Evaluation of land tenure on household food security and child nutrition among smallholder farmers in Nigeria

by

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Abstract

Secure land tenure is essential to improve smallholder food security and children's nutrition. However, evidence of this association is lacking. This study sought to address this gap by investigating three sub-objectives: the causal effect of smallholder land tenure on household food security; the effect of smallholder land tenure on child malnutrition; and the relationship between smallholder household food insecurity and child nutrition in Nigeria between 2012 and 2019. Panel data from Nigeria's living standards measurement study's integrated surveys on agriculture from 2012/13, 2015/16 and 2018/19 were analysed using flexible conditional difference-in-difference and logistic regression models. The land tenure types investigated included land acquisition via family inheritance, community distribution, outright purchases, rent and free land use and formal land certificates and informal land documents. The Consolidated Approach for Reporting Indicators of Food Insecurity (CARI); food expenditure shares; the household dietary diversity score (HDDSs); the food consumption score (FCSs); asset ownership and the Livelihood Coping Strategy (LCS) were used as proxies for household food security. Children's malnutrition indicators included stunting, wasting, underweight, overweight and stunted-overweight. Household socioeconomic and demographic characteristics were used as controls in the analysis. Land ownership via family inheritance and holding informal land documents might support smallholder food security by increasing their dietary diversity and lowering their food expenditure shares. Households on family-inherited land were 57% more likely to consume diverse diets (HDDS) but were 20% less likely to have high FCSs. On the other hand, smallholder farmers holding informal documents were more likely to have lower FCS (-12%), higher HDDS (+84%) and higher LCS (+2%). Smallholder land tenure had a small but relevant effect on reducing child malnutrition with community-level land distribution and informal land documents in Nigeria. Households on community-distributed land (allocated by community leaders) were eight and five percent less likely to have stunted and underweight children. In addition, while the formal land certificate holders had a 13% chance of having stunted children, informal land document holders were seven and five percent less likely to have wasted and underweight children. Food-insecure households (with poor or borderline FCSs) were more likely to have stunted and wasted children.

Households with fewer than three assets were less likely to have overweight children. Children from households with high food expenditure shares were more likely to be stunted, wasted and underweight. Children in food-insecure households (with low HDDSs and LCSs) were more likely to be stunted. The Nigerian government should formalise existing informal land documents and recognise the role of customary land acquisition with certificates among smallholder farmers to support food security and nutrition policies.

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Declaration 1: Originality

I declare that this thesis, which I submitted in partial fulfilment of the Doctor of Philosophy in Agricultural Economics at the University of Pretoria, is my work and has never been submitted for a degree award at this or any other institution. The thesis findings are my original work. I avoid plagiarism by adequately acknowledging and referencing other sources used in the thesis.

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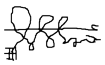
Signed: 

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Declaration 2: Papers for publication

The following paper has been published based on chapter four and five of this thesis:

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Dedication

I dedicate this thesis to God Almighty, the Kobe family and my colleagues.

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Acronyms and Abbreviation

AfDB	African Development Bank
AFSNS	Agricultural Sector Food Security and Nutrition Strategy
APP	Agricultural Promotion Policy
ATE	Average Treatment Effect
AU	African Union
AUC	African Union Commission
BAZ	BMI-for-age z-scores
BMI	Body Mass Index
CARI	Consolidated Approach to Reporting Indicators of Food Security
CBN	Central Bank of Nigeria
CFS	Committee on World Food Security
CGAP	Consultative Group to Assist the Poor
CIA	Central Intelligence Agency
DHS	Demographic Household Survey
DID	Difference-in-difference
DRC	Democratic Republic of Congo
ECA	Economic Commission for Africa
FAO	Food and Agriculture Organization
FCS	Food Consumption Scores
FCT	Federal Capital Territory
FSI	Food Security Index
F&G	Guidelines on Land Policy in Africa
FE	Fixed effect model
HFIAS	Household Food Insecurity Access Scale
Flexiblepaneldid	Flexible Panel Difference-in-difference
FMARD	Federal Ministry of Agriculture and Rural Development
GHS	General Household Survey
GDP	Gross Domestic Product
Gologit	Generalised Ordinal Logistic Regression
HAZ	Height-for-age z-scores

HBZ	Height-for-BMI z-scores
HDDS	Household Dietary Diversity Scores
HLPE	High-Level Panel of Experts
ICF	International Classification of Functioning Disability and Health
IFAD	International Fund for Agricultural Development
LCS	Livelihood Coping Strategy
LFN	Laws of Federal Republic of Nigeria
LPI	Land Policy Initiate in Africa
LUA	Land Use Act
LULC	Land Use and Land Change
LSMS-ISA	Living Standards Measurement Study - Integrated Surveys on Agriculture
MICS	Multiple Indicator Cluster Survey
NATIP	National Agricultural Technology and Innovation Policy
NBS	National Bureau of Statistics
NFMH	Nigerian Federal Ministry of Health
NNHS	National Nutrition and Health Survey
NPC	National Population Commission
OECD	Organisation for Economic Co-operation and Development
PCA	Principal Component Analysis
PPO	Partial Proportion Odds
PSM	Propensity Score Matching
PTCR	Presidential Technical Committee for Land Reform
RAI	Principle for Responsible Investment in Agriculture and Food Systems
RD	Regression discontinuity
RE	Random effect model
SDG	Sustainable Development Goals
SOFI	State of Food Insecurity in the World Report
SSA	Sub-Sahara Africa
TLU	Tropical Livestock Units
UN-Habitat	United Nations Habitat
UN	United Nations

UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
US HSSFM	United States Household Security Survey Module
VGGT	Voluntary Guidelines on Responsible Governance of Tenure of Land in the Context of National Food Security
WAZ	Weight-for-age z-scores
WFP	World Food Programme
WHA	World Health Survey
WHO	World Health Organization
WHZ	Weight-for-height z-scores

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Chapter 1 : Introduction

1.1 Background

The Voluntary Guidelines on the Responsible Governance of Tenure of Land in the Context of National Food Security (VGGTs) and Frameworks and the Guidelines on Land Policy in Africa (F&G) were established to address access to land and tenure security to achieve food security and improve nutrition among smallholder farmers. Despite efforts to domesticate and implement the VGGTs and F&G across member state signatories to the United Nations (UN) and African Union, respectively, there is little empirical evidence to link land tenure to changes in household food security and the nutritional status of children.

Food security and land tenure are different facets of studies in the development literature (Ghebru & Holden, 2013). Research in food security typically focuses on ensuring that "all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets dietary needs and food preference for an active and healthy life" (High-Level Panel of Experts HLPE, 2020 p.7).). Land tenure studies typically focus on strengthening household property rights to land, reducing uncertainty and increasing confidence in international land deals and agricultural investments (Besley, 1995). Another stream of literature focuses on the linkages between the two development policy issues and understanding the impact of agricultural growth on hunger and nutrition (United States Agency for International Development USAID, 2016; Gillespie et al., 2012).

Agriculture has been the primary source of livelihood in developing countries, where smallholders have dominated production yet constitute the largest share of food-insecure people (Fan & Rue, 2020). Limited access to land and weak tenure security may affect each dimension of food security in Africa, where the livelihood of over 70% of people is contingent on land and natural resource exploitation (United Nations Economic Commission of Africa ECA, 2004; Landesa, 2012). In Africa, different types of land tenure persist due to the diverse tenure institutions and changes in economic, cultural, political, and legal systems (ECA, 2004; Simbizi et al., 2014). The types of land tenure in terms of perceived land rights, land ownership and tenure institutions may provide a better understanding of the effects of tenure security and land ownership on different dimensions of food security (ECA, 2004). Secure land tenure is central to promoting rural livelihoods in Africa

because people derive food and income directly from their land (ECA, 2004). Climate change and natural resource degradation affect sustainable food security. Agricultural productivity declines amidst land resource degradation, soil erosion, salination, desertification and deforestation (Lubowski et al., 2006). Likewise, population growth, rapid urbanisation, changing diets and economic development raise competition over limited land, causing conflicts and reducing the available land for food production (Holden, 2020; Lawry et al., 2017; Lay et al., 2021). Land tenure security can overcome these problems, motivating investment and promoting sustainable agricultural systems (Lay et al., 2021; USAID, 2013).

The United Nations General Assembly endorsed the 2030 agenda for sustainable development in 2015 (UN, 2015). The importance of land tenure security is reflected in Goal one and found relevant in meeting Sustainable Development Goal SDG2 targets (end hunger, achieve food security, improve nutrition, and promote sustainable agriculture) of the agenda (African Union AU, 2017a). The land tenure indicator of SDG1 states that by 2030, "all men and women, in particular, the poor and the vulnerable, have equal rights… [of] ownership and control over land" (UN-Habitat & World Bank, 2018, p. 1). Understanding the indicator and its concepts stresses the international guidelines of VGGTs, which link food security to land tenure (Van Haren & Van Boxtel, 2017). The VGGTs endorsed the UN Committee on World Food Security (CFS) in May 2012 to promote secure tenure rights and ensure equitable access to land that could increase food security through land quality improvements and conflict-free land transfer (AU, 2017b).

Before the adoption of the VGGT framework (2009), African leaders had declared land tenure to be a crucial strategy for attaining the goals of the African Union's (AU) Agenda 2063 (AU, 2017a). Sound land governance is necessary for achieving AU Goal five (agriculture), mainly to reduce hunger. The Land Policy Initiative (LPI) in Africa supports member states in attaining the agricultural production targets of AU Goal five by building financial, human and technical capacities to domesticate the F&G and VGGTs (AU, 2017a).

African leaders also adopted the 2014 Malabo Declaration, which considers land tenure key to doubling agricultural productivity and eradicating hunger in Africa by 2025 (AU, 2020a). Appropriate policies and management assure equitable access to land and secure land rights of smallholders are highlighted in the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods. The implementation of the

Malabo Declaration includes a commitment by the Heads of State and Governments that all smallholder farm households should have ownership or security of land rights by 2025 (Target3 1vi) (AU, 2017a). The AU member states also acknowledged the Principles for Responsible Investment in Agriculture and Food Systems (RAI), which, in Principle five, emphasises respecting people's tenure rights as an essential component for attracting more significant and sustainable investment in agriculture and food systems (Committee on World Food Security CFS, 2014).

Responding to implementing the Malabo Declaration, the AU member states have domesticated the Africa F&G and the international VGGTs to address land tenure issues and promote food security and nutrition. However, despite all the efforts in addressing land tenure issues, many African countries are off-track to meet the target of the AU Agenda 2063 in addressing hunger through sustainable agriculture (AU, 2020b). Therefore, we need to deepen our understanding of the link between food security and nutrition and land tenure in smallholder agriculture.

1.2 Problem Statement

The proportion of food-insecure and malnourished people has risen globally (Food and Agriculture Organisation FAO, International Fund for Agricultural Development IFAD, United Nations International Children's Emergency Fund UNICEF, World Food Programme WFP & World Health Organisation WHO, 2022). The increase raises concern for development experts on the feasibility of meeting the 2030 target of SDG2, which calls to end hunger, achieve food security, improve nutrition and promote sustainable agriculture (UN, 2015). The proportion of severely food insecure households in Nigeria increased from 11% in 2014-16 to 19.1% in 2019-21 (FAO et al., 2022). Stunting among children under five years of age increased by five million and wasted children reduced by two million between 2019 and 2020 (FAO et al., 2022; FAO, IFAD, UNICEF, WFP & WHO, 2019). Yet, the risk of death and disease due to poor nutrition is not falling, especially in Asia and Africa (FAO et al., 2022). Increasing food insecurity and malnutrition affect the productivity and development of food-insecure households' physical, social, emotional, and cognitive health (Pérez-Escamilla, 2017; Schönfeldt et al., 2017). Most food-insecure people are found in developing countries, where people's livelihoods depend on small and insecure farmland (Keyman, 2012).

Africa's leaders have prioritised food security and the nutrition-sensitive agricultural sector to address hunger and malnutrition (FAO, 2018a). Nutrition-sensitive agriculture is a nutrition-sensitive intervention strategy with the potential to improve food security and nutrition by addressing the underlying causes of malnutrition (WFP, 2014). Land is crucial for sustainable agriculture and development. In densely populated places in Africa, unequal access to land, conflict and uncompensated evictions limit the potential for agricultural systems to support food security and nutrition (Keyman, 2012; Muraoka et al., 2018). Without secure tenure, farmers are less motivated to make agricultural investments or participate in income-generating land contracts (Simbizi et al., 2014; Besley, 1995).

There are limited studies of the relationship between land tenure security and food security and nutrition worldwide. Existing literature has conceptualised the relationship between food security and land tenure (Holden, 2020; Maxwell & Wiebe, 1999; Rockson et al., 2013; ECA, 2004), but few studies have researched the linkages. Maxwell & Wiebe (1999) argued that no one-size-fits-all indicators explain food security, nutrition and land tenure. Existing studies suggest that measuring land tenure systems and food security indicators should be multidimensional (Carletto et al., 2013; Fenske, 2011; Fitawek et al., 2020; Simibizi et al., 2014). Narrow approaches may impede a complete analysis in developing contexts (Simbizi et al., 2014; Carletto et al., 2013; Hendriks et al., 2016; van den Brink et al., 2006).

Most available papers have based their arguments on one aspect of food security or land tenure measures, like subjectively asking whether households have secure food or secure land tenure or not (Allendorf, 2007; Chirwa, 2008; Mabikke et al., 2017; Mendola & Simtowe, 2015; Mueller et al., 2014; Muraoka et al., 2018; Nkomoki et al., 2019; Nyirenda, 2019), but do not address the broader food security and land tenure problems respectively.

A few studies have reported mixed empirical evidence or diverse findings on the association of land tenure with food security (Chirwa, 2008; Lawal et al., 2019; Mabikke et al., 2017; Mendola & Simtowe 2015; Mueller et al., 2014; Nkomoki et al., 2019; Santos et al., 2014; Shittu et al., 2019). Many studies found no relationship between land tenure and food security or weak associations (Muraoka et al., 2018; Santos et al., 2014). These conflicting findings may be attributed to the lack of consensus on the choice of how to measure land tenure (Deininger & Ali,

2008; Simbizi et al., 2014; Lawry et al., 2017; Van Gelder, 2010) and food security (Carletto et al., 2013; Vaitla et al., 2015; Hendriks et al., 2016).

There is also limited evidence of the outcomes of the nutritional status of children under different land tenure statuses of plot holders. A handful of studies report studies investigating the relationship between tenure and nutritional status (Allendorf, 2007; Vogl, 2007; Rodgers & Kassens, 2018; Harris-Fry et al., 2020). Even fewer have looked at food security and nutrition outcomes of land tenure security (Ghebru & Holden, 2013; Merten & Haller, 2008; Rammohan & Pritchard, 2014). In addition, nutritional outcomes may be underestimated due to the limited use of anthropometric measures (Pomati & Nandy, 2020; Hendriks et al., 2016; Carletto et al., 2013).

On the other hand, land tenure challenges such as tenure security and access to land cannot be adequately addressed using one approach (Simbizi et al., 2014). Increasing demand for strengthening tenure security for all has created the need for a core set of land tenure indicators with national application and global compatibility. In the 'spirit of leaving no one behind' in development approaches and monitoring the issue of tenure security, indicator 1.4.2 of Sustainable Development Goal one considers types of tenure-related documents, perceived tenure rights and types of land tenure as potential proxies to measure and inform tenure security of households (Food and Agricultural Organisation FAO, World Bank, UN-Habitat, 2019). Analysis of different types (i.e., elements – perception, *de jure* and *de facto*) of land tenure, the relationship and interaction between components must be undertaken to understand the land acquisition modes and land right documentation (ECA, 2004; Simbizi et al., 2014). These elements range from holding tenure-related documents, owned land, rented land, community distributed land and a bundle of perceived rights (ECA, 2004).

Against this backdrop, the relationship between the land tenure status of smallholders and food security or nutrition is poorly understood. This thesis offers the following contributions to the body of knowledge:

The research is the first to investigate the effect of the mode of land acquisition and land tenure documentation on food security and child nutrition. The study goes beyond the typical assessment of the effects of formal and informal land tenure categorisations to compare food security and nutrition between holders and non-holders of land documents and land acquisition modes. Africa's formal land tenure system coexists with customary land tenure institutions. The findings of these

cohabitations in Nigeria are novel to food security and nutrition. They will serve as a lesson in other African settings where similar land tenure and agricultural conditions persist.

The findings from the more disaggregated analyses have significant implications for land tenure policy, including that national frameworks for and surveys of agriculture, food and nutrition must include detailed attention to land ownership types and documentation. Although the Nigerian National Agricultural Technology and Innovation Policy (NATIP) highlights the importance of formal land titles, informal land documents are more accessible than formal land certificates. However, land with informal documents may need to be improved to ensure access to loans. Therefore, this thesis informs the need to formalise existing informal land documents and recognise the role of the customary mode of land acquisition among smallholder farmers to support food security and nutrition. The study's findings could inform a review of the Nigerian Land and facilitate dialogue with smallholders regarding land registration and rights documentation constraints.

Many food security studies use one or two indicators of food security. This study used six food security and five child nutritional indicators. These indicators measure food security from multiple angles, covering the four key elements of food security namely availability, access, nutrition and stability. The main insights and findings gained from using different food security and land tenure indicators are to capture the components of the concepts and reveal specific effects into contexts, which could be more possibly achieved using aggregate measures. For example, using land without ownership (i.e., rent or rent-free) has implications for dietary diversity. The rent-free landholders will need more commitments to diversify crops and invest in land improvements as they know landlords could take their land at any time. The element of being overweight is not often included in studies of food security in developing countries. However, this study shows the need to have indicators of children overweight in empirical data. This indicator will become more important as food systems in developing countries transform and urbanisation increases.

Finally, this thesis subjects Nigeria's General Household Surveys (GHS) panel data (i.e., 2012/2013, 2015/2016 and 2018/2019) to a combined flexible conditional difference-in-difference (*flexpaneldid*) approach with regressions to investigate the effect of land tenure on food security and child nutrition. The combination of matching-based *flexpaneldid* with regression adjustment is generally better than either alone to address endogenous biases due to observed and unobserved

factors. The findings from the combined matching-based *flexpaneldid* with regression adjustments were robust for understanding the food security and nutrition implications of land tenure. This thesis adopted random effect-logistic regression to examine the link between food security and nutrition in farm households, sourcing further insights from available data.

1.3 Research Objectives

The overall objective of this study was to evaluate the association between land tenure, household food security and the nutritional status of children using nationally representative panel data from Nigeria's General Household Survey (GHS) for 2012/2013, 2015/2016 and 2018/2019 farming seasons. This study addressed three specific objectives:

i) To evaluate the effect of land tenure among the sampled households across their food security indicators using the Consolidated Approach to Reporting Indicators of Food Security (CARI), the share of expenditure on food, Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), Livelihood Coping Strategy (LCS) and asset index.
ii) To examine the nutritional status of children under five years of age across the smallholder land tenure type using anthropometric indicators such as Height-for-age z-scores (HAZ), Weight-for-height z-scores (WHZ), Weight-for-age z-scores (WAZ), Boby Mass Index-for-age z-scores (BAZ) and Height-for-BMI z-scores of children. The anthropometric indicators measured the sampled children's stunting, wasting, underweight, overweight and stunted-overweight.
iii) To assess the nutritional status of children under five years of age across household food insecurity levels in the GHS using anthropometric deficits such as stunting, wasting, underweight, overweight and stunted-overweight of the sampled children.

1.4 Hypotheses

The following hypotheses were proposed for each study sub-objective.

i) Sampled landholders with formal land certificates or informal land documents (and formal land tenure) are more likely to be food secure than landholders without land documents (and customary land tenure). Land tenure is changing in many places with land redistribution, land-titling programmes, increasing reliance on non-farm work in

rural areas and migration to urban areas (Holden & Otsuka, 2014). In Africa, the effects of land tenure on food security are diverse due to the coexistence of a wide range of land tenure systems and different levels of food security. Secure land tenure through smallholder agricultural and non-agricultural activities could link to food security. If food is the main output of smallholders, who partly consume what they produce and sell the surplus for purchasing power, secure land tenure will likely enhance household food security (Holden & Ghebru, 2016). In addition, if land can be used as collateral to access credit for investment on the land, the improved investment may stimulate land productivity and further enhance food security (Holden & Ghebru, 2016).

ii) Children of sampled landholders with formal land certificates or informal land documents (and formal land tenure) are less likely to be stunted, wasted, underweight, overweight and stunted-overweight than children of landholders without land documents (and with customary land tenure). Since farmers earn their livelihood from agriculture, land plays a significant role in improving nutrition. Increases in agricultural growth correlate with decreases in hunger, stunting and child mortality in Sub-Sahara Africa (SSA) countries (Pingali & Abraham, 2020). While improved agriculture depends on secure tenure and land ownership to enhance nutrition-sensitive agricultural investments and food production (Harris-Fry et al., 2020), land tenure can potentially address malnutrition outcomes in children. Therefore, it is necessary to understand whether land tenure may reduce malnutrition among children of sampled households to support nutrition-sensitive agriculture.

iii) Children from food-insecure households were more likely to be stunted, wasted, underweight, overweight and stunted-overweight than children from food secure households. Food security was paramount to addressing child malnutrition in the development plan. Households with limited or uncertain availability of nutritionally adequate and safe food or the ability to acquire food in socially acceptable ways may have severely malnourished children (FAO, IFAD, UNICEF, WFP & WHO, 2018; 2019). Food price shocks increase food expenditure share and reduce consumption of healthy (safe and nutritious) diets, leading to a high prevalence of undernutrition among children (Ecker et al., 2018). The high prevalence of chronic malnutrition among

children may primarily result from nutrition-related diseases and inadequate intake of diverse and quality diets (Maitra, 2018).

1.5 Thesis outline

The remainder of this thesis is structured into six chapters. Chapter two provides a review of relevant literature to conceptualise the study objectives. The study areas, General Household Survey (GHS) data, key variables of interest and methods of data analysis are described in Chapter three. Chapter four reports the findings of the first specific objective. Then, in Chapter five and Chapter six, the findings for the second and third objectives are presented, respectively. Finally, chapter seven concludes the thesis by summarising the result findings, suggesting policy interventions, and recommending areas of limitations and future research needs.

Chapter 2 : Literature review

2.1 Introduction

Nigeria faces a policy disconnect between the land reform (i.e., Land Use Act, 1978) policy intent and other agricultural and food-related policies such as the Agricultural Promotion Policy (2015 - 2020) and the Agricultural Sector Food Security and Nutrition Strategy (2019 -2025). The country has diverse tenure systems for land and poor formal land governance and administrative services. In Nigeria, customary land tenure coexists with formal land tenure, creating unequal land acquisition and insecurity of land rights for producing food on less than two hectares. The Land Use Act (LUA) is a Nigerian land tenure law established in 1978 that defines the formal land tenure system (Laws of Federal Republic of Nigeria LFN, 2004). The Law expresses the principles and conditions of land tenure and the rights of occupiers. It highlights the duties of occupiers and the powers of governors and local government authorities over the use, allocation, expropriation, revocation and compensation of land rights and proof of occupancy (LFN, 2004). The smallholders cannot afford the formal land titles (i.e., proof of occupancy) provided in the LUA due to the high registration cost (Ghebru et al., 2014). Tenure insecurity of smallholders may lower productivity and degrade welfare outcomes regarding food security and their households' nutrition (Van Haren & Van Boxtel, 2017).

Smallholders' different land tenure may contribute to food insecurity and child malnutrition. The land tenure institutions (i.e., customary and formal tenure systems) that protected the land tenure among households with regulations (related to community-social norms and formal laws) lacked consensus and hindered agricultural development in Nigeria (Hall et al., 2019). Population growth, adverse environmental conditions and poor land governance increase the land demand pressure and land tenure insecurity, especially in the agricultural sector (Ghebru at al., 2014). Given the unstable state of crude oil prices, Nigeria's government is committed to transforming its economy to promote nutrition-sensitive agricultural strategies to improve food security and nutrition, create jobs and alleviate poverty (Federal Ministry of Agriculture and Rural Development FMARD, 2016). Children from households that experience a high level of food insecurity may face the risk of severe malnutrition (Shahraki et al., 2016). Understanding the association between land tenure,

food insecurity and child malnutrition can guide the implementation of nutrition-sensitive agricultural strategies and plans for addressing household food insecurity and child malnutrition.

This thesis evaluated the association between land tenure, household food security and child malnutrition among smallholder farmers. This chapter reviews existing literature and provides a framework for conceptualising the thesis objectives. There are five sections to this chapter. Section 2.2 explains the factors influencing smallholder land tenure. Section 2.3 discusses the background of land tenure systems in Nigeria. Section 2.4 focuses on nutrition for children and households in Nigeria. Finally, Section 2.5 reviews the data and analytical methods from the previous empirical literature.

2.2 Factors affecting smallholder land tenure

Secure land rights remain essential pro-poor instruments for sustainable and productive agricultural development. In theory, good land governance offers incentives to invest in improved and sustainable technologies and engage in profitable land, credit and insurance transactions, reducing uncertainty and increasing farmers' potential to earn a high income (Besley, 1995). These incentives can promote smallholder agriculture, especially in Sub-Sahara Africa (SSA), to address food insecurity and malnutrition. However, investments can influence land rights during land acquisition. For example, tree planting during a land acquisition period in Wassa, Ghana, seemed to affect land rights and enhanced incentives for land improvement by farmers (Besley, 1995). In addition, the risk of population pressure, natural shocks, social discrimination, evictions and expropriations can influence land competition and hinder equal land access, rights and tenure security (AU, 2017a). Several factors are associated with the risk of land tenure insecurity (Hayes et al., 1997). These factors include land scarcity, land rights documentation, socio-cultural and demographic features, land disputes, and racketeering.

Land scarcity may put traditional institutions under stress to ensure equitable land distribution services to people, leading to many land disputes and possibly traditional chiefs transferring land for private gain rather than community benefits. Boserup (1965) proposed that population density causes scarcity and provokes institutional change. An increase in population growth influences land use and land use change (LULC), large-scale land acquisition for large-scale agriculture, mining and urban development and climate change, which reduces land needed for smallholder agriculture (Nara et al., 2021).

Land rights may be insecure without formal land certificates. Legal land title ownership signifies the security of land ownership. However, implicit or explicit restrictions on rights may undermine the scope of land ownership for practical use. Three issues often encountered in land ownership are:

- Explicit restrictions on land rental markets, including the risk of land loss if the land is leased out and thus perceived as unnecessary or not used effectively.
- Neglect of existing rights in case of expropriation by providing compensation only for improvements or well below market values, often combined with a broad interpretation of state powers beyond the narrow provision of public goods.
- Limited documentation of rights or the lack of registered land rights is an issue that would discourage longer-term transactions (Sitko et al., 2014). Holding a land title could influence land rights. Some factors include geographical distribution (e.g., urban), education wage employment (especially in public sectors), migration status, political influence, human capital, gender and age can influence access to land titles (Sitko et al., 2014).

Land right equity and tenure security can be affected by socio-cultural and demographic factors such as status, disability, age, gender, birth, death, ethnicity, urbanisation and class within a land tenure system (Payne & Durand-lasserve, 2012). Social proximity (kinship) to family or customary institution leaders contributes to securing land rights (Honig, 2019). Weak land rights are more prevalent among female household heads and migrant household members with customarily controlled land rights (Bambio & Agha, 2018). These groups face discrimination to inherit land alongside circumstances beyond their control (as mentioned earlier), like widowhood, divorce, childlessness and bearing only female children (Payne & Durand-lasserve, 2012). Finally, gaining financial power has significantly influenced accessing land and benefiting from land-related rights (Bambio & Agha, 2018).

Speculations on future land value appreciation, an absence of legal backing or the unclear role of customary law can influence land rights and tenure insecurity (Nara et al., 2021). Other factors that affect land tenure security include the inadequacy of relevant land laws guiding the land market system, poor implementation of the general laws and the courts' inability to effectively resolve land rights and tenure-related disputes during land market transactions (Edeh et al., 2022). While the risk of land disputes is higher among women, the collective risk of land expropriation

is lower among the political class (Ghebru & Girmachew, 2018). A lack of farm insurance and highly covariate risks such as natural disasters or economic shocks can cause price fluctuations, triggering poor smallholders to sell their land cheaply during a crisis (e.g., drought). In the 2007/2008 food crisis, farmers made distress sales of farmlands to meet immediate subsistence (Mittal, 2009).

2.3 Background to land tenure systems in Nigeria

Land tenure systems in Nigeria range from statutory to customary tenure systems. The statutory or legal system embraces the *de jure* (formal) regulation. In contrast, the customary land tenure system focuses on the *de facto* (informal) situation to define land acquisition (how land is held) and land rights (what the holder may do with the land) (Hall et al., 2019). The 1978 Nigerian Land Use Act (LUA) defines the formal system and fully vests land ownership to the State and Local governments. The Act abolished customary land freehold rights and granted leasehold rights to land users for 99 years (Ghebru et al., 2014). The State Governor and local government councils give legal recognition of land use rights by issuing a statutory certificate of occupancy to urban land users and a customary certificate of occupancy to rural land users. Farmers are, by law, either statutory or official customary occupiers of land. The term "customary certificate of occupancy" in the 1978 LUA was formalised and did not mean that the certificate is connected to the customary land tenure system, which defines land acquired and land rights using communal accepted rules (Hall et al., 2019).

Despite the significance of formal land titles to secure land use rights, rent-seeking and corruption under the 1978 LUA and the high cost of processing land registration limit the acquisition of legal land titles and initiate the use of informal land right documents (Ghebru et al., 2014; Kehinde et al., 2021). Registration of land rights at the state or local land registry involves submitting informal land documents such as a deed of transfer or perimeter survey plan (Kehinde et al., 2021), limiting the suitability of formal land registration for land users with no document.

The land purchases occur in Nigeria under the 99-year lease afforded by the 1978 LUA rather than freehold titles. Unless such transactions are registered with the state, there is no formal entitlement or recognition of rights. Without the formal land right documentation, such land cannot be used as collateral. The low demand for formal land certificates attracted the 2009 land reform programme to address the shortcomings of the 1978 LUA (Hall et al., 2019). However, the land reform

programme failed because of disagreements between customary and formal tenure institutions (Hall et al., 2019). No change to the 1978 LUA has yet been affected.

While the study focused on the context of Nigerian smallholder farm households, the findings may be relevant for other developing countries, where smallholder agriculture relies on similar land tenure systems as Nigeria. Table 2.1 presents examples of Africa countries with untitled land of customary tenure alongside formal land laws. The 13 African states (in Table 2.1) have land policies and laws that one hand, recognise customary land tenure but are widely untitled (Burundi, Cameroon, Comoros, Ivory Coast, Madagascar, Namibia, Niger, Sierra Leone, Zambia) (Wily, 2018; USAID, 2016). Others abolished customary freehold land tenure, while the land was held or perceivably owned under customary tenure institutions (Nigeria, Senegal, Tanzania, Zimbabwe) (Wily, 2018; USAID, 2016). As a result, unregistered land became prevalent and susceptible to conflict and expropriation by governments in these countries (USAID, 2015).

Theory predicts that the mode of land acquisition and formal land right documentation can give people a sense of access to and control over land rights (Ghebru et al., 2014). This paper investigated whether the mode of land acquisition and land right documentation under formal and informal tenure systems influenced household food security and child nutrition in Nigeria between 2012 to 2018. The findings could inform the decision for urgent policy reform in Nigeria and other African countries with state ownership of land to address child malnutrition.

Table 2.1: African countries with untitled land of customary tenure alongside the statutory land laws

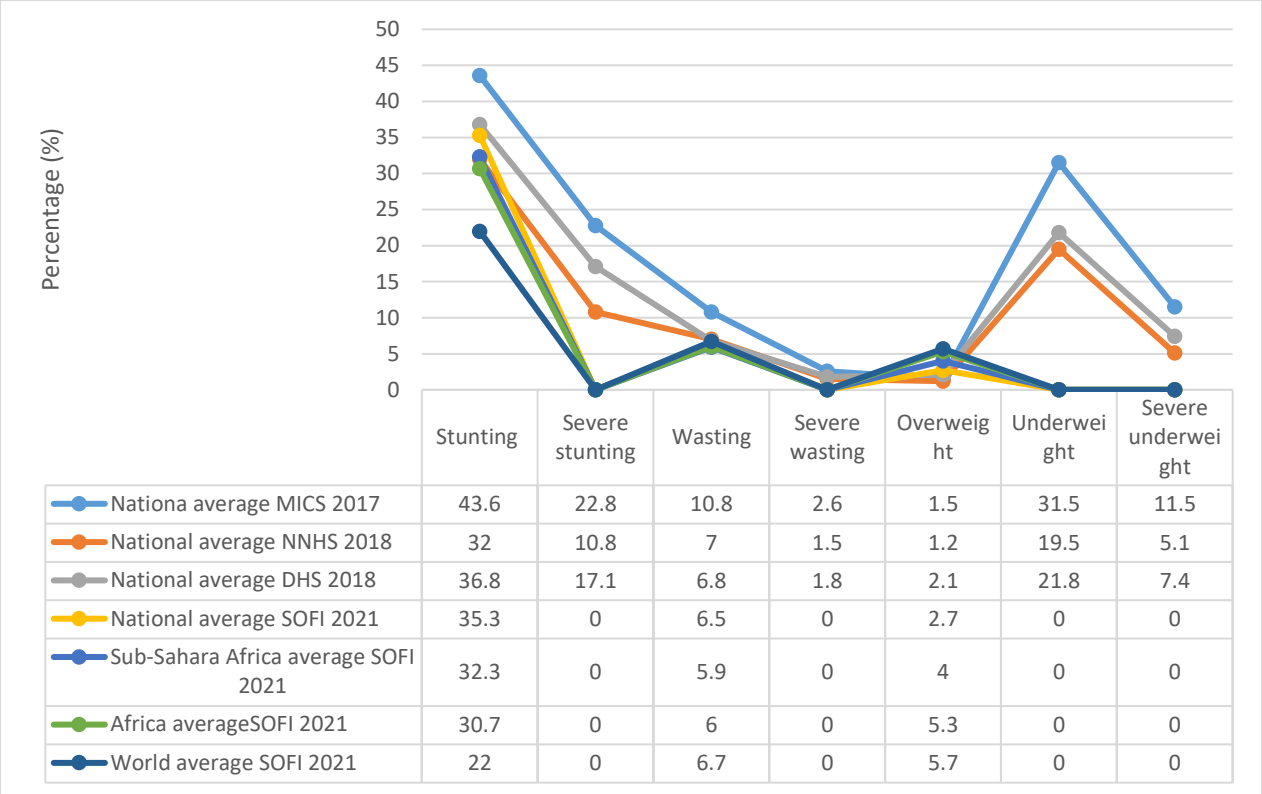
Country	Statutory	Customary	Dominant tenure system	Reason for untitled land
Burundi	The untitled land owned by the state through the 2011 Land Code	Only titled customary lands recognised by law	Untitled customary land (less than five percent of all land is registered)	The costly and complex registration process
Cameroon	The untitled land owned by the state through the 1974 Land Law	Only registered customary ownership recognised by law	Untitled customary lands (less than three percent of rural land is registered)	The costly and complex administration process
Comoros	The illegal occupation of land belonging to the state under the 2015 Land Law	The registered customary land ownership recognised by law	Unregistered customary lands (a low proportion of all land is registered	Costly registration process
Cote d'lvoire	All unregistered land is the property of the state under the 1998 Rural Land Law	The registered customary rights to land are recognised by law	Unregistered customary rights to lands (less than two percent of rural land registered)	Costly registration process
Madagascar	The 2005 National Land Law recognised both titled untitled land	The government passed a law to assert that untitled land be titled to recognise rights	Unregistered customary land (Only around seven percent land is titled)	Land registration is demanded and based on contestable procedures. The local land office is under-funded with poor technical training support
Namibia	Unregistered ownership rights to land are unknown by the 1998 National Land Reform Act	Registered customary lands were recognised under law	Unregistered customary land	Slow registration of right. The process of formal titling is time-intensive
Niger	The 1993 Rural land code declared all unregistered land as property of the state	Recognised by the law and land can be registered	Unregistered customary land	Under-functioning of commission to register land
Nigeria	Both titled and untitled land owned by the state through the 1978 Land Use Act	Existing despite being abolished by 1978 LUA	Unregistered customary land (less than three percent land registered)	High cost and procedures of obtaining formal certificates, lack of administrative support for service delivery
Tanzania	Both titled and untitled land belongs to the state under the 1999 Land Act and Village Land Act	Formal law recognises customary land rights but formally grants (statutory) usufruct land rights	Customary (unwritten) tenure arrangements dominate	The process of issuing Certificates of Village Land (CVL) as Certificates of Customary Right of Occupancy has been slow
Senegal	The government owns 97% titled and untitled land according to the 1964 National Domain Law. Only 2-3% of registered private freehold land	Despite efforts of formal law to control land tenure, customary land tenure institution continues to define land rights	Unregistered customary landholdings. Few registered landholdings (ownership of rights to land) in rural and urban areas	High cost of titling and long registration process of occupancy rights.
Sierra Leone	Sierra Leone's 2005 National Land Policy protects the common national or communal property held in trust for the people	Unwritten customary land, though some have purchase and sales agreements/title deeds and tax clearance certificates as proof.	Chieftaincy or community land tenure	No registration or legal framework, application of uncodified customary law, no reliable record of landholdings, the prevalence of fraudulent land documents, ignoring/changing terms of a lease
Zambia	Non-customary land is deemed to be State land under the 1995 Land Act	Recognised customary (often unwritten) under law	Three percent of customary landholders have some form of customary landholder certificates (outside Statutory)	High cost, low level of awareness,
Zimbabwe	Both titled and untitled lands are in the state through the Zimbabwe National Union-Patriotic Front Law	The customary/informal land tenure is active despite the nationalisation of land in some rural areas	Informal settlements exist.	The country has no legislative framework for the regularisation of informal settlements

Source: USAID 2016; Habitat III 2016

2.4 The situation of nutrition for children and households in Nigeria

Nigerians face a significant burden of Africa's undernourishment and malnutrition (FAO et al., 2022). The undernourished population in Africa have reduced from 21.1% in 2004-06 to 19.1% in 2019-21 (FAO et al., 2022). Yet, the proportion of undernourished households in Nigeria increased from approximately seven percent in 2004-06 to 12.7% in 2019-21 (FAO et al., 2022). In 2020, Nigeria's children under five years of age had an approximately estimated seven percent wasting and 35% stunting (FAO et al., 2022). Figure 2.1 compares the prevalence of malnutrition among Nigerian children to the cases of African and global child malnutrition. The stunted and wasted children population in Nigeria has risen above the African and global averages of acute and chronic malnutrition (see Figure 2.1). The prevalence of overweight in children increased from approximately two percent in 2018 to six percent in 2021 (Figure 2.1). In 2019, approximately three percent children under five years of age were stunted and wasted and one percent were stunted and overweight (United Nations Children's Fund, Division of Data, Analysis, Planning and Monitoring 2020). The prevalence of obesity in the adult population increased from approximately seven percent in 2012 to nine percent in 2020 (FAO et al., 2022).

Micronutrient deficiencies (minerals and vitamins) are prevalent in Nigeria (FMARD, 2017). The deficiencies in key micronutrients (e.g., iron, zinc, vitamin A, folic acid and iodine) affected the Nigerian population. For example, the proportion of women aged 14 to 49 years suffering from anaemia increased from 54.9% in 2012 to 55.1% in 2019 (FAO et al., 2022), while 68% Nigerian children of 6 – 59 months were anaemic in 2018 (National Population Commission NPC & International Classification Functioning, Disability and Health ICF 2019). Thirty-one percent non-pregnant women of reproductive age were iodine deficient in 2018 (NPC & ICF 2019). Approximately 30% children in Nigeria were deficient in vitamin A in 2018 (NPC & ICF 2019). Folic acid deficiency increases the risk of neural tube defects, affecting about 9,500 births in 2018 (NPC & ICF 2019). Twenty-one percent people in Nigeria had inadequate zinc intake in 2018 (NPC & ICF 2019).



	Stunting	Severe stunting	Wasting	Severe wasting	Overweight	Underweight	Severe underweight
Nationa average MICS 2017	43.6	22.8	10.8	2.6	1.5	31.5	11.5
National average NNHS 2018	32	10.8	7	1.5	1.2	19.5	5.1
National average DHS 2018	36.8	17.1	6.8	1.8	2.1	21.8	7.4
National average SOFI 2021	35.3	0	6.5	0	2.7	0	0
Sub-Sahara Africa average SOFI 2021	32.3	0	5.9	0	4	0	0
Africa averageSOFI 2021	30.7	0	6	0	5.3	0	0
World average SOFI 2021	22	0	6.7	0	5.7	0	0

Figure 2.1: Comparing the prevalence of under 5 years children affected by malnutrition
Source: 5th Multiple Indicator Cluster Survey MICS (NBS & UNICEF 2017), National Nutrition and Health Survey NNHS (NBS, NPC & NFMH 2018) and 6th Nigeria Demographic and Health Survey NDHS (NPC & ICF 2019). The State of Food Insecurity in the World SOFI (FAO et al., 2021)

The poor state of nutrition in Nigeria reflects inadequate dietary intake, inadequate access to health care, living in an unhealthy environment and inadequate care of children and women (Nigerian Federal Ministry of Health NFMH, 2014; NBS, NPC & NFMH, 2018). The determinants of malnutrition in Nigeria include food insecurity; inadequate nutrient intakes; poor infant and young child feeding practices; high rates of illness; lack of access to health care; water, sanitation, and hygiene; armed conflict (prevalence in the north); high food prices; irregular rainfall; high unemployment; and poverty (USAID, 2021).

