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Vulnerability to Food Insecurity Index: A multi-dimensional model for measuring household's food security and vulnerability in low, middle-income countries

PhD in Food and Agricultural Economics

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Declaration of original authorship

Declaration: I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Otu William Ibok

Dedication

This thesis is dedicated to my loving wife, Mrs Grace Ibok and son, Ediomo Ibok, for their support and motivation.

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Abstract

This thesis developed and validate a multidimensional food security indicator called the Vulnerability to Food Insecurity Index (VFII). Currently, there is no standard indicator of vulnerability analysis in food security research and this thesis responds to this challenge. The first research objective was to demonstrate how to develop this indicator and establish its validity through comparison with other traditional food security indicators such as per capita calorie consumption (PCC), food consumption score (FCS) and coping strategy index (CPI). The second objective was to systematically evaluate the effect of some assumptions on the robustness of the VFII. The aim was to examine how data type, weighting scheme, normalization method and excluding/including of variables, affect the output of the index using sensitivity and uncertainty analysis. The third objective was to verify the result of the VFII with real-life experience and to understand why households are vulnerable to food insecurity using qualitative insight.

The research applied both quantitative and qualitative method. The study used the World Bank LSMS panel dataset for households in South-South Nigeria to design the index, while fieldwork was used to verify the results of the index. In designing the VFII four steps were used. The first developed a conceptual framework for vulnerability to food insecurity, which helped to select indicators for the index. Structurally, Vulnerability to Food Insecurity Index is a multidimensional index of the probability of covariate shock occurring (exposure), the accumulative experience of food insecurity (sensitivity) and coping ability of households (adaptive capacity). The second step applies equal weight to each component of the index based on the evidence from the sensitivity and uncertainty analysis. In the third step, variables were normalised using the min-max normalization method. In the last step, a linear aggregation method was applied to generate the score of the index. For the uncertainty and sensitivity analysis, the one-at-a-time and global sensitivity approach were applied to examine the robustness of the index. Using the one-at-a-time approach, the research explored how the VFII output responds to different weighting schemes, normalisation method and inclusion/exclusion of variables. For the global approach, Monte Carlo simulation and Sobol first-order index and total-effect index were used to explore the uncertainty and sensitivity of VFII. In the qualitative phase, the results of the index from the quantitative phase were verified in the field using qualitative methods. Food vulnerability maps for households in South-South Nigeria were used to purposively select Akwa Ibom State for the verification exercise. Key informant interviews and a scoping visit identified one urban and one rural community in Akwa Ibom State that is vulnerable to food insecurity. A focus group discussion was conducted in each community to identify local perceptions that characterise household food security and vulnerability. Local perceptions served as indicators to select 30 households that were either highly vulnerable, mildly vulnerable or not vulnerable to food insecurity.

The major findings from this research were that the choice of measurement does matter for identifying and targeting of intervention for households vulnerable to food insecurity. Traditional indicators of food insecurity like FCS and PCC do not reflect a multidimensional concept needed for vulnerability to food insecurity and had exclusion/inclusion errors. However, the VFII was able to reflect elements of FCS, PCC, and CPI. The robust analysis showed that the VFII was stable to changes when equal weight and min-max normalization method was applied. The research adopted equal weight and min-max normalization method in designing the index. The result of the sensitivity analysis showed that although the exposure variables were the main input that introduces uncertainty to output of the VFII, the index is highly sensitive to shocks and better at capturing the vulnerability component of the index. Fieldwork verification further strengthened the validity of the index. At both community and state level, all the variables used to design the index were relevant in operationalizing vulnerability to food insecurity. In addition, the index can be applied to a heterogeneous context because it can pick up some context-related factors. Using equal weight at the community level was not feasible because the relative importance of VFII indicators varies between community. Households were vulnerable to food insecurity because of current socio-economic challenges at the macro-level, inability to manage food shocks and lack of safety net programmes. The research concluded that the VFII is fit for purpose based on the assumption used. However, to reduce the uncertainty of the exposure variables, better data is required in future modelling of the index. Where the goal is to ensure accurate targeting of long-term support to vulnerable households, policymakers who seek to address the underlying cause of food insecurity cannot rely on single indicators and for this type of goal, the VFII makes a useful contribution.

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List of Abbreviations

AKADEP – Akwa Ibom State Agricultural Development Programme

AKS – Akwa Ibom State

CPI – Coping Strategy Index

FAO – Food and Agricultural Organization

FCS – Food Consumption Score

FIEMS – Food Insecurity Experience Based Measurement Scales

FIVIMS - Food Insecurity and Vulnerability Information and Mapping Systems

GHS – General Household Survey

HES – Household Expenditure Survey

HFIAS – Household Food Insecurity Access Scale

HHS- Household Hunger Scale

HLPE – High Level Panel of Experts on Food Security and Nutrition

IFPRI – International Food Policy Research Institute

IPCC – Intergovernmental Panel on Climate Change

LSMS – Living Standard Measurement Survey

MAHFP – Months of Adequate Household Food Provisioning

MOA – Ministry of Agriculture and Food Sufficiency

NBS – Nigerian Bureau of Statistics

OAT – One-at-a-Time Approach

OECD - Organisation for Economic Co-operation and Development

OLS – Ordinary Least Square Regression

PCA – Principal Component Analysis

PCC – Per Capita Calorie Consumption

PDF – Probability Distribution Function

SDG – Sustainable Development Goals

UNDP – United Nation Development Programme

USAID – United State Agency for International Development

VFII – Vulnerability to Food Insecurity Index

WFP – World Food Programme

WHO – World Health Organisation

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Chapter 1 : Introduction

1.1 Background of Study

According to IFPRI (2018), global hunger is on the rise as conflict, famine and refugee crises persist. The number of people who are chronically undernourished has increased from 777 million in 2015 to 815 million in 2016 although still below 900 million in 2000 (FAO et al., 2017). The report reiterated that the surge in global hunger has increased rather than decreased and there was concern that the recent increase of global hunger could reverse the trend of international commitment to end hunger by 2030 (FAO et al., 2017; FAO et al., 2018). Further evidence from the FAO et al. (2017) report emphasises that the prevalence of child stunting globally has continued to decrease while overweight is becoming an increasing problem among children less than 5 years. At the same time, food security in terms of consuming adequate energy intake is deteriorating globally.

The increase in global hunger is worsening by a reduction in food availability, increase in food prices, and a consistent rise in conflict and violence over the past decade in many parts of the world. Principally, conflict has led to deteriorating pace of global food security and cause famine in parts of the world including Nigeria (FAO et al., 2017; FAO et al., 2018; Olayide and Alabi, 2018). The IFPRI (2018) report estimate 38 million people face famine in Nigeria, Somalia, South Sudan and Yemen. Also, food security situation has worsened in parts of South-Eastern Asia, Western Asia and Sub-Saharan Africa. Nigeria was identified as one among other countries where the food insecurity situation was at risk of turning into famines (FAO et al., 2017; FAO et al., 2018).

Nigeria is the largest population in Africa, with an estimation of more than 160 million people and agriculture is the mainstay of the economy contributing about 40 per cent of its GDP (IFAD, 2012; Abdullah, 2017; Devereux, 2018). This sector also employs about two-thirds of the economy labour force and is a source of livelihood for about 90% of the rural population (IFAD, 2012). Poverty is still a major menace in the country as about 70% of the population live on less than US$1.25 per day (Okoli and Tedheke, 2018). According to Akinyele et al. (2010) and Ashagidigbi et al. (2017) more than half of the Nigerian population have been deprived of social amenities, and many households are not food secure especially women and children. Malnutrition has rapidly spread, households are vulnerable to chronic food shortages, poor food quality, unstable food supply and fluctuating food prices (Okoli and Tedheke, 2018). Food insecurity remains a fundamental challenge in Nigeria (Olomola, 2017). The FAO (2015) enlisted the country among countries faced with severe food insecurity problems. Over 40% of households across all agro-ecological zones in Nigeria face the problem of severe food insecurity (Mariya-Dixton et al., 2004). Food and nutrition insecurity problems are further exacerbated by the lack of adequate policy analysis and implementation capacity. This gap frequently leads to failed policies and interventions, poor targeting of food-insecure households, programme mismanagement, misdirected resource location and weak responses to food insecurity challenges (Akinyele et al., 2010; Nwalie, 2017). Households exposed to shocks are always at the receiving end of failed policies combined with the fact that their livelihood activities are not sustainable, making them highly vulnerable to food insecurity.

Nevertheless, the slow progress and recent increase of global hunger, including in Nigeria, means that in order to meet the "challenge of leaving no one behind" more research that can address specific food security issues are needed to strengthen the resilience and adaptive capacity of food systems (FAO et al., 2018). One such research area is the application of vulnerability in food security research. However, the slow progress and recent increase of global hunger including in Nigeria means that in order to meet the "challenge of leaving no one behind" more research that can address specific food security issues are needed to strengthen the resilience and adaptive capacity of food systems (FAO et al., 2018). Vulnerability analysis is needed in food security research to understand the root causes of susceptibility to harm and build resilience by developing appropriate strategies for targeting interventions to vulnerable groups at particular levels (Nanda et al., 2019). A general understanding is that vulnerability can be used to evaluate the extent of a negative outcome on a particular sociological group (Ionescu et al., 2009) and that this approach can be used to investigate how different sociological groups, exposed to specific shocks, are affected and how they differ in terms of their sensitivity and adaptive capacity (Miller et al., 2010). This research adopts a vulnerability approach because the project aims to design an index that measures food insecurity and vulnerability across households. In addition, it seeks to explore the underlying causes of food vulnerability, the scale at which this vulnerability occurs, the major actors involved, and remedial action needed to reduce risk, while targeting interventions to those most vulnerable (Ribot, 2017; Miller et al., 2010). By applying a vulnerability lens, this research is able to capture a multifaceted phenomenon like vulnerability to food insecurity, which cannot be captured by traditional food security indicators (Ogundari, 2017). This approach advances and contributes to a growing demand for multidimensional indicators in food security evaluation, which aim to understand and characterize food insecurity for improved targeting, support international and local comparison, and could end the dispute for "best measure" across the food security and vulnerability domain (Tandon et al., 2017; Krishnamurthy et al., 2014).

This research develops a multidimensional food security indicator called the Vulnerability to Food Security Index (VFII). The index uses a multidimensional approach to measure and identify households that are at risk of becoming food insecure. Compared to traditional food insecurity indicators, such as per capita calorie consumption, which reflect current consumption intake of households (Maxwell et al., 2014) and Food Insecurity Experience Scale (FIES), which measures people's ability to obtain adequate food using experience-based metric of severity of food insecurity (FAO et al., 2018); the VFII developed in this research does something different. The VFII looks at how multiple risk factors place households at risk of becoming food insecure and the ability of households to cope or withstand this risk. Particularly, restriction is placed on only food-related risk. This research refers to defined food-related risk as a negative event that causes long-term deviation from household ability to have access to nutritious food (d'Errico and Di Giuseppe, 2018). By doing this, the VFII has the ability to identify those marginalised households that could be vulnerable to food insecurity but if using single indicator for this purpose could mask this information. The VFII potentially serves to identify and anticipate actions to avoid food insecurity, which is different from traditional single indicators. This is very useful for policymakers and NGOs who are interested in enacting long-term policy to reduce household vulnerability to food insecurity. The next section presents the research gap in this thesis.

1.2 Research Gap

They have been growing concern of food security crises that have rekindled the interest of researchers and policymakers (Moragues-Faus et al., 2017; Barrett and Palm, 2016). According to Barrett (2010), over 1 billion people are estimated to lack sufficient dietary energy availability, and twice this number suffers from micronutrient deficiencies. Barrett (2010) emphasised that to know where scarce resources should be directed to; there is a need for reliable information to be provided as to who is food insecure, where, when, and why. This requires the improvement of traditional food security indicators commonly used to measure food security.

Khalid et al. (2018) and Capaldo et al. (2010) also emphasised that food policy should be design to address the uncertainty and risk commonly faced by households. This is where vulnerability analysis comes in as a solution. A standard model for vulnerability analysis in food security research has not yet been revealed even though different analytical methods exist (Capaldo et al., 2010; Bashir and Schilizzi, 2012). The problem is further compounded in literature as scholars argue that vulnerability is relative and cannot be measured (Hinkel, 2011; Moss et al., 2001). Also, there is no goal standard in measurement, and many researchers are using similar but slightly different approaches.

Also, researches like Ogundari (2017), Maxwell et al. (2014) has shown that using single measures or traditional indicators of food security does not address the threat or risks that households face. For instance, per-capita caloric intake has been used as a "gold standard" to measure food insecurity at the household level. While per capita calorie intake reflects current consumption, it does not address other complicated elements of food insecurity like quality; vulnerability and risks; fluctuations and trends in consumption over time (Maxwell et al., 2014). Using a single indicator can result in underestimation and misclassification of possible food insecure households (Ogundari, 2017). Moreover, food security is a multidimensional concept, and no single food security indicator can adequately capture the entire dimension (Meenar, 2017).

Due to the inadequacies of existing traditional food security indicators, and the gap in literature that no standard model for vulnerability analysis in food security research exists, this research developed a multidimensional food security indicator (Wiesmann, 2004; UNDP, 2014; Dotter and Klasen, 2014; Kovacevic and Calderon, 2015; Weithungerhilfe et al., 2015; Wiesmann et al., 2015; Alkire and Santos, 2010) that incorporate vulnerability dimension called Vulnerability to Food Insecurity Index.

1.3 Research Objectives and Questions

The specific objectives and research questions for this research are:

1. To develop a multidimensional food security indicator -Vulnerability to Food Insecurity Index, that incorporates vulnerability and establishes validity through comparison with other traditional food security indicators.
    a. How can the vulnerability dimension be incorporated into the assessment of food security?
    b. How sensitive is the vulnerability to food insecurity index better capture the component of vulnerability compared to other traditional measures of food insecurity?

2. To systematically evaluates the effect of some methodological assumptions on the robustness of vulnerability to food insecurity index.
    a. How does the output of the VFII rank compare using different assumptions?
    b. What is the major source of uncertainty in the VFII ranking?
    c. What are the most influential input factors that cause this uncertainty in VFII ranking?

3. To use ground truth evidence to verify the vulnerability to food insecurity index and investigate the drivers of household's vulnerability to food insecurity qualitatively.
    a. What is the implication of verifying the VFII with a ground-truthing assessment?
    b. Are the indicators of VFII relevant to real-life experience, if not how divergent are they?
    c. Qualitatively, what are the factors that drive households vulnerability to food insecurity?

1.4 Research Justification

The benefits of using a composite index such as the Vulnerability to Food Insecurity Index is that it adequately captures multifaceted phenomena, e.g. food security and vulnerability, which could not be captured by single indicators. Using a multi-dimensional approach, the VFII makes the concepts of food security and vulnerability to be understood in the broader context spanning sectors, components and levels (Nazari et al., 2015). The index facilitates the ease of international and local comparison; and it could end the dispute for "best measure" across various food vulnerability research disciplines and institution (Wiesmann, 2004; Krishnamurthy et al., 2014)

Secondly, the Vulnerability to Food Insecurity Index developed in this thesis has contributed to filling the methodological gap is found in the literature. According to Capaldo et al. (2010), no standard model exists in literature that can measure food insecurity and vulnerability. Therefore, the Vulnerability to Food Insecurity Index will assist researchers, academics, government organisation and Non-Governmental Organisations to bridge the methodological gap and positioning the index for further improvement.

Thirdly, using the Vulnerability to Food Security Index for targeting of intervention reduces the impact of measurement error regarding inclusion and exclusion of households. The Food Vulnerability maps produce by VFII is an essential tool for geographical targeting of intervention. This will help to assess the degree of food insecurity in some geographical regions, therefore, helping policymakers to prioritise assessment and response. In the long-run helping to assist the hungry poor by accurately presenting their conditions to those organisations that need this information in other to assist them (Klennert, 2005). The VFII can be used to monitor food insecurity and vulnerability progress over time, effectively allocate scares resources and evaluates the impact of food vulnerability programmes (Krishnamurthy et al., 2014).

Finally, the Vulnerability to Food Index is designed to provide development organisations, policymakers and food security expert a practical tool for building long-term food vulnerability policy strategy. VFII is a valuable tool to systematically evaluate the causes of food vulnerability and how it can be reduced (Neset et al., 2018). It can be used to provide a suitable strategy to adopt for reducing vulnerability to food insecurity and lifting households out of food poverty.

1.5 Why South-South Nigeria?

According to World-Poverty-Clock (2018), poverty is currently rising in Nigeria, and about 44.3% of the country's population of 197, 407, 293 live in extreme poverty. Nigeria has overtaken India to become the country with the highest poverty rate in the world with 87 million people living in extreme poverty (Crespo Cuaresma et al., 2018; Beaumount and Abrak, 2018; PUNCH, 2018). A report from the African Development Bank estimated that about 80% of the Nigerian population lived on less than $2 per day (Beaumount and Abrak, 2018).

The rising poverty rate in Nigeria has also influenced the food security situation in the country. ACAPS (2018) projected that the food security situation in Nigeria is expected to be worst in coming months aligning with the seasonal trend. The production of staple and cash food crops has considerably been reduced and below average. Food price is higher compared to five years ago and is projected to remain the same throughout 2018. This affect mainly staples food crops like local-milled rice, maize, etc. The main reason is that of the high cost of transportation of food items from the surplus producing areas to markets and areas that are in need. Weak Nigerian currency profoundly impacts food access. This means that the availability of basic food and goods is limited in the local market making the price high at all level. In turn, food producers are increasing their exports while it becomes challenging to import because of weak Nigerian currency. Currently, household's income is low, coupled with high price this reduce purchasing power, further prevent access to food (ACAPS, 2018).

Nigeria is divided into 36 states, and the states are group into six different geopolitical zones namely North Central, North East, North West, South East, South-South and South-West (Kuku-Shittu et al., 2013). The thesis focuses on the South-South region of Nigeria because this region was known for low food poverty rate of about 39.8% (Sowunmi et al., 2012). However, about 61.68% of households in Nigeria are vulnerability to food poverty with the South-South zone having a considerable ration of 63.33% (Ozughalu and Ogwumike, 2013). The considerable rise in household's food poverty in the South-South that most of the industries and export crops in Nigeria motivated the selection of the region for this thesis.

1.6 Thesis Structure

According to the policy of the Graduate School, University of Reading, this thesis is structured as a collection of papers. This means that some chapters are presented in the format of papers already submitted or ready for submission to an academic journal. Regarding this, chapter 1, chapter 2 and chapter 3 are introductory chapters of this thesis while chapter 4, chapter 5, chapter 6 are papers submitted or ready for submission to an academic journal and chapter 7 presents summary and conclusion of critical findings.

Chapter 2 contains literature reviewed for this thesis. This literature are used to conceptualise and build frameworks for understanding food security and vulnerability. This chapter also includes food security measurement debate, definitions of vulnerability, how vulnerability concept has change over time, important component of vulnerability, approaches and method for assessing food vulnerability.

Chapter three is research methodology. This thesis used both quantitative and qualitative research method. All the methods used in data analysis are thoroughly discussed in chapter three. The chapter begins with exploring the research approach adopted for this thesis, then describes the research study area and data sources, then concludes with discussing all quantitative and qualitative method applied in this thesis.

Chapter four is the first paper from this thesis submitted to Journal of food policy and has been published. A copy published paper is included in the appendix. This paper demonstrates how Vulnerability to Food Insecurity Index (VFII) was developed. It also compares the validity of this index with other single indicators of food insecurity like per capita calorie consumption, food consumption score and coping strategy index.

Chapter five deals with the internal validation of the VFII. This chapter is submitted as an appendix of the first paper to Journal of Food Policy which has been published. This chapter evaluates the effect of some methodological assumption on the robustness of vulnerability to food insecurity index using Sobol's sensitivity and uncertainty analysis.

Chapter six is the second paper from this thesis and yet to be submitted to a journal as at when this thesis was compiled. The paper compare's the result of the VFII with the ground to experience. The thesis used this chapter to verify the result of the quantitative index with real-life experience of households in Akwa Ibom State, Nigeria

Chapter seven present the summary of the key findings from this research and the implication of conceptualizing vulnerability to food insecurity assessment. It also discusses the implication of this research for policy and practice, then concludes with the research limitation and suggestion for future research.

Chapter 2 : Literature Review

This chapter discusses the core conceptual ideas that are used in this thesis to frame the concept of measuring vulnerability to food insecurity and designing an index that captures food insecurity and vulnerability. The chapter begins by reviewing the concept of food security and the implication for assessing food security. It is important to consider how different approaches to assessment have emerged and the benefit and constraints of these approach in food security research. Therefore, the chapter moves on to review concept underpinning vulnerability in food security in order to explore the meaning, investigate the component, the changes of the construct of vulnerability over time, and how it can be applied in food security. This concept enables this research to integrate the vulnerability concept into food security research. And finally, the chapter takes a look at vulnerability assessment approach and how it has evolved over time. Aiming at choosing a novel method that fit into this research and adds a new dimension to the way vulnerability to food security is operationalised.

2.1 Conceptualising food security

Food security generally refers to the ability of individuals to have access to sufficient food on a day-to-day basis. It is also defined as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (USAID, 1992; Cafiero et al., 2018; FAO et al., 2018). When these conditions are not met, people are referred to as being food insecure (Woller et al., 2013). From this definition, food security has four main dimensions or components namely food availability, food accessibility, food utilisation and food stability (Tandon et al., 2017).

Food availability which can be simply defined as the physical presence of food to households whether it is from own production (like farm, garden,) or market (Chen et al., 2018). A more detail meaning of food availability can be found in the definition given by USAID (1992). Accordingly, it is defined as when “sufficient quantities of appropriate, necessary types of food from domestic production, commercial imports, commercial aid programs, or food stocks that are consistently available to individuals or within their reach". Other determining factors of food availability include but not limited to macroeconomic trends, government policies, functioning international and domestic market and physical, economic infrastructure (Tandon et al., 2017).

Food accessibility: This is defined as "when individuals have adequate assets or incomes to produce, purchase, or barter to obtain levels of appropriate foods needed to maintain consumption of an adequate diet/nutrition level" (USAID, 1992; Tandon et al., 2017; FAO et al., 2017). This definition means that a household can either produce, buy or exchange resources to obtain food. The assets portfolio or endowment determine the ability of households to produce, buy or exchange resources to obtain food.

Food utilisation refers to "the actual food that is consumed by individuals; how it is stored, prepared, and consumed; and what nutritional benefits the individual derives from consumption" (Woller et al., 2013:4). Food utilisation is categorised into two dimensions: socio-economic and biological dimension (USAID, 1992; King, 2018). The socio-economic dimension deals with the type of food that is consumed and how food is allocated within the household which is determined by the intra-household dynamics and social customs. The biological dimension is concern with how the human body transforms food into nutrients needed for daily activities or storing energy for future use by the body. Food utilisation requires that household's members eat a healthy diet, have a healthy body and live in a healthy physical environment that includes having access to a safe source of drinking water and maintaining good sanitary conditions. It also requires a practical knowledge of proper health care, food storage, food preparation and feeding practices (King, 2018).

Food stability: This is the fourth dimension of food security which cut across the other three dimensions because it involves the time-frame or temporal dimension in the definition that infers to "at all time" (Smith et al., 2017). Hence, food stability is defined as the "ability to access and utilise appropriate levels of nutritious foods over time" (Woller et al., 2013:5; USAID, 1992). Chronic and temporary food security and two important concepts that fall into this dimension. In chronic food, security households are unable to meet foods needs for an extended period while in transitory food security households only have short-term food deficit. Transitory food security is divided into two groups: cyclical or seasonal food insecurity (happens on a predictable basis, e.g. lean season) and temporary food insecurity (occurs in limited time due to unforeseen circumstance). Both cyclical and temporary food insecurity can interact to cause individuals in households to be vulnerable to food insecurity. For instance, regular session of transitory food insecurity can cause households to sell off or disposed their productive assets and hence shift them into the state of being chronic food insecure (Tandon et al., 2017).

The way food security is conceptualised give way to different methods used in measuring food security. Therefore, the next section (section 2.1.1) looks at the emerging food security measurement debate and how it has evolved over time.

2.1.1 Food Security measurement debate

The way food security was conceptualised in the pre-1980 and post-1980 period gave rise to the way government and aid organisations approach food security measurement and challenges (Haysom and Tawodzera, 2018). During the pre-1980 period, food security was understood as the " availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady food expansion and to offset fluctuations in production and prices" (UN, 1975; Napoli et al., 2011). From this definition, food insecurity could be remedy by increasing food production and sending food aid to countries experiencing food deficit (Barrett, 2010). This focus made it difficult for food security practitioners to pay attention to issues of food access.

The Green Revolution in the 1980s and the persistent food crises in Africa in the mid-1980s disprove this proposition. Even though food production was on the increase, the problem of food insecurity and inequality remains unresolved. Food supply was not the problem; it was that people had low purchasing power to access remaining foods (Borton and Shoham, 1991; Napoli et al., 2011). Prosekov and Ivanova (2018), in their paper researching on the present challenge of food insecurity, argued that hunger could not be remedied by concentrating only on increasing productivity or stocking grain but by increasing the income of people in developing countries and making food products accessible to a more significant number of the populations. The work of Sen (1981) emphasises that starving often results from being denied access to food rather than only the unavailability of food. This perspective led to a major shift from assumptions about the natural causes of food insecurity to focus on social and political causes of food insecurity (Maxwell, 1996; Haysom and Tawodzera, 2018). This restructuring of the debate causing a shift from food production towards individual-specific approaches to resolving hunger, with food security strategies based on poverty reduction, food price and social protection policies (Barrett, 2010). This resulted in the reconceptualisation of the definition of food security in the post-1980s era. This led to a new definition of food security.

The FAO (1996) defines food security "as a situation that exists when all people at all times have physical and economic access to sufficient, safe and nutritious food that meet their dietary needs and food preference for an active and healthy life". This definition introduces four dimensions of food security: availability, access, utilisation and stability while restructuring food security approach. Although the definition remains contestable, it is more inclusive and looks at how systems, structures and policies can be put in place to ensure that food is available and accessible during times of hunger (Haysom, 2017).

Changes in the way food security was conceptualised led to a realignment in its measurement to monitor progress. The main reason for seeking a precise and agreed-upon definition of food security was to understand the problem, design solutions, target policies and assess progress (Upton et al., 2016). In the pre-1980s food, security measurement was directed towards measuring food availability at the national, international and global levels, paying attention to shocks that affect only production and food prices (Maxwell and Smith, 1992). While in the post-1980s, the focus of food security measurement has shifted from nationalistic measures to include individuals ability and ways to access food (Smith et al., 2017; Haysom and Tawodzera, 2018).

Recently, authors have rethought approaches to food security measurement and begun advocating for measurements that apply a multidimensional approach (Aiga, 2015; Tandon et al., 2017; Cafiero et al., 2018; Chen et al., 2018). According to Tandon et al. (2017), it is essential to use different (multi-dimensional) food security measurement or metrics to understand and characterise food insecurity in a holistic way. Combining multiple metrics of food insecurity can help to provide a holistic assessment of food insecurity rather than using food security with single metrics (Tandon et al., 2017).

As a result of the evolution in food security measurement debate, more holistic but also complex approach are needed to advance this perspective. The next section explores the different approaches to measure food insecurity and the implications of taking these different approaches.

2.1.2 Approaches used in measuring food security

The evolution of food security measurement approaches can be categorised into four eras (Haysom and Tawodzera, 2018). The first era follows the pre-1980s conceptualisation of food security that focuses mainly on food surplus and production. The second era resulted from the work of Sen (1981), where measurement approaches began to investigate individual and household access to food. In the third era, the emergence of food security measurement included cultural dimensions and individual/household perceptions of food shortage. Finally, the fourth era, which is applied to this research, uses a multi-dimensional approach to address food security measurement and attempts to be holistic in approach (Haysom and Tawodzera, 2018).

Irrespective of the evolution of food security measurement in these eras, there are broadly three main measurement approaches for assessing food security namely anthropometrics, direct household tools and proxy tools (Haysom and Tawodzera, 2018). This thesis focuses on grouping different food security metrics into measurement approaches and does not concern itself with a detailed review of the individual food security metrics. These three approaches are discussed below.

Anthropometrics is commonly used to determine individual nutritional status, such as wasting, stunting and maternal obesity (Motbainor et al., 2015; Gubert et al., 2017; Nettle et al., 2017). It is used to provided information on the proportion of people in a population that is malnourished (Perez-Escamilla et al., 2017; Pérez-Escamilla and Segall-Corrêa, 2008). The main data collected for anthropometric measurement are child weight-for-age (measuring underweight), height-for-age (measuring stunting) and height-for-weight (measuring wasting) (Mukhopadhyay and Biswas, 2011). The advantages of anthropometric measurement are that the indicators are simple to measure, a highly standardised measurement, the methodology is easy to reproduce, it is relatively inexpensive, and the threshold is widely accepted based on evidence (Pérez-Escamilla and Segall-Corrêa, 2008). Additionally, anthropometry can be used to map nutrition food insecurity from local to national scale, identify populations at risk, track changes in nutritional status and design intervention for the affected population (Jones et al., 2013a). There are three major limitations of anthropometry. The indicators measure indirect effect of food insecurity (Pérez-Escamilla and Segall-Corrêa, 2008); the relationship between food security and obesity is very complex (Haysom and Tawodzera, 2018); and anthropometry data collection requires highly train staff to ensure accurateness and reliability of the data following highly standard protocols (Perez-Escamilla et al., 2017).

The next category of food security measurement is the *direct households' tools* which are Food Insecurity Experience-Based Measurement Scales (FIEMS). The FIEMS is an experience-based measure that captures the severity of food insecurity based on individual's perception, psycho-emotional experience and physical experiences; using yes/no responses from several questions regarding access to adequate food (FAO et al., 2017; FAO et al., 2018; Haysom and Tawodzera, 2018). Although developed and adopted by the FAO, it was inspired by United States Household Food Security Survey Modules and the Latin American and Caribbean Household Food Security Scale (FAO et al., 2017). FIEMS is widely adopted because it is not expensive to administer, focuses directly on individual experience and ease of cross-country comparison (Jones et al., 2013a). The primary challenge is that it generalises the result across countries with different cultures and there is difficulty in establishing a threshold for classifying households (Nathalie, 2012). Other measurements within the FIEMS are Household Food Insecurity Access Scale Indicator (HFIAS), the Household Food Insecurity Access Prevalence Indicator (HFIAP) and Months of Adequate Household Food Provisioning (MAHFP) (Haysom and Tawodzera, 2018).

Finally, food security measurement can be categorised as *proxy tools* namely the Household Expenditure Survey (HES), Coping Strategy Index (CSI) and dietary intake measurement. These metrics all use data generated as a proxy to measure food security.

HES is used to estimate household food consumption pattern from national or household survey data. They measure food insecurity using consumption and expenditure survey over a reference period (Jones et al., 2013a). "Information on expenditure is used to determine quality, generating a general understanding of food security dimensions" (Haysom and Tawodzera, 2018:121). HES is not expensive to administer compared to 24 hours dietary recall. HES is also used to generate dietary data to identify food-insecure households, mapping vulnerable population and evaluating food nutritional programs (Pérez-Escamilla and Segall-Corrêa, 2008). The drawbacks for HES are that it estimates food acquisition and not consumption and takes time to collect information, and because of this HES cannot be administered frequently (Jones et al., 2013a).

The CSI measures the frequency and severity of specific behaviours employed by households when there is a food deficit. The CSI measures both current food security situation and is a good predictor of future food vulnerability of households (Maxwell and Caldwell, 2008). CSI uses a series of questions about how households manage food consumption in times of food deficit, then convert these questions to a single numeric score used to determine if food insecurity is improving or not (Vaitla et al., 2017). The CSI score enables ease of comparison across household's community and even regions (Maxwell et al., 2013). It is useful for targeting and monitoring of food aid during emergency situations (Jones et al., 2013a).

Dietary Diversity Scores (DDS), Food Consumption Scores (FCS) and Food Frequency Scores (FFS) are food insecurity indicator that collectively measures dietary intake. They are used as proxy indicators of food security (Headey and Ecker, 2012). DDS was developed to track the changes in access to adequate quantity and quality of food consumed in a household within 24 hours (Leroy et al., 2015). FCS is a food security indicator developed by the World Food Program that measures the dietary diversity of food consumed in households with a seven days recall period (Vaitla et al., 2017). The FFS is used to measure long-term dietary intake and therefore help in epidemiological studies on dietary pattern (Freedman et al., 2017). The drawback of dietary measures is that they rely on people's memory to recall and this can result in measurement error (Jones et al., 2013a). Also, it excludes foods that are not consumed at home (Haysom and Tawodzera, 2018).

Most of the food security metrics explained in this section are traditional food security indicators. None of these metrics directly measure vulnerability to food insecurity. This thesis used the multidimensional approach to construct a vulnerability to food insecurity index, and compare's the index with traditional food security metric like per capita calories consumption, coping strategy index, and food consumption score. The vulnerability to food insecurity index applies to household's food security. Therefore, it is necessary to understand the dynamics of food security at the household level. The next section explains this in detail.

2.1.3 Intra-household structure and dynamics related to food security

The definition of food security applies to individuals, but this research is dealing with food security at the household level. Hence, this section will discuss this concept as it applies to households. In order to explain the structure and dynamics (like preference, incentives, or power) of food security within households, certain assumptions are made to simplify this concept. Under this, households are assuming to be homogenous and independent units that work together to maximise their satisfaction or utility. In reality, households are heterogeneous unit embedded within different social networks, comprising of members having different preferences, incentives and power (Maxwell and Smith, 1992). The following activities, relationships and processes occur in households, which in turn contribute to household food security.

Asset control: Due to culture or traditions and intra-household power everyone in the household has different access to and control over some assets. This, in turn, affects how labour and non-labour resources are distributed in households for income generation, thereby helping to secure food for household members. To operationalise the concept of food security, therefore, requires a proper understanding of how asset control and income-generation are assigned within households and its effect on different members of the household.

Income control: Inequality often exists in households, and this can affect how income and food are allocated. Who controls the income in households will significantly affect the food security level of other members. For instance, when the mother controls income, this significantly affects the family health, and particularly the children compare to paternal income effect. Also, the effect of stress or shocks can have different outcome among members of the household. For example, Behrman and Deolalikar (1990) showed that nutritional stress excessively increases food insecurity among women and girls in households.

Social norms: The society and its culture also affect the intra-households' relationships of households. Household's food security cannot be separated from the norms in the society that influences the behavioural pattern. Such behavioural patterns may decide the income generating activities of individuals in households, who can have access to food and how food can be utilised (Mallick and Rafi, 2010; Kabeer, 1990). According to Woller *et al.* (2013:6) "models of individual or household behaviour that fail to give due weight to the effect of social norms are undoubtedly miss-specified".

The structures and dynamics within a household influence household access to food as explained in this section. However, food-related risks are another dynamic within the household that influence food security. When a risk occurs, households take steps or measures to ameliorate the impact. The susceptibility of risks to cause harm to households is referred to as vulnerability. The concept of vulnerability as it applies to household's food security has been argued that it cannot be measured (Hinkel, 2011). This thesis focuses on designing a method to measure food vulnerability. The next section unpacks vulnerability concepts as it applies to food security and concludes with concepts that this research draws from to operationalize food vulnerability.

2.2 Vulnerability

Operationalizing vulnerability to food security involves reviewing concepts of vulnerability to get insight into how different disciplines or perspective conceptualize and measure vulnerability. The insight from this review is used to design a vulnerability to food insecurity framework adopted for this research. Hence, this section reviews vulnerability concept and frameworks adopted for this research. The section begins with reviews of vulnerability definitions based on different perspective or discipline, then present how the concept of vulnerability changes over time, discussed components of vulnerability, and role of livelihood asset against food vulnerability.

2.2.1 Definitions of vulnerability

Vulnerability definitions differ according to the discipline in question (Serrat, 2017; WFP, 2002; Alwang et al., 2000). Irrespective of the discipline, vulnerability definition depends on three themes - risks in question, the outcome of the risk and the response of households to these risks. The way each discipline conceptualises these themes give rise to diverse methods to assess vulnerability. Therefore, this section focuses on definitions of vulnerability and the way selected disciplines conceptualise it.

Sustainable Livelihood Perspective

The terminology was promoted by scholars at the Institute for Development Studies at the University of Sussex and builds on the work of Amartya Sen (Sen, 1981). In this perspective, livelihood is used to define those assets (both material and social resources), capabilities and activities needed for a means of living. “A livelihood becomes sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base” (WFP, 2002).

Sustainable livelihood literature defines vulnerability as the probability that stress will occur, which affects household livelihood. Thus, sustainable livelihood perspective is interested in livelihood vulnerability. In this perspective, livelihood vulnerability has two side – the external and internal sides. The external side of vulnerability consists of means of risks, shocks and stress while the internal side consists of a means of coping or mitigating against shocks without incurring losses (Lovendal and Knowles, 2005). The concept of vulnerability viewed by the sustainable livelihood discipline is dynamic and forward-looking. This is because this school of thought focus on how resources can be managed sustainably to increase the means of wellbeing (Scoones, 1998; Scoones, 2009; Serrat, 2017).

The strength of the livelihood framework is that it can be used to evaluate livelihood vulnerability and reflect on how it has changed over time. Vulnerability according to the sustainable livelihood approach is characterised as insecurity in the wellbeing of households in the face of shocks that occurs in their external environment (Serrat, 2017). Empirically, it is mostly used in qualitative study assessment and examines how variables are affecting sensitivity and resilience change over time. However, it is difficult to aggregate changes over time, when some indicators show negative change and others show positive change. The aggregation problem sometimes makes comparisons difficult. Much of the focus of this literature is on the description of livelihood vulnerability and how it has changed over time, while less effort has been devoted to empirical "measures" of vulnerability (Alwang et al., 2001).

Food Security Perspective

From a food security focus, vulnerability can be categorised into two groups, which are the risk-response-outcome and outcome-based approach. In the risk-response-outcome, "vulnerability refers to the full range of factors that place people at risk of becoming food insecure" (Lucas and Hilderink, 2005; FAO and FIVIMS, 2002) . This definition explicitly recognises the risk-response-outcome linkages of vulnerability. While the outcome-based approach defines vulnerability to food insecurity as the probability of an acute decline in food accessibility below a certain food security threshold due to exposure to food related risk (WFP, 2002; Adger, 2006). Other literature that defines vulnerability according to this approach are Dilley and Boudreau (2001); Lovendal and Knowles (2005); Burg (2008); Capaldo et al. (2010); and Daly and Farley (2004). In this context, vulnerability is because of several processes such as exposure to natural hazard, economic processes like price fluctuation, social processes like civil unrest and similar processes which reduces the capacity of the people to cope with such hazards (Villagrán de León, 2006). It is interesting to note that in this approach vulnerability is defined regarding benchmarks, such as a food security threshold. The concept of vulnerability from a food security focus is forward-looking because it shows that, the current food security status of a household at any point in time is affected by past status, which in turn affects their future status.

However, this focuses on "food insecurity" as the outcome and investigates food vulnerability. Many indicators have been developed to measure food vulnerability based on the outcome-based approach and risk-response approach. In the outcome approach, mapping exercise has typically been employed. Common indicators of interest include measures such as rainfall patterns, forest cover, and soil productivity to spatially identify areas that are vulnerable to crop failures and food insecurity. These indicators which are mostly source using remote sensing and their importance shows the role of risk in determining vulnerability to food stress. Examples of vulnerability of indicators used as proxies to food security in the risk-response approach are examining sources of household income, cattle and land ownership, the frequency of coping strategies used, migration, asset sales, etc. All these proxy variables used for food security shows the way household responds to food vulnerability (Alwang et al., 2001).

Human Development Studies

Another discipline that conceptualizes vulnerability in a multidimensional context is the human development studies, which is authored by the United Nations Development Programme (UNDP). UNDP focuses on human vulnerability (UNDP, 2014). According to UNDP (2014:15) "human vulnerability is described as the prospect eroding human development achievement and their sustainability". A person or community or country is vulnerable when exposed to a high risk of future deterioration of achievements. In this perspective vulnerability is view as a forward-looking concept.

The human development arguments on vulnerability are centred on two propositions. The first is that people's vulnerability is influenced by their capabilities and social context. Secondly, the failure in protecting people against vulnerability is because of dysfunctional social institutions and inadequate policies. Unlike other disciplines in vulnerability research that seeks to measure only one aspect of vulnerability, (for example, economic literature focus on vulnerability to poverty, food security discipline focus on food vulnerability, etc.) the human development studies focus on understanding vulnerability in a broader aspect. Here, human vulnerability is view from a multidimensional perspective, which encompasses vulnerability to any type of adverse event that can reduce people's capabilities and choice. This involves looking at how social cohesion such as social violence and discrimination, conflict, terrorism, climate change, natural disaster, and financial shocks expose people to deterioration and therefore erode human achievement. Furthermore, the human development discipline goes beyond the mere interpretation of vulnerability as exposure to risk to include the role of people's capabilities in minimizing the adverse effect from shocks and persistent threats. It also emphasizes other important factors that cause vulnerability, such as exclusion and discrimination that would not have been included from a risk-based approach alone. While a risk-based approach will suggest policies such as insurance to manage risk, the human development approach will canvas for a broader policy that will build the strength of individual and the societies. This discipline opined that human development approach is never complete until it incorporates human vulnerability and human resilience in its analysis.

The strength of this approach includes using a broad and multidimensional approach towards vulnerability, well advanced and universal, and the UNDP index can be compared across different countries. The weakness is that human development approach to vulnerability analysis is mostly made in a macro-perspective and challenging to adapt this model in a micro-environment. One of such challenge is that the index is unable to reflect cultural and economic diversity of the society at the micro-level. Also, the UNDP is developed to meet the policy target of the United Nation Development Programmes. At this macro-level, the index successfully meets the intended purpose. However, at the grass root level, where the development need is multi-facetted, the index faces the challenge of not being able to capture what is going on in the society (Moldan and Dahl, 2007). Finally, a major setback for this approach is the issue of relating the indicator to different scale. The index can have different meaning when applied to different scale or context. For example, at a macro-scale, a country may show high level of human development score, at a micro-level, this score may be hiding significant inequalities between various group in the society and subregions in the country (Moldan and Dahl, 2007)

Disaster Risk Perspective

This perspective focuses on a specific risk, which is natural hazard. The common idea is that vulnerability is defined with respect to natural disaster and how people or the community are vulnerable to the damages caused by natural disaster (Kreimer and Arnold, 2000). In this perspective, vulnerability is defined as “the degree to which a system or a person is likely to experience harm due to exposure to natural hazard and thereby identifies unsustainable states and processes” (Lucas and Hilderink, 2005:3). Literature in this discipline is interested in analysing vulnerability to natural hazards. Here, everyone is vulnerable to natural disaster, but the level of vulnerability differs according to the choice of people’s location. The discipline incorporates time dimension into vulnerability analysis, which explicitly shows that the extent of disaster cannot be measured without incorporating the coping mechanism used by the affected groups over time. In other words, vulnerability, as viewed by disaster risk research, is a dynamic and forward-looking concept (Blaikie et al., 1994; Wisner et al., 2004).

However, disaster research categorizes vulnerability into two components – risk mitigation or disaster preparedness and disaster relief. The risk mitigation activities involve risk reduction, mitigation and some coping activities while disaster relief is referred to the coping activities to the external sources when the disaster occurs. The widely accepted aggregation equation in disaster research is vulnerability = hazard – coping. Hazard is a function of risk value (primacy), duration of the impact of hazard (prevalence), level of warning available (predictability), and magnitude of the impact (pressure). While coping is a function of perception, private actions and public actions (e.g. Webb and Harinarayan (1999); Sharma et al. (2000)). Like the food security discipline, disaster research has developed resources for carrying out vulnerability mapping. This helps to assess the overall risk caused by natural hazards, identify the probability of a different natural hazard occurring in a region, and to show the level of risks that community/households are exposed to in dangerous areas (IDB, 2000).

In summary, irrespective of the way vulnerability is defined or conceptualized by different disciplines or perspectives; the following factors are commonly associated with vulnerability: exposure to risk, people capability to manage the risk, specific outcome of interest, e.g. food insecurity, forward-looking, and multidimensional. These factors are must be incorporated into how this research conceptualises and operationalizes an index of vulnerability to food insecurity. The next section discusses how the concept of vulnerability changes over time and presents the most recent approach adopted in vulnerability assessment.

