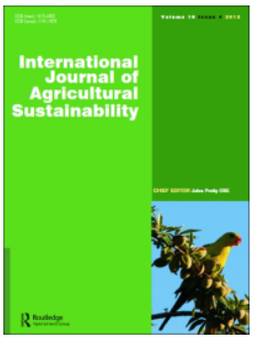

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The effect of land tenure across food security outcomes among smallholder farmers using a flexible conditional difference-in-difference approach

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ABSTRACT

The paucity of literature on the influence of land tenure across a range of food insecurity outcomes may impede a complete analysis in developing countries. This paper examines the association between land tenure and food security among 1434 sampled smallholders from the Nigeria Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) three-round panel dataset. The data were analyzed by a flexible conditional difference-in-difference model and a generalized ordered logit regression. The regression results showed that smallholders who owned land and acquired plots for free were less likely to have high Household Dietary Diversity Scores (HDDS). On the other hand, owners of family-inherited plots were more likely to consume diverse diets and hold more assets. Holders of informal land documents were more likely to be food secure by having a low food expenditure share, high HDDS and Livelihood Coping Strategy (LCS). Meanwhile, perceived rights to mortgage land for a loan may be enhanced with having formal land certificates than informal land documents. The study concluded that formal land governance should recognize land ownership via family inheritance and holding informal land documents to support smallholder food security by increasing their dietary diversity and lowering their food expenditure shares.

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KEYWORDS
Food security; land tenure; smallholder farmers; difference-in-difference model

1. Introduction

The sound governance of land tenure is core to ensuring food security and nutrition and sustainable development (High Level Panel of Experts HLPE, 2020). Strengthening land tenure governance through tenure security and equitable access to land can promote sustainable agriculture and food systems (Higgins et al., 2018). Smallholder farmers dominate food production in developing countries yet constitute the largest share of food-insecure people and account for most of the world's poor and hungry (Fan & Rue, 2020). Limited land access and insecure tenure rights may weaken food security in Africa, where over 70% of people depend on land and natural resource exploitation for livelihood (Africa Union AU, 2020; Landesa, 2012). Climate change and natural resource degradation affect sustainable food security (Lubowski et al., 2006). Likewise, population growth, rapid urbanization, changing diets and economic development raise competition over limited land, affecting food security (Holden, 2020). Smallholders' limited access to and control over land may hinder their access to innovations and finance.

One of the constrains to food security and economic diversification in Nigeria is the lack of secure title of agricultural land (Federal Ministry of

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Agriculture and Rural Development FMARD, 2022). The National Agricultural Technology and Innovation Policy (NATIP 2022–2027) has highlighted the need to reexamine formal land titles under the 1978 Land Use Act (LUA) to secure agricultural land entitlements to achieve food security (FMARD, 2022). The LUA embraces a formal land tenure system (Law of Federal Republic of Nigeria (LFN), 2004) that enables the state (governors and local government authorities) to secure, allocate, expropriate or revoke land and landholders certificates of occupancy and compensate for any revoked land rights (LFN, 2004). Under the formal tenure system, landholders hold formal land certificates to secure land rights (Yemadje et al., 2014). However, less than 3% of Nigerian households hold formal land titles (Ghebru et al., 2014). Rent-seeking and the high cost of processing land registration constrian legal titles, reviving customary land tenure and initiating the use of informal land right documentations (Ibrahim et al., 2022). The Voluntary Guidelines on the Responsible Governance of Tenure of Land in the Context of National Food Security (VGGT) (Food and Agriculture Organization FAO, 2017) and the Frameworks and Guidelines on Land Policy in Africa (UN-ECA, AUC, AfDB, 2022) were established to guide the governance of land tenure to achieve food security. Despite the importance of these guidelines (FAO, 2017), there is a lack of literature on the effect of land tenure (measured as mode of land acquisition and documentation of land rights) among smallholder farmers across a range of food security outcomes. While the existing literature has conceptually described the relationship between food security and land tenure (Holden, 2020; Maxwell & Wiebe, 1999), few studies have researched the empirical linkages. Studies investigating the connection have not addressed the relationship across each level of food insecurity outcomes, impeding complete analysis in developing country contexts (Carletto et al., 2013; Hendriks et al., 2016; Simbizi et al., 2014). This study sets out to examine the effect of mode of land acquisition and documentation of land rights under formal and informal land tenure systems across a range of food insecurity indicators.

2. Land tenure and food security linkages: conceptual and empirical overviews

Demand for land increases the need for secure tenure rights to ensure equitable land distribution, support livelihoods and promote food security (Holden & Otsuka, 2014). Vulnerable groups and smallholders may fear losing their land rights to encroachment and appropriation by the government (German et al., 2013). Large-scale land acquisitions tend to occur where land tenure systems are weak (Deininger et al., 2011).

Secure land tenure rights can enhance household food security's availability, access, and utilization dimensions (Holden & Ghebru, 2016). Secure tenure rights can generate benefits for food security through three pathways. First, improved land tenure motivates farm input investments (including soil improvements, labour and capital), leading to enhanced smallholder productivity and farm incomes (Holden, 2020; Holden & Ghebru, 2016; Yemadje et al., 2014). These investments make food available for home consumption and provide income from selling the surplus (Borychowski et al., 2022; FAO, 2017), leading to positive changes in household expenditure patterns (Ajefu & Abiona, 2020).

Second, farmers with formal land certificates can generate non-farm-related income like wages, rent and loans. Theory suggests that formal titling interventions can lead to land-related investments, efficient land markets and mortgaging for lending funds (Fenske, 2011). Land certificates can be used as collateral to access credit and reduce transaction costs for formal loan acquisition (Ghebru & Holden, 2013). Secure land rights can facilitate farmers' transitions to the non-farm economy and develop efficient land markets to support the process (Hazell, 2020). Many transition farmers with secure land rights, especially those interested in part-time farming activities, can rent out land or leave their farm fallow without fear of land eviction and expropriation by government or private land grabbers. The fallow practice improves soil fertility and the proceeds from the rental market or non-farm economy enhance farm technology adoption that improves farm productivity and food security (Hazell, 2020). Market-based purchased and rented land can increase access to land through reallocation (Holden & Otsuka, 2014) and is more likely to improve household food security.

Third, access and secure tenure rights to land can serve as resilience to crises or shocks and improve livelihood. Farmers rely on agriculturally based livelihoods, which are affected by seasonal weather conditions and investment of improved inputs. Having

secure tenure rights enables a buffer against production failures due to drought, flood or pest and against income shocks from lean harvest, price and financial risks (Ajefu & Abiona, 2020; Fan & Rue, 2020). Land certificates or documents can be used as collateral for loans or land market risk insurance to address liquidity constrains, which support household food security during shocks (Holden & Otsuka, 2014). Research from the high food price crisis in 2007–2010 revealed that vulnerable groups such as the poor and smallholders with insecure tenure rights are less motivated to invest in modern technology (Holden, 2020).