A high malnutrition rate in Nigeria slows development and leads directly to suffering and death (FMARD, 2017). Children of malnourished women are more likely to face cognitive problems, short stature, lower resistance to infections, and a higher risk of disease and death (NBS, NPC & NFMH 2018). Maternal undernutrition results in low birth weight, contributing to high infant mortality and a significant factor leading to increased maternal mortality in Nigeria (MBNP, 2016). The most critical risks of non-communicable diseases NCDs in Nigeria include high blood

pressure, high concentrations of fat in the blood, high blood glucose levels, overweight or obesity, diabetes mellitus, and cardiovascular diseases, posing public health concerns (FMARD, 2017).

Policymakers are concerned by the rise and consequences of malnutrition in Nigeria (USAID 2021). Preventing and addressing malnutrition can be achieved by balancing policies and planned actions to achieve policy objectives (MBNP, 2020). The Sustainable Development Goals (SDGs) call for eradicating malnutrition 'in all its forms' (UN, 2015). Nigeria's government is committed to reducing malnutrition to meet the second SDGs by designing and implementing a multi-sectoral and multidisciplinary policy framework and programmes (MBNP, 2016).

Table 2.2 lists policies and activities designed to prevent and address malnutrition in Nigeria. The National Policy on Food and Nutrition was reviewed in 2016 to address the problem of malnutrition in Nigeria and incorporate emerging concerns such as nutrition in the first one thousand days of life, nutrition during emergencies and an upsurge of diets – causing non-communicable diseases NCDs (MBNP, 2016). Agricultural Food Security and Nutrition Strategies (AFSNS, 2016 - 2023) is a multi-sectoral framework established to implement the nutrition component of the Agricultural Policy Project's objectives (FMARD, 2017). The strategy aimed to promote nutrition-sensitive agricultural practices to reduce hunger and malnutrition (FMARD, 2017). The AFSNS is one of the sectoral action plans under the National Multisectoral Plan of Action for Food and Nutrition (MFBP, 2020). Other sectoral activities cover education, public health, women's development, science and technology, water, sanitation, hygiene, and finance (MFBP, 2020).

The activities (in Table 2.2) under policies and programmes are adopted to address malnutrition among children, women, aged and adolescents. Nutrition-specific interventions can address immediate causes of malnutrition (inadequate dietary energy intake and diseases) (Ruel & Alderman, 2013). These interventions include micronutrient and food supplementations, promotion of exclusive breastfeeding and optimal complementary feeding, immunisation, fortification and water, sanitation and hygiene interventions (Table 2.2). Implementing nutrition-specific policies can only improve the nutritional status of one in five stunted children (Bhutta et al., 2013).

To further reduce malnutrition, nutrition-sensitive agriculture, social protection and education can address low food supply per capita, poverty, inadequate health services, caregiving and poor sanitation and hygiene (Bhutta et al., 2013). Nutrition-sensitive agriculture enhances nutritious food supply and farm revenue to access more nutritious food intake and health care for a healthy life (Ruel et al., 2018; Hawkes et al., 2020). The nutrition-sensitive programmes increase the effectiveness and coverage of nutrition-specific interventions, reducing the risk of child malnutrition (Ruel et al., 2018). An understanding and monitoring household nutritional status (i.e., body growth surveillance) are essential in identifying the interventions needed to address malnutrition (FMARD, 2017). The present research measures the nutrition situations of children from food insecurity levels and landholders of different land acquisitions and documentation.

Table 2.2: List of calls, policies and activities to address nutrition in Nigeria

SN	Calls/Events	Policy/Strategy/Programmes	Examples of intervention/activity
1	2000 Millennium Development Goals	2002 National Policy on Food and Nutrition (National Planning Commission 2002)	Micronutrient supplementation; oral rehydration therapy; nutrition education; growth monitoring and promotion; dietary diversification and food fortification; nutrition labelling of local food, gender-sensitive nutrition surveillance
2	The Maputo Declaration on Agriculture and Food Security (AU 2003)	2004 National Plan of Action on Food and Nutrition (National Planning Commission 2004)	Training on adequate nutrition counselling and care; Provision of micro-nutrient supplements, anti-helminthics and family planning service; monitoring school feeding programmes to promote and advocate for exclusive breastfeeding, paternity leave and nutritionally adequate complementary food production
3	Scaling up Nutrition SUN (2011)	2010 National Policy on Maternal Infant and Young Child Feeding in Nigeria (Federal Ministry of Health FMH, 2010)	Exclusive breastfeeding; complementary feeding, solution of oral rehydration salt or salt sugar solution (ORS/SSS); micronutrition (vitamin A and zinc) supplements; regular growth monitoring and promotion; immunisation; Nutritional counselling; community-based breastfeeding supports
4	2nd International Conference on Nutrition (FAO&WHO, 2014), Rome Declaration on Nutrition (FAO&WHO, 2014) Malabo Declaration on Nutrition Security for Inclusive Economic Growth and Sustainable Development in Africa (AUC 2014)	2014 National Strategic Plan of Action for Nutrition (2004-2019) (Federal Government of Nigeria FGN, 2014)	Micronutrient supplements for pregnant women and children; de-worming; nutrition education on bio-fortified foods; Dietary counselling during pregnancy and lactation; breastfeeding promotion and support; complementary feeding promotion; advocacy for monitoring and strengthening enforcement of the international code of marketing breast milk substitutes; community nutrition programmes for behavioural change
5	Agenda 2063, The Africa we want: First ten-year implementation plan (AUC 2015) Sustainable Development Goal (2015–2030)	2016 Food and Nutrition Policy (MBNP, 2016)	School-based nutrition education, gardening and feeding programmes; provision of micronutrient supplements; promoting dietary diversification and food fortification; social protection programmes; growth monitoring and evaluation
6	2016 UN Decade of Action on Nutrition (FAO and WHO 2017)	2017 Agricultural Sector Food Security and Nutrition Strategy 2016 - 2025 (FMARD 2017)	Increase micronutrient-rich food production through biofortification and farm diversification; provision of resilience and social protection nets; improve agricultural sector extension capacity; women empowerment; nutrition surveillance and monitoring, nutrition education; social marketing; enhance agricultural value chain for nutrition.
7	Sustainable Development Goal (2015 – 2030)	2020 Nigeria-National Multisectoral Plan of Action for Food and Nutrition in Nigeria (2021-2025) (MFBP 2020)	Nutrition-sensitive social protection; school-based feeding programmes; nutrition education; exclusive breastfeeding; micronutrient supplements; food fortification; investment in agriculture biofortification; water sanitation and hygiene; health care services; nutrition surveillance for early warning
8	Sustainable Development Goal (2015 – 2030)	2019 National Policy on the Health and Development of Adolescent and Young People in Nigeria (2020-2024) (FMH 2019)	Nutritional support services like Adolescent and youth-friendly nutrition education; micronutrient supplementation programmes for adolescents and youth.
9	Sustainable Development Goal (2015–2030)	2020 Nigeria Food and Nutrition Response Plan for COVID-19 Pandemic (FMH, 2020)	A cash transfer to households with pre-school (five years) and primary school children; input support for homestead gardening; food assistance and social protection measures food safety measures through the value chain; female empowerment and youth engagement in the food systems; nutrition education via social media.
10	Sustainable Development Goal (2015–2030)	2022 National Agricultural Technology and Innovation Policy (FMARD 2022)	Investment in diversification and production of nutrient-rich foods, nutrition-sensitive agricultural activities, and nutrition education through extension services and social media

Source: Author, 2022

2.5 The relationship between smallholder land tenure, food security and nutrition

Food security refers to the situation when "all people, at all times have physical, social and economic access to sufficient, safe, nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996; 2001). The definition reflects six important dimensions, which include availability (food supply), access (equitable and inclusive), utilisation (nutritional uptake), stability (resilient), agency (empowering) and sustainability (regenerative) (HLPE, 2020). However, the first four dimensions of food security remain the central of interest in this study. Due to the multiple dimensions associated with food security, one indicator alone cannot completely measure the concept (Hendriks et al., 2016).

Food security goes beyond just food production. The role of secure land tenure in formalised land tenure and its contribution to food production via productivity enhancing investments, collateral for credit opportunities and income generation from land markets have been recognised (Michler & Shively, 2015). This study focused on the effect of land tenure on food security using internationally recognised indicators such as a Consolidated Approach to Reporting Indicators of Food Security (CARI), food expenditure share, household dietary diversity, food consumption scores, household asset ownership and livelihood coping strategies. A broad body of literature has looked conceptually at the relationship between land tenure and food security (Holden, 2020; Maxwell & Wiebe, 1999; Rockson et al., 2013; ECA, 2004). Few other empirical studies adopted narrow approaches to measure land tenure and food security, ignoring the differences in land tenure systems and multi-dimensionality of food security concepts to target households (Allendorf, 2007; Chirwa, 2008; Mabikke et al., 2017; Mendola & Simtowe, 2015;; Muraoka et al., 2018;).

The activities of agriculture are mainly driven by smallholder farmers in Nigeria. However, empirical evidence on the relationship between land tenure and food security from the perspective of smallholder farmers is lacking in the literature. In addition, a current nationwide policy has highlighted the need to achieve food security in Nigeria by reexamining the formal land title under the 1978 Land Use Act (LUA) (FMARD, 2022). The current study addressed this gap using panel data from 2012/13, 2015/16 and 2018/19 Nigeria's General Household Surveys (GHS), which capture, different land tenure in the country and household food security dimensions. The study provided evidence to enlighten not only Nigeria but also other countries, where food security dimension are driven by both customary and formal land tenure systems.

The problems related to sustainable agriculture and food security are interconnected but linked to land (Childress et al., 2022). Farmers access land and secure land rights to cause positive changes in loan access, investment, productivity, income and food (Maxwell & Wiebe, 1999). Farmers who risk losing land to conflicts, unfair government expropriation and gender discrimination, are more likely to be vulnerable to food insecurity and malnutrition (Childress et al., 2022). Also, landowners transfer their land to productive use(r)s when factors and output markets perform poorly (Holden & Ghebru, 2016). Farmers with secure tenure will be efficiently involved in land markets and earn more from low transaction costs. The farmers selling or temporarily transferring land spend the income from land markets to achieve food security and improve their family nutrition (Mittal, 2009).

The conventional theory of property rights to land (or land tenure) suggests that "unless property rights are sufficiently secure to assure potential investors (i.e., farmers) that they will be able to reap the returns from doing so, such investment may not be forthcoming" (Deininger & Ali, 2008, P. 869). Based on this theory, land tenure (via acquisition and documentation) is directly linked to farm investment. Input demand function is necessary for a direct link between land tenure and food production (Hayes et al., 1994). The food security and child nutrition status in households selling surplus production changed due to access to foods beyond the household production mix. Therefore, the links between land tenure, food security and nutrition are complex, requiring a theory of change (diagram) to show the pathways.

Figure 2.2 explains the conceptual framework of the study. Land tenure governance is recognised based on formal and customary land tenure systems. Under each tenure system, households acquire land, while some possess (formal or informal) land right documents. The holders of formal land documents are expected to have secure land rights and motivation to invest in inputs, access credit and market, help to increase production, and improve food security and nutrition. On the other hand, land transfer helps households obtain income from land transactions or off-farm work to diversify their diets. The government can compensate Legitimate land holders (with cash) if land is revoked for national development. Households with weak (or informal) land tenure invest less in farm inputs, cannot access formal loans and suffered production decline, experience high food price, leading to food insecurity and child malnutrition (Figure 2.2).

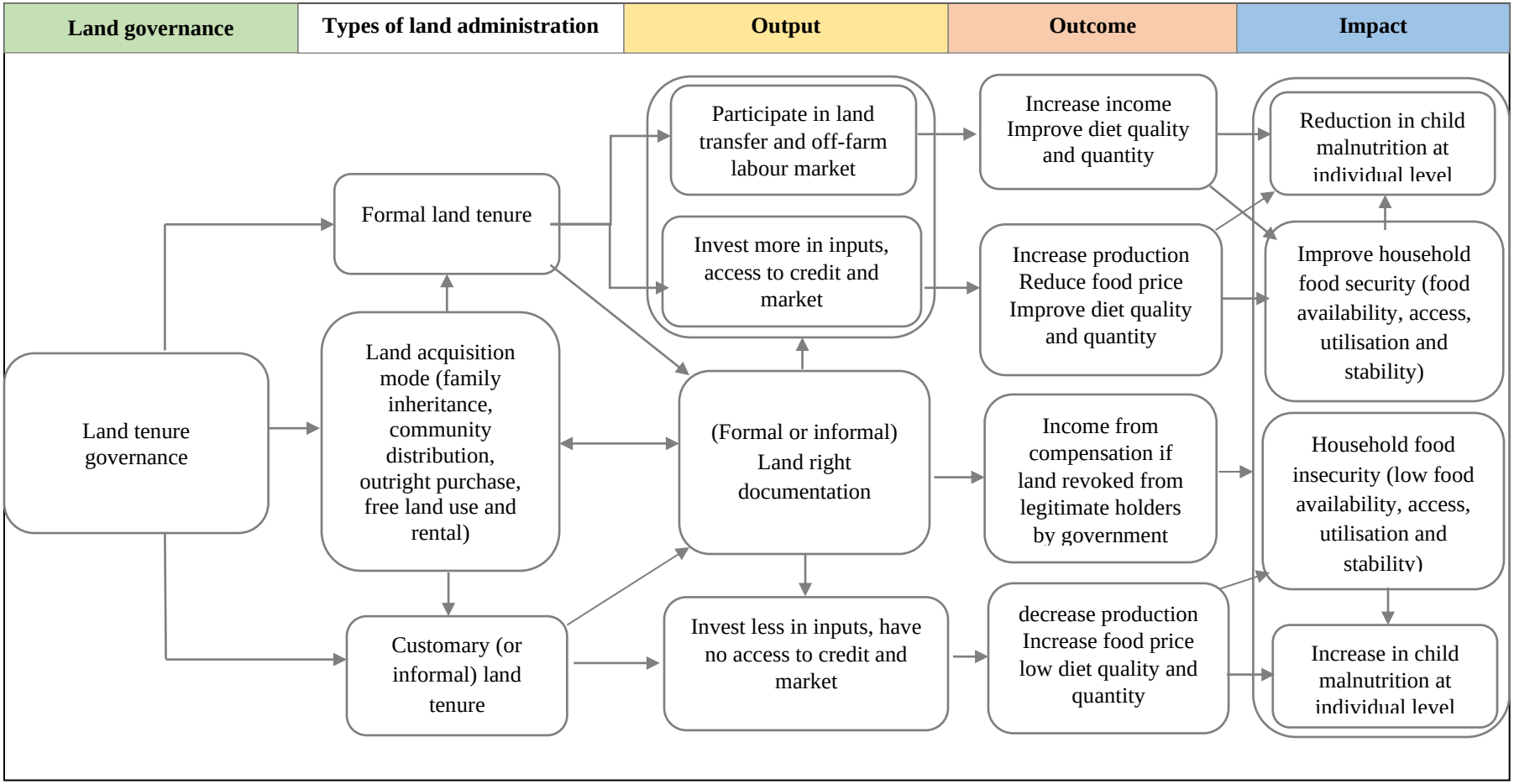


Figure 2.2: Conceptual framework on the effect of land tenure among smallholder farmers
Source: Own work.

2.6 Review of model and econometric data analysis using impact evaluation methods

A household is classified as either being involved in farm or non-farm livelihoods (Vu et al., 2021). As the study focused on farm livelihood, land tenure was a significant factor in household access to food (Maxwell & Wiebe, 1998). The study focused on farmers; the land tenure variables are endogenous but influenced farmers' food security and nutrition. Following Muraoka et al., (2018), farmers' food demand can be expressed as:

$$C_{ijt} = f(L_{ijt}, Z_{ijt}) \qquad \text{Equation 1}$$

The farmers' food demand function (specified in Equation 4) shows the relationship between land tenure and food security and nutrition. As a result, the proxy variable *L* (land tenure) was selected based on its importance to farm livelihood and farmers' food access decisions. Farmers need land to produce and earn income from produce to enhance food consumption at the individual level (i.e., child nutrition) (Muraoka et al., 2018). Therefore, differences in land tenure (as acquisition modes or documentation types) will affect farmers' food security. This thesis addresses the endogeneity challenges affecting the effect of land tenure on food security and child nutrition using matching-based *flexpaneldid* models).

Based on the theoretical set up of this study (in Equation 1), Two potential sources of biases can evolve from estimating land tenure's effect on food security and child nutrition. These included a possible selection bias due to observed household socioeconomic factors and a potential residual confounding bias from unobserved factors. In addressing these endogenous challenges, several identification strategies (i.e., impact evaluation techniques) were suggested depending on the purpose and data available for analysis in the literature. These methods include Randomisation, Propensity Score Matching (PSM) and Average Treatment Effect (ATE), Difference-in-difference (DID), Regression discontinuity (RD), Instrumental Variable-Fixed effect (IV-FE) regression or two-stage Least Square (IV-2SLS) regression approaches (Goldstein, 2020).

Impact evaluation methods are usually determined by the wealth of the data used to support bias-free analysis. Cross-sectional data will only allow for the difference between the outcomes of the program participant groups and non-participant groups without considering the simultaneous possibility of inter-temporal and individuality situations of the groups. The PSM and ATE address

the time-invariant counterfactuals by matching the caparison groups of similar observable characteristics and determining the differences in the outcomes of the matched comparison group using cross-section data (Goldstein, 2020). Panel data build on time-invariant counterfactuals by observing individuals' before- and after-effects and isolating the effects of land right possession and other factors on the outcomes over time (Goldstein, 2020). A limited number of studies of this thesis' objective used panel survey data (Chirwa 2008; Mendola & Simtowe, 2015; Mueller et al., 2014; Muraoka et al., 2017; Santos et al., 2014; Vogl 2007; Ghebru & Holden, 2013; Kosec & Shamyekina, 2018; Vu et al., 2021; Humphries et al., 2015). The data type and endogeneity of independent variables influence impact evaluation methods such as matching-based DID and IV-FE-regression models.

Table 2.2 highlights previous panel studies of the thesis' objective that applied impact evaluation methods. The IV-FE model estimations are the standard approach of quasi-experimental design where policy change is not exogenously assigned (Muraoka et al., 2017). Also, IV results may not be generalised to other contexts when different instruments answer different economic questions. The IV model may be biased when the treatment of observation may significantly influence the outcome of other untreated samples through externalities or spillover effects (Bernard et al., 2008). Holders and non-holders of land documents (and mode of land acquisition) may fall into these shortcomings of the IV model through fertiliser run-off that enhances farm productivity and food security and nutrition of untreated observations (i.e., landholders with no document).

The PSM is a data-generating model and it is not like flexible panel DID. The application of PSM for cross-section data requires the use of the ATE to produce causal effect coefficients. The DID estimates the ATE coefficients of panel data. Both ATE (for a cross-sectional study) and DID (for a panel study) can use PSM-generated data to produce matching-based results. Similarly, matching-based data can be fitted to the regression model. The *flexpaneddid* model is a special DID model function with the exact matching algorithm, suitable for time information from the pre-selection process of panel samples (Dettmann et al., 2020). The exact matching algorithm improves the matching quality. The matching-based DID method produces non-parametric results that can control for changes over time (unobserved) and individual-specific (observed) biases (Daw & Hatfield, 2018). A few studies have used a matching-based DID to evaluate land tenure's impact on food security (Mendola & Samtowe, 2013; Mueller et al., 2014). However, a

conventional matching-based DID cannot examine effects and outcomes with more than two rounds of data. The DID combined with the matching technique corrects for non-random sample selection and adjusts for period-treatment differences that affect the outcome estimates.

For these reasons, this thesis adopted a matching-based flexible panel difference-in-difference (*flexpaneldid*) approach and regressions to estimate the impact of land tenure on food security and child malnutrition using three-round panel data from Nigeria's General Household Survey. The matching-based DID estimator avoided specifying a fully parametric model for outcomes. The combination of matching-based *flexpaneldid* and regression adjustment was found appropriate than adopting each approach alone to fix specification problems and bias due to residual confounding (Rubin 2006). A combined *flexpaneldid* matching with a regression adjustment strategy was therefore used to identify the causal effect of land tenure on food security. The results of this panel study generated from DID (panel data ATE), regression, matching-based *flexpaneldid* and *flexpaneldid* matching-based regression. A panel logistic regression was applied to examine the relationship between food security and nutrition outcomes. The methodology (in the following sections) provides a detailed explanation of the data and methods to analyse the effect of land tenure on the food security and nutrition of smallholder farmers in Nigeria.

Table 2.3: The impact evaluation methods for panel studies related to the thesis' objectives

Impact evaluation Method	The topic of articles*	Authors
A non-matching weighted econometric approach	Land tenure, farm investments and food production in Malawi	Chirwa, (2008)
Matching-based Difference-in-difference	The welfare impact of land redistribution: Evidence from a Quasi-Experimental Initiative in Malawi	Mendola and Simtowe, (2015)
Matching-based impact evaluation	Resettlement for food security's sake: Insights from a Malawi land reform project	Mueller at al., (2014)
First-difference estimation and Fixed-effect-IV	Land access, land rental and food security: Evidence from Kenya	Muraoka et al., (2017)
Inverse propensity-weighted regression	Can government-allocated land contribute to food security? Intrahousehold analysis of West Bengal's Microplot Allocation Program	Santos et al., (2014)
Difference-in-difference	Urban land rights and child nutritional status in Peru, 2004	Vogl, (2007)
Regression/econometric model	The link between tenure security and food security: Evidence from Ethiopia	Ghebru and Holden, (2013)
Regression/econometric model	Land reform and child health in the Kyrgyz Republic	Kosec & Shemyakina (2018)
A random-effect probit regression model	The role of land ownership and non-farm livelihoods on household food and nutrition security in rural India	Vu et al., (2021)
Non-parametric approach (i.e., correlation)	Cross-section and longitudinal associations between household food security and child anthropometry at ages 5 & 8 years in Ethiopia, India, Peru and Vietnam	Humphries et al., (2015)

* The articles reported longitudinal studies, control for time-varying factors and bias that impact estimates.
Source: Author, (2021)

Chapter 3 : Methodology

3.1 Introduction

This chapter has five sections. Section 3.2 presents an overview of the study area. Section 3.3 describes the sample selection and data and variables used to achieve the specific objectives of the thesis. Section 3.4 explains the methods of data analysis of each objective of the thesis. The final section (3.5) recaps the methodology of the thesis.

3.2 Description of the study area

This study was conducted using data from Nigeria. Nigeria lies between approximately the four latitude (4°) and 14°N and three longitudes (3°) and 15°E has different landscapes (World Atlas, 2015). Nigeria is located in the west of the African continent. The country shares land borders with Niger on the northern side, the Republic of Benin on the western side, and Chad and Cameroon on the eastern side. The nation's coast lies on the Gulf of Guinea in the southern part and is connected to Lake Chad in the northeast section of the country (World Atlas, 2015). Figure 3.1 depict the location of Nigeria. The government comprises 36 states, which are divided into six geopolitical zones for development planning. The zones include North-Central, North-East, North-West, South-East, South-South and South-West.

Nigeria has a land area of 923,763 square kilometres and an agricultural land area of 69.12 million hectares to support the food supply to feed over 196 million people (Central Intelligence Agency CIA, 2018). Seven in ten people depend on agriculture for livelihood (FMARD, 2016). Although smallholder farmers dominate the country’s agricultural activities (FAO, 2018b), the critical challenge is that the farmland remains insecure due to poor land tenure (FMARD, 2016). As a result, the sector's potential has not been fully tapped, contributing 26.57% to Nigeria’s Gross Domestic Product (GDP) (NBS, 2022).

A tropical rainforest climate characterises the southern part of Nigeria and the annual rainfall ranges from 60 -80 inches (1,500 – 2000mm) per year (World Climate Guide, n.d.). The southwest and southeast are known for coastal plains and the forest zones are primarily defined as saltwater swamps called mangrove swamps. In the north of the freshwater wetland is the rainforest, which keeps the saltwater swamp with different vegetation. The core north has savannah – categorised into Guinea forest-savannah mosaic, Sudan and Sahel savannah – with limited rainfall extended

between 20 – 60 inches (500 and 1500mm) per year. Desert is encroaching in the Sahel region and the rain is declining to less than 20 inches (<500 mm) per year (World Climate Guide, n.d.). In addition to the rapid population growth, deforestation, indiscriminate sewage and oil spillage, the desert encroachment in the north and flooding from the south contribute to arable land shortages and tenure insecurity in the country, affecting smallholder welfare.

Figure 3.1: Map of Nigeria with their states
Source: World Atlas, (2015)

3.3 Sample selection and description of data for the study

This study used data from Nigeria's national representative panel data of the living standards measurement study's integrated agricultural surveys (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 (NBS & World Bank, 2013; 2016; 2019). Each survey round collected data twice, first during the post-planting and post-harvest periods to serve agricultural activities. Households were drawn from the total population in 2012/13 (wave2), 2015-16 (wave3) and 2018-19 (wave4) general household survey. The panel database provided information on socioeconomic characteristics, land tenure, food security and child nutritional outcomes under different contexts. Table 3.1 provides the summary of variables needed to analyse the objectives of this thesis.

Table 3.1: Summary of variables for analysing the objective of the thesis

Class of variable	Data requirement	Unit of measurement	Expected sign
At the household level			
Food security measures	List of indicators in Table3.2	Categorical outcome	
At the individual (i.e., children) level			
Child nutritional outcome of under 60 months in a household	Height	Centimetres	Derivation of indicators in Table3.3
	Weight	Kg	
	Age	Month	
	Sex	female=1, male=0	
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 and control
	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 (A) level, 8=NCE/OND/Nursing, 7=BA/BSC/HND, 8=Technical director/Professor, 9=Master and Doctorate	
	Cooperative membership	1=yes, 0=no	
	Literate	1=yes, 0=no	
	Off-farm income	Naira	
	Remittance	Naira	
	Household-head relationship with a child	1=adopted child, 2=stepchild, 3=own child, 4=grandchild, 5=brother/sister, 6=niece/nephew, 7=brother/sister-in-law, 8=other relation and 9=other non-relation	
	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).

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. The community-distributed lands are assigned through customary rights in a community, where chiefs or community heads transfer land to family heads who distribute it to family members. In communal land tenure, land cannot be accessed by non-members of the community. Households use the cost-free land without paying rent to the landlords, who happen to abandon the land. Rent-free land can be taken from land users at any point in time. Land that was purchased outright is bought from the original owners. The inherited land was accessed by the heir(s) upon the death of the owners or parents. Inheritance is sometimes determined by lineage. Due to the customary land tenure norms of a given society, an individual may inherit land through matrilineal or patrilineal inheritance (Berge et al., 2014). Patrilineal inheritance is dominant in Nigeria, where land is passed directly to males. Land rentals occur when farmers pay rent (or charges) to the owners.

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 and customary certificates 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 recognised by Nigerian's 1978 Land Use Act as formal land titles (NBS & World Bank, 2021). In other words, this study considered holders and non-holders of each (formal or informal) land document; holders and non-holders of each land acquisition mode (in Table 3.1). Perceived land rights, including the right to sell, right to bequeath, right to use land as collateral and right to fallow, were used in the descriptive analysis.

The food security of smallholders was measured using six (6) available food security indicators (Table 3.2), namely:

- The food expenditure share included non-purchased and purchased foods in the household's total monthly expenditure, classified into four-point scales according to WFP (2015) (see Table 3.2).

- The Household Dietary Diversity Scores (HDDS) measured dietary quality at individual and household levels (Hendriks et al., 2016; FAO, 2010). It included 12 food groups derived from 115 food items consumed in the last seven days. HDDS were categorised into three groups using the Simpson index and the cut-offs presented by FAO (2006).
- The Food Consumption Scores (FCS) measured the diversity and frequency of food groups consumed in the past seven 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 pulses, 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 3.2.
- 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.

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 latter domain comprises two indicators: share of food expenditure (as economic vulnerability) and Livelihood Coping Strategies (LCS) (as asset depletion). The Food Consumption Score (FCS) represents the current status (WFP, 2015). Using the cut-off of WFP, (2015), the FSI was categorised into four scales, as indicated in Table 3.2. Following Maxwell et al., (2013) and WFP (2015), the food security indicators were converted into binary classification (i.e., food secure & food insecure units) in Table 3.2. Combining categories simplify result presentation and enhance sensitivity analysis but such binary outcome obscures the real world situations about food security indicators (Maxwell et al., 2013).

Table 3.2: Descriptive classification of food security indicators

Indicators	Category number	Category description	Range	Converted binary classification
Food expenditure share	1	.	<0.5	Food secure
	2	.	0.50 - 0.64	
	3	.	0.65 - 0.74	Food insecure

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

Table 3.3 presents a range of anthropometric measures of children under five years of age. These measurements were derived from the standard deviation scores (z-scores) using the mean of the reference population to calculate the anthropometric indicators (WHO, 1995; 2006). Children whose height-for-age was less than two standard deviations (-2SD) below the median of the recommended reference population were classified as stunted (short for their age). Children whose weight-for-height was below minus two standard deviations (-2SD) from the median of the recommended reference population would be wasted (WHO, 1995; 2006). The Body Mass Index (BMI) was derived from children's weight divided by their height in centimetres square (Table 3.1). Children whose BMI-for-age was above plus two standard deviations (+2SD) from the median of the recommended reference population were considered overweight (WHO, 2006). The World Health Organisation Anthropometric STATA command helped categorise BMI into normal, overweight and obesity (World Bank, 2008). While the WHO growth standards include a BMI chart beginning at birth, the authors acknowledge that using the BMI-for-age growth chart is not recommended for children younger than two years. The BMI in infancy is based on recumbent length rather than stature and, there has been little research on what BMI calculated from length means in infancy and the consequences of high or low BMI in infancy.

Table 3.3: Classification of child anthropometry, cut-off range and prevalent reference

Indicator†	Anthropometric variable	Cut-off value‡	Prevalent reference (%)
Stunting	Height-for-age (HAZ)	<-2 z-scores	Very low (2.5-<10), Low (2.5-<10), Medium (10-<20), High (20-<30), Very high (≥30) (UNICEF, WHO, WBG. 2021).
Wasting	Weight-for-height (WHZ)	<-2 z-scores	Very low (<2.5), Low (2.5-<5), Medium (5-<10), High (10-<15), Very high (≥15) (UNICEF, WHO, WBG. 2021).

Overweight	BMI -for-age (BAZ)	>2 z-scores	Very low (<2.5), Low (2.5-<5), Medium (5-<10), High (10-<15), Very high (≥15) (UNICEF, WHO, WBG. 2021).
Underweigh t	Weight-for-age (WAZ)	<-2 z-scores	Low (<10), Medium (10-19), High (20-29), Very high (≥30) WHO (1995).
Stunted-overweight	Height-for-BMI (HBZ)	<-2 z-scores	.
Obese	BMI-for-age	>3 z-scores	.
Normal weight	BMI-for-age	=2 z-scores	.

Note: BMI is Body Mass Index. † derived using 2006 WHO's Z-anthro Stata commands. ‡ represented the cut-off value recommended by WHO (1995)

The double anthropometric indicator of height-for-BMI (i.e., stunted-overweight to describe a child who was both stunted and overweight) was used. Children whose weight-for-age was below minus two standard deviations (-2SD) from the median of the recommended reference population were underweight (thinner for their age) (WHO, 1995). Children whose height-for-BMI was below minus two standard deviations (-2SD) from the median of the recommended reference population were stunted-overweight (shorter for their weight). The new international reference population recommendations (i.e., prevalent thresholds) for wasting, overweight and stunting in children under five years of age as established by the WHO-UNICEF Technical Advisory on Nutrition Monitoring (United Nations International Children's Emergency Fund UNICEF, World Health Organisation WHO, World Bank Group WBG, 2021) were used as cut-off values. The prevalent threshold WHO recommended (1995) was used for underweight.

3.4 Methods of data analysis

The analysis of this thesis is motivated by the farmers' food demand theory at household and individual levels (as indicated in Equation 4, Chapter Two). The data of the sampled households were described with descriptive statistical tools such as mean, mean difference, percentage and chi-square. The data of the sampled households were analysed with a matching-based flexible panel difference-in-difference (*flexpaneldid*) model and logistic regressions as set out by Dettmann et al., (2020) for achieving objectives 1 and 2 of the thesis. The *flexpaneldid* model applied a matching technique to address the self-selection bias and examine the time-varying effects of land tenure on food security among smallholders. The model attempted to address the self-selection bias by using control variables (X) to estimate matching-based coefficients. The matching-based procedure reduced the potential confounding bias due to observable and improved the comparability of sample units (Daw & Hatfield, 2018). The exact matching algorithm was suitable and selected for this study to consider the time information from the pre-selection process of

matching (Dettmann et al., 2020).) The random effect (RE) logistic regression was used to data for examining objective 3 of the thesis.

3.4.1 **Matching-based flexible panel difference-in-difference**

Unlike the standard difference-in-difference method limited to two-period data and baseline information, *flexpaneldid* technique used multiple-period or panel data to address self-selection bias (non-random assignment of treatment). The *flexpaneldid* model applied a propensity score matching (PSM) technique to derive matched data for estimating causal effect estimates. The matching technique in *flexpaneldid* model aims to pair treated and control groups with similar socioeconomic characteristics *X*.

In matching process of *flexpaneldid* model, propensity scores (PS) of holders of land tenure measures were estimated through the first logistic regression. The regression predicts the probability of pairing each non-holder and holder of land tenure with similar socioeconomic factors (*X)*. The common knowledge for the use of matching procedures is that one should include the covariate variables (*X*) that influence the treatment assignment and the outcome (Heckman et al., 1999). This thesis considered the socioeconomic variables that influenced land tenue and food security and nutrition in the matching analysis. Household socioeconomic properties (in Table 3.1) such as age, sex, literacy, educational attainment, household size, number of plots, cooperative membership, zone and sector used to conduct matching analysis. The matching process reduced the potential confounding bias due to observables and improved the sample units' comparability in the groups (Daw & Hatfield, 2018). The matching technique addresses self-selection bias and counterfactual challenges of what the effect would have been if holders of certain land tenure measures were to be non-holders. Here, the counterfactual is based on a parallel trend assumption, where the mean difference between treated and control group remain constant overtime in the absence of treatment.

The matching method is found useful in *flexpaneldid* to support in isolating the impact of treatments. The validity of PSM depends on two conditions: namely, (a) conditional independence (that, unobserved factors do not affect holders of land tenure after controlling for observed characteristics,) and (b) sizable common support or overlap in propensity scores across the treatments and control samples. The Kolmogorov-Smirnov (KS) test was adopted to check for

common support and the former assumption was tested using PS test. The PS test shows whether the means of all the matching variables balanced to explain outcome dev using the determination of coefficients PS R^2.(i.e., goodness of fit). In case of Kolmogorov-Smirnov (KS) test, the corrected p-value (i.e., ≤ 0.05) indicates that the data does not fit the normal distribution (i.e., no overlap) and thus, rejecting the null-hypothesis. To check for the matching quality, the exact matching option (i.e., matching algorithm) was suitable for time information from the pre-selection process (Dettmann et al., 2020). Using the matched sample data, the matched-based *flexpaneldid* model estimated the non-parametric effect of land tenure on household food security, specified as:

$$\begin{aligned} F_{it}^{q} = {} & F_{D=1}^{T=1}\left((t_{2018})|p(X) - F_{D=0}^{T=1}(t_{2018})|p(X)\right) \\ & - \left(F_{D=1}^{T=1}(t_{2015})|p(X) - F_{D=0}^{T=1}(t_{2015})|p(X)\right) \\ & - \left(F_{D=1}^{T=1}(t_{2012})|p(X) - F_{D=0}^{T=1}(t_{2012})|p(X)\right) \\ & = \delta_{2018} - \delta_{2015} - \delta_{2012} \end{aligned} \qquad \text{Equation 2}$$

In Equation 2, each level of food security measurement 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 the final (2018/19) stage were outcome variables. The *flexpaneldid* technique selected households 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 matching-based *flexpaneldid* technique also generates non-parametric food security results, derived from data that lack a specific distribution of sampled population.

Analysing child nutrition from household data, matching-based *flexpaneldid* model estimates the non-parametric effect of household land tenure on child malnutrition. The model uses the holders of land tenure measures (in Table 3.1), and anthropometric indicators (in Table 3.3) Thus, following Dettmann et al., (2020), the matching-based *flexpaneldid* model for non-parametric effect of household land tenure on child nutrition can be expressed as:

$$\begin{aligned} DID^{N} = {} & \left(A(t_{2018})|p(X) - C(t_{2018})|p(X)\right) \\ & - \left(A(t_{2015})|p(X) - C(t_{2015})|p(X)\right) \\ & - \left(A(t_{2012})|p(X) - C(t_{2012})|p(X)\right) \\ & = \delta_{2018} - \delta_{2015} - \delta_{2012} \end{aligned} \qquad \text{Equation 3}$$

The $A(t_{2018/19})$ showed the child's nutritional outcome in the documented landholding unit at the final period. The $C(t_{2018/19})$ indicated child nutritional outcome in the non-documented landholding unit at 2018/19 General Household Survey (GHS). The $A(t_{2012/13})$ and $A(t_{2015/16})$ represented child nutritional outcome of the documented landholding unit at the initial stages. The $C(t_{2012/13})$ and $C(t_{2015/16})$ denoted the child nutritional outcome of the non-documented landholding unit at the initial periods of 2012/13 and 2015/16 of GHS.

3.4.2 *Flexpaneldid-Gologit* regression model for the effect of land tenure on food security

The matching-based *flexpaneldid* estimator suffered from non-specification of fully parametric model for outcomes and omitted variable bias. The combination of matching-based *flexpaneldid* with regression adjustment is generally better than either alone to fix specification strategy, observed and unobserved household factors (Rubin 2006; Gangl 2014). The *flexpaneldid*-based data fitted to generalised logistic (*Gologit*) regression to estimate the parametric effect of land tenure on household food security levels. After estimating the absolute *flexpaneldid* mean difference from Equation 1, matching-based logit regression was estimated to further address a potential residual confounding bias due to unobserved factors. A FE regression model was not suitable to capture the ordered-categorical outcomes. 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. Food security (*F)* was an ordered categorical variable with q =1…6 as indicated in Table 3.2. This regression model was conditionally adopted to estimate ordered-categorical outcomes that suffered bias from unobserved household factors (α) such as household management ability, risk preference, and unknown individual assets.) The *Gologit* model fitted the *flexpaneldid*-matched data is expressed as:

$$P(F_{it}^{q} > j|p(X)) = \alpha + \mu(D_i|p(X)) + \gamma(T_t|p(X)) + \beta(D_i|p(X) * T_t|p(X)) + \varepsilon_{it}, i = 1 \ldots . N_m, t = 1 \ldots T \quad \text{Equation 4}$$

In Equation 4, 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 potential sources of bias to the strategy were the lack of exogenously assigned land tenure to sampled smallholders, which may subject our estimates to self-selection bias from observed and unobserved

household factors. While the study adopted the matching-based *flexpaneldid* technique to address selection bias on (time-invariant & time-varying) observables, the *Gologit* model (as a method to FE logit that cannot estimate ordered-categorical outcome variable *F*) was used to limit selection bias due to unobserved household factors (in α). The land tenure measures as the explanatory variables were fitted to Equation 4. The *Gologit* regression expression to estimate household food security *F* is given as:

$$P(F_{it}^{q} > j) = \frac{\exp\left(\alpha_j + (D_i * T_t)\beta_j\right)}{1 + [\exp(\alpha_j + (D_i * T_t)\beta_j)]}, j > 1 \ldots . M \qquad \text{Equation 5}$$

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. For robustness check, the ordinal outcome variable *F* data was transformed into binomial units and fitted to FE logit model.