2.2.2 How vulnerability concept changes over time

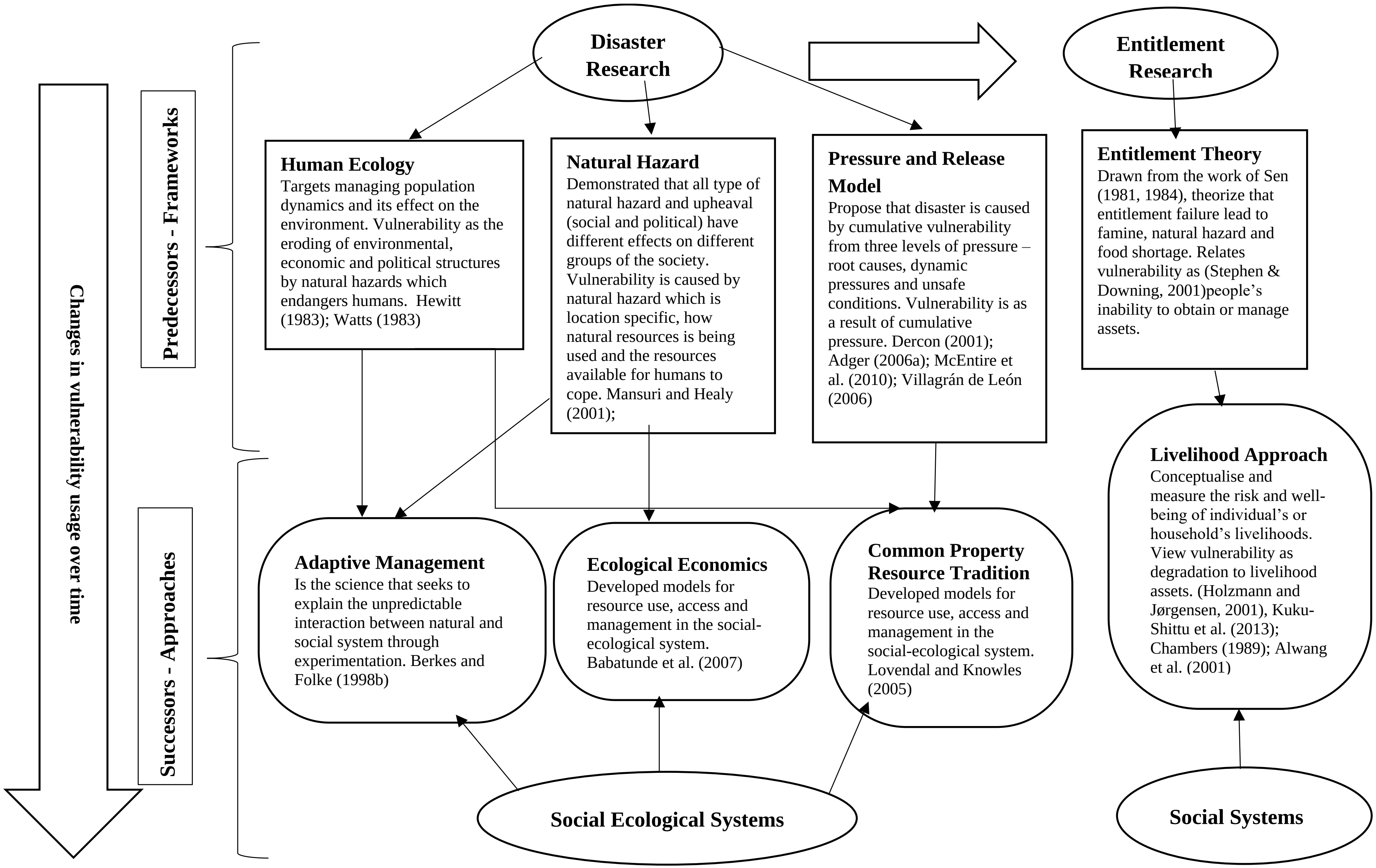
The concept of vulnerability evolution can be used to develop a framework to analyse and describe the state of susceptibility to harm including the marginality of both physical and social process of a system (Adger, 2006a). This is illustrated in Figure 2.1. Disaster and entitlement research from the 1970s were the bedrock from which other vulnerability research areas have evolved (Adger, 2006a). This disaster perspective focuses on environmental hazards as the main source of vulnerability, where disaster risk is a function of natural hazard and vulnerability (Dilley and Boudreau, 2001). This then allows for analysis of vulnerability to natural hazard to explain how different types of natural disaster impacts society. Disaster research can be delineated into three overlapping areas: human ecology, natural hazard, and pressure and released model. Human ecology views vulnerability as the erosion of environmental and political structures by natural hazards that then endangers human life. Those that take a natural hazard perspective argue that vulnerability is caused by natural disaster, which differs according to people's location, how people use their natural resources and how people cope with the available resources. A pressure and release model views vulnerability as the effect of cumulative pressure caused by three types of pressure: the root cause, dynamic pressures and unsafe conditions. The disaster perspective mainly focuses on vulnerability caused by natural hazard in the society, this became a major drawback of this perspective leading to the emergence of entitlement research, drawn from the work of Sen (1981); Sen (1984). Entitlement theory explains that why a lack of individual entitlement or sudden entitlement failure can lead to food shortage and famine even where there are no natural hazards or how this can exacerbate the impacts of natural hazards for the most vulnerable people. The debate, therefore, shifted away from a focus on the environmental aspect (natural disaster) alone as the cause of vulnerability to now include societal aspects (Alwang et al., 2001). According to Adger (2006b:270), "entitlement-based explanations of vulnerability focussed almost exclusively on the social realm of institutions, well-being and on class, social status and gender as important variables while vulnerability research on natural hazards developed an integral knowledge of the environmental risks with human response drawing on geographical and psychological perspectives in addition to social parameters of risk".

Therefore, disaster risk and entitlement ideas still frame much of the vulnerability frameworks used in vulnerability analysis. Even though the disaster risk and entitlement ideas were the bedrock of vulnerability discourse, they focused on measuring multiple outcomes of vulnerability that resulted from single physical stress. The frameworks were not originally multidisciplinary, limiting the opportunity for integration of ideas within the environmental-social system. This became a significant weakness in terms of explaining vulnerability to food insecurity because frameworks were not holistic (Turner et al., 2003). To become holistic required systems-oriented research thinking and the inclusion of natural and social indicators in assessment.

Consequently, the focus has been to develop a holistic understanding of vulnerability through social-ecological system thinking as shown in Figure 2.1. Social-ecological systems propose that human actions and social structures are coupled and interactive. Vulnerability is therefore seen as the ability to absorb and adapts to these multiple shocks (Berkes and Folke, 1998a) and can be broadly divided into three areas: adaptive management, ecological economics and common property resource tradition. This can be supplemented with ideas from livelihood approaches, which focus on implications for the social system. Unlike the traditional focus on disaster risk, these more interdisciplinary approaches were reflected in the development of the new methodology. For example, natural hazard ideas contribute to current thinking about vulnerability in ecological economics and adaptive management; human ecology contributes to ideas of adaptive management and common property resource thinking; entitlement theory contributes to livelihood approaches and ecological economics. The point is that today vulnerability research has now moved away from using a single framework to recognition of the value of interdisciplinary and holistic approaches.

This allows analysis of the different elements of vulnerability (exposure, sensitivity and adaptive capacity) and multiple drivers of vulnerability to food insecurity. This current use of a multidisciplinary framework can be used to design a vulnerability to food insecurity index (VFII), as a multi-dimensional index incorporating the three components of exposure, sensitivity and adaptive capacity. The next section explains these components and includes examples of how the approach will be used within this research.

Figure 2.1: Ontological foundation of vulnerability and changes over time



Source: Develop by author

2.2.3 Important components of vulnerability

This section will explore and discuss the main components of vulnerability, based on current thinking. The vulnerability of a system has been described as a component of exposure, sensitivity and adaptive capacity (McCarthy et al., 2001; Antwi-Agyei et al., 2012). This focus has evolved from research that has sought to understand the impacts of climate change (Adger, 2006b; O'Brien et al., 2007; Pearson and Langridge, 2008). Vulnerability in this context is a function of "the character, magnitude, and the rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPPC, 2007). A system will be vulnerable if it is both exposed and sensitive to the impacts of climate change and also has a limited capacity to adapt. By contrast, a system that is less exposed, less sensitive and has a strong capacity to adapt is not vulnerable (Antwi-Agyei et al., 2012). Although the understanding of these components of vulnerability has emerged from the climate change discourse, the ideas are applicable to related research areas, including food security research. This is because it helps to describe how the biophysical and socio-economic aspects of a system cause vulnerability to food insecurity (Polsky et al., 2007).

It is essential to review the meaning and characterization of these vulnerability components and their applicability in this research study. *Exposure* is widely defined as the degree to which a system or unit of analysis faces particular stress (Antwi-Agyei et al., 2012; Fellmann, 2012; IPPC, 2001). It does not only involve the degree of exposure but also the extent and duration of this stress. Methodologically, research can also define exposure to suit the content of their research focus. For example, Antwi-Agyei et al. (2012); Fraser (2007) UNDP (2007); and Tilahun (2006) define exposure as the intensity to which a system is exposed to drought. Therefore, this research study adopts the definition that exposure is the intensity to which households are exposed to food insecurity risk. To accurately represent the exposure component of vulnerability, research has characterized this component to involve stressors (like climatic variation, food insecurity) and the number of people under stress (i.e. the expose unit - group, region, country or resources). For example, Hahn et al. (2009) analysed the livelihood vulnerability index of two districts in Mozambique using the number of natural disaster that occurred in the past 6 years to represent the expose unit and average standard deviation of the maximum and minimum monthly temperatures and monthly precipitation to capture the stressor (climatic variability).

The *sensitivity* of a system refers to how well the system is affected, either positively or negatively by any stress, e.g. climate change, or food insecurity (Fellmann, 2012). Alternatively, it is the degree of responsiveness of a system to stress which may be influenced by the underlying socio-economic and ecological conditions (IPPC, 2001). Sensitivity can affect a system both directly or indirectly. Components used for sensitivity must be able to represent the first-order effect of the stress in question. For example, Antwi-Agyei et al. (2012) use harvest losses to represent the first effect of drought. Hahn *et al.* (2009) use the current state of food and water security, and health status to show the degree of responsiveness of Mabote and Moma districts in Mozambique to climate variability. Whereas Polsky et al. (2007) investigated the effect of drought on local water supply system in the central Pennsylvania HERO study site, characterizing sensitivity using the following components: water system technology (physical size of distribution network and infrastructure age), demographics (age and income) and supply response (reservoir level-rainfall correlation and water table height).

The combined effect of exposure and sensitivity shows the impact of stress on the system being studied. Even though a system is highly exposed or sensitive, this does not necessarily mean that the system is vulnerable. This is because neither exposure nor sensitivity accounts for the ability of a system to adapt to the stress being study (Adger et al., 2007; Fellmann, 2012). Thus IPPC (2007) defines *adaptive capacity* as the ability of a system, community, or region to adjust successfully to the effects of climatic stress. In this research study, adaptive capacity is defined as the ability of rural households to adjust to the effect of food insecurity successfully. This component is generally accepted as a positive attribute in reducing vulnerability in a system. A system with higher adaptive capacity will mean that the system stands a better chance of adjusting and hence reducing vulnerability to food insecurity (Engle, 2011). The adaptive capacity component is characterized by how households respond, exploit opportunities and resist or recover from the effect of food insecurity (Polsky et al., 2007; IPPC, 2007). Research has shown that the adaptive capacity of households is closely related to the livelihood assets own and households with high adaptive capacity tend to have more assets (Engle, 2011). This means that the more assets (natural, financial, human, physical and social) households have the less likely these households will be vulnerable (Moser, 1998; Moser and Satterthwaite, 2008; Gbetibouo et al., 2010). According to Adger et al. (2007), other determinants of adaptive capacity comprises of adjustment of behaviours, resources and technology, and socio-economic factors. Socio-economic determinants may be generic (such as education, income, and health) and specific (such as institutions, knowledge and technology).

The next section presents the importance of sustainable livelihood approach in understanding how household's asset aid in securing livelihoods and managing food vulnerability.

2.2.4 Household livelihood assets and food security

According to Chambers and Conway (1992:6) the term "livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable when it can cope and recover from stress, maintain or enhance households capabilities and assets, and provide sustainable livelihood opportunities for the next generation in the short and long term".

The primary focus of the sustainable livelihood approach is on households, and it allows emphasis on how a household uses their assets to build their livelihood security (defined as having adequate and sustainable resources, such as income, to meet basic needs (Frankenberger, 1996). Households have a range of needs that are important to meet, including food, education, health, and personal needs. However, the approach recognises that there will be trade-offs in how a household manages its assets and resources to meet food security. Three are competing needs, competing demands of household members and a social-cultural context to additionally consider. Thus, this approach is helpful to contextualise the relationship between food security decisions and multiple livelihood pathways.

Livelihood assets are generally classified into six categories and can be defined as the resource holding of a household that is used to generate a secure livelihood to meets basic needs, manage risk and cope with shocks or risk. The six categories of livelihood asset are human, physical, social financial, natural and political assets. Human assets refer to the knowledge and capability that individual households possess, for example, education, access to health services, clean water, or sanitation. Physical assets are economic infrastructure (like roads, railways, hospitals, and communication facilities); and productive assets (like farm animals, agricultural machinery, land which households can easily draw upon for their livelihood activities. Social assets refer to the available social capital that gives households connection to social support networks in society and are recognised as highly important for vulnerable people facing food insecure situations. Financial assets are resources available to households in terms of savings, credit, insurance, remittances, pensions, and cash transfer from social welfare. Natural assets are resources that a household control for livelihood activities and include land, water, forest, wildlife, and biodiversity. Finally, political assets are the rights and power dynamics that households have access to in the society. Therefore, livelihood assets are broad and dynamic and can be used as productive assets to develop livelihood and food security but also in a protective way during times of crisis to protect the basis of livelihood. This will lead to different choices by different households and individuals.

Productive assets used to generate income can further enhance household food security, while protective assets from financial, physical, and social resources can be readily converted into cash or goods during food insecure situations. Table 2.1 shows the relationship between household livelihood assets and food security. In particular, it shows that food-secure households often use only a small portion of their available assets and households that are in the best position to secure adequate access to food. In contrast, food-insecure households that are in the worst positions usually make use of a more significant proportion of their available asset yet fail to secure adequate access to food. This means that households with a larger proportion of asset resources generally translate into those with better livelihood opportunities and greater food security (Woller et al., 2013).

Table 2.1: Household livelihood asset and food security

Available Asset	**Food secure household**	**Food insecure household**
Uses a small proportion of available assets	Best off	Not too difficult to improve
Uses a large proportion of available assets	Food secure, but at high risk	Worst off

Source: Adapted from Woller et al. (2013)

Assets help households to manage losses during vulnerable periods (Alinovi et al., 2010) and there are three distinct stages where households may dispose or convert their assets to manage loss. This process is dynamic and different households or individuals may move between these stages at different times. While the simplicity of the ideas is recognised, for example, cultural aspects may mean that these stages are not applicable in all circumstances it is helpful to explain asset use in food insecure situations conceptually. The first stage also known as the non-erosive stage, involves the disposal of protective assets. At this stage, asset disposal does not affect a household’s long-term productive capacity because such measures can easily be reversed as shown in Table 2.2. However, as vulnerable households face constant and adverse shocks with more substantial impacts, they tend to use more desperate coping strategies. As such, they tend to sell or exchange productive assets and use severe coping strategies that include a reduction in food consumption. This is the second stage and strategies used are erosive because it becomes difficult to reverse and can affect a household's long-term productive capacity. At the third stage, a household's situation becomes more difficult because they may become destitute when assets have been completely depleted, or there are few coping mechanisms available to them. Figure 2.2 illustrates this stage. Where the productive asset is sold or exchanged as a last resort, the coping mechanism has failed to help households recover from their food deficit. At the first stage, so long as a household remains in this stage, any deterioration in their livelihood and food security is transitory. While at stage two and stage three households face the danger of slipping into chronic livelihood and food insecurity crises because of low chances of recovering (Woller et al., 2013).

While this framework helps in understanding how households cope with shocks using short-term measures rather than adaptations to long-term changes (Singh, 2014), it lacks the ability to capture the dynamism of politics, power relationships and governance over time (Reed et al., 2013; Scoones, 2009) and highlights the importance of ground-truthing any vulnerability index to understand the impact of these factors on the robustness of the results.

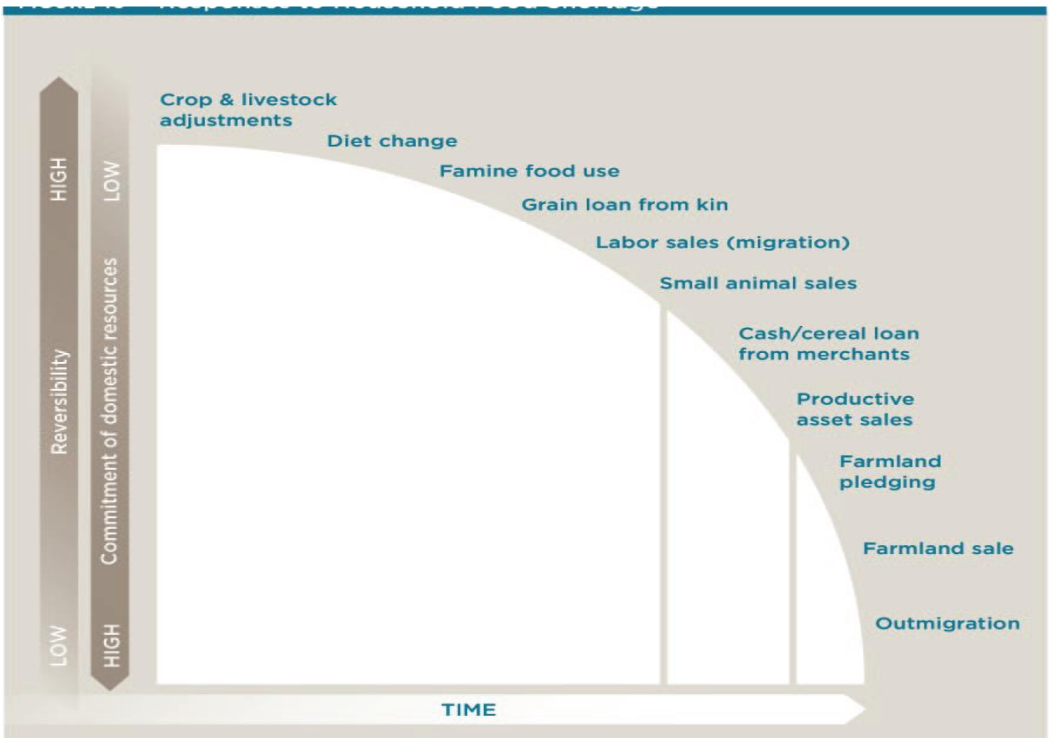
The next section presents the relationship between vulnerability and resilience and emphasises why this research adopt vulnerability analysis in food security research.

Table 2.2: Stages in asset conversion during shocks

Stages	Strategies
Stage 1: Disposal of self-insurance assets (none – erosive strategies)	▪ Taking wage labour or migrating to find paid work ▪ Switching to producing low maintenance subsistence crops ▪ Liquidating savings accounts ▪ Selling or exchanging jewellery, livestock, or other assets ▪ Drawing down social capital by calling on extended family or community obligation ▪ Borrowing from formal sources or credit ▪ Reducing spending on education and health ▪ Consuming wild fruits ▪ Reducing the quality and/or quality of food consumption
Stage 2: Productive asset disposal (erosive strategies)	▪ Selling or exchanging land, equipment, tools, or animals used for farming ▪ Borrowing at high-interest rates ▪ More reduction in spending and food consumption ▪ Reducing the amount of land farmed and types of crops produced
Stage 3: Destitution	▪ Depending on charity ▪ Breaking up household ▪ Migrating under distress ▪ Going without food ▪ Engaging in transactional or commercial sex

Source: Woller et al. (2013)

Figure 2.2: Response to households' food shortage



Source: Adapted from Woller et al. (2013)

2.2.5 Relationship between resilience and vulnerability

This section presents the differences and the relationship between resilience studies and vulnerability research. The purpose is to show the difference including similarities between vulnerability and resilience research. This section concludes with a discussion on why vulnerability analysis for food security was adopted.

Resilience is defined as the ability of a system to absorb shock, not to fall into a new state that is impossible to reverse and to recover after a disturbance (d'Errico and Di Giuseppe, 2018; Resilience-Alliance, 2009). According to Chodur et al. (2018) “resilience refers to the ability of a system to prepare for, resist, and recover from adverse situation". Resilience focuses on the persistence of a system to recover after a disturbance without changing its original function and the time it takes for a system to return to its original state (Holling, 1996). In contrast, vulnerability has many definitions based on the context or perspective involved, revealing the multifaced nature of the problem under enquiry (Adger, 2006). Irrespective of the myriad of definitions, a common consensus is that vulnerability evaluate the extent of a negative outcome (Ionescu et al., 2009). Although vulnerability approach may differ according to different perspective, a common theme that cut across vulnerability approach is that it often investigates how different sociological groups/community exposed to shock are affected and how they differ in terms of their sensitivity and adaptive capacity (Miller et al., 2010).

Using different approaches both vulnerability and resilience community looks at how a system response to changes (Miller et al., 2010). The resilience community mostly use the systemic approach while the vulnerability community prefer the actor-oriented approach (Nelson et al., 2007; Walker and Salt, 2012). Using a systemic approach, resilience studies expand the understanding of systems dynamics and the interaction between systems like socio-ecological relations and feedbacks with this system. But vulnerability understands systems as a unit of analysis such as social group, livelihood group, or sector or human-environmental system. In the actor-based approach, preferred by the vulnerability research, it seeks to address and examine issues such as power, social change, access, entitlements, conflict and equity which are critical matters of the socio-ecological system management and resources. Whereas these issues are not the centre of resilience thinking, however, resilience deal with them in the context of management and governance of resources and ecosystem service. Miller et al. (2010) argue that the actor-based and systemic view applied in vulnerability and resilience approaches are complementary, while the actor-based analysis looks at the process of decision making, negotiation and action, the system dynamics examined the interaction of these process.

The main disciplines that are the root contributors to resilience theory are natural science and ecology (Folke, 2006; Gallopín, 2006). It is just recently that more integrated approaches in resilience theory have been diversified (Miller et al., 2010; d'Errico and Di Giuseppe, 2018). In contrast, vulnerability research has seen more diverse contributions for various discipline such as geophysical science, human ecology, political economy, constructivism, and political ecology (Eakin and Luers, 2006; Adger, 2006a; Alwang et al., 2001).

In terms of similarity, both the concept of resilience and vulnerability are multi-dimensional concept (Nanda et al., 2019). Resilience is dependent on three different dimensions namely absorptive (ability of a system to persist), adaptive (ability of a system adjusting incrementally) and transformative (ability of a system to change profoundly above threshold) while vulnerability is composed of exposure (degree of the effect of a particular stress), sensitivity (degree of responsiveness of a system to stress) and adaptive capacity (ability of a system to adjust effective to stress) (Béné et al., 2014; Doherty et al., 2019; d'Errico and Di Giuseppe, 2018). This reflects that resilience is associated with adaptation and transformation of a system (Folke et al., 2010; Walker and Salt, 2012) while vulnerability is mainly associated with the impact and adaptation of a sociological unit to particular stress (Fellmann, 2012). Furthermore, both terms are used in sustainability research. Vulnerability adds to sustainability research by evaluating the extent of a negative outcome on a sociological group or community (Ionescu et al., 2009). While resilience is a necessary but not a sufficient condition of sustainability but seen as pathway to sustainability because it builds the capacity of a system to continue its core activities over a period of time despite disturbance (Tendall et al., 2015; Brück et al., 2019; Doherty et al., 2019).

The research adopted vulnerability approach in measuring food security because it sought to explore the underlying cause of food vulnerability, the scale at which it occurs, the major actor involved and seek remedial action to reduce risk while targeting intervention to vulnerable groups (Miller et al., 2010; Ribot, 2017). By applying the vulnerability lens to food insecurity this research is able to capture a multifaceted phenomenon like vulnerability to food insecurity, which cannot be captured by traditional food security indicators using a multi-dimensional approach (Ogundari, 2017). This approach advances and contribute to the growing demand of multidimensional indicators in food security which aims at fully understanding and characterizing the food insecurity population, ease of international and local comparison, and could end the dispute for “best measure” across the food security and vulnerability domain (Tandon, et al., 2017; Krishnamurthy et al., 2014; Wisemann, 2004). For instance, Areal et al. (2018) measured sustainable intensification of cereals production in England and Wales by designing a multidimensional sustainable intensification composite indicator that accounts for the economic performance of cereal farm and positive environmental impact of production. A major finding from this research was that farms ranking using single indicator that measure farms environmental performance do not always reflect what they measure. Their research contributes to existing literature argues that using a multidimensional approach for indicator development provide a greater depth of information than the traditional approach.

In addition, vulnerability analysis is needed to help build resilience into socio-ecological groups that are food insecure or at the risk of becoming food insecure. According to Doherty et al. (2019), resilience analysis deals with using a system coping mechanism and adaptive capacity to overcome the exposures and sensitivities associated with vulnerability. On the other hand, vulnerability analysis is needed in food security research in other to investigate the root cause of susceptibility to harm and build resilience by to developing appropriate strategies for targeting of intervention to vulnerable groups (Nanda et al., 2019). In the macro level, the vulnerability approach in food security research strengthens the resilience and adaptive capacity of food systems in other to reduce the recent increase in global hunger and thus achieving the UN SDG of zero hunger (FAO et al., 2018).

The next section presents the social risk management framework that conceptualises vulnerability to food insecurity. Then this thesis extracts ideas and concepts from this framework to build its own conceptual framework.

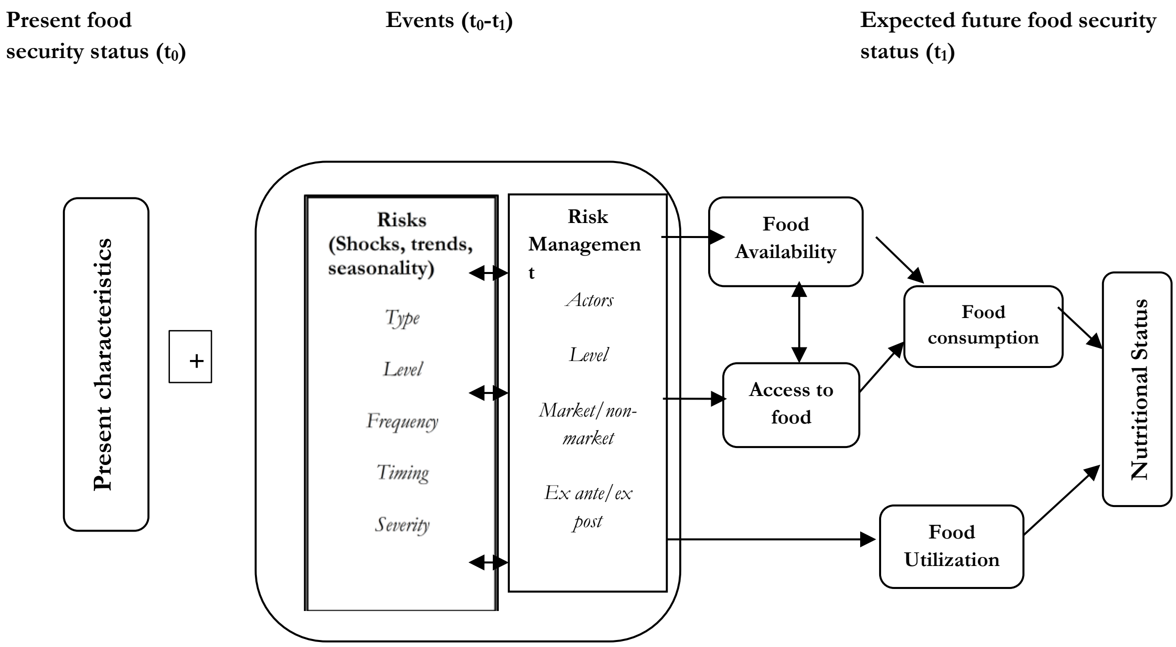
2.3 Framework used in conceptualising vulnerability to food insecurity

The framework on social risk management served as a foundation in which this thesis draws from to design its own vulnerability to food insecurity framework which is discussed in chapter 4. This section presents a thorough review of social risk management framework and how this framework conceptualises vulnerability to food insecurity, authored by Lovendal and Knowles (2005) and

Capaldo et al. (2010). The social risk management conceptualises vulnerability to food insecurity in a forward-looking way - meaning that several factors interact to influence household food vulnerability which in turn influences the future harm that occurs to households.

In Figure 2.3, the present characteristics of households are factors like food security status, asset portfolio, livelihood activities, policies, institution, and organization. All these factors play an important role in household's risk management capabilities and affect food security status. The *food security status* identifies how households move in and out of food security. Basically, households will fall into one or more of the following categories: food secure, transitory and chronic food insecure. The food insecurity status of households can have a negative influence on individuals. For example, undernourished mothers can give birth to children with low birth weight while malnourished children tend to have low cognitive abilities, which affect their education. The type of *asset* that households have can become a handy resource when faced with risk. Households with large assets portfolio can quickly recover from a shock compared to a household with low asset portfolio. Another present characteristic is the type of *livelihood* activities that household engaged in to meet their daily needs like food production, fishing, etc. Finally, the type of *policies* (laid down rules) can affect the present characteristic of household by either supporting or constraining access to food or other social needs (Lovendal and Knowles, 2005).

Figure 2.3: Social risk management framework used to conceptualise vulnerability to food security



Source: Løvendal and Knowles, 2005; Capaldo *et al.*, (2010) Risk threatens household food availability, accessibility and utilization. The *type* of risks that can affect household future food security status is categorized into political, social, economic, health, natural and environmental risk. These risks have different level of effect. It can affect individuals or households (micro-level), community/region (Meso-level), national (macro-level) or global/regional (supra-macro level). Risk at the meso, macro and supra macro level is also called covariate risk because it has the same effect across all levels. Risk at the micro-level is called idiosyncratic risk because the effect differs from one household or individual to another. The *frequency* of these risks can be transitory (occurring occasionally and includes unpredictable event or predictable seasonal events, trends (movements of events over time such as falling gross domestic products or declining agricultural yield) and structural risks (risks that has been integrated into a political, social and economic system for an extended period) like gender discrimination, inequalities, and poor working condition. Ability to manage risks also varies according to the *time* in which it occurs. During the time of hardship, a single idiosyncratic shock will push a vulnerable household into the worst state of food insecurity while in buoyant times such risk could easily handle. The striking time also matters. It could be *concatenated risk* (occurring within short intervals between them) or *compounded risk* (occurring simultaneously). When this happens, it places a more significant strain on household risk management capability. In addition, the strength and intensity of risks is another contributing factor. For instance, the severity of a flood or an economic shock will be described by their duration, coverage and the number of people affected (for the flood) as well as the sectors affected (for the economic shock). In summary, the higher the risk, the higher would be the resources needed to manage it (Lovendal and Knowles, 2005).

In managing risk, individuals, households and communities do not just wait until an adverse event occurs, but they also try to prevent these events from occurring. However, when it occurs, they seek to reduce the negative impact by using different risk management strategies. In this paragraph, the discussion will be tailored to understand the risk management instruments used and the potential effectiveness in relation to ensuring food security. The risk is managed at different *levels* such as individual, household, community and national or global level. For risk to be managed effectively, it requires that the effects be shares across time or between the affected or non-affected people. For instance, an idiosyncratic risk occurs at the household level, which requires access to credit. Therefore, the must be the financial sector (which is at the macro level) that has already been set up in the society having the mandate to make credit available in other to manage this risk. In other words, instruments available at one level will help or assist instrument at another level. In this illustration effective risk management cut across several levels simultaneously (Baulch and

Hoddinott, 2000). Different levels at which risk is associated with require different risk management *actors*. At the individual and household level, food insecurity risks that are not managed by other actors are left for individuals or households. At this level, households/individuals are mainly involved in managing risk related to food access and utilization. For example, when there is a food shortage, parents specifically the mothers tend to reduce their own food consumption and distribute their portion to other members of the household. Although this has a short-term benefit of stabilizing consumption, it comes at the cost of rendering parents food insecure. The community-based organization (CBO), for instance, *susu* scheme in West Africa, helps in managing risk by preventing it from occurring. CBOs do this by providing local base infrastructures for their communities (Marsh, 2003). Private sector institution helps to manage risk by providing and pursuing a business opportunity. For example, market traders ensure that food is always available at local and national level even in times of shortfall or difficult harvest seasons. Finally, the national government helps to manage risk to food insecurity by enacting policies and providing budgetary allocation as well as the legislative framework that will assist other actors in managing risk.

In summary, vulnerability to food security emanates from two repeated process, which is the current socio-economic and the future characteristics of households (Lovendal and Knowles, 2005; Capaldo et al., 2010). The current characteristics are risk households are exposed to while the future characteristics are household risk management capacity. The framework states that current food insecurity status of households at any point in time is affected by their past status which in turn affects their future status. The illustration is shown in Figure 2.3**Error! Reference source not found.**. The framework shows that households have a two-period lifetime which consists of the present denoted as t_0 and the future (t_1). Current food security status of households is determined by their present characteristics, and these characteristics are known to households and policymakers. But the future characteristics are not known to households and policymakers. Between the present and future ($t_0 - t_1$), different kinds of risks manifest themselves and determine the future food security status of households, depending on the ability of households to manage risk. The result of this risk is then measured through the different dimensions of food security shown in the diagram, including food consumption and nutritional status. Therefore, both present and expected future food security status of households determine the overall food security status over a given period of time. Since this framework make used of present and future event to determine the food security status of households, vulnerability to food security is forward-looking and dynamic (Capaldo et al., 2010). Component of this framework such risks, time dimension and the holistic picture that this framework uses to describe the process of food vulnerability was integrated into this thesis vulnerability to food insecurity conceptual framework discussed in chapter 4.

After discussing frameworks or concept in vulnerability that expatiated the understanding of vulnerability to food insecurity, this thesis then proceeds to discussed approaches used in vulnerability assessment with the intent of selecting an approach that suit this research. The next section presents the discourse on the concept used to assess vulnerability to food insecurity.

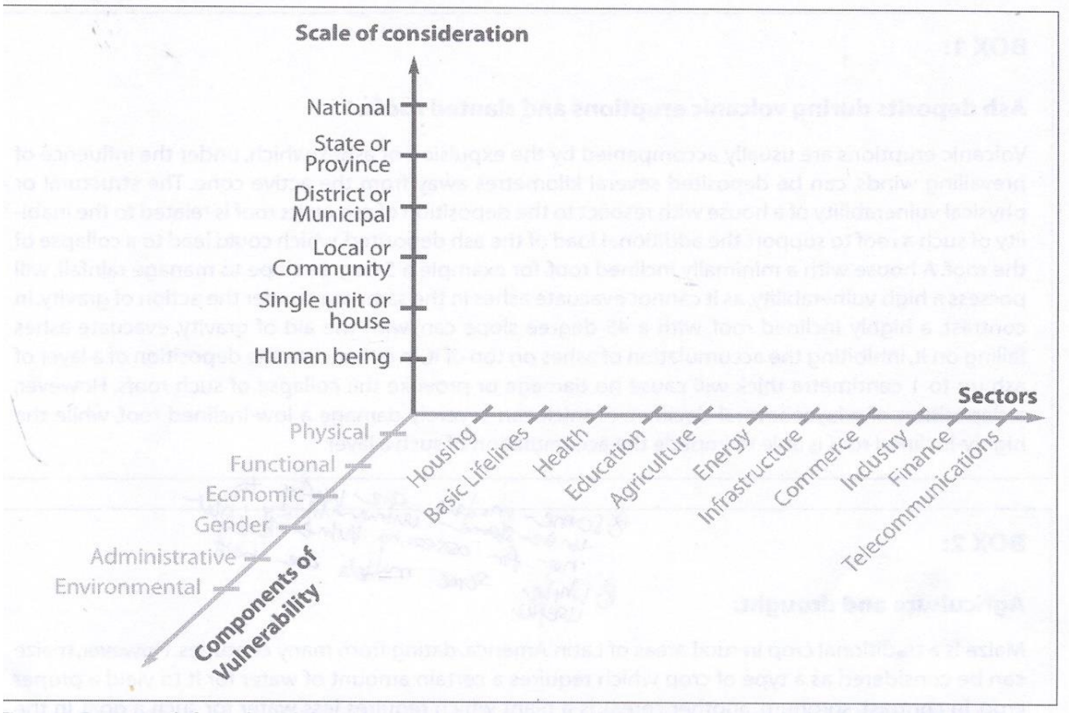
2.4 Food vulnerability assessment concepts

This section presents the conceptualisation adopted in this thesis to understand how vulnerability to food insecurity can be assessed. It begins with a review of frameworks that can be used for deconstructing vulnerability according to scale, and then present the approach commonly used to assess vulnerability and concludes with methods for accessing vulnerability to food insecurity.

2.4.1 Deconstructing vulnerability: Considering scales

Villagrán de León (2006) argues that there are three main reasons why quantifying vulnerability is difficult. The first reason is that vulnerability cuts across all social, institutional, political, and economic contexts - sectors, systems, livelihoods, organisations, and processes - and therefore, there is a need to develop framework across these contexts that will allow us to quantify vulnerability. The second reason is the lack of agreement among researchers and professionals on how to define and measure vulnerability. Lastly is the challenge of data availability. There are also multiple definitions of vulnerability depending on the discipline which can mean that the components that are too broad and this results in no accepted guidelines on how to assess each component individually nor how to link each component to give a final figure of merit regarding vulnerability. Hence, there is need to deconstruct vulnerability according to scale in other to make methodological progress towards better vulnerability assessment. To solve this problem, Villagrán de León (2006) developed a methodological review of vulnerability and proposed a framework for deconstructing vulnerability as shown in Figure 2.4. Although this framework is based on the context of disaster discipline, it can be applied to food security approaches. He deconstructs vulnerability assessment into three-axis or dimensions. The sector, which is the first axis, consists of different sectors of the economy, namely housing, basic lifelines, health, education, agriculture, energy, infrastructure, commerce, industry, finance and telecommunications. These are further differentiated into six components (represented in the second axis) as physical, functional, economic, human condition/gender, administrative and environmental. These components can be described as "susceptibilities". The third axis is the scale of consideration, which spans from the national scale to individual people.

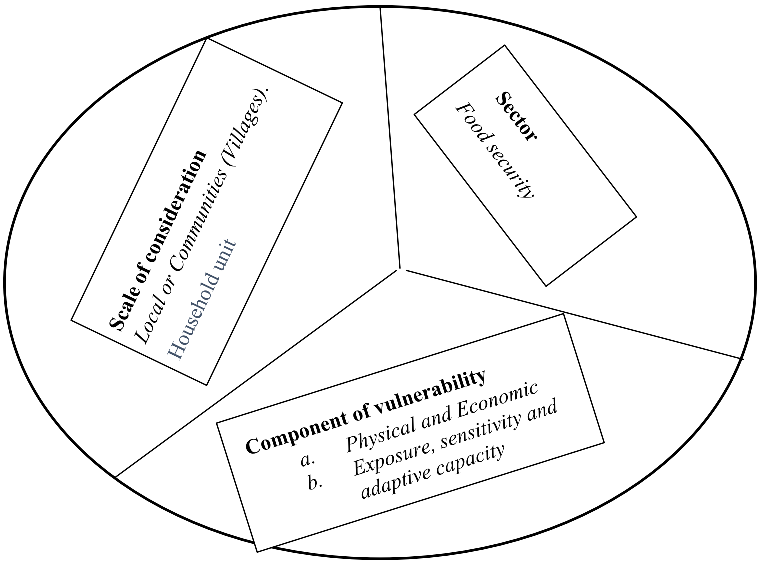
Figure 2.4: Villagran de Leon framework for decomposing vulnerability



Source: Villagrán de León (2006)

It is pertinent to note that according to this framework any vulnerability assessment must start by defining which risk is being addressed, then the sector, followed by the geographical level at which the assessment is made, and finally the component of vulnerability being assessed. However, this framework does not explicitly include coping capacities even though the review above identifies this as helpful in explaining vulnerability. Another weakness is in the component axis, which is too generic, and more useful for vulnerability analysis in the disaster discipline. The framework does help to shape ideologies of carrying out a vulnerability assessment broadly, which can be adopted for this study. Interestingly, it has enhanced the understanding that vulnerability methodology depends on the specific research objectives, research discipline, preferred scale, the type of environment under consideration and the kind of information desired. For example, vulnerability analysis carried out under an emergencydriven consideration (condition) will have different constraints and goals from vulnerability analysis carried out for a development purpose. This research study focuses on the implications for the latter, with a focus on supporting longer-term food security. Using the ideas in this framework, this study will deconstruct food vulnerability according to scale, sector and components (as shown in Figure 2.4).

Figure 2.5: Villagran de Leon framework for decomposing vulnerability



Source: Developed by author

Figure 2.5 shows that in this research, the geographical scale of consideration will be the village level (local) and the unit of analysis will be urban and rural households (Nguyen et al., 2017). This focus will help to avoid interpretation problems as identified by Stephen and Downing (2001), where it is not always possible to interpret across scale because different scales require different interpretation and "processes appearing homogeneous at an aggregated scale may be heterogeneous at finer scale" (pg 115). In Figure 2.5, the exposure, sensitivity and adaptive capacity are components used to design the vulnerability to food insecurity index. This strengthens the framework and makes it suitable to be used for quantifying vulnerability analysis related to food insecurity.

The next section (section 2.4.2) compares two main approaches commonly applied in vulnerability assessment- contextual and outcome vulnerability approaches. This section also illustrates the reason for adopting a contextual vulnerability approach for this research and using it to draw out vulnerability to food insecurity conceptual framework adopted for this research which is discussed in chapter 4.

2.4.2 Approach to vulnerability assessment

There are two major approaches for use in assessing vulnerability – outcome and contextual vulnerability approaches (Nazari et al., 2015; Nagoda, 2015; Nguyen et al., 2016; Olayide and Alabi, 2018). This section compares the two-vulnerability approaches while emphasizing the reason for adapting contextual vulnerability for this thesis.

Outcome vulnerability is otherwise known as “end-point interpretation” is an approach that considers vulnerability as a potential net effect of certain risk on the expose unit (might be biophysical or social) after feasible adaption has been accounted for; whereas contextual vulnerability approach, which can also be known as starting-point interpretation, considers vulnerability as present state of a system’s inability to cope with certain conditions caused by risk (O'Brien et al., 2007; Adger, 2006a) . The contextual vulnerability approach recognises that biophysical conditions, as well as dynamic social, political, economic, institutional and technological processes, influence a system vulnerability while outcome vulnerability approach only consider information on biophysical and socio-economic capacity to cope and adapt (Adger, 2006a; O'Brien et al., 2007; Nazari et al., 2015). According to Fellmann (2012), outcome vulnerability approach is based on natural science (for example climate change) and using future model scenario for its analyses, for example, Ruiter et al. (2017) and Krellenberg and Welz (2017). This approach mainly concerns itself with biophysical changes in a closed system and firmly draws a boundary between nature and society. The emphasis is mostly on the biophysical components and marginalizes the role of socio-economic component in ameliorating the effect of risk. Accordingly, the system considered to be most vulnerable is that which will undergo the most dramatic physical changes. A contextual approach emphasis that vulnerability is characterized by multiple factors surrounding the ecological and social system (Krishnamurthy et al., 2014; de Grosbois and Plummer, 2015; Zurovec et al., 2017; Adu et al., 2018). This argument confirms the earlier argument that vulnerability research has evolved from the disaster risk discourse toward socio-ecological systems research, which adopts a multidisciplinary approach (Adger, 2006a; Berkes and Folke, 1998a). Compared to outcome vulnerability, context vulnerability is based on social science and not natural science and focus on current socio-economic determinants or drivers of vulnerability. Such determinants include but not limited to marginalization, inequality, food and resource entitlements, presents and strength of institutions, economics and politics (Cardona et al., 2012). This makes this approach highly suitable for this research study because it recognizes that not only does the biophysical environment affect the food security of a system but considers the socio-economic conditions. In this context, there is a strong connection between the environment and humans, therefore making it applicable for household food security and vulnerability analysis. There is a relationship between nature and society, unlike the outcome approach where there is a firm boundary. Table 2.3 further summarize the difference between outcome and contextual vulnerability.

Table 2.3: Further comparison of outcome and contextual vulnerability approaches

S/N	Outcome vulnerability	Contextual vulnerability
1.	Focus on adopting technological innovation for adaptation and reduction of vulnerability.	Focus on sustainable development by adaptation of policy that will reduce vulnerability and increase broader social development.
2.	Focus on future vulnerability.	Focus on current vulnerability.
3.	Concentrate on physical vulnerability	Concentrate on socio-economic vulnerability
4.	Follows a top-bottom approach	Follows bottom-top approach

Source: Extracted from Fellmann (2012)

The contextual vulnerability approach makes use of socio-economic and biophysical conditions to decide the vulnerability of a system. Therefore, most studies that adopt the contextual vulnerability approach focus on sustainable development strategies that aim to increase the response and adaptive capacity of people to deal with food security-related vulnerabilities. The approach seeks to consider which social groups or regions tend to be more vulnerable to food insecurity (O'Brien et al., 2007)? Adopting the contextual vulnerability approach for this thesis means that the indicators and variables for designing a Vulnerability to Food Insecurity Index must represent both biophysical and socio-economic condition of households in the study area.

As such the next section further discusses methods commonly used to assess vulnerability namely index or indicator method and econometrics method.

2.4.3 Method for assessing vulnerability

The vulnerability index method and the econometric method are the two available methods used in assessing vulnerability. This section discusses these methods and their potential for use in this study.