Household tenure rights and obligations are defined by formal institutional tenure elements (i.e. land certificate) or recognized socio-cultural norms (i.e. perceived tenure rights) (Deininger & Feder, 2009). According to the Food and Agriculture Organisation, World Bank, UN-Habitat (2018), all forms of tenure that provide people with a degree of land ownership and land right documentation can protect people from arbitrary eviction and ensure their rights are not violated or infringed. People's perceptions of tenure security are foundational to their willingness to invest in farmland (FAO; World Bank; UN-Habitat, 2018). Perceptions of tenure security are connected to a fear of involuntary loss of the land and the landholder's rights to bequeath, sell, fallow and use land as collateral (Shittu et al., 2019; FAO; World Bank; UN-Habitat, 2018). In addition, the fears of nature-related events, economic or health shocks, displacement due to government or private land investment and family disputes can affect the perception of land rights (FAO; World Bank; UN-Habitat, 2018). In the spirit of 'leaving no one behind', the SDG indicator 1.4.2 considers perception of land rights, documentation of land rights and mode of land acquisition as potential proxies to measure and inform the tenure situations of households (FAO, World Bank and UN-Habitat, 2018).

A few empirical studies have reported the impact of land tenure on food security worldwide. Mendola and Simtowe (2015) and Mueller et al. (2014) found that access to land improved the incomes and food access of beneficiaries of land acquisition programmes in Malawi. Santos et al. (2014) found no significant association between government land allocation, registration programmes and nutritious food consumption in rural West Bengal. Qualitative research has revealed that households consider land a critical way to offset cash expenditure on food purchases in rural West Bengal (Santos et al., 2014). Some studies have found higher dietary diversity and *per capita* food intake associated with increased per capita land size in India (Harris-Fry et al., 2020) and Myanmar (Rammohan & Pritchard, 2014). However, most food insecure households in rural India held no or marginal household agricultural land (Goli et al., 2021).

There is little evidence reported on the influence of land registration and formal land certificates and informal land documents ownership on food security in Africa. Kehinde et al. (2021) found no significant association between formal land certification programmes and food security for cross-section study in Nigeria. Other studies found increased per capita food expenditure and food security by owning formal land title deeds in Ethiopia (Ghebru & Holden, 2013) and Malawi (Ajefu & Abiona, 2020). Qualitative analysis of food security projects in South Africa (Kepe & Tessaro, 2014) and other natural resources such as fishery, pasture, wildlife and woodland in Zambia (Merten & Haller, 2008) showed that land tenure could improve food security. However, empirical evidence on land tenure among smallholders across the range of food insecurity outcomes is scanty.

3. Study data and methodology

3.1. Data description

This study used data from Nigeria's national representative panel data of the living standards measurement study's integrated surveys on Agriculture (LSMS-ISA). The data collection (round one) started in 2010/11 with a representation of 5000 households across the 36 states in Nigeria and the Federal Capital Territory (FCT). Rounds two, three and four of the survey were conducted in 2012/13, 2015/16 and 2018/19, respectively (National Bureau of Statistics NBS & The World Bank, 2021). Each survey round collected data twice during the post-planting and post-harvest periods to serve agricultural activities. This study considered households that operated small plots (i.e. ≤ 2 ha) as a subset of the panel database to have enough sub-samples for our analysis. A total of 1434 sampled households were drawn from the three-wave panel datasets of 2012/13 (wave2), 2015/16 (wave3), and 2018/19 (wave4). The panel database provided information on socioeconomic (i.e. plot-level, household-

level, geospatial-level and intervening) characteristics, land tenure and food security.

3.2. Definition of variables

The explanatory variables were derived from two land tenure categories. First, a binary variable was created for each of the five modes of land acquisition: community distribution, land obtained free of charge, inherited land, purchased land (state registered or unregistered) and rentals. A second analysis considered a binary variable for formal and informal tenure security regardless of the acquisition mode. The first category included formal documentation of rights and entitlements by holding formal land certificates including statutory certificate of occupancy, customary certificate of occupancy. The second category included informal documentation of rights and entitlements by having informal land documents such as approved and unapproved survey plans, registered and unregistered purchase agreements, building plans, government allocation receipts and family receipts not recognized by Nigerian's 1978 LUA as formal land titles (LFN, 2004; NBS & World Bank, 2021). Socioeconomic features (as listed in Table 1) were used to conduct matching analysis, preparing the data for regression analysis. Perceived land rights include the right to sell, right to bequeath,

Table 1. Summary of variables included in the analysis.

Class of variable	Data requirement	Unit of measurement	Expected sign
Dependent variable			
Food security	List of indicators in Table 2	Categorical outcome	
Explanatory variable			
Land tenure category*	Indicator		
Mode of land acquisition	Family-inheritance	1 = inherited, 0 = otherwise	+
	Outright purchased	1 = purchased, 0 = otherwise	+
	Community distribution	1 = allocated, 0 = otherwise	+
	Used land free	1 = used, 0 = otherwise	+
	Rented	1 = rented, 0 = otherwise	+
Land right documentation	Formal land certificate	1 = yes, 0 = otherwise	+
	Informal land document	1 = yes, 0 = otherwise	+
Control factors			
Socioeconomic features	Age	Years	Used for matching technique
	Gender	1 = female, 0 = male	
	Marital status	1 = married(monogamous), 2 = married (polygamous), 3 = informal union, 4 = divorce, 5 = separated, 6 = widowed, 7 = never married	
	Tree owned	Number	
	Household size	Number	
	Total plot areas	Hectare (Ha)	
	Plot area owned	Hectare (Ha)	
	Number of plots	Number	
	Plot acquired year	1 = After 1978 LUA, 0 = before	
	Household education	1 = none, 2 = FSLC, 3 = MSLC, 4 = Voc., 5 = JSS, 6 = SSS (O level certificate), 7 = Advanced level certificate, 8 = NCE/OND/Nursing, 9 = BA/BSC/HND, 10= Master and Doctorate, 11 = Technical director/ Professor	
	Cooperative membership	1 = yes, 0 = no	
	Total livestock units	Number	
	Sector	Rural = 1, 0 = Urban	
	Survey year	1 = 2012/13, 2 = 2015/16, 3 = 2018/19	
	Zone	1 = North-Central, 2 = North-East, 3 = North-West, 4 = South-East, 5 = South-South, 6 = South-West	

Note: First school leaving certificate (FSLC), Mid-school leaving certificate (MSLC), Vocational school certificate (Voc), Junior Secondary School (JSS), Senior Secondary School (SSS – Ordinary level), A level certificate, National Certificate of Education (NCE), Ordinary National Diploma, Bachelor of Art (BA), Bachelor of Science (BSC) and Higher National Diploma (HND).

right to use land as collateral and right to fallow were used in the descriptive analysis. Table 1 presents the summary of variables for data analysis.