3.4.3 *Flexpaneldid*-FE logit regression model for the effect of land tenure on child nutrition

The matching-based *flexpaneldid* technique produces the non-parametric estimates DID^{N}. The non-parametric technique addresses the non-random selection bias due to the observed confounding factors of the counterfactual group using exact matching algorithm. The non-parametric technique didn't give the true results for meaningful policy predictions due to its non-specification of fully parametric model that addresses the residual confounding bias in the outcome function (Gangl, 2014). The combination of matching-based *flexpaneldid* with regression adjustment is generally better than either alone to address endogenous biases (i.e., observed & unobserved household factors) (Rubin 2006). A *flexpaneldid*-fixed-effect (FE) logistic regression model was used to provide more robust estimates than the non-paramteric estimates of the matched-based *flexpaneldid* model for nutrition analysis. Using matching-based *flexpaneldid* data, the FE logistic regression model to estimate parametric causal effect can be expressed as:

$$P(Y_{it}^{r}|p(X)) = \alpha_h + \mu(D_h|p(X)) + \gamma(T_t|p(X)) + \beta(D_h|p(X) * T_t|p(X)) + \varepsilon_{ht}, i = 1 \ldots . . N_i, \quad \text{h} = 1 \ldots . N_h, t = 1 \ldots T \qquad \text{Equation 6}$$

In Equation 6, r was a vector for the anthropometric measured child malnutrition. The X_{it} represented the control variables (i.e., the socioeconomic features) for selecting the matched samples. The α_i is a household fixed effect that captures unobserved factors like landholder's management ability, landholder risk preferences, and unmeasured landholder wealth, which are correlated with land tenure and child nutrition. The existence of α_i would cause OLS estimates to be biased and inconsistent. The FE logistic regression further addresses omitted variable bias. This thesis used the logit expression suggested by Vogl, (2007), in which the nutritional status *Y* of child *i* in household *h* at year *t* is given as:

$$Prob\ (Y_{iht} = 1|\theta_{ht}) = Y(\theta_{ht}, \varepsilon|H) = \frac{e^{\theta_{ht}}}{1 + e^{\theta_{ht}}} \qquad \text{Equation 7}$$

The θ was the vector for the mode of land acquisition and land right documentation indicators of households *h* at year *t*, given *H* vector for household-head socioeconomic characteristics for matching analysis. The ε was the vector for the error term. If the mode of land acquisition and land right documentation indicators were recorded at the initial stage θ^i, children from tenure secure households at θ^t would be less likely to be stunted, wasted, underweight, overweight and stunted-overweight.

In summary, the conceptual framework (in theory of change) shows that the relationship between land tenure and food security is complex (i.e., indirect), calling for fitting the representative samples in the identification strategy (i.e., model). Running only a DID model or a regression would give biased results because of the non-representative samples/data (i.e., self-selection bias based on the type of land tenure and documentation) fitted to the models. A matching technique helps to randomly draw the representative samples/data (known as matching-based data), which fitted into the DID and regression models. The two models work jointly because *flexpaneldid* (a type of DID) can handle three-wave panel data and work with matching techniques to generate new data called matching-based *flexpaneldid* data. Ordinary DID models cannot handle three-wave panel data sets and do not give matching-based results from representative samples. First, ATE produces *flexpaneldid* estimates from the matching-based *flexpaneldid* data, free from endogenous bias due to observed household factors. This *flexpaneldid* analysis is called a matching-based *flexpaneldid* model. Then, generalised ordered logit provides regression estimates from the matching-based *flexpaneldid* data, free from endogenous bias due to observed and

unobserved household factors. This regression is called a matching-based *flexpaneldid* regression. Dettmann et al., (2020) have provided detailed explanations about the applications of the *flexpaneldid* model. The combination of matching with regression adjustment was more appropriate than each approach alone to address endogenous biases (i.e., observed and unobserved factors) (Rubin, 2006). However, the non-matching-based analyses were biased due to the non-representation of samples, which hindered the findings' generalisation to a broader population and context. Hence, the unmatched regression results were reported in the Appendix.

3.4.4 Random effect-logit regression model for the link between food security and nutrition

The parametric method of random effect (RE) multi-level logistic regression was used to examine the relationship between food insecurity and child malnutrition. Following Fotso et al., (2011), the model was defined as:

$$\begin{cases} Logit\left(Y_{ij}^{k}\right) = ln\left[\dfrac{Y_{ij}^{k}}{1-Y_{ij}^{k}}\right] = \beta_{0j} + \sum_{q=1}^{p} \beta_q F_{ij}^{(q)} \\ \beta_{0j} = \beta_0 + \varepsilon_{0j} \end{cases} \qquad \text{Equation 8}$$

Where i and j refer to the child and observation, respectively; the Y_{ij}^{k} was the probability (for coefplot) or the odd-ratio that the child i from household j who was suffering from anthropometric deficit k; the $F_{ij}^{(q)}$ represented the *qth* food insecurity predictor of household j with child i; the β_q represents the vectors of the *qth* explanatory variables; the β_{0j} referred to the intercept modelled to randomly vary between households with children, i.e., no self-selection of children here because household food consumption over-shadow the food security status of children under five years of age; β_0 represents the fixed intercept; and the ε_{0j} was the error term, which normally identically and independently distributed (iid) as $N(0, \sigma_u^2)$ (Rasbash et al., 2002). The RE model allowed for variability in the set of levels of each food security outcome. Given that the data comprised repeated longitudinal observations, we use random intercept of a logistic model to control the clustering of observations at the child level. The specification of logit estimation model is:

$$Logit(Y_{ij}^{k}) = ln\left[\frac{Y_{ij}^{k}}{1 - Y_{ij}^{k}}\right] = \beta_{0j} + \sum_{q=1}^{p} \beta_q F_{ij}^{(q)} + X_{ij} \quad \text{Equation 9}$$

This study controlled for socioeconomic and demographic characteristics *X* of household *j* with child *i* in Equation 9. The Random effect (FE) model accounted for time-varying heterogeneity in characteristics of households. We adopted Random effect (RE) instead of Fixed effect (FE) for data analysis because the model has the feature of generating low standard deviation and high significant coefficients of regression estimates. The FE assumes that variation between individual-specific factors is constant over time. The model developed an intercept for each household, estimated by demeaning and eliminating the individual-specific factors. Although the results from the RE model may introduce endogeneity due to unaccounted or omitted variable bias, the model estimates were efficient in guiding policy decisions for addressing the risk of child malnutrition through the levels of household food insecurity.

Table 3.4 highlights the methodological approach, which includes the data requirements and methods of analysis for each objective of the thesis. The regression analyses (as summarised in Table 3.4) will be detailed for each sub-objective in the respective chapters.

Table 3.4: Data requirement and analytical methods for each objective of the thesis

Objective list	Variables	Data requirement	Unit	Analytical method
1	**Dependent variable:** Food security measure	Share of expenditure of food, food consumption score (FCS), coping strategy index (CSI), food insecurity experience scale (FIES), household dietary diversity score (HDDS), consolidate an approach to reporting indicators of food security (CARI) and asset index.	Categorical outcome	Matching-based flexible Conditional DID and *gologit* regression
	Independent variable: Land tenure inventory	Land acquisition type, land right documentation and Perceived tenure rights	Binary outcome	
2	**Dependent variable:** Child nutritional outcomes	Stunting, wasting, underweight, overweight and stunted-overweight derived from anthropometric indicators	Binary outcome using WHO Z-score standard	Matching-based flexible Conditional DID and FE-logistic regression
	Independent variable: Land tenure inventory	Land acquisition type, land right documentation and Perceived tenure rights	Binary outcome	
3	**Dependent variable:** Child nutritional outcomes	Stunting, wasting, underweight, overweight and stunted-overweight derived from anthropometric indicators	Binary outcome using WHO Z-score standard	RE-logistic regression

	Independent variable: Food security measure and binary land tenure to moderate the relationship	Share of expenditure of food, food consumption score (FCS), coping strategy index (CSI), food insecurity experience scale (FIES), household dietary diversity score (HDDS), consolidate an approach to reporting indicators of food security (CARI) and asset index.	Categorical outcome	

3.5 Summary

This chapter describes the study area, method of sample selection and data. The analysis used secondary data from three waves (2012/2013, 2015/2016 and 2018/2019) of the Nigerian LSMS-ISA survey. The dependent, explanatory and control variables are defined and measured from the selected datasets to achieve the specific objectives of the thesis. The chapter sets up and explains the matching-based *flexpaneldid* logistic regressions to reveal the robust parametric results of land tenure effect on food security and child nutrition. Objective one is addressed in Chapters Four by fitting the selected data to Matching-based flexible Conditional DID, *Gologit* regression (for ordinal food security measures) and FE-logit model (binary food security measures) to achieve the first research objective. In Chapter Five, selected data fitted to Matching-based flexible Conditional DID and FE-logistic regression to examine the second research objective of the thesis. Chapter Six presents empirical findings for objective three using econometric RE-logistic regression analyses of the data discussed in the methodology.

Chapter 4 : The association between land tenure and smallholder food security using a flexible conditional Difference-in-Difference Approach

4.1 Introduction

The sound governance of land tenure is core to ensuring food security, 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, accounting 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 (AU, 2020a; Landesa, 2012). Climate change and natural resource degradation affect sustainable food security (Lubowski et al., 2006). Likewise, population growth, rapid urbanisation, changing diets and economic development raise competition over limited land, affecting food security (Holden, 2020). Smallholders' limited access to land ownership may hinder their access to innovations and finance.

One of the constraints that hindered agriculture from achieving food security and economic diversification in Nigeria is the insecurity of agricultural land and investments (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 and investments to achieve food security (FMARD, 2022). The LUA empowers the state (governors and local government authorities) to secure, allocate, expropriate or revoke land and certificate of occupancy of landholders and compensate revoked land rights (LFN, 2004). Under a formal tenure system, landholders held formal land certificates to secure land rights (Yemadje et al., 2014). However, less than three percent of households had formal land titles in Nigeria (Ghebru et al., 2014). Rent-seeking and the high cost of processing land registration limit households from having legal land titles, reviving customary land tenure and initiating the use of informal land rights documentation (Ibrahim et al., 2022). The advantages of formal land acquisitions and documentation, including enhanced food security, remain largely untapped.

The Voluntary Guidelines on the Responsible Governance of Tenure of Land in the Context of National Food Security (VGGT) (FAO, 2012; FAO, 2017) and the Frameworks and Guidelines on Land Policy in Africa (African Union Commission AUC, African Development Bank AfDB and United Nation Economic Commission for Africa UNECA, 2010) 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 impact of land tenure among smallholder farmers across various food security outcomes. While the existing literature has conceptually described the relationship between food security and land tenure (Holden, 2020), few studies have researched the linkages and even fewer have explored the relationship between land tenure and child nutrition (Higgins et al., 2018). Furthermore, studies investigating the connection have not addressed the relationship across food insecurity outcomes, impeding complete analysis in developing country contexts (Simbizi et al., 2014; Carletto et al., 2013; Hendriks et al., 2016).

This chapter evaluates the effect of land tenure on household food security using a combined matching and flexible conditional difference-in-difference (*flexpaneldid*) approach. The study is the first to investigate the effect of the mode of land acquisition and land tenure documentation on food security. The study compared food security between holders and non-holders of each (formal or informal) land document and between holders and non-holders of each land acquisition mode. The study findings from the disaggregated analyses have significant implications for land tenure policy. The national framework for agriculture and food security needs to include elements of land ownership and policies must be aligned. While informal land documents are more accessible than formal land certificates to promote food security of farmers, land with informal documents may constrain access to loans. Therefore, the results of this thesis inform the need to formalise existing informal land documents and recognise the role of customary land acquisition among smallholder farmers to support food security. The links between food security and land tenure are dynamic and many food security studies use one or two indicators of food security from cross-section data. This study fitted Nigeria's General Household Surveys (GHS) three-wave panel data to give dynamic perspectives and estimates of six food security implications of land tenure using matching-based *flexpaneldid-Gologit* regression. The findings from the combined models address endogenous biases and provide robust estimates of food security (in level & binary units) in different and tenure measures.

There are five sections to discuss this chapter. The first section gives the background to the chapter and the second section discusses the empirical overviews of the link between land tenure and household food security status. Section three describes the method of data analysis. The fourth section presents and discusses the results. The final section summarises the issues that have been discussed in this chapter.

4.2 Land tenure and food security linkages: conceptual and empirical overviews

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

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), enhancing 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 (FAO, 2017; Borychowski et al., 2022), 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. The theory of property rights to land suggests that formal titling interventions can lead to land-related investments, efficient land markets and mortgaging to borrow 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 farmers with secure land rights, especially those interested in part-time farming activities, can rent out land or leave their land fallow without fear of eviction or expropriation by the 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, improving 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 can buffer crises or shocks and improve livelihoods. Farmers rely on agriculturally based livelihoods, which are affected by seasonal weather conditions and investment in improved inputs. Having secure tenure rights provide a buffer against production failures due to drought, flood or pests and against income shocks from lean harvest, price and financial risks (Fan & Rue, 2020; Ajefu & Abiona, 2020). Land certificates or documents provide collateral for loans or land market risk insurance to address liquidity constraints and 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).

People's perceptions of tenure security are foundational to their willingness to invest in farmland (FAO; World Bank; UN-Habitat, 2019). 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., 2018; FAO; World Bank; UN-Habitat, 2019). 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, 2019). Household tenure rights and obligations are defined by formal institutional tenure elements (i.e., land certificates) or recognised socio-cultural norms (i.e., perceived tenure rights) (Deninger & Feder, 2009). 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. In the spirit of 'leaving no one behind', the SDG indicator1.4.2 considers the 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, 2019).

A few empirical studies have reported the impact of land tenure on food security worldwide. Mendola & 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. Yet, Santos et al. (2014) found no significant association between government land allocation, registration programmes and nutritious food consumption in rural West Bengal. Muraoka et al., (2018) utilises household- and parcel-level data from rural Kenya to study the relationship between land access (in rented and owned land sizes) and food consumption. 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 (Rammahan & Pritchard, 2014). However, most food-insecure households in rural India hold no or marginal household agricultural land (Goli et al., 2021).

Little evidence is reported on the influence of land registration, formal land certificates, and informal land document ownership on food security in Africa. Kehinde et al. (2021) found no significant association between formal land certification programmes and food security for a 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 woodlands in Zambia (Merten & Heller, 2008) showed that land tenure could improve food security. However, there is scanty empirical evidence on land tenure among smallholders across the range of food insecurity outcomes.

4.3 Methodology

The methodology was described in Chapter Three of this thesis. This study depended on secondary data from Nigeria's General Household Survey (GHS). A total of 1434 sampled households operated small plots (i.e., ≤ 2ha) were drawn from the total population in 2012/13 (wave2), 2015-16 (wave3) and 2018-19 (wave4) general household survey. The sampled data were analysed to examine the effect of land tenure on household food security. The data of the sampled households (as highlighted in Chapter Three) were described with descriptive statistical tools such as mean, mean difference, percentage and chi-square. The data of the matched sample households were analysed with a flexible panel difference-in-difference (*flexpaneldid*) model set out by Dettman et al., (2020) and a generalised ordered logistic (*Gologit*) regression specified in Chapter Three to generate the parametric estimates.

In summary, Equation 2 showed the expression for calculating matched-based *flexpaneldid* estimates, free from selection bias due to observed household features. However, the model did not address the selection bias due to unobserved household characteristics. Therefore, Equation 4 fitted the matched-based *flexpaneldid* data to adjust for unobserved household factors (in α).

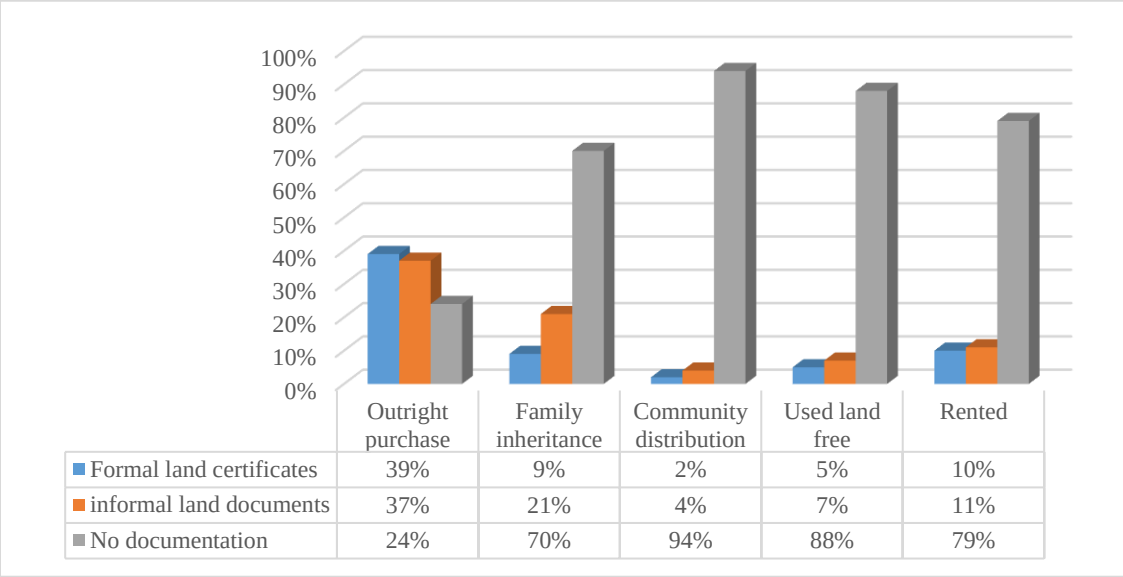
Equation 5 was an expression for *flexpaneldid-Gologit* to estimate *F* in Equation 2 to produce parametric estimates free from unobserved household factors. The results of Equation 5 are reported in the ratio of odds ratios (ROR) as exponential coefficients (likelihood of event occurrence) of food security measures in categories compared to the reference category. 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).

4.4 Results and discussion

Figure 4.1 presents the summary of land right documentation by the mode of land acquisition (as set out in Table 3.1). Informal land documents were held by landholders more so 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 formally certificated land and seven percent held informally documented land. 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 land document 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 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, informal land tenure occurs when there is a land transfer to unofficial landlords or land users from official landlords. Like the purchased land,

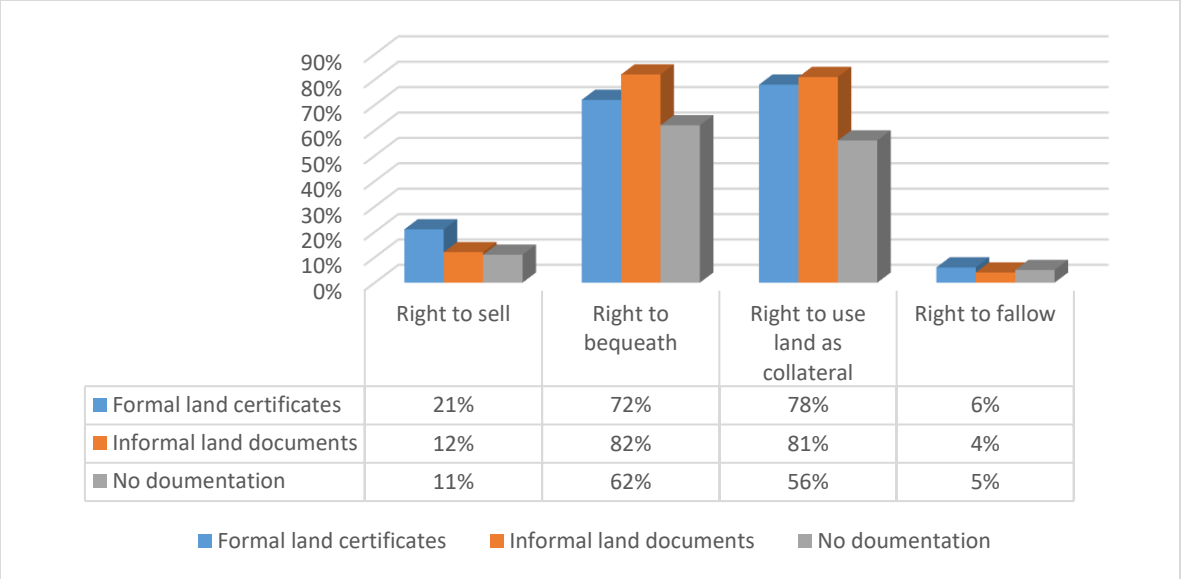
informal transfer deeds or witnessed paper-based contracts for land use could be exchanged between landlords and tenants (Yemadje et al., 2014).



	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 4.1: Proportion of tenure documentation across land acquisition mode
Note: Land acquisition indicator (Observation N): Outright purchase (142), family inheritance (774), community distribution (449), used land free (176) and rented land (149).
Source: Author, (2021)

Figure 4.2 illustrates the household perception of land rights by land right documentation. Households who (21%) held formal land certificates perceived they had rights to sell more than (12%) who held informal land documents and (11%) no document. About 80% of households who held informal land documents perceived they had rights to bequeath and use land as collateral, while at least 60% who held formal land certificates and no land document perceived similar land rights. A small proportion (6%) of households who held formal land certificates and even less (4%) who held informal land documents perceived they had the right to fallow. Generally, while the perception of land rights was a subjective measurement, most households who perceived they had rights to sell (21%), bequeath (> 70%), fallow, (> 6%) and use land as collateral (> 70%) associated their land rights with land documentation. As a result, these households felt tenure secure when their land rights were strengthened by functioning formal tenure rules.



	Right to sell	Right to bequeath	Right to use land as collateral	Right to fallow
Formal land certificates	21%	72%	78%	6%
Informal land documents	12%	82%	81%	4%
No doumentation	11%	62%	56%	5%

Figure 4.2: Proportion of the perception of land rights by tenure documentation
Note: Land right documentation indicator (Observation N): Formal land certificates (67), Informal land documents (195), No documentation (1172)
Source: Author, (2021)

Table 4.1 presents the summary statistics for the socioeconomic features of the smallholders across land ownership indicators. On average, the age of smallholders was between 46 years and 53 years. The lowest age average was found among family-inherited landholders. Almost all sampled landholders belong to the polygamous section (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 (4.85), 'free of use' land and rented land held Junior Secondary School certificates (category 5 of education completed). Households with inherited land and community-distributed land had vocational school certificates (category 4 of education completed). Less than eight percent of the landholders were cooperative society members, irrespective of the acquisition mode. Lands acquired through family inheritance and household community distribution 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 receiving land through outright purchase, family inheritance, free land use and renting dominated during the 2018 survey compared to the subsequent surveys. More households acquired community-distributed land during the 2012/13 survey conducted during the 2011 Agricultural Transformation Agenda reign.

Table 4.1: 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	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	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

Source: Author, (2021)

Table 4.2 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. Most of the sampled household heads that held land-related documents were married (polygamous) and had at least six (6) household members. The education attainment of households was between vocational (category 4) and junior secondary school (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 who 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 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 so than rural smallholders. The results suggest that only a few small-scale farmers existed in the urban areas (about four percent of the sample households). Urban farmers may have more legal knowledge of the benefits and processes regarding formal land right documentation than rural land users. The results were consistent with Ghebru et al., (2014). Over 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. Since the sampled households depend on land sources and land documents for farming livelihood, this study assumed that food security across the selected survey years would differ.

Table 4.2: 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	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	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

Source: Author, (2021)

Table 4.3 compares the mean difference in land tenure between smallholder female and male household heads. The results suggested that inequality in 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% households used land free. The results showed that the mean difference of gender in land acquired through outright purchase and renting was statistically significant at the one percent 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 six percent more land and acquired two percent 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 five percent and 10% significance levels. More (4% & 7%) male households held formal land certificates and informal land documents than female households. With a high prevalence of inherited family land acquired by sampled households,

smallholders perceived more right to bequeath and use land as collateral. However, formal loan acquisition may be complex for smallholders when collateralised land is 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 4.3: 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 (0.30)	0.04 (0.01)	0.11 (0.01)	-0.07*** (0.02)
	Family inheritance	0..54 (0.50)	0.51 (0.03)	0.55 (0.01)	-0.04 (0.04)
	Community distribution	0.31 (0.46)	0.33 (0.03)	0.31 (0.01)	0.02 (0.03)
	Used land free	0.12 (0.33)	0.10 (0.02)	0.13 (0.01)	-0.03 (0.02)
	Rented	0.10 (0.31)	0.15 (0.02)	0.10 (0.01)	0.06*** (0.02)
Land right documentation	Held a formal land certificate	0.07 (0.25)	0.04 (0.01)	0.07 (0.01)	-0.04** (0.02)
	Held an informal land document	0.14 (0.34)	0.08 (0.02)	0.15 (0.01)	-0.07*** (0.03)
Perception of land rights	Right to sell	0.12 (0.33)	0.07 (0.02)	0.13 (0.01)	-0.06*** (0.02)
	Right to bequeath	0.65 (0.48)	0.55 (0.03)	0.67 (0.01)	-0.12*** (0.03)
	Right to fallow	0.05 (0.22)	0.06 (0.02)	0.05 (0.01)	0.01 (0.02)
	Right to use as collateral	0.63 (0.48)	0.41 (0.03)	0.66 (0.01)	-0.25*** (0.04)
	Observation	1434	217	1217	

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1.
Source: Author, (2021)

Table 4.4 presents the mean difference in land tenure measures across smallholder zones. There were low incidences of outright land purchase, community land distribution, free land usage and renting across the smallholders' zones. In Nigeria, smallholders of the South-West zone had the highest prevalence of outright land purchase (27%) and free land usage (33%). Land acquired through renting by smallholders was prevalent in the South-South zone. Over 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%) of 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.

Table 4.4: 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.
Source: Author, (2021)

4.4.1 Descriptive results of food security indicators

Figure 4.3 summarises 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. However, with 37% budgeting, more than 74% of total income and 18% of households budgeted between 65% and 74% of total revenue on food, fifty-five percent of the sample smallholders spent more than 65% of their total budget on food, which classified them as food insecure.

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 two percent and 13% of smallholders were in emergency and crisis levels of the LCS, which classified them as food insecure (Figure 4.3).

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 correlate positively 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 constructing the indexes.

For food security measures, there were variations in the measurements of the variables (either level or binary unit) across survey waves except for livelihood coping strategies (LCS level), with 9% of the 1434 households stressed, 13% in crisis and 2% in an emergency. Other food measures with low observations were found in 6% food secure level in FSI and 12% of the households who spend 50-64% total income in food expenditure share. A small proportion of a level in a variable of multiple levels cannot affect regression results with an appropriate non-linear probability model. For example, the categorical food security variable used in the regression analysis had observations from 6% food secure, 27% marginally food insecure, 51% moderately food insecure and 16% severely food insecure households (Figure 4.3). Also, the binary food security variable used in the regression analysis had observations from 33% food secure and 67% food insecure households. Using a category as a variable in a regression model will never provide results due to lack of variations in a category. In simple term, a category is not varied for all observations, while a variable has varied values for all observations from different categories. However, variables (in either categorical or binary observations) with multiple categories in an appropriate non-linear probability regression model will give empirical results.

As shown in Table A1 (in the appendix), 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 concerning the FCS, HDDS, household asset ownership and the LCS. More than half of 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 with formal land certificates were classified as food secure through the FCS, HDDS, household asset ownership and the LCS (as presented in Table A2 in the appendix).

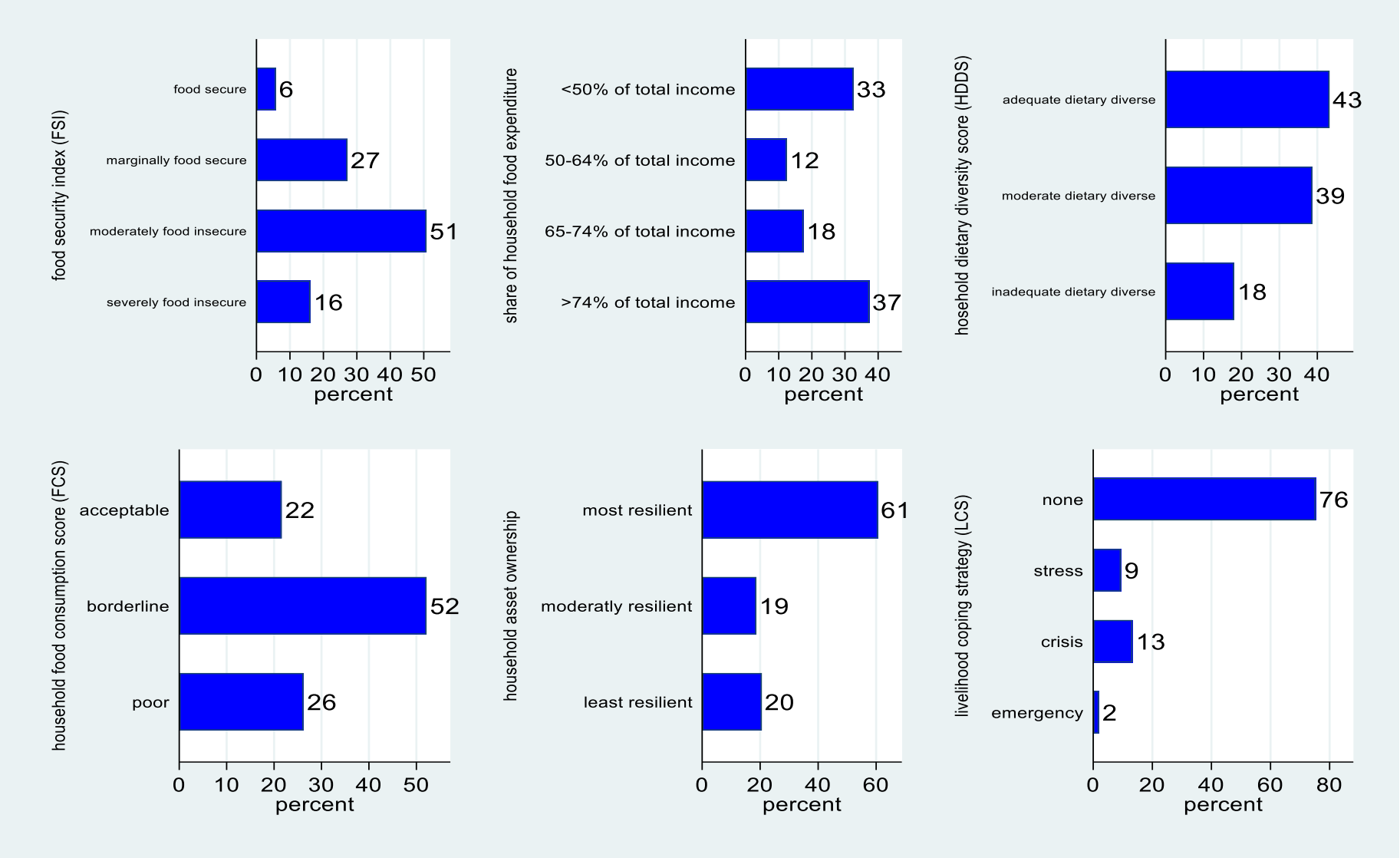


Figure 4.3: Descriptive summary of food security indicators of households operated ≤2ha plot
Note Total sampled population N=1434.
Source: Author, (2021)

Table 4.5 presents the statistical results for the variations of food security (binary) and land tenure across survey years. Sampled households holding inherited land increased from 0.4% in 2012/13 to 64% in 2015/16 and dropped to 49% in 208/19. Land inheritance transfer to the heirs rose in 2015/16 in the study area. Across the survey years, households purchased and rented more land in the 2018/19 survey but acquired more community distributed land in 2012/13. While the proportion of landholders with no document was gradually declining across survey years, there was an increase in formal land certificates holders from 1% in 2012/13 to 9% in 2018/19 survey years. The highest proportion (17%) of sampled households held informal land documents in the 2015/16 survey year. Chi-square test for the variability of the variables across each wave of the datasets. Chi2-test signified that the group-mean differences for all land tenure indicators across the survey years were statistically significant.

For land tenure measures, 7% of the 1434 observations had formal land certificates, 14% of had informal land documents. Also, 12% of the observations used land for free; 10% held rented land; 10% acquired purchased land; 54% held inherited land and 31% acquired community-distributed land. Only inherited and community-distributed landholders had a proportionally large number of observations. These statistics showed the proportions for the categories within variables used in the regression. The variables used in the regression analysis had observations from holders and non-holders of a document or an acquired land. So, a dummy variable derived from 7% holders of formal land certificates and 79% households without documents was used in the regression analysis. Also, a dummy variable derived from 14% holders of informal land documents and 79% households without documents was used in the regression analysis.

Table 4.5: Statistical results of food security (binary) and land tenure variations across survey years

Variable	Total	2012/13	2015/16	2018/19	Chi^2 test
Land acquisition mode					
Inheritance	54%	1%	69%	57%	512.72***
Purchased	10%	2%	5%	12%	41.48***
Community distribution	31%	77%	8%	5%	760.88***
Rented	10%	8%	8%	11%	2.65
Free of charge	12%	12%	10%	15%	6.48**
Land right documentation					
No document	79%	96%	66%	83%	141.85***
Informal document	14%	3%	38%	10%	138.07***
Formal certificate	7%	1%	6%	7%	19.95***
Binary food security indicator					
FSI	33%	14%	26%	59%	233.52***

Food expenditure share	45%	18%	22%	96%	752.08***
HDDS	82%	88%	79%	79%	19.52***
FCS	22%	14%	27%	24%	27.81***
Household assets	79%	73%	85%	81%	21.48***
LCS	85%	85%	83%	86%	0.94
	1434	478	478	478	

Note: Number of observations in parenthesis, Significant level: *p<0.1, **p<0.05, ***p<0.01
Author, (2021)

Table 4.6 shows statistical results of food security (level) and tests of variations across waves. The highest proportions of sampled households were moderately food insecure (56% & 50%) in FSI in the 2012/13 and 2015/16 survey years. However, about 91% households spent less than 50% of their monthly budget on food in the 2018/19 survey year. High proportions of households were in the "none" level of LCS and the "least resilient" level of household assets across the survey years. Most households were high in FCS's borderline and moderate HDDS. There were significant variations in the proportion of households in each level of food security (measured in FSI, food expenditure share & household assets) across survey years. Significant variations in the proportions of households were identified in adequate and inadequate levels of HDDS, acceptable and poor FCS levels and emergency LCS levels across survey years.

Table 4.6: Statistical results of food security (level) and tests of variations across survey waves

Food security (levels)	2012/13	2015/16	2018/19	Chi^2 test
FSI				
Food secure	1%	1%	16%	68.63***
Marginal food secure	13%	25%	44%	112.82***
Moderately food insecure	56%	55%	40%	33.65***
Severely food insecure	29%	18%	1%	234.40***
food expenditure share				
<50	4%	3%	91%	1109.11***
0.50 – 0.64	14%	18%	5%	52.33***
0.65 – 0.74	22%	29%	1%	238.55***
>75	60%	49%	3%	657.73***
HDDS				
Adequate	51%	38%	41%	19.34***
Moderate	37%	41%	38%	1.70
Inadequate	12%	21%	21%	22.93***
FCS				
Acceptable	14%	27%	23%	31.56***
Borderline	53%	52%	52%	0.07
Poor	33%	21%	25%	22.23***
Household assets				
Most resilient	53%	61%	68%	24.18***
Moderately resilient	2%	23%	13%	20.54***
Least resilient	27%	15%	19%	20.28***
LCS				
None	73%	75%	77%	2.11

Stress	12%	8%	8%	4.03
Crisis	12%	15%	14%	2.42
Emergency	3%	2%	1%	7.34**
Obs	478	478	478	

Notes: ***$p<0.01$, **$p<0.05$, *$p<0.1$ represented the significant level for equality of group-mean using the likelihood ratio (LR chi2 test)
Author, (2021)

4.1.1 Factors of the likelihood of land tenure using logit regression for matching analysis

Table 4.7 presents the logit results for estimating the propensity score matching of land acquisition treatment for food security analysis. The results derived from data of households with less than two hectares of land to allow analysis of farmers' food security. The results showed that the model used correct estimates with prediction of over 60% of sampled households from each land acquisition mode and documentation type and with statistically significant likelihood ratios of sample distributions.

Households who were male, adults, married, resided in rural and southern regions, planted more trees and operated on high plot sizes were more likely to have access to inherited farmland. Farmers who own a small number of trees and plots, more family members in the urban and northern regions were more likely to purchase farmland to improve livelihood. Older, male and married households with low plot areas and large family size were more likely to secure land through community distribution. Those households' high number of plots with a low year of acquisition were likely to secure community distributed lands. Farmers were more likely to rent land when educated, resided in the urban-south and owned low numbers of livestock, plots and plot areas. Farmers who owned a low plot sizes and livestock units were more likely to use abandon land free of rent. Households who perceived that land had been acquired or abandoned for a long year were more likely to rent land or used land for free of rent, respectively.

Table 4.7: Logit results of the factors of land acquisition for matching in food security analysis

Variable	Inherited land vs no inherited land	Purchased land vs no purchased land	Community distributed vs no community distributed land	Rented land vs no rented land	Free used land vs no free land
Household size	1.02 (0.02)	1.07*** (0.03)	1.90*** (0.29)	1.03 (0.03)	1.00 (0.03)
Age	0.98*** (3.62e-03)	1.01 (0.01)	1.02*** (4.72e-03)	1.00 (0.01)	1.00 (4.77e-03)
Tree on land	1.00** (6.60e-04)	0.01*** (4.29e-04)	1.00 (3.56e-04)	1.00 (7.39e-04)	1.00 (4.74e-04)
Number of plots	1.44*** (0.11)	1.06 (0.08)	1.18** (0.09)	0.31*** (0.10)	0.14* (0.08)

Plot area owned	5.07*** (1.64)	0.07*** (0.04)	0.46* (0.20)	0.13*** (0.04)	0.22*** (0.08)
Total plot area	0.24*** (0.08)	0.36 (0.25)	0.87 (0.36)	0.83*** (0.18)	0.40*** (0.17)
TLU	1.00 (4.60e-03)	1.00 (0.01)	1.00 (3.52-03)	0.94*** (0.02)	0.95*** (0.02)
Gender	0.58* (0.18)	0.45 (0.24)	2.84*** (1.09)	1.31 (0.57)	0.80 (0.02)
Cooperative	0.93 (0.34)	0.80 (0.43)	1.34 (0.60)	0.82 (0.47)	0.92 (0.48)
Household education	0.99 (0.02)	1.02 (0.02)	1.00 (0.02)	1.04** (0.02)	1.01 (0.02)
Marital status	1.20*** (0.08)	1.05 (0.09)	0.63*** (0.06)	1.08 (0.09)	1.03 (0.08)
land acquisition year	1.00 (0.25)	#	0.42** (0.11)	5.40** (4.02)	3.32** (1.77)
Sector	1.76** (0.45)	0.56* (0.20)	1.27 (0.44)	0.40*** (0.12)	0.71 (0.22)
Zone	0.84*** (0.06)	1.02** (0.11)	1.14 (0.10)	0.39*** (0.13)	1.10 (0.09)
Cons	1.29 (0.82)	0.05*** (0.04)	0.13** (0.11)	0.01*** (0.01)	0.04 (0.03)
Pseudo R^2	0.22	0.31	0.34	0.36	0.17
LR Chi square	147.20	73.90	116.05	117.97	55.47
Observation	1024	924	1024	1024	1024

Note: standard errors in parenthesis. This table reported another transformation from logit regression of land tenure on the observed characteristics for matching analysis. *** $P<0.01$, $P<0.05$, *$P<0.1$.
Source: Author, (2021)

Table 4.8 presents the logit results for estimating the propensity score matching of land documentation treatment for food security analysis. Increase in household sizes and residing in urban and southern regions were more likely to influence households' access to formal land certificates. Households who own high livestock units belonging to cooperative societies and marriage were more likely to access informal land documents than households without livestock units, cooperative and marital relationships. Male households were more likely to hold informal land documents than female households.

Table 4.8: Logit results of the factors of land documentation for matching in food security analysis

Variable	Formal land certificate vs no document	Informal land document vs no document
Household size	1.15*** (0.03)	1.01 (0.02)
age	1.01 (0.01)	1.00 (4.13e-03)
Tree on land	0.99 (4.45e-03)	1.00 (3.26e-04)
Number of plots	0.95 (0.94)	0.97 (0.07)

Plot area owned	2.65 (1.65)	1.19 (0.42)
Total plot area	0.60 (0.39)	1.30 (0.47)
TLU	0.99 (0.01)	1.01* (0.01)
Gender	0.78 (0.47)	0.34*** (0.13)
Cooperative	2.00 (0.99)	1.85* (0.66)
Household education	1.03 (0.02)	1.02 (0.02)
Marital status	1.02 (0.11)	1.15** (0.08)
land acquisition year	1.91 (1.05)	0.78 (0.22)
sector	0.35*** (0.13)	1.02 (0.31)
zone	0.83* (0.08)	1.13 (0.08)
Constant	0.12 (0.13)	0.09*** (0.07)
Pseudo R^2	11.28	0.04
LR Ch12	66.08	63.72
Observation	1024	1024

Note: standard errors in parenthesis. This table reported another transformation from logit regression of land tenure on the observed characteristics for matching analysis. *** $P<0.01$, $P<0.05$, *$P<0.1$.
Source: Author, (2021)

4.1.2 Matching-based *flexpaneldid* tests and results of the land tenure effect on food security

Table 4.9 presents the matching-based *flexpaneldid* tests and the estimates of the effect of land tenure on food security (level) indicators. The non-matching regression results were closely similar to the reported matching-based regression results. The ordered-categorical outcome variables *F* data were transformed into binary food security units (Table 3.2). The results of matching-based regressions were reported in Tables 4.9 – 4.11. There were large observations for each food security indicator (variables) from non-matching Average Treatment Effect (ATE) (Tables A3 & A4 in the Appendix) and regression (Tables A5 & A6 in the Appendix). Yet, the categorical and binary food security results from matching-based regressions were closely similar to the results from non-matching regressions with large observations.