Vulnerability Index Method

This method uses a deductive approach in developing an index from indicating variables (observable variables). To define the state of vulnerability of a system, the index method, applies scientific theories, frameworks or model in the selection of variables. The selection of indicating variables are guarded by a laid down theory. For instance, in developing a vulnerability index for researches in climate change discipline, the IPPC (2007) specifies three components of vulnerability (namely: exposure, sensitivity and adaptive capacity) that are used to select variables. Also, researches like Hahn et al. (2009); Singh (2014); which were set out to understand livelihood vulnerability of a system uses the sustainable livelihood framework to develop an index. A critical weakness of the index method is that the frameworks or theories involved do not provide arguments for aggregation of variables. This causes authors and researchers to resort to using different aggregation approach to produce the vulnerability index. Nevertheless, this method has helped to reduce complex variable with different variability to single figure for ease of interpretation and representation of the result. During this process, Abson et al. (2012) argue that many information is lost and this makes the index method unable to tell the accurate picture of vulnerability of a system. Although it does not capture the forward-looking aspect of vulnerability because variables do not interact. However, it is mainly used as a development and adaptation planning tool (Hahn et al., 2009). With the GIS software, the index method is used to produce vulnerability maps which provide guidance to areas that need urgent attention. These maps show the vulnerable hotspot of an area due to high exposure, high sensitivity and low adaptive capacity (de Sherbinin et al., 2014)

Econometrics methods

This method uses an inductive approach and attempts to use both secondary and primary data of a system or unit to come to a conclusion in explaining the state of harm (Hinkel, 2011; Singh, 2014). The econometric methods use data as indicators to build a statistical model that operationalizes vulnerability. This method heavily relies on the availability of data and uses econometrics models. Cross-sectional, repeated cross-sections and longitudinal data are mostly used. However, the best-suited data for micro vulnerability analysis is the panel data or longitudinal data (Hoddinott and Quisumbing, 2003; Hoogeveen et al., 2004; Chaudhuri et al., 2002; Günther and Harttgen, 2009). Panel data has superior advantages compared to the cross-sectional data. Compare with the cross-section data, panel data gives precise estimation of changes in variables means, provide accurate data on past events, cheap to collect data in terms of being able to collect data on the sample (selected individual) over a period of time and most importantly it is suitable for fixed-effect analysis, enabling the researcher to have control over time-invariant variables (Hoddinott and Quisumbing, 2008). Some of the econometric models used in vulnerability analysis includes: structural dynamic models (Elbers and Gunning, 2003; Scaramozzino, 2006), three-stage feasible generalized least square (Chaudhuri et al., 2002; Capaldo et al., 2010; Adepoju et al., 2011), multilevel analysis (Günther and Harttgen, 2009), Value at Risk (Scaramozzino, 2006), limited-dependent variables (Scaramozzino, 2006; Corral et al., 2015), instrumental variable estimation (Karfakis et al., 2011), generalized maximum entropy (Corral et al., 2015), and two-stage least square (Christiaensen and Boisvert, 2000). A common point to note in this method (which has become its main strength), is the ability to estimate vulnerability to some future date (Elbers and Gunning, 2003). However, panel data are not readily available in most developing countries and sometimes when available have limited or unrepresentative cross-sectional component, therefore, reducing the usefulness for policy analyses (Chaudhuri et al., 2002).

Conclusion

In summary, vulnerability assessment has evolved from using single frameworks to applying multi-disciplinary frameworks. Recent food security measurement debate favours using multi-dimension metrics to measure food insecurity, and a contextual approach helps to combine biophysical and socioeconomic factors. Adopting these ideas has helped to construct a clear conceptual framework for the development of an index that assesses vulnerability to food insecurity and is more relevant to operationalization in practice.

Chapter 3 : Research Methodology

3.1 Introduction

This chapter presents details of all the research methods applied in this thesis. The chapter begins with presenting the research approach adopted for this study; then it describes the study area, followed by discussing the data and its sources, present all the quantitative methods and concludes with the qualitative methods applied in this research.

3.2 Research approach

This thesis adopts a mixed-method research approach. According to Creswell and Plano Clark (2007:7), a mixed-method is a "research design based on the assumptions that guide the collection and analysis of data and mixture of qualitative and quantitative approaches".

Quantitative research uses deductive reasoning to come to specific conclusions by testing a general premise through a series of steps. It uses an objective approach to test these hypotheses through a series of steps and provide generalised findings. In contrast, a qualitative research dimension is based on inductive reasoning and starts from a general premise to reach a general conclusion based on an investigation of how people perceive and experience the world around them (Crotty, 1998; Wheeldon, 2010; Wheeldon and Åhlberg, 2012).

The quantitative research approach stems from the understanding that post-positivists have of the world, which sees human understanding based not on fact but diverse understandings. The central theme of post-positivists' argument is that these ideas can be tested through scientific methods; the external world exists but does not relate to an individual's experience, therefore knowledge is not constructed. The quantitative research approach often explores and validates theories through a process of falsification. This leads quantitative researchers to focus on sample size and statistical analysis that showcase broad generalisation. Therefore, widely known criticism of quantitative research is that the models are statistically dependent, cannot capture the complexity associated with human behaviour, and miss the information about culture, power or politics (Wheeldon and Åhlberg, 2012; Goertzel and Fashing, 1981). Qualitative research often draws on a constructivist perspective where meaningful understanding includes these dimensions of culture, power or politics to explain how people socially construct reality in different ways (Creswell and Plano Clark, 2007). This perspective encourages research to explore how people perceive and experience society – environment linkages or risk and generates theories grounded in interpretive or individualised processes. The inherent challenges for a qualitative approach are the difficulty in dealing with representative or predictive research at complex scales and accurately reporting the understanding of complex ideas (Creswell and Plano Clark, 2007; Bryman, 2016).

To overcome the shortcomings of either a quantitative or a qualitative research approach, this thesis, therefore, adopts a mixed-method research approach. The quantitative method is applied to construct the Vulnerability to Food Security Index while a qualitative research approach is used to verify the result of the index with real-life experience. By combining reliability from the quantitative analysis and validity through life experience from the qualitative analysis, this thesis can address the complex research questions in food security and vulnerability. The next section presents a description of the study area.

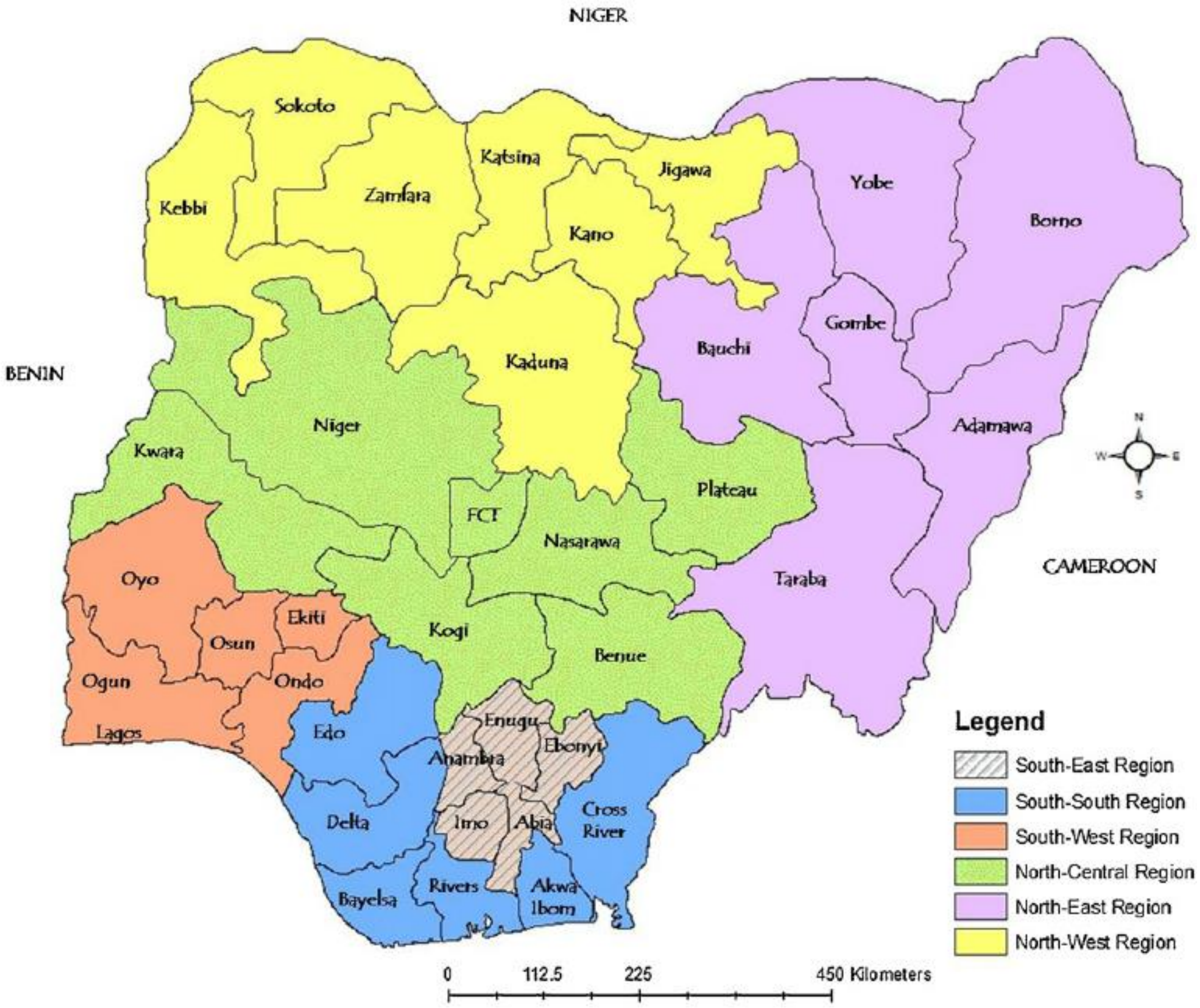
3.2 Description of Study Area

This section explains the characterisation of the study locations within Nigeria. The justification for selecting Nigeria as a case study was explained in Chapter 1. The first location was the South-South region of Nigeria, which is used for the quantitative analysis, and the second location is Akwa Ibom State, used in the qualitative fieldwork visit.

3.2.1 The South-South Region of Nigeria

Nigeria has 36 states plus Abuja which is the Federal Capital city. The 36 states are divided into six distinct geopolitical zones, namely North Central, North East, North West, South East, South-South and South-West (Kuku-Shittu et al., 2013). The South-South region of Nigeria is the study location used for this thesis (Figure 3.1). South-South Nigeria is also called the Niger Delta region (including three other states that are excluded from this research because these states are not in the South-South region of Nigeria). It is comprising of six states, namely Edo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross River state.

Figure 3.1: Map of Nigerian showing South-South region of Nigeria



Source: Ekong et al. (2011)

The South-South region accounts for 7.5% of the total land area in Nigeria, and all the six states are oil-producing states (Ite et al., 2013). The tropical rainforest and mangrove forest characterise the ecological zones in South-South Nigeria. The livelihood activities of the coastal area of the Niger Delta region are mostly artisanal fishing and small-scale agriculture because of the freshwater floodplains and saline swamp (Ite et al., 2013). Mangrove forest covers a land mass of 633, 669 hectares and is the largest in Africa, ranked fifth in the world (Giri et al., 2011).

The South-South region enjoys a warm temperature with long rainy season and mean annual rainfall of 4000 mm. The rainfall, freshwater floodplain and fertile alluvial soils make this region the most agriculturally productive part of the country (Kuku-Shittu et al., 2013). While tree and root crops are commonly cultivated in this region, flooding from the Niger River commonly occurs affecting crop production and thus food availability (Ifeanyi, 2011). There are relatively low poverty rates in this area of the country with the South-South zone experience 39.8% consider to be in poverty according to Sowunmi et al. (2012). The Southern zone is supported by industry and export cropping as compared to the northern zone that remains agricultural and with a fragile climatic environment due to incessant occurrence of drought (Sowunmi et al., 2012). The Nigerian Demographic and Health Survey (2013) report that 70% of households in the South-South region had access to improved source of drinking water, compared to 60% of households nationally. Other development indicators show neonatal mortality at 32%, postneonatal mortality at 26%, infant mortality at 58%, child mortality at 35% and under-five mortality at 91% (NPC, 2013). Stunting of children under the age of five differs across the region: the South-South region accounts for 18% of stunting in Nigeria while Edo state accounts for 16%, Delta (15%), Bayelsa (21%), Rivers (16%), Akwa Ibom (22%) and Cross River (22%) (NPC, 2013). These development indicators show that in the South-South region child mortality is highly prevalent while stunting mildly prevalent compared to other region in Nigeria.

The qualitative fieldwork was carried out in Akwa Ibom State which is one among six states in South-South region of Nigeria. Hence, the next section gives an overview of the state and describes the socio-economic position of the state.

3.2.2 Akwa Ibom State

Akwa Ibom State is named after the *Qua Iboe* River. The State is located in the coastal South-Southern part of the country Figure 3.2, covers has 8,412 square kilometres and is situated between latitudes 4°32' and 5°33' North and longitudes 7°25' and 8°25' East. It is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the South by the Atlantic Ocean and the southern-most tip of Cross River State.

The State has a population of about 3.92 million people (NPC, 2006) who are made up of more than ten homogenous ethnic tribes and Christians make up 90% of the religion (AKSGonline, 2012). The state is composed of the following ethnic tribes: *Ibibio (50%), Annang (30%), Oron (10%), Ibeno* (5%), and *Andoni (5%)*. The average population density of the state is about 280 persons per square kilometre. Over 80% live in rural areas, and some districts are highly populated. Out of the 1,614 settlements, 1557 are villages ranging from hamlets to expanded villages (onlinenigeria, 2003). The main rural areas are *Ikono, Ini, Mbo, Okobo, Urefong, Etim Ekpo, Ika, Essien Udim, Nsit Ubium, Ibiono, Ekpe-Atai* and *Uquo Ibeno* communities. There are nine settlements which can be considered as more substantial urban areas: *Abak, Eket, Uyo, Etinan, Ikot Abasi, Ikot Ekpene. Itu, Oron* and *Ukanafun* (onlinenigeria, 2003). Administratively, Akwa Ibom state is divided into 31 local government area, and its capital city is *Uyo* with over 500,000 inhabitants.

Figure 3.2: Map of Akwa Ibom State, Nigeria

Source: Adapted from Ite *et al.*, (2014)

In the southern coastal area, there is mangrove forest while the inland areas have thick rainforest. There are two distinct climate seasons: the wet or rainy season (May to October) and the dry season (November to April). The annual rainfall ranges from 2000-3000 mm. The pattern of the rainfall is bi-modal and has a two weeks dry spell commonly referred to as "August break" in August (Umoh, 2008). The area is characterised by climatic shocks, like floods, salinity intrusion from the Atlantic Ocean, severe windstorms, flooding, soil erosion, riverbank erosion and rise in temperature which make households vulnerable to the impacts of climate change and variability which in turn cause food insecurity (Umoh, 2008).

The State has abundant natural resources including crude oil, natural gas, minerals and as oil palm, cocoa, rubber, plantain, cassava, yam, beans. Seventy per cent of the best soils are located in the tertiary coastal plain. Agriculture remains the largest sector in terms of economic activity, followed by the petroleum sector. Farming is mostly small-scale (peasant) and few commercial farms. Those who practice smallholder farming focus on cultivating food crops such as cassava, maize, rice, yam and cocoyam for family consumption with any surplus being sold in local markets. For commercial farming, cash crops such as rubber, cocoa, rice and palm oil are mostly cultivated. Being surrounded by estuarine waters, seafood and fish can be fished, including catfish, sharks, sardines, croaker, shrimps, crayfish, snappers, bivalves, barracuda and oyster (AKSGonline, 2012). The state remains the largest producer of crude oil in Nigeria (Nicholas, 2012), with large onshore and offshore deposits. Mineral deposits include limestone, clay, natural gas, salt, coal and nitrate. These resources have caused disputes locally like civil unrest, between states (Alao et al., 2012) such as border disputes (Ugorji, 2012), and political and economically motivated violence, including kidnapping, land conflict and a rate of 17% for violent deaths (Ichite, 2015).

Rural poverty remains deeply entrenched in the State. The increase in population (to about 3.9 million people) has intensified land demand and risk of household food insecurity (Etim and Edet, 2013). Single-parent poverty, mostly for households headed by women, and child labour is prevalent. Ekpo and Agu (2014) found that 97% of farmers in rural communities were women who had small rainfed farms. Poor households are reported to afford to eat only one meal per day, and their quality of food is not always considered (Adawo, 2010), with diets depending on carbohydrate or starchy meals (like *garri*, *fufu*, yam) and little protein. The ease of growing starchy crops and therefore the low price for these meals is one of the main reasons why many households prefer eating it. Protein sources like beef, chickens, and fish are considered expensive for rural households and are eaten only for festivals or social events. This leads to malnutrition in rural areas (Opara et al., 2012).

Society remains traditional and is guided by these social norms, which shape gender roles and lead to gender inequality in terms of decision making and resources (Essien and Ukpong, 2012) Men are still seen as the household head who will inherit land while families continue to pay dowry for girls that marry out of the household. It is complicated in local politics and even taboos in some rural areas for a woman to head any traditional structures in society. This can have implications for gender inequality. The next section describes the data used in this thesis.

3.3 Data

This section describes the sources of data used in this thesis and details of the specific data used in the quantitative and qualitative data as well as the data cleaning method used for the quantitative analysis.

3.3.1 Sources of data

There are two primary sources of data used in this thesis. The World Bank General Household Survey is the source for the quantitative data, while the qualitative data is from the fieldwork carried out from 11/01/2018 to 11/03/2018.

The General Household Survey Panel (GHS-Panel) is a Living standard Measurement Study (LSMS) survey for Nigeria, sponsored by the World Bank and Bill & Melinda Gate Foundation. The dataset contains a panel component (GHS-Panel) that is a randomly selected sub-sample of 5,000 households from a cross-sectional survey of 22,000 households carried out annually throughout the country. The dataset contains information on human capital, economic activities, access to services and resources, food security and additional information on agricultural activities and household's consumption collected from the panel households. The GHS-Panel had two waves: the first wave (2010-2011) and second wave (2012-2013). Data survey visits were carried out within two periods to panel households. The first period took place during the post-planting visit in August-October 2010 (wave 1) while September - November 2012 (for wave 2) and the second period during the post-harvest visit in February-April 2011 & 2013 for both waves respectively. A one time visit was carried out for the cross-section, along with the post-harvest visit to the panel households (NBS and LSMS, 2015; NBS, 2015; Corral et al., 2015). The data are collected between different time period could have an effect on the research result. The GHS-panel data used in this thesis was the updated version. For the wave 1 data set, the second version was used, while for wave 2 data set, the third version was used. The following section describes the quantitative dataset used in this research.

3.3.2 Description of quantitative data

The primary source of quantitative data is the World Bank General Household Survey (World-Bank and NBS, 2015; World-Bank and NBS, 2014). The GHS-Panel data are grouped into three categories. The first category is the household data set. This contains all information collected on households. The second is the agriculture data and contains all information collected from households that engaged in farming activities, such as crop farming, livestock farming and any other agricultural activities. The third is a community dataset that contains information on the socio-economic indicators of the enumerations areas where the households reside. Table 3.1 and Table 3.2 presents a summary of all data sets from GHS used in this thesis. The datasets are briefly described below.

1. *Individual roster:* contains demographic data on individuals in the households and relationship to the household head.
2. *Education:* contains information on educational attainment, school characteristics and school expenditure for each academic year.
3. *Health:* contains general health data on all individuals in the households. Anthropometrics data was the chief information that was of interest for this thesis.
4. *Food security:* contains data on the food security status of households for the past seven days or twelve months.
5. *Household Assets:* contains information or lists of assets owned by households.
6. *Housing:* contains data on the type of house, the facilities in the house available to members of households and cost of utilities used by households. Examples of data include main source of lighting, drinking water and cooking; type of outer wall, roof, floor, toilet facilities, and refuse disposal; and cost of utilities like electricity, water, and mobile phone service.
7. *Other income:* contains additional households income data from savings interest or other investment, renting of property (apart from agricultural land), and any other type of regular income.
8. *Household food expenditure:* contains data on the quantity and monetary equivalent of food items consumed in the household within the last seven days. The food items are grouped into the following food category: grains and flour; starchy roots, tubers and plantain; pulses, nuts and seeds; oil and fats; fruits; vegetables; poultry and poultry products; meat; fish and seafood; milk and milk products; coffee, tea, cocoa and other

beverages; sugar, sweets and confectionery; condiments; non-alcoholic drinks; and alcoholic drinks (bottle and TOT).

9. *Non-farm enterprise and income-generating activities*: contains information on non-farm income-generating enterprise owned by any member of the households. Data are available on the ownership status of the enterprise, labour, value of stocks, sales, business cost, and constraint to opening and operating the business.
10. *Economic shock:* contains data on economic shocks affecting household in the last five year starting from the year the data was collected. Information on economic shocks such as death or disability of an adult working member of the households, job loss, non-farm business failure, flooding that caused harvest failure, etc. are available.
11. *Food consumption and expenditure:* contains consumption and expenditure data on food items consumed in the last seven days which are grouped into the following categories: grains and flours; starchy roots, tubers and plantain; pluses, nuts and seeds; oil and fats; fruits; vegetables, meat and meat products; fish and seafood; milk and milk products, coffee, tea, cocoa and beverages; sugar, sweets and confectionery; condiments, non-alcoholic drinks; and alcoholic drinks (bottle and can).
12. *Aggregated food consumption* contains two sets of information. The first set of information is on how many days in a week that the households or any member of the household consume food item categorised as grains and flour; starchy roots, tubers, and plantains; pulses, nuts and seeds; vegetables; meat, fish and animal products; meat fish and animal products used as condiments; fruits; milk or milk products; oil and fats; sugar/sugar products/honey; and spices/condiments. The second set of information/data is on the number of days and number of meals in a week shared with any other person that is not a member of the households.
13. *Agriculture production:* Harvest of field and tree crops: contain data on the quantity, and the value of field crop production for farming households.
14. *Landholding:* contains land inventory data on plot acquisition, tenure and use. Data such as land size is available in this section.
15. *Livestock holdings:* Data such as the numbers of different farm animals owned by the household.
16. *Geospatial data:* The GHS-panel data contains a set of geospatial data that was generated using the georeferenced plot and household locations. The geospatial data are produced using GPS data. It contains two separate files – household plot-level files and household-level file. Some data in the household level file was used in this thesis.

The household data file contains variables measuring household distance to essential amenities, climatology, landscape, typology, soil and terrain, and growing season parameters.

The next section (section 3.3.3) describes the qualitative data used in this research including the source.

Table 3.1: All wave 1 data set used in this thesis

Questionnaire Section	Data Set (Wave 1 - Post Planting)	Data Set (Wave 1-Post Harvest)
1. Households	1. Individual Roster 2. Household Assets 3. Housing 4. Education 5. Other income 6. Household food expenditure 7. Food security	1. Health 2. Food security 3. Housing structure 4. Non-farm enterprise 5. Economic shocks 6. Food consumption and expenditure Aggregate food consumption
2. Agriculture	1. Landholding 2. Livestock	1. Agriculture production: Harvest of field and tree crop
3. Geospatial data	Households level	Not Applicable

Table 3.2: All wave 2 data set used in this thesis

Questionnaire (section)	Data Set (wave 2 – Post Planting)
1. Household	1. Households food and expenditure

3.3.3 Description of qualitative data

The qualitative data are divided into three categories. The first set of data is from key informants, who were Heads of Department of Government organisations in Akwa Ibom State, Nigeria. Guided interview generated data was collected on activities for food security support or that each organisation performed in the community, criteria the organisation uses to characterise households and information on the food security situation for the State.

The second qualitative data set is from two focus group discussion that was carried out in *Ibesikpo* and *Ikono* communities in Akwa Ibom State. Data were collected on past shocks that affected the community, a participatory exercise to provide community map to understand location to be visited within the community, wealth ranking to generate local indicators that characterise household food vulnerability, a summary of coping strategies used, and validation of the indicators used in constructing Vulnerability to Food Insecurity Index.

The third qualitative data set is data from in-depth interviews of 30 households. Data collected are summarised into the following categories: ranking of shocks and its impact on households, adaptive capacity of households and food security questions. All the questionnaires for the key informant interview with government organisation, focus group discussion with the stakeholders in the community and in-depth interview with households are included in the appendix of this thesis.

3.3.4 Data cleaning

This section explains the process used to clean the data and estimate missing observations when constructing per capita calorie consumption and the Vulnerability to Food Insecurity Index. Not all the indicators or variables need this process.

3.3.4.1 Computing missing observation for per capita calorie consumption and VFII

In filling this missing observation for calorie consumption, the research used multiple imputation method. Regressing calorie consumption with households socioeconomic variables like age, household size, sex of household age, sector (urban or rural), and household adult equivalence. Then the missing observation was replaced with the imputed values.

Various check was performed to investigate the effect of missing data or missing observation on the VFII. Out of twelve variables used to construct the VFII, only four of these variables needed to be corrected for missing observation. These variables are shock, hunger, household literacy and household income. This affected the computation of VFII composite score. Therefore, OLS linear regression was used to fill-in the missing observations for these variables and then compute the VFII again. The predicted values for each of these variables was used to replace with the missing observation.

Finally, sensitivity analysis was carried out to check the effect of data type (i.e. variables with missing observation and variables that had complete observation after fill-in missing observation using OLS on the output of VFII. The result showed that the output of the VFII was not robust and was sensitive to not filling missing observations when unequal weight was applied to each component of the index. However, the output of the VFII was robust irrespective of the data type when each component of the index was equally weighted (see Chapter 5 for detail).

3.3.4.2 Data cleaning for per capita calorie consumption

Data cleaning was performed after constructing per capita calorie consumption using wave 1 and wave 2 datasets. For the data files showing the main dataset that was used in constructing per capita calorie consumption see Table 8.4 in this thesis appendix. At the end of the data cleaning, only calorie consumption from wave 2 households was used in this research. This is because per capita food consumption for households in wave 1 was exceptionally very high even after cleaning the data. For example, a household consumed 165,196.3 kilocalories per day. The extremely high values occurred when converting food items in non-standard unit to grams. For example, when converting 2 "pieces" of bread to grams. Wave 1 data contained a number of food items with a non-standard unit, which did not have a conversion factor. In contrast, Wave 2 data had the conversation unit for all non-standard food item

The following procedure was implemented to clean the data for both waves, investigating the sources of errors and correcting these errors. Data cleaning was carried out in two batches. The first batch was for households that had per capita calorie consumption above 10, 000 kilocalories per day while the second batch was for households that consumed above 5,000 kilocalories but less than 10,000 kilocalories. For each batch the following data cleaning process was carried out:

1. Correcting errors caused by the researcher's calculation: For example, the researcher mistakenly used millilitre for centilitre, inserting 20kg for 2.0 kg and using the wrong conversion formula to compute the calorie consumption of some food items. All these mistakes were investigated and corrected.
2. Checking and correcting outliers:

   The quantity of food items consumes (in Kg) from the dataset had large outliers. These outliers eventually caused the computed calories for the affected household to be extremely high and above the recommended threshold. An outlier was identified by plotting the histogram of the affected food item using the normal distribution function and looking at the kurtosis, mean, 50% percentile and skewness. The food items that inflated the values of household calories consumption were those with large mean that are far away from the 50% percentile and had high kurtosis. Using this method some food items value was corrected. For example, 30kg of potatoes was corrected to 3.0kg. Food items affected were sweet potatoes, cassava, yellow-garri, sugar, condiments, palm oil, bread, and unshelled maize. The assumption was that it was preferable to underestimate calorie consumption than to over-estimate it.

3. Using the "item_cd" to clean the data: The research summarises the variable -food quantity (measured in grams per week). This assisted the research to identify households with food items that had extreme values. These food items were identified, and the extreme values were corrected.
4. Food items that did not have energy equivalent or the energy equivalent were not found were drop. Table 3.3 shows the food items that were dropped.

Table 3.3: Food items dropped

Food items	Frequency	Percentage
Cake	23	1.92
Buns/pofpof/donuts	51	4.25
Biscuits	300	24.98
Meat pie/sausage roll	87	7.24
Fruits: other fruits	14	1.17
Poultry and poultry products: duck	2	0.17
Sugar, sweets and confectionary: other	2	0.17
Non-alcoholic drinks: bottled water	31	2.58
Non-alcoholic drinks: sachet water	206	17.15
Non-alcoholic drinks: malt drinks	197	16.4
Non-alcoholic drinks: soft drinks	241	20.7
Non-alcoholic drinks: other non-alcohol	8	0.67
Alcoholic drinks (bottle and tot): gin	32	2.66
Alcoholic drinks (bottle and tot): other	7	0.58
Total	1,200	100

5. Checking food energy and edible portion conversion factor: The food energy and edible portion conversion factor was sourced from FAO (FAO et al., 2012) and USDA. They both gave different food energy values, and this inflated the per capita calorie consumption for households. To correct for this, where there were two different values for food energy, the one with the lowest value was applied to the analysis. For example, if 1 gram of palm oil had 900 kilocalories (FAO) or 884 kilocalories (USDA), this research used 884 kilocalories.
6. Correcting for adult equivalence scale: The first adult equivalent scale estimated per capita consumption per adult male. In other words, it looks at what the consumption of households will be if these households consist of only male. However, this research is interested in the actual energy consumption of households. So, the adult equivalent scale was corrected to reflect actual household consumption.

3.4 Quantitative methods

The techniques including the statistical models and theories surrounding its application are presented in this section in addition to the concept that defines the working of these methods. The section begins with discussing the general principles applied in vulnerability assessment, steps used in constructing the VFII, and traditional food security indicators. Then concluded with the method for uncertainty and sensitivity analysis used to check the robustness of VFII.

3.4.1 Principles for vulnerability assessment

Vulnerability assessment according to Villagrán de León (2006) should be carried out in a transparent and systematic manner. This section reviews the key literature to understand the relevant general principles applied in vulnerability assessment. Answers to questions such as what specific guidelines should be used in the vulnerability assessment, what are the important indicators to select and what makes vulnerability methodology robust can then be addressed. Adger (2006) and Alwang et al. (2001) argue that vulnerability is a dynamic phenomenon and therefore measurement must reflect this complex social process as well as the material outcomes within a system. Due to the complexity involved in vulnerability measurement, it is difficult to quantify vulnerability or reduce it to a single metric. Trying to quantify these complex parameters can reduce the impact of vulnerability and hide the complexity, which makes the results unusable for policy or practice. Villagrán de León (2006) emphasizes that contrary to many definitions of vulnerability, which emanate from different disciplines, the number of methods for holistic vulnerability assessment is actually very limited. In fact, some disciplines such as within the sociology/anthropology area even argue that vulnerability cannot be measured easily at all, with only proxies used to represent it. Against this background, Schröter et al. (2005) have proposed an eight-step method for assessing vulnerability. These are:

- Define the study area together with stakeholders;
- Get to know the study area over time by reviewing literature, contacting researchers, spending time in the field with stakeholders, and exploring nearby areas;
- Hypothesize who is vulnerable to what and refine the focus on stakeholder sub-groups to identify drivers;
- Develop a conceptual framework for the vulnerability assessment and then use the framework to build a model that can assess vulnerability;
- Find indicators for the element or component of vulnerability (exposure, sensitivity, and adaptive capacity);
- Operationalize models of vulnerability and apply weight to models, aggregate indicators and validate results;
- Apply the model to project future or present vulnerability.
- Communicate vulnerability creatively to stakeholders, using multiple interactive media and be clear about uncertainty.

Designing a model for vulnerability assessment must account for the dynamics and severity of vulnerability (Adger, 2006a). It should not only show the number of people or households in a population that is vulnerable to stress (e.g. food insecurity) but must also account for the severity of vulnerability and be sensitive to the redistribution of risk within the population (Zurovec et al., 2017). Generally, a good vulnerability model should meet three important conditions. First, a good vulnerability model seeks to measure an outcome by incorporating the material aspect hence it must focus on human well-being (Adger, 2006a). For example, if the outcome of vulnerability was mainly economic, income could be used for measuring the well-being of the individuals or households. In this thesis, where the outcome is food insecurity, food consumption expenditure or malnutrition parameters can be used. The second condition is that the model must account for the temporal dynamics dimension of risk-whether the risk is temporal or chronic. The third condition is that the model must be able to account for the distribution of risk within the system. For example, in the case of flood, the way in which a smallholder farmer will take measure to manage this risk will be different from that of a large commercial farmer. Therefore, the model should be sensitive to this change. Luers (2005) highlighted that such a generalized model that meets the above-discussed criteria could not escape the need to create a threshold for measuring the severity of the risk. Stephen and Downing (2001) emphasized that a food vulnerability model should be able to account for the livelihood conditions of the targeted groups (i.e. rural or urban poor, female-headed households, pastoralists and the unemployed), coping mechanisms, socio-economic characteristics, stress indicators reflecting social and economic behaviour.

There are also several issues to consider when selecting an indicator for vulnerability assessment. A good indicator must be valid (measure the important element under consideration), sensitive (account for changes in outcome), available (easy to collect information and measure), reliable (consistent over time), objective (be able to reproduce under changing conditions), affordable (obtain at a reasonable cost of money, resources and time), simple (easy to understand by decision makers and other users), and transparent (should be verifiable and reproducible by persons other than the original producer) (Briguglio, 2003; Hahn, 2003; Hahn et al., 2009; Vincent and Cull, 2014; Neset et al., 2018). Appropriate indicator for vulnerability assessment will help to overcome methodological shortcomings (Stephen and Downing, 2001). According to Villagrán de León (2006), and Eriksen and Kelly (2007) the used of indicators for vulnerability assessment is based on their expected need. Three aspects are very important to consider when choosing an indicator. These are inherent properties or characteristics of the indicator, the methodology that this indicator will be used, and availability of data for such an indicator. Maclaren (1996) specifies a process to be used when designing an indicator. Such a process must begin with:

- Identifying the goals for which such indicator is needed. For example, a goal might be the reduction of food insecurity in a food vulnerability analysis;
- Scoping, this process helps to get the number of indicators that will be used, as well as the time frame and the geographical location where the indicators are measured. This is carried out bearing in mind the targeted audience needs, perceptions, and capabilities to understand and interpret result;
- Selection of the appropriate indicator based on the framework. Examples of such frameworks are domain (environment, economy, society); goals (basic human needs,

economic prosperity); sectors (housing, health, agriculture,); issues (hunger, malnutrition, unemployment, pollution); causal (conditions, stresses, responses) and combined frameworks;

- Selecting indicators based on specific criteria such as validity, reliability, easiness of calculation, accuracy, and cost-effectiveness to collect and process such data;
- Identifying and choosing indicators in terms of the framework and selection criteria;
- Lastly, assessment of indicator performance in terms of the pre-established criteria.

The principles discussed in this section serve as a guide and aid the research to focus on best practice in designing the vulnerability to food security index. The next section explains the methodological process used in constructing the vulnerability to food insecurity index.

3.4.2 Construction of Vulnerability to Food Security Index

This thesis followed a three-step process to construct the VFII (OECD, 2008). The first step involved selecting indicators and variables guided by the conceptual framework developed for VFII. The second step involved normalization of these indicators while the last step involved the aggregation of these indicators. This section also includes the threshold for the VFII.

3.4.2.1 Step One - Selection of indicators and variables

Using the IPCC (2007), VFII is a multidimensional index with three components: exposure, sensitivity and adaptive capacity as shown in Table 3.4. The conceptual framework was used to build the index including its indicators, then the panel data from Nigerian Living Standard measurement Survey was used to extract data need for these indicators. Section 3.4.2.1 describes these variables and their justification. After selecting the data for the VFII, then the next step was normalization.

Table 3.4: Variable and indicators of Vulnerability to Food Security Index

Index Dimension	Indicators	Description of variables
Exposure (probability of covariate shocks occurring)	Health shock	Illness of income-earning member
	Unemployment shock	Job loss
	Civil conflict shock	Theft of crops, cash, livestock or other
		Kidnapping/Hijacking/robbery/assault
	Agro-climatic shock	Poor rain that caused harvest failure
		Flooding that caused harvest failure
	Food price shock	Increase in price of major food items consumed
Sensitivity Previous/accumulative experience of food insecurity	Malnutrition	Length/height-for-age (stunting)
	Child mortality	Total number of children dead in each household
	Hunger	Total number of days' households gone without eating any food.
Adaptive Capacity how household respond, exploit opportunities, resist or recover from food insecurity shocks	Wealth Index	Household assets used to assess information
		Mobility assets used in households
		Livelihood assets own by households
		Housing structure characteristics
	Access to infrastructure	Household distance to nearest major road (km).
		Household distance to nearest market (km).
		Time taken to walk one way to the water source from household dwelling (minutes).
	Livelihood activities	Total income from savings, rental of properties and other types of income.
		Estimated revenue from non-farm enterprises
		Total yield of crops harvested (kg)
	Household literacy	Cumulative years of schooling for household heads or closest individual[1] in the household.

Description and justification of variables used in constructing VFII

The VFII has three dimensions, namely exposure, sensitivity, and adaptive capacity. This section discusses each variable used in each dimension of the Vulnerability to Food Insecurity Index.

Exposure variables

Illness of income-earning member: From the household dataset "illness of income-earning member" was selected and used as Health Shock in the Food Security and Vulnerability Index. Health shock such as "illness of income-earning member" can cause adverse economic outcome to communities and household living in such communities. High out-of-pocket expenditure due to illness of income-earning member could pose a risk of destitution, loss of income and a fall in consumption and push a household into food insecurity and vulnerability. Other challenges that this shock could cause are hindering the progress of economic development, increasing inequality, loss of productive time and poor coping abilities (McIntyre et al., 2006; Wagstaff, 2008; Alam and Mahal, 2014).

Job loss: Job loss used as a variable to represent unemployment shock in the Food Security and Vulnerability Index. Job loss reduces the ability of households to buy food, get clean water and medicines because of loss of income, and increases household food insecurity and vulnerability. Long-term unemployment shock can result in household engaging in criminal activities such as looting, banditry.; employing extreme coping mechanism like selling of productive asset and eating less nutritious meals making them more vulnerable to malnutrition in the near future (FAO and WHO, 1996).

Theft and Kidnapping: From the household survey data, the variable used to represent Civil conflict shock are: "Theft of crops, cash and livestock" and kidnapping/ hijacking/ robbery/ assault". The rationale for choosing using this indicator was because civil conflict is most prevalent in countries with low economic development and high levels of food insecurity. Food insecurity because of conflict can become a catalyst for political instability. Households in communities prone to conflict often experience poor economies, forceful immigration, refugee population, disease, social trust collapse and acute food insecurity. Conflict and violence, namely: stealing of crops and livestock, kidnapping, hijacking, robbery, etc. destroy food systems and causes persistence food insecurity and vulnerability. Households in such communities are likely to be malnourish, experiencing high infant death, food shortage, seizure or destroying of food stock, extortion of unarmed household for food and other productive resourced. These activities often result in humanitarian crises, famine as the farming population tend to flee, destruction of infrastructure, disruption to market accessibility and invariably causing food stock to be very expensive. In the long run, conflict threatens the ability of the society to achieve the SDGs, increases chronic undernutrition and persistence hunger (Jeanty and Hitzhusen, 2006; Brinkman and Hendrix, 2011; Breisinger et al., 2014; Breisinger et al., 2015; Waal, 2015).

Poor rainfall and flooding: Agro-climatic shocks have the potential for increasing food insecurity and malnutrition. Based on the household's survey data the variables used for agro-climatic shocks are: "poor rain that caused harvest failure" and "flooding that caused harvest failure". These shocks increase the risk of hunger and malnutrition for communities. Flood not only caused harvest failure but also destroys crops, asset in the community, critical infrastructure, therefore, deteriorating livelihoods and exacerbating poverty. Poor rain affects food production by decreasing crops yield in quantity and quality. Extreme rainfall devastates agricultural land, food stores, and increases the risk of waterborne disease. In turn, this affects the safety of food and makes the community vulnerable to food insecurity. Agro-climatic shocks cause shortage in food production, therefore, increasing the prices of major crops in the community (Schmidhuber and Tubiello, 2007; Krishnamurthy et al., 2012).

High food price: Food price shocks, such as increased in price of major food items, affect household food security by reducing the purchasing power of households, resulting to an increase in household's vulnerability to food insecurity by pushing them into a poor and hungry situation (HLPE, 2011). Rising food price, shift the consumption pattern of households causing them to eat less quality food, reduced their dietary diversity which can have a negative impact on the nutritional status (Holmes et al., 2009; Krishnamurthy et al., 2012). From the household survey data, the variable used to represent food price shock is "increase in price of major food items consumed".

Sensitivity variables

These variables represent the previous or accumulative experience of food insecurity. These are stunting, child mortality and hunger.

Stunting: Malnutrition is the most widely accepted and policy relevance variable commonly used are wasted, stunted, and underweight (Klennert, 2005). However, this research prefers to use stunting as an indicator of malnutrition. The reason is that stunting results from inadequate nutrition over a long period of time commonly referred to as chronic malnutrition. It is a good indicator of growth failure and does not reflect recent changes, unlike underweight. This means that stunting is useful for long-term planning and policy development because the timescale for it to occur is slow and cumulative. The definition suit the intention of the sensitivity dimension of the Vulnerability to Food Insecurity Index which seeks to reflect the accumulative experience of food insecurity. Wasting can easily be reversible by optimal feeding, and health and is unlike stunting, which cannot be easily be reversed. Children who are stunted suffer from chronic malnutrition and grow up to be smaller adult. For this rationale, stunting is preferred to other indicators of malnutrition (Young and Jaspars, 2006).

Child mortality: This indicator differs from the standard mortality statistics. Initially, it is the number of dead children between 0 – 5 years per 1000 children that were born alive. However, in this research, it is represented with the number of children (either male or female or both) born into a household that had died in the past 12 months prior to the survey start date. Form the household survey data, questions were asked on "number of male children" and/or "female children" reported dead in each household. Child mortality, defined as the total number of dead children in each household was derived by summing these data.

Hunger: This research refers to hunger as the physical discomfort caused by a lack of food (Bickel et al., 2000; Barrett, 2010) and not as a result of dieting or being too busy to eat. As such it represents hidden hunger, that is micronutrient deficiencies (Jones et al., 2013b). Thus, hunger is a severe stage of food insecurity. In deriving this indicator, the research adopts the Household Hunger Scale (HHS) methodology with a little modification due to inadequate data availability. The HHS is an indicator used to measure household hunger in food-insecure areas (Ballard et al., 2011; Jones et al., 2013b), and it is a subset of the Household Food Insecurity Access Scale (HFIAS) (Ballard et al., 2011). The scale reflects a more severe situation of household food insecurity which is linked to food deprivation and hunger. The HHS is specially developed to measure the prevalence of hunger and has been validated across different cultures and settings. The result of the validation showed that the HHS produces comparable and valid result across different cultures and setting (Deitchler et al., 2010; Deitchler et al., 2011). This makes the HHS be the most preferred method used in this research to calculate household hunger. It is widely used in food security research for policy formulation and designing targeted measures or monitoring the impact of anti-hunger policies in countries or regions.

Adaptive capacity variables

These variables capture how household responded, resisted or recovered from food insecurity shocks.

Wealth Index: The wealth index is a measure of economic status of households to ascertain their relative wealth. Compared to other measure of economic status like household income or consumption expenditure, the wealth index presents a more permanent form of household's wealth being that it uses different households' characteristics and assets to produce a composite score. The score is then used to categorize and rank households into poor or non-poor quintiles. Unlike the household income and consumption expenditure that has a common problem of volatility and not being able to capture all form of wealth (Ruststein and Johnson, 2004; Fry et al., 2014). Furthermore, the wealth index can be used to recognise the problem that limits poor households to access food comparing to wealthy households. It is very reliable in that wealth can easily be measured and requires fewer questions compare to income and consumption expenditure. The wealth index used in this research uses various household assets including information assets, mobility assets, livelihood assets, and housing characteristics to design the index. The following variables were used when designing the wealth index: *Livelihood assets:* Table, mattress, bed, mat, fridge, freezer, sofa set, chair, sewing machine, kerosene stove, other assets, generator, size of agricultural land, broiler chicken, cockerel, local chicken, goat, pig, duck and sheep. *Mobility assets:* Bicycle, motorbike, cars and other vehicles. *Information asset:* Radio, TV set, computer, satellite dish, DVD player, GSM mobile phone/landline, cassette recorder. *Housing structure characteristics:* Outer wall, roof materials, floor material, members per room, lighting fuel, cooking fuel, access to electricity, main source of drinking water during dry season, main source of drinking water during the wet season, type of toilet facilities, type of user who shared toilet facilities, and refuse disposal facilities.

Access to infrastructure: It is not only the wealth status of households that can improve the adaptive capacity of households but also the available social and public infrastructure in the society. How households easily have access to essential social amenities like schools, hospital, major roads, markets and water can immensely assist individuals in households to recover from shocks. This research uses distance to major roads, distance to markets and time taken to get to the nearest water source to represent a single indicator called "assess to infrastructure".

Livelihood activities: Income sources, revenue from non-farm enterprises and agricultural activities are used as variables to represent livelihood activities. The reason for using these variables is that livelihood activities should reflect how easy or difficult a household can use their resources when there is a sudden occurrence of shocks. The more household livelihood activities are diversified, the better chance this household may be in responding to a vulnerable situation. There are three significant livelihood sources identified in the LSMS household survey data. The data from these sources were combined to produce a measure of livelihood activities in the research.

Household Literacy: The Day-to-day decision of households is influenced by the knowledge and capabilities possessed by key members of the household. This is one of the reasons why household literacy is an important indicator that will seek to improve or worsen the ability of households to recover from food insecurity shocks. Cumulative years of schooling by the household head, or closest individual, is one of the main criteria used in defining household literacy. Years of schooling are used as a proxy for literacy and level of understanding of household members, including household heads. An individual is considered literate if he or she has at least five years of education (Dotter and Klasen, 2014). Each household will benefit from at least one literate person of any age (Basu and Foster, 1998). Only post-planting season data was used to derive this indicator, because it contains information on household head needed to represent literacy level of household. In rare cases where there was no data on household head, the *closest individual* in educational achievement that had at least five years of schooling is used as a replacement for household head. If educational qualifications are the same for more than one individual, the most senior individual in age is used. Post-harvest season data was not used because it contains only data on additional new households' member and whereas this variable is interested in the household head.