3.3. Measurement of food security indicators

The food security of smallholders was measured using six (6) available food security indicators (Table 2), namely:

- The food expenditure share included non-purchased and purchased foods in the household's total monthly expenditure (World Food Programme WFP, 2015), classified into four-point scales according to WFP (2015) (see Table 2).
- The Household Dietary Diversity Scores (HDDS) measured dietary quality at individual and household levels (FAO, 2010; Hendriks et al., 2016). It included 12 different food groups derived from 115 food items consumed in the last seven (7) days. HDDS were categorized into three groups using the Simpson index and the cut-offs presented by FAO (2006). The Simpson index (SI) accounted for the diversity between the total number (N) of food groups and the total number of food items (n) in each food group. The SI expressed as:

$$SI = \frac{N(N-1)}{\sum n_i(n_i-1)} \quad (1)$$

- The Food Consumption Scores (FCS) measured the diversity and frequency of food groups consumed in the past seven (7) days at the household level (WFP, 2008). It explains the food nutritional values through assigned weights i.e. half (0.5) for oil and sugar, one (1) for fruits and vegetables, two (2) for staples, three (3) for pulse, and four (4) for meat, fish and milk developed by WFP (2008). The FCS were classified into three groups based on the assigned cut-offs by WFP (2008).
- A total number of household assets measured the stability of access and household resilience to sudden shocks or the ability to cope with long-term risk (Mawoko et al., 2018). Household asset ownership was based on a simple count method and classified into four groups, as indicated in Table 2.
- The Livelihood Coping Strategy (LCS) measured the severity of households' livelihood stress and asset depletion (WFP 2015). The procedure presented in WFP (2015) was used to classify LCS.

Table 2. Descriptive classification of food security indicators.

Indicators	Category number	Category description	Range
Food expenditure share	1	.	<0.5
	2	.	0.50–0.64
	3	.	0.65–0.74
	4	.	>74
Household Dietary Diversity Scores (HDDS)	1	Adequate dietary diversity	≥6
	2	Moderately dietary diversity	4–5
	3	Inadequate dietary diversity	≤3
Food Consumption Scores (FCS)	1	Acceptable	>35
	2	Borderline	>21–≤35
	3	Poor	≤21
Household asset ownership	1	Most	≥10
	2	Moderately	3–6
	3	Least	<3
Livelihood Consumption Strategy (LCS)	1	None	.
	2	Stressed	.
	3	Crisis	.
	4	Emergency	.
Consolidated Approach to Reporting Indicators of Food Security (CARI)	1	Food secure	.
	2	Marginal food secure	.
	3	Moderately food secure	.
	4	Severely food secure	.

The Consolidated Approach to Reporting Indicators of Food Security (CARI) console measured the overall Food Security Index (FSI) from the average values of current status and coping capacity (WFP, 2015). The later domain comprises two indicators: share of food expenditure (as economic vulnerability) and Livelihood Coping Strategies (LCS) (as asset depletion). The Food Consumption Score (FCS) represented the current status (WFP, 2015). Using the cut-off of WFP (2015), the FSI was categorized into four scales as indicated in Table 2.

3.4. Analytical method and model specifications

A flexible conditional difference-in-difference (*flexpaneldid*) and generalized ordered logistic (*Gologit*)

regression models were used to analyze the data for this study.

- The *flexpaneldid* model is an advanced approach of the standard difference-indifference (DID) that estimates the outcomes of explanatory variables for multiple periods in panel data (Dettmann et al., 2020). Following Mendola and Simtowe (2015), the standard DID model assumed that:

$$F_{it} = \alpha + \mu D_i + \gamma T_t + \beta(D_i * T_t) + \varepsilon_{it},\ i = 1 \ldots..N,\ t \in (0,\ 2) \quad (2)$$

In Equation (2), F_{it} indicates a vector representing the outcomes of household i at time t, which was the discrete period interval before and after a particular status. D_i indicated whether a household i acquired land or held a land right document, vector T_t was the binary variable, showing the period when outcome information was acquired i.e. $T = 0$ if $t = 0$ (before land right status) and $T = 1$ if $t = 2$ (after land right status).

The DID technique eliminated α (individual-specific effect become constant over time) and μ (tenure status effect remained constant over time) because it involved the difference in $(F_{i1} - F_{i0})\forall i$. The coefficient γ controlled for any year-related effect. The error structure assumed $\varepsilon_{it} \sim$ iid $(0,\sigma)$ such that $E(\varepsilon_{it}|D = 1, T = 1) = (\varepsilon_{it}|D = 0, T = 1) =)$ $(\varepsilon_{it}|D = 1, T = 0 = (\varepsilon_{it}|D = 0, T = 0) = 0$. The standard DID estimator was defined as:

$$\begin{aligned} DID &= E[\beta|p(X)] \\ &= [E(F_{D=1}^{T=1}\ |p(X)) - E(F_{D=0}^{T=1}\ |p(X))] \\ &\quad - [E(F_{D=1}^{T=0}|p(X)) - E(F_{D=0}^{T=0}|p(X))] \\ &= \delta_e \end{aligned} \quad (3)$$

The standard DID model addressed time-varying unobserved factors that were restricted to two periods – pre-land right and post-land right holding periods. The covariates and outcomes in the pre-land right period when $t = 0$ were derived using *flexpaneldid* technique. We address self-selection bias by using control variables X to derive matching estimator in Equation (3). The matching process reduced the potential confounding bias due to observables and improved the sample units' comparability in the groups (Daw & Hatfield, 2018). When outcomes of documented landholding and undocumented landholding units at the initial stage were similar i.e. $E(F_{D=1}^{T=0}|p(X)) - E(F_{D=0}^{T=0}|p(X)) = 0$, the subtracted value of the outcomes becomes zero.

When the period of acquiring or holding land right instruments become a continuous variable t_r, where $t_r \in (0, \infty)$, the standard DID estimator cannot observe the long-term time-varying factor represented by α in Equation (2). The first measures of outcomes were made at $t_1 > t_0$. The conditional DID estimator (i.e. *flexpaneldid* estimator) was given as:

$$\begin{aligned} DID' &= (F_{D=1}^{T=1}(t_e) - F_{D=0}^{T=1}(t_e)) \\ &\quad - (F_{D=1}^{T=0}(t_1) - F_{D=0}^{T=0}(t_1)) \\ &= \delta_e - \delta_1 \end{aligned} \quad (4)$$

then, $DID - DID' = \delta_e - (\delta_e - \delta_1) = \delta_1 > 0$.

Equation (4) implies the DID > DID'; that is, the conditional DID underestimate a positive effect after a long period. Generally, with the first and second initial measurements of outcomes t_0 *and* t_n, then $t_0 < t_n < t_e$, $n = 1 \ldots.e$ and the change was $\delta_n = F_{D=1}^{T=1}(t_n) - F_{D=0}^{T=1}(t_n)$. The conditional DID estimators for the subsequent impact of mode of land acquisition and land right documentation were expressed as:

$$\begin{aligned} DID\ &= (F_{D=1}^{T=1}(t_e) - F_{D=0}^{T=1}(t_e)) \\ &\quad - (F_{D=1}^{T=1}(t_n) - F_{D=0}^{T=1}(t_n)) \\ &= \delta_e - \delta_n \end{aligned} \quad (5)$$

The residual for post-land right information was $\varepsilon(t) = DID - DID\ = \delta_e - (\delta_e - \delta_n) = \delta_n > 0$. When $F_{D=1}^{T=1}$(t) and $F_{D=0}^{T=1}$(t) were diverging, the DID > DID was $t_n \to t_0$, $\delta_n \to 0$. Therefore, $\varepsilon(t) \to 0$ as $t_n \to t_0$.