Table 4.9: Matching-based *flexpaneldid* tests and results of the effect of land tenure on food security (level)

	Land acquisition mode					Land documentation	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
FSI							
Food secure	-0.01	-0.04	-0.02	-4.27e-03	8.08e-04	0.02	0.02

	(0.03)	(0.04)	(0.06)	(0.04)	(0.04)	(0.04)	(0.02)
Marginal food secure	0.01 (0.05)	0.07 (0.08)	0.03 (0.04)	-0.20*** (0.08)	0.01 (0.07)	0.09 (0.07)	0.02 (0.04)
Moderately food insecure	0.02 (0.06)	-0.03 (0.09)	0.03 (0.11)	0.13 (0.08)	4.84e-03 (0.08)	-0.06 (0.08)	-1.92e-03 (0.04)
Severely food insecure	-0.01 (0.04)	3.45e-03 (0.06)	-0.04 (0.05)	0.07* (0.04)	-0.02 (0.05)	-0.05 (0.06)	-0.04 (0.03)
PS test R^2	0.48	0.11	0.77	0.34	0.45	0.28	0.06
Corrected KS p-value	0.54	1.00	1.00	0.99	1.00	1.00	0.22
Observations	657	132	144	150	174	141	606
Food expenditure share							
Less than 50%	-0.02 (0.05)	-0.05 (0.08)	0.01 (0.11)	0.01 (0.08)	3.23e-03 (0.07)	0.02 (0.08)	0.05 (0.04)
50 – 64%	-0.08** (0.04)	-0.02 (0.05)	-0.01 (0.09)	-0.01 (0.06)	0.05 (0.06)	-0.03 (0.05)	-0.01 (0.03)
65 – 74%	0.04 (0.04)	0.04 (0.07)	0.06 (0.09)	4.10e-03 (0.07)	0.01 (0.06)	-0.03 (0.07)	0.03 (0.03)
Greater than 74%	0.07 (0.05)	0.03 (0.08)	-0.06 (0.10)	-0.01 (0.07)	-0.06 (0.07)	0.05 (0.08)	-0.34* (0.04)
PS test R^2	0.36	0.07	#	0.20	0.26	0.34	0.05
Corrected KS p-value	0.00	1.00	0.03	1.00	1.00	1.00	0.23
Observations	684	136	144	153	174	138	606
HDDS							
Adequate	-0.04 (0.05)	-0.05 (0.08)	0.04 (0.09)	-0.03 (0.08)	0.05 (0.07)	0.11 (0.09)	-0.03 (0.04)
Moderate	0.11** (0.05)	0.01 (0.08)	-0.06 (0.11)	-0.04 (0.08)	-0.04 (0.07)	0.07 (0.08)	0.01 (0.04)
Inadequate	-0.06 (0.04)	0.04 (0.07)	0.02 (0.10)	0.07 (0.07)	-0.01 (0.07)	0.04 (0.07)	0.02 (0.03)
PS test R^2	0.36	0.12	0.70	0.17	0.19	0.48	0.04
Corrected KS p-value	0.98	1.00	0.32	1.00	0.78	0.99	0.89
Observations	678	138	147	153	177	135	612
FCS							
Acceptance	-4.35e-03 (0.04)	-0.01 (0.07)	-0.04 (0.10)	-0.10 (0.07)	-2.53e-03)	0.06 (0.07)	-1.03e-03 (0.03)
Borderline	0.01 (0.05)	0.15* (0.09)	0.01 (0.11)	0.05 (0.08)	0.01 (0.08)	0.08 (0.09)	0.04 (0.04)
Poor	-2.43e-03 (0.04)	-0.14* (0.07)	0.03 (0.07)	0.05 (0.07)	-2.53e-03 (0.06)	-0.14** (0.07)	-0.04 (0.04)
PS test R^2	0.38	0.16	1.00	0.41	0.38	0.23	0.04
Corrected KS p-value	0.03	0.34	0.20	1.00	0.99	1.00	0.99
Observations	684	135	144	150	171	135	612
Household Assets							
High	-0.11** (0.05)	-0.07 (0.08)	-0.03 (0.10)	-0.056 (0.08)	0.09 (0.07)	0.10 (0.09)	0.06 (0.04)
Medium	0.06 (0.04)	-0.02 (0.07)	0.10 (0.08)	-1.07e-03 (0.06)	-0.05 (0.05)	-0.05 (0.06)	-0.03 (0.03)
Low	0.05 (0.04)	0.08 (0.07)	-0.07 (0.08)	0.06 (0.07)	-0.04 (0.06)	-0.05 (0.07)	-0.03 (0.04)
PS test R^2	0.36	0.17	0.72	0.56	0.22	0.27	0.03
Corrected KS p-value	0.002	0.98	0.20	1.00	1.00	0.99	0.13

Observations	683	138	147	150	177	129	614
LCS							
None	-0.03 (0.04)	0.02 (0.08)	0.08 (0.09)	-0.10 (0.07)	-0.09 (0.06)	0.02 (0.08)	0.01 (0.04)
Stress	0.02 (0.03)	1.45e-03 (0.05)	0.03 (0.05)	-0.03 (0.04)	0.01 (0.04)	0.02 (0.06)	0.02 (0.03)
Crisis	-0.05 (0.04)	-0.02 (0.06)	-0.13 (0.08)	0.11** (0.05)	0.09* (0.05)	-0.04 (0.06)	-0.02 (0.03)
Emergency	0.01 (0.01)	-2.17e-03 (0.02)	0.03 (0.03)	0.01 (0.02)	-0.01 (0.02)	-2.54e-03 (0.02)	-0.01 (0.01)
PS test R^2	0.43	0.11	1.00	0.18	0.27	0.25	0.06
Corrected KS p-value	1.00	1.00	0.32	0.87	1.00	1.00	1.00
Observations	657	129	144	153	171	138	600

Note: # means convergence does not achieve.
Source: Author, (2021)

Table 4.10 presents the matching-based *flexpaneldid* tests and estimates of the effect of land tenure on food security (binary) indicators.AI robust standard errors in parenthesis. This study reported non-regression *flexpaneldid* estimates using the exact matching method to ensure the best possible matches are included in the matched samples. Matches control variables are those without each selected treatment in land acquisition modes and land documentation types. In the case of Kolmogorov-Smirnov (KS) test for equality of distribution functions, consistent bias-corrected estimator as proposed in Abadie & Imbens (2006, 2011). The p-value values for the Chi square test statistic (i.e., ≤ 0.05) indicate that the data does not fit the normal distribution and thus, rejecting the null-hypothesis. The null hypothesis of Chi square test states that data are taken normally distributed population. When $P > 0.05$, null hypothesis accepted, and data are normally distributed (Dettmann et al., 2020). PS R2 shows the means of all the matching variables balanced to explain outcome dev.

Table 4.10: Matching-based *flexpaneldid* tests and results of the effect of land tenure on food security (binary)

	Land acquisition mode					Land documentation type	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
FSI	0.17*** (0.10)	0.11 (0.24)	-0.42* (0.26)	-0.57*** (0.16)	-0.01 (0.20)	-0.09 (0.18)	0.03 (0.07)
PS test R^2	0.46	0.11	0.80	0.35	0.33	0.25	0.05
Corrected KS p-value	0.54	1.00	1.00	1.00	1.00	1.00	1.00
Observations	657	119	103	138	163	133	598
Food expenditure share	0.21*** (0.04)	-0.18 (0.11)	0.78*** (0.20)	-0.33** (0.15)	0.07 (0.14)	0.02 (0.08)	-0.04 (0.04)
PS test	0.35	0.09	1.00	0.43	0.42	0.26	0.05
Corrected KS p-value	0. 34	1.00	0.03	1.00	1.00	1.00	1.00
Observations	682	128	98	138	166	90	607

HDDS	0.12* (0.07)	0.03 (0.13)	-0.66 (0.49)	-0.23* (0.14)	0.10 (0.13)	-0.12 (0.15)	0.16* (0.10)
PS test	0.36	0.14	0.70	0.16	0.28	0.29	0.04
Corrected KS p-value	1.00	1.00	1.00	1.00	0.78	1.00	0.89
Observations	682	128	103	141	166	133	
FCS	-0.28*** (0.07)	0.23 (0.15)	-0.52* (0.29)	-0.12 (0.16)	0.04 (0.14)	-1.50e-03 (0.17)	-0.04 (0.06)
PS test	0.38	0.11	0.75	0.34	0.32	0.21	0.04
Corrected KS p-value	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Observations	684	125	96	138	163	133	607
Household Assets	0.03 (0.08)	-0.14 (0.14)	0.11 (0.25)	-0.18 (0.22)	0.11 (0.15)	-0.23 (0.13)	0.14** (0.06)
PS test	0.36	0.14	0.72	0.39	0.22	0.35	0.05
Corrected KS p-value	0.22	0.98	1.00	1.00	1.00	1.00	1.00
Observations	683	125	103	138	169	136	609
LCS	0.18** (0. 05)	-0.27 (0.18)	0.02 (0.36)	-0.07 (0.12)	-0.03 (0.11)	0.01 (0.20)	-0.03 (0. 05)
PS test	0.43	0.11	1.00	0.48	0.29	0.28	0.05
Corrected KS p-value	1.00	1.00	0.68	1.00	1.00	1.00	1.00
Observations	657	116	103	138	169	136	592

Source: Author, (2021)

4.4.2 Matching-based regression results of land acquisition across the food security (level) indicators

Table 4.11 shows the coefficients of two land ownership indicators: family-inherited land and accessed land for free. These 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) than those without inherited land. Also, land ownership through inheritance increased total household assets by 95%. However, households with inherited land were 20% less likely to have high FCSs than those without inherited land. The livelihood coping capacity of households was reduced by 43% when they acquired land through inheritance. The overall food security index decreased 56% for households with inherited land. Smallholders who accessed land for free were 47% less likely to consume diverse diets than holders of no free land. 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. 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 of the present land tenure measures to explore food security outcomes. Accessing additional lands through the land rental market unoperated owned land has become a prevalent land tenure measure to capture household food security in the literature (Harris-Fry et al., 2020; Ghebru & Hoden, 2013; Muraoka et al., 2017; Rammohan & Pritchard, 2014). Although the effect of community distributed land access was not statistically significant here, some studies found significant food security implications of program-based land transfers (Goli et al., 2021; Mendola & Simtowe, 2013; Mueller et al., 2014).

Table 4.11: Matching-based regression results of the effect of land acquisition on food security (level)

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 (0.64)	0.57** (0.27)	2.08 (2.24)	2.41 (1.57)	0.91 (0.65)
	Marginally food secure	0.88 (0.64)	0.57** (0.27)	2.08 (2.24)	2.41 (1.57)	0.91 (0.65)
	Moderately food insecure	0.88 (0.64)	0.57** (0.27)	2.08 (2.24)	2.41 (1.57)	0.91 (0.65)
	Severely food insecure[u]					
	Matched observation	122	657	103	166	138
Food expenditure share	<0.5	1.77 (1.75)	0.51 (0.36)	0.70 (1.65)	1.70 (1.65)	2.08 (1.89)
	0.50-0.64	1.77 (1.75)	0.51 (0.36)	0.70 (1.65)	1.70 (1.65)	2.08 (1.89)
	0.65-0.74	1.77 (1.75)	0.51 (0.36)	0.70 (1.65)	1.70 (1.65)	2.08 (1.89)
	>0.74[u]					
	Matched observation	128	684	103	166	141
HDDS	Adequate	0.68 (0.47)	1.57** (0.74)	1.16 (1.12)	0.53* (0.32)	2.23 (1.49)
	Moderate	0.68 (0.47)	1.57** (0.74)	1.16 (1.12)	0.53* (0.32)	2.23 (1.49)
	Inadequate[u]					
	Matched observation	128	678	105	169	141
FCS	Acceptable	1.30 (0.93)	0.80** (0.37)	1.45 (1.53)	2.10 (1.34)	1.43 (0.96)
	Borderline	1.30 (0.93)	0.80** (0.37)	1.45 (1.53)	2.10 (1.34)	1.43 (0.96)
	Poor[u]					
	Matched observation	125	684	103	163	138
Assets	Most	1.63 (1.19)	1.95* (1.13)	0.85 (0.90)	0.16 (0.16)	0.28 (0.24)
	Moderate	1.63 (1.19)	1.95* (1.13)	0.85 (0.90)	17.29 (22.82)	6.55 (6.49)
	Least[u]					
	Matched observation	128	683	106	169	138

Indicator	Land tenure	Land acquisition indicators				
LCS	None	0.67 (0.60)	0.43* (0.24)	0.40 (0.54)	4.81 (5.91)	0.93 (0.83)
	Stressed	0.67 (0.60)	0.43* (0.24)	1.95e04	4.81 (5.91)	0.93 (0.83)
	Crisis	0.67 (0.60)	0.43* (0.24)	1.68	4.81 (5.91)	0.93 (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
Source: Author, (2021)

4.4.3 Matching-based regressing regression results for land documentation across food security (level) indicators

Table 4.12 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 compared to when farmers held no land document. 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, compared to farmers without documents. 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. The 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 significantly increased HDDS, suggesting that households consumed highly diverse diets when they had informal 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* expectations of holding formal land certificates to improve food security in Nigeria. This study's findings on formal land titles were contrary to the results of the

studies outside Nigeria. For example, holding a formal land certificate increased the per capita calorie availability among farmers in Ethiopia (Ghebru & Holden, 2013). Ajefu & Abiona (2020) found land tenure index that contained the title deed component a significant factor in mitigating the drought shock effect on food security in Malawi. Meanwhile, formal land certificates provide opportunities to use land as collateral. However, if the household does not have other assets to offset losses, the farmer can lose land if they fall behind on repayments or suffer shocks that lead to an inability to repay loans.

Table 4.12: Matching-based regression results of the effect of land documentation across food security (levels)

Food security Indicator		Formal land certificate	Informal land document
	Scale	Coeff. (Std error)	Coeff. (Std error)
FSI	Food secure	0.74 (0.53)	0.93** (0.32)
	Marginally food secure	0.74 (0.53)	0.93** (0.32)
	Moderately Food insecure	0.74 (0.53)	0.93 (0.32)
	Severely food insecure[u]		
	Matched observation	139	601
Food expenditure share	<0.50	0.64 (0.67)	1.02* (0.57)
	0.50-0.64	0.64 (0.67)	1.02* (0.57)
	0.65-0.74	0.64 (0.67)	1.02* (0.57)
	>0.74[u]		
	Matched observation	136	601
HDDS	Adequate	1.26 (0.88)	1.84*** (0.63)
	Moderate	1.26 (0.88)	1.84*** (0.63)
	Inadequate[u]		
	Matched observation	133	607
FCS	Acceptable	0.60 (0.44)	0.88*** (0.30)
	Borderline	0.60 (0.44)	0.88*** (0.30)
	Poor[u]	.	.
	Matched observation	133	607
Assets	Most	1.42 (1.18)	0.82*** (0.29)
	Moderate	1.42 (1.18)	0.82*** (0.29)
	Least[u]		
	Matched observation	136	595
LCS	None	1.99 (1.61)	1.02** (0.45)
	Stressed	1.99 (1.61)	1.02** (0.45)
	Crisis	1.99 (1.61)	1.02** (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
Source: Author, (2021)

4.1.3 Matching-based regression results of the effect of land tenure on food security (binary) indicators

Table 4.11 presents the effect of land tenure on binary food security analysis at the household level (as indicated in Table 3.2). While the result showed very few significant estimates, the result was related to the previous results when food security indicators were in levels. The previous results found that family-inherited landholders were food secure with high FSI, HDDS and household assets but food insecure with low FCS. In the present results, family-inherited landholders were food secure with high FSI and low food expenditure share. An additional estimate revealed that purchased land was also statistically significant in influencing food security with high HDDS. All other estimates from land acquisition modes and land documentation types were not statistically significant. One could have gotten more statistically significant results using simple Ordinary Least Square or Probability Linear Regression models, but the nature of the data and variables could not permit us to adopt those models. In trying to address endogenous biases (due to self-selections, time variations and unobservable factors), one needs more sophisticated econometric models to address the endogenous problems. Executing the matching-based *flexpanaldid* technique reduces the sample sizes of potential panel data, providing bias-free with low significant regression estimates.

Table 4.13: Matching-based regression results of the effect of land documentation across food security (levels)

Variable	FSI	Food expenditure share	HDDS	FCS	Asset ownership	LCS
Inherited land	1.30** (0.63)	2.87*** (1.06)	0.58 (0.59)	0.19 (0.62)	-0.66 (0.85)	0.99 (0.65)
Wald Chi^2	97.65	65.16	12.36	15.71	9.60	4.37
Observation	657	684	684	684	683	657
Purchased land	0.52 (1.26)	-1.59 (1.74)	2.97** (1.44)	0.01 (1.07)	-0.17 (1.17)	1.12 (1.21)
Wald Chi^2	11.49	18.39	5.55	1.73	6.33	4.19
Observation	119	128	128	125	125	116
Community distributed land	-0.02 (1.79)	2.64 (1.98)	0.06 (1.37)	-1.01 (1.78)	0.55 (2.26)	-1.06 (1.78)
Wald Chi^2	7.83	2.34	2.43	5.01	1.21	#
Observation	103	98	103	96	103	103
Rented land	-1.32 (1.00)	-6.17 (5.08)	-1.63 (1.22)	-0.16 (1.02)	0.49 (1.06)	-0.04 (1.43)
Wald Chi^2	16.57	125.85	5.32	4.91	2.56	5.40
Observation	138	138	141	138	138	138

Free use land	-1.28 (1.07)	-0.57 (1.92)	1.20 (0.98)	-1.75 (1.10)	0.37 (1.18)	-1.52 (1.41)
Wald Chi^2	18.41	12.82	4.43	5.74	3.04	5.04
Observation	163	166	166	163	169	169
Formal land certificates	0.72 (0.95)	#	-0.87 (1.09)	0.51 (1.02)	-1.18 (1.17)	-0.19 (1.07)
Wald Chi^2	19.06	0.35	5.44	6.59	4.58	3.16
Observation	133	90	133	133	136	136
Informal land documents	0.24 (0.56)	0.22 (0.87)	#	-0.03 (0.60)	0.45 (0.49)	0.19 (0.58)
Wald Chi^2	69.06	64.77	#	25.95	16.43	4.25
Observation	598	607	#	607	609	592

Note: # means convergence does not achieve, Significant level: *p<0.1, **p<0.05, ***p<0.01, standard errors in parenthesis
Source: Author, (2021)

4.5 Summary

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). The rent-free landholders will lack commitments to diversify crops and invest in land improvements as they know landlords will take their land at any time. With limited production diversity and productive investments, the free land users will earn low income to access diverse diets. Owners of family-inherited plots were more likely to consume diverse but low-quality diets than households without inherited land. Perceived rights to mortgage land for a loan significantly increased the likelihood of smallholders having high food consumption scores. A high proportion of sampled households produced crops on land acquired through family inheritance. Irrespective of their land documentation, the inherited landholders have a strong sense of ownership while perceiving they had the rights to sell, rent, bequeath and fallow and use as collateral than other modes of land acquisition. While the procedures for formal documentation of land are difficult to meet by households in Nigeria, the informal land document becomes another alternative to no land documentation. Holders of informal land documents were more likely to be food secure by having low food expenditure share, high HDDS and Livelihood Coping Strategy (LCS) compared to the households without land documentation. The coefficients between holders of formal land certificates and food security indicators were not statistically significant. Purchasing land with no legal title may not be patronised by farmers, affecting food security. Households who perceived they possessed the bundle of land rights will be motivated to invest in farm improvements and participate in output markets, leading to enhanced food security.

Chapter 5 : The effects of smallholder land tenure on child malnutrition in Nigeria

5.1 Introduction

Malnutrition is a global phenomenon which overburdens the public health system and constrains socioeconomic development (UNICEF, WHO & WBG, 2021). Many developing countries continue to suffer from chronic food insecurity and high levels of malnutrition (FAO et al., 2021). Malnutrition arises from the cumulative effects of inadequate energy and nutrient intake and infections preventing food assimilation (Bourke et al., 2016). In 2020, approximately two million children under five years of age suffered from wasting and twelve million children under five years of age suffered from stunting in Nigeria (FAO et al., 2021). The country had the second and third-highest number of stunted and wasted children globally, with respective national prevalence rates of 35.3% and seven percent of children under five years of age (FAO et al., 2021). Child overweight prevalence increased in Nigeria from approximately two percent in 2018 to six percent in 2020 (FAO et al., 2021).

Children of food-insecure households are at higher risk of severe malnutrition (Agbadi et al., 2017). Severe malnutrition exposes children to infections, morbidity and mortality (Khan et al., 2019). In addition, malnutrition leads to poor cognitive development, educational performance and ultimately, low adulthood productivity (Grantham-McGregor et al., 2007).

One way to address malnutrition among farmers is by integrating nutrition into agricultural programmes (Kadiyala et al., 2021). Increased agricultural growth correlates with decreased hunger, stunting and child mortality in sub-Saharan African countries (Pingali & Abraham, 2020). Nutrition-sensitive agriculture is a pathway to improve nutrition, increase the availability, access, and utilisation of nutritious foods, and create opportunities for generating income from the sale of surplus (Hendriks et al., 2020; Ruel et al., 2018). Nutrition-sensitive farming practices can increase diverse diets and nutritious food intake through aquaculture, agricultural extension services, biofortification, homestead food production, irrigation intervention, livestock and dairy programmes and nutrition-sensitive value chains (Ruel et al., 2018; Hawkes et al., 2020). Nigeria's government is committed to addressing household malnutrition by implementing the Agricultural

Sector for Food Security and Nutrition Strategy (AFSNS 2016-2025) to promote nutrition-sensitive agricultural intervention (FMARD, 2017). The AFSNS does not mention the role of land tenure in improving food security and nutrition. However, the Agriculture Promotion Policy (2016 – 2020) recognises that the entitlement and documentation of land ownership are necessary to assist in using land as collateral to access loans, incentivise small farmers to invest in land improvements and raise their productivity, address gender biases and create a transparent and liquid market for agricultural land (FMARD, 2016).

While farmers are less motivated to make plausible investments or participate in income-generating land contracts, insecure land tenure constrains agricultural development and can contribute to poor child health (Simbizi et al., 2014; Harris-Fry et al., 2020). Amidst global demographic growth, rapid urbanisation, environmental degradation and climate change, increased competition to acquire land raises the demand for land in Nigeria (Ghebru et al., 2014). However, about 88% of farmers in Nigeria produced food on less than two hectares of land and were constrained by poor land tenure (Consultative Group to Assist the Poor CGAP, 2017; FAO, 2018b). Addressing poor land governance requires understanding the impact of existing land tenure systems on critical productivity and welfare indicators (Deininger & Ali, 2008). Children in farming households where land rights are insecure may face a higher prevalence of malnutrition (Kosec & Shemyakina, 2018). However, there is currently no available evidence of the effect of land tenure on child nutrition in Nigeria. The present paper sought to address this gap.

Using a Nigeria case study, this chapter explores how the different smallholder land tenure measures influence the nutritional status of children under five years of age. The chapter presents new insights from comparing anthropometric child nutrition between holders and non-holders of each (formal or informal) land document and between holders and non-holders of each land acquisition mode. This study examined the child nutrition implications from five existing anthropometric indicators among landholders. Households with inherited land were found to have malnourished children. The findings have significant implications for land tenure policy, revealing the transfer of inheritance to men from generation to generation leaves women and children more vulnerable to poverty and malnutrition. The national framework for agriculture needs to address the elements of patriarchal land ownership and formalise informal land documents to achieve nutrition-sensitive agricultural objectives. Given that intra-household child nutrition manifested in

the long term, this chapter fitted Nigeria's General Household Surveys (GHS) three-wave panel data to a combined matching-based *flexpaneldid*-FE regression to examine the effect of land tenure on child nutritional outcomes.

The chapter discusses five sections. The first section gives the background to the chapter. Section two explains the empirical views on the connection between land tenure and nutrition status. The third section describes the method of data analysis. The fourth section presents and discusses the results. The final section concludes the chapter.

5.2 Understanding the connections between land tenure and nutritional status

There are four ways in which land tenure can indirectly affect a child's nutritional status. First, land ownership can empower vulnerable households to make efficient production decisions, increasing food and incomes and raising access to healthy diets, including water and sanitation (Landesa, 2012; Rodgers & Kassens, 2018). Second, land registration in women's names enhanced women's land rights in Vietnam (Menon et al., 2014). Households with registered land titles have the potential to access formal financial services (Landesa, 2012) through collateral, which can ease liquidity constraints (Rodgers & Kassens, 2018).

Third, land rights can boost resilience to cope with shocks such as financial crises, land-related conflicts, unfair expropriation by the government and social discrimination (Allendorf, 2007). Households can also cope with food price shocks when land ownership encourages home gardening, providing a space for keeping poultry and livestock and producing fruit and vegetables for family consumption (Landesa, 2012). Fourth, farmers with secure tenure are incentivised to invest in farm technology (i.e., irrigation, improved seed varieties, biofortified seeds and pest management) (Holden, 2020). Thus, secure tenure can guarantee farmers reap high profits from farm surplus and potentially improve child and household nutrition and health outcomes (Allendorf, 2007).

There is limited evidence published on the relationship between smallholder land tenure and child malnutrition as measured using anthropometric indicators. In addition, the literature on the impact of land tenure has shown mixed findings on the nutritional outcomes of households and individuals across the globe. In Nepal, Allendorf (2007) found that female landowners (i.e., mothers) were less likely to have severely underweight children. Households with limited or no land are more

likely to be food insecure and have stunted and underweight children in India (Siddiqui et al., 2017). In the Democratic Republic of Congo, Kasiwa and Muzabedi (2020) reported that landowners with large farmland sizes had children with average body mass index (BMI) and mothers with a low risk of anaemia. A study in Papua New Guinea by Rodger and Kassen (2018) confirmed that mothers with livelihood assets, including land have fewer stunted and wasted children.

Ghebru and Holden (2013) reported that female land titleholders had well-breastfed and normal-weight children in Ethiopia. In the Kyrgyz Republic, Kosec and Shemyakina (2018) revealed that households that benefitted from long-term land titling programmes had fewer wasted children under 60 months. On the contrary, formal land titleholders in urban areas were more likely to have stunted and/or overweight children in Peru (Vogl, 2007). While the time of receiving land titles affects land rights and motivation to invest in land improvement in Peru, children from households with shorter title program exposure were more likely to be stunted. High weight gain among Peru's children was connected to unhealthy eating habits and unintended consequences of mothers who held land titles and worked more hours outside home (Vogl, 2007). Urban land titling study in Argentina improved weight-for-height but not height-for-age in children (Galiani & Schargrodsky, 2004). Merten and Haller (2008) used cross-section data in Zambia to explore how a loss of resources such as pasture, fishery and woodland reduced the height-for-age and weight-for-height z-scores of children that could lead to acute and chronic malnutrition. To the author's knowledge, no studies have been conducted in Nigeria that linked smallholder land tenure to child malnutrition.

Many malnutrition cases are associated with unequal land distribution and food insecurity (Bishwajit 2015; FAO et al., 2019). Kasiwa and Muzabedi (2020) reported that 70% of households with poor diets owned agricultural land in 2014 Demographic and Health Survey of the Democratic Republic of Congo (DRC). The study argued that access to land may be necessary, but what matters is how to access and control agricultural land (Kasiwa & Muzabedi, 2020). The study sought to understand whether smallholder land tenure in terms of land right documentation and land acquisition mode influences child nutrition.

5.3 Methodology

The methodology in Chapter Three has explained the study area, data and data analytical method used for this chapter. The data used were drawn from Nigeria's General Household Survey (GHS).

One thousand, eight hundred and fifteen sub-sampled smallholders with 1,669 children aged 0 – 59 months were sampled from 2012/13 (Wave2), 2015/16 (Wave3) and 2018/19 (Wave4) GHS used for this chapter. Statistical analysis was conducted using STATA15.1 statistical software (StataCorp, 2017). The mean, percentage, correlation, Chi^2, z-scores and t-test statistics were used for descriptive analysis. The households' mode of land acquisition, land right documentation (in Table 3.1), and child anthropometric indicators (in Table 3.3) were fitted to non-parametric and parametric statistics of the flexible panel difference-in-difference (*flexpaneldid*) models, specified in Chapter Three. The technique analyses the sampled data to examine the effect of household land tenure on child malnutrition.

The response *Y* estimates were derived from the maximum likelihood estimates of matching-based *flexpaneldid* FE logit regression in Equation 7. The present paper further compared the estimates of the matching-based *flexpaneldid* FE logit from Equation 7 and the Average Treatment Effect (ATE) (as DID for panel data) estimates from Equation 3 after and before matching the data. The f*lexpaneldid* ATE after the matching process represents the non-parametric *flexpaneldid* estimates. The estimates of matching-based *flexpaneldid* FE logit were reported in odds ratios. The results of Equations 3 and 8 are reported in the odds ratios (OR) as exponential coefficients (likelihood of event occurrence) of child nutritional outcomes.

5.4 Results and Discussion

A summary of the dependent, independent and control variables is presented in Table 5.1. Just over half (52%) of the children were male. With an average age less than three years old (29 months), the sampled children had an average weight of 12.81kg. The sampled children had an average of less than a meter height (88cm) and had an own-child type of relation with the household heads. The average age of the household heads was 49 years old. Six (6) percent of the household heads were female. About 66% of the households were literate and held junior secondary school certificates. Most children and household heads were blood relatives. Some results of land rights are described in Table 5.1. About 51% of households had family-inherited land and 67% of households had the right to bequeath and use land as collateral. Landholders' variations in the proportions of rights describe the differences in land-related documents to secure land rights (tenure). Households (14%) who held informal land documents were slightly greater than the holders of formal land certificates.

Table 5.1: Descriptive statistics with the variables used for analysis

Variable	Mean (Standard error)
Children characteristics	
Height (cm)	87.92 (19.84)
Weight (kg)	12.81 (5.48)
Age (month)	29 (18.38)
Sex (female children %)	0.48 (0.50)
Perceived land rights	
Right to sell (%)	0.13 (0.34)
Rights to bequeath (%)	0.67 (0.47)
Rights to fallow (%)	0.06 (0.23)
Rights to use land collateral (%)	0.67 (0.47)
Mode of land acquisition indicators	
Family-inheritance (%)	0.51 (0.50)
Outright purchased (%)	0.14 (0.35)
Community distribution (%)	0.28 (0.45)
Used land free of charge (%)	0.16 (0.37)
Rented land (%)	0.11 (0.31)
Land right documentation indicators	
Formal land certificate (%)	0.11 (0.31)
Informal land documents (%)	0.14 (0.35)
Household characteristics	
Age (years)	49 (12.56)
Sex (female %)	0.06 (0.23)
Literate (%)	0.66 (0.47)
Educational attainment	5 (4.79)
Household size (number)	8 (3.68)
Number of plots (number)	3 (1.56)
Household-head's relationship with a child	3 (1.10)
Cooperative membership (%)	0.08 (0.27)
Zone	3 (1.62)
Sector (in rural %)	0.75 (0.43)

Note: Observations of landholders with children is 1815, Sample size of children is 1669
Source: Author, (2021)

Table 5.2 presents the mean difference in land right documentation across households' modes of land acquisition. A significant proportion of the purchased landholders held formal land certificates and informal land documents. The results revealed that purchased land facilitated the demand for land rights documentation more than any other mode of land acquisition. A few users of free land held formal land certificates and informal land documents. A low proportion of rented landholders owned informal land documents. More holders of community-distributed land had no formal land certificates or informal land documents. The results implied that the lack of formal land titles by community-distributed landholders might hinder the potential for land use as collateral to acquire credits. Inherited landholders obtained informal land documents rather than formal land certificates to secure land rights. Holders of inherited land had a stronger sense of informal (*de facto*) tenure security, limiting their demand for formal land certificates.

Table 5.2: Mean of tenure security indicators by land ownership among smallholders

Mode of land acquisition	Land right documentation indicator

	Formal land certificates	Informal land documents
Purchased land	0.53 (0.03)	0.38 (0.03)
No purchased land	0.04 (0.01)	0.10 (0.01)
Mean difference	0.49*** (0.01)	0.28*** (0.02)
Inherited land	0.13 (0.01)	0.21 (0.01)
No inherited land	0.09 (0.01)	0.07 (0.01)
Mean difference	0.04*** (0.01)	0.14*** (0.02)
Community distributed land	0.03 (0.01)	0.03 (0.01)
No community distributed land	0.14 (0.01)	0.19 (0.01)
Mean difference	-0.12*** (0.02)	-0.15*** (0.02)
Used land free of charge	0.07 (0.02)	0.08 (0.02)
Don't used land free of charge	0.12 (0.01)	0.15 (0.01)
Mean difference	-0.05** (0.02)	-0.07*** (0.02)
Rented land	0.13 (0.02)	0.10 (0.02)
No rented	0.11 (0.01)	0.15 (0.01)
Mean difference	0.02 (0.02)	-0.05** (0.03)
Observation	1815	1815

Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Figure 5.1 presents the distribution of z-scores for child anthropometry expressed in the normal population distribution of the sampled children. The histogram bars of anthropometric data for height-for-age followed the fitted line of the normal distribution with zero means of z-score. The weight-for-age, weight-for-height, and height-overweight diagrams illustrated the spread of values for the child anthropometry indicators clustered around the WHO standard z-scores thresholds (i.e., z-scores < -2). The histogram bars of the child anthropometrics followed the probability distribution function for the sampled population. The BMI-for-age indicator had few observations and its data clustered negatively away from the WHO standard mean for BMI-for-age z-scores (z-scores > +2).

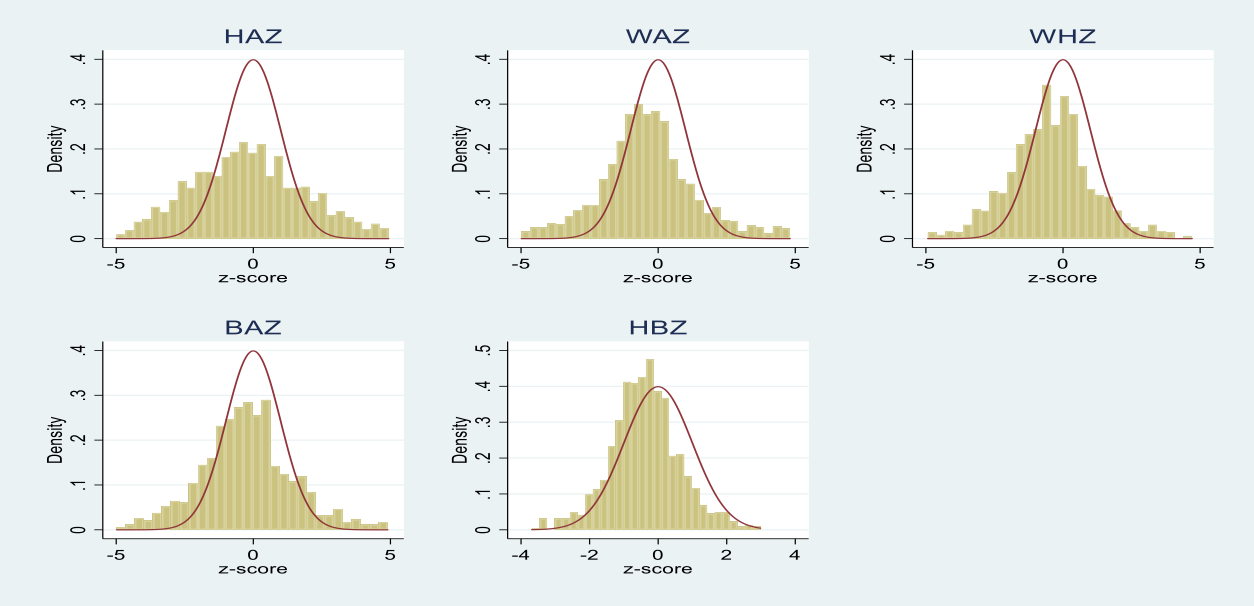


Figure 5.1: Distribution of z-score between 2012 and 2018 in Nigeria
Source: Author, (2021)

Figure 5.2 illustrates the relationship between the anthropometric indicators from 2012 to 2018 in Nigeria. There was no correlation between weight-for-height and height-for-age z-scores or between height-for-age and BMI-for-age z-scores. The result showed the possibility of having underweight (weight-for-age z-score <-2) and stunted-overweight (height-for-BMI z-score<-2) children.

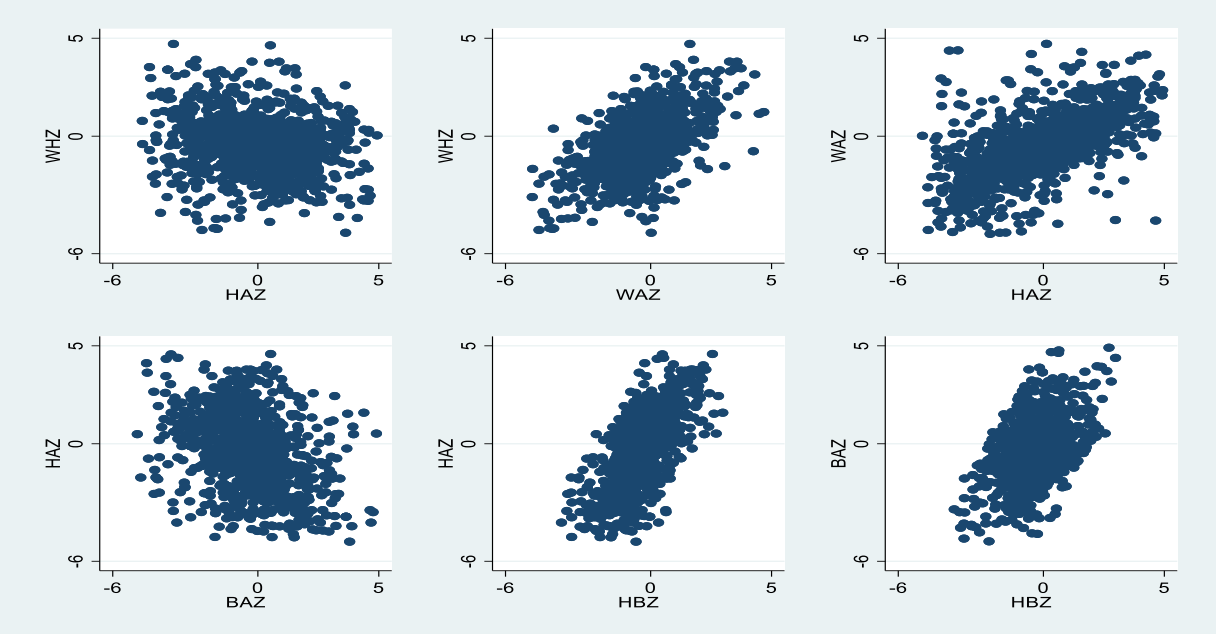


Figure 5.2: Correlation between child anthropometric indicators between 2012 and 2018 in Nigeria

Source: Author, (2021)

Table 5.3 presents the summary statistics for the incidence of child malnutrition between 2012 and 2018 in Nigeria. As presented in Table 5.3, eight percent of children were overweight. Twenty percent of children were stunted and 14% of children were wasted. These proportions of stunted and wasted children were classified as high levels of malnutrition according to UNICEF, WHO and WBG, (2021). Overweight children were within the median reference range. Fourteen percent of children were underweighted for their age, whereas four percent suffered from stunting and being overweight. Approximately fourteen (14.13) percent of sampled children were underweighted. This proportion was classified within a medium prevalence (10-19) of underweight following WHO (1995) reference in Table 3.3. Approximately two percent (1.59%) of children were severely overweight. Except for severely wasted children (2.17%), the proportion of severely stunted (4.58%) and underweight (3.43%) children was below the national average in 2018 and 2021 (in Figure 2.1).

Table 5.3: Descriptive summary of child anthropometric indicators

Anthropometry	N	Mean	SD	% Below -2 S.D.	% Below -3SD
HAZ	1321	-0.17	2.03	19.91	4.58
WHZ	1098	-0.45	1.50	14.21	2.17
WAZ	1394	-0.38	1.71	14.13	3.43
HBZ	1003	-0.38	1.01	3.79	
Anthropometry	N	Mean	SD	% Above 2 S.D.	
BAZ	1047	-0.25	1.65	8.31	1.59

Note: SD means standard deviation, n is total observed samples and % represents the percentage
Source: Author, (2021)

Table 5.4 presents the child demographic characteristics by BMI categories. There were significant differences in the distribution BMI category for gender ($p<0.05$), sector ($p<0.01$) and zone ($p<0.01$). Female children were more overweight (11%) and obese (9%) than male children. The North-Central zone had the highest proportion (14%) of overweight and obese children. While more overweight children were found in rural areas (10%), obese children (12%) were more prevalent in urban areas. The incidence of overweight children in the rural sector can be attributed to the high-calorie intake of staple foods (Bishwajit, 2015). At the same time, the consumption of junk and processed foods rich in sugar and salt is more likely responsible for child obesity in urban areas (Bishwajit, 2015).

