. The Breusch-Pagan (BP) test verifies the use of the SURE model, as it is statistically significant at the 1 percent level. The results indicate that several factors have statistically significant effects on the land shares of major crops. Some of these factors are common in both countries, but other factors are specific to each country.

Share of Area Under Major Crops

The results exploit exogenous variation in rainfall and indicate that rainfall shocks have negative effects on the land share of some crop categories and positive effect on the land share of other crop categories in both countries. Rainfall shocks increase the land share of pulses in both countries. A rainfall shock of one standard deviation increases the land share of pulses by 19 percent in Nigeria and 6 percent in Uganda. Rainfall shocks also increase the land share of cereal crops in Nigeria. However, rainfall shocks have a negative effect on the land share of tuber crops in Nigeria and cash crops in Uganda. The results indicate that farmers who experience rainfall shocks in Nigeria respond by making changes in crop choices from tuber crops to pulses and cereal crops, whereas farmers who experience rainfall shocks in Uganda respond by making changes in crop choices from cash crops to pulses. This finding may indicate that pulses are less affected by rainfall shocks, particularly if tolerable thresholds are not exceeded. This is consistent with the literature, which indicates that farmers tend to allocate land to crops that are comparatively less impacted by weather change (Ebanyat et al. 2010; Chalise and Naranpanawa 2016; Asante et al. 2017).

Table 7.1 Determinants of farm crop choice decisions (SURE FEs models) for major crops categories

Determinant	Share of area under crop							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Rainfall shock	0.196***	-0.237***	-0.045	0.212***	0.056***	-0.005	-0.017**	-0.008
	(0.035)	(0.041)	(0.026)	(0.041)	(0.014)	(0.016)	(0.008)	(0.014)
Land cover index	-0.516***	-0.250*	0.062	0.436***	-0.080	0.215***	0.147***	-0.149*
	(0.106)	(0.134)	(0.082)	(0.114)	(0.052)	(0.059)	(0.038)	(0.077)
Age of household head	0.031	0.049	0.011	-0.040	-0.003	-0.000	0.023***	-0.015
	(0.036)	(0.047)	(0.026)	(0.039)	(0.007)	(0.008)	(0.005)	(0.014)
Household size—AEU	0.086***	-0.140***	-0.017	0.117***	0.029***	-0.030***	0.003	0.036**
	(0.024)	(0.029)	(0.016)	(0.025)	(0.006)	(0.007)	(0.004)	(0.014)
Education of head	-0.002	0.000	0.006*	-0.002	-0.010***	-0.010***	-0.002	-0.009***
	(0.005)	(0.007)	(0.004)	(0.006)	(0.002)	(0.003)	(0.002)	(0.003)
Gender of head	-0.023	-0.116	0.032	-0.025	-0.027***	-0.019***	0.010**	0.018
	(0.059)	(0.162)	(0.085)	(0.115)	(0.006)	(0.006)	(0.004)	(0.017)
Dependency ratio	0.003	-0.003	0.005	-0.003	0.002	0.003	0.000	-0.004
	(0.005)	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)	(0.001)	(0.003)
Apply fertilizer	0.004	0.033***	0.010	-0.051***	-0.016**	0.019**	0.045***	0.018**
	(0.008)	(0.012)	(0.006)	(0.009)	(0.007)	(0.008)	(0.005)	(0.009)
Apply agrochemicals	-0.010	0.035***	-0.005	-0.024***	0.019**	-0.005	0.038***	0.010
	(0.008)	(0.012)	(0.006)	(0.008)	(0.008)	(0.009)	(0.005)	(0.010)
Access to extension	0.005	-0.048***	-0.002	0.042***	0.020**	-0.007	0.005	-0.007
	(0.012)	(0.016)	(0.009)	(0.012)	(0.009)	(0.011)	(0.007)	(0.011)
Access to credit	0.032***	-0.025***	-0.016***	0.020***	0.004	-0.013	0.003	0.006
	(0.007)	(0.009)	(0.005)	(0.008)	(0.010)	(0.011)	(0.007)	(0.012)
Land size	0.202***	-0.423***	-0.065***	0.374***	-0.001	0.011*	0.015***	0.025***
	(0.019)	(0.029)	(0.011)	(0.025)	(0.006)	(0.007)	(0.004)	(0.008)
Livestock—TLU	-0.005	-0.008	0.008**	-0.005	0.014**	-0.002	-0.008	0.001
	(0.005)	(0.007)	(0.003)	(0.006)	(0.007)	(0.008)	(0.005)	(0.012)
Asset value	0.000	-0.007***	-0.000	0.013***	0.002	0.001	0.004***	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Wage income	-0.005***	0.003***	0.002***	-0.000	-0.000	-0.000	-0.001**	-0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Self-employment income	0.003***	-0.005***	0.000	0.002***	0.000	-0.000	-0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Remittance income	0.001	0.005	-0.002	-0.003	0.000	0.001*	0.000	-0.000
	(0.003)	(0.004)	(0.002)	(0.003)	(0.000)	(0.000)	(0.000)	(0.001)

Table 7.1 Continued

Determinant	Share of area under crop							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Distance to main road	0.020***	0.017**	0.001	-0.012**	0.042***	0.020**	0.010**	-0.029
	(0.005)	(0.007)	(0.004)	(0.006)	(0.008)	(0.009)	(0.005)	(0.030)
Plot slop (%)	-0.002**	0.013***	-0.000	-0.012***	0.000	0.002**	0.001*	-0.001
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)
Plot wetness index	0.004***	-0.007***	-0.002***	0.005***	0.001**	-0.001***	-0.000	-0.000
	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Cons	0.335	0.505*	0.091	0.109	-0.044	0.136**	-0.181***	0.306*
	(0.219)	(0.269)	(0.154)	(0.325)	(0.053)	(0.060)	(0.039)	(0.162)
N	9,912	9,912	9,912	9,912	7,161	7,161	7,161	7,161
F.	58.50***	71.57***	36.98***	88.88	58.50***	71.57***	36.98***	88.88
R^2	0.353	0.452	0.211	0.552	0.353	0.452	0.211	0.532
BP test	7,655.267***				5,744.700***			