3.4.2.2 Step Two – Normalization and weighting of variables:

Variables were normalised to ease comparison and for all variables to have an equal unit (OECD, 2008). The normalization method used is a min-max method and shown in equation 3.1.

$$I_{VFII} = \frac{X_{fvi} - X_{min}}{X_{max} - X_{min}} \dots\dots\dots\dots\dots.. \quad [3.1]$$

Where X_{max} and X_{min} are the minimum and maximum values of the normalised food vulnerability index variables (I_{VFII}) and having the values lying between 0 (laggard) and 1 (leader), respectively (UNDP, 2007; Hahn et al., 2009; OECD, 2008; Singh, 2014; Freudenberg, 2003).

The next step was to generate weight for these variables. Four methods exist in the literature to assign weight to variables: by quality of data (OECD, 2008), expert opinion (Brooks et al., 2005; Malcomb et al., 2014; de Sherbinin, 2014; Singh, 2014), equal weighting (Lucas and Hilderink, 2005) and statistical method such as principal component analysis (Gbetibouo et al., 2010; Madu, 2012). This study used both equal weights and unequal weight for the VFII variables. The principal component analysis was used to generate unequal weight while each component of the VFII was assigned equal weights of 0.33. PCA was used because its groups together linear indicators that are correlated to form composite indicator that captured as much as possible the information common to individual indicator (Abson et al., 2012; Madu, 2012). In addition, each factor of the PCA indicates the set of indicators with the strongest association (OECD, 2008). The first principal component was used to assign the weight to each variable of the VFII. This is because, the first principal components “accounts for the maximum possible proportion of the variance of the set of indicators used” (OECD, 2008:63).

The justification for using equal weight was from the findings of uncertainty and sensitivity analysis conducted. The result shows that the output of the VFII was stable to changes and was robust when equal weight was used. In contrast, using unequal weight made the output of the VFII to be unstable to changes and the output was not robust. Nevertheless, after performing uncertainty and sensitivity analysis, thesis adopted equal weight for the index (*see chapter 5 for details*). So, each component of the VFII was assigned equal weights. The individual weight for variables is derived from dividing 0.33 by the total number of variables in each component as shown in Table 3.5. For example, the adaptive capacity component has 8 variables, each variable has a weight of 0.0412 after dividing 0.33 by 8. However, for the exposure component, this is different. Because the data for the exposure variables are derived from the enumeration area and not household level, there is only one column. Thus, by default this column is weighted 0.33 since the data for each shock variable has been aggregated into this column.

Table 3.5: Equal weight for individual indicators

VFII component	Indicators	Individual weight	Overall weight
Exposure	Shocks variable*	0.33	0.33
Sensitivity	Stunting	0.11	0.33
	Child mortality	0.11	
	Hunger	0.11	
Adaptive Capacity	Wealth Index	0.0412	0.33
	Dist-to-Road	0.0412	
	Dist-to-Water	0.0412	
	Dist-to-Market	0.0412	
	Income sources	0.0412	
	Non-farm income	0.0412	
	Crop yield	0.0412	
	Household literacy	0.0412	

3.4.2.3 Step Three – Aggregation of variables:

Finally, to compute the VFII score for each household, the aggregation method shown in equation 3.2 was applied. Where E_i is the exposure index, S_i is the sensitivity index and AC_i is adaptive capacity index.

$$VFII_i = \sum AC_i \ - \left(\sum E_i + \ \sum S_i\right) \qquad (3.2)$$

For each component of the VFII equation, 3.2b was used to compute the composite score

$$V_i = \sum_{i=0}^{n} w_1 x_1 + \cdots + \ w_n x_n \qquad (3.2b)$$

Where V_i represent each VFII component such as the exposure E_i, sensitivity S_i and the adaptive capacity AC_i, w_n is the weight for each variables and x_n is the individual variables used in each component of the VFII.

Households with lesser and negative VFII composite values are more vulnerable to food insecurity compare to households with higher and positive VFII composite scores. In other words, the higher the composite value of VFII, the lower the vulnerability impact on household food security.

3.4.2.4 VFII Threshold

A household can be highly exposed or sensitive to food insecurity, but this is not a sufficient condition to say that this household is vulnerable to food insecurity. Thus, a vulnerable household is one in which their adaptive capacity is too low to help such household adjust successfully to the stress caused by exposure and sensitivity ((IPPC, 2007; Fellmann, 2012). The VFII threshold is defined as a point where household adaptive capacity is higher than the combined effect of exposure and sensitivity. Given that the VFII has three components which are equally weighted, each component has a weight of 0.33. In other words, each component represents 1/3 dimension of vulnerability.

Mathematically, when:

- (E+S) > AC, such household is said to be vulnerable to food insecurity
- (E+S) < AC, such household is not vulnerable to food insecurity

From the understanding of this mathematical notation, at what point canna household be vulnerable or not vulnerable to food insecurity using the VFII composite score? A household will be at two points:

- First, is when a household VFII composite score is less than 1/3 mean of total VFII composite score for all households. At this point, a household is severely vulnerable to food insecurity.
- Second, is when a household VFII composite score is less than 2/3 mean of total VFII composite score for all households and greater than 1/3 mean of total VFII composite scores. At this point, a household is vulnerable to food insecurity.

Using this threshold method provide a cut-off point that is meaningful and reflect different vulnerability stories from the sample bearing in mind that vulnerability is context and place-specific. Using the aggregation method in equation 3.2 to compute the VFII, the index composite score responds to positive values, and the magnitude is in ascending order. That is vulnerability ranges from a positive value to a negative value. The more positive the score, the less the households are vulnerability to food insecurity and vice versa. This score is used to categorise households into three different food vulnerability groups. The first group are households that are highly vulnerable to food insecurity. These are households in dire and worst level of food insecurity and vulnerability, and their composite score is less than or equal to -0.0530. The next group are households that are mildly vulnerable to food insecurity. Their composite score is higher than -0.0530 but less than -0.0265. The last group are households that are not vulnerable to food insecurity. The composite score is higher than -0.0530.

3.4.3 Construction of traditional food security indicators

The traditional food security indicators used in this thesis are per capita calories, food consumption score and coping strategy index. The thesis restricted the comparison of the VFII to these three traditional food security indicators because of the constraint of time, data availability and the indicators are the most widely used single food security indicators. The is discussed their meaning, what these indicator measures and how they were constructed.

3.4.3.1 Food energy consumed per capita (Per capita calories consumption)

Food energy consumption is an indicator that measures the total dietary quantity of food energy consumed in each household. Energy in food is vital for survival, performing physical activities and for survival. This indicator measures the sufficiency of energy available in food eaten by households and also used to indicate the ability of households to have access to food (Dary and Imhoff-Kunsch, 2010; Smith and Subandoro, 2007). The following procedures were used to compute this indicator. All non-standardized food quantities recorded in the household dataset were converted from the local unit (e.g. bunch or rubber) to standardise unit in grams. By multiplying the quantities of local food items by their metric weight, the household survey data set provided the metric weight for each food item. Food items with missing weight were removed. The total energy content of food acquire by each household was derived using the following equation, total food energy (kilocalories) = Food quantity in grams per day * edible portion * (food energy conversion factors/100). The energy conversion factor of food items was gotten from FAO et al. (2012), and FAO (1968). Finally, total daily calorie availability per adult equivalent for households was computed by dividing total energy acquisition per household per day by adult equivalent factor. Using multiple imputation techniques, an OLS regression with the independent variables that are household's characteristics was used to compute missing calorie availability for households that had this data missing. The FAO recommends an average food consumption of 2360 kcal/person/day; this value was used as the threshold score for households in this study.

3.4.3.2 Food Consumption Score (FCS)

FCS is a food security indicator developed by the World Food Program that measures the dietary diversity of food consumed in the households with a seven days recall period (Vaitla et al., 2017). It is possible for a household to meet their food energy requirement but could not leave a healthy and active life because of deficiency of other macronutrient (like protein) and micronutrients such as iron, vitamin A, and iodine (Smith and Subandoro, 2007). Hence, FCS monitor changes in food nutrition within the households (Jones et al., 2013a). It is a composite index that is made up of 9 weighted food groups. The weight attached to each food groups are: cereals and tuber=2, pluses = 3, vegetables = 1, fruit = 1, meat and fish = 4, milk = 4, sugar = 0.5, oil = 0.5 and condiments = 0. The frequency of each food group consumed is multiplied by the assigned weight; the scores obtained now sum to get the FCS for each household. The overall score range between 0 -112. There two threshold categories are given by WFP for grouping households: a household with oil and sugar consume daily and household that does not consume oil and sugar daily. This study adopted the threshold for households that consume oil and sugar. Households with FCS above 42 are considered acceptable, scores between 28.5 - 42 are borderline, and scores within 0-28 are poor food consumption (Maxwell et al., 2014; Vaitla et al., 2017).

3.4.3.3Coping Strategy Index (CSI)

The CSI measures the frequency and severity of specific behaviours employed by households when there is a food deficit. The CSI measures both current food security situation and is a good predictor of future food vulnerability of households (Maxwell and Caldwell, 2008). To compute the CSI, the frequency of coping strategy used by households is multiplied by the weight. The weight ranges from 1 (least severe category) to 4 (most severe coping behaviour). The coping strategies and weight are: borrowing food or rely on friends or relatives (2), limits the variety of foods eaten (3), reduce number of meals eaten in a day (3), limit portion size at meal-times (4), restrict consumption by adults in order for small children to eat (4), have no food of any kind in the house (4), sleep hungry at night because of no food (4), and go a whole day and night without eating anything (4). The weighted frequencies then sum to derive the CSI score. There is no universal guideline to interpret the CSI score. However, Maxwell et al. (2014) suggested scores within 0-2 (food secure), 3-12 (mildly food insecure), 13-40 (moderately food insecure), and above 40 (severely food insecure).

3.4.4 Sensitivity and uncertainty analysis

In designing the Vulnerability to Food Insecurity Index, several assumptions such as different type of normalization method, weighting method, inclusion and exclusion of variables, and the aggregation method have been applied. Sensitivity and uncertainty analysis are needed to test the impact of these assumptions on the VFII and to establish the robustness/reliability of the index. Also, the uncertainty and sensitivity analysis helps to choose the normalization and weighting method to be adopted for the index (Saltelli, 2017).

Two approaches were used in conducting the uncertainty and sensitivity analysis namely One-at-a-Time approach (OAT) and global sensitivity approach. The OAT approach changes one factor or assumption at a time and then compares the output while the global sensitivity approach explores the entire effect of each factor or assumptions on the model output (Saltelli et al., 2004). These approaches are discussed in detail in section 3.4.4.1 and 3.4.4.2.

3.4.4.1 One-at-a-Time Approach

This approach tests the effect of a single input or factor on the output one at a time. This method was used to test the performance of the VFII on different weighting method, normalisation method and excluding/including a variable. Data with missing or incomplete observations and data with complete observation were used for comparison purpose and to test the robustness of the VFII.

3.4.4.2 Global Sensitivity Approach

To test the robustness of VFII, this thesis performed an uncertainty analysis and used Sobol's sensitivity indices on the VFII using global sensitivity approach. This section discusses in detail the application of these methods.

Uncertainty analysis

This study applied the global sensitivity approach for the uncertainty analysis. The uncertainty analysis focuses on quantifying uncertainty in VFII model output. The primary source of uncertainty in the ranking of states by the VFII is investigated (Saltelli, 2017). The difference between the composite score output ($VFII_{BE}$) of two states (Bayelsa and Edo states) was investigated in this thesis as shown in equation 3.3

$$VFII_{BE} = \left(VFII_{Edo\ state} - VFII_{Bayelsa\ state} \right) \qquad (3.3)$$

To quantify the primary source of uncertainty in equation 3.2 involves ascertaining the presence of uncertainty in the input factors used to produce the output of VFII and equation 3.3. The main interest is on the following assumptions that can introduce uncertainty in the VFII output: selection of variables, normalisation method, weighting schemes and exclusion/inclusion of variables. The input factors used for uncertainty analysis are present in Table 3.6 and are defined as everything that causes a variation or uncertainty in the output of the model (Saltelli et al., 2008). These are 12 weighted variables with their probability distribution function (PDF). Also included are additional three trigger variables to represent the type of normalisation (either min-max or z-score), weighting scheme (equal or unequal (PCA) weight) and exclusion or inclusion of variable (either child mortality or distance-to-water-source).

Table 3.6: Uncertainty input factor probability distribution function

Input factor	Description	PDF	Range
SH	Weighted shock	Normal	-
CM	Weighted child mortality	Normal	-
ST	Weighted stunting	Normal	-
HU	Weighted hunger	Normal	-
WI	Weighted wealth index	Normal	-
DR	Weighted distance-to-road	Normal	-
DM	Weighted distance-to-market	Normal	-
DW	Weighted distance-to-water	Normal	-
IS	Weighted income-savings	Normal	-
NI	Weighted non-farm-income	Normal	-
CY	Weighted crop yield	Normal	-
HL	Weighted household literacy	Normal	-
X_1	Weighting method (either equal weight or unequal (PCA) weight	Discrete	[0,1] where [0,0.5] =equal weights and (0.5,1] =PCA weight
X_2,	Normalization method (min-max or z-score values)	Discrete	[0,1] where [0,0.5] =min-max and (0.5,1] = z-score
X_3	Inclusion-Exclusion (either excluding child mortality and distance-to-water source or including child mortality and excluding distance-to-water-source	Discrete	[0,1] where [0,0.5] = excluding child mortality and distance-to-water source and (1, 0.5] = including child mortality and excluding distance-to-water-source

Monte Carlo analysis was used, which is based on using the probabilistic value of the model input to estimate multiple model evaluations and then using these evaluations to determine (1) the uncertainty in the model prediction and (2) the input factors that caused the uncertainty. This thesis followed the procedure laid out by Saltelli et al. (2004) and Saltelli et al. (2008). Details can be found in chapter 5.

Sensitivity Analysis

The variance-based sensitivity method was used for analysis. The interest is to find out how the overall uncertainty in the input factors affects the output rather than testing one input at a time. The variance-based sensitivity method decomposes the uncertainty in input factors according to their variance and shows how output depends on this variance (Saisana et al., 2005; Saltelli et al., 2008). The variance-based method applied in this thesis is Sobol' sensitivity indices (Sobol', 1996), which are the first-order and total effect sensitivity indices.

First-order sensitivity index:

Consider the following model

$$Y = f(X_1, X_2, \dots., X_k) \qquad (3.4)$$

Y is the output and the input factors $X_1, X_2, \dots., X_k$ are supposed to be independent random variables described by known probability distributions. These distributions reflect the uncertain knowledge of the system. The sensitivity index of an input factor X_i can be measure by comparing the contribution of it variance to a model output due to uncertainty in X_i (Saisana et al., 2005).

Assuming one can quantify the importance of an input factor X_i on the variance Y to fix it s true value x_i^*. this assumtion is called the conditional variance

$$V_{X_{-i}}(Y|X_i = x_i^*)$$

Because the true value of X_i is not known, we take the average of all possible values of X_i :

$$E_{X_i}(V_{X_{-i}}(Y|X_i))$$

Using the law of total variance:

$$E_{X_i}\left(V_{X_{-i}}(Y|X_i)\right) + V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right) = V(Y)$$

And after normalization, the equation becomes

$$1 = \frac{V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right)}{V(Y)} + \frac{E_{X_i}\left(V_{X_{-i}}(Y|X_i)\right)}{V(Y)}$$

Therefore, the first-order sensitivity index for factor X_i is given by:

$$S_i = \frac{V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right)}{V(Y)} \quad \dots\dots\dots (3.5)$$

S_i is known as the first-order sensitivity index. S_i is a number that ranges between 0 and 1. A higher value denote an important variable. It represents the main effect contribution of each input to the output variance singly (Homma and Saltelli, 1996). When a model first-order term does not add up to one such model is called nonadditive model $(i.e.\ \sum_{i=1}^{r} S_i \leq 1)$. Alternatively, first-order term add up to one or equal to one, such a model is an additive model (Saltelli et al., 2008).

Total-effect sensitivity index:

First-order sensitivity index measures the effect of individual input on the variance of the output not considering the interaction. Thus, total effect index account for the total contribution to the output variation due to factor X_i. It is the combination of first-order effect and higher-order effect due to interactions.

Total effect can be computed by decomposing unconditional variance into main effect and residual:

$$V(Y) = V\big(E(Y|X_i)\big) + E\big(V(Y|X_i)\big) \qquad (3.6)$$

To obtain the total effect index for X_i, we divide by $V(Y)$:

$$S_{T_i} = \frac{E\big(V(Y|X_{-i})\big)}{V(Y)} = 1 - \frac{V\big(E(Y|X_{-i})\big)}{V(Y)} \qquad (3.7)$$

Total effect index (S_{T_i}) provide an answer to the question: "which factor can be fixed anywhere over its range of variability without affecting the output?" If $S_{T_i} = 0$, this means X_i has meet the condition of not being an influential factor. If $X_i \cong 0$, then X_i can be fixed at any range without affecting value of the output variance $V(Y)$ (Tarantola et al., 2007). The next section – section 3.5 discusses the qualitative method applied in this research.

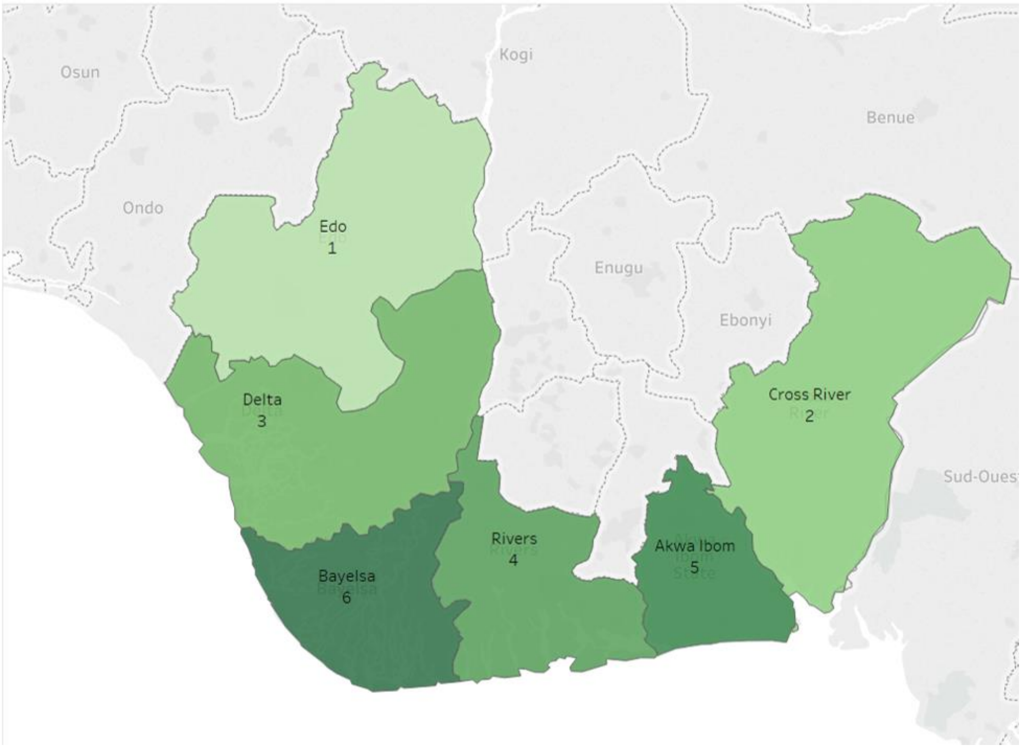
3.5 Qualitative methods

This section describes the selection of the study location for the field visit, sampling of the community and households. It also explains the methods used to analyse the qualitative data and consideration of research ethics.

3.5.1 Selection of location

The food vulnerability map produced by the VFII (Figure 3.3) was used to select Akwa Ibom State within the South-South region of Nigeria. The State represents a location with high vulnerability to food insecurity and is, therefore, suitable for the verification exercise.

Figure 3.3: Food vulnerability map of states in the South-South Region of Nigeria



Source: Data Analysis using Tableau

Secondary data collection and three key informant interviews with the Heads of Department from within the Akwa Ibom State Agricultural Development Programme (AKADEP) and the Ministry of Agriculture and Food Sufficiency, Akwa Ibom State (MOA) were conducted. A purposive sampling approach was used to consider potential communities, and the key informants indicated a selection of study communities that were characterised by vulnerability to food insecurity. After a scoping visit, two communities, *Ibesikpo* and *Ikono*, were selected to represent an urban and a rural context respectively. They were also safe to visit and relatively accessible due to local contacts.

3.5.2 Sampling of community

In each community, a focus group discussion was initially conducted and included the locally important stakeholders, including the village head and village council members to obtain permission and gather general community information. This information included mapping of community resources, understanding food-related shocks that had affected the community within the past four years, characterizing households by a local wealth ranking, characterizing the coping strategies used by the community, and validating the VFII indicators. Participatory exercises were used during the focus group discussion for resource mapping, wealth ranking, and proportional pilling (WFP, 2001).

The information from the focus group discussion provided the researcher with a geographical understanding of the context, a better understanding of local food insecurity, helped to guide the researcher to locate specific households needed for the research and to compare the VFII indicators with local perceptions. Most importantly, the focus group discussion generated local indicators that characterised households who were considered as highly vulnerable, mildly vulnerable and not vulnerable to food insecurity.

3.5.3 Sampling of households

Using a local guide and two research assistants, households were selected for in-depth interview using the local perception from the focus group discussion. These helped identify and categorised households into three food vulnerable groups namely highly vulnerable, mildly vulnerable and not vulnerable to food insecurity.

A snowball sampling technique was then used to identify fifteen households from each of the contrasting urban and rural communities, generating a total of 30 households for the study (Table 3.7). Based on the three-food insecurity and vulnerability groups, five households were interviewed within each group in-depth, providing a total of 15 household interviews per community. Snowball sampling was used to select households for the in-depth-interviews based on local indicators earlier generated from the focus group discussion. During the household in-depth interview, a short participatory exercise, like matrix ranking was conducted. The in-depth individual household interview was conducted with the household head or a member of the household that was knowledgeable regarding food security, although other household members were present and willingly contributed to the discussion. The interview focused on questions about the impact of food-related shocks on households: household's response to these shocks; formal food support program available to households; recent problems hindering access to adequate food; reasons and measure taken by households to solve these problems and a season calendar. Questions were constructed to ensure that interviewees were not led to particular answers and the process was subjected to a University ethical review process. The qualitative data were analysed using a thematic coding process to identify the important local indicators of vulnerability to food insecurity, what their relative importance was by the group, and how these indicators were different by locational context, as well as providing insight about perceptions from the different groups and contexts with indicators from the index.

Table 3.7: Sampling size for focus group discussion and households' interview

Activity	Urban Community (*Ibesikpo*)	Rural Community (*Ikono*)	Total
Focus group discussion	1	1	2
Households interview	5 non-vulnerable households	5 non-vulnerable households	30
	5 mildly vulnerable households	5 mildly vulnerable households	
	5 highly vulnerable households	5 highly vulnerable households	
Sub-total	15 households	15 households	

3.5.4 Method used to analyse qualitative data

The small sample for the qualitative data did not make frequency data meaningful and the analysis focused on insights from sample using thematic coding (Nowell et al., 2017) to explore what local perceptions about the critical indicators of vulnerability to food insecurity, what their relative importance was considered to be by each group, and how the indicators might be different by rural or urban context. The analysis also compared perceptions of these characteristics by group and context with those indicators from the index.

3.5.5 Research ethics

The fieldwork instruments and participant information sheets (see thesis appendix for details) as well as the safety of the study location followed University of Reading procedure and was approved by the University Research Ethics Committee. The researcher abided by the rules of the committee laid out by Foreign and Commonwealth Office (FCO). For safety reasons, all travel to riverine areas and oil-producing community in the Akwa Ibom State were avoided and this influence decision about sampling locations. All participants (both groups and individuals) were informed of the participant information sheet, acknowledging the terms and conditions of the research and gave their approval. Participation was entirely voluntary, and the researcher sought to present their research as independent to any local politics. Personal information was not collected, in rare instance where name or email was collected for contact purposes, it was held confidentially and later destroyed, and participant remains anonymous. Pictures were taken if the participants gave their consent and all discussion was audio-recorded if the participant agreed.

Reflecting on the fieldwork experience, this was interesting but also challenging. The fieldwork experience gave the researcher first-hand information on food insecurity problems in the community. Sometimes it was traumatizing to see and listen to households express their experience of hunger. At one point the in-depth interview had to be summarized to leave that household. The researcher had to change accommodation frequently to avoid being rob because the researcher was considered as an outsider especially when mentioning University of Reading, UK. During the scoping visit, the research questionnaire was amended to enable the researcher to ask question in the way that respondents understand without influencing their views.

Several challenges were encounter during the fieldwork. The research involves frequent travelling for one location to another, and poor road network made travelling very difficult and stressful. The researcher laptop was damage as the researcher was travelling from one household's location to another. The period for the research was short because of the cost involved and considering the time needed to complete my PhD programme. Organizing community stakeholders for a focus group discussion was difficult because the timing was not convenient for everyone.

Chapter 4 : Advancing a new index for measuring household vulnerability to food insecurity

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A copy of the publish paper is included in this thesis appendix.

Abstract

This paper develops a Vulnerability to Food Insecurity Index (VFII). Currently, there is no standard indicator of vulnerability analysis in food security research, and this paper responds to this challenge. The primary objective in this paper is to demonstrate how to develop a potential indicator and establish its validity through comparison with other traditional food security indicators, such as per capita calorie consumption (PCC), food consumption score (FCS) and the coping strategy index (CSI). Structurally, Vulnerability to Food Insecurity Index is a multidimensional index of the probability of covariate shock occurring (exposure), the accumulative experience of food insecurity (sensitivity) and coping ability of households (adaptive capacity). The paper applies the index to households in southern Nigeria, using the World Bank's generalised household panel dataset. The results show 61% of households in the study to be highly vulnerable to food insecurity, 12% mildly vulnerable and 27% not vulnerable. Traditional and single indicators, such as FCS and PCC are not good indicators of vulnerability to food insecurity whereas CSI is a better indicator of vulnerability to food insecurity compared to FCS and PCC. The VFII developed in this paper includes components of FCS, PCC, and CSI and regarding ranking, the VFII was found to be reliable. Most importantly, the analysis using the VFII reveals how dietary diversity or calorie consumption indicators can exclude some households who are vulnerable to food insecurity. The paper concluded that accurately target long-term support to vulnerable households, policymakers who seek to address the underlying causes of food insecurity cannot rely on single indicators, and for this type of goal, the VFII makes a useful contribution.

Keywords: food vulnerability, vulnerability, food security, vulnerability measurement, index,

4.1. Introduction

There has been growing concern about food insecurity crises globally, which has rekindled the interest of researchers and policymakers to provide improved disaster risk reduction planning, prediction, and targeting of support to the food vulnerable. This is a complex challenge, with over 1 billion people estimated to suffer from micronutrient deficiencies and insufficient dietary energy availability (Barrett, 2010) and a combination of factors operating across multiple scales to influence individual's food insecurity (Vaitla et al., 2017). To accurately target limited resources, better predictive models are needed that measure these subjective aspects of food security, including vulnerability (Vaitla et al., 2017). Food security definition is widely accepted as a situation that exists "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This definition emphasises the multidimensional nature of food security and any holistic model to measure food insecurity needs to reflect this. However, designing holistic models is difficult, and as a result, there is no one standard model available.

Maxwell et al. (2013) argue that single measures or indicators of food security are therefore commonly used for assessment of "access", but these consider only current access to food without a good understanding of the wider risks that households face. For example, per-capita caloric intake has been used as a "gold standard" to measure food insecurity at the household level especially for rapid assessment needs (Maxwell et al., 2014). However, while per capita calorie intake will reflect current consumption, it will not reflect other more complicated elements of food insecurity, like quality, vulnerability and risks, or fluctuations and trends in consumption over time and therefore not provide an understanding of how to manage long-term or seasonal vulnerability. Moreover, using a single indicator can result in underestimation and misclassification of possible food insecure households (Vaitla et al., 2017).

As a result, policymakers often have incomplete information available during planning decisions. Capaldo et al. (2010) have emphasised that policy should be designed to address this uncertainty and provide a range of risk management options to support different household needs. This emphasis reflects the importance of including vulnerability analysis in any assessment of food insecurity. However, applying the concept of vulnerability to food insecurity assessment is relatively new, and few studies have focused on it (Bashir and Schilizzi, 2012). A standard model for vulnerability analysis in food insecurity has not yet been developed, even though different analytical methods exist (Capaldo et al. (2010). The problem is further compounded as the literature on vulnerability argues that the concept is relative and therefore difficult to measure (Hinkel, 2011; Moss et al., 2001). A further challenge is that there is no official goal for measurement, so researchers use similar but slightly different approaches for different aspects of the problem. This can lead to different interpretations of the nature of the problem and can result in policy responses that are ineffective in the long-term or exclusionary for some households.

This paper seeks to contribute to this gap in knowledge by presenting how it is feasible to develop a prototype food insecurity indicator that is based not only on current consumption, wealth or income levels but also incorporates a vulnerability dimension. This indicator is called the Vulnerability to Food Insecurity Index (VFII) and is a multidimensional index that measures household's food insecurity and vulnerability. In doing so, it considers the risk and uncertainty associated with food insecurity by reflecting on how food-related shocks influence food vulnerability for a household. The VFII also provides an improved methodology for food insecurity analyses and serves as a better tool to accurately profile vulnerable households for cost-effectively targeting of interventions. The primary objective of this paper is to present how the VFII was developed and to establish its validity, by comparison with other traditional indicators. We ask to what extent is this index better captures components of food insecurity and vulnerability as compared to traditional measures of food insecurity? The VFII can be compared with results from per capita food consumption, food consumption score and coping strategy index. An uncertainty and sensitivity analysis on the VFII can be performed to test its robustness on assumptions used in the model. The next section provides an overview of the current debate in the literature, in particular, conceptualisations used to understand and assess food insecurity and vulnerability. Section 4.3 outlines the methodology used, and section 4.4 summarises the sensitivity and robustness analysis, with sections 4.5 and 4.6 presenting the results, discussion and conclusions.

4.2. Conceptualising vulnerability to food security

There is an extensive discourse on food insecurity and vulnerability in the literature, and this section is restricted to illustrating how these conceptualisations of vulnerability to food insecurity have guided this research, and how approaches related to these different views can be used to operationalise vulnerability.

4.2.1 The value of understanding contextual vulnerability for food insecurity assessment

Vulnerability is commonly defined as the degree to which a system is likely to experience harm due to hazards (Villagrán de León, 2006). Food vulnerability exists when food-related shocks stress a household's ability to acquire safe and nutritious food. This stress emanates from the biophysical and socio-economic systems operating across multiple scales to influence the household. Outcome vulnerability and contextual vulnerability can be explored to understand these systems, but each comes from a different focus and uses a different approach.

According to Fellmann (2012), outcome vulnerability is based within the natural sciences, most recently as a result of interest in climate change outcomes and uses future model scenario as a basis for analyses. It concerns itself primarily with biophysical changes in a closed system, with a boundary between nature and society. As a result, the role of socioeconomic components in ameliorating the effect of risk is not explicitly included. Accordingly, a system considered to be vulnerable will be that which will experience the most dramatic physical changes. Those who adopt a focus on outcome vulnerability adopt a more closed system approach in their attempts to operationalise vulnerability. For example, econometric approaches are inductive and try to use both secondary and primary data of a specific system or unit to come to conclude the level of harm (Hinkel, 2011; Singh, 2014). The use of statistical models heavily relies on the availability of data, with cross-sectional, repeated cross-sections and longitudinal data most commonly used. However, the best-suited data for micro-vulnerability analysis is panel or longitudinal data (Hoddinott and Quisumbing, 2003; Hoogeveen et al., 2004; Chaudhuri et al., 2002; Günther and Harttgen, 2009). Panel data has advantages because it gives a more precise estimation of change in variables means, provides accurate data on past events, is cheap to collect for selected individuals over a specific period and is suitable for fixed-effect analysis, enabling the researcher to have control over time-invariant variables (Hoddinott and Quisumbing, 2008). Examples of econometric models used in vulnerability analysis include structural dynamic models (Elbers and Gunning, 2003; Scaramozzino, 2006), three-stage feasible generalized least square (Chaudhuri et al., 2002; Capaldo et al., 2010; Adepoju et al., 2011), multilevel analysis (Günther and Harttgen, 2009), Value at Risk (Scaramozzino, 2006), limited-dependent variables (Scaramozzino, 2006; Corral et al., 2015), instrumental variable estimation (Karfakis et al., 2011), generalized maximum entropy (Corral et al., 2015), and two-stage least square (Christiaensen and Boisvert, 2000). The main strength of this approach is the ability to estimate vulnerability for a future period (Elbers and Gunning, 2003) but the method is dependent on reliable panel data. This method heavily relies on panel data but, according to Chaudhuri et al. (2002), panel data are not readily available in most developing countries and sometimes when available have limited or unrepresentative cross-sectional component.

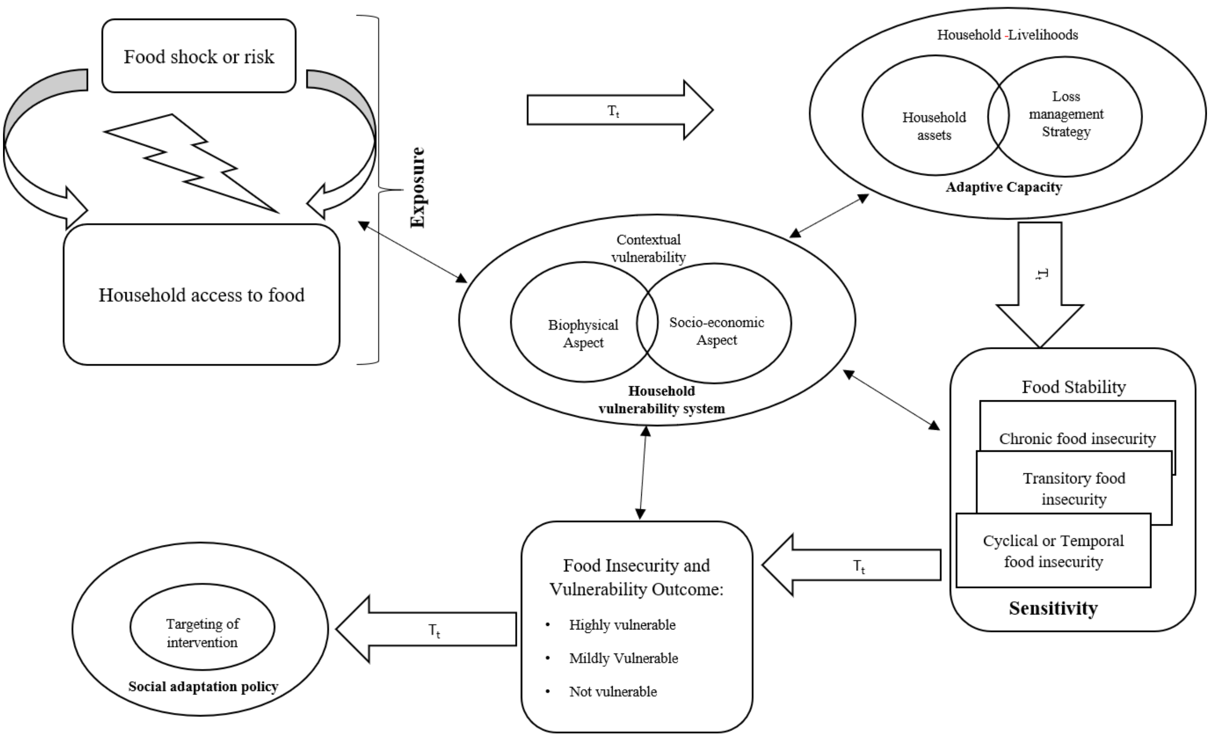
By contrast, taking a contextual vulnerability perspective develops an interest in multiple factors that shape the socio-ecological system and requires the researcher to adopt a multidisciplinary approach (Adger, 2006; Berkes and Folke, 1998). Contextual vulnerability therefore includes both the biophysical and assessment of the socio-economic drivers of vulnerability, including social marginalization, economic inequality, available household food and resource entitlements, the effectiveness of local and broader support institutions, economic and political systems (Cardona et al., 2012; Adger, 2006; O'Brien et al., 2007). This approach helps us to understand which social groups or regions tend to be more vulnerable to food insecurity (O'Brien et al., 2007), making this approach highly relevant to conceptually underpin the development of a more holistic vulnerability to food insecurity index. This approach can be operationalised using a vulnerability index methodology of the observable variables and uses a deductive approach. To define the state of vulnerability of a system, the index method can apply a concept, framework or model for the selection of variables. Examples include IPPC (2007) characteristics of exposure, sensitivity and adaptive capacity (IPCC 2007) and a sustainable livelihoods framework (Hahn et al., 2009b; Singh, 2014). A weakness of this approach is that the frameworks do not provide arguments for aggregation of variables and, thus, researchers resort to using different aggregation approaches to produce a vulnerability index.

Nevertheless, this method has helped to reduce complex variables with different variability to single figure for ease of interpretation and comparing the result. Abson et al. (2012) argue that information is lost during aggregation. Despite not capturing the forward-looking aspect of vulnerability, it is applied as a development and adaptation planning tool (Hahn et al., 2009). The index method can be used to construct vulnerability maps, offering guidance about areas needing either urgent response or longer-term support to reduce vulnerability to food insecurity. These maps of hotspots reflecting locations with high exposure and sensitivity but adaptive capacity (de Sherbinin et al., 2014).

4.2.2 Household vulnerability to food insecurity

The vulnerability of a household to food security can be understood as its exposure, sensitivity and adaptive capacity (IPPC, 2007; McCarthy et al., 2001; Antwi-Agyei et al., 2012) (Figure 4.1). Exposure refers to food-related shocks that affect household access to safe and nutritious food and is widely defined as the degree to which a system faces risk, shock or hazard (Antwi-Agyei et al., 2012; Fellmann, 2012; IPPC, 2001). When shocks occur, these affect different levels of a system. A covariate shock has the same effect across households, community or a nation while an idiosyncratic shock can occur at the household level and the effect may differ from one household to another (Lovendal and Knowles, 2005). Food-related shocks threaten household food availability. For instance, the frequency and intensity of a drought or flood can threaten food supply and trigger food crisis for households.

Figure 4.1: Vulnerability to food insecurity conceptual framework



Source: Developed by author

The occurrence of food-related shocks causes households to make use of their assets and initiate a series of loss management strategies to improve their household food security. Using a vulnerability lens, the ability of the household to respond is referred to as its *adaptive capacity*. We define adaptive capacity as the ability of households to successfully adjust to the effect of food-related shocks through coping mechanisms (Engle, 2011). A household with high adaptive capacity will likely stand a better chance of adjusting to food vulnerability. Adaptive capacity is widely accepted as a positive attribute in reducing the vulnerability of a system (Polsky et al., 2007; IPPC, 2007). Of course, households when exposed continuously to shocks; they make use of the assets to manage the stress induced by the shock. Households with more assets and better livelihood opportunities generally translate into those with greater long-term food security (Woller et al., 2013). Households who can use only a small portion of their available assets will retain their ability to respond to future challenges.

In contrast, already impoverished and food-insecure households may need to make use of a more significant proportion of available assets yet may still fail to secure adequate access to food. If assets and means of livelihood cannot manage the shock, households begin to employ more desperate coping mechanisms. Over time this causes households to move in and out of distinct levels of food insecurity such as chronic, transitory, cyclical or temporal food insecurity. In the food security literature, these cascades of food insecurity can be considered as the level of food stability, and in the vulnerability literature, this is referred to as *sensitivity*. Sensitivity in this context can mean the underlying vulnerability of a household to be able to respond as a result of food shocks (Fellmann, 2012). It is also considered the degree of responsiveness of a system to stress (IPPC, 2001). The component of sensitivity represents the first-order effect of food shocks in households (Hahn et al., 2009b; Antwi-Agyei et al., 2012) and the sensitivity component is used in the vulnerability to food insecurity index to mean previous or accumulative experience of food insecurity, such as stunting, child mortality, and hunger within the household. For example, undernourished mothers can give birth to children with low birth weight, while malnourished children tend to experience reduced cognitive ability, which affects their educational attainment. Adopting this understanding avoids the confusion commonly found in vulnerability literature on the distinction between adaptive capacity and sensitivity.

Finally, the response of a household to a shock will lead to several outcomes in the food vulnerability continuum. This outcome can be used to classify households into different groups of food vulnerability. These groups are households that are highly vulnerable to food insecurity, mildly vulnerable households and households that are not vulnerable to food insecurity.

Taking a contextual vulnerability approach and drawing on the framework of vulnerability to food insecurity determined through indicators of exposure, adaptive capacity, and sensitivity, we seek to determine how better to operationalise a multi-dimensional index.

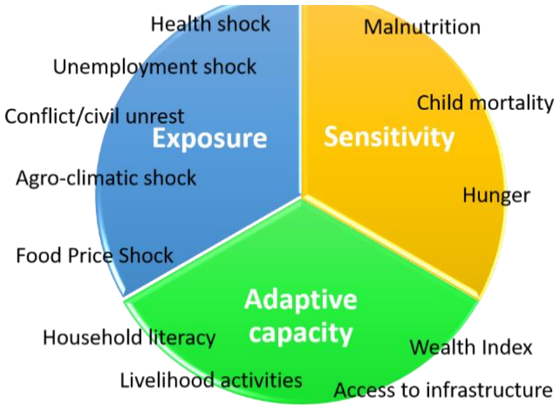
4.3. Methodology

In this section, we present the design of the vulnerability to food insecurity index (VFII), the redefined exposure component and how traditional indicators of food insecurity were used to compare the strength and weakness of the new composite index. We also briefly present the uncertainty and sensitivity analysis performed on the VFII.

4.3.1 Construction of the Vulnerability to Food Insecurity Index

The conceptual framework for household vulnerability to food insecurity was applied (as outlined in section 4.2) to design a VFII that has three main components: exposure, sensitivity and adaptive capacity. Using panel data from the Nigerian Living Standard Measurement Survey (NBS, 2015; NBS and LSMS, 2015; World-Bank and NBS, 2015; World-Bank and NBS, 2014), indicators and variables were selected based on the components from the framework. Figure 4.2 categorises the VFII components and related indicators from the Nigerian Living Standard Measurement Survey. Further details of these indicators can be found in Table C, located in Appendix A.

Figure 4.2: Vulnerability to Food Insecurity Index and its indicators



Source: Develop by author

After selecting each variable to represent an indicator as shown in Table 4.1, we proceeded to normalize these variables.

Table 4.1: Indicators and variables used for the Vulnerability to Food Insecurity Index

Index Dimension	Indicators	Description of variables
Exposure (probability of covariate shocks occurring)	Health shock	Illness of income-earning member
	Unemployment shock	Job loss
	Civil conflict shock	Theft of crops, cash, livestock or other
		Kidnapping/Hijacking/robbery/assault
	Agro-climatic shock	Poor rain that caused harvest failure
		Flooding that caused harvest failure
	Food price shock	Increase in price of major food items consumed
Sensitivity Previous/accumulative experience of food insecurity	Malnutrition	Length/height-for-age (stunting)
	Child mortality	Total number of children dead in each household
	Hunger	Total number of days' households gone without eating any food.
Adaptive Capacity how household respond, exploit opportunities, resist or recover from food insecurity shocks	Wealth Index	Household assets used to assess information
		Mobility assets used in households
		Livelihood assets own by households
		Housing structure characteristics
	Access to infrastructure	Household distance to nearest major road (km).
		Household distance to nearest market (km).
		Time taken to walk one way to the water source from household dwelling (minutes).
	Livelihood activities	Total income from savings, rental of properties and other types of income.
		Estimated revenue from non-farm enterprises
		Total yield of crops harvested (kg)
	Household literacy	Cumulative years of schooling for household heads or closest individual[1] in the household.

[1]This is the next individual in the household if education is missing for the household head, who has the highest level of education, and at least five years of schooling. If educational qualifications are the same for more than one individual, the most senior individual in age is used.

We normalised variables to ease comparison and for all variables to have an equal unit (OECD, 2008). We used the min-max normalization method shown in equation 1.

$$I_{VFII} = \frac{X_{fvi} - X_{min}}{X_{max} - X_{min}} \ldots\ldots\ldots\ldots\ldots \quad [1]$$

Where X_{max} and X_{min} are the minimum and maximum values of the normalised vulnerability to food insecurity index (I_{VFII}) and having the values lying between 0 (laggard) and 1 (leader), respectively (UNDP, 2007; Hahn et al., 2009b; OECD, 2008; Singh, 2014; Freudenberg, 2003). The next step we generated a weight for these variables. Four methods exist in literature that is used to assign weight to variables: by quality of data (OECD, 2008), expert opinion (Brooks et al., 2005; Malcomb et al., 2014; de Sherbinin, 2014; Singh, 2014), equal weighting (Lucas and Hilderink, 2005) and statistical method such as principal component analysis (Gbetibouo et al., 2010; Madu, 2012). We used both equal weights and unequal weight for the VFII variables. However, after performing uncertainty and sensitivity analysis, we adopted equal weight for the index (*see chapter 5*). So, each component of the VFII was assigned equal weights.