Table 5.4: Proportion (%) of child BMI category by child demographic characteristics

Characteristics	Group	Normal weight	Overweight	Obese	N	Pearson Chi2 (p-value)
Gender	Male	0.86	0.08	0.06	590	7.76** (0.02)
	Female	0.80	0.11	0.09	510	

Sector	Rural	0.83	0.10	0.07	827	12.46*** (0.00)
	Urban	0.83	0.05	0.12	273	
Zone	North-Central	0.72	0.14	0.14	197	40.54*** (0.00)
	North-East	0.80	0.12	0.09	223	
	North-West	0.83	0.10	0.07	296	
	South-East	0.92	0.04	0.04	125	
	South-South	0.94	0.04	0.02	140	
	South-West	0.86	0.05	0.09	119	
Year	2012/13	0.85	0.09	0.05	358	5.43 (0.25)
	2015/16	0.83	0.08	0.09	458	
	2018/19	0.81	0.10	0.09	284	
Child Relationship to Households	Own child	0.82	0.10	0.08	972	7.45 (0.92)
	Stepchild	0.86	0	0.14	7	
	Adopted child	0.80	0.20	0	5	
	Grandchild	0.88	0.07	0.05	10.3	
	Brother/Sister	0.80	0	0.20	5	
	Niece/Nephew	0.83	0	0.17	6	
	Brother/Sister In-law	1	0	0	1	
	Other Relation	1	0	0	1	
	Combined	0.83	0.09	0.08	1100	
	N	913	101	86	1100	

Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Table 5.5 summarises the statistics of child anthropometry across child demographic characteristics. Although sex differences in child anthropometric indicators were not statistically significant at the five percent level of significance, stunting (21%) and underweight (15%) were more prevalent among male children. On the other hand, more female children were overweight (10%), wasted (15%) and stunted for their BMI (19%). As normal-weight children declined by two percent from 2012 to 2018 in Nigeria, a slight increase in overweight and obese children occurred from 2012 to 2018 (Table 5.5).

There were significant differences ($p \leq 0.05$) in the rates of child stunting, underweight and stunted-overweight between rural and urban sectors. The rural sector had 22% stunted and underweight children, while 28% of urban children suffered from both stunting and overweight. The zones differences in stunting, wasting and overweight were also statistically significant ($p \leq 0.05$). Stunted and underweight children were more prevalent in the North-East and North-West, while the North-Central took the lead in having overweight and stunted-overweight children. About 30% of stunted children resided in the North-West zone, 19% of wasted children were in the South-West zone. Twenty percent and 26% of children were underweight and stunted-overweight in the North-Central. As the underweight and overweight children of sampled smallholders decreased from 2012 to 2018, the stunted children increased from 2012 to 2018.

Table 5.5: Descriptive statistics of child anthropometry by child demographic characteristics

Characteristic	Group	HAZ<-2	WHZ<-2	WAZ<-2	BAZ>2	HBZ<-2
Gender	Male	0.21	0.14	0.15	0.07	0.12
	Female	0.18	0.15	0.14	0.10	0.19
	Pearson Chi2 (p-value)	0.52 (0.47)	0.17 (0.68)	0.35 (0.56)	2.86* (0.09)	2.73* (0.10)
Sector	Rural	0.22	0.14	0.16	0.08	0.13
	Urban	0.13	0.14	0.09	0.10	0.28
	Pearson Chi2 (p-value)	13.13*** (0.00)	0.03 (0.86)	10.02*** (0.00)	1.25 (0.26)	6.06*** (0.01)
Zone	North-Central	0.18	0.12	0.11	0.14	0.26
	North-East	0.26	0.11	0.17	0.10	0.14
	North-West	0.30	0.17	0.20	0.08	0.14
	South-East	0.07	0.10	0.06	0.03	0.10
	South-South	0.09	0.15	0.11	0.03	0.08
	South-West	0.10	0.19	0.12	0.06	0
	Pearson Chi2 (p-value)	66.16*** (0.00)	9.15* (0.10)	25.14*** (0.00)	20.28*** (0.00)	7.51 (0.19)
Year	2012/13	0.13	0.14	0.09	0.06	0.13
	2015/16	0.22	0.14	0.16	0.10	0.16
	2018/19	0.24	0.15	0.18	0.08	0.16
	Pearson Chi2 (p-value)	18.15*** (0.00)	0.45 (0.80)	17.00*** (0.00)	5.23* (0.07)	0.33 (0.85)
Relationship to HH	Own Child	0.21	0.14	0.14	0.08	0.15
	Stepchild	0.14	0.33	0.14	0.17	1
	Adopted child	0.14	0	0.14	0.25	1
	Grandchild	0.13	0.17	0.11	0.06	0.56
	Brother/Sister	0.25	0	0.20	0.20	0
	Niece/Nephew	0.33	0.33	0.17	0.17	0.50
	Pearson Chi2 (p-value)	6.62 (0.58)	5.79 (0.56)	1.68 (0.99)	4.39 (0.73)	14.52*** (0.01)
	Combined	0.20	0.14	0.14	0.08	0.04
	N	263	156	197	87	38

Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

The relationship of the child to the household head influences a child's nutritional status. Children who had a brother/sister (20%), niece/nephew (17%) and stepchild (14%) relation to the household head were more likely obese than children (8%) of the household heads. Adopted children (12%) were two percent more in overweight than children of the household heads (10%). More than half of the stunted and overweight children were the household head's grandchild and niece/nephew.

There were statistically significant variations in the child stunting, wasting child underweight and child overweight measures across the survey years (as indicated in Table 5.5). However, no statistically significant variations found with child stunted-overweight indicators across survey years, causing omission of some results for this variable (as shown in Table 5.3). Only 3.79% of the 1003 children subjected to height-body mass index z-scores (HBZ) test was stunted-overweight, which were 38 children. Each variable had malnourished children category and those who were not malnourished were used in the regression analysis. A dummy variable derived from

20% stunted children and 80% children without stunting were used in the regression analysis. Also, a dummy variable derived from 3.79% stunted-overweight children and 96.2% children without stunted overweight were used in the regression analysis.

Table 5.6 presents the descriptive summary of the mode of land acquisition by household demographic characteristics. The findings revealed no significant results for gender in the households that acquired land through purchase, family inheritance, community distribution and renting. However, more male households acquired land free of charge than female household heads. The urban households (significantly) held purchased and rented land more than the rural households. Rural households had more land than urban households through family inheritance and community distribution mode of land acquisition.

There were significant variations in the land acquisition mode across the zones in Nigeria. Households that held land via purchase and free of charge (for abandoned land) were significantly more prevalent in the South-West. In contrast, more than half of sampled households held inherited land in the North-Central, North-East, North-West and South-East zones of Nigeria. More than one-fifth of households held land in the North-Central (24%), North-East (38%), North-West (24%), South-East (35%) and South-South (21%) through community distribution. More households held land free and rented in the South-West (31%) and South-South (27%). Households held more land through purchases (25%), inheritance (72%) and renting (15%) in the year 2018 compared to the subsequent years of data collection. The incidence of tenants was prevalent in the South-South. About ten percent households held more land free in 2015/16, while 72% and 15% held land through inheritance and rent in 2015/16 and 2018/19, respectively. With exception of holders in rent-free land, there were variations in the proportions of landholders with certain land acquired across survey years.

Samples were selected based on the landholding status of household heads with children. The variables were combined with two landholders' categories. The statistics of each category include 11%, 14% and 16% of the 1815 landholders rented land, purchased and used rent-free land, respectively. Also, 11% and 14% of the 1815 landowners held formal land certificates and informal documents, respectively. Based on Kothari & Gaurav, (2015), none of these categories has a small sample size. A dummy variable derived from 11% holders of formal land certificates and 76% households without documents were used in the regression analysis. . Also, a dummy variable derived from 14% holders of informal land documents and 79% households without

documents was used in the regression analysis. Using these variables (in binary observations) in an appropriate non-linear probability regression model will give results.

Table 5.6: Descriptive statistics of the mode of land acquisition by household demographic characteristics

Characteristic	Group	Purchased land	Inherited land	Community distributed land	Free use land	Rented land	Observation
Gender	Male	0.14	0.51	0.28	0.16	0.11	1712
	Female	0.09	0.49	0.29	0.09	0.13	103
	Pearson Chi2 (p-value)	2.42 (0.12)	0.33 (0.57)	0.09 (0.76)	4.16 (0.04)	0.31 (0.58)	
Sector	Rural	0.12	0.53	0.30	0.15	0.10	195
	Urban	0.31	0.34	0.13	0.22	0.23	1620
	Pearson Chi2 (p-value)	55.31*** (0.00)	25.08*** (0.00)	22.84*** (0.00)	5.26** (0.02)	32.84*** (0.00)	
Zone	North-Central	0.06	0.51	0.24	0.18	0.07	310
	North-East	0.11	0.53	0.38	0.15	0.09	447
	North-West	0.21	0.52	0.24	0.15	0.08	505
	South-East	0.03	0.58	0.35	0.08	0.09	243
	South-South	0.18	0.48	0.21	0.19	0.27	219
	South-West	0.35	0.33	0.13	0.31	0.16	91
	Pearson Chi2 (p-value)	101.53*** (0.00)	17.46*** (0.00)	50.77*** (0.00)	29.32*** (0.00)	76.04*** (0.00)	
Year	2012/13	0.06	0.03	0.75	0.06	0.09	551
	2015/16	0.08	0.72	0.07	0.10	0.07	567
	2018/19	0.25	0.72	0.07	0.08	0.15	697
	Pearson Chi2 (p-value)	123.52*** (0.00)	741.59*** (0.00)	881.93*** (0.00)	0.26 (0.88)	23.49*** (0.00)	

Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Table 5.7 presents the descriptive summary of household demographic characteristics across land rights documentation. Male households held more formal land certificates and informal land documents than female household heads. More urban households had formal land certificates and informal land documents than rural households. This result could be due to the relatively high prevalence of land market transactions in urban areas. Across the southern zones, households held more informal land documents than formal land certificates. Acquisition of land-related documents remains lower and unchanged in the Northern zones. The Chi-square test showed that there was significant variations in the proportion of landholders in documentation types across survey years. While the proportion of landholders with no document was gradually declining across survey years, there was an increase in formal land certificate holders from 3% in 2012/13 to 9% in the 2018/19 survey years. The highest proportion (24%) of sampled households held informal land documents in the 2015/16 survey year. More household heads held formal land certificates in 2018/19 and informal land documents in 2015/16. Only three percent of household heads had land-related documents in 2012/13, despite the implementation of Nigeria's 2009 land reform programme. The programme's purpose was to encourage formal land certificates but rather

supported leasehold rights over customary freehold rights that were abolished by 1978 LUA (Hall et al., 2019).

Table 5.7: Summary of land right documentation by household demographic characteristics

Characteristics	Group	Formal land certificate	Informal land documents	Observation
Gender	Male	0.12	0.15	1712
	Female	0.03	0.07	103
	Pearson Chi2 (p-value)	7.39*** (0.01)	5.04** (0.03)	
Sector	Rural	0.09	0.13	1620
	Urban	0.25	0.24	195
	Pearson Chi2 (p-value)	43.82*** (0.00)	15.28*** (0.00)	
Zone	North-Central	0.08	0.12	310
	North-East	0.11	0.11	447
	North-West	0.16	0.16	505
	South-East	0.03	0.86	243
	South-South	0.12	0.21	219
	South-West	0.14	0.30	91
	Pearson Chi2 (p-value)	34.42*** (0.00)	39.15*** (0.00)	
Year	2012/13	0.03	0.03	551
	2015/16	0.08	0.24	567
	2018/19	0.20	0.15	697
	Pearson Chi2 (p-value)	105.12*** (0.00)	105.92*** (0.00)	

Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

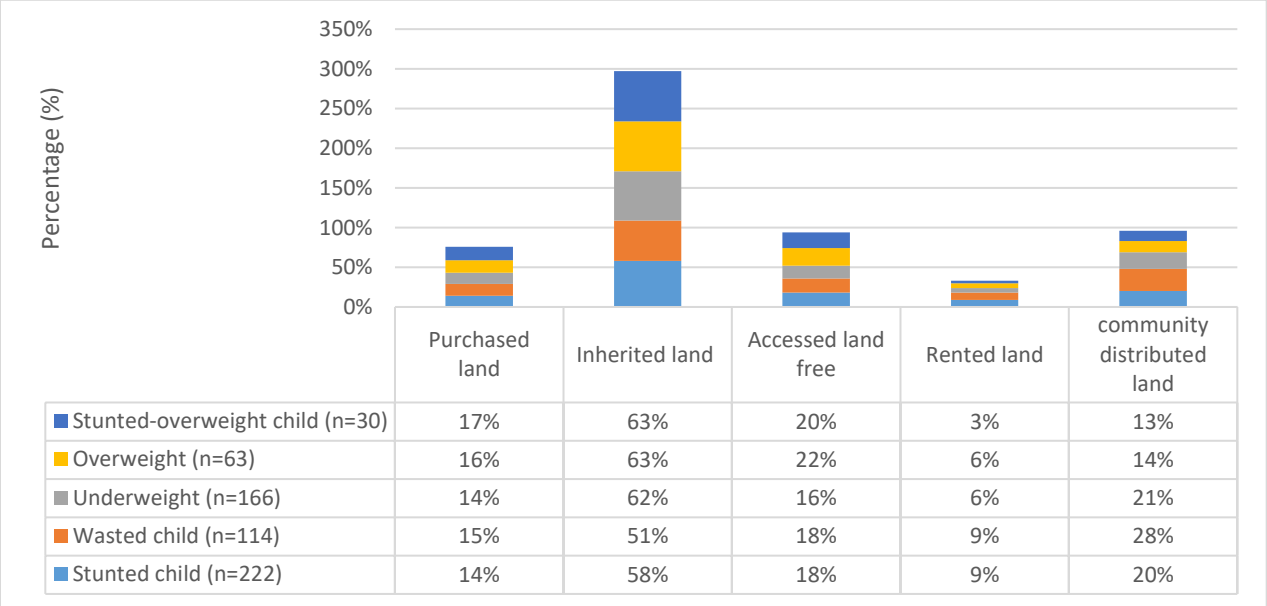
Table 5.8 shows the age-specific summary of sampled children across household head-children relation types. The average age of sampled children was less than three years old. Most (88%) of the sampled children were averagely less than three years old and had own-child type of relation with the household heads.

Table 5.8: Mean age of children by their relationship with household-heads

Relationship to Household-heads	Mean age (years)	N	%
Own child	2.00	1473	88
Stepchild	3.00	9	0.50
Adopted child	3.00	7	0.40
Grandchild	2.00	161	10
Brother/Sister	3.00	7	0.40
Niece/Nephew	3.00	8	0.50
Brother/Sister in-law	5.00	1	0.06
Other Relation	3.00	1	0.06
Other Non-relation	1.00	2	0.10
Combined	3.00	1669	100

Source: Author, (2021)

Figure 5.3 illustrates the percentage of malnourished children by smallholders' mode of land acquisition. Of the households that purchased land, 14% children were stunted. Although purchased landholders as one of the owned landholders had less than 20% malnourished children, children in households that acquired inherited land were more likely to be malnourished. Households with inherited land had more than 50% of the malnourished children measured by stunting (58%), wasting, (51%), underweight (62%), overweight (62%) and stunted-overweight (63%) indicators. The results suggested that family conflicts may prevent inherited landholders to improve farmland for productive or nutrition-sensitive agriculture that enhances food security and nutrition. Households who acquired land through community distribution, renting or free of charge had less than 30% malnourished children. Fewer than ten percent of malnourished children were found in households with secure access to rented land.

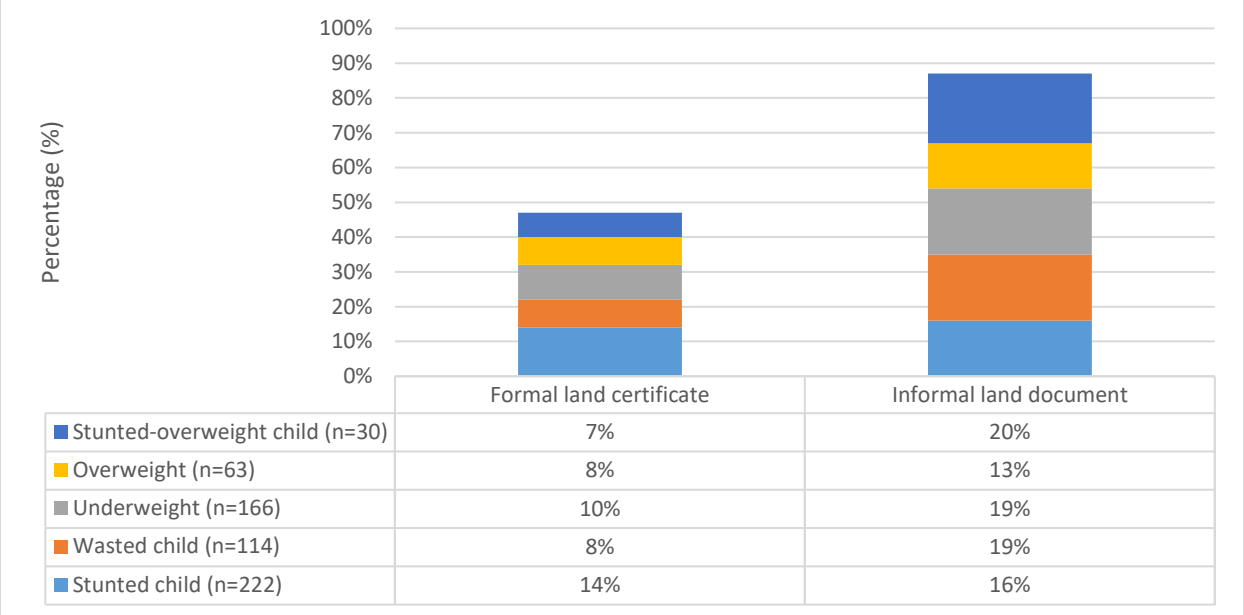


	Purchased land	Inherited land	Accessed land free	Rented land	community distributed land
Stunted-overweight child (n=30)	17%	63%	20%	3%	13%
Overweight (n=63)	16%	63%	22%	6%	14%
Underweight (n=166)	14%	62%	16%	6%	21%
Wasted child (n=114)	15%	51%	18%	9%	28%
Stunted child (n=222)	14%	58%	18%	9%	20%

Figure 5.3: Percentage of malnourished children by smallholders' mode of land acquisition
Source: Author, (2021)

Figure 5.4 illustrates the proportion of malnourished children by smallholders' land right documentation type. Fewer than 21% of the undernourished children lived in households holding formal land certificates or informal land documents. Child malnutrition rates were low among households with formal or informal land documents to secure their land rights. The higher the proportion of malnourished children within landholding units, the less likely households held or used formal land certificates as collateral to acquire a formal loan to enhance farm investments and improve food security and child health. However, obtaining the formal land certificate might

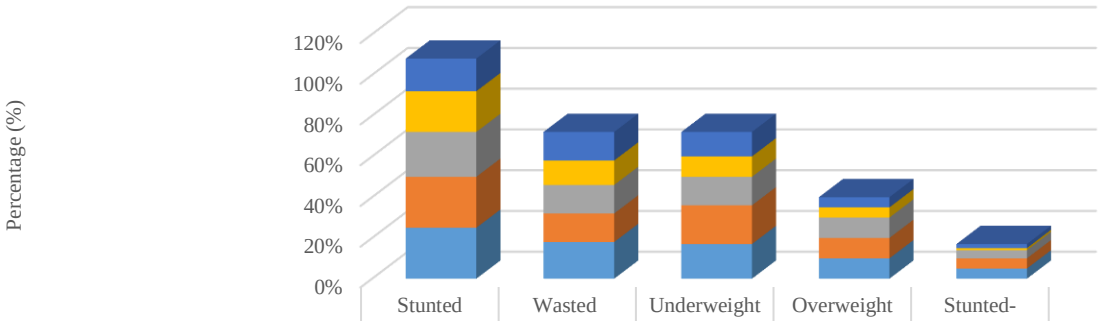
be challenging due to the high cost of land titling and bureaucratic processes, which influence the demand for more informal land documents.



	Formal land certificate	Informal land document
Stunted-overweight child (n=30)	7%	20%
Overweight (n=63)	8%	13%
Underweight (n=166)	10%	19%
Wasted child (n=114)	8%	19%
Stunted child (n=222)	14%	16%

Figure 5.4: Percentage of malnourished children by smallholders' land right documentation
Source: Author, (2021)

Figure 5.5 illustrates the proportion of smallholders by modes of land acquisition with at least a malnourished child. Of the households that purchased land, 25% had at least one stunted child. Less than 20% of households with purchased land had a least a child with other malnutrition indicators (such as wasting, underweight, overweight and stunted-overweight). Fewer than 26% of households with inherited land had malnourished children measured by stunting, wasting, underweight, overweight and stunted-overweight indicators. The results suggested that the landholders who perceived insecurity of their land acquired by family inheritance may underinvest in farmland improvements for productive or nutrition-sensitive agriculture that enhances food security and nutrition. Less than 23% of households who acquired land through community distribution, or free of charge had malnourished children. Fewer than 21% percent of sampled households with secure access to rented land had malnourished children.



	Stunted child	Wasted child	Underweight	Overweight child	Stunted-overweight child
Community distributed land (n=508)	16%	14%	12%	5%	2%
Rented land (n=200)	20%	12%	10%	5%	1%
Accessed land free (n=290)	22%	14%	14%	10%	4%
Inherited land (n=925)	25%	14%	19%	10%	5%
Purchased land (n=254)	25%	18%	17%	10%	5%

Figure 5.5: Percentage of landholders with mode of land acquisition by malnourished children
Source: Author, (2021)

Figure 5.6 illustrates the proportion of smallholders by land right documentation type with at least a malnourished child. Forty-one percent of households with no land document had at least one stunted child. At least 15% landholders with no document had a at least one wasted, underweight, overweight or stunted-overweight child. Few households holding formal land certificates or informal land documents had at least a stunted, wasted or underweight child. The results implied that households with formal land certificates could use their land as collateral to acquire a formal loan that enhances farm investments and improves food security and child health.

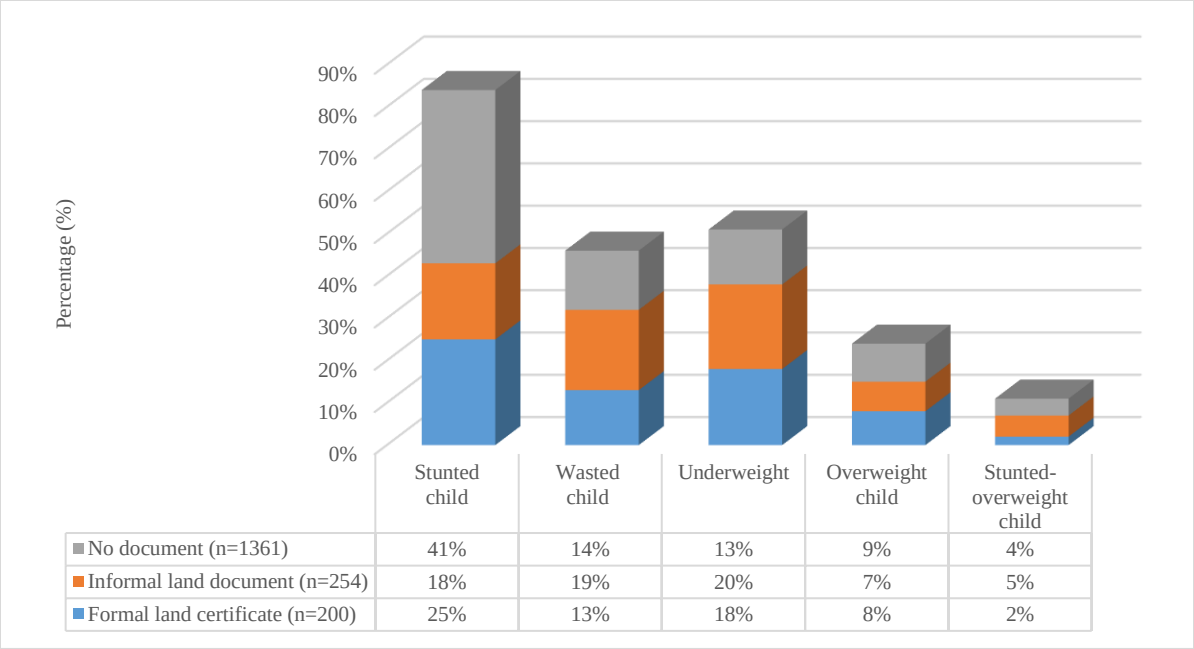


Figure 5.6: Percentage of landholders with land right documentation by malnourished children
Source: Author, (2021)

5.4.1 Factors of the likelihood of land tenure using logit regression for matching analysis

Table 5.9 presents the logit results for estimating the propensity score matching of land acquisition treatment in nutrition analysis. The results were derived from data of households with children to allow analysis of nutrition. The results showed that the model used correct predictors with the prediction of over 60% of sampled households from each land acquisition mode and documentation type and with statistically significant likelihood ratios of sample distributions.

The factors significantly influencing households to acquire inherited land include age, household biological relation and household size and number of plots. Male households who are literate and have high household size and number of plots were more likely to purchase land. However, male households who were uneducated and indigene were more likely to receive land from the community. Young and female households with high household sizes and non-indigenes were more likely to rent land from landlords. Households were likely to rent land by residing in the urban and southern regions, while they were likely to use rent-free land by domicile in rural areas. The findings could be attributed to rural areas having an open swath of land with a lower population density and few homes and buildings than urban areas (FAO, 2018c).

Table 5.9: Logit results of the factors of land acquisition for matching in child nutrition analysis

Variable	Inherited land vs no inherited land	Purchased land vs no purchased land	Community distributed vs no community distributed land	Rented land vs no rented land	Free-used land vs no free land
Household size	1.08*** (0.02)	1.08*** (0.03)	0.89 (0.02)	1.06** (0.03)	1.01 (0.03)
Age	1.01*** (3.92e-03)	1.00 (0.01)	0.99 (3.85e-03)	0.99** (0.01)	1.00 (0.01)
Literate	1.28* (0.17)	1.64** (0.36)	0.79* (0.11)	0.85 (0.18)	1.16 (0.22)
Number of plots	1.52*** (0.08)	1.20*** (0.08)	0.94 (0.05)	1.26*** (0.08)	1.01 (0.07)
Gender	1.32 (0.23)	0.50* (0.19)	0.69** (0.12)	1.85** (0.45)	0.80 (0.21)
Household education	0.99 (0.02)	1.02 (0.02)	1.02 (0.02)	1.02 (0.02)	0.99 (0.02)
Cooperative	0.68 (0.18)	1.23 (0.47)	1.10 (0.29)	1.27 (0.47)	0.86 (0.34)
Household biologically related to child	1.25*** (0.04)	0.59 (0.41)	0.82*** (0.04)	0.91* (0.05)	0.94 (0.05)
Zone	0.97 (0.04)	1.10 (0.08)	0.95 (0.04)	1.48*** (0.12)	1.07 (0.07)
Sector	1.41 (0.31)	0.82 (0.27)	1.62 (0.39)	0.50*** (0.13)	1.45*** (0.12)
Cons	0.04*** (0.02)	0.07 (0.07)	1.15 (0.67)	0.08*** (0.06)	0.50 (0.34)
Pseudo R^2	0.09	0.07	0.05	0.08	0.02
LR Ch12	157.38	59.75	80.47	68.79	15.53
Observation	1336	1336	1336	1336	1336

Note: standard errors in parenthesis. This table reported another transformation from logit regression of land tenure on the observed characteristics for conducting matching analysis. *** $P<0.01$, $P<0.05$, *$P<0.1$.
Source: Author, (2021)

Table 5.10 shows the logit results for estimating propensity score matching of land documentation treatment for nutrition analysis. The results were derived from data of households with children for nutrition analysis. The results revealed that literate farmers, members of cooperative society, and resided in urban and southern regions were more likely to hold formal land certificates. In contrast, literacy, gender and being members of a cooperative society were statistically significant factors influencing farmers' access to informal land documents.

Table 5.10: Logit results of land documentation for matching in child nutrition analysis

Variable	Formal land cert vs without	Informal land cert vs without
Household size	1.16*** (0.03)	1.01 (0.02)
Age	1.00 (0.01)	1.00 (0.01)
Literate	1.74** (0.45)	1.47** (0.27)

Number of plots	1.06 (0.09)	1.10 (0.07
Gender	0.83 (0.34)	0.54** (0.15)
Household education	1.03 (0.03)	1.03 (0.02)
Cooperative	2.45** (0.94)	1.73* (0.53)
Household biologically related to child	0.94 (0.06)	1.05 (0.04)
Zone	0.77*** (0.06)	1.06 (0.06)
ssSector	0.35*** (0.11)	1.09 (0.32)
Cons	0.24 (0.22)	0.05*** (0.04)
Pseudo R^2	0.10	0.03
LR Ch12	66.08	27.20
Observation	1336	1336

Note: standard errors in parenthesis. This table reported another transformation from logit regression of land tenure on the observed characteristics for matching analysis. *** $P<0.01$, $P<0.05$, *$P<0.1$
Source: Author, (2021)

5.4.2 Matching based *flexpaneldid* tests and results of land tenure effect on child nutrition

Table 5.11 presents the tests and results of matching-based *flexpaneldid* model for the effect of land tenure on child nutrition. The non-matching regression results were closely similar to the reported matching-based regression results. The results of matching-based regressions were reported in Tables 5.11 – 5.13. There were large observations for each nutrition indicator (variables) from non-matching Average Treatment Effect (ATE) (Table A7 in the Appendix) and regression (Table A8 in the Appendix). Yet, the binary nutrition results from matching-based regressions were closely similar to the results from non-matching regressions with large observations.

AI robust standard errors in parenthesis. This study reported non-regression *flexpaneldid* estimates using the exact matching method to ensure the best possible matches are included in the matched samples. Matches control variables are those without each selected treatment in land acquisition modes and land documentation types. In the case of Kolmogorov-Smirnov (KS) test, consistent bias-corrected estimator as proposed in Abadie & Imbens (2006, 2011). The p-value values for the Chi square test statistic (i.e., ≤ 0.05) indicate that the data does not fit the normal distribution and thus, rejecting the null-hypothesis. The null hypothesis of Chi square test states that data are taken

normally distributed population. When $P > 0.05$, the null hypothesis accepted, and data are called as normally distributed (Dettmann et al., 2020). PS R2 shows the means of all the matching variables balanced to explain outcome dev.

Table 5.11: Matching-based flexpaneldid tests and results of the effect of land tenure on child nutrition

	Land acquisition mode					Land documentation types	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
Stunting	0.03 (0.04)	0.02 (0.04)	-0.02 (0.04)	-0.03 (0.05)	0.03 (0.04)	0.02 (0.05)	0.00 (0.04)
PS test	0.06	0.05	0.08	0.08	0.03	0.057	0.03
Corrected KS p-value	1.00	1.00	1.00	0.99	1.00	1.00	0.90
Observations	857	374	624	288	500	295	443
Wasting	0.05* (0.03)	0.03 (0.04)	0.06 (0.04)	-0.02 (0.05)	0.03 (0.03)	-0.02 (0.04)	-0.07* (0.04)
PS test	0.06	0.06	0.08	0.05	0.05	0.05	0.04
Corrected KS p-value	0.62	0.78	0.65	1.00	0.83	1.00	0.56
Observations	622	272	485	224	358	209	331
Underweight	0.02 (0.03)	-1.83e-03 (0.04)	-0.01 (0.03)	0.03 (0.03)	0.03 (0.03)	0.02 (0.04)	-0.01 (0.03)
PS test	0.04	0.06	0.06	0.09	0.04	0.07	0.02
Corrected KS p-value	0.17	1.00	0.86	1.00	0.98	1.00	0.99
Observations	606	263	409	205	331	205	319
Overweight	0.06** (0.03)	0.01 (0.04)	0.02 (0.03)	0.03 (0.04)	0.05* (0.03)	-0.03 (0.04)	0.02 (0.03)
PS test	0.04	0.06	0.06	0.03	0.03	0.04	0.03
Corrected KS p-value	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Observations	935	398	677	305	536	320	475
Stunted-overweight	-0.02 (0.02)	-0.00 (0.02)	-0.72e-04 (0.02)	-0.01 (0.02)	0.02 (0.02)	-0.00 90.02	0.01 (0.02)
PS test	0.05	0.06	0.07	0.07	0.03	0.04	0.03
Corrected KS p-value	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Observations	560	246	386	191	216	191	287

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

5.4.3 Regression results of the effect of land acquisition on anthropometric child nutrition

The results of the household land acquisition type affecting child malnutrition are presented in Table 5.12. These results were reported in odds ratios and compared with non-regression estimates. There were no significant *flexpaneldid* coefficients of rented land before and after matching observations for the effects of rented land on child malnutrition. Statistical inferences were also not made for the fixed-effect model's non-significant estimates of rented land. However, the DID (panel data ATE) estimates before matching revealed that more stunted, underweight and stunted-overweight children were associated with households that owned inherited land. After sample matching, the DID estimates of inherited land suggested that wasted and overweight children were

more likely to be found in households with inherited land. Although there were no significant coefficients of inherited land fitted in the fixed-effect model, the DID results indicated that children in households that acquired inherited land were more prone to malnourishment than those without inherited land. The results implied that improving smallholder child nutrition is less likely when households on inherited farmlands lack well-defined property rights and experience family land conflict, leading to insecurity. Although most of the existing literature did not capture land acquisition modes of land tenure, female landowners in Nepal and Papua New Guinea were less likely to have underweight children (Allendorf, 2007; Rodger& Kassen, 2018).

The DID coefficients of community-distributed land before matching were negative and significant in explaining child malnutrition. The results implied that households with community-distributed land were eight percent, five percent less likely to have stunted, underweight and overweight children, respectively, compared to those without community-distributed land. While the matching-based *flexpaneldid*-Fixed effect (FE) and DID estimates after matching observations were not statistically significant, the estimates of community-distributed landholders before matching had a greater impact on reducing child malnutrition. These results supported the possibility that individual use of community-distributed land provides a sense of de facto tenure security due to the existing customary norms and networks protecting land rights and entitlements (Hall et al., 2019). Similar results were found by Siddique et al., (2017) and Kasiwa and Muzabedi, (2020) in India and Congo, where accessing more farmlands had increased the chance of reducing child stunting, underweight and risk of anaemia among mothers. After matching observations, the DID coefficients for free land access for overweight outcomes were positively significant ($p<0.1$), meaning that overweight children were more likely to be found in households who had accessed free land compared to children of those who did not access free land. The DID estimates before matching observations and matching-based *flexpaneldid*-FE coefficients of free land access were not statistically significant. As with the results of the effect of rented land, there were no significant coefficients of purchased land to determine child malnutrition.

Table 5.12: The regression results of the effect of land acquisition on child malnutrition

Mode of land acquisition	Model	Stunted child	Wasted child	Overweight child	Underweight child	Stunted-overweight child	Matching	Fixed Effect
Rented land	1	1.03 (0.04)	1.02 (0.04)	0.97 (0.03)	0.94 (0.04)	1.04 (0.02)	No	No
	n	995	807	781	1047	749		
	2	0.97 (0.05)	0.98 (0.05)	1.03 (0.04)	1.03 (0.03)	0.99 (0.02)	Yes	No

	n	288	224	305	205	191		
	3	0.65 (0.71	1.00 (1.42)	0.23 (0.34)	#	#	Yes	Yes
	n	89	45	85	17	4		
Inherited land	1	1.06** (0.03)	1.03 (0.02)	1.03 (0.02)	1.07*** (0.02)	1.02** (0.01)	No	No
	n	995	807	781	1,047	749		
	2	1.03 (0.04)	1.05* (0.03)	1.06** (0.03)	1.02 (0.03)	0.98 (0.02)	Yes	No
	n	857	622	935	606	560		
	3	1.88 (1.48)	2.23 (2.80)	1.47e07 (1.82e10)	9.44e06 (2.79e10)	#	Yes	Yes
	n	296	133	268	74	33		
Community-distributed land	1	0.92*** (0.03)	1.00 (0.03)	0.95*** (0.02)	0.95* (0.03)	0.97 (0.02)	No	No
	n	995	807	781	1047	749		
	2	0.98 (0.04)	1.06 (0.04)	1.02 (0.03)	0.99 (0.03)	1.00 (0.02)	Yes	No
	n	624	485	677	409	386		
	3	0.90 (0.66)	221.41 (2.65e03)	1.43 (0.96)	3.00 (4.60)	#	Yes	Yes
	n	120	70	118	36	14		
Used land free of charge	1	1.00 (0.03)	1.00 (0.03)	1.03 (0.03)	0.98 (0.03)	1.01 (0.02)	No	No
	n	995	807	781	1047	749		
	2	1.03 (0.04)	1.03 (0.03)	1.05* (0.03)	1.03 (0.03)	1.02 (0.02)	Yes	No
	n	500	358	536	331	216		
	3	0.53 (0.42)	0.36 (0.42)	0.70 (0.56)	6.18 (1.39e-04)	#	Yes	Yes
	n	136	57	114	37	11		
Purchased land	1	1.03 (0.04)	1.04 (0.04)	1.03 (0.03)	1.02 (0.03)	1.02 (0.02)	No	No
	n	995	807	781	1047	749		
	2	1.02 (0.04)	1.03 (0.04)	1.01 (0.04)	1.00 (0.04)	1.00 (0.02)	Yes	No
	n	374	272	398	263	246		
	3	1.17 (1.57)	0.42 (0.72)	0.49 (0.62)	4.01 (6.95)	#	Yes	Yes
	n	118	59	122	33	7		

Note: n represents the number of observations in each model of the analysis. # signifies convergence does not achieve.
Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

5.4.4 Matching-based regression results of the effect of land documentation on anthropometric child nutrition

The results of the land right documentation affecting child malnutrition are presented in Table 5.13. These results were reported in odds ratios and compared with non-regression estimates. While the matching-based *flexpaneldid*-FE and DID (panel data ATE) coefficients of formal land certificates on child malnutrition after matching observations were not statistically significant, the

DID estimate of holding a formal certificate before matching observations was significant at one percent for households with stunted children. The significant result indicated that households that held formal land certificates were more likely to have stunted children than those without formal land certificates. The result was consistent with *apriori* expectations. Similar results were reported by Kehinde et al. (2021) and Vogl (2007) that formal titling did not improve household food security in Nigeria and the height-for-age of children in Peru, respectively. Binding land right alienation (rent, mortgage or sales) with prior consent or approval of the government and ceiling lease landholding to 99 years may limit the private welfare benefits of formal land documentation in Nigeria. Political instability may institute poor land governance, jeopardising the fair compensation defined under 1978 LUA for revoked land rights. In addition, these clauses disincentivise long-term farm investment decisions and reduce the likelihood of land being used as collateral for formal loan acquisitions. The DID coefficient of informal land documents before matching observations was significant at 10% for child wasting and underweight.

Table 5.13: The regression results of the effect of land documentation on child malnutrition

Land right documentation Indicator	Model	Stunted child	Wasted child	Overweight child	Underweight child	Stunted-overweight child	Matching	Fixed Effect
Formal land certificate	1	1.14*** (0.06)	0.99 (0.04)	0.99 (0.03)	1.02 (0.04)	0.99 (0.03)	No	No
	n	995	807	781	1047	749		
	2	1.02 (0.05)	0.98 (0.04)	0.97 (0.04)	1.02 (0.04)	1.00 (0.02)	Yes	No
	n	295	209	320	205	191		
	3	0.32 (0.34)	0.25 (0.44)	0.26 (0.35)	0.84 (1.63)	#	Yes	Yes
	n	116	40	103	24	2		
Informal land documents	1	1.03 (0.04)	1.05* (0.03)	1.02 (0.03)	1.05* (0.03)	1.02 (0.02)	No	No
	n	995	807	781	1047	749		
	2	1.00 (0.04)	0.93* (0.04)	1.02 (0.03)	0.99 (0.03)	1.01 (0.02)	Yes	No
	n	443	331	475	319	287		
	3	1.06 (0.90)	2.39 (3.25)	0.14** (0.13)	1.00 (1.73)	#	Yes	Yes
	n	134	65	138	32	14		

Note: n represents the number of observations in each model of the analysis. # Signifies convergence does not achieve. Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

The DID and *flexpaneldid*-FE model coefficients of informal land documents after matching observations were negative and statistically significant for child wasting and overweight. The results implied that households holding informal land documents were respectively seven percent and five percent less likely to have wasted and overweight children, respectively, than those

without land documents. Galiani & Schargrodsky (2004), Ghebru and Holden (2013) and Vogl (2007) found the same results for formal titling studies in urban Argentina and Peru, where land title reduced child weight-for-height and increased or normalise body weights, respectively.