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form except land cover and plot wetness index; All wealth indicators variables are given in adult equivalent unit (AEU); Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

The results indicate that an increase in land cover change decreases the land share of pulses and tuber crops, whereas it increases the land share of cereal crops in Nigeria. For Uganda, an increase in land cover change increases the share of land of tuber crops and cash crops, whereas it decreases the share of land of cereal crops. We also find that family size has a positive and statistically significant effect on the land share of pulses and cereal crops in both countries, whereas it has negative and statistically significant effect on the share of land of tuber crops in both countries. This finding might be explained by the fact that the production of pulses and cereal crops requires a high-level of labor input.

Farmers with a high education level plant more cash crops in Nigeria, whereas farmers with a high education level in Uganda plant fewer crops in all major crop categories. Farmers with a higher education level in Uganda may focus more on off-farm employment or self-employment and might not be able to spend as much time planting crops. The use of fertilizer has a positive effect on the land share of tuber crops but a negative effect on the land share of cereal crops in Nigeria, whereas it has a positive effect on the land share of tuber crops, cash crops, and cereal crops and a negative effect on the land share of pulses in Uganda. The use of agrochemicals has a positive effect on the land share of tuber crops but a negative effect on the land share of cereal crops in Nigeria. It has a positive effect for both tuber crops and cash crops in Uganda. Access to extension services increases the land share of cereal crops but reduces the land share of tuber crops in Nigeria, whereas it increases the land share of pulses in Uganda. We also find that access to credit increases the land share of pulses and cereal crops while it reduces the land share of tuber crops and cash crops. It has a positive effect on pulses but no significant effect on land use decisions on tubers, cash crops, and cereal crops in Uganda.

We also find that the size of farmland has a positive and statistically significant effect on the land shares of pulses and cereal crops, while it reduces the land share of tuber crops and cash crops in Nigeria. This finding may suggest that land-constrained smallholder farmers in Nigeria tend to maximize their consumption by first allocating more available land to tuber crops and cash crops before considering pulses and cereal crops. However, farmland size has a positive and statistically significant effect on the land share of tubers, cash crops, and cereal crops in Uganda. Asset holdings of a household increases the land share of cereal crops and decreases the land share of tuber crops in Nigeria while it increases the land share of cash and cereal crops in Uganda. Wage income increases the land share of tuber crops and cash crops but reduces the share of pulses in Nigeria, whereas it reduces the land share of both cash crops and cereal crops in Uganda. We find that income from self-employment increases the land share of pulses and cereal crops and reduces the land share of tuber crops in Nigeria.

Distance to the main road increases the land share of pulses and tuber crops, while it decreases the land share of cereal crops in Nigeria. In Uganda, distance to the main market increases the share of land to pulses, tuber crops, and cash crops but decreases the share of cereal crops. This data may indicate that access to a market encourages farmers to produce higher value-added agricultural products, such as fruits and other commercially viable products, compared with cereal crops. This is consistent with other studies (e.g., Briassoulis 2009; Ebanyat et al. 2010; Jiang, Deng, and Seto 2013; Mwaura and Adong 2016), which found that distance to and accessibility of output markets influences shifts in the land share allocated to crops in Uganda. The average slope of the plot increases the land share of tuber crops, while it reduces the share of land of pulses and cereal crops in Nigeria. On the other hand, it increases the land share of tuber crops and cash crops in Uganda. The average wetness index of the plot increases the land share of pulses and cereal crops, while it reduces the land share of tuber crops and cash crops in Nigeria.

The Share of Income of the Major Crops

When we look at the effect of rainfall shocks and land cover change on the share of income of the major crops (Table 7.2), we find that rainfall shocks in Nigeria increase the share of income of pulses and cereal crops and reduce the income share of tuber crops and cash crops. Similarly, rainfall shocks in Uganda increase the share of income of cereal crops but reduce the income share of tuber crops. An increase in land cover change in Nigeria increases the income share of cash crops and cereal crops while it reduces the income share of pulses and tuber crops. In Uganda, an increase in land cover change increases the income share of pulses, cash crops, and cereal crops.

Table 7.2 Determinants of income of major crops categories (SURE FEs models)

Determinant	Share of income							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Rainfall shock	0.146***	-0.092*	-0.145***	0.170***	-0.009	-0.086***	-0.018	0.093***
	(0.037)	(0.050)	(0.036)	(0.047)	(0.024)	(0.024)	(0.014)	(0.024)
Land cover index	-0.433***	-0.681***	0.265***	0.706***	0.274***	0.116	0.167***	0.573***
	(0.099)	(0.160)	(0.089)	(0.133)	(0.089)	(0.088)	(0.051)	(0.091)
Age of household head	-0.003	0.217***	-0.024	-0.117**	-0.013	0.018	0.022***	-0.018
	(0.035)	(0.059)	(0.029)	(0.048)	(0.012)	(0.012)	(0.007)	(0.012)
Household size—AEU	0.078***	-0.092**	-0.054***	0.090***	0.032***	0.055***	0.004	0.040***
	(0.022)	(0.036)	(0.019)	(0.030)	(0.010)	(0.010)	(0.006)	(0.011)
Education of head	0.001	-0.008	-0.000	-0.003	-0.009**	0.001	0.003	0.006
	(0.005)	(0.008)	(0.004)	(0.007)	(0.004)	(0.004)	(0.002)	(0.004)
Gender of head	0.022	-0.039	-0.000	-0.022	-0.017*	-0.029***	-0.000	0.001
	(0.046)	(0.143)	(0.145)	(0.068)	(0.009)	(0.009)	(0.005)	(0.010)
Dependency ratio	-0.007	0.009	0.003	-0.001	0.003	0.004	0.001	0.001
	(0.005)	(0.008)	(0.004)	(0.006)	(0.003)	(0.003)	(0.002)	(0.003)