Finally, to compute the VFII score we used the aggregation method shown in equation 2. Where E_i is the exposure index, S_i is the sensitivity index and AC_i is adaptive capacity index.

$$VFII_i = \sum AC_i - \left(\sum E_i + \sum S_i\right) \quad (2)$$

Households with lesser and negative VFII composite values are more vulnerable to food insecurity compare to households with higher and positive VFII composite scores. In other words, the higher the composite value of VFII, the lower the vulnerability impact on household food security.

4.3.2 VFII threshold

A household can be highly exposed or sensitive to food insecurity, but this is not a sufficient condition to say that this household is vulnerable to food insecurity. Thus, a vulnerable household is one in which their adaptive capacity is too low to help such household adjust successfully to the stress caused by exposure and sensitivity. We defined our VFII threshold as a point where household adaptive capacity is higher than the combined effect of exposure and sensitivity. Given that the VFII has three components which are equally weighted, each component has a weight of 0.33. In other words, each component represents 1/3 dimension of vulnerability.

Mathematically, when:

- (E+S) > AC, such household is said to be vulnerable to food insecurity
- (E+S) < AC, such household is not vulnerable to food insecurity

From the understanding of this mathematical notation, at what point can we say that a household is vulnerable or not vulnerable to food insecurity using our VFII composite score? A household will be at two points:

- First, is when a household VFII composite score is less than 1/3 mean of total VFII composite score for all households. At this point, a household is severely vulnerable to food insecurity.

- Second, is when a household VFII composite score is less than 2/3 mean of total VFII composite score for all households and greater than 1/3 mean of total VFII composite scores. At this point, a household is vulnerable to food insecurity (Table 4.2).

Using this threshold method will provide a cut-off point that is meaningful and reflect different vulnerability stories from the sample bearing in mind that vulnerability is context and place-specific. Using the aggregation method in equation 2 to compute our VFII, the index composite score responds to positive values, and the magnitude is in ascending order. That is vulnerability ranges from a positive value to a negative value. The more positive the score, the less the households are vulnerability to food insecurity and vice versa. We then used this score to categorise households into three different food vulnerability groups. The first group are households that are highly vulnerable to food insecurity. These are households in dire and worst level of food insecurity and vulnerability, and their composite score is less than or equal to -0.0530 (see Table 4.2). The next group are households that are mildly vulnerable to food insecurity. Their composite score is higher than -0.0530 but less than -0.0265. The last group are households that are not vulnerable to food insecurity. The composite score is higher than -0.0530.

Table 4.2: Threshold for VFII, FCS, CSI and PCC

Food security Indicators	Classification	Description	Range	Remark
VFII	1	Highly vulnerable	<= -0.0530	The higher the score, the better
	2	Mild vulnerable	> -0.0530 & < -0.0265	
	3	Not vulnerable	> 0.0530	
FCS	1	Poor	0 – 28	The higher the score the better
	2	Borderline	28.5 – 42	
	3	Acceptable	> 42	
CSI	1	Least severe	0 – 2	The lower the scores, the better
	2	Moderately severe	3 – 12	
	3	Severe	13 – 40	
	4	Most severe	> 40	
PCC	0	Poor consumption	< 2360 kcal/day	The higher the score the better
	1	Acceptable consumption	>= 2360 kcal/day	

4.3.3 Redefining the exposure component of the VFII

The exposure as define by IPPC (2007) is the occurrence of shocks that affect household food security. Invariably, this component of food vulnerability index is mostly characterised by its intensity and duration (Krishnamurthy et al., 2014). One weakness of this definition is that the occurrence of a shock does not necessarily mean that it could be used as an indicator of exposure for a given geographical area. For example, the occurrence of malaria in a household does not necessarily indicate that households in this area are more exposed to malaria. Because of this, we redefine exposure to mean the probability of occurrence of a shock. Consider that a household is standing on a precipice (precarious state of food insecurity), the exposure, in respect to this scenario is the probability of this household receiving a shock or a push which could further lead to a major fall into a more dangerous food security situation. Using this concept, the exposure variables used in this research is rather from the enumeration area (community level) and not the household level. In other words, the research derived exposure from household data by looking at the proportion of households in each enumeration area that report that they have been affected by the occurrence of selected shocks in the past five years. The shock with the highest percentage is now used for that enumeration area. For examples, if 50% of households in *Abak* (an enumeration area in Akwa Ibom state) reported that they had been most affected by an increase in prices of major food commodities consume, then households in this area are prone to food price shocks. Thus, using this information, all households in this area are given the value of 50% to represent food price shock irrespective of that fact that they might or might not experience this shock. The reason for doing this is because there is no macroeconomic data on the prevalence of selected shocks used in this research.

4.3.4 Data

The dataset used for this research is General Household Survey Panel (GHS-Panel), which is a Living Standard Measurement Study (LSMS) survey from the World Bank. The dataset contains a panel component (GHS-Panel) which is a randomly selected sub-sample of 5,000 households from a cross-sectional survey of 22,000 households carried out annually throughout Nigeria. The dataset contains information on human capital, economic activities, access to services and resources, food security and additional information on agricultural activities and household’s consumption are collected from the panel households. As at the time this research was carried out, the GHS-Panel had two waves: the first wave (2010-2011) and second wave (2012-2013). In each wave, visits are carried out within two periods to panel households. The first period is the post-planting visit in August-October 2010 (wave 1) while September - November 2012 (for wave 2) and the second period is the post-harvest visit in February-April 2011 & 2013 for both waves respectively. A onetime visit is carried out for the cross-section along with the post-harvest visit to the panel households (NBS, 2015; NBS and LSMS, 2015; World-Bank and NBS, 2015; World-Bank and NBS, 2014; Corral et al., 2015). We made use of both wave 1 and wave 2 datasets in designing the Vulnerability to Food Insecurity Index.

4.3.5 Construction of other traditional food security indicators

In this section, we discuss the methods used in designing per capita calories consumption, food consumption score and coping strategy index.

4.3.5.1 Food energy consumed per capita (Per capita calories consumption)

Food energy consumption is an indicator that measures the total dietary quantity of food energy consumed in each household. Energy in food is vital for survival, performing physical activities and for survival. This indicator measures the sufficiency of energy available in food eaten by households and also used to indicate the ability of households to have access to food (Dary and Imhoff-Kunsch, 2010; Smith and Subandoro, 2007). The following procedures were used to compute this indicator. All non-standardized food quantities recorded in the household dataset were converted from the local unit (e.g. bunch or rubber) to standardise unit in grams. By multiplying the quantities of local food items by their metric weight. The household survey data set provided the Metric weight for each food item. Food items with missing weight were removed. The total energy content of food acquire by each household was derived using the following equation, total food energy (kilocalories) = Food quantity in grams per day * edible portion * (food energy conversion factors/100). The energy conversion factor of food items was gotten from FAO et al. (2012), and FAO (1968). Finally, total daily calorie availability per adult equivalent for households was computed by dividing total energy acquisition per household per day by adult equivalent factor. Using multiple imputation techniques, an OLS regression with the independent variables that are household's characteristics was used to compute missing calorie availability for households that had this data missing. The FAO recommends an average food consumption of 2360 kcal/person/day; this value was used as the threshold score for households in this study.

4.3.5.2 Food Consumption Score (FCS)

FCS is a food security indicator developed by the World Food Program that measures the dietary diversity of food consumed in households with a seven days recall period (Vaitla et al., 2017). It is possible for a household to meet their food energy requirement but could not leave a healthy and active life because of deficiency of other macronutrient (like protein) and micronutrients such as iron, vitamin A, and iodine (Smith and Subandoro, 2007). Hence, FCS monitor changes in food nutrition within the households (Jones et al., 2013b). It is a composite index that is made up of 9 weighted food groups. The weight attached to each food groups are: cereals and tuber=2, pluses = 3, vegetables = 1, fruit = 1, meat and fish = 4, milk = 4, sugar = 0.5, oil = 0.5 and condiments = 0. The frequency of each food group consumed is multiplied by the assigned weight; the scores obtained now sum to get the FCS for each household. The overall score range between 0 -112. There two threshold categories are given by WFP for grouping households: a household with oil and sugar consume daily and household that does not consume oil and sugar daily. This study adopted the threshold for households that consume oil and sugar. Households with FCS above 42 are considered acceptable, scores between 28.5 - 42 are borderline, and scores within 0-28 are poor food consumption (Maxwell et al., 2014; Vaitla et al., 2017).

4.3.5.3 Coping Strategy Index (CSI)

The CSI measures the frequency and severity of specific behaviours employed by households when there is a food deficit. The CSI measures both current food security situation and is a good predictor of future food vulnerability of households (Maxwell and Caldwell, 2008). To compute the CSI, the frequency of coping strategy used by households is multiplied by the weight. The weight ranges from 1 (least severe category) to 4 (most severe coping behaviour). The coping strategies and weight are: borrowing food or rely on friends or relatives (2), limits the variety of foods eaten (3), reduce number of meals eaten in a day (3), limit portion size at meal-times (4), restrict consumption by adults in order for small children to eat (4), have no food of any kind in the house (4), sleep hungry at night because of no food (4), and go a whole day and night without eating anything (4). The weighted frequencies then sum to derive the CSI score. There is no universal guideline to interpret the CSI score. However, Maxwell et al. (2014) suggested scores within 0-2 (food secure), 3-12 (mildly food insecure), 13-40 (moderately food insecure), and above 40 (severely food insecure).

4.3.6 Uncertainty and Sensitivity

We carried out an uncertainty and sensitivity analysis to evaluate the robustness of the VFII. We evaluated how serval assumptions used in the index construction could have an impact on its output. A summary of the uncertainty and sensitivity analysis result is present in the next section (Section 4.4).

4.4. Sensitivity and Robustness

We systematically investigated the effect of some methodological assumptions on the robustness of Vulnerability to Food Insecurity Index. The focus was to examine how alternative data type, weight scheme, normalisation method and exclusion/inclusion of variables affect the index using uncertainty and sensitivity analysis. We used two approaches: One-at-a-time and global sensitivity approach for the analysis. Using one-at-a-time approach, we explore how the VFII output response to alternative data type, different weighting scheme, normalisation method and inclusion/exclusion of variable. For the global approach (Saltelli, 2017), we used Sobol' first-order index and total effect index to explore the uncertainty and sensitivity of VFII (Sobol', 1967). The result of the robustness analysis indicated that VFII performance is stable to changes in the variables and normalisation method when equal weight is applied. Using the min-max normalisation method produces highly robust estimate than z-score. Hence, we adopted equal weight and min-max normalisation method for the VFII. The main input factor that influenced the variance of VFII output is the shock variable. This means that the VFII is highly sensitive to shock, therefore better capturing the vulnerability component of food security. We conclude that the index is fit for purpose and will perform better than other indicators of food security in terms of vulnerability. For detail explanation of the uncertainty and sensitivity see Chapter 5.

4.5. Application and Discussion

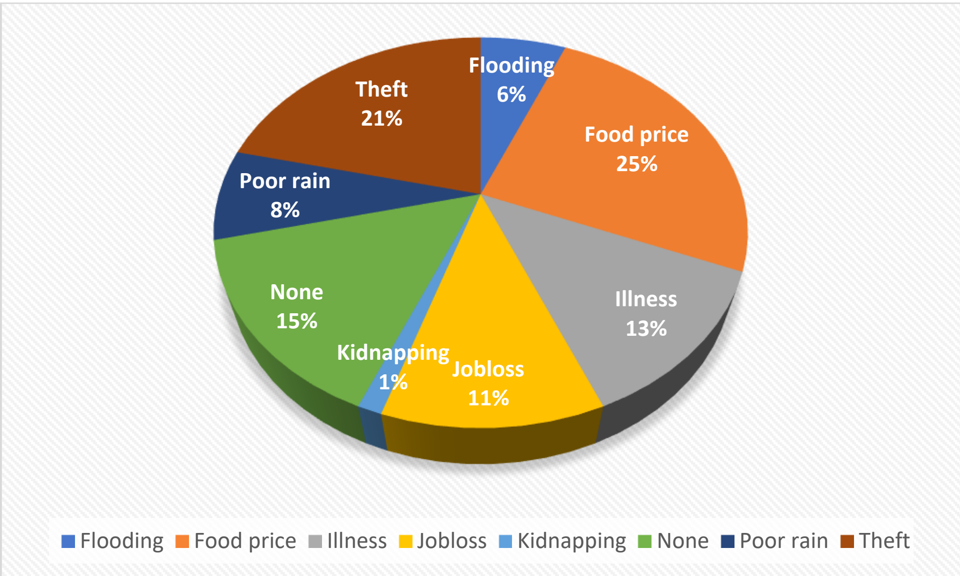
In this section, we applied our methodology to households' dataset in the South-South region of Nigeria and discussed the result. Specific results presented in this section are: descriptive statistics result; distribution of households in terms of VFII, CSI, FCS and PCC; the relationship between indicators, the proportion of households classified into different food vulnerability group by FCS, PCC, and CSI; and ranking of states by VFII.

4.5.1 Descriptive statistics

The descriptive statistics result for the data used in the construction of Vulnerability to Food Insecurity Index is presented in Table 4.3 and Figure 4.3. In Figure 4.3, South-South region of Nigeria, about 25% which are the majority of households are exposed to high food price shocks. Other shocks that households experience according to their magnitude are: theft of crops, cash and livestock (21%), illness of income-earning member (13%), loss of job (11%), poor rain that caused harvest failure (8%), flooding that caused harvest failure (6%) and kidnapping (1%). About 15% of households did not experience any of these shocks as at the time the data were collected.

On average, the z-score for length/height-for-age (stunting) for children within 0-60 months in households is 1.068. Approximately, one child died on average, and household stayed for at least 5 hours per day without any food on average. The average distance to the nearest major road is 11.05 km, nearest market is 62.51 km, and it will take 24 minutes on average for households to walk one way to the nearest water source. The estimated revenue for a household that had non-farm revenue is -34,146.3 naira and total revenue from savings/rental of properties is 91,110.39 naira on average. The total yield of harvested crops for households that had farm is 1,510.41 kg. On average household heads or closest individual had 9.12 years of schooling. The wealth index composite score is -0.49 on average.

Figure 4.3: Shocks that affected households



Source: Data analysis

Table 4.3: Descriptive statistics of VFII variables

Variable	Observation	Mean	Std.Dev.
Stunting	800	1.068462	5.676223
Child mortality	800	0.53	1.35606
Hunger	800	0.20625	0.752941
Wealth Index	800	-0.49638	2.892449
Distance-to-road	800	11.04825	13.26008
Distance-to-market	800	62.50875	37.52519
Distance-to-water source	800	23.89885	65.63988
Income-from-Savings	800	91110.39	137746
Non-farm business-income	459	-34146.3	169359.7
Crop yield (KG)	391	1510.411	2726.564
Household literacy	800	9.12	4.963002

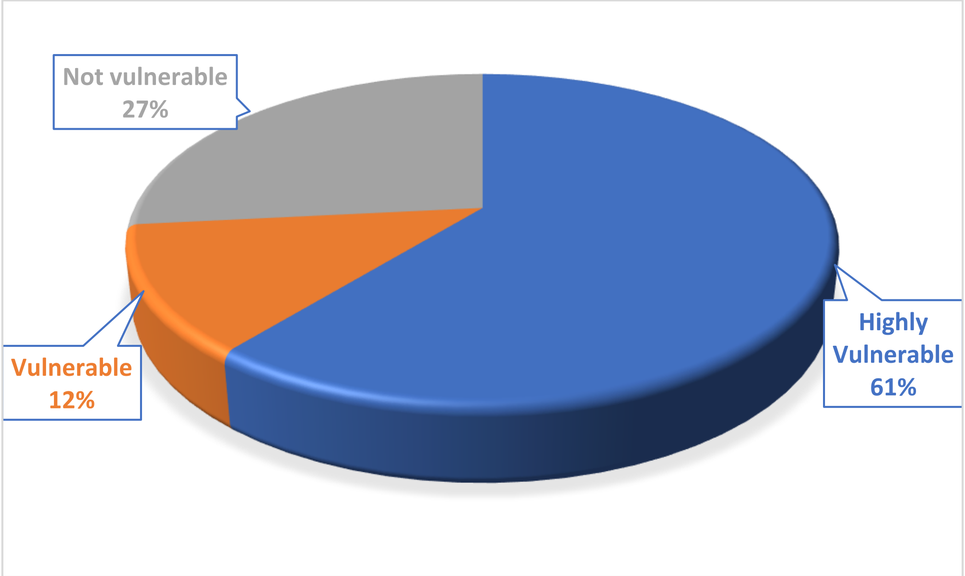
Source: Data analysis

4.5.2 What is the distribution of poor/non-poor households in terms of VFII, CSI, FCS, and PCC?

The distribution of households by VFII and other traditional indices we used in this paper are shown in Figure 4.4, 4.5, 4.6, and 4.7. The Vulnerability to Food Insecurity Index (VFII) result showed that 61% of households in the study are highly vulnerable to food insecurity, 12% are mildly vulnerable and 27% are not vulnerable to food insecurity (Figure 4.4). About 73% of households is the proportion that is vulnerable to food insecurity although the category of vulnerability differs. Coping strategy index (CSI) result for post-planting and post-harvest households are presented in Figure 4.5. The result indicates that majority of the households (33.77%) used severe coping strategy while 29.47% used least severe coping strategy when there is food deficit during the post-planting season. The reverse is the case during the post-harvest season. During this period majority of households used least severe (43.22%) and moderately severe (25.13%) coping strategy when there is food deficit.

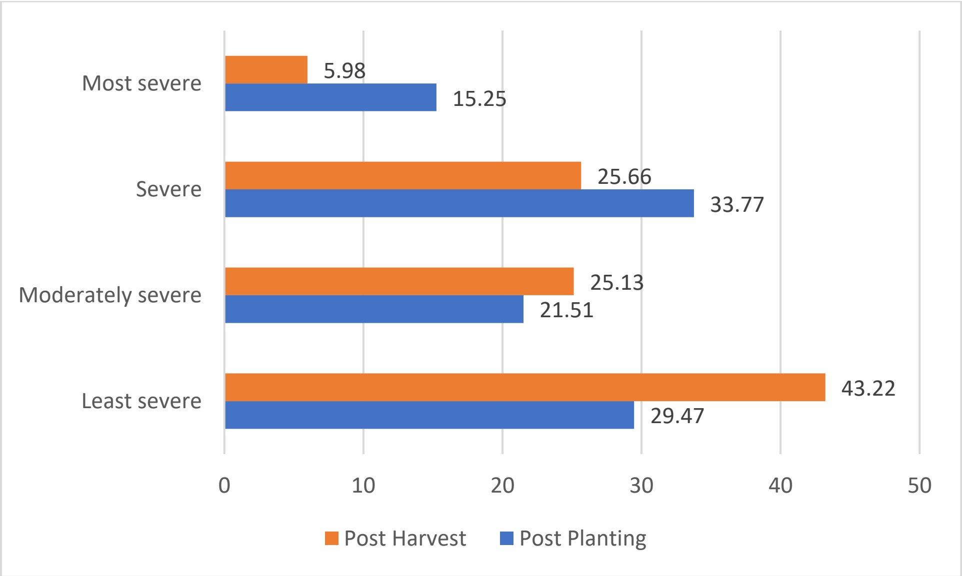
The food consumption score (FCS) in Figure 4.6 showed that 86.78% of households had an acceptable level of food consumption, 10.55% had borderline, and only 2.67% had poor consumption. The FAO recommended average dietary energy intake for Nigeria is 2360 kcal/person/day. We used this threshold as our cut-off point our per capita calorie consumption (PCC). In Figure 4.7, the result shows that 75% of households had poor calories consumption. In other words, these households had consumed less than 2360 Kcal/day after adjusting for adult equivalent. Only 25% of households had consumed either exactly or above the recommended level of calories per day.

Figure 4.4: Distribution of food insecurity and vulnerability in South-South Nigeria



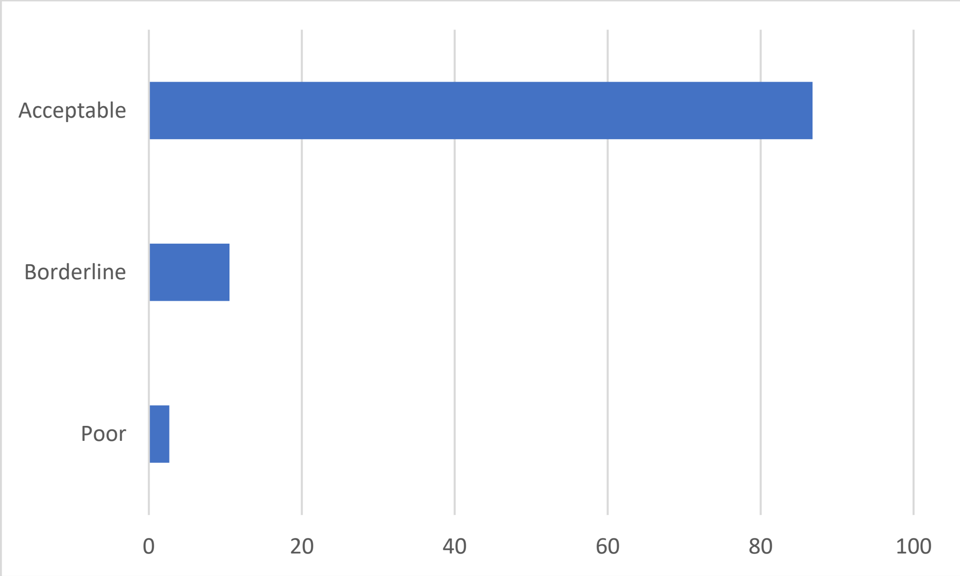
Source: Data Analysis

Figure 4.5: Coping Strategy Index distribution for households in South-South Nigeria



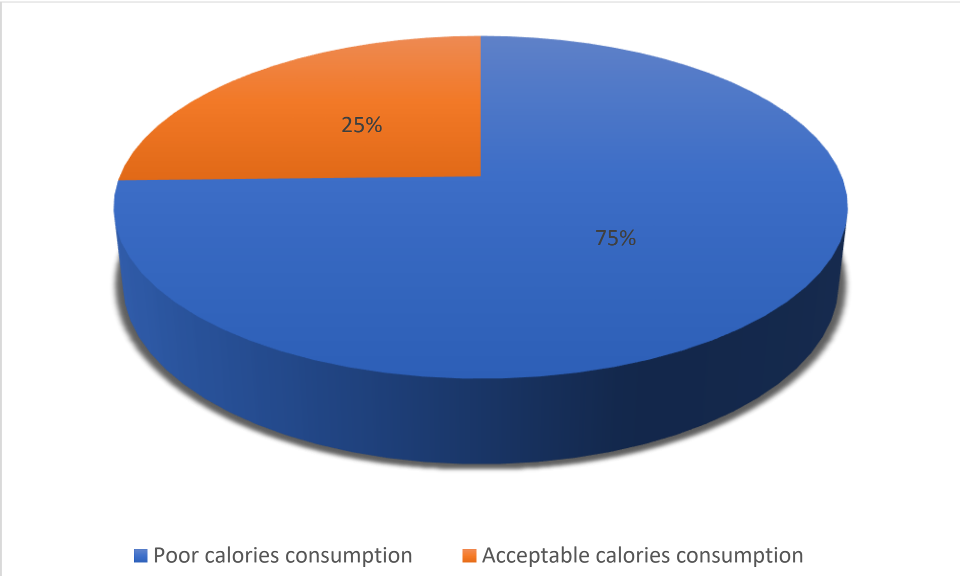
Source: Data analysis

Figure 4.6: Food Consumption Score distribution for households in South-South Nigeria



Source: Data Analysis

Figure 4.7: Per capita calories consumption distribution of households in South-South Nigeria



Source: Data Analysis

4.5.3 Comparing the differences between VFII, FCS, CSI and PCC

4.5.3.1 Differences in VFII, FCS, CSI and PCC

We present in Table 4.4 the correlation results between vulnerability to food insecurity index, coping strategy index (both post-planting and post-harvest season), and per capita calories consumption. We present the correlation result using three different correlation analyses, but only the Pearson coefficient is discussed because it has the highest correlation coefficient. All the results are from the first wave data except for per capita calorie consumption which we used the second wave data. This is because we had extremely high values of calories after estimating calories form the first wave data. They were two main reasons for this - measurement errors and no standardise unit for converting some local unit.

VFII/FCS: The positive relationship between VFII and food consumption score implies that they both in the same dimension of food security and classify households similarly. However, a weak but highly significant correlation coefficient of 0.11 shows that both FCS and VFII measure two different food security phenomena that are not closely related. It also indicates that the VFII capture other dimensions of food security that the FCS do not capture.

VFII/CSI: The correlation coefficient between VFII and coping strategy index is present in Table 4.4 for both post-planting and post-harvest households. There is a negative relationship between VFII and CSI indicating that both indicators are in different dimension of food security. The negative relationship also signifies the chances of household to be vulnerability to food insecurity decrease as household uses less severe coping strategies. Compared to the correlation coefficient of other indicators in Table 4, the correlation coefficient of VFII and CSI is lowest (about 7%) and significant at 10%. This further confirms that the VFII capture other components of food security that CSI could not capture.

VFII/PCC: The relationship between VFII and per capita calorie consumption (PCC) is highly significant at 1% level. There is a positive association between VFII and PCC. However, the correlation coefficient value of 0.15 shows that the relationship is not a perfect one. The relationship between VFII and PCC account for only 15% variation. This means that several other factors contribute to household's vulnerability to food insecurity. It is commonly assumed that households that are not vulnerable to food insecurity should be consuming sufficient calories per day. However, this result shows that consuming sufficient calories is not enough to overcome vulnerability to food insecurity. Because vulnerability to food insecurity requires more than consuming adequate calories.

The evidence of low correlation between the VFII and other traditional indicator shows that the VFII capture other components of food insecurity that the single indicators do not capture. Also, it shows that what the VFII is capturing goes beyond what other single indicators are capturing. This result support the conceptual argument of Vaitla *et al.* (2017), Coates (2013), and Ravallion (2011) that multidimensional concept like vulnerability to food insecurity is better captured using a set of indicators that represent each key dimension of the phenomena rather than using single indicator which is not able to represent clearly the contribution of each dimension.

All pairs were weakly correlated and statistically significant except VFII and CPI for post-planting households. The degree of correlation between these indicators depicts their differences. From the weak correlation coefficient of these traditional indicators with the VFII, it is reliable to say that these indicators should not be used interchangeably. For instance, Per capita, calorie consumption indicator should not be interchanged to represent vulnerability to food insecurity.

Also, the weak correlation between the VFII and other traditional food security indicators indicates the difficulty of comparing a multidimensional indicator with a single scale indicator (Vaitla et al., 2017). This shows the limitation of using single indicators for vulnerability to food insecurity analysis. Rather than relying solely on single indicators for targeting of intervention to a vulnerable population, a multidimensional indicator like VFII should be used in addition to single indicator for better accuracy.

Table 4.4: Correlation result between VFII, FCS, CSI, and PCC

	VFII			
Indicator	Pearson	Spearman	Kendall Tau-a	Kendall Tau-b
FCS	0.1180***	0.1190***	0.0807***	0.0810***
CSI_PH	-0.0744*	-0.0952*	-0.0627**	-0.0678**
CSI_PP	-0.0409	-0.0653*	-0.0443*	-0.0459*
PCC	0.1530***	0.1435***	0.0944***	0.0944***

Source: Data Analysis

4.5.3.2 Proportion of households that are classified into different groups of vulnerability to food insecurity by FCS, PCC, and CSI

We went further to investigate the proportion of households that are classified into different groups of food vulnerability by FCS, PCC, and CSI. In Table 4.5, we observed that majority (51.27%) of households that are classified as highly vulnerable to food insecurity by VFII had an acceptable level of food consumption. In other words, the majority of highly vulnerable households consumed highly diversify food. This further proves that FCS is not consistent in classifying households that are vulnerable to food insecurity. In contrast, VFII can pick some elements of dietary diversity, because most households (23.77%) that were not vulnerable to food insecurity had consumed highly diversify food. This situation also holds for per capital calories consumption in Table 4 6. Majority of the households (17.88%) that are either highly vulnerable or vulnerable to food insecurity had consumed above the recommended per capita calorie. However, it is expected that households with adequate per calorie consumption should not be vulnerable to food insecurity, this was not the case. Also, Table 4.6 showed that majority of the households (19.13%) that were not vulnerable to food insecurity had poor calorie consumption. Again, strengthening our argument that single indicators like PCC are inconsistent in identifying households that are vulnerable to food insecurity. In Table 4.7, the result shows that 32.33% of households that are highly vulnerable to food insecurity used severe coping strategy during the post-planting season. It is expected that households that are vulnerable to food insecurity should be using adverse coping strategy to secure food during a time of food deficit. The reverse is the case for households that were not vulnerable to food insecurity. Majority of households that were not vulnerable to food insecurity (14.21%) used the least coping strategy during the post-planting season. Here, there is a bilateral relationship between CSI and VFII. This means that the CSI better captures and is consistent in identifying households that are vulnerable to food insecurity compare to FCs and PCC. It further proves that our VFII can pick a component of CSI even though we used different indicators and method in their design. The result of CSI for post-harvest households shows that across all groups of VFII, households used the least coping strategy during the post-harvest season (Table 4.8).

In summary, our VFII can pick some component of FCS, PCC, and CSI. However, FCS and PCC are inconsistent when used for identifying households that are vulnerable to food insecurity. CSI betters capture food vulnerability issues compare to FCS and PCC.

Table4.5: VFII and FCS

	Food Consumption Score (%)			
VFII groups (%)	Poor	Borderline	Acceptable	Total
Highly Vulnerable	2	8.14	51.27	61.42
Vulnerable	0.27	0.93	11.75	12.95
Not vulnerable	0.4	1.47	23.77	25.63
Total	2.67	10.55	86.78	100

Source: Data analysis

Table 4.6: VFII and PPC

	Per capita calorie consumption (%)		
VFII groups (%)	Poor consumption	Above recommended level	Total
Highly Vulnerable	47.63	13.25	60.88
Vulnerable	7.88	4.63	12.5
Not vulnerable	19.13	7.5	26.63
Total	74.63	25.37	100

Source: Data Analysis

Table 4.7: VFII and CSI for post-planting households

	CSI for post-harvest households (%)				
VFII groups	Least severe	Moderately severe	Severe	Most severe	Total
Highly Vulnerable	24.6	14.49	17.55	4.65	61.3
Vulnerable	6.25	2.26	3.59	0.66	12.77
Not vulnerable	12.37	8.38	4.52	0.66	25.93
Total	43.22	25.13	25.66	5.98	100

Source: Data Analysis

Table 4.8: VFII and CSI for post-harvest households

	CSI for post-harvest households (%)				
VFII groups	Least severe	Moderately severe	Severe	Most severe	Total
Highly Vulnerable	16.95	13.04	21.51	10.82	62.32
Vulnerable	4.17	2.61	3.52	1.83	12.13
Not vulnerable	8.34	5.87	8.74	2.61	25.55
Total	29.47	21.51	33.77	15.25	100

Source: Data Analysis

4.5.4 Ranking of states in South-South Region of Nigeria by VFII, PCC, CSI and FCS

Table 4.9 shows the ranking of 6 states in South-South Nigeria by VFII, PCC, CSI, and FCS. Except for the CSI which ranks by descending order, other indicators use ascending order to rank states (see Table 4.2 for their threshold). We compared the output of two states -Edo and Bayelsa because they represent two extremes of vulnerability -least vulnerable (Edo) and highly vulnerable (Bayelsa) state.

In Edo state which had the least vulnerability to food insecurity, households tend to have consumed sufficient calories, and they rank second in per capita calorie consumption. On average, post-planting households use least coping strategy as they ranked second, while post-harvest households use mildly severe coping strategy as they ranked fourth. Their food consumption score was the highest and ranked first, meaning that, compared to other states, Edo state households consumed highly diversify food.

Comparing Edo states with Bayelsa state, households in Bayelsa state are classified as highly vulnerable to food insecurity by VFII. They had the worst level of vulnerability to food insecurity. Their per capita calorie consumption was the worst; they ranked sixth. Both post-planting and post-harvest households used a severe coping strategy; they ranked fifth. The food consumption score was ranked fourth meaning that on average household's dietary diversity consumption in this state was borderline. From this discussion, we showed that VFII is a valuable tool for policy making and its ranking are reliable because the VFII incorporates vulnerability dimension in addition to other dimensions of food security. Also, the VFII is consistent with other single indicators of food security but goes beyond what other indicators capture.

Table 4.9: Ranking of State by VFII and other traditional indicators

States	VFII ranking	PCC ranking	CSI_PH ranking	CSI_PP ranking	FCS ranking
Edo	1	2	4	2	1
Cross River	2	1	6	6	6
Delta	3	3	1	1	5
Rivers	4	5	2	3	2
Akwa Ibom	5	4	3	4	3
Bayelsa	6	6	5	5	4

Source: Data Analysis

4.6. Conclusion

In this paper, we have shown how we designed an indicator that addresses the problem of vulnerability to food insecurity and comparing it to other traditional indicators of food security. We have also shown how single indicators can be misrepresentative regarding vulnerability to food insecurity. Because traditional food security indicators measure different food security phenomena. Therefore, in other to successfully target intervention to vulnerable household, the

VFII can get the right measurement. Thus, ensuring that the exclusion error is drastically reduced and scare resources are adequately targeted to the needed groups of vulnerable households. For example, in Table 4.6, there are two significant insight from this table. The first insight is that out of 74.63% of households who had poor per capita calorie consumption, 19.13% of households were not vulnerable to food insecurity although they had deficient calorie consumption. Secondly, a more significant proportion of households, 17.88% out of 25.37%, had consumed above the recommended per capita calorie consumption yet they were either highly vulnerable or mildly vulnerable to food insecurity. The implication of this is that using per capita calorie consumption alone to capture food vulnerability will provide a misleading result because of the exclusion and inclusion error. The evidence from this paper shows that using per capita calorie consumption alone for long-term targeting of intervention would include 19.13% of households that should not have been included. Similarly, 17.88% of households will be excluded, that should have been included in long-term intervention when using per capita calorie consumption. Another insight from VFII is that using households' current dietary diversity alone is not a consistent indicator of vulnerability to food insecurity. Table 5 shows out of 86.78%, 63.02% of households had consumed food with acceptable levels of dietary diversity yet these households were either vulnerable or highly vulnerable to food insecurity.

The overall takeaway point from using single indicators is that they represent different food security phenomena and they do not take in to account multidimensional issues of food security like food vulnerability. The evidence presented in this paper justifies the need for a robust model like our vulnerability to food insecurity index. We showed in section 5.3 that VFII being a multidimensional index can capture food vulnerability and other single food indicators like current calories consumption, dietary diversity and coping strategy. For long-term food security intervention, policymakers need to target households based on their vulnerability and not their current consumption or dietary diversity. In conclusion, to accurately target long-term support to vulnerable households, policymakers who seek to address the underlying causes of food insecurity cannot rely on single indicators, and for this type of goal, the VFII makes a useful contribution.

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4.8. Appendix A

How malnutrition variables were derived and computed:

Anthropometric information is widely and commonly used to determine an individual nutritional status. Statistically, it is expressed using either the standard deviations from the median (commonly called the z-scores) or percentage of the median (Webb and Bhatia, 2005; LSHTM, 2009). This study uses the z-scores to express the anthropometrics information of children from 0 – 60 months in the study. To do this, data such as weight of child(kg), height of child (cm), age (in months) and gender from the panel survey were used. Using WHO child growth standard macro (WHO, 2011) which is design to calculates z-scores statistics for four anthropometry indices such as weight-for-age (underweight), length/height-for-age (stunting), weight-for-length/height (wasting), and BMI-for-age. The macro (*igrowup_resricted.ado*) in combination with five permanent WHO child growth standards read-only stata data sets, estimates the prevalence of under/over nutrition and summary statistics (mean and standard deviation) of the z-scores for each anthropometrics. Only the z-scores for the stunting was retained and used for further analysis. Table 4.10 shows these z-scores values are to classify households.

Table 4.10: Cut-off point of malnutrition for underweight, stunting, and wasting based on z-scores.

Classification	**z-score values**
Adequate	-2< Z-score < +2
Moderately malnourished	-3< Z-score < -2
Severely malnourished	Z-score < -3

Sources: Webb and Bhatia (2005)

How hunger indicator was derived and calculated:

To calculate hunger, the HHS uses three core questions and three frequencies to estimates the percentage of households in a population that are affected by hunger as shown in Table 4.11

(Deitchler et al., 2011). Categorizing the hunger result into three different severities - (1) little to no household hunger (2) moderate household hunger; and (3) severe household hunger. However, this research is limiting its interest only to get the values and not categorising the values. These values are now used to represent the hunger indicator for the sensitivity dimension of the vulnerability to food insecurity index.

Table 4.11: Shows in brief the HHS core questions and frequencies

S/N	Core questions (Scale items)	Frequency categories (Response codes)
1	No food to eat of any kind in your household	Never, Rarely or Sometimes, Often
2	Go to sleep at night hungry	Never, Rarely or Sometimes, Often
3	Go a whole day and night without eating	Never, Rarely or Sometimes, Often
	Recall Period: 4 weeks	

Source: Adapted from (Deitchler et al., 2011)

Based on the frequency selected on each core question, a total score is gotten, which is the HHS score. This score ranges from 0 (minimum) to 6 (being the maximum). It is derived by summing the response codes which are never=0, rarely or sometimes=1 and often=2. So, the total HHS score is now used to categorise levels of severity of hunger. The lower the score, the lesser the experience of hunger in the household but the higher the score the severe hunger level in households. Using this concept, this research computed the hunger score for households in the study with a moderate change because the frequency category was missing from the dataset used in this research. Instead of using the three questions design for HHS, the research used only question 2 and 3 (Table 4.11). The reason is that these two questions represent the extremities of hunger which captures the hidden hunger and micronutrient deficiencies. Also, the minimum recommended recall period to be used in the HHS is four weeks or 30 days but, in the household, dataset it was seven days only. Since there was no frequency category, using only two core questions instead of three questions and using seven days' recall period, the maximum HHS score is 14, and the minimum is 0. For example, a household was asked out of 7 days in a week how many days do you: (a) go to sleep at night hungry (b) go a whole day and night without eating. The answer was 4, and 5 days respectively. Thus, the HHS score will be 4+5=9. This method was repeated for all household to generate the hunger score. According to (Deitchler et al., 2011), the pitfall with using a shorter recall period like seven days over the recommended four weeks (30 days) period is that this may not capture the full extent of hunger deprivation experience since fluctuation in food accessibility is common within 1-month recall.

Caveat: There are two subsets of household panel data in a wave, these are: post planting and post harvesting. Both have food security data and specifically the data needed to be used for calculating hunger. It will be good to compare hunger changes between the two periods, but since the VFII is not design for either season but a wave or year, the research made use of hunger data from the post-harvesting period only.

Procedures used in designing wealth index:

1. Sorting of variables: variables were commonly grouped into three categories: agricultural (livestock, land, crops); assets (livelihood asset, mobility asset, information asset) and housing structure characteristics. The following steps were used to prepare these variables for analysis:
    a. In sorting out variables needed for the wealth index, some were dropped, and others merge.
    b. Created dichotomous variable - this help to regroup variables.
    c. Variables with zero variance were remove
    d. Finally, replace variables with missing observation with zeros
2. Standardization of variables: Each variable used in the wealth index calculation was standardised so that they are all on the same scale and can be compared.
    a. The standardised score was calculated using this: standardise score = (variable - mean)/standard deviation
3. Factor weight: To calculate the factor weight, Principal Component Analysis (PCA) was run, and the first principal component (eigenvectors) was retained. These values were then used to multiply by the standardise scores to get the factor weight. Thus, factor weight = standardize * first principal components (eigenvectors).
4. Computing the wealth index: summing all factor weight of each variable for each household produces the wealth index scores.
5. Categorizing wealth index scores: The wealth index scores were categorized into five quintiles, with the lowest score being the poorest and the highest score being the wealthiest.

How livelihood activities are derived

There are three significant livelihood sources identified in the LSMS household survey data. The data gotten from these sources are combined to produce a measure of livelihood activities in the research. They are discussed in detail below:

- Income sources: - These are total income from savings, rental of property and any other type of income. The following computation is used to generate "income sources": Total income household received from savings interest or investment since the new year plus Total amount household usually receive from the rental of property (excluding agricultural land) within the new year plus Total regular income of any other type. The data used for "income sources" come from post planting data because it is the primary source of information compared to the post-harvest data that which has only additional income available after the post-planting visit.
- Non-farm enterprises operated by households: Non-farm enterprise is defined as any member of the household who worked for him/herself other than on a farm or raising animals. Such enterprise includes personal business, trade, self-employed professional or craftsman. The computation used to generate this variable is to calculate revenue made from non-farm enterprises: Total sales - Total cost of the business (includes the following cost: salaries and wages, purchase of goods for sale, transport, insurance, rent, interest, raw materials and others).
- Agricultural activities: These are livelihood activities derived from crop farm. The data is generated by collating the total yield of crop harvested per year in kilograms for each farming household.

Food energy conversion table

Table 4.12: Food Composition Table for Food Items used in Nigeria (100 Grams Edible portion)

Item code	Food item	Food energy (kilocalories)[A]	Food energy (calories)[B]	Edible Portion
10	Guinea corn/sorghum	344	350	1.00
11	Millet	348	349	1.00
12	Maize	349	357	1.00
13	Rice - local	349	344	1.00
14	Rice - imported	352	353	1.00
15	Bread	249	261	1.00
16	Maize flour	354	365	1.00
17	Yam flour	312	335	1.00
18	Cassava flour	335		1.00
19	Wheat flour	351	364	1.00
20	Other grains and flour		345	1.00
30	Cassava - roots	347	357	1.00
31	Yam - roots	141	112	0.81
32	Gari - white		351	
33	Gari - yellow		351	
34	Cocoyam	136	102	1.00
35	Plantains	140	135	0.65
36	Sweet potatoes	115	121	1.00
37	Potatoes	80	82	1.00
38	Other roots and tuber	137		1.00
40	Soya beans	410	405	1.00
41	Brown beans	318	342	1.00
42	White beans	335	338	1.00
43	Groundnuts	578	549	1.00
44	Other nuts/seeds/pulses	593		0.37
50	Palm oil	900		1.00
51	Butter/Margarine	730		1.00
52	Groundnut oil	900		1.00
53	Other oils and fats	900		1.00
60	Bananas	106	88	0.64
61	Orange/tangerine	45		0.73
62	Mangoes	76		0.71
63	Avocado pear	154		0.74
64	Pineapples	54		0.51
65	Fruit canned	N/A	N/A	N/A
66	Other fruits	N/A	N/A	N/A
70	Tomatoes	22		0.91
71	Tomato puree (canned)	20		1.00
72	Onions	33		0.91
73	Garden eggs/egg plant	30		0.81

74	Okra - fresh	33		0.86
75	Okra - dried	N/A	N/A	N/A
76	Pepper	45		0.73
77	Leaves (cocoyam, spinach, etc.)	42		0.80
78	Other vegetables (fresh or canned)	42		0.80
80	Chicken	218		0.66
81	Duck	N/A	N/A	N/A
82	Other domestic poultry	232		0.65
83	Agricultural eggs	139		0.88
84	Local eggs	139		0.88
85	Other eggs (not chicken)	139		0.88
90	Beef	126		1.00
91	Mutton	257		0.82
92	Pork	265		1.00
93	Goat	165		0.74
94	Wild game meat	N/A	N/A	N/A
95	Canned beef/corned beef	243		1.00
96	Other meat (excl. poultry)	127		0.76
100	Fish - fresh	124		0.71
101	Fish - frozen	124		0.71
102	Fish - smoked	151		0.64
103	Fish - dried	151		0.64
104	Snails	N/A	N/A	N/A
105	Seafood (lobster, crab, prawns, etc.)	119		0.54
106	Canned fish/seafood	220		1.00
107	Other fish or seafood	126		0.55
110	Fresh milk	65		1.00
111	Milk powder	495		1.00
112	Baby milk powder	519		1.00
113	Milk tinned (unsweetened)	135		1.00
114	Other milk products	73		1.00
120	Coffee	354		1.00
121	Chocolate drinks (including Milo)	386		1.00
122	Tea	0		1.00
130	Sugar	400		1.00
131	Jams	Dropped		
132	Honey	326		1.00
133	Other sweets and confectionary	Dropped		
140	Condiments (salt, spices, pepper, etc)	348		1.00
150	Bottled water	Dropped		
151	Sachet water	Dropped		
152	Malt drinks	Dropped		

153	Soft drinks	Dropped		
154	Fruit juice canned/Pack	44		1.00
155	Other non-alcoholic drinks	Dropped		
160	Beer (local and imported)	35		1.00
161	Palm wine	34		1.00
162	Pinto	Dropped		
163	Gin	Dropped		
164	Other alcoholic beverages	Dropped		

Source: FAO et al. (2012) and FAO (1968)

Table 4.13: Household Adult Equivalent

Males					**Female**	
Age (years)		Energy (Kcal/day)	Ad. Eq.		Energy (Kcal/day)	Ad. Eq
<1		661	0.22		661	0.22
1	2	950	0.31		850	0.28
2	3	1125	0.37		1050	0.34
3	4	1250	0.41		1150	0.38
4	5	1350	0.44		1250	0.41
5	6	1475	0.48		1325	0.43
6	7	1575	0.52		1425	0.47
7	8	1700	0.56		1550	0.51
8	9	1825	0.60		1700	0.56
9	10	1975	0.65		1850	0.61
10	11	2150	0.70		2000	0.66
11	12	2350	0.77		2150	0.70
12	13	2550	0.84		2275	0.75
13	14	2775	0.91		2375	0.78
14	15	3000	0.98		2450	0.80
15	16	3175	1.04		2500	0.82
16	17	3325	1.09		2500	0.82
17	18	3400	1.11		2500	0.82
18	30	3050	1.00		2400	0.79
30	60	2950	0.97		2350	0.77
>=60		2450	0.80		2100	0.69

Source: Dary and Imhoff-Kunsch (2010)

Chapter 5 : Uncertainty and Sensitivity Analysis: Robustness check for Vulnerability to Food Insecurity Index

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Abstract

This paper systematically evaluates the effect of some assumptions on the robustness of Vulnerability to Food Insecurity Index. The focus was to examine how data type, weighting scheme, normalisation method and excluding/including of variables, affect the output of the index using uncertainty and sensitivity analysis. The paper used two approaches: One-at-a-time and global sensitivity approach for the analysis. Using one-at-a-time approach, the paper explored how the VFII output response to different weighting scheme, normalisation method and inclusion/exclusion of variable. For the global approach, we used Sobol' first-order index and total effect index to explore the uncertainty and sensitivity of VFII. The result of the robustness analysis indicated that VFII ranking is stable to changes when equal weight is applied irrespective of the data type and normalization method used. In contrast, the output of the index was not robust when unequal weight was applied. In general, the min-max normalisation method produces a highly robust estimate compare to the z-score method. As such the paper adopted equal weight and min-max normalization method in designing the index. The result of the sensitivity analysis showed that although the exposure variables were the main input that introduces uncertainty to output of the VFII, it also indicated that the index is highly sensitive to shocks and better capture the vulnerability component of the index. The paper concluded that the index is fit for purpose based on the assumption used. However, to reduce the uncertainty of the exposure variables better data is required in future modelling of the index.