Policymakers may seek to understand the effects of land right instruments at t_0, t_n and t_e on outcomes measured at the period t_0, t_n and t_e. The conventional DID estimation of such an effect would be affected by self-selection bias because of the limitation of two periods. However, the estimates of the effects are less likely to be confounded by observed and time-invariant unobserved variables when the matched samples produce a conditional DID estimator (Balasubramanya et al., 2018). This study employed a matched-based *flexpaneldid* model set out by Dettmann et al. (2020) to address the self-selection bias and examine the long time-varying (more than two periods) effects of land tenure on food security

among smallholders.

$$\begin{aligned} F_{it}^{q} &= F_{D=1}^{T=1}((t_{2018})|\,p(X) - F_{D=0}^{T=1}(t_{2018})|p(X)) \\ &\quad - (F_{D=1}^{T=1}(t_{2015})|\,p(X) - F_{D=0}^{T=1}(t_{2015})|p(X)) \\ &\quad - (F_{D=1}^{T=1}(t_{2012})|\,p(X) - F_{D=0}^{T=1}(t_{2012})|p(X)) \\ &= \delta_{2018} - \delta_{2015} - \delta_{2012} \end{aligned} \tag{6}$$

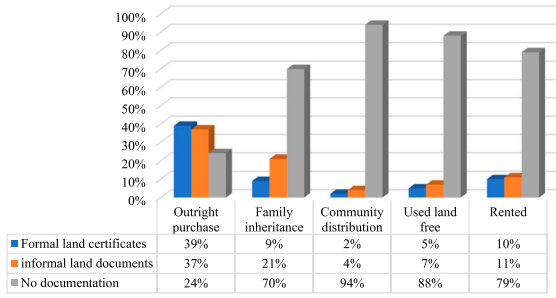
In Equation (6), each level of food security measurements for documented landholding unit ($F_{D=1}^{T=1}$) and non-documented landholding unit ($F_{D=1}^{T=0}$) at the initial stage (2012/13 & 2015/16) and at the final (2018/19) stage were outcome variables. The *flexpaneldid* technique selected households that are not or are in the process of acquiring or documenting land rights at the 2012/13 and 2015/16 surveys. The selected households become written and unwritten landholding units in the 2018/19 survey.

- The *Gologit* regression was selected to impose the Partial Proportional Odds (PPO) assumption (where upper levels of an outcome variable have a single coefficient) of the ordered logit regression. As food security (*F)* was an ordered categorical variable with $q = 1 \ldots 6$, the *Gologit* model fitted the *flexpaneldid*-matched data as expressed as:

$$\begin{aligned} &P(F_{it}^{q} > j|p(X)) \\ &\quad = \alpha + \mu(D_i|p(X)) + \gamma(T_t|p(X)) \\ &\qquad + \beta(D_i|\,p(X)*T_t|p(X)) + \varepsilon_{it},\ \ i \\ &\quad = 1 \ldots..N_m,\ \ t = 1 \ldots\ T \end{aligned} \tag{7}$$

$$P(F_{it}^{q} > j) = \frac{\exp(\alpha_j + (D_i*T_t)\beta_j)}{1 + [\exp(\alpha_j + (D_i*T_t)\beta_j)]}, j > 1 \ldots.M$$

In Equation (7), q was a vector for the food security indicator. The X_{it} represented the control variables (i.e. the socioeconomic features) for selecting the matched samples. The j referred to the comparison level (i.e. the least level) for each food security indicator scale, equal to one. The *Gologit* model did not violate the Partial Proportional Odds (PPO) assumption when the Parallel Line (PL) test showed a non-significant value. Hence, each food security indicator (i.e. $j > 1$) was expressed in equal coefficients of land tenure. The *Gologit* model analyzed Equation (7). The land tenure measures as the explanatory variables were fitted to Equation (7). This study reported the interaction effects on the *flexpaneldid-Gologit* regression model because the interaction coefficient between land tenure and year revealed the conditional DID effect. The analysis was conducted using STATA 15.1 software (StataCorp, 2017).



	Outright purchase	Family inheritance	Community distribution	Used land free	Rented
Formal land certificates	39%	9%	2%	5%	10%
informal land documents	37%	21%	4%	7%	11%
No documentation	24%	70%	94%	88%	79%

Figure 1. Proportion of tenure documentation across land acquisition mode. Note: Each land acquisition indicator (Observation N): Outright purchase (142), family inheritance (774), community distribution (449), used land free (176) and rented land (149).

4. Results and discussion

Figure 1 presents the summary of land right documentation by mode of land acquisition. Informal land documents were held by landholders more than formal land certificates to protect the land rights of landholders with family inherited land, community distributed land, free use land and rented land. There was insufficient documentation of land rights associated with family inherited land, community distributed land and free use land. The uncoded social norms and customary network attributes of family inherited land and community allocated land can reduce farmers' aspiration to document their land rights (Hall et al., 2019). Households may freely use land owned by someone else – 176 sampled households used land for free. Five percent of free land users held formal land certificates while 7% held informal documents. Household may freely use documented or undocumented land with consent of the landowners as a form of charity or obligated pledges.

While a high proportion (76%) of documented holders acquired outright purchase land, formal documentation of land rights was more prevalent among households, who held land through outright purchase. Formal land certificates were held by 39% of households who acquired land through outright purchase. Informal land documents were held by 37% of households, who had outright purchased land. About 79% of households with rented land neither held formally certificated land nor used informally

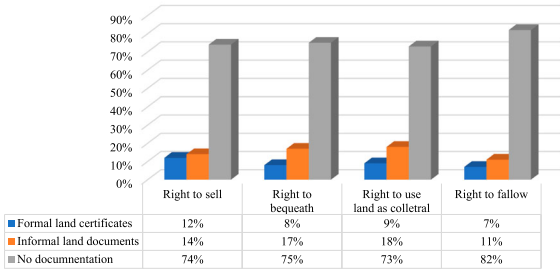


Figure 2. Proportion of tenure documentation across perception of land rights. Note: Each land right perception indicator (Observation N): Right to sell (172), Right to bequeath (934), Right to use land as collateral (898) and Right to fallow (67).

documented land, exposing the tenants to insecure use rights. The formal land tenure was defined under the auspices of the 1978 LUA, instructing the landlords (i.e. official landholders) to have a certificate of occupancy or official customary right of occupancy in Nigeria (LFN, 2004). However, the informal land tenure occurred when there is a land transfer to unofficial landlords or land users from official landlords in the country. Like the purchased land, informal transfer deeds or witnessed paper-based contracts for land use could be exchanged between landlords and tenants (Yemadje et al., 2014).

Figure 2 illustrates the land right documentation by the household perception of land rights. Households who perceived they had rights to sell (14%) held informal land documents more than they (12%) held formal land certificates. About 17% of households who perceived they had rights to bequeath and use land as collateral held informal land documents, while less than ten held formal land certificates. A small proportion (11%) of households who perceived they had the right to fallow held informal land documents and even fewer (7%) held formal land certificates. Generally, while the perception of land rights was a subjective measurement, most households who perceived they had rights to sell (74%), bequeath (75%), fallow (82%) and use land as collateral (73%) did not associate their land rights with land documentation. As a result, these households felt tenure insecure when their land rights were overruled with formal tenure rules of 1978 LUA, such as government consent requirement before land transfer and no freehold land rights.