Table 7.2 Continued

Determinant	Share of income							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Fertilizer application	-0.025***	0.027**	-0.011*	-0.094***	0.003	0.016	0.042***	0.004
	(0.008)	(0.014)	(0.006)	(0.010)	(0.012)	(0.012)	(0.007)	(0.013)
Agrochemicals application	-0.025***	0.059***	-0.007	-0.039***	0.013	0.015	0.055***	0.013
	(0.007)	(0.014)	(0.006)	(0.009)	(0.013)	(0.013)	(0.007)	(0.013)
Access to extension	-0.006	0.042**	-0.022**	-0.022	0.006	-0.038**	-0.004	-0.014
	(0.011)	(0.020)	(0.008)	(0.014)	(0.016)	(0.016)	(0.009)	(0.017)
Access to credit	0.014**	-0.037***	-0.008	0.034***	0.001	0.004	-0.013	-0.030*
	(0.007)	(0.011)	(0.007)	(0.009)	(0.017)	(0.017)	(0.010)	(0.018)
Land size	0.185***	-0.485***	-0.080***	0.444***	0.004	0.030***	0.011**	-0.005
	(0.023)	(0.029)	(0.012)	(0.030)	(0.010)	(0.010)	(0.006)	(0.010)
Livestock—TLU	0.000	-0.012	0.006	-0.004	0.041***	-0.025**	-0.005	0.022*
	(0.005)	(0.009)	(0.003)	(0.007)	(0.012)	(0.012)	(0.007)	(0.012)
Asset value	-0.004***	-0.005***	-0.001	0.009***	0.001	0.003	0.002*	0.002
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
Wage income	-0.004***	0.003***	0.001**	-0.001	-0.001	0.001	-0.000	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Self-employment income	0.002**	-0.004***	-0.001	0.003***	-0.000	-0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Remittance income	0.002	-0.001	0.000	-0.003	0.000	0.000	0.000	0.000
	(0.003)	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.000)	(0.001)
Distance to nearest road	-0.013***	0.006	0.002	0.006	0.012	0.020*	0.002	0.002
	(0.005)	(0.009)	(0.004)	(0.007)	(0.011)	(0.011)	(0.006)	(0.011)
Plot slope (%)	-0.002	0.018***	0.002**	-0.017***	0.003*	0.000	0.000	0.000
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Plot wetness index	0.004***	-0.012***	-0.002	0.008***	-0.000	-0.000*	-0.000	-0.000**
	(0.001)	(0.002)	(0.001)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Cons	0.302	0.116	-0.106	0.461*	-0.059	-0.055	-0.187***	-0.057
	(0.224)	(0.294)	(0.300)	(0.265)	(0.091)	(0.091)	(0.053)	(0.094)
N	9,912	9,912	9,912	9,912	7,161	7,161	7,161	7,161
F.	52.92***	70.38***	29.81***	82.13***	52.92***	70.38***	29.81***	82.13***
R^2	0.35	0.501	0.174	0.52	0.35	0.501	0.174	0.52
BP test	6,328.200***				4,634.700***			

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form, except land cover and plot wetness index; All wealth indicator variables are given in adult equivalent units (AEU)**;** Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

Determinants of Crop Area and Income Diversification

Results of the second set of regression models on the determinants of crop diversification are presented in Table 7.3. A negative and significant sign on a parameter implies a negative association with the crop area and income diversification and hence disfavors crop diversification, while a positive sign encourages households toward on-farm diversification. The significant variables across the two countries show different signs that are unique in each country.

The results indicate that rainfall shocks have a positive effect on crop area diversification in Nigeria, while they reduce crop income diversification. This finding may indicate that crop diversification is one of the shock-mitigating strategies of farmers in Nigeria. These findings are consistent with previous empirical evidence (e.g., Ellis 2000; Minot 2006; Birthal et al. 2014; Campos, Velazquez, and McCall 2014; Mitter, Heumesser, and Schmid 2015). In Uganda, rainfall shocks have a negative effect on both crop area and income diversification in Uganda, suggesting that households in Uganda are not pursuing crop diversification strategies to manage rainfall shocks. We also find that an increase in land cover change has a negative effect on both crop area and income diversification in both countries. This suggests that crop diversification is more pronounced in low-resource-endowed areas with poor suitability of land resources. It furthermore indicates that the greater the land cover and suitability, the higher the probability that households specialize in their crop production, confirming the validity of the classical Ricardian model of land allocation.

Households with older household heads and with a larger family size in Nigeria tend to have diversified crop portfolio. In Uganda, family size has a negative effect on crop area diversification. The years of schooling of the household head has a positive effect on crop area diversification in Uganda. Thus, it seems that highly educated households diversify their crop portfolio and income. Female-headed households have higher levels of crop area diversification in Nigeria, which may indicate that they are more risk-averse than male-headed households. Male-headed households have greater levels of both crop area and income diversification in Uganda. The use of fertilizer has a positive effect on both crop area and income diversification in both countries. Use of agrochemicals has a negative effect on both crop area and income diversification in both countries. Farmers who have access to extension services are more likely to diversify their crop portfolios in both countries, indicating that farmers would diversify more in their farm production if given improved access to extension services.