Keywords: Food security, vulnerability, food vulnerability index, sensitivity, robustness, first-order, total-effect

5.1 Introduction

Several assumptions have been used to construct the Vulnerability to Food Insecurity Index (VFII). Notably assumptions in the selection of indicators, the normalisation of indicators, the weighting of the indicators, the aggregation method used, and categorising the index. These assumptions can have a significant impact on the output and reliability of the Vulnerability to Food Insecurity Index. Therefore, sensitivity and uncertainty analysis are needed to establish the robustness of the methodology and the assumptions made in the construction of the VFII (Esty et al., 2006). We will also use sensitivity and uncertainty analysis to test if a useful conclusion can be made from Vulnerability to Food Insecurity Index. The sensitivity analysis will numerically quantify how variation or uncertainty in the VFII output can be apportioned to diverse sources in model input while the uncertainty analysis will focus on quantifying the uncertainty in the VFII output only (Saltelli, 2017). The accuracy and precision of the VFII depend on the following factors: the computational method for estimating missing data, the mechanism for inclusion and exclusion of variables, the transformation of variables when constructing the index, type of normalisation method, amount of missing data, weighting scheme adopted, the level and choice of aggregation method used. Using uncertainty and sensitivity analysis this research will systematically evaluate the effect of some of the above methodological processes on the robustness of the Vulnerability to Food Insecurity Index scoring and ranking. The following questions will be investigated:

1. How does the output of the VFII rank compare to different assumptions?

2. What is the major source of uncertainty in the VFII ranking?

3. What are the most influential input factors that cause this uncertainty in VFII ranking?

We use two main approaches to conduct uncertainty and sensitivity analysis namely: One-at-at-time (OAT) and global sensitivity analysis approach. Using one-at-time approach, we change one assumption or factor at a time and then compare the output. We use OAT to carry out only uncertainty analysis for some assumptions because it was the most suitable method to use base on our model. Although the uncertainty analysis using the OAT approach is criticised as being non-conservative (Saltelli,2007). Global sensitivity approach is widely preferred in literature because it explores the entire effect of each factor or assumptions on the model output and numerically quantifies the effect of different source of uncertainty in the model input (Saltelli et al., 2004).

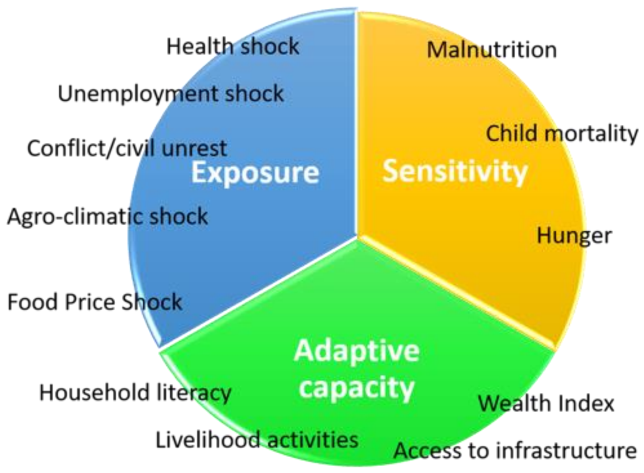
This paper is organised into sections. The next section (section 5.2) presents a thorough discussion of the research methodology applied. Section three discusses the result/insight from findings and section four presents the conclusion.

5.2 Methodology

5.2.1 Structure of Vulnerability to Food Insecurity Index

The VFII is a mathematical model derived from contextual vulnerability concept. The contextual approach, view's household vulnerability as a multidisciplinary system consisting of the biophysical and socio-economic environment (Fellmann, 2012). These two-system interaction influences household food vulnerability. Using the vulnerability lens to unpack the meaning and operationalise vulnerability measurement regarding food security. We discovered that vulnerability has three main components (Cardona et al., 2012; IPPC, 2007). These components are the exposure, sensitivity and adaptive capacity. In this paper, we define exposure as those food-related shocks that affect households' access to safe and nutritious food. Using the theme derived from conceptual vulnerability, that household vulnerability is affected by its socio-economic and biophysical condition; we selected indicators and variables for the exposure component (Fellmann, 2012; Adger, 2006). The sensitivity component of our VFII represents the previous or accumulative experience of food insecurity within the household such as stunting, child mortality and hunger (Hahn et al., 2009). Household ability to successfully adjust to the effect of food shocks using the livelihoods assets means that they have strong adaptive capacity (Woller et al., 2013). Households with a strong and more liquid livelihood asset will be less vulnerable to food insecurity. We used this conceptual underpinning to select the indicators and variable for the VFII, shown in Figure 5.1. A summary of indicators and variables are presented in Table 5.1. More detail information about these indicators are included in the appendix (see Table 5.16 in the Appendix of this Chapter).

Figure 5.1: Vulnerability to Food Insecurity Index components and indicators



Source: Developed by the author

Table 5.1: Indicators and variables used for the Vulnerability to Food Insecurity Index

Index Dimension	Indicators	Description of variables
Exposure *(probability of covariate shocks occurring)*	Health shock	Illness of income-earning member
	Unemployment shock	Job loss
	Civil conflict shock	Theft of crops, cash, livestock or other
		Kidnapping/Hijacking/robbery/assault
	Agro-climatic shock	Poor rain that caused harvest failure
		Flooding that caused harvest failure
	Food price shock	Increase in price of major food items consumed
Sensitivity *Previous/accumulative experience of food insecurity*	Malnutrition	Length/height-for-age (stunting)
	Child mortality	Total number of children dead in each household
	Hunger	Total number of days' households gone without eating any food.
Adaptive Capacity *how household respond, exploit opportunities, resist or recover from food insecurity shocks*	Wealth Index	Household assets used to assess information
		Mobility assets used in households
		Livelihood assets own by households
		Housing structure characteristics
	Access to infrastructure	Household distance to nearest major road (km).
		Household distance to nearest market (km).
		Time taken to walk one way to the water source from household dwelling (minutes).
	Livelihood activities	Total income from savings, rental of properties and other types of income.
		Estimated revenue from non-farm enterprises
		Total yield of crops harvested (kg)
	Household literacy	Cumulative years of schooling for household heads or closest individual in the household.

Note: The Closest individual is the next individual in the household if education is missing for the household head, who has the highest level of education, and at least five years of schooling. If educational qualifications are the same for more than one individual, the most senior individual in age is used.

5.2.1.1 Construction of the VFII

We developed a conceptual framework and selected indicators for the index (see Figure 5.1). Then we generated weight, either PCA or equal weight for variables and then each component of VFII; normalised these variables using either min-max or z-score method (see equation 3 and 4) and used the aggregation formula in equation (1) to generate the index scores (OECD, 2008).

$$VFII_i = \sum AC_i \; - \left(\sum E_i + \; \sum S_i\right) \qquad (1)$$

Where $VFII_i$ is the score for Vulnerability to Food Insecurity Index for i household, AC_i is adaptive capacity, E_i is exposure and S_i is sensitivity. The $VFII_i$ score are then used to rank and categorize household vulnerability to food security. The higher the value of VFII composite score, the less households are vulnerable to food insecurity and vice versa.

5.2.2 Data Source

The dataset used for this research is the General Household Survey Panel (GHS-Panel), which is a Living Standard Measurement Study (LSMS) survey from the World Bank. The dataset contains a panel component (GHS-Panel) which is a randomly selected sub-sample of 5,000 households from a cross-sectional survey of 22,000 households carried out annually throughout the country. The dataset contains information on human capital, economic activities, access to services and resources, food security and additional information on agricultural activities and household's consumption is collected from the panel households. The GHS-Panel has two waves: the first wave (2010-2011) and second wave (2012-2013). In each wave, visits are carried out within two periods to panel households. The first period is the post-planting visit in August-October 2010 (wave 1) while September - November 2012 (for wave 2) and the second period is the post-harvest visit in February-April 2011 & 2013 for both waves respectively. A onetime visit is carried out for the cross-section along with the post-harvest visit to the panel households (NBS, 2015; NBS and LSMS, 2015; World-Bank and NBS, 2015; World-Bank and NBS, 2014; Corral et al., 2015).

5.2.3 Normalization and Weighting Method

The normalisation method used in the construction of Vulnerability to Food Insecurity Index (VFII) variables are based on the Min-Max (equation 3) or standardise (equation 4) value method. Consider the $VFII$ value of selected states in Nigeria $c, c = 1, \ldots\ldots M$,

$$VFII_c = f_{rs}\left(I_{1,c}, I_{2,c}, \ldots I_{Q,c}, w_{s,1}, w_{s,2,}, \ldots.\, w_{s,Q}\right), \ldots\ldots\ldots\ldots (2)$$

$$where \begin{cases} I_{q,c} = \dfrac{x_{q,c} - min(x_q)}{range(x_q)} \ldots\ldots\ldots\ldots\ldots\ldots (3) \\ I_{q,c} = \dfrac{x_{q,c} - mean(x_q)}{std(x_q)} \ldots\ldots\ldots\ldots... (4) \end{cases}$$

The weighing method f_{rs}, where the index r refer to the linear aggregation scheme used, and index s refers to the weighting scheme (PCA weight and equal weights). The index is based on Q normalised individual indicators $I_{1,c}, I_{2,c}, \ldots I_{Q,c}$ for states in Nigeria and scheme-dependent weights $w_{s,1}, w_{s,2,}, \dots . w_{s,Q}$ for the individual indicators. $I_{Q,c}$ is the normalised and $x_{q,c}$ is the raw value of the individual indicator x_q for states in Nigeria.

5.2.4 Uncertainty and sensitivity analysis model

We used two approaches to carry out our uncertainty and sensitivity analysis, namely one-at-a-time and global sensitivity approach. The methods adopted from these approaches are explained in this section.

5.2.4.1 One-at-a-time-approach

This approach tests the effect of a single input or factor on the output one at a time. We used this method to test the performance of the VFII on different weighting method, normalisation method and excluding/including a variable. We applied two types of data in this approach for comparison purpose and to test the robustness of our VFII. Using dataset with missing or incomplete observations and data set that had complete observation. To get complete data, we used multiple imputation method, running a multiple regression with observable household characteristics variables to impute those variables that had missing data.

5.2.4.2 Uncertainty analysis

To know the primary source of variability in the ranking of states by the VFII, we carried out an uncertainty analysis. This focus on quantifying uncertainty in the model output (Saltelli et al., 2008). We investigated the difference between the output ($VFII_{BE}$) of two states (Bayelsa and Edo state) composite score as shown in the equation 5.

$$VFII_{BE} = \left(VFII_{Edo\ state} - VFII_{Bayelsa\ state} \right) \qquad (5)$$

In the first step, we must ascertain the presence of uncertainty in the input factors used to produce the output in equation 2 and equation 5. Our main area interest will be on the following assumptions that can introduce uncertainty in our output variables:

a. The selection of variables
b. The normalisation method
c. The weighting schemes
d. Exclusion and inclusion of variable(s)

The input factors defined as everything that causes a variation or uncertainty in the output of the model (Saltelli et al., 2008), is presented in Table 5.2. These are 12 weighted variables with their probability distribution function (PDF). Also included are additional three trigger variables to represent the type of normalisation (either min-max or z-score), weighting scheme (equal or unequal (PCA) weight) and exclusion or inclusion of variable (either child mortality or distance-to-water-source).

We use the Global approach to perform uncertainty analysis (Saltelli, 2017). Using Monte Carlo analysis, which is based on using the probabilistic value of the model input to estimate multiple model evaluations and then using these evaluations to determine (1) the uncertainty in the model prediction and (2) the input factors that caused the uncertainty. We followed the following procedures as laid out by (Saltelli et al., 2004; Saltelli et al., 2008):

I. Determine the probability distribution function (mean and standard deviation see table in Appendix VI) of each input factor parameters. $X_{1}, X_2, and\ X_3$ are triggers to select the weighting method, normalization method and variables excluded or included.

II. From each of these input factors, we produce a set of row vectors in such a way that the vectors are sampled from the PDF of input factor parameter.

III. Then we compute the model for all vectors, thereby producing a set of N values for the model output in equation 1 and 5.

IV. From these, we can now compute the average output, standard deviation, quartiles distribution, confidence bounds and plot these distributions.

V. To compute the number of simulation for a model with k factors, only $N(k+2)$ model runs were needed. Where k is the total number of input factors and N =1024 is quasi-random sample scheme (Sobol', 1967).

Table 5.2: Uncertainty input factor probability distribution function

Input factor	Description	PDF	Range
SH	Weighted shock	Normal	-
CM	Weighted child mortality	Normal	-
ST	Weighted stunting	Normal	-
HU	Weighted hunger	Normal	-
WI	Weighted wealth index	Normal	-
DR	Weighted distance-to-road	Normal	-
DM	Weighted distance-to-market	Normal	-
DW	Weighted distance-to-water	Normal	-
IS	Weighted income-savings	Normal	-
NI	Weighted non-farm-income	Normal	-
CY	Weighted crop yield	Normal	-
HL	Weighted household literacy	Normal	-
X_1	Weighting method (either equal weight or unequal (PCA) weight	Discrete	[0,1] where [0,0.5] =equal weights and (0.5,1] =PCA weight
$X_{2,}$	Normalization method (min-max or z-score values)	Discrete	[0,1] where [0,0.5] =min-max and (0.5,1] = z-score
X_3	Inclusion-Exclusion (either excluding child mortality and distance-to-water source or including child mortality and excluding distance-to-water-source	Discrete	[0,1] where [0,0.5] = excluding child mortality and distance-to-water source and (1, 0.5] = including child mortality and excluding distance-to-water-source

5.2.4.3 Sensitivity analysis

We applied the variance-based sensitivity method for our analysis. We are looking at how the overall uncertainty in the input factors affects the output rather than testing one input at a time. Using the variance-based sensitivity method we can decompose the uncertainty in input factors according to their variance and show how output depends on this variance (Saisana et al., 2005; Saltelli et al., 2008). Our primary objective is to look for those factors or groups of factors that when fixed to it true value will reduce the variance of VFII. The reduction in the output variance is highly desirable, and this will mean that the VFII is reliable and robust. We used Sobol' sensitivity indices (Sobol', 1996), which are the first-order and total effect sensitivity indices for our sensitivity analysis.

First-order sensitivity Index

The sensitivity index of an input factor X_i can be measure by comparing the contribution of it variance to a model output due to uncertainty in X_i (Saisana et al., 2005). Looking at the generic model in equation 6.

$$Y = f(X_1, X_2, \ldots., X_k) \qquad (6)$$

Each X in equation 6 has a certainty degree of uncertainty or variation, we want to determine what will happen to the uncertainty of Y if we could fix an input factor. Assuming a fixed factor X_i, at any value be x_i^*. This result to the conditional variance depending on X_i which is be fixed to x_i^*. Let $V_{X_{-i}}(Y|X_i = x_i^*)$, which is the resulting variance of Y taken over by all other factors except X_i. There are two problems to this approach: (1) it is impractical because the sensitivity measure will depend on the position of the point x_i^* and (2) the conditional variance will be greater than the unconditional variance. Instead of taking sensitivity measure at a fixed point, we rather take average of all possible points x_i^*. Then the dependence on x_i^* will be remove. Rewriting this as $E_{X_i}(V_{X_{-i}}(Y|X_i))$. This is always lower or equal to output variance $V(Y)$, and

$$E_{X_i}\left(V_{X_{-i}}(Y|X_i)\right) + V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right) = V(Y) \qquad (6.1)$$

A small $E_{X_i}\left(V_{X_{-i}}(Y|X_i)\right)$, or a large $V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right)$, will imply that X_i is an important factor. The conditional variance $V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right)$ is called the first-order effect of X_i on Y and the sensitivity measure:

$$S_i = \frac{V_{X_i}\left(E_{X_{-i}}(Y|X_i)\right)}{V(Y)} \qquad (6.2)$$

S_i is known as the first-order sensitivity index. S_i is a number that ranges between 0 and 1. A higher value denote an important variable. It represents the main effect contribution of each input to the output variance singly (Homma and Saltelli, 1996). When a model first-order term do not add up to one such model is called nonadditive model $(i.e. \sum_{i=1}^{r} S_i \leq 1)$. Alternatively, first-order term add up to one or equal to one, such a model is an additive model (Saltelli et al., 2008).

Total-effect sensitivity index

First-order sensitivity index measures the effect of individual input on the variance of the output not considering the interaction. Thus, total effect index account for the total contribution to the output variation due to factor X_i. It is the combination of first-order effect and higher-order effect due to interactions.

Total effect can be computed by decomposing unconditional variance into main effect and residual:

$$V(Y) = V\big(E(Y|X_i)\big) + E\big(V(Y|X_i)\big) \qquad (6.3)$$

Alternatively, total effect can be computed by decomposing the output variance into the main effect and residual, conditioning this with time with respect to all factors but one, i.e $X_{\sim i}$:

$$V(Y) = V\big(E(Y|X_{-i})\big) + E\big(V(Y|X_{-i})\big) \qquad (6.4)$$

"The measure $V(Y) - V\big(E(Y|X_{-i})\big) = E\big(V(Y|X_{-i})\big)$ is remaining variance of Y that would be left, on average, if $X_{\sim i}$ true values could be determine" (Saltelli et al., 2008). $X_{\sim i}$ are uncertainty input factors and their true values are unknown. To obtain the total effect index for X_i, we divide by $V(Y)$:

$$S_{T_i} = \frac{E\big(V(Y|X_{-i})\big)}{V(Y)} = 1 - \frac{V\big(E(Y|X_{-i})\big)}{V(Y)} \qquad (6.5)$$

Total effect index (S_{T_i}) provide an answer to the question: "which factor can be fixed anywhere over its range of variability without affecting the output?" If $S_{T_i} = 0$, this means X_i has meet the condition of not being an influential factor. If $X_i \cong 0$, then X_i can be fixed at any range without affecting value of the output variance $V(Y)$ (Tarantola et al., 2007).

5.3 Result and Discussion

The primary results presented in this section are guided by the questions raised in section 5.1. This section using the methods described earlier in section 5.2 presents the results and the discussion.

5.3.1 How do the VFII ranks compare under different weighting schemes, the normalisation method, and data types?

This section uses one-at-a-time approach to explore the sensitivity of the index to changes in data type, normalisation method, weighting scheme and exclusion and the inclusion of variable.

5.3.1.1 Using unequal weight

Using principal component analysis, we estimated the weights for each variable used to design the Vulnerability to Food Insecurity Index (VFII) (see Table 5.13 in Appendix, for unequal weight). PCA gave each component of the index different weight. Weight for exposure, sensitivity and adaptive capacity was 0.0871, -0.5645and 1.1322 respectively. Using these weights, we estimated the VFII score for each state using variables with missing data and variable with imputed data. In each scenario, we applied two types of normalisation method (min-max or z-score method). The results are shown in Table 5.3 and Figure 5.2. These show that irrespective of the data type or normalisation method applied, the VFII produces inconsistent ranking of states in South-South region of Nigeria when unequal weight is applied. The level of inconsistencies in ranking was higher when using missing data to estimate the VFII (Table 5.3). Only Cross River State maintains the same ranking while other states are ranked differently. The implication of using unequal weight means that it does produce a biased estimate of each state performance in terms of food security and vulnerability. This is because of how the VFII component was constructed. The sensitivity and adaptive capacity component have more than one variable compared to the exposure component. Due to data used in designing the index, all the variables in the exposure component were aggregated into one variable, and this made it have a lesser weight compared to another component.

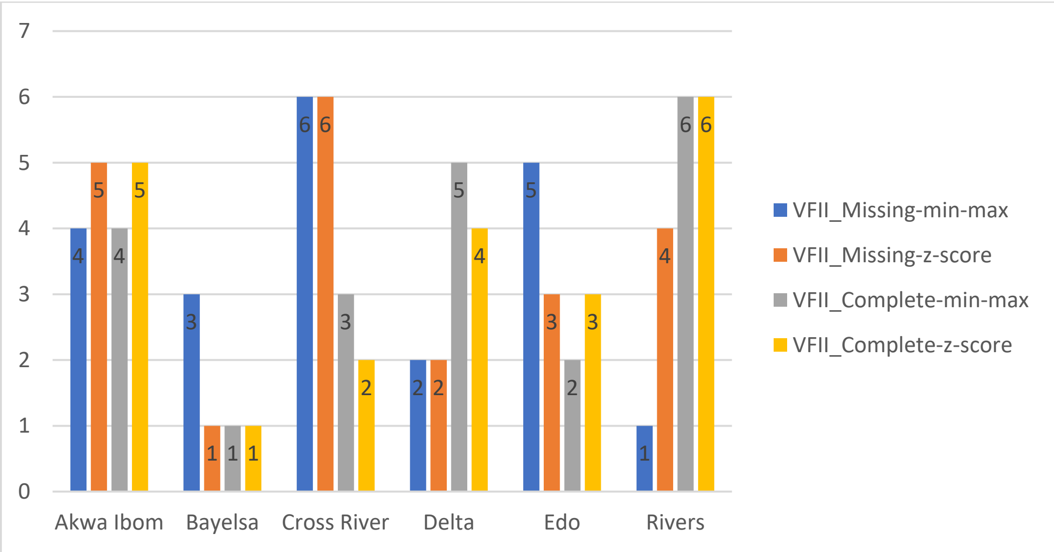
To test the robustness of different VFII specification as shown in Table 4, we computed their pairwise correlation coefficient. Table 5.4 shows that all the correlation coefficients were significant at 5% level and most relationships were negatively correlated. Only the combination of VFII with missing data and different normalisation method; and VFII with complete data and different normalisation method had a positive correlation coefficient of 0.85 and 0.69 respectively. With a negative correlation coefficient, we cannot conclude that using PCA weight or unequal with the index can produce a robust estimate.

Table 5.3: VFII ranking of states in South-South region of Nigeria using unequal weight and different normalisation methods

States	VFII_missing-min-max	VFII_missing-z-score	VFII_complete-min-max	VFII_complete-z-score
Akwa Ibom	4	5	4	5
Bayelsa	3	1	1	1
Cross River	6	6	3	2
Delta	2	2	5	4
Edo	5	3	2	3
Rivers	1	4	6	6

Source: Data Analysis

Figure 5.2: VFII ranking of States when unequal weight and different normalisation method is used



Source: Data Analysis

Table 5.4: All combinations of VFII pairwise correlation result using unequal weight and different normalisation method

Correlation Specifications	VFII_missing-min-max	VFII_missing-z-score	VFII_complete-min-max	VFII_complete-z-score
VFII_missing-min-max	1.00			
VFII_missing-z-score	0.85***	1.00		
VFII_complete-min-max	-0.70***	-0.47***	1.00	
VFII_complete-z-score	-0.63***	-0.56***	0.69***	1.00

Source: Data Analysis

5.3.1.2 Equal weighting

We decided to apply equal weight to each component of the index to compare its output. Each of the components was given a weight of 0.33, and these weights were equally shared among the variables in each component (see Appendix IV). Using different data types and normalisation method the result is present in Table 5.5 and Figure 5.3. These results show that applying equal weight to the Vulnerability to Food Insecurity Index produce a consistent output and ranking of state, irrespective of the data or normalisation method used. The result supports the notion that using equal weight across the index component produces estimates that are unbiased. According to this result, households in Bayelsa state are highly vulnerable to food insecurity whereas households in Edo state are least or not vulnerable to food insecurity.

To test the robustness of this ranking, we estimated a pairwise correlation coefficient for each specification as shown in Table 5.6. Across the table, the correlation coefficient exceeded 0.87 and was highly significant at 5% level. This suggests that VFII ranking using equal weight are highly robust in its estimate (Alkire and Santos, 2014) unlike using unequal weight as explained in section 3.1.1. Using either min-max or z-score normalisation method for the index will still produce the same output, but the min-max method will produce a better result because it had a correlation coefficient of 0.97. Based on this finding, we adopted equal weight and min-max normalisation method for our VFII.

Table 5.5: VFII ranking of states in the South-South region of Nigeria using equal weight and different normalisation methods

State	VFII_missing-min-max	VFII_missing-z-score	VFII_complete-min-max	VFII_complete-z-score
Akwa Ibom	5	5	5	5
Bayelsa	6	6	6	6
Cross River	2	2	2	2
Delta	3	3	3	3
Edo	1	1	1	1
Rivers	4	4	4	4

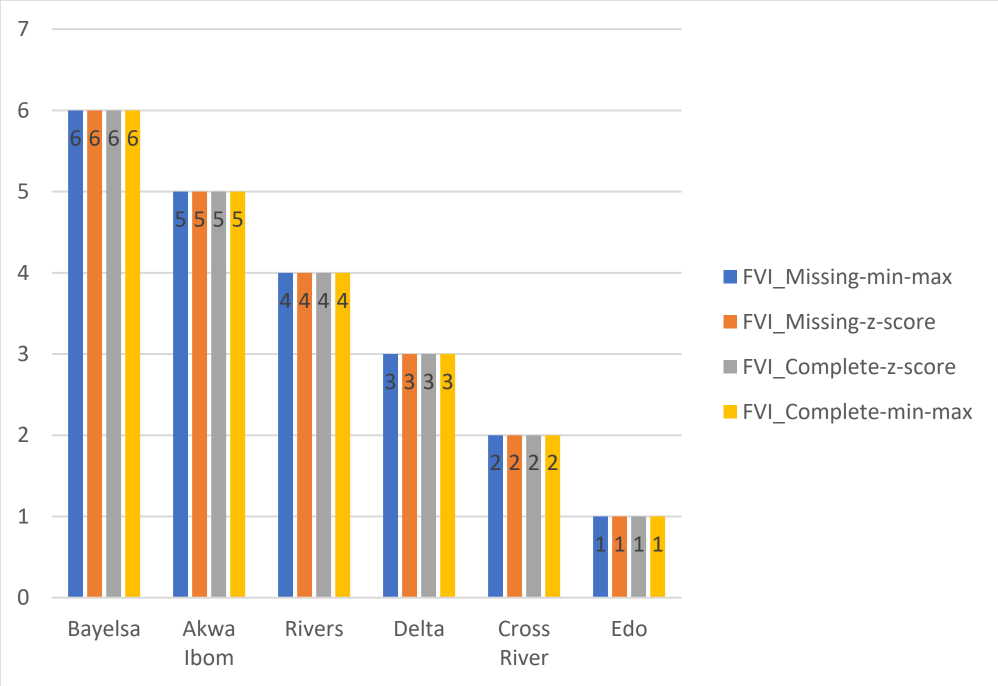
Source: Data Analysis

Table 5.6: VFII pairwise correlation result applying equal weight to the index

	VFII_missing-min-max	VFII_missing-z-score	VFII_complete-min-max	VFII_complete-z-score
VFII_missing-min-max	1.00			
VFII_missing-z-score	0.87***	1.00		
VFII_complete-min-max	0.97***	0.89***	1.00	
VFII_complete-z-score	0.91***	0.93***	0.94***	1.00

Source: Data Analysis

Figure 5.3: VFII ranking of States using equal weight and different normalisation method is used



Source: Data Analysis

5.3.1.3 Inclusion and Exclusion of variables

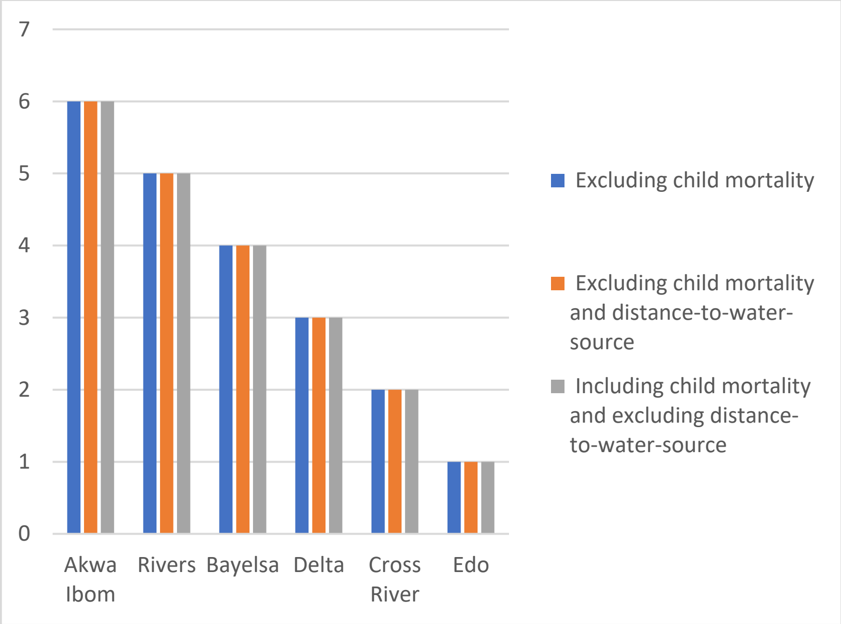
Finally, we went further to test the effect of excluding or including any variable on the index. To determine what variable(s) to be excluded, we estimated the squared multiple correlations of all the variables used in the VFII as shown in Table 5.7. The squared multiple correlation coefficient shows the interaction of each variable with all other variables. The larger the coefficient, the stronger the interaction of the variable. From Table 5.7, child mortality and distance-from-water-source were the two variables with the least correlation of 19.71% and 19.54%. Therefore, we used these variables to carry out the test of either excluding or including them. The result of this test is shown in Figure 5.4 and Table 5.8. Using equal weight (see appendix for each component weight), Figure 4 and Table 8 shows the robustness of the VFII output. Three specifications were explored: excluding child mortality only; excluding both child mortality and distance-to-water-source; and including child mortality and excluding distance-to-water source. Irrespective of any specification used the VFII ranking was stable across all specification. Comparing the result in Figure 5.4 and Figure 5.3, three states -Edo, Cross River, and Delta maintain the same ranking of first, second and third position. Akwa Ibom, Rivers and Bayelsa state ranking differs. For instance, Bayelsa state ranks sixth when using equal weighting method without excluding any variable. Alternatively, when child mortality and distance-to water-source were excluded/included, Bayelsa state ranked third. This slight alteration is expected because of the effect of excluding or including either child mortality or distance-to-water-source on the VFII. However, the overall performance of the VFII remains robust.

Table 5.7: Squared multiple correlations of variables with all other variables

Variable	**SMC**
Shock	0.3640
Stunting	0.5032
Child mortality	0.1971
Hunger	0.4113
Wealth index	0.5893
Road distance	0.2663
Market distance	0.3515
Distant-to-water-source	0.1954
Income source	0.3691
Non-farm Revenue	0.4725
Crop yield	0.4248
Household literacy	0.4836

Source: Data Analysis

Figure 5.4: VFII ranking when excluding or including variables



Source: Data Analysis

Table 5.8: VFII ranking of state when excluding or including child mortality or distance-to-water-source.

State	Excluding child mortality	Excluding child mortality and distance-to-water-source	Including child mortality and excluding distance to water source
Akwa Ibom	6	6	6
Bayelsa	4	4	4
Cross River	2	2	2
Delta	3	3	3
Edo	1	1	1
Rivers	5	5	5

Source: Data Analysis

5.3.2 Global Sensitivity Approach

This section discusses how variation or uncertainty in the output of the VFII can be apportioned to the input factors using global sensitivity analysis as described in section 5.2.4.2 and section 5.2.4.3. The area of interest investigated are:

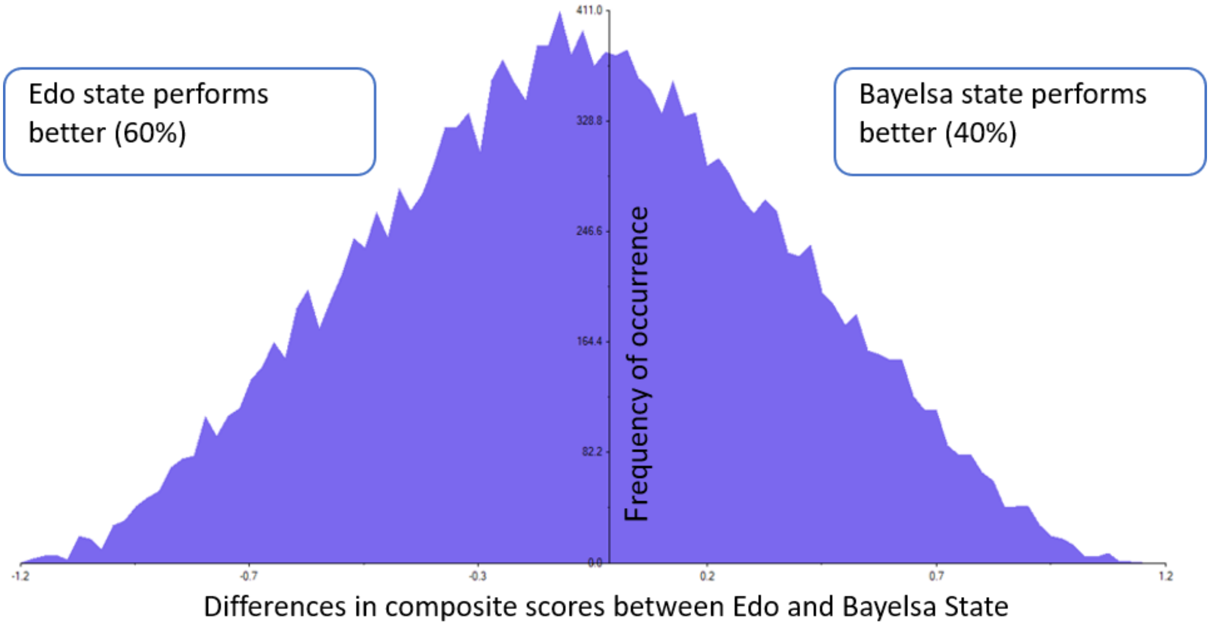
a) What are the major sources of uncertainty in the VFII ranking?
b) What are the most influential input factors that cause this uncertainty in VFII ranking?

The total number of Monte Carlo model execution estimated for the Sobol sensitivity measures – first order and total effect sensitivity indices is 29,696 (1024 *(27+2)), where 1024 is sample size adopted by quasi-random scheme (Sobol', 1967), 27 is the total number of input factor used for estimating the model.

5.3.2.1 Uncertainty Analysis -what are the most influential input factors that cause overlap in two state ranking?

To find out the primary cause of overlap in the VFII ranking, we compare the composite score output of two states – Bayelsa state and Edo state. These two states were selected because Edo is the best-performing state in term of having least food insecurity and vulnerability while Bayelsa state had the highest level of food security and vulnerability. Figure 5.5 presents the histograms of uncertainty analysis of the differences between the composite scores of these states, which correspond to 29,696 Monte Carlo runs. The left-hand region of Figure 5.5 shows that Edo state performs better than Bayelsa state in 60% of the cases. This implies that households in Bayelsa state are more vulnerable to food insecurity compare to Edo state. We must find out which uncertainty drive this result. To do this, we estimated the First order (S_i) and Total effect (S_{Ti}) sensitivity indices for Bayelsa and Edo state present in Table 5.9.

Figure 5.5: Uncertainty analysis of the difference in composite score between Edo and Bayelsa State. (Uncertainty input factors: 24 weighted indicator values, 3 triggers – weighting, normalisation, inclusion/exclusion)



Source: Data Analysis

5.3.2.2 Sensitivity Analysis

When interpreting Sensitivity analysis result, we are looking for important input factors that influence the output. When this input factor is fixed singly, it will reduce the variance of the output significantly. To determine which input factor is important the S_i >0.10, meaning that the input factor explains more than 1/k of the output variance (Saltelli, 2017).

Table 5.9 shows the result of the first-order sensitivity S_i. It shows the individual interaction and the main effect between the input factors and the output of Edo and Bayelsa state. Individually, none of the triggers, i.e. weighting scheme, normalisation scheme and inclusion/exclusion of variables had any effect on the output variance of the two states. In contrast, for Bayelsa state, the shock variable was the primary source of uncertainty in its composite score. Similarly, in Edo state, the primary source of uncertainty is from the shock variables. For both state, the individual influence between the input factors, do have an impact on the output variance as the total S_i is above 100%. The impact is mainly cause by the shock variable. This implies that the VFII is highly sensitive to shocks. The VFII is a food security indicator that incorporate vulnerability component. It is highly desirable that this index should be able to pick up the effect of the vulnerability component. As the index is highly sensitive to shocks, it proves that the index is reliable and meet the purpose for which it was design. Generally, input factors with a major contribution to variance of the VFII are: shock, child mortality stunting, hunger, wealth index, distance-to-road, distance- to-market and household literacy. Input with lesser contributions are: distance-to-water-source, income source, non-farm income, and crop yield.

The sum of the first-order sensitivity index for the two states is greater than 1, implying that the VFII model is an additive model. A model is said to be additive when it is possible to decompose the variance of its input factor quantitatively. The entire input factor is taken singly explain more than 100% of the output variance.

The total effect index represents the difference between the two states composite index score. It also measures how much an input factor interacts with other input factors. Our total effect sensitivity index S_{Ti} is less than S_i, this means that the input factors do interact with other input factors. However, the interaction between the input factors was low (-15.6%) due to the influence of the shock variable. The difference between the two states composite scores is mostly attributed to the shock variable of each state with a high score of 0.90 and 0.10 respectively. The triggers had a lesser effect of the output variance of the two state.

Table 5.9: Sobol sensitivity indices for composite scores of two states in South-Nigeria

Input Factors	First-order (S_i-Bayelsa)	First-order (S_iEdo)	Total effect (S_{Ti} Edo -Bayelsa)
$Shock_b$	1.06651	0	0.903442
$Child\ Mortality_b$	0.02805	0	0.019396
$Stunting_b$	0.004535	0	0.007513
$Hunger_b$	-0.000784	0	0.00163
$Wealth\ Index_b$	0.007421	0	0.00418
$Dist-to-Road_b$	0.069542	0	0.052796
$Dist-to-Water_b$	0.001171	0	0.001117
$Dist-to-Market_b$	0.001643	0	-0.00266
$Income\ Source_b$	0.000129	0	0.00042
$Non\ farm\ Income_b$	0.004479	0	0.002208
$Crop\ Yield_b$	-0.00108	0	-0.00109
$Household\ Literacy_b$	-0.0253	0	-0.0222
$Shock_e$	0	0.857508	0.107939
$Child\ Mortality_e$	0	0.033099	0.000859
$Stunting_e$	0	0.049124	-0.000146
$Hunger_e$	0	0.038877	-0.00287
$Wealth\ Index_e$	0	0.078605	0.011006
$Dist-to-Road_e$	0	0.037927	0.005205
$Dist-to-Water_e$	0	-0.00209	0.005037
$Dist-to-Market_e$	0	0.020292	-0.00434
$Income\ Source_e$	0	0.005667	0.00061
$Non\ farm\ Income_e$	0	-0.00402	-0.000326
$Crop\ Yield_e$	0	-0.000695	0.000996
$Household\ Literacy_e$	0	0.039294	-0.0247
Weighting	0	0	-5.55E-17
Normalization	0	0	-5.55E-17
Inclusion/Exclusion	0	0	-5.55E-17
Sum	1.156316	1.153588	1.066022

Source: Data Analysis

5.4 Conclusion

This paper investigated the robustness of the Vulnerability to Food Insecurity Index. We carried out a robust check using sensitivity and uncertainty analysis on the following assumptions used to design the index:

a) alternative data type (missing data or complete data)
b) alternative weighting scheme (equal or unequal weight)

c) alternative normalization scheme (min-max or z-score method)
d) excluding or including variables.

Using these assumptions, we collectively investigate the performance and the sources of uncertainty to the VFII, focusing on the following questions:

a) How does the output of the VFII rank compare to different assumptions?
b) What is the major source of uncertainty in the VFII ranking?
c) What are the most influential input factors that cause this uncertainty in VFII ranking?

Using the different assumptions, we tested the robustness of the VFII output and ranking of states. When we applied different weighting (i.e. each using PCA to determine the weight of each variable), the VFII produced an inconsistent ranking irrespective of the data type and the normalization method used. The ranking from applying different weightings was highly inconsistent when data with missing values were used. This inconsistency in ranking was mainly due to the computation of the exposure component of the VFII as a result of the lack of data from the data source. Thus, we could not conclude that the output and ranking from VFII are robust using different weight. However, when the three components of the index were equally weighted, the output and ranking of the VFII were consistent and gave highly robust estimates irrespective of the data type and the normalization method. Using the min-max normalisation method gave a highly robust estimate compared to using the z-score normalisation method when equal weight was applied to the VFII. This evidence led the research to adopt equal weighting and min-max normalization for constructing the VFII. We explored excluding or including variables, such as child mortality or distance-to-water-source, on the output of the index. The findings revealed that three states maintained the same ranking while three states changed ranking according to the specification used, showing the effect of excluding or including variables on the index output. However, the overall performance of the index remained robust.

Findings from uncertainty analysis reveal the presence of uncertainty between the VFII composite score of Edo and Bayelsa State, and we, therefore, went further to explore the source of this uncertainty using global sensitivity analysis. The main input that introduces uncertainty to the composite score of VFII was shock variables. Most significantly, this implies that the VFII is highly sensitive to shocks, and this is useful to policymakers interested in local targeting because it captures vulnerability, and it also shows that the exposure component of the VFII is the major source of uncertainty for the VFII. We conclude therefore that the VFII is fit for purpose based on the assumption we used in the VFII construction and offers a complementary role to existing indexes. However, future modelling of the VFII should focus on expanding and providing data for each variable in the exposure component of the index. This will help to reduce uncertainty, increase confidence and correct for the adoption of different weights that reflect the realities on the ground – the incorporation of vulnerability to food insecurity varies according to context and it is place specific. We acknowledge that vulnerability to food insecurity will vary for country to country and as such operationalising the index may require using different variables and weighting schemes, especially when different data sources are used. However, this research only used the World Bank data for the construction of the VFII and can provide a model to operationalize vulnerability to food insecurity.