5.5 Summary

The chapter presents new insights from comparing anthropometric child nutrition between holders and non-holders of each (formal or informal) land document and between holders and non-holders of each land acquisition mode. This study examined the child nutrition implications from five existing anthropometric indicators. Households with inherited land were found to have more malnourished children than children from households without inherited land. Nutrition of children in the households with family inherited land were less likely to increase compared to children from households without inherited land. The customary law of inheritance is dominantly patriarchal in Nigeria. Inherited land is usually passed on to men from generation to generation, leaving women and children more vulnerable to poverty and malnutrition. However, households with community-distributed land were less likely to have stunted, overweight and underweight children. While the formal land certificate holders had a 13% chance of having stunted children, the informal land document holders were seven percent and five percent less likely to have wasted and underweight children than the children of households without documents. Smallholder land tenure had a small but relevant effect on reducing child malnutrition with community-level land distribution and informal land documents in Nigeria. With land documentation, households could access innovations and use their land as collateral to acquire a formal loan that supports farm investments and achieves food security and child health. The national framework for agriculture needs to address the elements of patriarchal land ownership and formalise informal land documents to achieve nutrition-sensitive agricultural objectives. Given that intra-household child nutrition manifested in the long term, this chapter fitted Nigeria's General Household Surveys (GHS) three-wave panel data to a combined matching-based *flexpaneldid* -FE regression to examine the effect of land tenure on child nutritional outcomes.

Chapter 6 : Food insecurity and child nutritional status in Nigerian smallholder farm households

6.1 Introduction

Nigeria is home to a significant proportion of Africa's hungry and malnourished children under five years of age (FAO et al., 2022). Malnutrition is an abnormal physiological condition or outcome of poor nutritional intake resulting from insufficient quality food consumption, poor absorption and biological use of nutrients consumed due to diseases (FAO et al., 2022). Malnutrition, as often assumed in the literature to be similar to hunger, results from insufficient food intake (FAO, 2003). Anthropometrics measure malnutrition, which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and overweight (high weight for squared height). Nigeria accounted for 35.3% stunted children in 2020, which was above West Africa's average (30.9%) of stunted children in 2020 (FAO et al., 2022). Nigeria's wasted and overweight children were 6.5% and 2.7% in 2020, while West Africa's children were 6.9% wasted and 2.7% overweight in 2020 (FAO et al., 2022). However, children from farm households faced more severe malnutrition due to the vulnerable nature of agriculture in the country. Slightly 42% male and 39.5% female children under five years were stunted in 2019 in Nigerian farm households (NBS & World Bank 2019). The proportion of wasted children under five years was 8.6% girls and 7% boys in 2019 among farm households (NBS & World Bank 2019). The reasons for the high prevalence of child malnutrition among farm households in Nigeria have not been investigated from the context of food insecurity levels.

Food insecurity occurs when people lack “physical, social and economic access to sufficient, safe and nutritious food that meets dietary needs and food preference for an active and healthy life” (FAO 2009, p. 8). This concept appraises the inadequate or absence of food availability, accessibility, resilience, utilisation and stability dimensions of food security (FAO, 1996; HLPE, 2020). While the possibility of meeting the food security components differ at farm household levels (that rely on rain-dependent agriculture), food insecure households may likely have malnourished families with impaired normal body growth and development (Chegere & Stage, 2020). Nigeria is facing a high prevalence of severe food insecurity (FAO et al., 2022). The

country's majority of severe food insecurity has increased from 11% in 2014-16 to 19.1% in 2019-21, placing Nigeria as the sixth-highest hungry country in West Africa (FAO et al., 2022).

Nigerian smallholder farmers dominate food production and rely on relatively small farms of less than two hectares (FAO, 2018b). The food security of these farmers is positively related to their agricultural performance (Ecker et al., 2018). However, farm households may face high food insecurity due to the risky nature of food production in rural and urban areas. Farmers' sustainable farming practices are constrained by low access to land, insecure land rights and weather variability, and inadequate access to finance, insurance, inputs and markets (FAO, 2018b). These constraints contribute to smallholders' low per-capita agricultural food availability and income to promote the consumption of diverse and nutritious diets, reducing nutritional improvements (Hawkes et al., 2020).

Children and women in hungry households may experience a greater risk of adverse nutritional outcomes. Malnutrition in women is a major risk factor for poor health outcomes in offspring (Ersino et al., 2018). Nutritional deficiencies in children negatively affect their physical, cognitive and socioemotional development, productivity, birth weight, health and well-being into adulthood (Grantham-McGregor et al., 2007).

Despite the detrimental effect of nutritional deficits on individual households, there is a lack of evidence on the association between a range of food security indicators among farm household heads and several adverse nutritional outcomes among sampled children. Some studies suggest using specific food security measures as proxies could fit for anthropometric-measured child malnutrition due to inadequate nutrition information. With the child nutrition panel data in Nigeria’s General Household Survey (GHS), understanding the empirical relationship between food security measures and anthropometric indicators of child malnutrition becomes possible and important. Research for Objective Three aimed to see if the General Household Survey (GHS) panel data provided further insight into the type and depth of child malnutrition among food insecure households.

Some studies have reported nutrition as a component of food security (Hendriks, 2015; Pangaribowo et al., 2013). Many others regarded nutrition issues as diet-related health outcomes stemming from food insecurity (Bhattacharya et al.2004; Gundersen & Ziliak 2015). As a result, some researchers see food security and nutrition as separate concepts and others see malnutrition

(undernutrition, micronutrient deficiencies as well as overweight and obesity) as an outcome of food insecurity (Hendriks, 2015). Research for objective three aimed to see if the General Household Survey (GHS) panel data provided further insight into the type and depth of child malnutrition among food insecure households.

This chapter set out to see if the General Household Survey (GHS) panel data provided further insights into the type and depth of malnutrition from food insecure households. The study's results provide new insight to inform food policy debates on the food (in) security measures for intra-household (mal)nutrition with insufficient information. Being overweight is not often included in food security studies in developing countries. However, this study shows the need to have indicators of children overweight in such surveys. This indicator will become more important as food systems in developing countries transform and urbanisation increases. This is a policy-oriented contribution given the current nutrition transitions in terms of lifestyle, diversity, and reviving of underutilised and neglected diets. The chapter fitted Nigeria's General Household Surveys (GHS) three-wave panel data to RE regression to examine the effect of food security (in levels & binary units) on child nutrition. While both food security and nutrition remain the outcomes of potential means, the findings from the chapter should be considered as a correlation but relevant to clarify the cloudy use of the two concepts.

The chapter has six sections. The first section gives the background to the chapter. Section two and three discusses the pathways and reviews studies on the relationship between household food insecurity and child nutrition. The fourth section describes the method of data analysis. The fifth section presents and discusses the results. The final section concludes this chapter.

6.2 The relationship between food insecurity and child malnutrition: Overview and pathways

People who are severely food insecure are probably hungry and malnourished (FAO et al., 2022). Unfortunately, the world is far from achieving the World Health Assembly (WHA) and SDG two targets (FAO et al., 2021) related to child malnutrition. However, national leaders committed to the 2015 Sustainable Development Agenda to end hunger and malnutrition by 2030 (UN, 2015) and the 2016 UN Decade of Action on Nutrition to meet the WHA nutrition targets (UN, 2016). In addition, governments across the globe reaffirmed their commitments to eradicating hunger at the 2021 United Nations (UN) Food Systems Summit (UN, 2021). Yet, the proportion of hungry

people and malnourished children increased in Nigeria from 2014-16 to 2016-18 (FAO et al., 2022). Undernourishment is when food insecurity results from consuming an "insufficient amount of dietary energy required to maintain a normal, active and healthy life" (FAO et al., 2022, p. 206).

Figure 6.1 shows the trends of undernourished people and anthropometric deficits (i.e., stunting, wasting and overweight) of children under five years of age from 2014-16 to 2018-20 in Nigeria. With the increase in undernourished people from 7.9% in 2014-16 and 13.4% in 2016-18 in Nigeria, stunted and wasted children increased by 10.7% and 3.6% (Figure 6.1). However, the prevalence of stunted and wasted children dropped by 8.3% and 4.3% between 2016-18 and 2018-20, when the undernourished population increased from 13.4% in 2016-18 to 14.6% in 2018-20 (Figure 6.1). Despite the increase in the undernourished population in Nigeria, children's levels of stunting and wasting slowly dropped from 2016-18 to 2018-20 (FAO et al., 2021). This slow decline in the prevalence of child undernutrition may be attributed to the impact of the 2014 National Strategic Plan of Action for Nutrition (2014 – 2019), which attempted to address malnutrition through nutrition-specific interventions (Federal Government of Nigeria FGN, 2014).

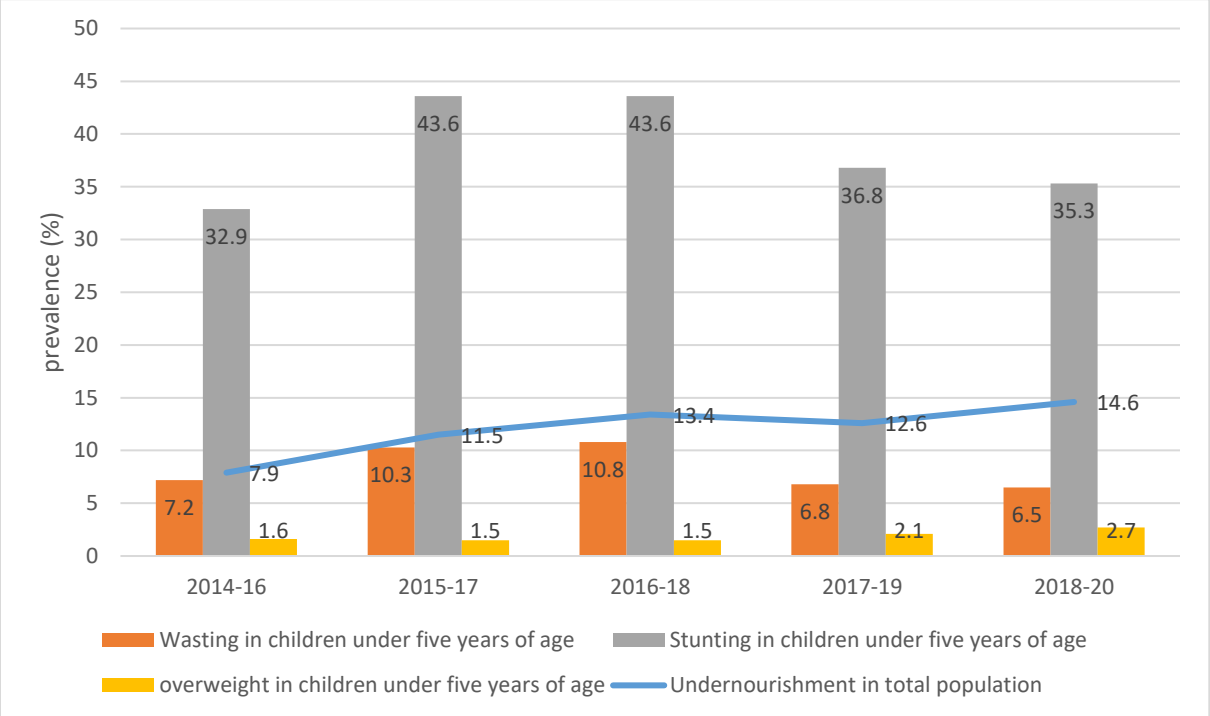


Figure 6.1: The trends of undernourished people and anthropometric deficits of children in Nigeria
Source: SOFI 2017 – 2022 reports (FAO et al., 2017, 2018, 2019, 2020 & 2021)

There are several pathways through which food insecurity can contribute to malnutrition. First, poor child growth and development can be due to low quantity, diversity and quality of dietary intake (FAO et al., 2019). Although food insecurity is associated with decreased dietary diversity and energy intake, poverty is closely linked with increased food insecurity (Mutsiya et al., 2015). Low incomes and high food prices tend to subject household members to limiting/skipping food, increasing the risk of stunted growth, wasting and being underweight in children (Shahraki et al. 2016). Second, mothers in food-insecure households are more likely to be stressed and depressed, contributing to child undernutrition through poor breastfeeding and care practices (Maitra 2018; FAO et al., 2019).

Third, the higher cost of nutrient-rich foods and their substitution with cheaper energy-dense foods contribute to the relationship between food insecurity and overweight and obesity (FAO et al., 2019). Poor households cannot afford nutrient-rich food but consume and nourish their children with cheap, highly processed and energy-dense food, which increases the risk of being overweight in children and obese adults (Nettle et al., 2017). Access to energy-dense food relative to nutritious food among the poor is a form of food insecurity, more prevalent in high-income countries than in middle- and low-income countries in Africa (Levine 2011). As a result, children in high-income countries who grow up in poor households are more likely to become overweight or obese adults (Nettle et al., 2017). Obese individuals have been linked to a low socioeconomic status such as income, education or occupation, influencing excessive consumption of unhealthy (sugar-sweetened) diets and increasing energy intake relative to energy expenditure (Nettle et al., 2017; FAO et al., 2021). The positive association of food insecurity with obesity is more likely to occur in urban settings, where highly processed, energy-dense foods are readily available or/and affordable (FAO et al., 2019).

Fourth, various public policies play a role in influencing food consumption (Maitra 2018). For example, intervening factors related to personal preferences, socioeconomic status, food stamps and food assistance programs, nutrition-sensitive and education programs, taxing unhealthy and incentivising the consumption of healthy foods and quality community childcare programs can influence the association (Maitra 2018).

6.3 Review of empirical studies on the relationship between household food insecurity and child malnutrition

Many studies have been conducted on the association between food insecurity and child malnutrition globally, but little evidence has been reported for Africa. For example, some African studies found a positive relationship between household food insecurity and stunting (low height for age) or linear growth failure of children under five years of age. These studies include Nkurunziza et al. (2017) in Burundi, Ali et al. (2013); Berhane et al. (2020); Belayneh et al. (2020); Berra (2020); Betebo et al. (2017); Jemal et al., (2016); Hagos et al., (2017); Humphries et al., (2015); Roba et al., (2019); Wolde et al., (2015) in Ethiopia, Frempong and Annim (2017) in Ghana; Bukania et al., (2012); M'Kaibi et al. (2017); Mutisya et al., (2015) in Kenya, Hatløy et al. (2000); Makamto Sobgui et al., (2018) in Mali, Agho et al., (2018) in Rwanda, Chakona & Shackleton, (2018); Drysdale et al., (2020); Harper et al., (2022a; 2022b) in South Africa and Chegere and Stage, (2020); Khamis et al. (2019); Psaki et al., (2012) in Tanzania. However, studies in Ghana (Saaka & Osman 2013) and Ethiopia (Motbainor et al. 2015; Mulu & Mengistie 2017) have found no association between household food insecurity and child stunting.

No association between household food insecurity and wasting (low weight for height) of children under five years of age was found in studies in Ethiopia (Ali et al., 2013; Abdurahman et al., 2016; Betebo et al., 2017; Berra, 2020; Jemal et al., 2016; Mulu & Mengistie 2017), Ghana (Saaka & Osman 2013; Frempong & Annim 2017), South Africa (Psaki et al., 2012; Chakona & Shackleton, 2018) and Tanzania (Chegere & Stage, 2020; Psaki et al., 2012; Khamis et al., 2019). However, Wolde et al. (2015); Belayneh et al. (2020) and Motbainor et al. (2015) in Ethiopia; Sambu (2013) in Kenya, Ajao et al. (2010) in Nigeria, Makamto Sobgui et al., (2018) in Mali and Rose et al., (2015) in Mozambique reported a significant positive association between household food insecurity and wasting. On the other hand, studies in Kenya (Shinsugi et al. 2015) and Mozambique (Rose et al. 2015) have reported no significant association between household food insecurity and underweight (low weight for age) in children. Only studies from Ethiopia (Wolde et al. 2015; Berra 2020; Betebo et al. 2017; Mulu & Mengistie 2017), Kenya (Sambu, 2013), Mali (Hatløy et al. 2000) and Tanzania (Chegere & Stage, 2020; Khamis et al., 2019) have found a significant positive association between household food insecurity and underweight in children.

In addition, in Africa, studies investigating the relationship between household food insecurity and overweight (high weight for twice height) in children have only been reported for Ethiopia (Humphries et al., 2015) and the beneficiaries of the Egyptian food subsidy system (Ecker et al., 2016). Likewise, studies have been conducted on overweight children in Ethiopia (Humphries et al., 2015; Berhane et al., 2020) and women in Ghana (Saaka & Osman, 2013) and Uganda (Chaput et al., 2007). The studies in Ghana and Ugandan showed no association between child overweight and household food insecurity (Saaka & Osman, 2013; Chaput et al., 2007). Children and mothers in Egypt who benefitted from food subsidies were overweight due to high-calorie consumption (Ecker et al., 2016).

The review study by Maitra, (2018) submitted that the evidence of the relationship between household food insecurity and child malnutrition is inconclusive due to several methodological limitations. However, there may be a possibility that the existing findings were inconclusive for other reasons. Some studies measured food insecurity in terms of low household dietary diversity scores, resulting in increased child undernutrition (Belayneh et al., 2020; Bukania et al., 2014; Chakona & Shackleton, 2018; Chegere & Stage, 2020; Frempong & Annim, 2017; Harper et al. 2022a; 2022b; Hatløy et al., 2000; Khamis et al., 2019; M'Kaibi et al., 2017; Roba et al., 2019; Sambu, 2013). Other existing literature on the relationship adopted the experiential-based food security scales, including the Household Food Insecurity Access Scale (HFIAS) (Abdurahman et al. 2015; Ali et al. 2013; Belayneh et al., 2020; Berhane et al., 2020; Berra 2020; Betebo et al. 2017; Chakona & Shackleton 2018; Hagos et al. 2017; Humphries et al. 2015; Jemal et al. 2016; Makamto Sobgui et al. 2018; M'Kaibi et al., 2017; Motbainor et al. 2015; Nkurunziza et al. 2017; Psaki et al. 2012; Roba et al. 2019; Saaka & Osman 2013; Shinsugi et al. 2015; Wolde et al. 2015); Household Hungry Scale (Berra 2020); the Radimer/Cornell Scale (Chaput et al. 2007; Mutisya et al. 2015) and the United States Household Food Scarcity Survey Module (US HSSFM) (Ajao et al. 2010). These indicators captured households' experiences with difficulties in accessing food due to resource constraints (Maitra 2018).

However, no single internationally recognised standard captures all the dimensions of food insecurity (Maxwell et al., 2014; Hendriks et al., 2016). Several food security indicators are required to understand all dimensions of food security and to guide policy decisions to address hunger and malnutrition (Tiwari et al., 2013). Applying different food insecurity indicators may

enhance the comparability of estimates across different individual households. Although Roba et al., (2019) adopted more than two food insecurity measures (e.g., household and infant dietary diversity, food consumption scores and HFIAS), the study did not account for child malnutrition derived from anthropometric indicators. Furthermore, few studies classify food-insecure households into severity levels, limiting the potential insights into the relationship between food insecurity and the risk of child malnutrition (Moradi et al. 2019). We found no current study examining different indicators of food insecurity in their different severity levels and associations with different forms of child malnutrition. These levels of severity refer to the degree to which the study population suffers from food insecurity situations, e.g., food security, mild food security, moderate food insecurity and severe food insecurity (Moradi et al. 2019).

Most studies reviewed in the present study have used a cross-section design. Only Chegere and Stage (2020), Humphries et al. (2015) and Harper et al. (2022a) have used longitudinal data to study the relationship between household food insecurity and child malnutrition in Africa. While children's nutritional outcomes reflected a long-term cumulative process, incongruences in the timing of data collection may complicate the cross-section analysis of the association between food insecurity and adverse nutritional outcomes (Arimond & Ruel, 2004). Econometric challenges such as sampling selection bias, omitted variable bias and simultaneous bias were problematic for studies analysed with a cross-section design. But, the biases can be mitigated under a longitudinal study design to address the location- and time-invariant unobserved factors (Maitra 2018). This study advanced on previous literature by adopting micro-level data from nationally representative panel surveys. It employed several food insecurity indicators in their severity levels and their association with various forms of child anthropometric deficits in Nigeria. The study further explores the association from the context of the rural-urban locations of sampled households.

6.4 Methodology

The data used for this study has been described in Chapter Three. The data set out to examine the relationship between household food security and child nutrition. The data were drawn from 2012/13 (Wave2), 2015/16 (Wave3) and 2018/19 (Wave4) General Household Survey (GHS) in Nigeria. Two thousand, four hundred and forty-eight sub-sampled smallholders with 1,669

children aged 0 – 59 months were sampled respondents used to examine objective three. The data was analysed with the random effect (RE) logistic regression model described in Chapter Three.

The models specified in Equation 11 and Equation 12 were fitted using the STATA *"xtlogit"* command. The food insecurity indicators were categorised into severity levels. The first category of the severity levels for each food insecurity indicator was considered the reference group to interpret the estimates of other severity levels in the regression model. The regression results presented the following severity levels' coefficient, symbolising household food insecurity. The coefficient estimates were reported in odds ratios as exponential coefficients (likelihood of event occurrence) of child nutritional outcomes. The interpretation method has been discussed in the method section. After fitting Equation 11 and Equation 12 to data, the *xtlogit* causal analysis was conducted using Stata15.1 (StataCorp, 2017).

6.5 Results

Table 6.1 presents the descriptive statistics of the socioeconomic characteristics of the sampled household heads by location. Fewer than twenty percent of the household heads resided in an urban area. Female household heads were under-represented in Nigeria's general household data. About 19% average female household heads were represented in the 2018-19 general household survey, three percent greater than the proportions in the previous general household surveys in Nigeria (NBS & World Bank, 2019). Female sampled household heads used for this study were six percent, as lower as the proportion of female household heads in the 2018 GHS. Female sampled household heads in rural areas were three percent greater than the female sampled household heads in urban areas. The sampled household heads' average age was 33 years and the average household size was eight. The mean differences in age and household size were higher for rural than urban sampled households.

Sampled household heads managed an average of two plots of land and earned an average of ₦12,462 (i.e., $40.69) per season from off-farm work. Rural sampled households managed an average of one more plot of land and earned (₦31,553 /$103) less income from off-farm work than the urban sampled households. One in two sampled household heads could read and write (i.e., literate) and the literacy level was 29% lower in rural areas than in urban areas. Twelve percent of the sampled households benefited from foreign remittances. About five percent of urban sampled households received more foreign remittances than the rural sampled households. The households

held an average of eight total livestock units (TLU) and rural sampled households owned more (10) units than the urban sampled households. Only five percent of the sampled household heads were members of a cooperative society. About 13% rural sampled farmers were cooperative members, while 18% urban sampled households participated in cooperative society.

About 39% of sampled households held family inherited land and nine percent held outright purchased land. One in five sampled households acquired land through community distribution and one in ten held free use land. Only one in ten sampled households held rented land. Market-based land transfers for outright purchase and rentals were popular among urban sampled households. Most rural sampled households held land via a non-market mode of land acquisitions, including family inheritance, community distribution and free use. About 5% of sampled households held formal land certificates and 11% held informal land documents to enhance the security of their land (NBS & World Bank 2013; 2016; 2019). More sampled households in the rural areas had informal land documents but fewer had formal land certificates than the urban sample households. Generally, most (84%) of the sampled households did not document their land.

Table 6.1: Descriptive summary sampled household heads' factors and factors differences by location

Household head features (unit)	Total mean	Rural mean	Urban mean	Zonal Mean diff.
Sex (female %)	0.04(0.20)	0.05(0.01)	0.02(0.01)	0.03*(0.01)
Age (year)	33.00(25.84)	40(0.54)	14(0.98)	26*(1.08)
Household size (number)	8.00(3.89)	8.00(0.09)	7.00(0.14)	1.00*(0.18)
Literate (%)	0.44(0.25)	0.23(0.02)	0.51(0.01)	-0.29*(0.02)
Plot number	2.00(1.74)	3.00(0.04)	1.00(0.04)	2.00*(0.07)
location (rural %)	0.89(0.31)	.	.	.
Cooperative (%)	0.08(0.07)	0.05(0.00)	0.18(0.02)	-0.13*(0.01)
Off-farm income (₦)	21214(84621)	13360(19340)	44913(3484)	31552(3920)
Remittance (%)	0.11(0.10)	0.10(0.01)	0.15(0.01)	-0.05*(0.01)
Total Livestock Unit (number)	8.00(21.55)	11.00(0.57)	1.00(0.11)	10.00*(0.98)
Mode of land acquisition				
Family inheritance (%)	0.39(0.24)	0.41(0.01)	0.26(0.03)	0.15*(0.04)
Outright purchased (%)	0.09(0.08)	0.08(0.01)	0.23(0.03)	-0.16*(0.02)
Community distribution (%)	0.26(0.19)	0.28(0.01)	0.11(0.02)	0.17*(0.03)
Rented (%)	0.10(0.09)	0.09(0.01)	0.18(0.03)	-0.09*(0.02)
Free of charge (%)	0.16(0.13)	0.22(0.03)	0.15(0.01)	0.06*(0.03)
Land documentation				
Formal land certificates (%)	0.05(0.05)	0.04(0.01)	0.05(0.01)	-0.01(0.01)
Informal land documents (%)	0.11(0.09)	0.12(0.01)	0.07(0.01)	0.05(0.01)
No land documents (%)	0.84(0.13)	0.88(0.01)	0.83(0.01)	0.05*(0.02)
Total observation	2447	1828	619	

Note: In parenthesis is the standard error, Significant level: *p<0.05, Nov 2018, Central Bank of Nigeria's exchange rate: US$1= ₦306.30
Source: Author, (2021)

Table 6.2 presents the descriptive summary of child malnutrition and household food insecurity by location in the sample. The results showed that one in five children in the samples suffered from stunting, 14% suffered from wasting and underweight. Less than ten percent of children in the samples were overweight or stunted-overweight. The proportion of children in the rural samples who suffered from stunting and underweight was greater than that of urban sampled households. Overweight children were common among urban sampled households, signifying the prevalence of sugar- and salt-rich food consumption habits in the urban areas that likely influence overweight (Nettle et al., 2017).

The severely and moderately food insecure households accounted for almost six in ten households as measured by the Food Security Index (FSI) derived from a consolidated approach to reporting food security indicators (CARI). The results revealed that 65% of household heads spent more than half their expenditure on food. The proportions of food secure and moderately food secure in urban sampled households were greater than their proportion in rural areas. Food expenditure share can indicate both the vulnerability of households to food insecurity and the possibility of household food security, i.e., it is bimodal. High food prices could drive poor households to spend most of their income on food and less on nutritious food utilisation, reflecting the vulnerability of households to food insecurity (Lele et al., 2016). Households who spend a larger portion of their income on food may have low purchasing power for other non-food items (i.e., water, fuel, transportation, health, education and storage facilities), contributing to nutritious food consumption. One would assume that allocating a larger portion of monthly income to food can result in purchasing a variety of food that increases diverse diet consumption. However, households may not consume the food variety purchased effectively without considering the nutrition-enhancing non-food items. A low expenditure share on food purchased might also be attributed to own-farm crop consumption, cushioning high food price effects (Ecker et al. 2018). The proportion of sampled households spending less than 50% (low food expenditure share) and 50-64% (medium expenditure share) was greater in rural areas than urban areas.

Although only 24% of sampled households had acceptable food consumption scores (FCS), close to 43% households had adequate dietary diversity scores (HDDS). Households with less diverse and quality diets were likely more vulnerable to food insecurity. The proportion of sampled households who consume adequate diversified diets was greater in rural than urban areas. A greater

proportion of urban sampled households had acceptable food consumption scores than the rural sampled households. Consumption of diverse foods by households without the contribution of all food groups may likely underscore poorly nutritious food (Lele et al., 2016).

The results showed that two percent of the sampled households had very low Livelihood Coping Strategies (LCS). While only 76% of the households were food secure with low LCSs, 11% were stressed and in crisis. By two percent, the rural sampled households had lower LCS than urban sampled households. The low livelihood coping strategies intensified the severity levels of household food insecurity and the risk of having malnourished children. Household heads owned liquid assets such as house furniture, electrical appliances, mobile phones, kitchen and laundry utensils, and vehicles, which are resilient in coping with the stress of accessing food. About 69% of the sampled households owned fewer than three assets. According to Mawoko et al. (2018), households with fewer than three low-valued assets may have low resilience to cope with food insecurity shocks. A higher proportion of rural sampled households had fewer three assets than their proportion in urban areas.

Table 6.2: Descriptive summary of child malnutrition and food insecurity among sampled households

Child malnutrition	Total	Obs	Rural	Obs	Urban	Obs	Mean diff.
Stunting	0.20(0.01)	1321	0.22(0.01)	1002	0.13(0.02)	319	0.09*(0.03)
Wasting	0.14(0.01)	1098	0.14(0.01)	817	0.14(0.02)	281	0.00(0.02)
Underweight	0.14(0.01)	1394	0.16(0.01)	1057	0.09(0.02)	337	0.07*(0.02)
Overweight	0.08(0.01)	1047	0.08(0.01)	786	0.10(0.02)	261	-0.02(0.02)
Stunted-overweight	0.04(0.01)	1003	0.04(0.01)	753	0.04(0.01)	250	0.01(0.01)
Household FSI							
Food secure	0.08(0.01)	2429	0.05(0.01)	1814	0.15(0.01)	615	-0.10*(0.01)
Marginal food secure	0.29(0.01)		0.25(0.01)		0.40(0.02)		-0.14*(0.02)
Moderate food insecure	0.48(0.01)		0.50(0.01)		0.42(0.02)		0.08*(0.02)
Severely food insecure	0.15(0.01)		0.20(0.01)		0.04(0.01)		0.16*(0.02)
Food Expenditure share							
< 50% of total income	0.35(0.01)	2444	0.33(0.01)	1826	0.41(0.02)	618	-0.08*(0.02)
50-64% of total income	0.13(0.01)		0.09(0.01)		0.24(0.02)		-0.14*(0.02)
65-74% of total income	0.17(0.01)		0.17(0.01)		0.17(0.02)		0.00(0.02)
> 74% of total income	0.35(0.01)		0.40(0.01)		0.17(0.02)		0.23(0.02)
HDDS							
Adequate diverse diet	0.43(0.01)	2447	0.48(0.01)	1828	0.28(0.02)	619	0.20*(0.02)
Moderate diverse diet	0.39(0.01)		0.37(0.01)		0.45(0.02)		-0.08*(0.02)
Inadequate diverse diet	0.18(0.01)		0.15(0.01)		0.27(0.02)		-0.12*(0.02)
FCS							
Good	0.24(0.01)	2447	0.18(0.01)	1828	0.39(0.02)	619	-0.21*(0.02)
Borderline	0.51(0.01)		0.50(0.01)		0.52(0.02)		-0.02(0.02)
Poor	0.25(0.01)		0.31(0.01)		0.09(0.01)		0.22*(0.02)
Asset ownership							
High	0.72(0.01)	2432	0.67(0.01)	1823	0.88(0.01)	609	-0.20*(0.01)
Moderate	0.14(0.01)		0.16(0.01)		0.08(0.01)		0.08*(0.02)

Low	0.14(0.01)		0.17(0.01)		0.05(0.01)		0.12*(0.02)
LCS							
None	0.76(0.01)	2429	0.74(0.01)	1814	0.84(0.01)	615	-0.10*(0.02)
Stress	0.11(0.01)		0.12(0.01)		0.06(0.01)		0.06*(0.01)
Crisis	0.11(0.01)		0.12(0.01)		0.10(0.01)		0.02(0.01)
Emergency	0.02(0.00)		0.03(0.00)		0.01(0.00)		0.02*(0.00)

Note: Significant level: *p<0.05, the total households' observations (0bs) =2448 and children's observations=1669
Source: Author, (2021)

Table 6.3 reveals the summary statistics of food security (levels) and tests of variations across the survey years (waves) of data collection. The results showed that more than 50% households were moderately food insecure in 2012/13 and 2015/16, while most (45%) households were marginally food secure in the 2018/19 survey. The proportions of households at the "borderline" level in FCSs', at the "high" level in assets and at the "none" level in LCSs' indicators remain high across wave years. With unequal distributions, most households in food expenditure shares spent less than 50% in 2018/19 and more than 75% in 2012/13 and 2015/16. A similar trend goes for the proportion of households with at least moderate ordered levels in HDDS across survey waves. Chi-square statistics were adopted to check for the distribution of households in food security indicators (levels) across survey waves. Generally, there were significant variations in the proportions of households in the food security index (FSI), food expenditure share and asset number across the waves. Some significant variations were also found in the proportions of households in adequate and inadequate levels in acceptable and poor levels; in none, stress and emergency levels of HDDSs', FCSs' and LCSs' food security indicators across survey years, respectively.

Table 6.3: Summary statistics of food security (levels) and tests of variation across survey waves

Food security (levels)	2012/13	2015/16	2018/19	Chi2 test
FSI				
Food secure	1%	2%	21%	162.23***
Marginal food secure	16%	25%	45%	169.93***
Moderately food insecure	54%	55%	33%	103.75***
Severely food insecure	29%	18%	1%	378.08***
food expenditure share				
<50	5%	6%	95%	2343***
0.50 - 0.64	14%	23%	2%	211.37***
0.65 - 0.74	21%	29%	1%	439.83***
>75	60%	41%	2%	1056***
HDDS				
Adequate	53%	40%	37%	51.70***
Moderate	36%	41%	40%	4.74
Inadequate	11%	19%	24%	54.11***
FCS				
Acceptable	17%	26%	28%	40.49***
Borderline	52%	52%	49%	3.14
Poor	31%	21%	23%	22.52***

Asset number				
High	65%	72%	80%	46.47***
Medium	16%	16%	10%	17.83***
Low	19%	12%	10%	28.62***
LCS				
None	73%	76%	79%	7.56**
Stress	13%	9%	9%	9.76***
Crisis	10%	13%	11%	4.35
Emergency	3%	1%	1%	10.27***
Obs	816	816	816	

Notes: ***$p<0.01$, **$p<0.05$, *$p<0.1$ represented the significant level for equality of group-mean using the likelihood ratio (LR chi2 test)
Source Author, (2021)

Table 6.4 presents the statistical summary of food security (binary) and nutrition across wave years. Except for households in FCS with less than 50% proportion, most households in the 2018/19 wave year were food secure in FSI, food expenditure shares, HDDS, household assets and LCS indicators. In the 2012/13 and 2015/16 surveys, greater than 50% households were food secure in HDDS, household assets and LCS indicators. The proportions of households in food security (binary) indicators such as FSI, food expenditure shares, HDDS, FCS and household assets were significantly varied across wave years. There was no significant variation in the proportion of households in LCSs' food security (binary) indicator. For yearly child anthropometrics statistics, it is important to note that the children included are not the same as the intervals are usually 5 years. This study measures children under 5 years of age, so each child is only included one year. There were significant variations in proportions of households that have a stunted, underweight and overweight child across the sampled years. The household proportions change with child stunting and underweight increased from 2012/13 to 2018/19 survey years. The proportion of those with child overweight slightly dropped from 10% in 2015/16 to 8% in 2018/19. However, there were no significant differences in the proportions of households who have a wasted and stunted-overweight child across the sampled years.

Table 6.4: Summary statistics of food security (binary), nutrition and test of variation across survey waves

Variable	Total	2012/13	2015/16	2018/19	Chi^2 test
Binary food security indicators					
FSI	36% (2448)	17% (816)	27% (816)	65% (816)	443.49***
Food expenditure share	48% (2448)	18% (816)	30% (816)	97.3% (816)	1.2e+03***
HDDS	82% (2448)	89% (816)	81% (816)	76% (816)	48.58***
FCS	24% (2448)	17% (816)	26% (816)	28% (816)	36.05***
Household assets	86% (2432)	79% (816)	88% (816)	89% (816)	43.96***
LCS	86% (2448)	86% (816)	85% (816)	86% (816)	0.29
Child nutritional outcomes					
Stunting	20% (1321)	13% (446)	22% (527)	24% (345)	18.15***

Wasting	14% (1098)	14% (380)	14% (432)	15% (286)	0.45
Underweight	14% (1394)	9% (478)	16% (558)	18% (358)	17.35***
Overweight	8% (1047)	6% (334)	10% (438)	8% (275)	5.23*
Stuover	4% (1003)	2% (323)	4% (412)	5% (268)	3.54

Note: Number of observations in parenthesis. Significant level: *p<0.1, **p<0.05, ***p<0.01
Source: Author, (2021)

Figure 6.2 summarises the prevalence of child malnutrition in the sample. About 39% of children (1665) in the sampled households faced a particular anthropometric deficit. The results showed that wasted children accounted for 24% of the malnourished children in the sample. Underweight children accounted for one in four malnourished children, while one in three children of sampled smallholders was affected by chronic malnutrition (i.e., stunting). Only 13% and seven percent of the total malnourished children (737) were overweight and stunted-overweigh, respectively.

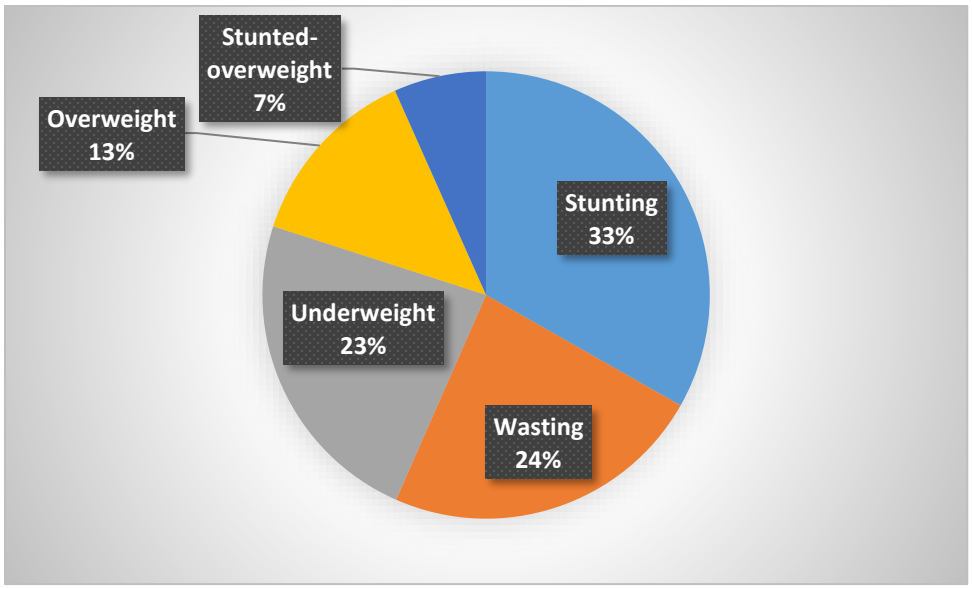


Figure 6.2: Descriptive summary of child anthropometric outcomes
Note: Children facing anthropometric deficits with sampled households (n=652)
Source: Author, (2021)

Table 6.5 summarises Spearman's correlation coefficients between binomial anthropometry and categorical food security measures by location of the sample households. Household food insecurity through FSI had a significant positive association with child stunting. However, food secure households with high HDDS, FCS and LCS were negatively correlated with child stunting. Increased consumption of quality and diverse diets in households was positively associated with adequate nutrient intake, reducing children's exposure to malnutrition (Thorne-Lyman et al., 2010). Household food security measured using FCS and LCS was negatively correlated with the underweight children. Households with high asset ownership were more likely to expose children

to the risk of being overweight and stunted-overweight. Food secure sampled households with high HDDS and FCS were negatively correlated with stunted children in rural areas. Food secure households with high FCS and assets had a negative relationship with children being overweight in rural areas. We estimated the relationship between child malnutrition and household food security for urban sampled households but the associations were not statistically significant at five percent.

Table 6.5: Spearman rho's correlation between child malnutrition and food security (binary) in the sample

		Anthropometric deficits measure				
		Stunted	Wasted	Underweight	Overweight	Stunted-overweight
Classified food security measures for all samples	FSI	-0.07*	0.01	0.04	0.01	-0.00
	Food expenditure share	0.00	0.00	-0.03	0.00	0.04
	HDDS	-0.10*	-0.02	-0.03	-0.05	-0.04
	FCS	-0.09*	-0.01	-0.05*	0.02	-0.00
	Asset number	0.04	0.03	0.01	-0.09*	-0.07*
	LCS	-0.06*	-0.01	-0.07*	-0.04	-0.03
Classified food security measures for samples in rural area	FSI	-0.04	-0.01	-0.02	-0.07	-0.03
	Food expenditure share	0.02	-0.02	0.03	-0.03	-0.06
	HDDS	-0.09*	-0.02	0.01	0.05	0.02
	FCS	-0.09*	0.03	-0.03	-0.09*	-0.04
	Asset number	-0.01	-0.05	0.03	-0.08*	-0.08*
	LCS	-0.005	-0.01	-0.01	0.02	0.01
Classified food security measures for samples in urban area	FSI	-0.01	-0.03	0.01	-0.05	-0.11
	Food expenditure share	-0.06	-0.04	-0.03	-0.01	-0.08
	HDDS	-0.06	-0.05	-0.02	-0.02	-0.01
	FCS	0.07	-0.02	0.02	-0.04	-0.05
	Asset number	0.04	0.07	0.01	-0.001	0.01
	LCS	-0.04	-0.01	0.04	-0.08	-0.05

Note: * the coefficient was significant at the 0.05 level
Source: Author, (2021)

Table 6.6 presents the prevalence of child malnutrition across food insecurity outcomes. The results showed that moderately and severely food insecure households for FSI had at least 20% stunted, 13% wasted, 14% underweight, six percent overweight, and three percent stunted-overweight children. Households who spent less than half their expenditure on food had a higher prevalence of stunting (23.48%), wasting (14.60%), underweight (17.05%), overweight (9.33%) and stunted-overweight (4.45%) among children. While low food expenditure shares would likely indicate food security, households do not consume some purchased food due to loss, waste, diseases and theft, compromising child nutrition. With these factors, accessing food from

household income with high purchasing power does not necessarily translate to food utilisation and nutritional improvements. The prevalence of child stunting, wasting, overweight and stunted-overweight was higher among inadequate dietary diverse households than those with higher HDDS. Households with low diverse diets become susceptible to imbalance or insufficient macro and micronutrient intakes, which cause poor nutritional consequences. The proportions of child stunting (13%), underweight (12%), overweight (6%) and stunted-overweight (4%) were lower among households with acceptable FCS compared to a household with a low FCS. Many children from food-insecure households (with low FCS) were generally stunted, wasted, underweight and overweight.