Land size has a positive effect on both crop area and income diversification in Nigeria. This result may suggest that farmers with relatively larger pieces of land are more likely than their counterparts to have more cultivatable space to experiment with different crops. In Uganda, however, land size has a negative effect on both crop area and income diversification, suggesting that farmers with larger landholdings specialize in a certain number of crops for sales.

Asset holding has a positive effect on crop area diversification in Nigeria. It is possible that farmers with larger asset holdings may have greater access to resources that can help them easily diversify their crops. Conversely, asset holding has a negative effect on both crop area and income diversification in Uganda. Wage income has a negative effect on both crop area and income diversification in Nigeria, indicating that households with higher wage income tend to have less diversified crop area and income portfolios. In Uganda, both crop area and income diversification increase with wage income, implying that Ugandan households are more likely to further diversify their crop portfolios and income when wage income increases. Income from self-employment has a positive effect on both crop area and income diversification in both countries. This finding indicates that a significant output complementarity exists in nonfarm self-employment and crop diversification (de Janvry, Sadoulet, and Zhu 2005).

Average plot slope has a negative effect on both crop area and income diversification in both countries. The results may also indicate that steeper plots are more susceptible to erosion, which could encourage farmers to reserve the plot for pasture, woodlot, or minor crops (Clay, Reardon, and Kangasniemi 1998). We also find that slope wetness has a negative effect on both crop area and income diversification. The results furthermore indicate that distance to the main road tends to increase the opportunity to grow more diversified crop portfolios in both countries.

Table 7.3 Determinants of crop diversification (fixed-effects regression models)

Determinant	Nigeria		Uganda	
	Simpson—area diversification index	Simpson—income diversification index	Simpson—area diversification index	Simpson—income diversification index
Rainfall shock	0.108***	-0.052**	-0.100***	-0.474***
	(0.032)	(0.025)	(0.016)	(0.026)
Land cover index	-0.479***	-0.234***	-0.193***	-0.288***
	(0.099)	(0.054)	(0.060)	(0.097)
Age of household head	0.177***	0.011	0.001	0.000
	(0.035)	(0.009)	(0.008)	(0.013)
Household size—AEU	0.079***	0.000	-0.016**	-0.096***
	(0.022)	(0.009)	(0.007)	(0.011)
Education of head	0.001	0.000	0.016***	0.045***
	(0.005)	(0.002)	(0.003)	(0.005)
Gender of head	-0.171**	0.006	0.020***	0.024**
	(0.082)	(0.007)	(0.006)	(0.010)
Dependency ratio	0.008*	0.001	-0.001	-0.004
	(0.005)	(0.002)	(0.002)	(0.004)
Fertilizer application	0.037***	0.023***	0.020**	0.055***
	(0.009)	(0.006)	(0.008)	(0.014)
Agrochemicals application	-0.019**	-0.025***	-0.008	-0.029**
	(0.008)	(0.006)	(0.009)	(0.014)
Access to extension	0.075***	0.005	0.022**	0.056***
	(0.010)	(0.008)	(0.011)	(0.018)
Access to credit	0.002	0.004	-0.002	-0.001
	(0.007)	(0.005)	(0.012)	(0.019)
Land size	0.059***	0.027**	-0.014**	-0.052***
	(0.017)	(0.012)	(0.007)	(0.011)
Livestock—TLU	0.002	0.005	0.003	-0.029**
	(0.004)	(0.003)	(0.008)	(0.013)
Asset value	0.002*	0.000	-0.005***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.002)
Wage income	-0.003***	-0.004***	0.001**	0.002**
	(0.001)	(0.001)	(0.000)	(0.001)
Self-employment income	0.002***	0.001**	0.001***	0.001
	(0.001)	(0.000)	(0.000)	(0.001)
Remittance income	-0.002	-0.000	-0.000	-0.000
	(0.003)	(0.002)	(0.000)	(0.001)
Distance to nearest road	0.029***	0.011***	0.019***	0.032***
	(0.005)	(0.003)	(0.007)	(0.012)

Table 7.3 Continued

Determinant	Nigeria		Uganda	
	Simpson—area diversification index	Simpson—income diversification index	Simpson—area diversification index	Simpson—income diversification index
Plot slope (%)	-0.003**	-0.001	-0.002**	-0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Plot wetness index	-0.004***	-0.000	0.000**	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Cons	0.401**	0.353***	0.877***	1.196***
	(0.197)	(0.102)	(0.062)	(0.099)
N	9,912	9,912	7,161	7,161
F.	14.45***	12.35***	13.28***	41.56***
R^2	0.230	0.190	0.281	0.352

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form except land cover and plot wetness index; All wealth indicators variables are given in adult equivalent units (AEU)**;** Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

Tables 7.4-7.6 provide estimates using a dummy that captures extreme events. Consistent with previous findings, Tables 7.4-7.6 show that negative rainfall shocks increase the land share of pulses in both countries. Negative rainfall shocks also increase the land share of cash crops in Nigeria and decrease the share of land to cereal crops. In Uganda, negative rainfall shocks have a negative effect on the land share of cash crops and positive effect on the land share of cereals crops. The results indicate that farmers who experience negative rainfall shocks in Nigeria respond by making changes in crop choices from cereals crops to pulses and cash crops, whereas farmers who experience negative rainfall shocks in Uganda respond by making changes in crop choices from cash crops to pulses and cereals crops. This finding may indicate that pulses are less affected by negative rainfall shocks.