Appendix

Table 5.10: VFII score for each state using unequal weighting

States	VFII_Missing-min-max	VFII_Missing-z-score	VFII_Complete-min-max	VFII_Complete-z-score
Akwa Ibom	0.677	-0.047	-0.130	-0.456
Bayelsa	0.689	0.309	0.033	0.834
Cross River	0.574	-0.360	-0.051	0.668
Delta	0.731	0.162	-0.166	0.069
Edo	0.666	0.072	-0.036	0.418
Rivers	0.739	0.012	-0.225	-0.610

Table 5.11: VFII score for each state using equal weighting

State	VFII_missing-min-max	VFII_missing-z-score	VFII_complete-min-max	VFII_complete-z-score
Bayelsa	-0.096	-0.153	-0.093	-0.118
Akwa Ibom	-0.092	-0.103	-0.093	-0.075
Rivers	-0.092	-0.021	-0.091	-0.037
Delta	-0.072	0.007	-0.082	0.007
Cross River	-0.072	0.041	-0.065	0.077
Edo	-0.047	0.168	-0.041	0.153

Table 5.12: VFII score for excluding or including a variable

State	Excluding child mortality	Excluding child mortality and distance-to-water-source	Including child mortality and excluding distance to water source
Akwa Ibom	-0.121	-0.110	-0.082
Rivers	-0.120	-0.109	-0.080
Bayelsa	-0.113	-0.098	-0.078
Delta	-0.107	-0.096	-0.071
Cross River	-0.088	-0.077	-0.054
Edo	-0.069	-0.056	-0.028

Table 5.13: Equal-weight used in designing VFII

VFII component	Indicators	Individual weight	Excluding child mortality	Excluding distance-to-water source	Excluding child mortality and distance to water source	Overall weight
Exposure	Shocks	0.33	0.33	0.33	0.33	0.33
Sensitivity	Stunting	0.11	0.165	0.11	0.165	0.33
	Child mortality	0.11	-	0.11	-	
	Hunger	0.11	0.165	0.11	0.165	
Adaptive Capacity	Wealth Index	0.04125	0.0412	0.0471	0.0471	0.33
	Road distance	0.0412	0.0412	0.0471	0.0471	
	Market	0.0412	0.0412	0.0471	0.0471	
	Water source	0.0412	0.0412	-	-	
	Income savings	0.0412	0.0412	0.0471	0.0471	
	Revenue non-farm	0.0412	0.0412	0.0471	0.0471	
	Crop Harvested	0.0412	0.0412	0.0471	0.0471	
	Literacy	0.0412	0.0412	0.0471	0.0471	

Table 5.14: Unequal weight used in designing VFII

VFII component	Indicators	Individual weight	Overall weight
Exposure	Shocks	0.0871	0.0871
Sensitivity	Stunting	-0.0058	-0.5645
	Child mortality	-0.2628	
Adaptive Capacity	Hunger	-0.2959	1.1322
	Wealth Index	0.5363	
	Road distance	0.0907	
	Market	0.0607	
	Water source	-0.3767	
	Income savings	0.4437	
	Revenue non-farm	-0.0593	
	Crop Harvested	-0.0035	
	Literacy	0.4403	

Table 5.15: Distributions (μ, σ) for inputs and triggers for inclusion-exclusion, missing data, weighting and normalisation method

			Weighed Variables										
State	Distribution	Shock	Stunting	Child Mortality	Hunger	Wealth Index	Distance-to-water	Income Savings	Non-farm-income	Crop yield	Household Literacy	distance-to-road	Distance-to-market
AKS	Mean	0.10888	0.06182	0.00521	0.00440	0.02054	0.00168	0.00823	0.03502	0.00101	0.01587	0.00256	0.01482
	Std. Dev.	0.08529	0.00687	0.01329	0.01446	0.00729	0.00365	0.00491	0.00157	0.00140	0.00893	0.00249	0.00367
Bayelsa	Mean	0.12178	0.06255	0.01194	0.00052	0.02179	0.00021	0.00333	0.03455	0.00154	0.01827	0.01603	0.01814
	Std. Dev.	0.10662	0.00616	0.02100	0.00325	0.00879	0.00027	0.00222	0.00492	0.00191	0.00902	0.01275	0.00384
CRS	Mean	0.07619	0.06225	0.00948	0.00207	0.01474	0.00090	0.00597	0.03543	0.00482	0.01441	0.00532	0.02819
	Std. Dev.	0.03425	0.00563	0.01774	0.00630	0.00743	0.00129	0.00169	0.00053	0.00797	0.00997	0.00503	0.00505
Delta	Mean	0.09919	0.06064	0.00574	0.00148	0.02501	0.00074	0.00499	0.03524	0.00576	0.01664	0.00770	0.00949
	Std. Dev.	0.04676	0.00614	0.01547	0.00451	0.00779	0.00208	0.00146	0.00272	0.00742	0.00986	0.00566	0.00581
Edo	Mean	0.07355	0.06039	0.00385	0.00208	0.02295	0.00114	0.00466	0.03529	0.00458	0.01618	0.00302	0.02419
	Std. Dev.	0.03225	0.00534	0.01006	0.00870	0.00975	0.00280	0.00115	0.00067	0.00549	0.00857	0.00319	0.00478
Rivers	Mean	0.10764	0.06048	0.00299	0.00303	0.02355	0.00131	0.00692	0.03435	0.00185	0.01992	0.00400	0.00651
	Std. Dev.	0.09240	0.01066	0.01212	0.00961	0.00782	0.00409	0.00133	0.00204	0.00380	0.00843	0.00406	0.00454

Table 5.16: Detailed description of indicators and variables

Index components	Indicators	Variables description and rationale
Exposure *probability of covariate shocks occurring*	Health shock	From the household dataset "illness of income-earning member" was selected and used as Health Shock in the Vulnerability to Food Insecurity Index.
	Unemployment shock	"Job loss" is used as a variable to represent unemployment shock in the Vulnerability to Food Insecurity Index. Job loss reduces the ability of households to buy food, get clean water and medicines because of loss of income, therefore increasing household food insecurity and vulnerability (FAO and WHO, 1996).
	Civil conflict shocks	From the household survey data, the variable used to represent Civil conflict shock are: "Theft of crops, cash and livestock" and "kidnapping/Hijacking/robbery/assault".
	Agro-climatic shocks	Agro-climatic shocks have the potential for increasing food insecurity and malnutrition. Based on the household's survey data the variables used for agro-climatic shocks are: "poor rain that caused harvest failure" and "flooding that caused harvest failure.
	Food price shock	From the household survey data, the variable used to represent food price shock is "increase in price of major food items consumed".
Sensitivity previous or accumulative experience of food insecurity	Malnutrition	Malnutrition is the most widely accepted and policy relevance variable commonly used are wasted, stunted, and underweight (Klennert, 2005). However, this research prefers to use stunting as an indicator of malnutrition. Stunting was preferred because it shows inadequate nutrition over a prolonged period (Young and Jaspars, 2006).
	Child mortality	Child mortality, defined as the total number of dead children in each household was derived by adding "number of male children" and/or "female children" reported dead in each household.
	Hunger	This research refers hunger to the physical discomfort caused by a lack of food (Bickel et al., 2000; Barrett, 2010) and not as a result of dieting or being too busy to eat. As such it represents hidden hunger, that is micronutrient deficiencies (Jones et al., 2013a). Thus, hunger is a severe stage of food insecurity. To derive this indicator, the research adopts the Household Hunger Scale (HHS) methodology with a little modification due to inadequate data availability.
Adaptive capacity *how household respond, exploit opportunities, resist or*	Wealth Index	The wealth index is a measure of economic status of households to ascertain their relative wealth (Ruststein and Johnson, 2004; Fry et al., 2014). The wealth index used in this research uses various household asset such as information assets, mobility assets, livelihood assets, and housing characteristics to design the index. The following variable were used in designing the wealth index: **Livelihood assets:** Tables, mattress, bed, mat, fridge, freezer, sofa set, chair, sewing machine, kerosene stove, other assets, generator, size of agricultural land, broiler chicken, cockerel, local chicken, goat, pig, duck and sheep. **Mobility assets:** Bicycle, motorbike, cars and other vehicles. **Information asset:** Radio, TV set, computer, satellite dish, DVD player, GSM mobile phone/landline, cassette recorder. **Housing structure characteristics:** Outer wall, roof materials, floor material, members per room, lighting fuel, cooking fuel, access to electricity, main source of drinking water during dry season, main source of drinking water during the wet season, type of toilet facilities, type of user who shared toilet facilities, and refuse disposal facilities.

recover from food insecurity shocks	Access to infrastructure	This research uses distance to major roads, distance to markets and time taken to get to nearest water source to represent a single indicator called "assess to infrastructure".
	Livelihood activities	Income sources, revenue from non-farm enterprises and agricultural activities are used as variable to represent livelihood activities. These are three major sources of livelihood identified in the LSMS household survey data.
	Household literacy	Cumulative years of schooling of household head or closet individual is one of the main criteria used in defining household literacy. Years of schooling are used as a proxy for literacy and level of understanding of household members, including household heads. An individual is considered literate if he or she has at least five years of education (Dotter and Klasen, 2014). Only post-planting season data were used to derive this indicator because it contains information on household head needed to represent literacy level of the household. In rare cases where there was no data on household head, the *closest individual* in educational achievement that has at least five years of schooling is used as a replacement for household head. If educational qualifications are the same for more than one individual, the most senior individual in age is used.

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Chapter 6 : Verifying the relevance of a Vulnerability to Food Insecurity Index in practice for households in South-South Nigeria

This chapter is has been submitted to *Journal of Poverty* for publication.

Abstract

This paper examined the relevance of the Vulnerability to Food Insecurity Index (VFII) in practice for households in South-South region of Nigeria. The main objectives were to verify the result of the VFII with real-life experience and to understand why households are vulnerable to food insecurity using qualitative insight. The paper applied both quantitative and qualitative methods. The quantitative method was used in designing the VFII, then the result of the index was verified in the field using qualitative methods. In the qualitative phase, a food vulnerability map which was produced form VFII score for households in South-South Nigeria was used to purposively select *Akwa Ibom* State for the verification exercise. Key informant interview and a scoping visit were used to identify one urban and one rural community in *Akwa Ibom* State that is vulnerable to food insecurity. A focus group discussion was conducted in each community to identify local perception that characterises household food security and vulnerability. These local perceptions serve as indicators that were used to select a total of 30 households that were highly vulnerable, mildly vulnerable and not vulnerable to food insecurity. The findings reveal that at both the community and state level, the same set of shocks used to design VFII was the same shocks that households experience on the ground. Comparing the prevalence of shock at the community level with the result of VFII, the paper found out that VFII can be applied in a heterogeneous context because the index can pick up some context-related factors. Using equal weight at the community level is not feasible because the relative importance of VFII indicators varies from community to another. Households were vulnerable to food insecurity because of current socio-economic challenges in the macro-level, inability to manage food shocks and lack of safety net programs.

Keywords: Food security

6.1 Introduction

Vulnerability has been extensively explored as a theoretical construct with a range of definitions and as a result, it can be challenging to identify an appropriate set of indicators to measure vulnerability without being specific about the sector, system, goal and scale (Hinkel, 2011). There are multiple approaches within the literature used to operationalise the concept of vulnerability. This is because of the need to improve assessments that help target support to those who are most vulnerable, and the increasing demand by policymakers for decision making (Himes-Cornell et al., 2016; Zurovec et al., 2017; Eriksen and Kelly, 2007). Operationalising the concept into practical methodologies remains a contemporary challenge, particularly in the area of food security (Ibok et al., 2019).

Conventional approaches to vulnerability assessment are based on outcome and context. The outcome approach considers how a system might be vulnerable as a result of natural hazards. It is therefore focused on how the biophysical condition of a system affects its vulnerability, for example, climate change risk. The difficulty in applying this approach to the concept of food security is that it ignores social, economic, political and cultural factors (Fellmann, 2012; Nguyen et al., 2016). Using a contextual approach is more helpful in the context of food security because it considers vulnerability in a more holistic manner, allowing an analysis of the influence of biophysical, social, political, economic processes and structural aspects on people's food security. Unlike the outcome approach, the contextual approach also considers the sensitivity and adaptive capacity of a system (Nguyen et al., 2016). This makes the structural approach widely adaptable in operationalising vulnerability and causing a significant shift in the debate from physical vulnerability to social vulnerability (Cutter et al., 2003).

One important methodology used to operationalise vulnerability in social science is the construction of indices (Nguyen et al., 2017; Krishnamurthy et al., 2014), for example, the use of the livelihood vulnerability index (Adu et al., 2018). Currently, social vulnerability indices are under intense criticism because of a lack of ground-truth evidence to validate the quantitative analysis (Maguire, 2015; Himes-Cornell et al., 2016). There is a risk that policy decisions about long term initiatives to enhance food security in a vulnerable population may otherwise not be effective or have unintended consequences. According to Himes-Cornell et al. (2016), the goal of decision-making using vulnerability indices should be to create a reliable and appropriate policy, and this will only be delivered when measurement and reality on the ground are consistent.

This paper responds to this challenge by using ground-truth evidence to verify a vulnerability to food insecurity index (VFII). The VFII is a multidimensional food security indicator that measures household food vulnerability (Ibok et al., 2019). Food vulnerability is defined as a situation that occurs when food-related shocks cause households to be vulnerable to food insecurity (Lovendal and Knowles, 2005). A VFII was developed to improve on traditional food security indicators which are not sufficient to address the challenges posed by multiple risk factors that affect household food vulnerability (Nagoda, 2015; Ibok et al., 2019). Innovative approaches and methodologies are urgently needed to address the risks of pockets of food insecurity at the local level and to support national planning. Supporting food security nationally will help in securing the agenda of global food insecurity embedded within the Sustainable Development Goals (UNDP, 2015; FAO et al., 2017). Barrett and Palm (2016) assert that an unacceptably large proportion of people globally continue to suffer from chronic or transitory food insecurity. FAO et al. (2017) estimate that the number of undernourished people globally has increased from 777 million in 2015 to 815 million in 2016. The VFII developed in Ibok et al. (2019) can be applied to locations where there is a need to better understand the patterns of rising food insecurity and poverty, and for this paper, the case study of Nigeria is used (Owoo, 2018). According to FAO (2015), the number of undernourished people in Nigeria increased from 10 million in 2010 to 13 million in 2012. Currently, Nigeria has the highest rate of poverty in the world with 87 million people living in extreme poverty (Crespo Cuaresma et al., 2018).

The main objective of this paper is to use ground- truth evidence to verify VFII index results using empirical data from Nigeria. Specifically, the paper will verify whether the indicators used in the VFII are relevant and how divergent the results are from the ground truth experience. This process will identify how robust and reliable the index is, and offer important reflections on the potential value of using ground truth evidence in index construction.

To contextualise the importance of this research paper, a short review of the relevant literature follows in section 6.2. The methodology used is then outlined in section 6.3, and in section 6.4 the results are presented. A discussion of the implications of these results is given in section 6.5 followed by the conclusion in section 6.6.

6.2 The value of identifying reliable vulnerability indexes for practice

The development of improved vulnerability indexes food security is becoming increasingly important within social science research, particularly for the international development agenda. The focus of this development is to identify a reliable index that uses a multi-dimensional assessment approach to support decision making for policy makers and practitioners (Tandon et al., 2017; Chen et al., 2018). Vulnerability indexes are used to identify the cause of vulnerability and explain the attributes of a vulnerable system (Füssel, 2010). In the context of food security, vulnerability indexes are used primarily to target intervention to food-poor households, thereby reducing the underlying cause of vulnerability and strengthening households' abilities to confront stressors (Ribot, 2017). Irrespective of the relevance of vulnerability indexes, there remains a gap in the knowledge about how these approaches using quantitative indexes compare to the reality on the ground (Hinkel, 2011; Nagoda, 2015; Nazari et al., 2015; Barrett and Palm, 2016; Nguyen et al., 2017). Scholars have consistently called for the development of a vulnerability index that relates the theoretical construct of a multidimensional understanding of vulnerability to food insecurity to pragmatic assessments that are reliable on the ground (Himes-Cornell et al., 2016). Using quantitative methods to verify the quantitative results of an index is useful in achieving this (Perez-Escamilla et al., 2017; Meenar, 2017). According to Neset et al. (2018), after evaluating the role of indicators to assess agricultural vulnerability to climate change, it is important to integrate both qualitative and quantitative data approaches in the final design of a vulnerability index. However, there is little in the methodological literature that reports ways of performing this stage of verification. Himes-Cornell et al. (2016) therefore call for a more effective way of testing for an index's validity and suggest comparing the convergence of the qualitative data with the rankings of the quantitative data. They suggest that a quantitative index that shows a high correlation with the qualitative ground-truth evidence is likely to be best oriented toward reality on the ground and therefore most reliable for practice.

This gap in understanding arises because of important challenges. The first is that the term "vulnerability measurement" itself remains conceptually debated. Hinkel (2011) argues that vulnerability is not an observable phenomenon, and therefore cannot be measured. Instead, he argues that the term "vulnerability measurement" should be replaced with the term "operationalising vulnerability." Despite this, Nelson et al. (2016), de Grosbois and Plummer (2015), Zurovec et al. (2017), and Bayes and Kelman (2018) have produced a range of methodologies for measuring vulnerability. This debate highlights the value of this paper in contributing to the development of approaches to operationalising vulnerability through more effective assessment tools.

An additional challenge is that there is a serious lack of good quality data for use in vulnerability index analyses. According to de Grosbois and Plummer (2015), data used to design vulnerability indices are often inadequate. This encourages the use of different approaches and methodologies to deal with this challenge. For example, two common approaches are (a) the data-driven or inductive approach, which lacks theoretical insight during indicator selection, and (b) the theory-driven or deductive approach, which does not aggregate data for composite indices in constructing a vulnerability index (Vincent and Cull, 2014).

Developing indicators when using poor quality data may result in the vulnerability index representing an inaccurate scenario of differential food insecurity at the ground level (Vincent and Cull, 2014; Neset et al., 2018; Wiréhn et al., 2017). According to Vincent and Cull (2014), vulnerability is multi-dimensional, and it is impossible for vulnerability indices to represent the different drivers and interaction of current vulnerability experiences in practice. Vulnerability indices may only present a snapshot of the current condition of a system being measured. Fellmann (2012) labels this snapshot as 'static vulnerability'. Therefore, vulnerability indices represent current conditions but do not provide guidance on future conditions. However, the principal objective of vulnerability analysis is to show changes from an intertemporal dimension. This is because a household that is vulnerable today, may not remain in the same condition forever, and overtime may be able to secure its livelihood and food security. This means that vulnerability index assessments should be accompanied by evidence from ground-truth case studies and be subjected to regular testing and refinement to ensure they are a robust assessment tool (Vincent and Cull, 2014; Malone and Engle, 2011). Ribot (2017) emphasises that vulnerability index assessment is the first step in the process of vulnerability assessment and policy development. This is important because vulnerability and its causes are diverse, yet vulnerability assessment tools are often not able to deal with local-level differentiation and the specific problems found in different locations.

The development of vulnerability assessment tools must be accompanied by empirical ground-truth case studies to convince policymakers and practitioners of the relevance of a tool and inform them of the local interpretation needed to ensure the approach is useful for reducing vulnerability in a particular context. Incorporating information from case studies adopts a place-based approach to vulnerability assessment which is otherwise missing, and allows consideration of peoples' social, cultural, and production systems, accounting for the specific risks they face within the community. Therefore, while a vulnerability index can inform decision-makers about patterns for the general population to be targeted, case studies generate insights that help with effective interpretation and implementation. The few examples of this approach include a method by Bayes and Kelman (2018), who designed an index for measuring vulnerability to environmental hazard in Bangladesh, using both quantitative modelling and insights from a qualitative case study.

To consolidate this approach and manage the disparity between qualitative index results and the reality on the ground, increasingly the focus in the literature is to provide evidence of best practice. Providing a robust methodology that includes an evaluation of index validity and reliability using a qualitative case study methodology is accepted as the best way to show the validity of an index (Vincent and Cull, 2014). This approach still requires a clear conceptual framework, stating the assumptions and sources of data to avoid the criticism of manipulation (de Grosbois and Plummer, 2015). Furthermore, it is important to explain how vulnerability indicators link to reality on the ground (Eriksen and Kelly, 2007; Wiréhn et al., 2017). Finally, it is clear that vulnerability assessment is most valuable when it is place-based, considers multiple interacting stressors and examines the differential adaptive capacity of those affected by food insecurity. Managing the limitations of a vulnerability index continues to be challenging, and users of the results obtained by this method should be aware that they show only a snapshot of the present conditions. Thus, interpretation of the policy or practice responses depends on their trust in the tool and their understanding of the assumptions and implications (Nguyen et al., 2016).

6.3 Methodology

This section presents a summary of the quantitative procedure used to design the VFII and the qualitative case study, including the study site selection, sampling and tools.

6.3.1 Quantitative methods used to design a Vulnerability to Food Insecurity Index

Firstly, a conceptual framework for vulnerability to food insecurity was developed, including the three main components of exposure, sensitivity and adaptive capacity (see Chapter 3). The VFII was applied to household data from the South-South region of Nigeria, covering the states of Edo, Bayelsa, Akwa Ibom, Cross River, Rivers and Delta. This data was publicly accessible from the World Bank and the first phase of the Nigerian Living Standard Measurement Survey was used in designing the index (World-Bank and NBS, 2015; World-Bank and NBS, 2014). Particular indicators and variables were selected to represent each of the core components of vulnerability, as shown in Table 6.1.

Subsequently, these variables were normalised to ease comparison and for all variables to have an equal unit (OECD, 2008). The variables were normalised using the min-max method based on the recommendation from the sensitivity and uncertainty analysis carried out in Chapter 5. The min-max normalisation method used is presented in equation 1

$$I_{q,c} = \frac{x_{q,c} - min(x_q)}{range(x_q)} \quad (1)$$

Where $I_{q,c}$ is the normalised value of each variable x_q, $x_{q,c}$ is the raw value of individual variables, $min(x_q)$ is the minimum value for each variable and $range(x_q)$ is the difference between the maximum and minimum value of the variable x_q.

The third step involved applying weight to these variables. Equal weight was applied to each component of VFII. This means that each component was given the same weight of 0.33, implying that all have the same "worth" for the index. However, within each component of the VFII, variables had different weight depending on the total numbers of variables. For instance, in the Adaptive Capacity component, each variable had a weight of 0.0412; while in the Sensitivity components all variables had the weight of 0.11, and the Exposure component variable had the weight of 0.33 (see Chapter 5, Table 5.13 for detail). Equal weight was adopted for the index after performing a robustness check comparing the effect of different weight and equal weight using a sensitivity and uncertainty analysis (see Chapter 5, section 5.3.1.2). The sensitivity analysis showed that applying equal weight to the VFII produced a robust output compared to using different weight generated from a principal component analysis (PCA). Moreover, variables in the VFII were grouped into three components, the component with a larger number of variables would have a higher weight if different weight was applied. Considering that the exposure component after final computation had only a single variable as a result of lack of data, this would result in an unbalanced structure of the VFII if the PCA weight was adopted. Apart from equal and unequal weight, this research did not explore weight from expert opinion because of constraints in the availability of experts during the field work.

Finally, the linear aggregation method, shown in equation 2, was used to generate the VFII score (OECD, 2008).

$$VFII_i = \sum AC_i \; - \left(\sum E_i + \; \sum S_i\right) \qquad (2)$$

The VFII categorised households into three different food vulnerability groups based on the score. These groups represent households highly vulnerable to food insecurity, mildly vulnerable and not vulnerable. The more positive the VFII score, the fewer households are vulnerable to food insecurity and vice versa (Ibok et al., 2019).

Table 6.1: Indicators and variables used for the Vulnerability to Food Insecurity Index

Index Dimension	Indicators	Description of variables
Exposure (probability of covariate shocks occurring)	Health shock	Illness of income earning member
	Unemployment shock	Job loss
	Civil conflict shock	Theft of crops, cash, livestock or other
		Kidnapping/hijacking/robbery/assault
	Agro-climatic shock	Poor rain that caused harvest failure
		Flooding that caused harvest failure
	Food price shock	Increase in price of major food items consumed
Sensitivity Previous/accumulative experience of food insecurity	Malnutrition	Length/height-for-age (stunting)
	Child mortality	Total number of children dead in each household
	Hunger	Total number of days households went without eating any food
Adaptive Capacity how household responds, exploits opportunities, resists or recovers from food insecurity shocks	Wealth Index	Household assets used to assess information
		Mobility assets used in households
		Livelihood assets owned by households
		Housing structure characteristics
	Access to infrastructure	Household distance to nearest major road (km)
		Household distance to nearest market (km)
		Time taken to walk one way to the water source from household dwelling (minutes).
	Livelihood activities	Total income from savings, rental of properties and other types of income.
		Estimated revenue from non-farm enterprises
		Total yield of crops harvested (kg)
	Household literacy	Cumulative years of schooling for household heads or closest individual[1] in the household

[1]This is the next individual in the household if education is missing for the household head, who has the highest level of education, and at least five years of schooling. If educational qualifications are the same for more than one individual, the most senior individual in age is used.

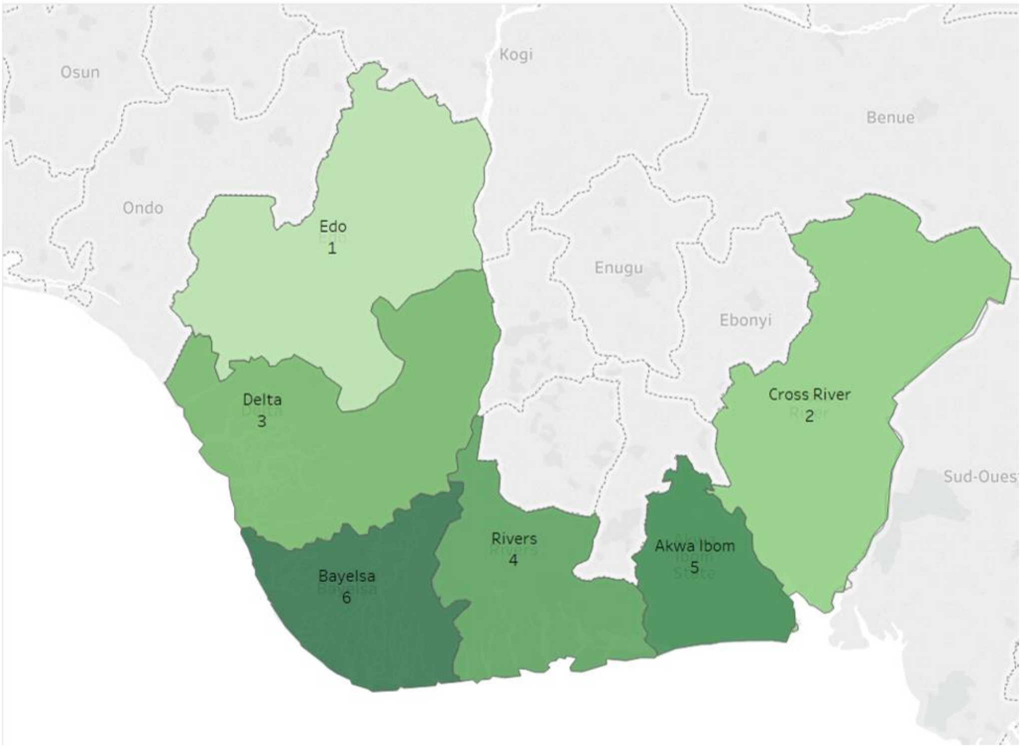
6.3.2 Qualitative methods: Ground-truth procedure

6.3.2.1 Selection of location

The quantitative results from the VFII analysis were used to produce a vulnerability to food insecurity map for the sample households in the South-South region of Nigeria, as shown in

Figure 6.1. This map ranked the six states according to their VFII composite score. The state that is ranked first has the smallest number of food vulnerable households while the state that is ranked sixth has the highest number of food vulnerable households. The map was used to purposely select Akwa Ibom State for the ground-truth data collection and verification exercise.

Figure 6.1: Food vulnerability map of states in South-South Region of Nigeria



Source: Author developed from the VFII results using Tableau

Secondary data collection and key informant interviews with the Akwa Ibom State Agricultural Development Programme (AKADEP) and the Ministry of Agriculture and Food Sufficiency, Akwa Ibom State (MOA) were conducted in the state. Key informants indicated communities that are vulnerable to food insecurity and a scoping visit identified two communities, Ibesikpo Asutan and Ikono, to illustrate an urban and a rural context respectively.

6.3.2.2 Sampling within the community

In each community, a focus group discussion was conducted with a range of locally-important stakeholders, including the village head and village council members, to obtain permission and necessary community information. This information included mapping of community resources, understanding the food-related shocks that had affected the community within the past four years, characterising households based on local wealth ranking, their coping strategies, and validation of the VFII indicators.

Participatory exercises, such as resource mapping, wealth ranking and proportional pilling (WFP, 2001) were used during the focus group discussions to capture community resources and to generate local perception that was used to classify households into categories of highly vulnerable, mildly vulnerable and not vulnerable to food insecurity. The information from the focus group discussions also enabled a comparison of the VFII indicators with local perception. Stakeholders were asked to identify what characterises household food insecurity and vulnerability and these local perceptions served as indicators to identify households that were within each of the 3 categories of food insecurity and vulnerability (Table 6.2).

Table 6.2: Local perceptions that characterise households into three food vulnerability groups

Not vulnerable	**Mildly vulnerable**	**Highly vulnerable**
All children have completed university	Children completed primary or secondary school	Children attend public primary schools and secondary schools
Enjoys a balanced diet	Out of 4 children, only one child may complete university	Children drop out of school often because of the death of the main breadwinner
Eats broilers chicken	Struggles to afford two square meals per day	Can afford only one square meal per day
Can afford three square meals a day	Meals do not contain much carbohydrate	Consumes high carbohydrate meals
Has a private business of over one million naira	Business net worth between one hundred and two hundred thousand naira	Eats only local chicken
Can make up to a 100-million-naira investment outside the community	Uses water system toilet	Begs for food
Uses water system toilet	May have a job like a junior civil servant	Pit toilet or no toilet
Job like a senior civil servant	Motorbike, tricycle	Jobs like farming, fishing, labouring, building
More than one car		Bicycle
Water system toilet		

Using a local guide and two research assistants, households were selected for in-depth interviews using the local perceptions of highly vulnerable, mildly vulnerable and not vulnerable to food insecurity established in the focus group discussions. A snowball sampling technique was used to identify fifteen households from each community, generating a total of 30 households in the ground-truth case study (see Table 6.3). Based on the three-food insecurity and vulnerability groups, five households were interviewed within each group. During the household in-depth interviews, a short participatory exercise of matrix ranking was conducted. Interviews were conducted with the household head or a member of the household who was knowledgeable regarding food security, although other household members were present and willingly contributed to the discussion. The interview focused on questions about the impact of food-related shocks on households or other factors hindering access to adequate food, household response, formal food support programmes available, and perceptions of the agricultural season calendar. Questions were constructed to ensure that interviewees were not led to particular answers and the process was subjected to the necessary ethical procedures. Qualitative data generated were analysed using a thematic coding process to identify important local indicators of vulnerability to food insecurity, the relative importance of these indicators as perceived by the group, and whether these indicators were different by locational context. Also, this data provided insight into the perceptions of the different groups and contexts of the indicators used in the VFII.

Table 6.3: Sample size for focus group discussion and household interview

Ground-truth activities	**Urban community**	**Rural community**	**Total**
Focus group discussion	1	1	2
Household interview	5 non-vulnerable households 5 mildly vulnerable households 5 highly vulnerable households	5 non-vulnerable households 5 mildly vulnerable households 5 highly vulnerable households	30
Sub-total	15 households	15 households	

6.4. Results

This section is organised according to the three components of the VFII to allow presentation of each stage and a comparison of local perceptions from the ground-truth evidence with the VFII indicators.

6.4.1 Results from the VFII showing the prevalence of shocks according to food vulnerability group and context at the macro level

Results from the VFII quantitative analysis were compared with the qualitative analysis from the ground-truth data. The prevalence of shocks for households in Akwa Ibom State is shown in Figure 6.2. The analysis shows that in the urban area job loss (25%) and theft (25%) were the most prevalent shocks that affected household vulnerability to food insecurity in 2011. However, about 50% of households in the urban area did not experience these shocks. In the rural area, theft (40%) and job loss (20%) were the most prevalent shocks to vulnerability of food insecurity. The rural area had more food-related shocks that affected vulnerability to food insecurity than the urban area in Akwa Ibom State. These shocks included flooding that caused harvest failure (10%), illness of the breadwinner (10%), and poor rainfall that caused harvest failure (10%). About 10% of households in the rural area were not affected by these shocks. Overall, job loss and theft were the shocks with the highest prevalence that affected vulnerability to food insecurity in Akwa Ibom State.

Figure 6.2: Prevalence of shocks by sector for households in Akwa Ibom State

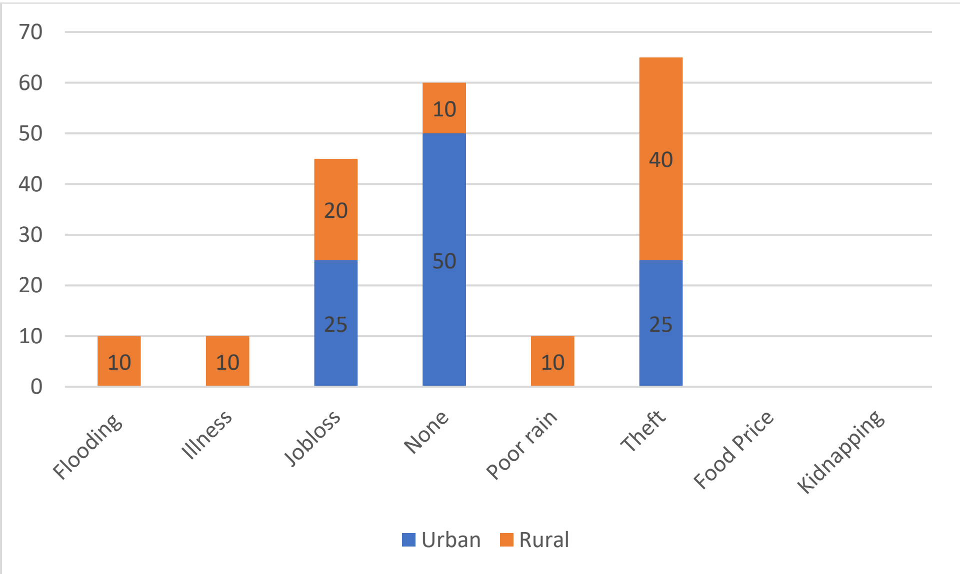


Table 6.4 presents the prevalence of food-related shocks by context and VFII groups for all sample households from the South-South region of Nigeria. The results show that kidnapping is only typical for households in urban areas, although this is a very low percentage. Table 6.4

also shows that in both the urban and rural communities, high food price and theft are the shocks with the highest prevalence.

In the rural community, households that are highly vulnerable to food insecurity were commonly affected by theft (28.26%), illness (23.6%), high food price (17.7%), flooding (14.29%), job loss (9.01%) and poor rain (6.52%). Mildly vulnerable households were commonly affected by theft (27.14%), illness (21.43%), high food price (18.57%), poor rain (12.86%), job loss (7.14%) and flooding (5.71). About 45.65% of households that were not vulnerable to food insecurity were not affected by any of these shocks. However, for those households that were affected and were classified as not vulnerable to food insecurity, poor rain (14.49%), theft (14.49%) and high food price (14.49%) were the shocks with the highest prevalence. Overall, for households in the rural community, theft, high food price and illness were the shocks with the highest prevalence in the urban areas (Figure 6.3).

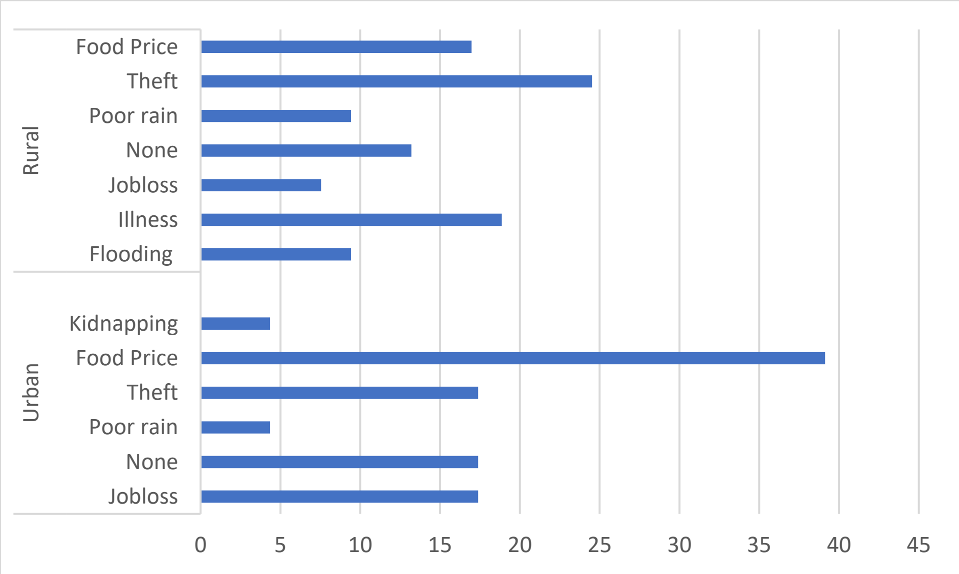
In the urban community, the shocks that mostly affected households that are highly vulnerable to food insecurity were high food price (39.1%), job loss (30.08%), theft (23.3%) and kidnapping (6.77%). Households that are mildly vulnerable to food insecurity were most affected by high food price (73.91%), theft (17.39%), and kidnapping (4.35%). About 52.7% of households that are not vulnerable to food insecurity were not affected by any of these shocks. Still, high food price (28.38%) was the shock with the highest prevalence, followed by poor rain (12.16%), and theft (6.76%). Overall, high food price, job loss and theft were the shocks with the highest prevalence in the urban community (Figure 6.3).

Table 6.4: Prevalence of food-related shocks by context and food vulnerability categories of sample households in South-South Nigeria

Community	**Shocks**	**Highly vulnerable (%)**	**Mildly vulnerable (%)**	**Not vulnerable (%)**
Urban	Job loss	30.08	--	--
	Poor rain	0.75	--	12.16
	Theft	23.31	17.39	6.76
	Food price	39.1	73.91	28.38
	Kidnapping	6.77	4.35	--
	None	--	4.35	52.7
Rural	Job loss	9.01	7.14	4.35
	Poor rain	6.52	12.86	14.49
	Theft	28.26	27.14	14.49
	Food price	17.7	18.57	14.49
	Illness	23.6	21.43	6.52

Flooding	14.29	5.71	--
None	0.62	7.14	45.65

Figure 6.3: Prevalence of food-related shocks by context for sample households in South-South Nigeria



6.4.2 Comparing the relative importance of VFII indicators at the community level

The focus group discussions involved community leaders, such as the village head, religious and youth leaders, and teachers. During these discussions, respondents were asked to collectively rank the VFII indicators according to their perceived level of importance. For shocks, they identified variables with the most significant cause of food vulnerability and scores were given. A shock with the highest score represents the most severe.

In the urban community (*Ibesikpo)*, the most severe shocks that were perceived to increase a household's vulnerability to food insecurity were unemployment and flooding that caused harvest failure (Table 6.5). This was followed by food price, illness of the breadwinner, theft, and robbery. High food price was perceived as the most severe shock that affected a household's vulnerability to food insecurity in the rural community (*Ikono)*. This was followed by unemployment, poor rains the caused harvest failure, flooding that caused harvest failure, illness of the breadwinner, theft and kidnapping (Table 6.5). ground-truth exercise, stakeholders in the community ranked shocks according to the relative importance to their community food system. The most severe shocks that influenced food vulnerability in the rural area were perceived as high food price, poor rain that causes harvest failure, unemployment and flooding that cause harvest failure. This is likely to be because the primary source of their livelihood is from agriculture. By contrast, in *Ibeskipo* the most severe shocks were perceived to be unemployment and flooding, reflecting the urban nature of the community setting, where livelihoods were more diversified with less reliance on agrarian activities.

For the rural community, the indicators perceived to have the highest impact on household adaptive capacity to food vulnerability were availability of good roads, water sources, provision of good housing structure, and sustainable income for jobs. Availability of good roads was accorded the highest priority as an adaptive capacity indicator in the rural area. This reflects local concern for transporting perishable farm produce to the market and the reliance on farming income as the primary source of livelihood for this community. In the urban area, education, income from non-farm enterprise, and water source were perceived as the most important adaptive capacity indicators, affecting a household's ability to cope with food vulnerability.

Finally, Table 6.5 shows how community leaders perceived the importance of the VFII indicators in their community. Child mortality was given the highest relevance and became the most severe effect of accumulative experience of food insecurity in *Ibesikpo* community. Child mortality was important as most households could not afford to pay hospital bills and resorted to using a native midwife. This was followed by hunger and stunting of growth. By contrast, hunger was the most severe effect of accumulative experience of food insecurity in the rural community (*Ikono*), followed by stunting of growth and child mortality.

Table 6.5: Relative importance of VFII indicators perceived by community leaders

Shock	Urban Community (*Ibesikpo*)	Rural Community (*Ikono*)
Illness of breadwinner	5	4
Theft/Robbery	4	3
Poor rain that caused harvest failure	2	6
Flooding that caused harvest failure	7	5
Increase in price of major food item	6	7
Kidnapping	1	2
Unemployment/Job loss	7	6
Adaptive capacity		
Household asset	3	5
Mobility asset	1	6
Livelihood asset	9	3
Housing structure	2	9
Good roads	7	11
Nearest market	6	1
Water source	8	10
Income from jobs	4	8
Income from non-farm enterprise	10	2
Harvest crops	5	7
Education	11	4
Sensitivity		
Stunting	1	2
Child mortality	3	1
Starvation (Hunger)	2	3
Additional indicators proposed by participants	• Erosion • Waste disposal	• Population • Culture

6.4.3 Comparison of the prevalence of shock from the fieldwork (ground-truth data) with the result of VFII

The sample households listed all natural, social, political, health and economic shocks perceived to have affected their food insecurity over the last five years. The five most important shocks were then ranked according to their severity and impact on household food insecurity. This section identifies which significant shocks are perceived to cause household vulnerability to food insecurity. The results are organised by the three food vulnerability groups and by sector.

6.4.3.1 Comparing the prevalence of shocks for urban households using evidence from fieldwork (ground-truth data) and VFII result

The results in Table 6.6 show household perception in the urban location of the prevalence of shocks at the community level within Akwa Ibom State. This perception can be compared with the VFII results at the state level.

Households in the urban community were mostly affected by theft, job loss and high food price (Table 6.6). Households that are highly vulnerable to food insecurity, identified job loss and high food price as the most prevalent shocks that affected their vulnerability to food insecurity. Mildly vulnerable households were influenced by theft and job loss. Households that were not vulnerable to food insecurity reported their experience differently because they were indirectly affected by shocks. For example, a private primary school owner experienced a reduction in income because of the job losses of pupils' parents, which affected their ability to pay tuition fees. Therefore, the shocks experienced by households that were not vulnerable to food insecurity were indirectly theft and job loss.

Comparing the perceptions of households in the urban locations with the VFII result (in Table 6.4) shows that the same shocks were reported by households at both community and state level to be important in characterising vulnerability to food insecurity (Table 6.6). For example, the VFII results show that urban households are affected by high food price, job loss and theft. These were the same shocks reported by households during the ground-truth exercise. However, moving from the state level to the community level, the level of prevalence was not comparable. Theft was perceived as the shock with the highest prevalence for urban communities during the fieldwork, while high food price was the shock with the highest prevalence using the VFII constructed at the state level.

Table 6.6: Perceptions of the prevalence of shocks experienced in urban communities (illustrative comments from fieldwork…)

Exposure component		
Highly Vulnerable	**Mildly Vulnerable**	**Not Vulnerable**
"I was a petty trader selling *Afang* in the market. As things became expensive, I started using my business capital to feed my children. In the long run, the capital got finish, and my business was closed down" [HH004NN]. "The shock that is affecting my household is high food price. My mother's generation, they used small money like N1,000 to buy much food. Now, with the same amount, I cannot even cook a good pot of soup not to talk about buying *garri*. This is why we are facing hardship. We cannot feed our children now and cannot send them to a good school" [HH002NN].	"For my households, the real problem we have is that for two years now we do not have electricity in this community. Because many houses have been built over time and the electricity load has increased making the transformer to overwork itself. This makes all transformers in the community to become damaged. Hence no electricity. This cause hoodlums and thieves to enter the community and when they do not see money to steal in your house, they kill you. Just yesterday, thieves entered a nearby neighbours' house [elderly woman], she did not have money, so instead, they ate her soup and used the pot to cover her head. This shows that there is hunger in the community" [HH007NN]	"My tenant grows pears, mangoes, cassava, plantain, and fish farm. However, thieves jump the fence to steal everything on his farm. For two years now, he cannot pay house rent. When he wakes up thieves have harvested all his crops" [HH012NN]. "There are no jobs now. So many people that are begging for money now. Some will ask that you should not send them the money rather use the money to buy food and send it to them. Things are very hard. Many people have withdrawn children from school. The parent cannot pay private tuition fees" [HH012NN]. "This group of people do not have a job. Those who do not have jobs lack income and cannot buy food. I have a group of friends who were former Directors in a Government organisation but are now pensioners. They cannot pay house rent. One among them relocated to live in his village. He cannot pay the fees of his children. Now if you see him, you cannot recognise him. Things are so hard that I can compare it to the period when Nigeria was in civil war. We used to see how people will die of starvation; many children had kwashiorkor and big head. When you lose your job, your financial obligations keep coming, like paying fees for children, feeding your family, transportation, accommodation, etc." [HH0015NN]

6.4.3.2 Comparing the prevalence of shocks for rural households using evidence from fieldwork (ground-truth data) and VFII result

Table 6.7 shows the perception of the prevalence of shocks at the community level for sample rural households in *Ikono* community, Akwa Ibom State, Nigeria. The most prevalence shocks reported by rural households during the ground-truthing exercise were broader than those reported by urban households. More shocks were perceived as highly prevalent in the rural community compared to the urban community. High food price, theft, job loss, illness, and poor rainfall were the shocks with the highest perception of prevalence for households in the rural community. Highly vulnerable households were most affected by high food price, which had a negative impact on vulnerability to food insecurity. The shocks that affected mildly vulnerable households were theft and illness, while households that were not vulnerable to food insecurity were affected by theft and poor rainfall.

The same shocks that affect households at state level was perceived to affect households at community level - when comparing the VFII results in Table 4 with the ground-truth data in Table 6.7. However, the level of prevalence did differ when comparing the findings of VFII with the result from the fieldwork. From our VFII result in Table6. 4, “job loss” and “theft” were the shocks with the highest prevalence for households in the rural community. From the fieldwork, “high food price” was the shock with the highest prevalence for households in rural community (Table 6.7).