Table 3 presents the summary statistics for the socioeconomic features of the smallholders across land ownership indicators. On average, the age of smallholders was between 46 and 53 years. The lowest age average was found among family-inherited landholders. Almost all sampled landholders belong to the polygamous section (median category 2) of marital status and had at least six (6) household members. The sampled households with family inherited land had the least trees (10 trees). The holders of rented land and 'free of use' land owned the least three livestock. Landholders owned at least two plots with land areas less than one hectare even if less than 90% of the lands were acquired before 1978 LUA. Households with purchased land, 'free of use' land and rented land held Junior Secondary

Table 3. Socioeconomic features of smallholders across their mode of land acquisition.

Land tenure measure	Mode of land acquisition				
Control variable	Outright purchase	Family inheritance	Community distribution	Used land free	Rented
Age (year)	50	46	53	48	49
Marital status (median category)	2	2	1	2	2
Tree own (number)	126	10	74	37	23
Household size (number)	8	7	6	7	7
Total plot area (ha)	0.79	0.60	0.50	0.59	0.65
Plot area owned (ha)	0.74	0.54	0.39	0.31	0.38
Plots (number)	3	3	2	2	3
Acquired land after LUA (%)	0.99	0.92	0.82	0.95	0.99
Total livestock units (number)	7	7	13	3	3
Household education (median category)	5	4	4	5	5
Cooperative membership (%)	0.06	0.04	0.05	0.05	0.07
Smallholder in rural sector (%)	0.10	0.55	0.32	0.11	0.09
Smallholder in urban sector (%)	0.13	0.47	0.23	0.22	0.23
2012/13 survey (%)	0.18	0.03	0.86	0.31	0.28
2015/16 survey (%)	0.21	0.47	0.09	0.28	0.28
2018/19 survey (%)	0.61	0.50	0.05	0.41	0.44
Observation	142	774	449	176	149

School certificates (median category 5 of education variable). Households with inherited land and community distributed land had vocational school certificates (median category 4 of education variable). Less than 8% of the landholders were cooperative society members irrespective of the mode of acquisition. Lands acquired through family inheritance and community distribution by households were more prevalent in the rural than urban sectors. Most urban households acquired land through outright purchase and renting, implying a high prevalence of land market activities in the urban areas. Households that receive land through outright purchase, family inheritance, free land use and renting dominated during the 2018 survey compared to the subsequent surveys used. More households acquired community-distributed land during the 2012/13 survey conducted during the 2011 Agricultural Transformation Agenda reign.

Table 4 presents the summary statistics for the socioeconomic features of the smallholders across land rights documentation. The average ages of sampled households with land-related documents were between 50 years to 51 years, slightly more significant than the overall age average (48 years) of sampled households. Middlemost of the sampled household heads that held land-related documents were married (polygamous – median category) and had at average six (6) household members. The education attainment of households was between vocational (median category 4) and junior secondary school (median category 5). The total land area managed by smallholders and across holders of land-related documents was less than one hectare and fewer than three plots. Most of the sampled smallholders that held land-related documents acquired their land after the 1978 LUA confirmation. The sampled households owned eight livestock and 326 trees, with those holding informal land documents owning more (10) livestock and (60) trees than what holders of formal land certificates had on their plots. The cooperative membership among households and those who held land-related documents were low. There was no difference in the small proportion of households that owned informal land documents in urban and rural areas. The formal land certificates were held by urban smallholders more than rural smallholders. The results suggest that only a few small-scale farming existed in the urban areas (about 4% of the sample households). The urban farmers may have the legal knowledge of the benefits and processes regarding formal land right documentation more than the rural land users. The results were consistent with Ghebru et al. (2014). More than half of the smallholders who held formal land certificates and informal land documents were observed during 2018/19 and 2015/16. Overall, a low proportion of smallholders had formal land certificates or informal land documents in Nigeria.

Table 4. Socioeconomic features of smallholders across land right documentation type.

Land tenure measure	Land right documentation indicators		
Control variable	Formal land certificate	Informal land document	Total
Age (year)	51	50	48
Marital status (median category)	2	2	2
Tree own (number)	1	60	323
Household size (number)	9	7	7
Total plot area (ha)	0.72	0.65	0.57
Plot area owned (ha)	0.65	0.56	0.45
Plots (number)	3	2	2
Acquired land after LUA (%)	0.94	0.90	0.89
Total livestock units (number)	8	10	8
Household education (median category)	5	5	4
Cooperative membership (%)	0.10	0.08	0.05
Smallholder in rural sector (%)	0.06	0.14	0.92
Smallholder in urban sector (%)	0.13	0.14	0.08
2012/13 survey (%)	0.12	0.08	0.34
2015/16 survey (%)	0.29	0.69	0.33
2018/19 survey (%)	0.59	0.25	0.33
Observation	98	195	1434

Table 5 compares the mean difference in land tenure between smallholder female and male household heads. The results suggested that inequality in the mode of land acquisition exists in Nigeria and between male and female households in the country. The results revealed that households who acquired family inherited land and community distributed land dominated smallholder agriculture in Nigeria. About 10% of the sampled households acquired rented and purchased land, while 12% of households used land free. The results showed that the mean difference of gender in land acquired through outright purchase and renting were statistically significant at the 1 and 10% levels, respectively. Through the outright purchase and family inheritance, male households acquired significantly more land (at least 4% more than female households). Female households rented 6% more land and

Table 5. Mean difference in land tenure between male and female smallholders.

Land tenure measure	Indicator	Total	Female	Male	Difference
Mode of land acquisition	Outright purchase	0.10	0.04	0.11	−0.07***
		(0.30)	(0.01)	(0.01)	(0.02)
	Family inheritance	0.54	0.51	0.55	−0.04
		(0.50)	(0.03)	(0.01)	(0.04)
	Community distribution	0.31	0.33	0.31	0.02
		(0.46)	(0.03)	(0.01)	(0.03)
	Used land free	0.12	0.10	0.13	−0.03
		(0.33)	(0.02)	(0.01)	(0.02)
	Rented	0.10	0.15	0.10	0.06***
		(0.31)	(0.02)	(0.01)	(0.02)
Land right documentation	Held a formal land certificate	0.07	0.04	0.07	−0.04**
		(0.25)	(0.01)	(0.01)	(0.02)
	Held an informal land document	0.14	0.08	0.15	−0.07***
		(0.34)	(0.02)	(0.01)	(0.03)
Perception of land rights	Right to sell	0.12	0.07	0.13	−0.06***
		(0.33)	(0.02)	(0.01)	(0.02)
	Right to bequeath	0.65	0.55	0.67	−0.12***
		(0.48)	(0.03)	(0.01)	(0.03)
	Right to fallow	0.05	0.06	0.05	0.01
		(0.22)	(0.02)	(0.01)	(0.02)
	Right to use as collateral	0.63	0.41	0.66	−0.25***
		(0.48)	(0.03)	(0.01)	(0.04)
	Observation	1434	217	1217	

Note: Standard error in parentheses, Significant level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

acquired 2% more community-distributed land than male households. While the holders of informal land documents were more than those who held formal land certificates, the results showed a significant mean difference in land right documentation between male and female households at the 5 and 10% significance level. More (4 & 7%) male households held formal land certificates and informal land documents than female households. With a high prevalence of family inherited land acquired by sampled households, smallholders perceived more right to bequeath and right to use land as collateral. However, formal loan acquisition may be difficult for smallholders when collateralized land was not formally registered. Male household heads perceived they had the right to sell (6%), right to bequeath (12%) and right to use land as collateral (25%) significantly more than the female household heads.