Table 7.4 Determinants of farm land use choices (SURE FEs models) of major crops categories

Determinant	Share of area under crop							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Negative rainfall shock	0.011**	-0.006	0.009**	-0.023***	0.026***	0.003	-0.008**	0.015***
	(0.005)	(0.007)	(0.004)	(0.006)	(0.005)	(0.005)	(0.003)	(0.005)
Land cover index	0.018	-0.248***	0.012	0.281***	0.184***	0.313***	0.171***	-0.067**
	(0.034)	(0.051)	(0.025)	(0.029)	(0.034)	(0.038)	(0.023)	(0.030)
Socioeconomic characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cons	0.026	0.533***	0.121***	0.130***	-0.170***	0.065	-0.285***	-0.073
	(0.042)	(0.061)	(0.032)	(0.050)	(0.042)	(0.047)	(0.029)	(0.048)
N	9,912	9,912	9,912	9,912	7,161	7,161	7,161	7,161
F.	58.50***	71.57***	36.98***	88.88	0.022***	0.001	-0.010***	0.019***
R^2	0.387	0.262	0.235	0.352	0.334	0.337	0.530	0.221
BP test	633.74***				541.76***			

Source: Authors-Based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form except land cover and plot wetness index. All wealth indicators variables are given in adult equivalent units (AEU).
Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

We find that negative rainfall shocks have a negative effect on the income share of tuber crops, while they increase the income share of cash and pulse crops in Nigeria. In Uganda, on the other hand, negative rainfall shocks increase the income share of pulses but reduce the income share of tuber and cash crops. We also find that negative rainfall shocks in Nigeria have a negative effect on crop area diversification but increase crop income diversification. In Uganda, negative rainfall shocks decease both crop area and income diversification.

Table 7.5 Determinants of income from major crops categories (SURE FEs models)

Determinant	Share of income							
	Nigeria				Uganda			
	Pulse crops	Tuber crops	Cash crops	Cereal crops	Pulse crops	Tuber crops	Cash crops	Cereal crops
Negative rainfall shock	0.012**	-0.022***	0.020***	-0.009	0.026***	-0.025***	-0.009*	-0.005
	(0.005)	(0.008)	(0.004)	(0.007)	(0.008)	(0.008)	(0.005)	(0.008)
Land cover index	-0.011	-0.408***	0.064***	0.258***	0.332***	0.284***	0.135***	0.301***
	(0.032)	(0.060)	(0.025)	(0.050)	(0.051)	(0.048)	(0.026)	(0.052)
Socioeconomic characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cons	0.039	0.593***	0.124***	0.138**	-0.206***	-0.129**	-0.176***	-0.064
	(0.041)	(0.070)	(0.032)	(0.059)	(0.068)	(0.065)	(0.037)	(0.069)
N	9,908	9,908	9,908	9,908	7,161	7,161	7,161	7,161
F.	52.92***	70.38***	29.81***	82.13***	52.92***	70.38***	29.81***	82.13***
R^2	0.323	0.271	0.329	0.241	0.323	0.271	0.329	0.241
BP test	1,385.356***				6,534.015***			

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form except land cover and plot wetness index; All wealth indicators variables are given in adult equivalent units (AEU); Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

Table 7.6 Determinants of crop diversification (FEs regression models)

Determinant	Nigeria		Uganda	
	(1)	(2)	(1)	(2)
	Simpson—area diversification index	Simpson—income diversification index	Simpson—area diversification index	Simpson--income diversification index
Negative rainfall shock	-0.012*	0.022***	-0.023***	-0.182***
	(0.007)	(0.007)	(0.007)	(0.014)
Land cove index	-0.438***	-0.492***	-0.237**	-0.840***
	(0.101)	(0.090)	(0.098)	(0.242)
Socioeconomic characteristics	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes
Cons	0.414**	0.586***	0.894***	1.376***
	(0.197)	(0.188)	(0.074)	(0.121)
N	9,912	9,912	7,161	7,161

Source: Authors' calculations based on LSMS-ISA surveys in Nigeria and Uganda.
Note: All continuous variables are given in log form except land cover and plot wetness index; All wealth indicators variables are given in adult equivalent units (AEU).; Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.0$.

8. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigates the determinants of farmers' crop choice decisions, crop area diversification, and income diversification in Sub-Saharan Africa using nationally representative panel data for Nigeria and Uganda. We use both the shares of land and income of the major crop categories to measure farmers' crop choice decisions.

Our main results using seemingly unrelated and fixed-effects regression models for land use decision and crop diversification are summarized as follows.

We find that weather shocks affect farmers' crop choice decisions, but effects differ across major crop categories. For example, we find that rainfall shocks increase the land share of pulses in both countries. However, rainfall shocks have a negative effect on the land share of tuber crops in Nigeria and cash crops in Uganda. We also find that land cover change in Nigeria decreases the land share of pulses and tuber crops, whereas it increases the land share of cereal crops. In Uganda, land cover change increases the land share of tuber crops and cash crops, whereas it decreases land share of cereal crops. The analysis also highlights the importance of household characteristics such as family size, education, access to inputs, wealth indicators and income from different sources, plot characteristics, and road accessibility in explaining farmers' crop choice decisions, which are measured using land shares and income shares of major crops.

We also examined the determinants of crop diversification using both crop area and income diversification. Our results show that significant variables are heterogeneous in signs and magnitude across the two countries. For example, we find that rainfall shocks in Nigeria have a positive effect on crop area diversification, while they reduce crop income diversification. In Uganda, rainfall shocks have a negative effect on both crop area and income diversification. We also find that land cover change has a negative effect on both crop area and income diversification in both countries. Similarly, we find that socioeconomic variables, access to inputs, wealth indicators, income sources, and plot characteristics play a significant role in explaining crop area and income diversification in both countries.