Households who owned more than ten assets had a low prevalence of child stunting (18.88%), overweight (7%) and stunted-overweight (3%) compared to those with less than ten assets. The proportions of child stunting (18%) and underweight (13%) were lower among households with diverse livelihood coping strategies. Although malnourished children were found among households with low food expenditure shares, child malnutrition was lower among more food secure households.

Table 6.6: Proportion of malnourished children across food insecurity (level) outcomes

	Stunted	Wasted	Underweight	Overweight	stunted-overweight	Observation
FSI						
Food secure	16%	16%	10%	11%	7%	90
Marginal food secure	17%	13%	13%	6%	3%	385
Moderately food insecure	20%	14%	15%	10%	3%	671
Severely food secure	25%	16%	16%	7%	4%	248
Food expenditure share						
Less than 50%	23%	15%	17%	9%	4%	393
50 – 64%	14%	12%	11%	5%	1%	194
65 -74%	14%	16%	14%	8%	1%	264
Greater than 74%	22%	14%	13%	9%	6%	543
HDDS						
Adequately diverse diet	24%	15%	15%	10%	5%	599
Moderately diverse diet	20%	13%	15%	7%	2%	542
Inadequately diverse diet	11%	14%	11%	7%	4%	253
FCS						
Acceptance	13%	15%	12%	6%	4%	339
Borderline	22%	14%	14%	9%	4%	704
Poor	23%	14%	17%	8%	3%	351
Asset ownership						
High	19%	14%	14%	7%	3%	1029
Medium	24%	12%	17%	13%	5%	191
Low	21%	19%	13%	13%	7%	164
LCS						

None	18%	15%	13%	9%	4%	1061
Stress	30%	10%	22%	7%	4%	147
Crisis	16%	15%	15%	6%	3%	155
Emergency	41%	14%	23%	5%	0%	31

Source: Author, (2021)

6.5.1 Regression results of child malnutrition across food insecurity levels

The regression results in coefficient plots reported and identified each food insecurity (level) indicator status connecting child anthropometric growth failures. The coefficient plots were derived from the RE logistic regression results (Table A9 in the appendix). The first levels of each food insecurity outcome were considered the reference category to interpret the regression results. The RE logistic regression results for binary-unit food security explanatory variables (Table A12 in the appendix) showed similar nutrition results from categorical-unit food security measures.

Figure 6.3 presents the coefficient plot for the association between food insecurity levels and the prevalence of child stunting. The results showed that the risk of child stunting was significant and likely decreased by 42% among households with moderate food expenditure shares. Sampled households could spend between 50% – 64% of their income to purchase food and use it for nutritional benefits may likely reduce the risk of stunting in children. The result implied that moderate food expenditure shares could likely enhance child nutrition if households still have a mild percentage of their income to pay for non-food items to improve nutrition. On the other hand, child stunting was significant and likely increased among households with inadequate dietary diversity. Households under stress and emergency levels of LCS were 67% and 107% (respectively) more likely to have stunted children. The results implied that the risk of child stunting increased when households were food insecure, as indicated by high food expenditure shares, low HDDSs and low LCSs.

Our results were consistent with most studies in Africa that found that child stunting was significant and likely increased in food-insecure households (Roba et al., 2019; Drysdale et al., 2020; Harper et al., 2022a; 2022b; Chegere & Stage, 2020; Khamis et al. 2019).

After controlling for socioeconomic characteristics (Table A10 in the appendix), households with borderline FCS were more likely to have stunted children than households with acceptable FCSs. Households that held community-distributed land against inherited land were less likely to have

stunted children. Children from households holding formal land certificates were less likely to be stunted than those without land documents. This result was consistent with the findings of Ibrahim et al. (2022), who reported formal land certificate holders had less chance of having stunted children. Children from households with larger family sizes were more likely to be stunted as high demand for food by large family could limit quality food consumption. Finally, households who were a member of cooperatives and received remittances were less likely to have stunted children. While remittances may ease farmers' financial constraints, cooperatives and producer organisations may likely raise farmers' potential for bargaining positions and increase access to training input and output markets (FAO et al., 2022), enhancing household income and improving food security and nutrition. Therefore, severe food insecurity in terms of low food diversity or quality and food resource scarcity relative to food price likely increased the risk of stunting in children. Children from rural sampled households with inadequate diverse diets, borderline FCS and inadequate LCS were more likely to be stunted (Table A11 in the appendix).

Figure 6.3: Coefficient plot between food security and stunted children in sampled households
Note: Significant level: ***p<0.01, **p<0.05, *p<0.1. ref. is reference level. Number of observations: 1313.
Source: Author, (2021)

Figure 6.4 presents the coefficient plot for the relationship between food insecurity levels and the prevalence of child wasting. There was a higher chance of child wasting among moderately and

severely food insecure households than among food secure households. The risk of child wasting was likely increased by 98% among households with high food expenditure shares. Households who spend over 65% of their income on food may likely have income reduction to access non-food items to improve food consumption and quality consumed. Also, households with borderline and poor food consumption scores were more likely to have wasted children than those with acceptable food consumption scores. The results implied that food security measured as low food expenditure shares and high FSI (measured by consolidated approach to reporting indicators of food security CARI) and high FCSs were less likely to have wasted children. These results confirm the findings of Ajao et al. (2010); Belayneh et al., (2020); Makamto Sobgui et al., (2018); Motbainor et al., (2015); Rose et al. (2015); Sambu, (2013); Wolde et al., (2015) that reported a positive association between child wasting and household food insecurity (especially from moderate level) in Africa.

After adjusting for the socioeconomic features (Table A10 in the appendix), food insecure households (measured by the FSI and poor FCS) were more likely to have wasted children than food secure households. Cooperative membership and household size were significant control variables and likely decreased child wasting (Table A9 in the appendix). Like regression results for stunted children, we expect additional household members will likely increase household expenditure on the least expensive/cheap food, increasing chronic malnutrition in children. Our results prove otherwise, as large households (with fewer dependents) may likely promote the division of labour, which increases output and reduces wastage and unit production cost. As a result, children in large households may not likely be wasted (acute malnutrition) but may likely face stunting (chronic malnutrition). Rural sampled households with high food expenditure share and low FCSs were more likely to have wasted children (Table A11 in the appendix). Urban sampled households with inadequate diverse diets were more likely to have wasted children (Table A10 in the appendix).

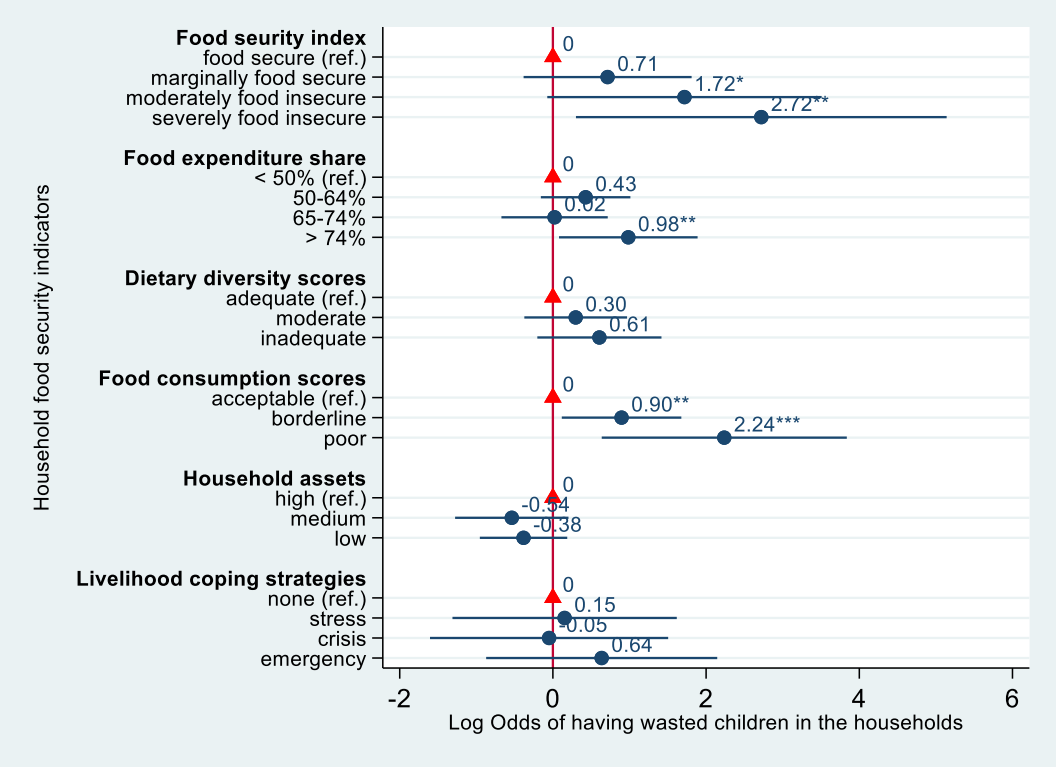


Figure 6.4: Coefficient plot between food security and wasted children in sampled households
Note: Significant level: ***p<0.01, **p<0.05, *p<0.1. ref. is reference level. Number of observations: 1090.
Source: Author, (2021)

Figure 6.5 reveals the coefficient plot for the association between food insecurity levels and the prevalence of underweight children. The results showed that the risk of children being underweight was significant and likely increased by 66% among households with high food expenditure share than households with low food expenditure share. Children were at higher risk of being underweight when households budgeted greater than 64% on food. Such households have little income to meet the nutrition-enhancing non-food items, likely affecting child nutritional outcomes. Our results were similar to Berra (2020); Betebo et al., (2017); Chegere & Stage, (2020); Hatløy et al., (2000); Khamis et al., (2019); Mulu & Mengistie (2017); Sambu, (2013) and Wolde et al., (2015) that reported that body weight for height dropped for children living in households that lack adequate resources to access nutritious and diverse food.

After controlling for the socioeconomic factors (Table A10 in the appendix), food-insecure households with low levels of FSI and high food expenditure share were more likely to have underweight children than food secure households. Children from household heads who acquired land through community distribution were less likely to be underweight than those with family-inherited land. The risk of underweight children was likely decreased among households who

earned off-farm income and had more farming experience (with household head age). Household heads with off-farm incomes and older to optimise farm incomes can likely improve nutritious food consumption and reduce the risk of being underweight in children. Rural households with a high food expenditure share were more likely to have underweight children (Table A11 in the appendix). Children from urban sampled households with low FCS were more likely to be underweight (Table A11 in the appendix).

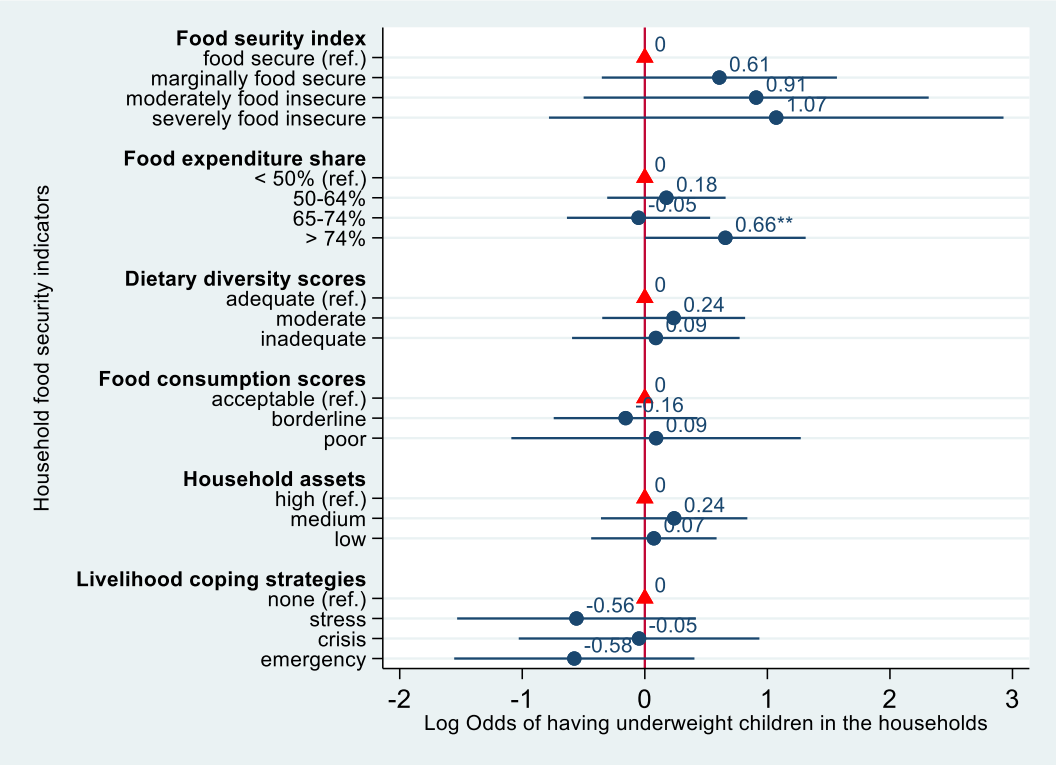


Figure 6.5: Coefficient plot between food security and underweight children in sampled households
Note: Significant level: ***p<0.01, **p<0.05, *p<0.1. ref. is reference level. Number of observations: 1384.
Source: Author, (2021)

Figure 6.6 presents the coefficient plot for the association between food insecurity levels and the prevalence of overweight children. The results showed that households with less than three assets were less likely to have overweight children than households with more than ten assets. The results implied that households with low assets were likely to be poor and food insecure. Their low income level made them vulnerable to food insecurity and undernourishment. However, children in poor households could become overweight due to an intake of high-energy, nutrient-poor, cheap foods. Ecker et al., (2016) have provided similar evidence, which confirmed the odds of overweight in children living in households that consume high-energy food items in Egypt.

We found similar results (Table A10 in the appendix) after controlling for household socioeconomic and demographic characteristics. While households who owned land and earned off-farm income were likely to have overweight children, households in rural areas were less likely to have overweight children than urban households. Children from households who acquired land through community distribution and rentals were less likely to be overweight than those with family inherited land. Households that earned off-farm income were less likely to have overweight children. Households that earn off-farm income can likely buy various diets, reducing the risk of consuming energy-dense food with more sugar and salt, which likely increases child overweight (Levine, 2011). Households with more than three assets in rural areas were less likely to have overweight children than urban sampled households (Table A10 in the appendix). However, households with higher FCS in urban areas were less likely to have overweight children (Table A11 in the appendix). The results implied that nutrition transition in the urban areas might be related to households and their children's sedentary and poor food consumption lifestyles, limiting the possibility of burning the excess weight gained from the consumption of energy-dense food (Nettle et al., 2017). Rural areas in our study represent low-income settings, where the cheapest energy-dense food consumption in the households may not be sufficient to cause overweight in children (Maitra, 2018).

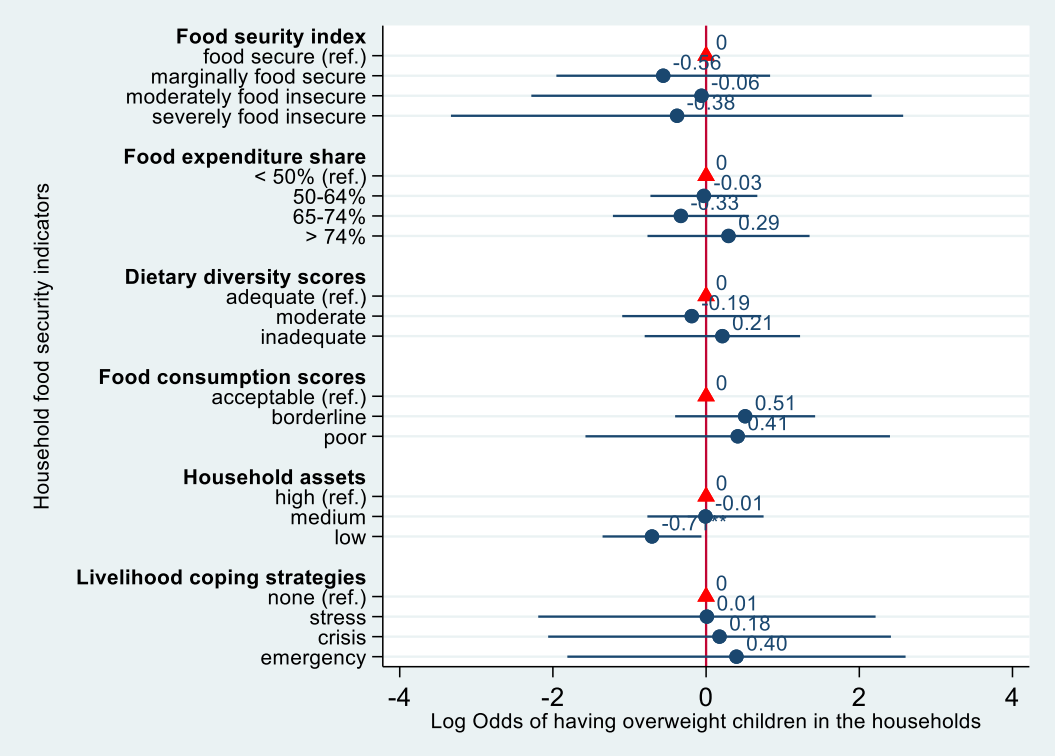


Figure 6.6: Coefficient plot of between food security and overweight children in sampled households
Note: Significant level: ***p<0.01, **p<0.05, *p<0.1. ref. is reference level. Number of observations: 1039.
Source: Author, (2021)

Figure 6.7 presents the coefficient plot for the association between food insecurity levels and stunted-overweight children. This is a peculiar case that lacks evidence from existing literature. Moderate and high food expenditure shares were the only significant food insecurity levels affecting stunted-overweight children. The risk of stunted-overweight among children decreased by 180.06% and 212.73% for households who had moderate (50% - 64% of income spent on food) and high (65%-74% income spent on food) food expenditure shares compared to households who spent less than 50% of their income on food. The results might likely be attributed to the low proportion of stunted-overweight children in sampled households or due to the extent of household poverty. Poor households (with low income) would either allocate a low portion of their income to accessing cheaper energy-dense food or spend less on food varieties. A higher intake of poorly diverse and quality food may likely expose children to height failure and weight disorder risks. In contrast, poor households that spend less on food varieties were likely vulnerable to stunted-overweight children.

After accounting for socioeconomic factors, households with less than three assets were more likely to have stunted-overweight children (Table A10 in the appendix). The least asset ownership may likely give households a low resilience to cope with food crises (Mawoko et al., 2018). Children from farmers with community distributed land (relative to family inherited land) were less likely to be stunted-overweight. However, stunted-overweight in children was more likely to increase with increased earned off-farm income. Households who earn off-farm income may likely reduce the risk of stunted-overweight in children by accounting for different food items from different food groups in proportion to enhance nutritious food consumption. Children from rural sampled households with high food expenditure share and less than three assets were likelier to suffer from stunting and overweight (Table A11 in the appendix).

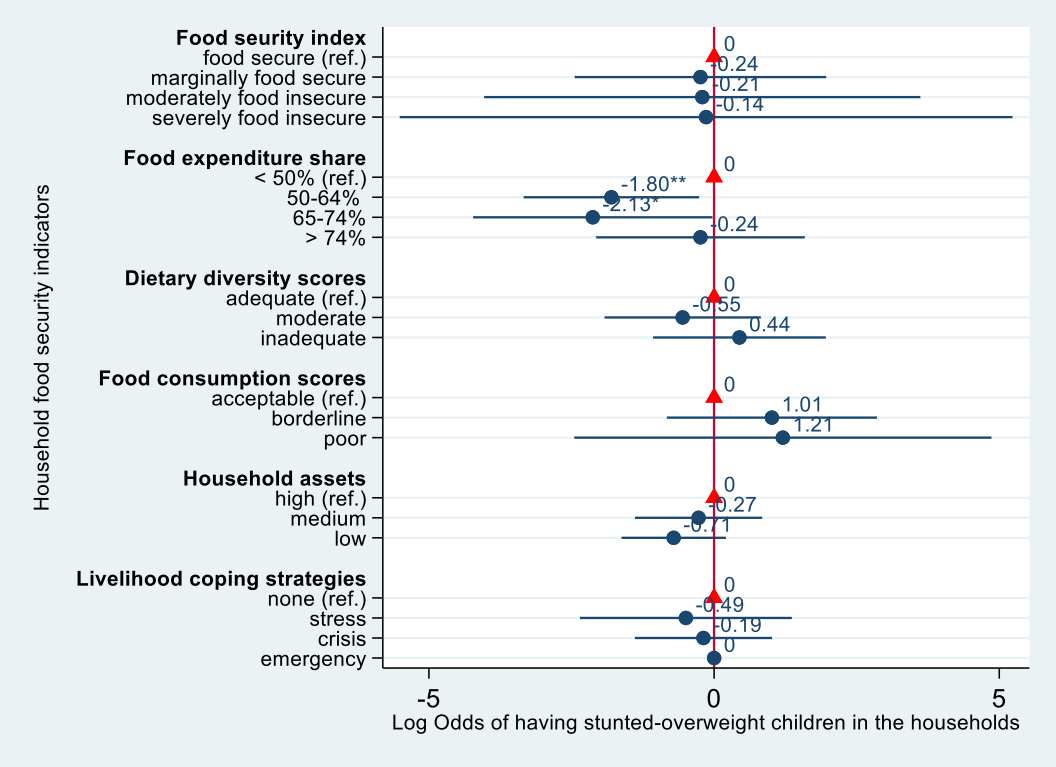


Figure 6.7: Coefficient plot between food security and stunted-overweight children in sampled households
Note: Significant level: ***p<0.01, **p<0.05, *p<0.1. ref. is reference level. Number of observations: 979.
Source: Author, (2021)

Our results for stunting, wasting and underweight were confirmed in the study by Wolde et al., (2015). The results of Ecker et al., (2016) supported our findings that the household with a high budget for energy-dense food had a chance of having overweight children (Ecker et al., 2016).

4.1.1 The relationship between food security (binary) and anthropometric child nutrition

Table 6.5 presents the relationship between anthropometric child nutrition and food security in binary classification units. Few food security indicators in binary units were statistically significant to associate with child nutrition. The results revealed that households who were food secure by high FCS were less likely to have a stunted child. The significant binary-unit FCS result was similar to the result from categorical-unit FCS against child nutrition after controlling for covariates (Table A9). While no binary-unit food security indicators were statistically significant in linking child wasting and underweight, households with more assets were less likely to have children with overweight and stunted-overweight children. However, after controlling for covariates, only households that were food secure by high household assets were statistically significant to have overweight and stunted-overweight children. The resultimplied that the binary-

unit food security indicators only simplified analysis with child nutrition but did not make results robust like categorical-unit food security indicators.

Some other covariates were statistically significant in explaining child nutrition (Table A12). Households with rented and community distributed land were more likely to have stunted, underweight and overweight children than the reference group (i.e., purchased landholders). The panel regression for binary-unit food security chose purchased land as a reference group, making the results difficult to compare with categorical-unit food security results. Adult and female households with low household sizes were less likely to increase child underweight and overweight. Households with many plots, low off-farm income and never belonged to a cooperative society were more likely to have stunted, wasted, underweight and overweight children. The covariates were in line with the results from categorical-unit food security indicators (Table A9).

Table 6.7: Regression results of the relationship between food security (binary) and child nutrition

Variable (binary units)	Stunting in odd ratio (std error)	Wasting in odd ratio (std error)	Underweight in odd ratio (std error)	Overweight in odd ratio (std error)	Stunted-overweight in odd ratio (std error)
FSI	1.28 (0.31)	0.91 (0.32)	0.91 (0.25)	0.81 (0.34)	1.72 (1.06)
Food expenditure share	1.08 (0.18)	0.94 (0.20)	1.20 (0.21)	1.08 (0.29)	0.63 (0.27)
HDDS	1.54 (0.44)	1.30 (0.43)	1.28 (0.37)	0.84 (0.36)	0.67 (0.41)
FCS	0.50** (0.15)	1.49 (0.60)	0.90 (0.30)	0.78 (0.40)	0.56 (0.41)
Household assets	0.96 (0.21)	0.64 (0.18)	1.10 (0.27)	0.59* (0.18)	0.47* (0.21)
LCS	0.96 (0.21)	0.90 (0.25)	0.85 (0.19)	1.49 (0.59)	1.45 (0.92)
Constant	0.18*** (0.07)	0.17 (0.09)	0.14*** (0.06)	0.12 (0.08)	0.07* (0.07)
Wald Ch12	17.86	4.04	4.72	6.18	5.42
Observation	1313	1090	1384	1039	997

Note: Significant level: *p<0.1, **p<0.05, ***p<0.01, standard errors in parenthesis
Source: Author, (2021)

6.6 Discussion

Food security is multidimensional and its measurement needs multiple indicators that reflect the situation (Hendriks et al., 2016). Anthropometric measures assess the effect of previous food consumption and health but do not tell us much about the quality of the diet, which is necessary for designing interventions (Hendriks et al., 2016). Food consumption accounts for dietary quantity

and quality at individual and household levels (Msaki & Hendriks, 2013). Unfortunately, the data available did not include individual food intake indicators and had to rely on household food intake recall data. Therefore, the study investigated the relationship of household food consumption indicators across child nutrition outcomes, controlling for land tenure. Such insight could inform the design of interventions and provide evidence-based support for land reform measures.

This analysis found that high food expenditure shares and low HDDSs and LCSs were more likely to be associated with child stunting. These findings concur with other studies that have shown that the risk of child stunting increases among households that did not have adequate diversity (Belayneh et al., 2021; Chegere & Stage, 2020; Frempong & Annim, 2017; Harper et al., 2022a; Hatløy et al., 2000; Khamis et al., 2019; M'Kaibi et al., 2017; Roba et al., 2019; Sambu, 2013). Harper et al. (2022a) found similar results, namely that food expenditure below the poverty line was related to child stunting. However, Bukania et al. (2014) and Harper et al. (2022b) found no significant relationship between child dietary diversity and child stunting.

However, this study also found that household with low expenditure shares were also more likely have stunted-overweight children, showing that chronic malnutrition, expressed as stunting may be more strongly influenced by dietary composition and the lack of dietary diversity rather than a lack of food *per se*. These findings concur with those of Hendriks et al. (2016) for households in some of South Africa's poorest communities. This result may indicate that the opportunities that secure land tenure brings, such as in improved incomes and crop diversification may have a positive influence on reducing malnourishment. However, more detailed analysis of individual food intake is needed to confirm this relationship. Unfortunately, this data was not available for the data on which this analysis was based.

This analysis found that food-insecure households with high food expenditure shares and poor FCSs were more likely to have a wasted child but no relationship was found between wasting and the HDDS. Likewise, as expected, the study also found that the risk of children being underweight significantly increased among households with high food expenditure shares (food insecurity). Roba et al. (2019) also found a positive association between FCSs and infant wasting, which is consistent with this study's nutrition findings.

Households with fewer than three assets (extremely poor) were also less likely to have overweight children. Households in rural areas were less likely to have overweight children than those in urban areas. This may be explained by aspects of lifestyle, food environments and physical activity patterns in rural and urban contexts.

6.7 Summary

The results showed that high food insecurity positively impacted child malnutrition. Children from households with high food expenditure shares and low HDDSs and LCSs were more likely to be stunted. Food-insecure households with high food expenditure shares and poor FCSs were more likely to have wasted children. The risk of children being underweight significantly increased among households with high food expenditure shares (food-insecure). Households with less than three assets were less likely to have overweight children. Households in rural areas were less likely to have overweight children than those in urban areas. Farmers with low expenditure shares may likely have stunted and overweight children.

The result of this study contributed to the existing literature by evaluating the relationship between food security and child nutrition in Nigeria, where most agricultural policies address hunger without addressing issues of malnutrition. Child malnutrition in Nigeria (as with many other countries in sub-Sahara Africa) has been attributed to multi-sectoral limiting factors such as food insecurity, a lack of adequate breastfeeding and caring practices, disease, nutrition education, poverty, socioeconomic status, water, sanitation and hygiene (WASH) (FMARD, 2017). However, this study found that the food expenditure share, dietary diversity, livelihood coping strategy and asset ownership instead of food security index (CARI) have the potential to explain child stunting, wasting, underweight and overweight. These results showed food security indicators through expanding of food expenditure share, dietary diversity, livelihood coping strategies and asset ownership of smallholder farmers are important to addressing child malnutrition.

There was no statistically significant relationship between the presence of stunted children and the food security measures of CARI, food consumption scores and household assets. The first reason for the result is that the CARI, FCS and household assets are measured at household levels and not measured for individuals in the households. The household food security measures may not guarantee the food security of household members, whose individual food security data was not available. For example, resources (including food) may not necessarily be appropriately distributed

among household members hindering nutrition. Collecting individual food security data at individual levels (such as the minimum dietary intakes for women and children) could provide deeper insight into child stunting. Secondly, the results that food expenditure share, diverse diets and livelihood coping strategy were more likely to reduce child stunting confirm the effect of poverty on child malnutrition. Literature has noted that food insecurity is connected to poverty of material and structural resources to access food (Hendriks, 2015). This view was first explained by Sen (1981) that people experience food deprivation not because of lack of market food supply but because of inadequate income and other resources to access food. Extended periods of poverty, lack of assets and inadequate access to productive and financial resources could cause structural food insecurity, worsening individual nutritional outcomes (Pangaribowo et al., 2013; Hendriks, 2015).

Household dietary diversity, household assets and livelihood coping strategies were not statistically and significantly linked with the presence of wasted children. The results can be connected to other factors relating to food utilisation of food security dimensions that were not able to be evaluated from the available data. Household assets and livelihood coping strategies ensure the stability of household food security, while diverse dietary consumption measures are an aspect of food utilisation. This study did not control for the confounding effects of health status in the relationship between food security and nutritional status.

The association between food security (measures in CARI, HDDS, FCS, household assets and LCS) and the presence of underweight children were not statistically significant. Only the food expenditure share was statistically significant in determining the presence of underweight children. Some households may not meet the total energy intake due to severe poverty, which increases the likelihood of children being underweight. This study did not control for other food utilisation elements such as access to clean water, hygiene and sanitation practices, which can influence the estimated relationship between food security measures and underweight children due to a lack of data.. The relationship between the selected food security measures except household assets and overweight children, was not statistically significant. The estimates that link food security to overweight may be statistically insignificant because of the underrepresentation (i.e., 8%) of overweight children in the sample. Also, overweight cases have been attributed to eating habits and lifestyle (i.e., physical activity) more than with food security measures in CARI, food

expenditure share, HDDS, FCS and LCS. However, households that have limited assets are more likely to consume less expensive and more energy-dense foods to maintain energy intake at less cost. Such households may largely consume refined grains and added sugar.

Of the selected six food security measures, only the food expenditure share measure of food security had a positive significant association with the presence of stunted-overweight children. Again, the lack of association may be due to the low proportion of overweight children in the sample.

Chapter 7 : Summary, conclusions and recommendations

7.1 Synthesis

The general objective of this study was to examine the relationship between land tenure, household food security and children's nutrition among smallholders in Nigeria. The main objective had three sub-objectives that aimed to:

i) evaluate the effect of land tenure on food security among the sampled smallholder farm households,
ii) examine the effect of land tenure on malnutrition of children under five years of age among sampled smallholder farm households and
iii) assess the relationship between food insecurity and children's nutritional status under five years of age among sampled smallholder farm households

These three sub-objectives were addressed in Chapters four, five and six. This study compared food security and nutrition between holders and non-holders of each (formal or informal) land document, and between holders and non-holders of each land acquisition mode. The study also examined whether children from food-insecure households were more likely to be stunted, wasted, underweight and overweight than children of food secure households. Table 7.1 summarises the methods adopted and findings for each sub-objective.

The analysis presented in Chapter four showed that smallholders that acquired plots by family inheritance were likely to hold more assets and consume more diverse diets but have low food consumption scores (i.e., low food quality) than households without family inherited land. Households that accessed free land had lower HDDSs than non-free landholders. The holders of free land may have lacked the incentives to invest in crop diversification and improved technologies that could increase dietary diversity due to the lack of formal certification of the land. When land is freely accessible without any regulation or control, it can lead to multiple households competing for limited agricultural resources. This competition can result in overutilization of land, leading to soil degradation, reduced crop productivity, and limited availability of diverse agricultural produce. As a result, households may have limited access to a variety of nutritious foods, leading to lower dietary diversity.

Although the Nigerian government instituted collecting formal land certificates through the 1978 LUA, this study found that formal land certificates did not significantly promote food security. However, smallholders who held informal land documents were more likely to consume diverse diets. Holders of informal land documents can engage in farm diversification and have the potential to access informal loans and initiate land transactions to enhance incomes and improve food security. The holders of informal documents also had lower food expenditure shares and adopted more livelihood coping strategies. The landholder households with informal documents were food secure due to the high purchasing power in their income to diversify and access more nutritious food.

Theory predicted that formal land certificates were more substantial forms of tenure security than holding informal or no documents. Poor smallholders in the sample predominantly held informal land or had no documents to secure their land rights. Smallholders with informal land documents were more food secure than those that held formal land certificates securing 99-year use rights and consenting to the government before transferring land rights. More female households accessed land through rentals than males. Households on purchased and rented land were less food secure due to the challenges connected to the land rights transfer. These challenges include limited lease periods of land use rights and waiting time for the government to approve land transactions. The study found that inheriting land was common among smallholders and promoted the HDDSs more than the dietary quality derived from the FCSs. The FCSs captured not only dietary diversity and food frequency but also the relative nutritional (or weighing) importance of different food groups. Surprisingly, farmers perceived they could use the land to acquire loans even if formal credit institutions demanded formal certificates as collateral. This perception may reflect the reliance on informal sector loans that may not require such certificates as collateral. The informal loans may not support long-term livelihood due to higher lending charges and poor borrowing supervision. The results rejected the null hypothesis that landholders with informal documents were less likely to be food secure than those without land documents.

Chapter five examined the effects of smallholder land tenure on child malnutrition. Children of smallholders that acquired land without documentation may face a higher likelihood of malnutrition. There was a low proportion of malnourished children in the rented landholder households than in the purchased landholder households. Households on family-inherited and free

land were likelier to have stunted, underweight, overweight and stunted-overweight children. Households that held community-distributed land were less likely to have stunted, overweight and underweight children than households without community distributed land. The findings suggest community land allocation can enhance smallholder farmland access and improve child nutrition. The individual use of community-distributed farmland provides a sense of tenure and food security from customary norms and networks that protect land rights and entitlements.

Holding formal land certificates seemed to reduce stunting among children. Children of formal land certificate holders had a 13% chance of being stunted more than children of informal or no document holders. Children of the holders of informal documents were seven and five percent less likely to be wasted and underweight than children of holders that had no informal documents. The results suggested that smallholder land tenure had a small but relevant positive effect on child nutrition. The results confirmed the second hypothesis that children of smallholders who acquired land with formal certificates were less likely to be stunted than those with no formal land certificate. In contrast, children from landholders with informal documents were less likely to be wasted and underweight compared to landholders with no and documents.

Chapter six assessed children's nutrition outcomes across the household food insecurity indicators. Children in households that spent more than half their income on food and had low dietary diversity and livelihood coping strategies were more likely to be stunted, wasted and underweight than children of food insecure households. Households with limited assets and proportionally high food expenditure shares were less likely to have overweight children than households with high assets and low food expenditure share. Poor households (with low assets and income) spent more on food, reducing the diversity and quality of their diets and their children's nutrition. Children in rural areas were less likely to be overweight than those in urban areas. Rural households' relatively low assets and incomes did not facilitate access to energy-dense foods as in urban areas. Urban children's parents may have had more resources to purchase energy-dense food and greater access to processed foods. However, urban lifestyles tend to be more sedentary.

After controlling for socioeconomic and demographic properties, the regression results showed that children from households that received remittances, earned off-farm incomes and participated in cooperative society were less likely to be stunted, wasted and underweight. An increase in household incomes (via remittances, off-farm labour and cooperative credit) enhanced access to

and consumption of nutritious food and improved children's nutrition. The findings suggest that children from severely food-insecure households faced a higher risk of undernutrition (stunting, wasting and underweight). These results confirmed the third hypothesis that children from food-insecure households were more likely to be stunted, wasted, underweight and overweight than children of food secure households.

Table 7.1: Summary table of the thesis from objectives to findings

No	Objective	Hypothesis	Method	Dependent	Smallholder land tenure indicators						
.	.	.	.	.	Land acquisition mode					Land right documentation	
1	To evaluate the effect of smallholder land tenure on household food security	H_1: Sampled households with weak tenure security and low access to land are more likely to have low levels of food security	Flexible Conditional DID and Generalised Ordered-logistic regression (*Gologit*) models	HH Food security indicators	Inherited land vs no inherited land	Purchased land vs no purchased land	Community distributed land vs no community distributed land	Free charge land vs no free charge land	Rented land vs no rented land	Informal documents vs no land document	Formal certificates vs no land document
				CARI	Low	.	.	.	.	Low	.
				Food expenditure share	.	.	.	.	.	High	.
				HDDS	Adequate	.	.	Inadequate	.	Adequate	.
				FCS	Poor	.	.	.	.	Poor	.
				Asset	More	.	.	.	.	Less	.
				LCS	Low	.	.	.	.	More	.
2	To examine the nutritional status of children under five years of age across the smallholder land tenure	Children of sampled households with weak land tenure are more likely to be malnourished	Flexible Conditional DID technique and FE-logistic regression model	Child anthropometric deficits	Inherited land	Purchased land	Community distributed land	Free charge land	Rented land	Informal documents	Formal certificates
				Stunting	More	.	Less	.	.	.	More
				Wasting	.	.	.	.	.	Less	.
				Underweight	More	.	Less	.	.	Less	.
				Overweight	More	.	Less		.	.	.
				Stunted-overweight	.	.	.	More	.	.	.
No	Objective	Hypothesis	Method	Dependent	Household food security indicators						
3	To assess the effects of household food insecurity (FI) on child nutritional status	Children from food-insecure households were more likely to be malnourished	Multi-level RE-logistic regression model	Child anthropometric deficit	CARI	Food expenditure share	HDDS	FCS	Asset	LCS	.
				Stunting	.	very High	Inadequate	Borderline	Limited	Limited	.
				Wasting	Severe FI	very High	.	Poor	.	.	.
				Underweight	Severe FI	very High	.	.	.	Limited	.
				Overweight	.	.	.	.	Limited	.	.
				Stunted-overweight	.	High	.	.	Limited	.	.

Note: vs represents versus

7.2 Conclusions

Secure smallholder land rights can improve food security and nutrition. However, different land tenure systems affected household food security and children's nutrition differently. Holding formal or informal certification of land rights supported food security and child nutrition. Smallholders' livelihood coping strategies, dietary diversity and food expenditure shares improved when they held informal land documents. Furthermore, households that acquired land via family inheritance were more food secure with high diverse food consumption but were less food secure with low food consumption scores.

In the descriptive results, most sampled household heads were farmers who acquired farmland through the customary inheritance rather than other modes of land acquisition modes. The inherited landholders became food secure when they chose to make productivity enhancing investments and produce more crops on inherited land that give them a strong sense of ownership (perceiving they had the rights to sell, rent, bequeath and fallow and use as collateral) than other modes of land acquisition. Lack of legal titles (for purchased and rented landholders) and of individualisation (for community distributed and free land users) may limit the households' sense of ownership compared to inherited landholders. Households who perceived they possessed a bundle of land rights through family inheritance will be motivated to invest in farm improvements, leading to enhanced productivity and food security than other modes of land acquisition.

Farmers who do not own land and do not pay rent to landlords for using land were classified as rent-free land users. The lack of secure title may limit investment in diversifying crops and investing in land improvements as they know that landlords could take their land at any time. With limited production diversity and productive investments, the free land users may earn lower incomes, constraining dietary diversification.

The food security and nutrition analyses of the sampled farmers who benefited from the customary inheritance reflected conflict results. Inherited landholders were incentivised to produce more crops to enhance food security rather than meeting their household nutritional needs. The surprising results can be attributed to the fact that land ownership through family inheritance is controlled by customary land tenure authorities. Countries dominated by inherited landholders, who were not recognised under formal land titles, like Nigeria's 1978 LUA, may deny inherited

landholders the opportunities of accessing formal credit, contract schemes and public subsidized inputs, hindering their possibility of practicing nutrition-sensitive agriculture. Reforming formal land title to recongnised family inheritance would motivate inherited landholders to invest in nutrition-sensitive agriculture and open their potential for consumption of nutritious diets.