Table 6 presents the mean difference in land tenure measures across the smallholders' zones. There were low incidences of outright land purchase, community land distribution, free land usage and renting across the smallholders' zones. Smallholders of the South-West zone had the highest prevalence of outright land purchase (27%) and free land usage (33%) in Nigeria. Land acquired through renting by smallholders was prevalent in the South-South zone. More than half of the sampled smallholders acquired land through family inheritance, which was similar (i.e. not significantly different) across the smallholders' zones. While the North-West zone had the most (14%) households who held formal land certificates, informal land documents were more held by (31%) smallholders of the South-West zone. The prevalence of land documentation (formal certificates or informal documents) in the two zones (North-West & South-West zones) could be attributed to their high rate of land market participation (i.e. outright land purchase). Households that perceived they had the right to bequeath and left land fallow were more than those that perceived they had the right to sell and use land as collateral across the zones.

4.1. Descriptive summary of food security indicators

Figure 3 summarizes the food security indicators. Except for the HDDS, asset ownership and LCS, most indicators showed that smallholders were food insecure. One in three (33%) sampled smallholders spent less than half their total budget on food, classifying them as food secure. With 37% budgeted more than 74% of total income and 18% households budgeted between 65 and 74% of total income on food, 55% of the sample smallholders spent more than 65% of their total budget on food, which classified them as food insecure.

Table 6. Mean difference in land tenure among smallholders across the zones in Nigeria.

Land tenure Measure	Indicator	North-Central	North-East	North-West	South-East	South-South	South-West	Chi2 (Prob)
Mode of land Acquisition	Outright Purchase	0.05	0.10	0.18	0.03	0.10	0.27	75.92* (0.00)
	Family Inheritance	0.54	0.58	0.53	0.57	0.53	0.36	10.54 (0.06)
	Community Distribution	0.28	0.40	0.28	0.39	0.25	0.17	28.23* (0.00)
	Used land free	0.14	0.09	0.13	0.07	0.16	0.33	41.56* (0.00)
	Rented	0.06	0.08	0.05	0.08	0.28	0.08	97.56* (0.00)
Land right Documentation	Held a formal land certificate	0.06	0.10	0.14	0.02	0.06	0.02	47.03* (0.00)
	Held an informal land document	0.13	0.15	0.15	0.07	0.17	0.31	34.75* (0.00)
Perception of land rights	Right to sell	0.22	0.23	0.08	0.10	0.08	0.06	47.36* (0.00)
	Right to bequeath	0.81	0.76	0.68	0.57	0.55	0.69	53.08* (0.00)
	Right to fallow	0.70	0.81	0.72	0.55	0.49	0.48	76.49* (0.00)
	Right to use as collateral	0.02	0.02	0.02	0.10	0.08	0.02	40.80* (0.00)
	Observation	195	144	354	431	246	64	

Note: Standard error in parentheses, Significant level: *$p < 0.01$.

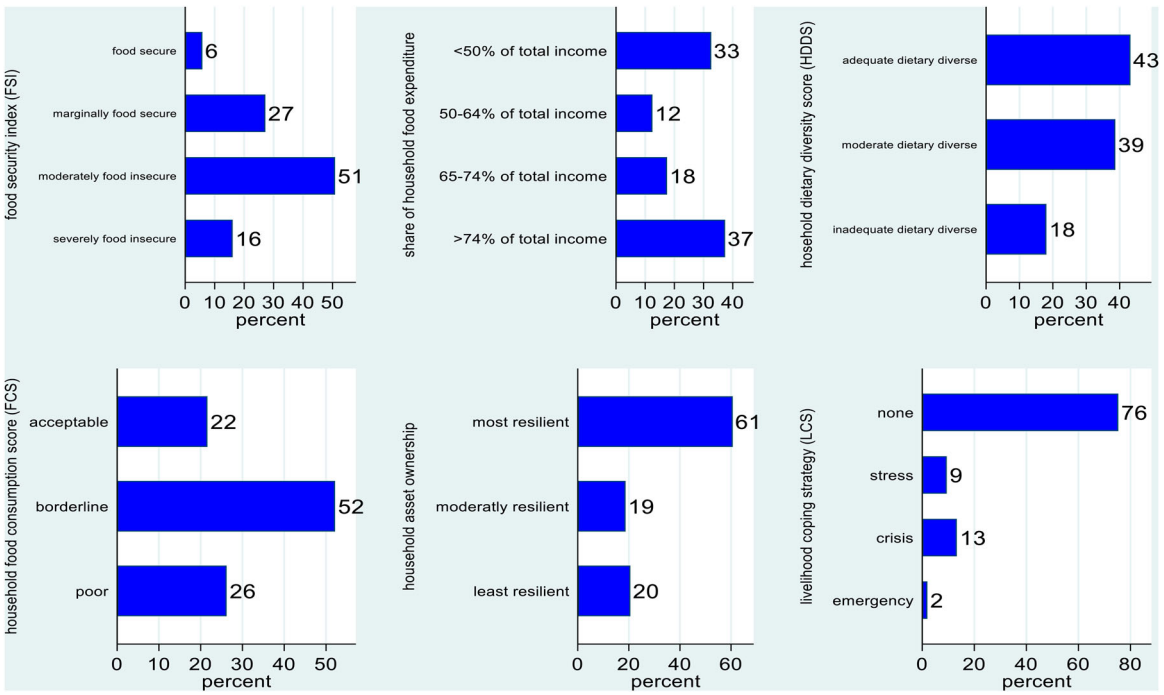


Figure 3. Descriptive summary of food security indicators of households operated ≤2ha plot. Note Total sampled population N = 1434.

About 61% of smallholders held ten or more assets. Approximately one (20%) in five smallholders were classified as food insecure, owning less than three assets, rendering them vulnerable to future shocks. Only 2 and 13% of smallholders were in emergency and crisis levels of the LCS, which classified them as food insecure (Figure 3).

The results revealed that 43% (adequate) and 39% (moderate) of the sampled smallholders had high HDDSs. However, 52% (borderline) and 26% (poor) of the smallholders had low FCSs. In other words, 82% (adequate & moderate) of households consumed diverse diets but only 22% (acceptable) consumed more nutritionally dense foods. The FCS and HDDS were expected to be positively correlated as both asked about food consumption (Hendriks et al., 2016). However, this study finds opposite results to the *a priori* expectation. The difference in the HDDS and FCS could be attributed to the method of construction of the indexes.

As shown in Appendix 1, more than half of sampled households who acquired land through renting and community distribution were moderately food insecure. The result reveals an increased proportion of marginal food insecure households acquired land through renting, purchasing, inheritance, community distribution and those who accessed land free of charge. More than half the households who held rented land, purchased land, inherited land and free land were considered food secure with respect to the FCS, HDDS, household asset ownership and the LCS. More than half the households who acquired land through communal distributed land were food secure as indicated by the HDDS, household asset ownership and the LCS. More food secure households held formal land certificates or informal land documents to secure land rights. For example, more than half the households who had formal land certificates were classified as food secure through the FCS, HDDS, household asset ownership and the LCS (as presented in Appendix 2).