Our results highlight varying farmers' crop choice decisions and crop diversification strategies across major crop categories in the two countries of focus in this paper. Farmers tend to allocate land to crops that are comparatively less impacted by weather change. For example, farmers in Nigeria who experience rainfall shocks respond by making changes in crop choices from tuber crops to pulses and cereal crops, whereas farmers in Uganda who experience rainfall shocks respond by making changes in crop choices from cash crops to pulses. Diversification of crop portfolios is one of the shock-mitigating strategies of farmers in Nigeria, whereas farming households in Uganda do not pursue crop diversification strategies in order to manage rainfall shocks. The choice of crop to be grown and area and income diversification depend on the degree of capability and suitability of the land resources. This means that the greater the land cover, the higher the probability that households specialize in their crop production. In-depth country-specific analysis of farmers' crop choice and crop diversification decision-making processes is timely and relevant for its elucidation of appropriate policymaking in response to rural transformation.

REFERENCES

Akanda, A. I. 2011. "Rethinking Crop Diversification Under Changing Climate, Hydrology and Food Habit in Bangladesh." *Journal of Agriculture and Environment for International Development (JAEID)* 104 (1/2): 3–23.

Asante, W. A., E. Acheampong, E. Kyereh, and B. Kyereh. 2017. "Farmers' Perspectives on Climate Change Manifestations in Smallholder Cocoa Farms and Shifts in Cropping Systems in the Forest-Savannah Transitional Zone of Ghana." *Land Use Policy* 66: 374–381.

Aubry, C., F. Papy, and A. Capillon. 1998. "Modelling Decision-Making Processes for Annual Crop Management." *Agricultural Systems* 56 (1): 45–65.

Ayehu, G. T., and S. A. Besufekad. 2015. "Land Suitability Analysis for Rice Production: A GIS Based Multi-Criteria Decision Approach." *American Journal of Geographic Information Systems* 4 (3): 95–104.

Baird, T. D., and C. L. Gray. 2014. "Livelihood Diversification and Shifting Social Networks of Exchange: A Social Network Transition?" *World Development 60*: 14–30.

Barbier, E. B. 1997. "The Economic Determinants of Land Degradation in Developing Countries." *Philosophical Transactions of the Royal Society of London: Biological Sciences* 352 (1356): 891–899.

Barrett, C. B., and M. R. Carter. 2013. "The Economics of Poverty Traps and Persistent Poverty: Policy and Empirical Implications." *Journal of Development Studies* 49: 976–990.

Barrett, C. B., M. B. Clark, D. C. Clay, and T. Reardon. 2005. "Heterogeneous Constraints, Incentives and Income Diversification Strategies in Rural Africa." *Quarterly Journal of International Agriculture*, 44 (1): 37–60.

Bert, F. E., E. H. Satorre, F. R. Toranzo, and G. P. Podestá. 2006. "Climatic Information and Decision-Making in Maize Crop Production Systems of the Argentinean Pampas." *Agricultural Systems* 88 (2): 180–204.

Bharathkumar, L., and M. A. Mohammed-Aslam. 2015. "Crop Pattern Mapping of Tumkur Taluk Using NDVI Technique: A Remote Sensing and GIS Approach." *Aquatic Procedia* 4: 1397–1404.

Birthal, P. S., D. S. Negi, A. K. Jha, and D. Singh. 2014. "Income Sources of Farm Households in India: Determinants, Distributional Consequences and Policy Implications." *Agricultural Economics Research Review* 27 (1): 37–48.

Björkman-Nyqvist, M. 2013. "Income Shocks and Gender Gaps in Education: Evidence from Uganda." *Journal of Development Economics* 105 (C): 237–253.

Briassoulis, H. 2009. "Factors Influencing Land-Use and Land-Cover Change." In *Encyclopaedia of Life Support Systems, Volume 1: Land Cover, Land Use, and The Global Change*, edited by, Willy H. Verheye *1*, 126–146: Oxford, UK: Eloss Publishers/UNESCO.

Campos, M., A. Velazquez, A., and M. McCall. 2014. "Adaptation Strategies to Climatic Variability: A Case Study of Small-Scale Farmers in Rural Mexico." *Land Use Policy* 38: 533–540.

Chalise, S., and A. Naranpanawa. 2016. "Climate Change Adaptation in Agriculture: A Computable General Equilibrium Analysis of Land-Use Change in Nepal." *Land Use Policy* 59: 241–250.

Christiaensen, L., L. Demery, and J. Kuhlc. 2011. "The (Evolving) Role of Agriculture in Poverty Reduction: An Empirical Perspective. *Journal of Development Economics* 96 (2): 239–254.

Clay, D., T. Reardon, and J. Kangasniemi. 1998. "Sustainable Intensification in the Highland Tropics: Rwandan Farmers' Investments in Land Conservation and Soil Fertility." *Economic Development and Cultural Change* 46 (2): 351–377.

Dahigamuwa, T., Q. Yu, Q., and M. Gunaratne. 2016. "Feasibility Study of Land Cover Classification Based on Normalized Difference Vegetation Index for Landslide Risk Assessment." *Geosciences* 6 (4): 45.

de Janvry, A., E. Sadoulet, and N. Zhu. 2005. *The Role of Non-Farm Incomes in Reducing Rural Poverty and Inequality in China.* CUDARE Working Paper. Berkeley, CA: Department of Agricultural & Resource Economics, University of California Berkeley.