Children from households with formal land certificates were less likely to be stunted, while children from households holding informal land documents were less likely to be wasted and underweight compared to children of landholders without land documents. Children from homes with community-distributed land were less likely to be undernourished (i.e., stunting, wasting & underweight) and overweight than children from households who had no community distributed land.

Finally, children from severely food-insecure households faced a higher risk of undernutrition (including stunting, wasting and being underweight) and less of being overweight in Nigeria. Severely food insecure households had inadequate dietary diversity scores, borderline/poor food consumption scores, limited livelihood coping strategies and low household asset ownership. It is important to note that some estimates of RE regression for food security-nutrition relationship analysis were not significant due to the influence of other factors besides food security. This study found that some socioeconomic properties such as age, remittance, household size, residential location (rural-urban) and cooperative membership of household heads strongly associated with nutrition. These findings confirmed that food security only is not sufficient to address malnutrition.

7.3 Policy implications and recommendations

Formal tenure documentation facilitates access to formal loans for improving farm inputs investment. However, the existing 1978 Nigerian Land Use Act (LUA) does not support formal tenure rights for smallholders. The Act can embrace inclusiveness to strengthen smallholder land rights and facilitate land dispute resolution by promoting land right documentation and strengthening institutional capacities at the local level. Smallholder farmers should be consulted to register their interests in revising 1978 LUA.

Most smallholders acquired land with informal documents. Formalisation of informal land documents through a low-cost titling system should be promoted. The Nigerian government should introduce a formal land policy framework at the national, state and local levels that support the

low-cost registration of undocumented and informal land – irrespective of the mode of acquisition – to secure the right of occupancy and use. The government should replace the existing manual land registry with a blockchain digital land registry across the state and local government councils to strengthen the confidence of stakeholders in land documents for land transactions. In addition, the Nigerian state and local governments should sponsor extension services and broadcast media programmes to inform smallholders about the importance of formally documenting their land.

The National Agricultural Sector for Food Security and Nutrition Strategy (AFSNS) does not mention the role of land tenure. Therefore, the AFSNS should be revised to incorporate the relevant land tenure with formal documentation to promote the nutrition-sensitive agriculture objective among smallholders. Nutrition policy design should be aware that food security only is insufficient to address malnutrition. Other factors need to be considered.

7.4 Study limitations

Food security is a multidimensional concept measured with several internationally recognised indicators. However, this study used available data to capture a limited number of relevant indicators. These thesis findings did not capture indicators like the Coping Strategy Index (CSI), Food Insecurity Experience Scale (FIES), Self-assessed measured of food security (SAFS) and Household Hunger Scale (HHS) due to inadequate information to measure the indicators in the dataset.

It has been acknowledged that most non-experimental studies include possible endogeneity biases. A causal-effect analysis requires a bias-free identification strategy such as a control trial randomisation experiment. This study does not claim causal relationships but focuses on understanding the associations between the underlying variables from survey datasets.

The survey respondents were household heads who reported on the household's food security. The household's food security status was assumed to reflect each member. However, the data did not consider intra-household food allocation and may have overestimated the consumption share of children.

The study used household and individual-level data from Nigeria's GHS. The findings of this study were limited to the microeconomic policy decisions rather than the macro-level phenomenon. This

study did not account for the context of aggregate food security and nutrition at national, regional and global levels.

Most significant estimates for land tenure-food security analysis skewed towards the holders of inherited land than the other land acquisition mode. The matching-based *flexpaneldid* model was adopted to limit the skewed sampled distribution. The skewness can be attributed to the large (50%) sampled farmers acquired land through inheritance, meaning that the remaining (50%) sampled farmers acquired land through rentals, purchased, community distribution land and free land use.

7.5 Recommendations for future research

Further research can replicate this study for other African countries. A comparative study would provide cross-country insights into the relationship of land tenure systems to food security and nutrition, revealing their peculiarities and similarities in Africa and informing national and regional policies. However, as used in this study, surveys for such analyses should include detailed information on the mode of land acquisition and specifics on the type of documentation held to enable such an analysis. Combining land acquisition categories as a variable or a categorical-unit land tenure should also be tested in the future food security studies.

The Nigerian and other governments could consider individual measures of food insecurity in the GHS, such as the minimum adequate dietary recall for children and the women's dietary diversity score. In addition, the impact of policy changes in food security and nutrition should be monitored and evaluated at individual-household levels.

The three-round data used in this study may not account for longer time-variant heterogeneity. Future studies can uncover the time differences in land right documentation across food security and nutrition outcomes using more than three-round or time-series datasets.

Although female landholders acquired more land through rentals and purchases, customary land (from community distribution and family inheritance) is predominant in Nigeria. Therefore, future research in Nigeria and other African countries should examine the gender-based land ownership inequality in customary land rights and explore the factors related to intra-household dynamics, especially women's rights.

Understanding the nutrition of all household members (i.e., children, adults and aged individuals) are relevant. However, this thesis did not analyse the malnutrition of adult and aged individuals due to a lack of adequate information on adult and old nutrition in the LSMS-ISA datasets. Future nutrition surveys on smallholder farmers should consider collecting comprehensive nutrition data that can capture and compare the nutrition of children, adults and aged individuals.

Skewed sample distribution was observed for inherited land. At least half the sampled households held land under family-inherited conditions. The sample was also skewed towards households with no documents as 79% of sampled households held neither informal land documents nor had formal land certificates. Future research should also consider combining land acquisition mode as categorical to see whether the variable transformation can ensure distribution normality.

7.6 Contribution to knowledge

The study is the first to investigate the effect of the mode of land acquisition and land tenure documentation on food security and child nutrition. The study compared food security and nutrition between holders and non-holders of each (formal or informal) land document and between holders and non-holders of each land acquisition mode. The study findings from the disaggregated analyses have significant implications for land tenure policy. The national framework for agriculture, food and nutrition needs to include elements of land ownership and policies must be aligned. The study's findings can inform a review of the Nigerian Land and facilitate dialogue with smallholders regarding land registration and rights documentation constraints.

The main insights and findings gained from using different food security and land tenure indicators are to capture the components of the concepts and reveal specific effects into contexts, which are not possibly achieved using aggregate measures. For example, using land without ownership (i.e., rent or rent-free) has implications for dietary diversity; the rent-free landholders may lack commitment to diversifying crops and investing in land improvements as they know landlords could take their land at any time. Households who acquire land through inheritance have more chances of being food secure but less chance of having well-nourished children. Customary inheritance norms in Nigeria tend to favour male heirs. The findings inform the need for examining sex-disaggregated data.

Although the National Agricultural Technology and Innovation Policy (NATIP) has highlighted the importance of formal land titles, informal land documents are more accessible than formal land certificates to promote food security and nutrition of farm households with no land documents. However, land with informal documents may constrain access to loans. The results inform the need to formalise existing informal land documents and recognise the role of the customary mode of land acquisition among smallholder farmers to support food security and nutrition. These efforts can be extended to other African countries, where informal land tenure predominantly drives household food insecurity and malnutrition. The study's findings can inform a review of the Nigerian Land and facilitate dialogue with smallholders regarding land registration and rights documentation constraints.

Many food security studies use one or two indicators of food security. This study used six food security and five child nutritional indicators. The findings show that land tenure and documentation affect food security and child nutrition indicators in distinct ways. The element of being overweight is not often included in studies of food security in developing countries. However, this study shows the need to have indicators of children overweight in such surveys. This indicator will become more important as food systems in developing countries transform and urbanisation increases. This is a policy-oriented contribution given the current nutrition transitions in terms of lifestyle, diversity and reviving of underutilized and neglected diets.

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Appendix

Table A1: Descriptive statistics of food security (level) across land acquisition type

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

Source: Author, (2021)

Table A2: Descriptive statistics of food security (level) across land right documentation type

Indicators	Sample size		Food insecure households		Vulnerable to food insecurity 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 expenditure share		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

Source: Author, (2021)

Table A3: Average Treatment Effect (ATE) results of the effect of land tenure on food security (level)

	Land acquisition mode					Land documentation type	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
FSI							
Food secure	0.07*** (0.01)	0.01*** (0.02)	-0.06*** (0.01)	0.06*** (0.02)	0.04** (0.02)	0.08*** (0.02)	0.03 (0.02)
Marginal food secure	0.17*** (0.02)	0.03 (0.04)	-0.18*** (0.02)	0.03 (0.04)	0.06* (0.04)	0.06 (0.05)	0.01 (0.03)
Moderately food insecure	-0.10*** (0.03)	-0.03 (0.04)	0.08*** (0.03)	0.01 (0.04)	-0.11*** (0.04)	-0.10** (0.05)	0.03 (0.04)
Severely food insecure	-0.14*** (0.02)	-0.07** (0.03)	0.16*** (0.02)	-0.10*** (0.03)	0.02 (0.03)	0.04 (0.04)	-0.07** (0.03)
Observations	1422	1422	1422	1422	1422	1422	1422
Food expenditure share							
Less than 50%	0.33*** (0.02)	0.29*** (0.04)	-0.36*** (0.02)	0.14*** (0.04)	0.08** (0.04)	0.28*** (0.05)	-0.06* (0.04)
50 – 64%	-0.02 (0.02)	-0.05* (0.03)	-1.52e-04 (0.02)	0.05* (0.03)	0.04 (0.03)	-0.07** (0.03)	0.01 (0.03)
65 – 74%	-0.05*** (0.02)	-0.08*** (0.03)	0.09*** (0.02)	-0.02 (0.03)	-0.08*** (0.03)	-0.09** (0.04)	0.07** (0.03)
Greater than 74%	-0.26*** (0.02)	-0.15*** (0.04)	0.27*** (0.03)	-0.16*** (0.04)	-0.04 (0.04)	-0.13*** (0.05)	0.02 (0.04)
Observations	1434	1434	1434	1434	1434	1434	1434
HDDS							
Adequate	-0.09*** (0.03)	-3.09e-03 (0.04)	0.08*** (0.03)	-0.07* (0.04)	-0.03 (0.04)	0.01 (0.05)	-0.10*** (0.04)
Moderate	0.02 (0.03)	-0.09** (0.04)	-2.52e-03 (0.03)	-0.05 (0.04)	0.01 (0.04)	0.10* (0.05)	0.03 (0.04)
Inadequate	0.08*** (0.02)	0.09*** (0.03)	-0.08*** (0.02)	0.12*** (0.03)	0.01 (0.03)	0.09** (0.04)	0.08*** (0.03)
Observations	1434	1434	1434	1434	1434	1434	1434
FCS							
Acceptance	0.12***	0.03	-0.11***	0.07*	0.03	0.03	0.10***

	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.04)	(0.03)
Borderline	-0.05* (0.03)	-0.02 (0.04)	0.01 (0.03)	2.09e-03 (0.04)	-0.02 (0.04)	-0.07 (0.05)	-0.01 (0.04)
Poor	-0.07*** (0.02)	-0.01 (0.04)	0.10*** (0.02)	-0.07* (0.04)	-0.01 (0.04)	0.04 (0.05)	-0.09*** (0.03)
Observations	1434	1434	1434	1434	1434	1434	1434
Household Assets							
High	0.09*** (0.03)	0.18*** (0.04)	-0.14*** (0.03)	0.06 (0.04)	0.08** (0.04)	0.20*** (0.05)	0.08** (0.04)
Medium	-0.02 (0.02)	-0.11*** (0.03)	0.04* (0.02)	-0.06* (0.03)	-0.05 (0.03)	-0.12*** (0.04)	-0.02 (0.03)
Low	-0.07*** (0.02)	-0.07** (0.04)	0.10*** (0.02)	2.29e-03 (0.04)	-0.03 (0.03)	-0.08* (0.04)	-0.05* (0.03)
Observations	1432	1432	1432	1432	1432	1432	1432
LCS							
None	3.04e-03 (0.02)	0.04 (0.04)	-0.02 (0.02)	0.04 (0.04)	0.05 (0.03)	0.05 (0.05)	-0.01 (0.03)
Stress	-0.01 (0.02)	-0.04 (0.03)	0.03 (0.02)	-0.05* (0.03)	-0.02 (0.02)	-0.02 (0.03)	-0.02 (0.02)
Crisis	0.01 (0.02)	-0.01 (0.03)	-0.03 (0.02)	0.02 (0.03)	-0.03 (0.03)	-0.03 (0.04)	0.04 (0.03)
Emergency	0.01 (0.01)	0.01 (0.01)	0.02** (0.01)	-0.02* (0.01)	-3.02e-03 (0.01)	9.96e-04 (0.01)	4.89e-03 (0.01)
Observations	1422	1422	1422	1422	1422	1422	1422

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Table A4:: Average Treatment Effect (ATE) results of the effect of land tenure on food security (binary)

	Land acquisition mode					Land documentation types	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
FSI	0.24*** (0.02)	0.11*** (0.04)	-0.24*** (0.03)	0.10** (0.04)	0.10*** (0.04)	0.14*** (0.05)	0.04 (0.04)
Observations	1422		1422	1422	1422	1422	1422
Food expenditure share	0.31*** (0.03)	0.23*** (0.04)	-0.36*** (0.03)	0.19*** (0.04)	0.12*** (0.03)	0.22*** (0.05)	-0.05 (0.04)
Observations	1434	1434	1434	1434	1434	1434	1434
HDDS	-0.08*** (0.02)	-0.09*** (0.03)	0.08*** (0.02)	-0.12*** (0.03)	-0.01 (0.03)	-0.09** (0.04)	-0.08*** (0.03)
Observations	1434	1434	1434	1434	1434	1434	1434
FCS	0.12*** (0.02)	0.03 (0.04)	-0.11*** (0.02)	0.07* (0.04)	0.03 (0.03)	0.03 (0.04)	0.10*** (0.03)
Observations	1434	1434	1434	1434	1434	1434	1434
Household Assets	0.07*** (0.02)	0.07** (0.04)	-0.10*** (0.02)	-2.29e-03 (0.04)	0.03 (0.03)	-0.08* (0.04)	0.05* (0.03)
Observations	1432	1432	1432	1432	1432	1432	1432
LCS	3.13e-03 (0.02)	4.74e-04 (003)	0.01 (0.02)	-1.97e-03	0.03 (0.02)	0.03 (0.04)	-0.03 (0.03)

				(0.03)			
Observations	1422	1422	1422	1422	1422	1422	1422

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Table A5: Generalised Ordered logit regression results of the effect of land tenure on food security (level)

	Land acquisition mode					Land documentation type	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
FSI (Ref category: severely food insecure)							
Food secure	0.56*** (0.12)	0.81 (0.19)	1.31 (0.34)	0.63 (0.21)	0.59** (0.13)	0.72 (0.18)	1.38* (0.24)
Marginal food secure	0.56*** (0.12)	0.81 (0.19)	1.31 (0.34)	1.04 (0.26)	0.59** (0.13)	0.72 (0.18)	1.38* (0.24)
Moderately food insecure	0.56** (0.12)	0.81 (0.19)	1.31 (0.34)	0.19** (0.15)	0.59** (0.13)	0.72 (0.18)	1.38* (0.24)
Inclusion of covariates	Yes						
LR Ch2	294.00						
Observations	1,012						
Food expenditure share (Ref category: Greater than 74%)							
Less than 50%	0.50*** (0.12)	0.31*** (0.09)	2.51** (0.77)	0.42*** (0.11)	0.41*** (0.11)	0.53** (0.15)	4.06*** (0.93)
50 – 64%	0.50** (0.12)	0.53** (0.16)	1.89** (0.55)	0.42*** (0.11)	0.41*** (0.11)	0.53** (0.15)	3.21*** (0.66)
65 – 74%	0.50*** (0.12)	0.68 (0.23)	1.16 (0.34)	0.42*** (0.11)	0.41*** (0.11)	0.53** (0.15)	1.71*** (0.35)
Inclusion of covariates	Yes						
LR Chi2	538.20						
Observations	1024						
HDDS (Ref category: Inadequate)							
Adequate	1.30 (0.28)	0.89 (0.22)	1.43 (0.35)	1.06 (0.24)	1.29 (0.29)	0.89 (0.22)	1.20 (0.20)
Moderate	1.30 (0.28)	1.66* (0.46)	1.43 (0.35)	1.06 (0.24)	1.29 (0.29)	0.89 (0.22)	1.20 (0.20)
Inclusion of covariates	Yes						
LR Chi2	232.71						
Observations	1024						
FCS (Ref. category: Poor)							
Acceptance	0.85 (0.19)	1.05 (0.25)	1.29 (0.33)	1.17 (0.27)	0.96 (0.22)	1.30 (0.32)	0.77 (0.13)
Borderline	0.85 (0.19)	1.05 (0.25)	1.29 (0.33)	1.17 (0.27)	0.96 (0.22)	1.30 (0.32)	0.77 (0.13)
Inclusion of covariates	Yes						
LR Chi2	240.23						

Observations	1024						
Household Assets (Ref. category: Low)							
High	1.14 (0.28)	0.74 (0.21)	1.87** (0.51)	1.06 (0.28)	0.74 (0.19)	0.70 (0.22)	1.01 (0.19)
Medium	1.66* (0.47)	1.24 (0.39)	1.87** (0.51)	1.91** (0.59)	0.74 (0.19)	1.36 (0.48)	1.01 (0.19)
Inclusion of covariates	Yes						
LR Chi2	173.42						
Observations	1024						
LCS (Ref. category: Emergency)							
None	0.56** (0.16)	0.78 (0.24)	0.54* (0.18)	0.85 (0.25)	0.65 (0.19)	0.68 (0.22)	1.08 (0.22)
Stress	0.56** (0.16)	0.78 (0.24)	0.54* (0.18)	0.85 (0.25)	0.65 (0.19)	0.68 (0.22)	1.08 (0.22)
Crisis							
Inclusion of covariates	Yes						
LR Chi2	68.66						
Observations	1012						

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1, Note: original results with their covariates are found in courier font below. Inclusions of covariates with no representative samples of the population give biased coefficients. So, findings from such samples cannot be generalized to the broader population or context. After addressing self-selection bias using relevant covariates, omitted variable bias will be an issue again.
Source: Author, (2021)

Table A6: FE-logit regression results of the effect of land tenure on food security (binary)

Category	Variable	FSI	Food expenditure share	HDDS	FCS	Household Assets	LCS
Land acquisition mode	Family inherited land	2.41* (1.10)	2.41 (1.84)	0.92 (0.48)	1.25 (0.67)	0.81 (0.56)	4.73*** (2.74)
	Outright purchased land	0.76 (0.40)	3.75 (3.45)	0.72 (0.39)	0.69 (0.38)	1.25 (0.91)	2.08 (1.21)
	Community distributed land	0.41* (0.20)	0.11*** (0.10)	1.45 (0.74)	0.40* (0.21)	1.45 (1.02)	5.46*** (3.16)
	Rented land	1.29 (0.64)	1.69 (1.92)	1.39 (0.82)	0.79 (0.42)	1.75 (1.23)	1.61 (0.93)
	Free use land	4.02*** (2.01)	14.43*** (13.98)	0.44 (0.25)	3.44** (2.01)	0.89 (0.67)	4.96 (2.95)
Land documentation types	Formal certificate	1.10 (0.51)	3.47 (3.58)	1.18 (0.62)	0.46 (0.26)	0.25* (0.21)	0.80 (0.51)
	Informal document	0.41*** (0.14)	0.16*** (0.09)	0.48* (0.21)	1.78 (0.71)	1.01 (0.43)	0.51 (0.24)
Controls	Household size	0.91* (0.05)	1.05 (0.09)	1.15*** (0.06)	0.86*** (0.05)	1.32*** (0.14)	0.97 (0.05)
	Age	1.00 (0.01)	0.99 (0.01)	1.00 (0.01)	0.98* (0.01)	1.00 (0.01)	1.01 (0.01)
	Tree owned	1.00 (8.62e0-4)	1.00 (7.79e-04)	1.00 (2.43e-03)	1.00 (2.22e-03)	1.00 (5.85e-04)	1.00 (2.38e-03)
	Number of plots	1.28*	1.89***	0.78*	1.06	0.82	1.07

		(0.18)	(0.44)	(0.11)	(0.15)	(0.15)	(0.16)
	Plot area owned	5.18*** (3.01)	4.40e+04*** (9.77e+04)	1.07 (0.66)	0.51 (0.34)	0.71 (0.56)	0.46 (0.29)
	Plot area	0.45 (0.29)	1.11e-04*** (2.36-04)	1.13 (0.75)	1.84 (1.33)	1.37 (1.15)	0.73 (0.49)
	TLU	0.96*** (0.01)	0.56*** (0.06)	0.98* (0.01)	1.02 (0.01)	1.03 (0.02)	0.98* (0.01)
	Cooperative	0.74 (0.46)	0.33 (0.37)	2.38 (1.71)	1.40 (1.10)	0.40 (0.40)	2.52 (1.77)
	Education	1.03 (0.05)	1.58*** (0.22)	0.96 (0.04)	1.07 (0.05)	1.03 (0.10)	1.01 (0.04)
	Marital status	0.91 (0.11)	0.99 (0.14)	0.80 (0.11)	1.06 (0.154)	1.30 (0.21)	0.91 (0.13)
	Years of land acquisition	1.93 (0.94)	1.60 (1.15)	0.57 (0.33)	0.92 (0.47)	0.92 (0.50)	1.62 (0.71)
	LR Chi2	125.29	451.76	33.31	46.63	25.23	34.33
	Observation	519	787	296	319	225	286
	Hausman test Prob>Chi 2	0.23	0.11	0.09	0.06	0.26	0.08

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1. Gender, zone and location had no results because the variables did not vary across survey waves. Hausman test examined the decision of choosing a fixed effect (FE) or random effect (RE) model and Insignificant (at 5%) Prob>Chi 2 means to reject the null hypothesis: RE/pooled model is suitable. Since this table rejected the null hypothesis, FE logit results were only reported.
Source: Author, (2021)

Table A7: FE-logit regression results of the effect of land tenure on food security (binary)

	Land acquisition mode					Land documentation types	
	Family inherited land	Outright purchased land	Community distributed land	Rented land	Free use land	Formal certificate	Informal document
Stunting	1.06** (0.03)	1.03 (0.04)	0.92*** (0.03)	1.03 (0.04)	1.00 (0.03)	1.14*** (0.06)	1.03 (0.34)
Observations	995	995	995	995	995	995	995
Wasting	1.03 (0.02)	1.04 (0.04)	1.00 (0.03)	1.02 (0.04)	1.00 (0.03)	0.99 (0.04)	1.05* (0.03)
Observation	807	807	807	807	807	807	807
Underweight	1.07*** (0.02)	1.02 (0.03)	0.95* (0.03)	0.94 (0.04)	0.98 (0.03)	1.02 (0.04)	1.05* (0.03)
Observations	1047	1047	1047	1047	1047	1047	1047
Overweight	1.03 (0.02)	1.03 (0.03)	0.95*** (0.02)	0.97 (0.03)	1.03 (0.03)	0.99 (0.03)	1.02 (0.03)
Observations	781	781	781	781	781	781	781
Stunted-overweight	1.02** (0.01)	1.02 (0.02)	0.97 (0.02)	1.04 (0.02)	1.01 (0.02)	0.99 (0.03)	1.02 (0.2)
Observations	749	749	749	749	749	749	749

Table A8: FE-logit regression results of the effect of land tenure on child nutrition (binary)

Category	Variable	Stunting	Wasting	Underweight	Overweight
Land acquisition mode	Family inherited land	0.98 (0.53)	1.05 (0.84)	0.54 (0.31)	0.25 (0.42)
	Outright purchased land	0.89 (0.51)	0.64 (0.49	0.75 (0.39)	10.67 (23.81)
	Community distributed land	0.50 (0.27)	1.09 (0.96)	0.34** (0.19)	0.01** (0.03)
	Rented land	1.36 (0.90)	0.76 (0.65)	0.34 (0.24)	2.22e-03* (0.01)
	Free use land	0.78 (0.42)	0.26 (0.24)	0.52 (0.28)	2.67 (3.56)
Land documentation types	Formal certificate	16.06*** (14.44)	1.74 (1.67)	2.68* (1.53)	1.47 (2.31)
	Informal document	2.08 (1.09)	0.80 (0.51)	1.39 (0.62)	0.05 (0.12)
Controls	Household size	1.04 (0.07)	0.81 (0.11)	1.12 (0.09)	0.96 (0.33)
	Age	1.01 (0.02)	0.99 (0.02)	0.97 (0.02)	0.87 (0.12)
	Literate	1.63 (0.66)	3.86** (2.61)	1.85 (0.87)	4.75* (0.01)
	Number of plots	1.06 (0.12)	1.02 (0.17)	1.17 (0.13)	1.92 (0.95)
	Education	0.86*** (0.05)	1.02 (0.12)	0.95 (0.04)	1.67* (0.48)
	Cooperative	0.04** (0.06)	2.80e-07 (6.70e-04)	1.36e-07 (3.04e-04)	6.50e+02** (2.14e+03)
	LR Chi2	45.76	15.73	29.89	30.05
	Observation	293	142	270	73
	Hausman Test Prob>Chi 2	0.36	0.41	0.50	0.85

Note: Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1. Gender, zone and location had no results because the variables did not vary across survey waves. Hausman test examined the decision of choosing a fixed effect (FE) or random effect (RE) model and Insignificant (at 5%) Prob>Chi 2 means to reject the null hypothesis: RE/pooled model is suitable. Since this table rejected the null hypothesis, FE logit results were only reported.
Source: Author, (2021)

Table A9: Regression results of the link between food security (level) and child nutrition

Variable	Level	Stunting	Wasting	Underweight	Overweight	Stunted overweight
	Marginally food secure	0.67 (0.30)	2.04 (1.14)	1.84 (0.90)	0.57 (0.41)	0.79 (0.89)
FSI	Moderately food insecure	0.54 (0.36)	5.57* (5.09)	2.48 (1.78)	0.94 (1.07)	0.81 (1.58)
	Severely food insecure	59.07 (0.53)	15.19** (18.75)	2.92 (2.76)	0.68 (1.03)	0.87 (2.38)
	Medium food exp share	0.66* (0.16)	1.53 (0.46)	1.19 (2.94)	0.97 (0.35)	0.17*** (0.13)
Food exp share	High food exp share	0.74 (0.16)	1.02 (0.36)	0.95 (0.28)	0.72 (0.33)	0.12** (0.13)
	V. high food exp share	1.18 (0.37)	2.68** (1.24)	1.93** (0.65)	1.34 (0.72)	0.79 (0.74)

Variable	Level	Stunting	Wasting	Underweight	Overweight	Stunted overweight
HDDS	Moderate diverse diet	1.57 (0.46)	1.35 (0.46)	1.27 (0.38)	0.83 (0.38)	0.58 (0.40)
	Inadequate diverse diet	1.99** (0.66)	1.84 (0.76)	1.09 (0.38)	1.24 (0.64)	1.56 (1.20)
FCS	Borderline	1.18 (0.33)	2.45** (0.98)	0.86 (0.26)	1.66 (0.78)	2.75 (2.59)
.	Poor	0.62 (0.36)	9.37*** (7.64)	1.10 (0.66)	1.51 (1.53)	3.34 (6.23)
Asset ownership	Moderate	1.17 (0.97)	0.58 (0.22)	1.27 (0.39)	0.99 (0.38)	0.76 (0.43)
	Least	0.97 (0.22)	0.68 (0.20)	1.08 (0.28)	0.49** (0.16)	0.49 (0.23)
	Stress	1.96*** (0.44)	1.17 (0.87)	0.57 (0.28)	1.01 (1.14)	#
LCS	Crisis	0.89 (0.26)	0.95 (0.75)	0.95 (0.48)	1.19 (1.36)	0.61 (0.58)
	Emergency	2.92** (1.36)	1.89 (1.45)	0.56 (0.28)	1.49 (1.67)	0.83 (0.51)
	Constant	0.24 (0.22)	4.45e-03 (7.72e-03)	0.08 (0.10)	0.08 (0.18)	0.05 (0.14)
	Chi-square	45.71	13.81	22.89	17.81	19.10
	Observation	1,313	1,090	1,384	1,039	979

Note: # signifies convergence does not achieve. Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Author, (2021)

Table A10: Regression results of the link between food security (level) and child nutrition with covariate

Variable	Level	Stunted	Wasted	Underweight	Overweight	Stunted overweight
FSI	Marginally food secure vs food secure	0.96 (0.54)	3.14* (2.06)	1.91 (1.08)	1.08 (1.08)	1.61 (2.28)
	Moderately food insecure vs food secure	1.40 (1.14)	7.93** (8.22)	3.62 (2.98)	1.84 (2.71)	2.39 (5.42)
	Severely food insecure vs food secure	2.88 (3.09)	15.27* (20.64)	6.45* (7.01)	1.73 (3.25)	2.95 (9.19)
Food expenditure share	Medium food exp share vs low	0.79 (0.23)	1.12 (0.41)	1.45 (0.42)	1.25 (0.56)	0.10** (0.11)
	High food exp share vs low	1.02 (0.37)	0.96 (0.44)	1.06 (0.43)	0.53 (0.35)	#
	V. high food exp share vs low	2.19* (0.90)	2.49* (1.39)	2.78** (1.16)	1.53 (1.04)	0.80 (0.86)
HDDS	Moderate diverse diet vs adequate	1.74 (0.64)	1.23 (0.54)	1.18 (0.43)	1.02 (0.68)	1.15 (1.10)
	Inadequate diverse diet vs adequate	2.63** (1.08)	1.92 (0.99)	1.12 (0.47)	1.54 (1.10)	2.39 (2.46)
FCS	Borderline vs good	2.06** (0.69)	1.86 (0.81)	1.27 (0.43)	1.42 (0.75)	2.05 (2.08)
	Poor vs good	2.42 (1.71)	9.14** (8.55)	2.78 (1.98)	1.43 (1.76)	5.03 (10.67)

Asset ownership	Moderate vs high	1.07 (0.33)	0.68 (0.27)	1.14 (0.37)	0.87 (0.39).	0.56 (0.35)
	Least vs high	0.97 (0.25)	0.78 (0.25)	0.96 (0.27)	0.36*** (0.15)	0.35* (0.20)
LCS	Stress vs none	1.94** (0.49)	1.91 (1.67)	0.54 (0.30)	1.65 (2.04)	0.81 (0.83)
	Crisis vs none	0.64 (0.23)	1.50 (1.39)	1.10 (0.62)	1.84 (2.31)	0.98 (0.62)
	Emergency vs none	2.62* (1.40)	2.85 (2.56)	0.74 (0.42)	1.66 (2.07)	#
Household features	Purchased land vs inherited land	0.89 (0.28)	1.38 (0.58)	0.69 (0.24)	1.56 (0.73)	1.35 (0.87)
	Community-distributed land vs inherited land	0.55** (0.13)	1.08 (0.33)	0.69* (0.17)	0.30** (1.44)	0.20** (0.13)
	Rented land vs inherited land	0.87 (0.28)	0.94 (0.41)	0.52 (0.29)	0.26* (0.21)	#
	Use land free vs Inherited land	0.89 (0.21)	1.11 (0.36)	0.80 (0.21)	1.01 (0.39)	0.58 (0.34)
	Informal land documents vs formal certificate	0.63 (0.23)	1.69 (0.93)	1.28 (0.52)	0.78 (0.56)	2.29 (2.74)
	No document vs formal land certificates	1.38*** (0.13)	1.06 (0.53)	0.86 (0.31)	1.59 (1.00)	4.01 (4.59)
	Age	0.99 (0.05)	1.01 (0.01)	0.99* (0.01)	1.00 (0.01)	0.99 (0.01)
	Sex	0.55 (0.36)	0.64 (0.44)	0.99 (0.57)	2.76 (1.79)	1.65 (1.98)
	Sector	1.20 (0.41)	1.34 (0.55)	1.86 (0.81)	0.39* (0.20)	0.21** (0.15)
	Number of plots	1.00 (0.06)	0.99 (0.08)	1.10 (0.06)	0.99 (0.10)	0.99 (0.15)
	Literate	0.93 (0.17)	1.46 (0.36)	1.34 (0.27)	0.85 (0.26)	0.81 (0.37)
	Household size	1.04* (0.02)	0.90*** (0.03)	1.02 (0.02)	1.03 (0.04)	0.98 (0.05)
	Off-farm income	1.00 (1.67e-06)	1.00 (2.94e-06)	0.99* (5.68e-06)	1.00* (3.81e-06)	1.00** (5.80e-06)
	Cooperative	0.29* (0.19)	0.29* (0.19)	0.32 (0.24)	1.09 (0.77)	0.39 (0.45)
	TLU	1.00 (4.09e-03)	1.01 (4.86e-03)	1.00 (4.34e-03)	1.01 (0.01)	1.01 (0.01)
	Remittance	0.49** (0.17)	1.31 (0.52)	0.69 (0.24)	0.43 (0.29)	0.31 (0.34)
	Constant	0.08* (0.10)	1.56e-03*** (3.510e-03)	0.01*** (0.02)	0.18 (0.50)	0.37 (1.36)
	Chi-square	60.58	26.98	49.56	23.97	27.54
	Observation	990	802	1042	777	600

Note: # signifies convergence does not achieve, vs represents versus for reference point. Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1
Source: Authors, (2021)

Table A 11: Location-specific regression results of the link between food security (level) and child nutrition

		Child malnutrition in rural area					Child malnutrition in urban area			
Variable	Household level	Stunting	Wasting	Underweight	Overweight	Stunted overweight	Stunting	Wasting	Underweight	Overweight
FSI	Marginally food secure	0.83 (0.48)	2.62 (1.88)	1.48 (0.84)	0.99 (1.17)	2.18 (4.62)	0.47 (0.55)	1.42 (2.03)	1.50 (1.81)	1.70 (0.29)
	Moderately food insecure	0.85 (0.67)	8.09* (8.68)	2.78 (2.25)	1.47 (0.97)	1.51 (1.70)	0.27 (0.56)	2.78 (7.52)	0.71 (1.41)	0.19 (0.64)
	Severely food insecure	1.22 (1.24)	20.24** (28.64)	4.31 (4.57)	#	#	0.08 (0.21)	53.17 (218.45)	#	#
Food expenditure share	Medium food exp share	0.74 (0.20)	1.31 (0.44)	1.44 (0.38)	1.36 (0.58)	0.23* (0.19)	0.65 (0.42)	3.31 (2.95)	0.77 (0.55)	0.20** (0.15)
	High food exp share	0.75 (0.26)	1.14 (0.48)	0.84 (0.33)	0.34 (0.28)	#	0.95 (0,57)	1.66 (1.54)	1.26 (0.81)	0.48 (0.32)
	V. high food exp share	1.60 (0.55)	2.35* (1.18)	2.62*** (0.96)	1.49 (0.94)	0.44 (0.49)	0.93 (1.04)	6.20 (9.58)	0.80 (0.85)	0.26 (0.45)
HDDS .	Moderate diverse diet	1.45 (0.52)	1.11 (0.47)	0.95 (0.34)	0.70 (0.48)	0.61 (0.61)	2.04 (1.12)	1.92 (4.37)	2.54 (1.47)	0.90 (0.61)
	Inadequate diverse diet	2.03* (0.80)	1.27 (0.64)	0.93 (0.38)	0.85 (0.61)	0.93 (0.99)	0.31 (0.24)	5.10* (4.37)	1.14 (0.94)	2.70 (2.26)
FCS .	Borderline	1.68* (0.53)	1.84 (0.80)	1.21 (0.40)	1.24 (0.76)	1.28 (1.30)	0.31 (0.24)	0.35 (0.54)	0.19* (0.17)	1.06 (1.99)
	Poor	1.02 (0.68)	8.12** (7.50)	1.71 (1.17)	0.60 (0.76)	0.73 (1.59)	0.16 (0.24)	#	0.14 (0.21)	#
Asset ownership	Moderate	1.07 (0.30)	0.57 (0.23)	1.36 (0.43)	1.08 (0.46)	0.65 (0.39)	1.83 (1.18)	0.63 (0.98)	0.48 (0.66)	0.25 (0.42)
	Least	0.96 (0.22)	0.75 (0.23)	1.19 (0.32)	0.40** (0.15)	0.37* (0.19)	#	0.22 (0.29)	0.63 (0.74)	0.24 (0.31)
LCS	Stress	1.97*** (0.46)	0.98 (0.75)	0.61 (0.33)	0.84 (0.99)	2.28 (1.27)	0.47 (0.60)	0.63 (0.64)	0.34 (0.46)	0.64 (0.80)
	Crisis	0.78 (0.26)	0.91 (0.74)	1.18 (0.64)	0.82 (1.00)	0.78 (0.53)	0.79 (0.65)	0.23 (0.38)	0.14 (0.23)	1.22 (1.92)
	Emergency	2.60* (1.31)	1.74 (1.37)	0.73 (0.40)	0.90 (1.07)	#	2.53 (3.92)	#	0.19 (0.26)	#
	Constant	0.12* (0.01)	0.01 (0.01)	0.05 (0.07)	0.11 (0.17)	0.07* (0.10)	0.94 (2.37)	0.08 (0.16)	2.66 (9.41)	4.01 (8.81)
	Chi-square	38.82	10.25	21.06	17.55	9.58	8.84	8.98	10.28	12.07
	Observation	999	814	1054	757	633	306	253	320	231

Note: # signifies convergence does not achieve, Standard error in parentheses, Significant level: ***p<0.01, **p<0.05, *p<0.1. There was no result for stunted-overweight children in the urban sampled households because of insufficient observations for the category. Source: Authors, (2021)

Table A12: Regression results of the link between food security (binary) and child nutrition with covariates

Variable (binary units)	Stunting	Wasting	Underweight	Overweight	Stunted-overweight
FSI	0.98 (0.28)	0.81 (0.32)	0.79 (0.24)	0.80 (0.39)	1.60 (1.14)
Food expenditure share	1.25 (0.29)	1.02 (0.29)	1.24 (0.29)	0.90 (0.32)	0.52 (0.29)
HDDS	1.65 (0.60)	1.24 (0.53)	1.10 (0.39)	1.03 (0.62)	0.99 (0.81)
FCS	0.84 (0.32)	1.72 (0.82)	1.33 (0.51)	0.66 (0.45)	0.57 (0.51)
Household assets	0.97 (0.25)	0.70 (0.21)	1.03 (0.27)	0.47** (0.17)	0.40* (0.20)
LCS	0.96 (0.25)	0.96 (0.31)	1.00 (0.26)	1.02 (0.43)	1.05 (0.70)
Purchased vs inheritance	0.94 (0.30)	1.43 (0.58)	0.73 (0.26)	1.77 (0.78)	1.79 (1.05)
Purchased vs community	0.59** (0.14)	1.08 (0.31)	0.67* (0.16)	0.32** (0.14)	0.31* (0.19)
Purchased vs rented	0.89 (0.29)	0.90 (0.39)	0.51* (0.20)	0.26* (0.20)	#
Purchased vs used free	0.91 (0.22)	1.09 (0.34)	0.75 (0.19)	1.03 (0.38)	0.81 (0.44)
Informal vs formal land document	0.52* (0.20)	1.51 (0.81)	1.19 (0.47)	0.82 (0.56)	2.38 (2.77)
Informal vs no land document	0.35*** (0.12)	0.98 (0.48)	0.80 (0.29)	1.50 (0.89)	3.00 (3.32)
Age	0.99 (0.01)	1.01 (0.01)	0.99* (0.01)	0.99 (0.01)	0.99 (0.01)
Gender	0.46 (0.31)	0.68 (0.45)	0.96 (0.83)	2.85* (1.76)	1.45 (1.61)
Sector	1.19 (0.41)	1.27 (0.51)	1.93 (0.83)	0.46* (0.21)	0.33* (0.21)
Number of plots	1.01 (0.06)	1.01 (0.07)	1.12** (0.06)	1.01 (0.10)	1.03 (0.14)
Literate	0.89 (0.16)	1.45 (0.35)	1.29 (0.25)	0.82 (0.24)	0.76 (0.33)
Household size	1.04** (0.02)	0.91* (0.03)	1.02 (0.02)	1.02 (0.04)	0.98 (0.05)
Off farm income	1.00 (2.01e-06)	1.00 (2.89e-06)	1.00** (5.67e-06)	1.00 (3.59e-06)	1.00* (4.40e-06)
Cooperative	0.24** (0.15)	0.31* (0.20)	0.30 (0.23)	1.03 (0.69)	0.53 (0.57)
Total livestock unit	1.00 (4.00e-03)	1.01 (4.59e-03)	1.00 (4.10e-03)	1.00 (0.01)	1.01 (0.01)
Remittance	0.57 (0.19)	1.44 (0.55)	0.82 (0.27)	0.51 (0.33)	0.41 (0.44)
Cons	0.37 (0.33)	1.11* (0.13)	0.06 (0.06)	0.84 (1.19)	0.81 (1.71)
Wald Ch12	39.21	21.33	36.37	26.07	21.17
Observation	990	802	1042	777	681

Note: # signifies convergence does not achieve. Significant level: *p<0.1, **p<0.05, ***p<0.01, standard errors in parenthesis
Source: Authors, (2021)