4.2. Regression results for mode of land acquisition across food security indicators

Table 7 shows the coefficients of two modes of land acquisition, such as family-inherited land and accessed land for free, which were statistically significant to explain food security indicators like FSI, HDDS, FCS, ownership of assets, and LCS. The coefficients of other land ownership indicators such as outright purchased land, rented land and community distributed land were not statistically significant, affecting the degree to explain their influence on the food security indicators. Households with family inherited land were 57% more likely to consume diverse diets (HDDS). Also, land ownership through inheritance increased total household assets by 95%. However, households with inherited land were 20% less likely to have high FCSs. The livelihood coping capacity of households was reduced by 43% when they acquired land through inheritance. The overall food security index was reduced by 56% for households with inherited land. Smallholders who accessed land for free were 47% less likely to consume diverse diets. This result implied that free land accessibility did not guarantee increased consumption of diverse diets among smallholders. Therefore, family-inherited plots contributed to improving food security.

Contrary to most food security studies that found land ownership through purchases and communal and lease arrangements reduced dietary diversity (Kehinde et al., 2021; Shittu et al., 2019), this study found no statistical significance evidence of this. Most previous studies relied on cross-sectional and non-nationally representative smallholders' data, which may have subjected their empirical estimates to endogenous problems. Other studies have not considered panel data approaches.

4.3. Regression results for land right documentation across food security indicators

Table 8 reveals that holding an informal land document was significant and more likely to affect FSI, HDDS, FCS, food expenditure share, the ownership of household assets and LCS. Smallholder farmers who secured tenure by holding informal documents were likely to have lower food expenditure shares (+2%), higher HDDS (+84%) and higher LCS (+2%), respectively. The results implied that informal land documents did not increase the high food expenditure share (i.e. greater than 74% of total monthly income), indicating households' food security. Production on the farm would lower the expenditure on food. On the other hand, informal land documents increased the LCS and HDDS.

Holding informal land documents was significant to increase HDDS, suggesting that households consumed high diverse diets when they had informal

Table 7. Regression results of the effect of land acquisition on food security.

Indicator	Land tenure	Land acquisition indicators				
	Scale	Outright purchase	Family inheritance	Community distribution	Access free	Rented
Food security indicator		Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)
FSI	Food secure	0.88	0.57**	2.08	2.41	0.91
		(0.64)	(0.27)	(2.24)	(1.57)	(0.65)
	Marginally food secure	0.88	0.57**	2.08	2.41	0.91
		(0.64)	(0.27)	(2.24)	(1.57)	(0.65)
	Moderately food insecure	0.88	0.57**	2.08	2.41	0.91
		(0.64)	(0.27)	(2.24)	(1.57)	(0.65)
	Severely food insecure[u]					
	Matched observation	122	657	103	166	138
Food expenditure share	<0.5	1.77	0.51	0.70	1.70	2.08
		(1.75)	(0.36)	(1.65)	(1.65)	(1.89)
	0.50–0.64	1.77	0.51	0.70	1.70	2.08
		(1.75)	(0.36)	(1.65)	(1.65)	(1.89)
	0.65–0.74	1.77	0.51	0.70	1.70	2.08
		(1.75)	(0.36)	(1.65)	(1.65)	(1.89)
	>0.74[u]					
	Matched observation	128	684	103	166	141
HDDS	Adequate	0.68	1.57**	1.16	0.53*	2.23
		(0.47)	(0.74)	(1.12)	(0.32)	(1.49)
	Moderate	0.68	1.57**	1.16	0.53*	2.23
		(0.47)	(0.74)	(1.12)	(0.32)	(1.49)
	Inadequate[u]					
	Matched observation	128	678	105	169	141
FCS	Acceptable	1.30	0.80**	1.45	2.10	1.43
		(0.93)	(0.37)	(1.53)	(1.34)	(0.96)
	Borderline	1.30	0.80**	1.45	2.10	1.43
		(0.93)	(0.37)	(1.53)	(1.34)	(0.96)
	Poor[u]					
	Matched observation	125	684	103	163	138
Assets	Most	1.63	1.95*	0.85	0.16	0.28
		(1.19)	(1.13)	(0.90)	(0.16)	(0.24)
	Moderate	1.63	1.95*	0.85	17.29	6.55
		(1.19)	(1.13)	(0.90)	(22.82)	(6.49)
	Least[u]					
	Matched observation	128	683	106	169	138
LCS	None	0.67	0.43*	0.40	4.81	0.93
		(0.60)	(0.24)	(0.54)	(5.91)	(0.83)
	Stressed	0.67	0.43*	1.95e04	4.81	0.93
		(0.60)	(0.24)		(5.91)	(0.83)
	Crisis	0.67	0.43*	1.68	4.81	0.93
		(0.60)	(0.24)		(5.91)	(0.83)
	Severe[u]					
	Matched observation	119	657	103	163	141

Note: u signified the compared category. Standard error in parentheses. Significant level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

documents such as a survey plan, government allocation receipt, purchase agreement, family receipt or building plan. However, holding informal land documents reduced the likelihood of an increased FCS by 12% and household asset ownership by 18%. These results suggest that despite their high dietary diversity, the consumption of nutritionally dense foods (such as animal products and pulses) was low among the holders of informal land documents. This result is due to the weighting of the FCS food groups. Although the coefficients of holding formal land certificates were positive for HDDS, asset ownership and LCS, there was a lack of statistical significance. The non-significant coefficients for formal land certificates are consistent with Kehinde et al.'s (2021) findings that formal land titling did not follow a *priori* expectation of holding formal land certificates to improve food security in Nigeria. Meanwhile, formal land certificates provide opportunities to use land as collateral. However, if the household

Table 8. Regression results of the effect of land right documentation across food security.

Food security Indicator	Scale	Formal land certificate Coeff. (Std error)	Informal land document Coeff. (Std error)
FSI	Food secure	0.74	0.93**
		(0.53)	(0.32)
	Marginally food secure	0.74	0.93**
		(0.53)	(0.32)
	Moderately Food insecure	0.74	0.93
		(0.53)	(0.32)
	Severely food insecure[u]		
	Matched observation	139	601
Food expenditure share	<0.50	0.64	1.02*
		(0.67)	(0.57)
	0.50–0.64	0.64	1.02*
		(0.67)	(0.57)
	0.65–0.74	0.64	1.02*
		(0.67)	(0.57)
	>0.74[u]		
	Matched observation	136	601
HDDS	Adequate	1.26	1.84***
		(0.88)	(0.63)
	Moderate	1.26	1.84***
		(0.88)	(0.63)
	Inadequate[u]		
	Matched observation	133	607
FCS	Acceptable	0.60	0.88***
		(0.44)	(0.30)
	Borderline	0.60	0.88***
		(0.44)	(0.30)
	Poor[u]	.	.
	Matched observation	133	607
Assets	Most	1.42	0.82***
		(1.18)	(0.29)
	Moderate	1.42	0.82***
		(1.18)	(0.29)
	Least[u]		
	Matched observation	136	595
LCS	None	1.99	1.02**
		(1.61)	(0.45)
	Stressed	1.99	1.02**
		(1.61)	(0.45)
	Crisis	1.99	1.02**
		(1.61)	(0.45)
	Severe[u]		
	Matched observation	136	595

Note: u signified the compared category. Standard error in parentheses, Significant level: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

does not have other assets to offset losses, farmers can lose land if they fall behind on repayments or suffer shocks that lead to an inability to repay loans.