Dercon, S. and L. Christiaensen. 2011. "Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia." *Journal of Development Economics* 96 (2): 159–173.

Dong, T., J. Liu, J. Shang, B. Qian, T. Huffman, Y. Zhang, C. Champagne, and B. Daneshfar. 2016. "Assessing the Impact of Climate Variability on Cropland Productivity in the Canadian Prairies Using Time Series MODIS FAPAR." *Remote Sensing* 8 (4): 281.

Ebanyat, P., N. de Ridder, A. De Jager, R. J. Delve, M. A. Bekunda, and K. E. Giller. 2010. "Drivers of Land Use Change and Household Determinants of Sustainability in Smallholder Farming Systems of Eastern Uganda." *Population and Environment* 31 (6): 474–506.

Ellis, F. 2000. "The Determinants of Rural Livelihood Diversification in Developing Countries." *Journal of Agricultural Economics* 51 (2): 289–302.

Fabiyi, O. O., O. Ige-Olumide, and A. O. Fabiyi. 2013. "Spatial Analysis of Soil Fertility Estimates and NDVI in South-Western Nigeria: A New Paradigm for Routine Soil Fertility Mapping." *Research Journal of Agriculture and Environmental Management* 2 (12): 403–411.

Ghandhi, G. M., S. Parthiban, N. Thummalu, and A. Christy. 2015. "Ndvi: Vegetation Change Detection Using Remote Sensing and GIS–A Case Study Of Vellore District." *Procedia Computer Science* 57: 1199–1210.

Hegazy, I. R., and M. R. Kaloop. 2015. "Monitoring Urban Growth and Land Use Change Detection with GIS and Remote Sensing Techniques in Daqahlia Governorate Egypt." *International Journal of Sustainable Built Environment* 4 (1): 117–124.

Hettig, E., J. Lay, and K. Sipangule. 2016. "Drivers of Households' Land-Use Decisions: A Critical Review of Micro-Level Studies in Tropical Regions." *Land* 5 (4): 32.

Hochman, Z., H. Horan, D. R. Reddy, G. Sreenivas, C. Tallapragada, R. Adusumilli, and D. Gaydon. 2017. "Smallholder Farmers Managing Climate Risk in India: Adapting to a Variable Climate." *Agricultural Systems* 150: 54–66.

Howden, S. M., J. Soussana, F. N. Tubiello, N. Chhetri, M. Dunlop, and H. Meinke. 2007. "Adapting Agriculture to Climate Change." In *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) 104: 19691–19696.

Jalan, J. and M. Ravallion. 2002. "Geographic Poverty Traps? A Micro Model of Consumption Growth in Rural China." *Journal of Applied Econometrics* 17: 329–346.

Jiang, L., X. Deng, and K. C. Seto. 2013. "The Impact of Urban Expansion on Agricultural Land Use Intensity in China." *Land Use Policy* 35: 33–39.

Kokoye, S. E. H., S. D. Tovignan, J. A. Yabi, and R. N. Yegbemey. 2013. "Econometric Modeling of Farm Household Land Allocation in the Municipality of Banikoara in Northern Benin." *Land Use Policy* 34: 72–79.

Lehmann, N., S. Briner, and R. Finger. 2013. "The Impact of Climate and Price Risks on Agricultural Land Use and Crop Management Decisions." *Land Use Policy* 35: 119–130.

Lubowski, R. N., A. J. Plantinga, and R. N. Stavins. 2008. "What Drives Land-Use Change in the United States? A National Analysis of Landowner Decisions." *Land Economics* 84 (4): 529–550.

Macinni, S., and D. Yang. 2009. "Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall." *American Economic Review* 99 (3): 1006–26.

Makate, C., R. Wang, M. Makate, and N. Mango. 2016. "Crop Diversification and Livelihoods of Smallholder Farmers in Zimbabwe: Adaptive Management for Environmental Change. *SpringerPlus* 5 (1): 1–18.

Marcos-Martinez, R., B. A. Bryan, J. D. Connor, and D. King. 2017. "Agricultural Land-Use Dynamics: Assessing the Relative Importance of Socioeconomic and Biophysical Drivers for More Targeted Policy. *Land Use Policy* 63: 53–66.

Mertz, O., C. Mbow, A. Reenberg, A., and A. Diouf. 2009. "Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel." *Environmental Management* 43 (5): 804–816.

Minot, N., ed. (2006). *Income Diversification and Poverty in the Northern Uplands of Vietnam* (Vol. 145). Research Report 145. Washington, DC: International Food Policy Research Institute.

Mitter, H., C. Heumesser, and E. Schmid. 2015. "Spatial Modeling of Robust Crop Production Portfolios to Assess Agricultural Vulnerability and Adaptation to Climate Change." *Land Use Policy* 46: 75–90.

Mottet, A., S. Ladet, N. Coqué, and A. Gibon. 2006. "Agricultural Land-Use Change and Its Drivers in Mountain Landscapes: A Case Study in the Pyrenees." *Agriculture, Ecosystems & Environment*, 114 (2): 296–310.

Mwaura, F. M., and A. Adong. 2016. "Determinants of Households' Land Allocation for Crop Production in Uganda." *Journal of Sustainable Development* 9 (5): 229.

Newsham, A. J., and D. S. G Thomas. 2009. *Agricultural Adaptation, Local Knowledge and Namibia*. Tyndall Working Paper No 140. Oxford: Tyndall Centre for Climate Change Research/ University of Oxford.

Nguyen, T. T., L. D. Nguyen, R. S. Lippe, and U. Grote. 2017. "Determinants of Farmers' Land Use Decision-Making: Comparative Evidence from Thailand and Vietnam." *World Development* 89: 199–213.