5. Conclusion and policy implications

The study found that smallholders were more likely to consume diverse diets and hold more assets when acquiring plots through family inheritance. The Household Dietary Diversity Score (HDDS) was lower when households accessed free land. While this study found no evidence to suggest that formal land certificates improved food security, smallholders who held informal land documents were more likely to consume more diverse diets. However, these households had lower food expenditure shares and adopted more livelihood coping strategies. The study also found that smallholders who perceived they had the right to use land as collateral were more likely to have formal land documents. This study suggests that land tenure security is important for food security and needs to be attended to in African settings.

This study concluded that smallholders who acquired land via family inheritance positively influenced household assets and dietary diversity.

The findings may reflect the short-term effect of family-inherited land ownership on food security. In the long-run, land acquired through family inheritance may likely reduce food consumption scores and livelihood coping strategy of smallholders. As family size expand, land conflicts may arise, causing insecurity of farm investments and increase the risk of food insecurity for household members. Policies that facilitate or encourage access to agricultural land should recognise and inform smallholder farmers on the long-term implications of customary land acquisition. Farmers that held land for free (as charity or a pledge) had lower dietary diversity scores. Therefore, accessing free farmland alone may not lead to food security. Policymakers should consider other factors (e.g. farming skills and aspirations) for sustainable agricultural practices and food security of free land users.

Smallholders' livelihood coping strategies, dietary diversity and food expenditure shares increased when smallholders had informal land documents – securing tenure through informal documents associated with improved food security. Although NATIP has highlighted the importance of formal land titles, informal land documents are more accessible than formal land certificates. However, land with informal documents may constrain access to loans. Therefore, the results point to the need to formalize existing informal land documents and recognize the role of the customary mode of land acquisition among smallholder farmers to support food security.

Smallholders need land and control over the land they manage to improve food security. Without documentation of land rights to facilitate loan acquisition and farm investment, land acquisition does not support smallholder food security. However, this study found that customary land (through family inheritance) and informal land documents supported the food security of smallholder farmers more than formal tenure arrangements. The study findings have significant implications for land tenure policy. The study's findings can inform a review of the Nigerian Land Laws and facilitate dialogue with smallholders regarding land registration and rights documentation constraints. The findings suggest that land allocation/distribution and land title reforms (of 1978 LUA) should be inclusive and friendly to support smallholder agriculture and reduce the risk of insecure land rights and food insecurity.

The paper's contributions to literature remain relevant to agricultural and food security policies. However, some setbacks constrain the findings of the study. First, while food security categorizes as a multidimensional concept, this paper used available data to capture a limited number of relevant indicators for the level of food insecurity among smallholder farmers. More studies need to investigate the dynamic of land tenure systems on more context-specific and policy-relevant food security indicators. Second, we subjected three-wave panel data to the *flexpaneldid-gologit* model to analyze the relationship between the mode of land acquisition and land right documentation across multidimensional food security indicators. Thus, this paper did not look at the cause of the increase, pressing the need for future research to harness more scientific impact evaluation such as natural experiments to control for several confounding factors and determine the food security impact of land rights under different land tenure systems. While this study's findings are limited to the three rounds of data from household-heads, more detailed and better targeted data are required for future studies to examine the relationship at the individual household level and to explore factors related to intra-household dynamics, especially with regard to women's rights. Finally, the formal land tenure system in Africa is heterogeneously coexisting with customary land tenure institutions. The findings from these cohabitations in Nigeria are novel and will serve as a lesson to other African settings where similar land tenure and agricultural conditions persist. Future research should revalidate our findings in other African countries' contexts.

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Appendices

Appendix 1: descriptive summary of food security across land acquisition mode

Indicators	Sample size		Food insecure households		Vulnerable to becoming food insecure households	Food secure households
Food security		Classification	Severely food insecure	Moderately food insecure	Marginal food secure	Food secure
Index	149	Rented	6.71	51.68	30.2	11.41
	142	Outright purchased	9.42	47.83	29.71	13.04
	774	Family inheritance	9.53	46.34	35.25	8.88
	449	community distribution	26.95	56.57	14.92	1.56
Food		Classification	>75	0.65–0.74	0.50–0.64	<0.50
expenditure	149	Rented	22.82	15.44	16.78	44.97
Share	142	Outright purchased	23.94	9.86	7.75	58.45
	774	Family inheritance	25.45	15.12	11.76	47.67
	449	community distribution	55.9	23.61	12.47	8.02
HDDS		Classification	.	Inadequate	Moderate	Adequate
	149	Rented	.	28.86	34.23	36.91
	142	Outright purchased	.	26.06	30.99	42.96
	774	Family inheritance	.	21.58	39.41	39.02
	449	community distribution	.	12.69	38.53	48.78
FCS		Classification	Poor	Borderline	.	Acceptable
	149	Rented	20.13	52.35	.	27.52
	142	Outright purchased	25.35	50	.	24.65
	774	Family inheritance	23	49.87	.	27.13
	449	community distribution	33.18	52.78	.	14.03
Asset		Classification	.	Least	Moderately	Most
	149	Rented	.	20.81	13.42	65.77
	142	Outright purchased	.	14.08	9.15	76.76
	774	Family inheritance	.	17.44	17.96	64.6
	449	community distribution	.	27.29	21.48	51.23
LCS		Classification	Emergency	Crisis	Stressed	None
	149	Rented	0	15.44	5.37	79.19
	142	Outright purchased	2.9	12.32	5.8	78.99
	774	Family inheritance	1.7	13.71	9.14	75.46
	449	community distribution	3.12	11.14	11.58	74.16

Appendix 2: descriptive summary of food security across land right documentation type

Indicators	Sample size		Food insecure households		Vulnerable to becoming food insecure households	Food secure households
Food security index		Classification	Severely food insecure	Moderately food insecure	Marginal food secure	Food secure
	98	Formal land certificate	12.37	41.24	32.99	13.4
	195	Informal land documents	10.31	53.61	27.84	8.25
Food		Classification	>75	0.65–0.74	0.50–0.64	<0.50
	98	Formal land certificate	25.51	9.18	6.12	59.18
	195	Informal land documents	35.9	23.59	13.33	27.18
HDDS		Classification	.	Inadequate	Moderate	Adequate
	98	Formal land certificate	.	26.53	29.59	43.88
	195	Informal land documents	.	24.62	41.03	34.36
FCS		Classification	Poor	Borderline	.	Acceptable
	98	Formal land certificate	29.59	45.92	.	24.49
	195	Informal land documents	18.46	51.28	.	30.26
Asset		Classification	.	Least	Moderately	Most
	98	Formal land certificate	.	13.27	7.14	79.59
	195	Informal land documents	.	15.9	16.92	67.18
LCS		Classification	Emergency	Crisis	Stressed	None
	98	Formal land certificate	2.06	10.31	7.22	80.41
	195	Informal land documents	1.55	16.49	7.73	74.23