Onţel, I., and G. Moroşanu. 2014. "Assessing Drought Severity and Its Impact on Vegetation Within Oltenia Plain Using NDVI from MODIS (2000–2010)." *Riscuri şi Catastrofe* 14 (1): 21–30.

Robert, M., J. Dury, A. Thomas, O. Therond, M. Sekhar, S. Badiger, and J. E. Bergez. 2016. "CMFDM: A Methodology to Guide the Design of a Conceptual Model of Farmers' Decision-Making Processes." *Agricultural Systems* 148: 86–94.

Rocha, R., and R. R. Soares. 2015. "Water Scarcity and Birth Outcomes in the Brazilian Semiarid." *Journal of Development Economics* 112 (C): 72–91.

Sakane, N., M. T. van Wijk, M. Langensiepen, and M. Becker. 2014. "A Quantitative Model for Understanding and Exploring Land Use Decisions by Smallholder Agrowetland Households in Rural Areas of East Africa." *Agriculture, Ecosystems & Environment* 197: 159–173.

Samal, D. R., and S. S. Gedam. 2015. "Monitoring Land Use Changes Associated with Urbanization: An Object Based Image Analysis Approach." *European Journal of Remote Sensing* 48 (1): 85–99.

Stuart, D., R. L. Schewe, and M. McDermott. 2014. "Reducing Nitrogen Fertilizer Application as a Climate Change Mitigation Strategy: Understanding Farmer Decision-Making and Potential Barriers to Change in the US." *Land Use Policy* 36: 210–218.

Tadesse, L., K. V. Suryabhagavan, G. Sridhar, and G. Legesse. 2017. "Land Use and Landcover Changes and Soil Erosion in Yezat Watershed, North Western Ethiopia." *International Soil and Water Conservation Research*.

Teklewold, H., and A. Mekonnen. 2017. "The Tilling of Land in a Changing Climate: Empirical Evidence from the Nile Basin of Ethiopia." *Land Use Policy* 67: 449–459.

Teklewold, H., M. Kassie, B. Shiferaw, and G. Köhlin. 2013. "Cropping System Diversification, Conservation Tillage and Modern Seed Adoption in Ethiopia: Impacts on Household Income, Agrochemical Use and Demand for Labor." *Ecological Economics* 93: 85–93.

Verburg, P. H., J. R. R. van Eck, T. C. de Nijs, M. J. Dijst, and P. Schot. 2004. "Determinants of Land-Use Change Patterns in the Netherlands." *Environment and Planning B: Planning and Design* 31 (1): 125–150.

Waha, K., C. Müller, A. Bondeau, J. P. Dietrich, P. Kurukulasuriya, J. Heinke, and H. Lotze-Campen. 2013. "Adaptation to Climate Change through the Choice of Cropping System and Sowing Date in Sub-Saharan Africa." *Global Environmental Change* 23 (1): 130–143.

Wallace, M. T., and J. E. Moss. 2002. "Farmer Decision-Making with Conflicting Goals: A Recursive Strategic Programming Analysis." *Journal of Agricultural Economics* 53 (1): 82–100.

Walsh, S. J., T. W. Crawford, W. F. Welsh, and K. A. Crews-Meyer. 2001. "A Multiscale Analysis of LULC and NDVI Variation in Nang Rong District, Northeast Thailand." *Agriculture, Ecosystems & Environment* 85(1): 47–64.

Wang, T., M. Luri, L. Janssen, D. A. Hennessy, H. Feng, M. C. Wimberly, and G. Arora. 2017. "Determinants of Motives for Land Use Decisions at the Margins of the Corn Belt." *Ecological Economics* 134: 227–237.

Willock, J., I. J. Deary, G. Edwards-Jones, G. G. Gibson, M. J. McGregor, A. Sutherland, and B. Dent. 1999. "The Role of Attitudes and Objectives in Farmer Decision Making: Business and Environmentally Oriented Behaviour in Scotland." *Journal of Agricultural Economics* 50 (2): 286–303.

Wooldridge, J. 2010. *Econometric Analysis of Cross Section and Panel Data* (2nd ed.). Cambridge, MA: MIT Press.

Yang, H., G. B. Villamor, Y. Su, M. Wang, and J. Xu. 2016. "Land-Use Response to Drought Scenarios and Water Policy Intervention in Lijiang, SW China." *Land Use Policy* 57: 377–387.

Yin, H., T. Udelhoven, R. Fensholt, D. Pflugmacher, and P. Hostert. 2012. "How Normalized Difference Vegetation Index (ndvi) Trendsfrom Advanced Very High-Resolution Radiometer (AVHRR) and Système Probatoire D'observation De La Terre Vegetation (SPOT VGT) Time Series Differ in Agricultural Areas: An Inner Mongolian Case Study." *Remote Sensing* 4 (11): 3364–3389.

You, L., M. Spoor, J. Ulimwengu, and S. Zhang. 2011. "Land Use Change and Environmental Stress of Wheat, Rice and Corn Production in China." *China Economic Review* 22 (4): 461–473.

Zellner, A. 1962. "An Efficient Method of Estimating Seemingly Unrelated Regression Equations and Tests for Aggregation Bias." *Journal of the American Statistical Association* 57: 348–368.

Zoungrana, B. J. B., C. Conrad, L. K. Amekudzi, M. Thiel, and E. D. Da. 2015. "Land Use/Cover Response to Rainfall Variability: A Comparing Analysis Between NDVI and EVI in the Southwest of Burkina Faso." *Climate* 3 (1): 63–77.

For earlier Discussion Papers

please click here

All discussion papers can be downloaded free of charge

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org