Table 6.7: Comments from the ground-truth exercise about the prevalence of shocks experienced by rural households in Ikono community, Akwa Ibom State (illustrative quotes from fieldwork data)

Exposure component		
Highly vulnerable	Mildly vulnerable	Not vulnerable
"Foodstuffs are costly. No money to buy enough food. I have many children, so this food is not enough for my children. My children are going to school and am paying their fees" [HH001IK]. "For example, fish that we use to buy like N10,000 it is over N30,000 now. The cost has increased by three times. *Garri* use to be 4 cups for N200, but now I cannot afford to buy *garri* and not to talk about eating good food" [HH004IK].	"It causes the people around me to be thieves because they are jobless. They are forced to steal. I kept 12 brooms outside my house, just in front of my corridor. By the time I came to look for it the next day, nine brooms were stolen. The yam that I planted all were harvested by thieves" [HH008IK] "I experience Arthritis because of eating poor quality food that contains too many unhealthy ingredients like Maggi. I used this unhealthy ingredient to substitute for a healthy ingredient like crayfish. Because crayfish is too expensive. [HH006IK].	"Even in your farm, you can go and see a thieve harvesting your plant. When you ask him why are doing this, the thief will say he does not want to die of starvation. On my farm, where I gave someone to plant for me, thieves came in and harvested the corn, plantain, cassava, and melon. This makes people abandon their farm. Neighbours all will release their goat into your farm, and this goat will eat everything on your farm. There are two categories of thieves: food/farm thieve and original thief" [HH0014IK]. "Because of poor rainfall my shrub called "hospital is too far" is dying. There is no sickness that this shrub cannot cue. However, because of poor rainfall, this plant is dying and has become stunted" [HH0015IK].

6.4.4 A comparison of the coping strategies of urban and rural households with the adaptive capacity component of the VFII

Data about perceptions of how households cope with food vulnerability was collected, and this was restricted to information about the period of food shortage, response to lack of food, formal food assistance and other support available, and locations where households particularly needed support. Table 6.8 show illustrative comments about coping strategies adopted by households. Households that are highly and mildly vulnerable to food insecurity in the urban and rural community employed the severe coping strategy of reducing consumption when faced with food shortage. Coping strategies used by urban households that are not vulnerable to food insecurity were least severe. They were able to diversify their livelihood activities using their extra assets and capacity and, in doing so, reduced the risk of food insecurity. By contrast, in the rural community, this same group was perceived to commonly use a mildly severe coping strategy, such as hawking food in the street. This suggests that households in the rural community have weaker coping abilities to recover from food shortage compared to households in the urban community.

The analysis did not directly compare the coping strategies used at the community level with the adaptive capacity component in the VFII because the latter uses indicators that identify long-term measures of vulnerability to food insecurity reduction, while the coping strategies identified by the communities were short-term measures. Rather, the comments from the ground-truth exercise provided data that can be used to make inferences about the state of households' assets, livelihoods and entitlements.

To improve households' adaptive capacity, the following areas were reported during ground-truth exercise as a priority: jobs for unemployed youths, high quality and affordable education, improved means of livelihoods, such as access to quality fertile land, housing, electricity, and increments in salary proportional to the current inflation rate. All these priorities reported by households were already included in either the exposure or adaptive capacity component of the VFII as specific indicators. This further confirms the relevance of the VFII indicators to adequately capture vulnerability to food insecurity.

Table 6.8: Coping strategies used by urban and rural households in Akwa Ibom State when food is lacking

Coping strategy	Highly vulnerable	Mildly vulnerable	Not vulnerable
Urban Households	"We borrow money to feed ourselves and pay house rent". "I had no alternative than to withdraw my children from school". "We stay hungry or reduce the quality and quantity of our food".	"I go and borrow money to feed my family". "We skip meals. If you eat in the morning, you skip the afternoon and eat dinner. Sometimes we go for obligatory fasting. Because we do not eat fine, there is malnutrition. We are not healthy because we are not well nourished."	"We look for where to buy food at a cheap rate". "Buy food in bulk". "Having additional business-like tailoring".
Rural Households	"We stay hungry and endure until we see food to eat". "We eat palm kernel, boiled cassava, and boiled cocoyam". "We plant cassava so that we will at least have food to eat. However, cows destroy it".	"When food is expensive we reduce the quality of our meal or skips some meal". "Whatever food I can find in my farm that is what we will eat. For example, cocoyam".	"Reduce the quality and quantity of the food". "Hawking of food in the street to augment household income".

There was no formal social aid available to households in the study area. During the ground-truth exercise, the community leader complained about a lack of regulation and the role of the market in exacerbating vulnerability to food insecurity and highlighted examples of the effect of high tax on the poor, difficulties in managing microcredit and even fraudulent organisations.

"We are living in a dilapidated building. Our market physical infrastructure has been dilapidating, and the government has not stepped in to help. The only thing that the government can do is to collect tax. Now in the market, we pay many taxes for petty foodstuff that we are selling. We have to escape from the market so that we do not pay these taxes. The total amount of waterleaf I sell is N150 per day but am given a tax of N200 per day" [HH004NN].

"No organisation has come in to help the community in terms offering food support. Rather the community has fallen into fraudulent hands. People come in to help, promising to empower households, but they only collect their money and run away. A

micro-finance group ran a 'Live above Poverty Organization'. They collected money and lent money at an exorbitant rate. If 50,000 naira is lent out, you must pay back the money within 23 weeks. This is very stressful for petty traders to be paying 4,000 naira every week. No major organisation is assisting households to live above the poverty line" [FGD_NN].

6.4.4.1 Period of food shortage

The data collected relating to the period of food shortage was, of course, found to vary according to activities and season. According to the communities, there is a period when households are perceived to be highly vulnerable to food insecurity between January and March and a period of mild food vulnerability between July and September. A detailed seasonal calendar is shown in Table 6.9 to illustrate these difficulties.

Table 6.9: Seasonal calendar for households in Ikono and Ibesikpo communities of Akwa Ibom State

Duration	Activities	Impact
January – March	• Money is scarce because of too much spending during Christmas and New Year celebrations. • Parents must return their children to school. Therefore, they have to pay tuition fees, buy school uniforms, books, etc. • This is also the planting season.	• People do not feed well during this period. Parents starve in other to return their children to school. • This is the peak of the hunger season.
April		People start recovering
July – September	• The peak of the rainy season.	• High food prices because of the rain. • Households are between hunger and being well fed
November – December	• Harvest season	• Food is available because essential food crops have been harvested.

6.4.5 Why households are vulnerable to food insecurity

In this section, additional factors that cause households to be vulnerable to food insecurity are discussed, however, it is important to note that the VFII is not designed to explain why households are vulnerable to food insecurity. Table 6.10 presents a summary of the most common reasons that were reported during the ground-truth exercise to explain why households in the community are vulnerable to food insecurity. These six reasons are: (1) hardship (households could not afford to buy or produce quality food because of hyperinflation or high food price); (2) infertile soils; (3) loss of income (caused by joblessness and depreciation in value of the Naira); (4) severe hunger (resulting from a high crime rate, theft and malnutrition); (5) economic challenges; and (6) corruption.

Table 6.10: Reasons that were reported for why households were vulnerable to food insecurity

S/N	Food vulnerability reason	Comments from households
1	Hardship	*"I reduce the quality of our meal because of hardship. I am a civil servant; the same money I used to collect in President Goodluck regime (when things were cheaper than now) is the same money I am collecting now. This salary cannot cope with the present high cost of food that we are experiencing. We have to manage; this means reducing the quality of the meals we eat" [IK].* *"If there are jobs, young people will not be engaging in this activity. They are very hunger in addition to hyperinflation of goods and services; this makes our youth to become armed robbers" [NN].*
2.	Infertile soil	*"Now we make use of fertiliser to plant. So, this makes our soil to be fertile. We use too much chemical like herbicide that is dangerous to our soil. When we use fertiliser during the planting of yam, it makes this yam to wilt and become watery during storage. The solution is for us to stop using fertiliser always and apply farm yard manure. But there is no sufficient quantity of farmyard manure, and if everybody wants to patronise this, it will not be affordable because of the high price" [IK].*
3.	Loss of income	*"There are no jobs now. So many people are begging for money now. Some will ask that you should not send them the money rather use the money to buy. Things are very hard. Many people have withdrawn children from school. The parents cannot pay private school fees" [NN].*
4.	Severe hunger	*"Since President Buhari came to power people are dying like flies. Hunger has killed several people in this community. There is no money to buy food to eat. People are not feeding the way they are supposed to feed. There are people at their very best that can only feed once in a day. Some*

		households have up to 5 or 6 children but it is very hard for them to feed three times in a day" [NN].
5.	Economic challenges	*"In President Goodluck's regime things were still difficult, but food was available in abundance. During his tenure, food items worth of N100, 000 was more than a food item of President Buhari regime. This is because of high food price and inflation in Buhari regime compared Goodluck regime. In Goodluck's regime, food was not as expensive as it is now. In Goodluck's regime, I used N150 stockfish head for cooking, but now am using N500 no matter if the soup is small. Eight cups of garri cost N200 then, now it is 3 cups for N200 for us, but in uyo, it is six small cups of garri at N200. One bag of rice was N11,000 but now one bag of rice costs N21,500" [NN].* *"Ten years ago, I used to use N250 and buy foodstuff. This foodstuff will fill my shopping bag. The cost of a bottle of oil was N50. My husband was a palm oil farmer. He would produce the palm oil, and I went to sell it and get N700 as profit. He would then remove N250 and give it to me to buy food for the house. I used to buy things from the market, and it would fill my shopping bag. Now if you are given N100,000 for household food shopping, you will go to the market and come back with a little small bag. The food items will not satisfy the household for up to three days. Things are so expensive now. Goodluck's regime was better than Buhari regime. It is not easy for households with three to four children to feed three square meal per day" [NN].*
6.	Corruption	*"I discovered that government would release money for a project, but the people handling this project steal the money or used the money for another thing. Do you have any idea or solution for this problem? I do not think in Nigeria there will be the solution to this problem because corruption starts from the top. The people at the top are very corrupt. A way out is to start fighting corruption from the top. So that money meant for a specific project will be well utilised. There should be a monitoring team to monitor and supervise any money released by the government" [IK].* *"Ordinary people also are the cause of difficulties in the economy. Nurses and Doctors steal equipment from government-funded hospitals are taking it to their private hospital. The government should set measures to prevent this" [NN].*

Source: Field work data

These reasons affected all households across the three food vulnerability groups. However, the impact was felt most by households who were highly and mildly vulnerable to food insecurity. The ground-truth exercise provides current reasons why households remain vulnerable to food insecurity and this supplementary information helps to contextualise the index approach.

6.5 Discussion

The VFII was internally validated by performing an uncertainty and sensitivity analysis (Ibok et al., 2019) and the results showed that the index is robust and highly sensitive in capturing the vulnerability component of food security. Therefore, it is deemed to be fit for purpose (Ibok, 2018). However, good practice in vulnerability analysis is to carry out an external verification of the VFII to identify the credibility of the index (Eriksen and Kelly, 2007) and, in this study, data from the South-South region of Nigeria was used to test the development of categories. This paper further validates the use of the VFII through a ground-truth exercise to verify the selection of indicators and consider both the local perceptions in Akwa Ibom State and the results of the VFII. Although the ground-truth exercise made use of a limited sample, it provided useful information that was used to make an inference to the study location only rather than the entire South-South region of Nigeria.

The findings in section 6.4 show similarities between results of the exposure component of the index and the ground-truth data. Irrespective of the food vulnerability group, the findings show that the shock indicators used in designing the VFII were the same shocks that households were experiencing on the ground.

However, there were differences between the most prevalent shock in the urban and rural communities when the fieldwork results were compared with the VFII. The fieldwork shows that households in the urban community held the perception that "theft" was the shock with the highest prevalence, while the VFII showed that "high food price" was the shock with the highest prevalence at the state level. The same outcome also occurred when comparing the result of VFII with those from the field work for households in rural community. From the field work, the most prevalent shock for the rural household was "high food price". However, at the state level, the result of VFII showed that "job loss" and "theft" were the shocks with the highest prevalence. The reason why the prevalence of shock did not match at the state and community level is because the data used in constructing the VFII was collected in 2011 while the verification exercise was done in 2018. Another reason could be as a result of the sampling size. Although the sampling size could not have captured the heterogeneity of all shocks in the community level, it is fairly representative for the purpose of validating the VFII. This is part of the challenges of validating a quantitative index on the ground.

In the rural context, a wide range of shocks was reported as most prevalent compared to the urban community, the VFII result at the state level was also sensitive to these differences. The VFII was able to reflect much of the differential experience of vulnerability to food insecurity reported by households. This suggests that the index is sensitive to context-related factors, and therefore can be applied to a more heterogeneous context. The implication of this finding strengthens the credibility of the VFII because a vulnerability index that can be applied to a heterogeneous context means that its indicators will be able to reflect real-life experiences on the ground.

Furthermore, the literature has focused on the problem of vulnerability indexes only providing a static measure of vulnerability (Vincent and Cull, 2014; Eriksen and Kelly, 2007; Himes-Cornell et al., 2016; Campbell et al., 2016). This study's findings emphasise the value of integrating an element of ground-truth data when designing vulnerability to food insecurity indexes because it allows for reflection and additions to be made to static indicators that most appropriately capture factors that affect households. The analysis showed that the indicators used in the index were highly relevant to operationalising vulnerability to food insecurity. None of the indicators was excluded as a result of the ground-truth exercise as none were identified as irrelevant when explaining vulnerability to food insecurity. Rather, the ground-truth exercise suggested that more indicators might be included in the index. In the urban community, 'erosion' and 'waste disposal' were suggested and in the rural community, 'population' and 'culture'. This implies that there may be some very localised issues that the index does not capture, but necessary trade-offs must be made and in this case, the number of indicators included reflects a lack of data and allows international comparison (OECD, 2008; Neset et al., 2018).

The ranking of indicators during the ground-truth exercise identified the relative importance of these indicators to the community. In the rural community, good roads, water sources, housing structure, income from jobs and harvested crops were considered the most important adaptive capacity indicators. Meanwhile, the most important adaptive capacity indicators in the urban community were considered to be education, income from non-farm enterprises, water sources and good roads. This implies that, for adaptive capacity indicators, rural households focused on the provision of basic infrastructure and livelihood resources to reduce vulnerability to food insecurity, while the urban community attached more importance to education, business and provision of basic infrastructure. Therefore, while in the VFII all indicators are equally important when using state-level data, this is not the case at the community level where differential weights will be required.

At household level, the factors identified as shaping vulnerability to food insecurity were severe hunger, unemployment, economic challenges, infertile soil, corruption and hardship. Economic challenges, infertile soils, corruption were not included in the VFII. By integrating these insights with the VFII design, the range of factors that cause households to be vulnerable to food insecurity are identified and shown in Figure 6.4. These factors are multidimensional, interrelated and often operate across different scales. For example, households cannot control inflation and the federal government's macroeconomic policies regulate inflation, but it is one of the factors that lead to severe hunger. This was reported because it causes an increase in the price of goods and services when real household income does not increase, which triggers the most vulnerable households into severe coping strategies.

Figure 6.4: Causes of food vulnerability at the household level

Source: Developed by the author from the ground-truth exercise in *Ikono* and *Ibesikpo* community

Thus, factors that lead to food insecurity interact but the VFII could not show this interaction despite its multi-dimensional design. While the VFII identifies the relevant target populations as the starting point of the vulnerability analysis, the ground-truth exercise ensured the design is relevant and generated a more detailed understanding of context (Vincent and Cull, 2014; Eriksen and Kelly, 2007; Himes-Cornell et al., 2016; Ribot, 2017). While VFII modelling produces a generalised result, ground-truth data provide more specific insight and may be used as guidance to policymakers and practitioners on how to interpret the results of the index (Ribot, 2017). For example, insight on how households resist or recover from food-related shocks can be linked to household adaptive capacity.

The findings illustrate the seasonality is associated with vulnerability to food insecurity, with the peak of the hunger season being from January to March. Highly vulnerable households were most affected and often enacted severe coping strategies that led to the depletion of productive assets. Households in chronic food insecurity stand a low chance of recovery (Woller et al., 2013). Mildly vulnerable households enacted less severe coping strategies but these too could become difficult to reverse in the future. The adaptive capacity component of the VFII uses indicators that identify long-term measures to reduce vulnerability to food insecurity while ground-truth coping strategies reflect short-term measures employed by households to recover from shocks that led to food insecurity. This implies that the VFII is useful for informing long-term food vulnerability reduction policies, but where short-term policies are needed, a ground-truth verification exercise should be used. Highly vulnerable households were vulnerable to food insecurity because of long-term erosion of livelihood activities. This implies that households' assets, entitlement, and livelihoods had failed to buffer these households against food shortage or they were not adequate and sustainable (Woller et al., 2013; Ribot, 2017). The lack of formal social protection mechanisms in Nigeria limits recovery for the most vulnerable. According to Merttens et al. (2013) and Hidrobo et al. (2018), social protection programmes boost household food security by improving the quantity and quality of food consumed. This increases asset holdings and may increase the savings rate by up to 13%. Based on the indicators identified locally, several factors are needed to improve household adaptive capacity. These are: a reduction in the rate of unemployment ; the development of an environment that encourages and sustains entrepreneurs; the provision of land for agriculture; the provision of free education by government; the improvement of general infrastructure , namely housing, roads, and electricity; the regulation of inflation and high food prices; and an increase in the minimum wage for civil servants.

6.6 Conclusion

The objectives of this study were to verify the results of a quantitative index (VFII) with real-life experiences on the ground and to qualitatively understand why households are vulnerable to food insecurity. The ground-truth exercise presented in this paper used a qualitative assessment method, which was compared with the results of the VFII, to validate the indicators.

The research found the ground-truth exercise identified the same factors as the VFII to explain household vulnerability to food insecurity. The same set of shocks was identified at the community level as were used to design the VFII from state-level data. The research also found all indicators included in the VFII to be relevant in explaining vulnerability to food insecurity at community and state level, and it was not necessary to exclude any indicators from the VFII as a result of the ground-truth exercise. However, at the community level and household level, supplementary indicators were identified that could be relevant to the local-level analysis. Households were also vulnerable to food insecurity because of livelihood exposure to macro-level socio-economic factors but were unable to manage food shocks without any social protection mechanisms to buffer household adaptive capacity.

However, the prevalence of shocks at the state level did not match what was reported in the community. For example, at the state level, high food price was the shock with the highest prevalence while theft was the shock with the highest prevalence for urban households. Also, moving from one context to another (i.e. urban to rural community) the level of prevalence did not match. The rural community experienced a more differential vulnerability compared with the urban community. The shocks with the highest prevalence for households in the rural community were high food price, theft, job loss, illness, and poor rainfall. While, for urban households, shocks with the highest prevalence were theft, job loss, and high food price. This implies that the VFII may be applied to heterogeneous contexts because the index can identify some context-related factors. Nevertheless, for a VFII developed at the state level to be useful at the community level, the issue of scale should be reflected upon at the point of interpretation before use for targeting of any interventions.

This paper also reinforces that use of equal weights for indicators at the community level is not appropriate. The VFII was designed with equal weights based on the justification from the sensitivity and uncertainty analysis that applying equal weight to the index provided a more robust and stable output compared to using different weights. However, the relative importance of VFII indicators varies from one community to another. For example, hunger was the sensitivity indicator with the highest importance for the rural community, while, for the urban community it was child mortality. Therefore, different weights should be applied at the community level, while equal weights can be retained at the state level. When moving from macro-level to micro-level, the application of different weights should stop at the community level because going further to apply household level would be expensive.

Combining the quantitative modelling within the VFII with ground-truth validation is important and complementary in the process of vulnerability analysis. An index is the starting point of vulnerability analysis because it identifies the location of the vulnerable population, which is important for targeting support. However, ground-truth validation ensures the analysis and recommendations from the index have local relevance at the point of interpretation. The VFII can, therefore, be useful in considering options for identifying long-term food vulnerability reduction policies and how these might impact different groups of people. However, where short-term policies are needed, ground-truth verification should be used.

Overall, the indicators used in the design of the VFII were the same as the indicators identified on the ground. However, application of the VFII below state level to identify food insecure households at the community level may require even greater consideration of the heterogeneous population and the relative importance of indicators. This means that, at the community level, the weight of indicators for the VFII should be adjusted to reflect the heterogeneous nature of the community. This involves deriving different weights for indicators using expert opinions. It is also recommended that a flexible weighting system should be applied when the index depends on local conditions.

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Chapter 7 : Conclusion

7.1 Introduction

This thesis designs and validates a multidimensional food security indicator called the Vulnerability to Food Insecurity Index (VFII). The VFII is needed because first, no standard model exists in the literature for measuring vulnerability to food insecurity and second traditional food security indicators, such as per capita calorie consumption, do not account for all the risks faced by vulnerable households. Once developed, the innovative VFII was applied to data from the World Bank Living Standard Survey to examine households in the South-South region of Nigeria. The results of this design and analysis were presented in Chapters 4, 5, and 6. The research followed a mixed-method research approach, using both quantitative and qualitative analysis. The quantitative phase involved the development of a conceptual framework to design the VFII, a review of literature to construct traditional food security indicators used in this research and statistical analysis of all secondary data for the models, including performing a robustness check on the index using a sensitivity analysis. In the qualitative phase, the results from the VFII were verified through fieldwork, which allowed the study to identify how appropriate the VFII would be in practice for households in South-South Nigeria. The following sections present the main findings from this research and are organised by the research objectives. The conclusions also reflect on the implication of this vulnerability assessment approach as applied to food security, implications for policy and practice and possible areas of further research.

7.2 Main findings

7.2.1 Designing vulnerability to food security index

This first research objective developed a multidimensional food security indicator (Vulnerability to Food Insecurity Index) that incorporates vulnerability and established its validity through comparison with other traditional food security indicators such as per capita food consumption, food consumption score and coping strategy index. The research questions and main findings are discussed in this section.

Can an indicator that incorporates vulnerability dimension be developed in the assessment of food insecurity?

In answering this question, this thesis successfully developed a Vulnerability to Food Insecurity Index (VFII) (Chapter 4). The VFII is a multidimensional model that uses a vulnerability lens to measure food insecurity. The VFII is a significant contribution from this thesis to methodological advancement of vulnerability analysis in food security research, addressing the problem of best fit. In contrast to authors such as Hinkel (2011) and Moss et al. (2001) that argue that it is impossible to measure vulnerability, this result suggests that it is possible to design a model that helps to operationalise vulnerability in food security research. This evidence has added to the current food security measurement debate that advocates for holistic model that applies a multidimensional approach in food security measurement rather than reliance on food security indicators that use singles metrics (Chen et al., 2018; Tandon et al., 2017; Haysom, 2017; Aiga, 2015; Alkire and Santos, 2010; Barrett, 2010).

How does the VFII perform when compared with other traditional food security indicators?

The study demonstrated differences between the Vulnerability to Food Insecurity Index (VFII), which is a multidimensional indicator, and traditional food security, such as Per-Capita Calorie Consumption (PCC), Food Consumption Score (FCS) and the Coping Strategy Index (CSI). The results showed that the VFII captures other components of food security that traditional food security indicators do not capture. This finding agrees with the conceptual argument of Vaitla et al. (2017), Coates (2013), and Ravallion (2011) that multidimensional concepts like vulnerability to food insecurity are better captured using a set of indicators that represent each key dimension of the phenomena rather than using a single indicator that is not able to represent clearly the contribution of each dimension. In addition, the results in this thesis showed that these indicators should not be used interchangeably because of their weak correlation coefficient meaning that they measure different things. For instance, the result of the Per-Capita Calorie Consumption indicator should be discussed to mean or interchanged to represent vulnerability to food insecurity. A weak correlation coefficient also indicates the difficulty in comparing a multidimensional indicator such as the VFII with single indicator such as PCC, FCS and CSI (Vaitla et al., 2017). The main observation was:

- The relationship between FCS and VFII proved that although these indicators are in the same dimension of food security, they measured different food security phenomena that are not closely related (Chapter 4, section 4.5.3.1) and the VFII captures other dimensions of food security that FCS do not capture.

- Similarly, the relationship between VFII and PCC showed that several factors contribute to a household's vulnerability to food insecurity and relying only on adequate calorie consumption to represent food vulnerability is insufficient because there are other components of vulnerability that PCC has excluded (Chapter 4, section 4.5.3.1).
- In contrast, the relationship between CPI and VFII agreed with the apriori expectation (chapter 4, section 4.5.3.1). Both indicators are of different dimension of food security. The relationship shows that the chances of household vulnerability to food insecurity decrease as a household uses less severe coping strategies.

The evidence from this thesis showed that using single indicators like PCC or FCS when making an intervention to support households vulnerable to food security can be problematic. This is because the results may be misleading due to the exclusion and inclusion error (Chapter 4, section 4.5.3.2). That is, some households identified by VFII as vulnerable are not identified as food insecure by single indicators and also some households identified by other indicators as being food insecure may actually not be vulnerable to food insecurity. This result is in line with a major finding of Areal et al. (2018). In their research that sought to measure sustainable intensification of cereal production in England and Wales using a multidimensional sustainable intensification indicator, it was found out that single indicators used in measuring and ranking farm environmental performance, do not accurately reflect what the measure.
The main observation was:

- Using per capita calorie consumption alone for long-term targeting of intervention would include 19.13% of households that should not have been included and exclude 17.88% of households that should have been included (Chapter 4, section 4.5.3.2). Also, households whose per capita calorie consumption was above the FAO recommended daily per capita calorie intake were still vulnerable to food insecurity, indicating the inconsistency of PCC classification.

- Similarly, 63.02% out of 86.78% of households that had consumed food with acceptable levels of dietary diversity were either vulnerable or highly vulnerable to food insecurity (Chapter 4, section 4.5.3.2). Using FCS for targeting of intervention will exclude 63.02% of households that are either highly vulnerable or vulnerable to food insecurity that should have been included in the long-term targeting of intervention.

- However, CPI, when used to classify households into food vulnerability groups, was more consistent in identifying households that are vulnerable to food security compared to PCC and FCS. The result showed that during post-planting seasons households that were highly vulnerable to food insecurity used severe coping strategies while households that were not vulnerable to food insecurity used fewer coping strategies. This means that compared to PCC and FCS, CPI is a consistent indicator for identifying food vulnerability groups (Chapter 4, section 4.5.3.2).

Another significant finding from this thesis is that, regardless that the VFII is consistent when used to measure vulnerability to food insecurity, it is also able to nest and reflect some of the traditional food security indicator components. The main observation was:

- The VFII was able to reflect some component of all the traditional food security indicators used in this thesis (Chapter 4, section 4.5.4). For example, regarding FCS, about 22.77% of households that were not vulnerable to food insecurity consumed highly diverse foods. The same situation was similar to PCC, with about 7.5% of households that were not vulnerable to food insecurity having sufficient calorie consumption above 269 kcal/day.

- Secondly, the evidence from VFII ranking of states in the South-South region of Nigeria confirmed that VFII does nest some of the traditional food security indicators or their components within it. That is, VFII incorporates the dimension of vulnerability in addition to other dimensions of food insecurity. This means that the VFII is consistent with other traditional food security indicators but goes beyond what these indicators capture. For example, in Edo state, which is the state with the least food vulnerable households, people tend to consume food with sufficient calories and have highly diverse foods, use coping strategies that are least severe during post-planting season and mildly severe during the post-harvest season. In comparison, Bayelsa state was ranked by the VFII as that state with the highest prevalence of food vulnerability. Per capita calorie consumption of households in Bayelsa State was the lowest; households use severe coping strategies during post-planting and post-harvesting to cope with food deficits and they consumed a less diversified diet. This confirmed that VFII is a reliable and valuable tool for policymakers.

7.2.2 Robustness check for vulnerability to food insecurity index

The second research objective sought to systematically evaluate the effect of the methodological assumptions on the robustness of the VFII, using sensitivity and uncertainty analysis. The research questions and the main findings are discussed in this section.

How does the output of the VFII compare using different assumptions?

The main assumptions used to test the sensitivity of the VFII were: change in the data type (complete and missing data), normalisation method (min-max and z-score), weighting scheme (equal versus unequal weight) and exclusion/inclusion of variables (Chapter 5). The following are the main findings.

- Applying unequal weight (or principal component weight) to the VFII resulted to inconsistency in its ranking of states in South-South region of Nigeria, irrespective of the data type or the normalisation method applied (Chapter 5, section 5.3.1.1). This means that unequal weight produces a biased estimate of each state performance in terms of food security and vulnerability. Also, the pairwise correlation result did not confirm that the output of VFII is robust.

- Applying equal weight to the VFII produces consistent output in the ranking of State, irrespective of the data or normalisation method used (Chapter 5, section 5.3.1.2). This implies that using equal weight across all component of the VFII produce output that is not biased. The pairwise correlation result revealed that using equal weight for the VFII produces highly robust estimate unlike using unequal weight. However, using either a min-max or z-score normalisation method for the index still produces the same output, but the min-max method produces better result compare with the z-score method. The finding led this research to adopt equal weights and a min-max normalisation method for the VFII. This result agrees with the finding of Esty et al. (2006), which showed that equal weight instead of PCA-derived weight had a positive effect on the Environmental Performance Index ranking or score.

- The effect of excluding/including either child mortality or distance-to-water-source was tested on the index using equal weight. Three specifications were explored, namely excluding child mortality only, excluding both child mortality and distance-to water-source, and including child mortality and excluding distance-to-water-source. The results revealed that irrespective of the specification used, the VFII ranking was stable across all specification, and the overall performance of the index remained robust (Chapter 5, Section 5.3.1.3).

What is the primary source of uncertainty in the VFII ranking?

The result of the uncertainty analysis using the global sensitivity approach showed that Edo State performs better than Bayelsa State in 60% of the cases. This means that households in Bayelsa State are more vulnerable to food insecurity as compared to Edo State (Chapter 5, section 5.3.2.1). The primary source of uncertainty was from the "shock" variable as explained by the first order and total-effect sensitivity indices explain in the next paragraph. Using the same approach, Tate (2013) investigated the uncertainty associated with the Social Environmental Index construction based on the indicator selection, scale of analysis, measurement error, data transformation, normalization and weighting. The result showed a high degree of uncertainty in the index ranking; comparing the performance of the index to alternative configuration, the index is statistically biased in some location; and the precision of variability of the index ranking decreases with increase vulnerability. Overall Tate (2013) showed areas where the social vulnerability index is mostly reliable while emphasizing the use of uncertainty analysis to improve the precision, transparency and credibility of the model. The findings from Tate (2013) paper emphasise the need for uncertainty analysis in identifying areas for improvement and the strength of a model, which is similar to the result of the uncertainty analysis for VFII. For the VFII, accurate data is needed for the exposure variables, which was the main source of uncertainty for the Vulnerability to Food Insecurity Index.

What are the most influential input factors that cause this uncertainty in VFII ranking?

The result of Sobol's first order and total effect sensitivity index showed that the difference between these state composite scores is mostly attributed to the impact of the shock variables (Chapter 5, section 5.3.2.2). Other inputs factors with a significant contribution to the variance of VFII are child mortality, stunting, hunger, wealth index, distance-to-road, distance-to-market and household literacy. Inputs with minor contribution are distance-to-water-source, income source, non-farm income, and crop yield. Individually, the triggers, i.e. weighting scheme, normalisation scheme, and exclusion/inclusion of variable, had a lesser effect for the output variance of the two-state (Chapter 5, section 5.3.2.2).

The result of the sensitivity analysis shows the importance of carrying this robustness test in a model to boost the confidence of its use while providing evidence that supports its validity and highlighting areas of improvement (Barnett et al., 2008; Schmidtlein et al., 2008; Saltelli et al., 2008). In addition, the result of this study is also similar to the findings from Esty et al. (2006); Tate (2012); and Saisana et al. (2005). Particularly, Esty et al. (2006) assess the robustness of the Environmental Performance Index (EPI) using a sensitivity analysis. They evaluated the validity of the EPI by assessing the sensitivity of the index to assumptions used in the index design and aggregation of its 16 indicators. The result showed that using a two-alternative ranking approach (EPI and median ranking), the EPI ranking was highly robust because it was modestly sensitivity to the choice of targeted values, indicator weighting and aggregation level. Using equal weight instead of the PCA-derived weight had a significant positive effect on the ranking of a few countries, overall the EPI showed minimal sensitivity when equal weighting assumption was evaluated. Aggregating the index at the indicator level instead of the category level had an average impact on 18 ranks and the performance varied across countries.

The result of uncertainty and sensitivity analysis for the VFII presented in this section contribute to the debate about how to evaluate a model's validity. According to Saltelli et al. (2008), it is realistic to show that a model has been extensively corroborated rather than validating the model. This means that a model should survive a series of test to verify its internal or external consistency and this would show the capacity to predict reality in a convincing and parsimonious way. The result from the uncertainty and sensitivity analysis has been able to present a series of tests to show that the VFII is fit for purpose based on the assumption used. In addition, while sensitivity and uncertainty analysis are widely used in physical science, in the food security domain this methodological concept is rarely used. For example, Tennøe et al. (2018) applied uncertainty and sensitivity analysis to three case studies relevant for neuroscience community, while Pianosi et al. (2015) and Pianosi et al. (2016) presented the importance of global sensitivity analysis in the development and assessment of an environmental model. However, in the food security domain, this methodological concept has not commonly been used. This thesis has presented a series of steps that contribute to existing knowledge about the concept of global sensitivity analysis which can be used in the food security research domain. The next section presents the main finding from the third research objective in Chapter 6.

7.2.3 Verifying the relevance of the vulnerability to food insecurity index in practice

The third research objective used ground-truth evidence to verify the vulnerability to food insecurity index and investigate qualitatively, the drivers of household's vulnerability to food insecurity (Chapter 6). The main findings are:

Are the indicators of VFII relevant to real-life experience, if not how divergent are they?

- When comparing real-life experience with the index quantitative result, this thesis discovered that irrespective of the food vulnerability group, the exposure variables used in designing VFII were the same variables that households were experiencing on the ground (Chapter 6, section 6.4.3.1, 6.4.3.2, and 6.5). For instance, the same shock reported by households in the urban community was the same shock the VFII reflected.

- However, the level of prevalence at the State level did not match with the community level. In the State level, "high food price" was the shock with the highest prevalence while "theft" was the shock with the highest prevalence in the community (Chapter 6, section 6.4.3.1, 6.4.3.2, and 6.5).

- In term of relative importance, the stakeholder's view is that all the indicators used in constructing the VFII were highly relevant in operationalising vulnerability to food insecurity. None of the indicators was excluded rather more indicators asked to be included in the VFII (Chapter 6, section 6.4.2 and 6.5).

- Also, the relative importance of indicators varies from the state level to the community level and from urban community to rural community (Chapter 6, section 6.4.2 and 6.5). For example, in the rural community hunger was the sensitivity indicators with the highest importance while child mortality was the indicator with the highest importance in the urban community. At the State level, the VFII indicators were equally weighted meaning all indicators are equally important, however, in the community, the study found out that differential weight is required.

Qualitatively, what are the factors that drive households vulnerability to food insecurity?

- The evidence from this study revealed that household-level socio-economic assets and situation, such as severe hunger, unemployment, economic challenges, infertile soil, corruption and hardship, were factors that influence vulnerability to food insecurity. These factors were the reasons why households become vulnerable to more general insecurity (Chapter 6, section 6.5).

- The study identified that households were vulnerable to food insecurity because of long-term depletion of their livelihood assets (Chapter 6, section 6.5). Livelihoods were not sustainable, therefore vulnerable households employed severe coping strategies that had long-term implications in order to cope with immediate food shortages and manage shocks.

- When comparing the VFII adaptive capacity component with ground-truth coping strategies, the relevant inference made was that the adaptive capacity component of the VFII uses indicators that identify long-term measures to reduce vulnerability to food insecurity while ground truth coping strategies are short-term measure employed by households to manage shocks that led to food shortage (Chapter 6, section 6.5).

7.3 Implications for conceptualising food security and vulnerability assessment

The vulnerability to food insecurity index developed in this thesis presents a methodological advancement for vulnerability analysis in the food security research area. The VFII was grounded in a clear conceptual framework, with critical analysis of methodological choices provided and was subjected to both quantitative and qualitative robustness tests. The VFII reflects contemporary approaches to food security and vulnerability measurement because it adopts a multidimensional approach.

Authors such as Barrett (2010); Barrett and Palm (2016); Himes-Cornell et al. (2016); Smith et al. (2017); Cafiero et al. (2018) and Haysom and Tawodzera (2018) have called for a methodological model that accurately assesses, predicts and monitors the incident of global food insecurity crises, in order to evaluate the progress towards the Sustainable Development Goals. The VFII contributes to this methodological gap and can be used to inform decision-makers interested in targeting support that will reduce household vulnerability to food insecurity.

The findings revealed that the choice of measurement does matter when identifying and targeting interventions to those households vulnerable to food insecurity. Using traditional food security indicators to represent a multi-dimensional concept like vulnerability to food insecurity will provide misleading information to policymakers and may lead to targeting the wrong population. This reinforces recent studies (Chapter 2), such as Ogundari (2017) who recently raised this concern in his study to capture the multidimensional nature of food security. He harmonized two single food security indicators of food expenditure and dietary diversity score to categorized households that are vulnerable to food insecurity in Nigeria. His study revealed that a single food security indicator could not capture the multidimensional nature of food security as they wrongly classified households as food secure whereas the harmonised food security indicators correctly identify households with multiple food insecurity problems, which would require a more holistic approach to food policy interventions. Azeem et al. (2018) also assessed consistency of using a multi-dimensional poverty model with a single dimensional poverty model for household vulnerability to poverty and found that 18% of households who were vulnerable to poverty were not captured by single-dimensional poverty measure. The results of this thesis give therefore greater credibility to the need for multi-dimensional indicator approaches.

Not only did this thesis design the VFII but it also carried out tests to identify that the index is reliable and valid. The internal validation using the sensitivity and uncertainty analysis justified that the VFII is highly sensitive to shocks. Therefore the index better captures the vulnerability component of food insecurity. This implies that the index is fit for purpose and performs better than other single indicators of food security when the emphasis is on vulnerability to food security. The ground-truth exercise further justifies that the VFII is reliable. All the indicators used in the index were relevant and important to operationalize vulnerability to food insecurity. In addition, the index was able to capture context-related factors and could be applied to a heterogeneous context. According to Vincent and Cull, (2014) and Hinkel, (2011), when the indicator of the index, such as VFII, can describe the state of a complex concept being measured in simple terms, applies a robust methodology, and is able to link indicators to elements of vulnerability in an intuitive and logical manner such index is valid.

Another important implication of the results is that it is important to take into consideration scale when developing tools for targeting and in the interpretation of the results. Villagrán de León (2006) argued that in order to make methodological advancements in vulnerability assessment, deconstructing vulnerability according to scale will foster the development of robust methods and this research reinforces this argument. If macro-scale measures, such as the VFII, are applied to the micro-level without adjustment for scale, the results will lead to inaccurate targeting of intervention. A macro-level measure is suitable when measuring food security at the national level, while at the community level a micro-level measure must be used. Therefore, when assessing vulnerability to food insecurity for the purpose of targeting long-term food security interventions, context and scale is of crucial consideration (Haysom and Tawodzera, 2018).

Applying equal weight or differential weight has a trade-off. The VFII was developed to reflect state-level context, hence equal weighting was used. However, moving from macro-level to micro-level required adjusting weight to suit the context. Using the VFII at the community level required the application of differential weight because vulnerability to food security varies from one community to another. However, one should bear in mind the cost of getting disaggregated data that suits the community context. Where such data is available at ease, then differential weight should be applied, but if such data is not available, then equal weights should be used. There will be trade-offs in the value of this detailed approach based on what is feasible in terms of cost but also based on the purpose of the tool.

Combining both quantitative modelling with a qualitative ground-truth exercise enhanced understanding of the range of issues relevant to food vulnerability. The finding from this thesis is that the VFII is the starting point of food vulnerability analysis because it identifies the location of the vulnerable population, while the ground-truth exercise provides evidence that further support the result of the quantitative index (VFII) by providing a detailed understanding of the causes of food vulnerability. This implies that ground-truthing identifies valuable potential guidance for the interpretation of vulnerability to food insecurity results. Policymakers can use the findings from ground-truthing to develop a comprehensive vulnerability reduction strategy which addresses food vulnerability. These findings collaborate with the work of Meenar (2017). Meenar (2017) developed a Place-Based Food Insecurity and Vulnerability Index for households in Philadelphia. The author argued that in order to measure multidimensional community food security an integrated participatory and mix-method approach was required because it gives a comprehensive result as compared to using a single approach. Ahmed and Kelman (2018) also developed a weight-based vulnerability index by using both quantitative and qualitative data to measure community vulnerability to environmental hazards. By integrating both qualitative PRA tools with quantitative data, the research contributed a better understanding of how to address vulnerability to environmental hazards at the community scale. This thesis has been able to do the same for food insecurity.

7.4 Implications for policy and practise

For policy that aims to reduce long-term food insecurity and vulnerability issues, targeting of interventions should be based on vulnerability and not calorie consumption. Policymakers should avoid using single indicators of food security such as per capita calorie consumption or a food consumption score because these single indicators are not consistent and able to reflect the multidimensional nature of food insecurity and vulnerability. Therefore, using single food security indicators for the purpose of long-term targeting of intervention will produce misleading information and may misdirect resources.

Using the VFII food security programmes, different policy should be designed, and programmes targeted to households based on the level of vulnerability to food insecurity. Programmes for households that are highly vulnerable to food insecurity should not be the same with households that are mildly vulnerable to food insecurity. Also, the index maps vulnerability to food insecurity that shows exposure, sensitivity and adaptive capacity serve as a valuable tool for policymaker because they enable identification of vulnerable hotspots.

The VFII is an additional methodology for policymakers to make use when planning for food security intervention programmes. The index is useful for comparing the performance of food security programmes and monitoring the progress of food insecurity crises in the state, country and would be applicable in other locations than Nigeria. The tools would enable policymakers to track the progress of development and the impact of their investment.

7.5 Future research

As in any research, there are areas which could be developed further which were beyond the scope of the researcher and the thesis.

- A general criticism that is made of vulnerability models design using the index method is that it is unable to provide forward-looking information for future vulnerability assessment. All indexes, including the VFII, captures static information about the nature of food vulnerability instead of the dynamic nature of vulnerability. Future work could use real-time data (such as big data) to test and forecast vulnerability in a dynamic way.

- Future research could explore ways to disaggregate the exposure component of the VFII to include specific shocks data - this data should be integrated into the Vulnerability to Food Insecurity Index. The threshold of VFII would then need to be subjected to sensitivity analysis to test the robustness and its limitation as it applies to the index.

- Another interesting future study could test more widely the application of the vulnerability to food insecurity index on households in South-South region of Nigeria and ideally, replicate the ground-truth exercise at the national level or even in other countries with different context. This would be a valuable study to explore how vulnerability assessment in food security could help in the better design and targeting of food security intervention in different national contexts.

- This research focuses on the modelling of the VFII that mainly includes the design and robustness test for the VFII. A future study could investigate quantitatively why households are vulnerable to food insecurity or what are characteristics of households that are vulnerable to food insecurity in further application. Using panel data would be one approach to investigate the trend of household vulnerability to food insecurity over time and then changes from one level of food vulnerability to another could be compared. This will also enable different insights to be drawn from the VFII to inform policy.

Chapter 8 : Thesis Appendix

Data files and folders used in quantitative analysis

Table 8.1: GHS-Panel data set used for exposure indicators of VFII

Indicators	Data Folder	Variables
• Health Shock • Unemployment shock • Civil conflict shocks • Agro-climatic shock	Wave 1-PH (HH) -Section 15A -economic shock	• Illness • Job loss • Theft • Kidnapping • Poor rain • Flooding • Food price

Table 8.2: GHS-Panel data set used for sensitivity indicators of VFII

Indicators	Data Folders	Variables	Transformation
Malnutrition	Wave 1-PP; individual roster (section 1) Wave 1-PH; Health (section 4a) - s4aq52 weight s4aq53 height	Stunting	Attached Do file
Child mortality	Wave 1-PH; Health (section 4a) - s4aq45a, s4aq45b,s4aq51	Total child dead	Adding both 45a and 45b
Hunger	Wave 1-PH; Food security - s12q1h + s12q1i	Days without food	

Table 8.3: GHS-Panel data set used for adaptive capacity indicators of VFII

Indicators	Data folders	Variables	Transformation
Wealth Index	Wave 1-PP(Agriculture)- Section 11A1(Land size); Wave 1-PP (Agriculture)- Section 11I (livestock); Wave 1-PP (Households)-Section 5 (household assets); Wave 1-PH (Households) -Section 8 (housing structure) Collect firewood Electricity Wave 1-PP(HH)- Section 8- Housing:Member per room (No. Room/HH size)	Livestock, Land, Livelihood Asset, Mobility asset, Information asset, Housing structure,	See do file
Household literacy	Wave 1-PP(Household) - Section 1 (individual Roster) and Section 2(Education)	Years of schooling	See do file
Access to infrastructure	Wave 1- PH(HH)- Section 8 (Housing-water:s8q34a); Wave 1(Geographic data)- Household level	Dist-to-road, Dist-to-market, Dist-to-water	None
Livelihood activities	Wave 1-PP(HH)- Section 10 (other income - s10q2 + s10q5 + s10q8); Wave 1-PH(HH)-Section 9(Nonfarm enterprise) Wave 1-PH (Agriculture)-Section A3 (crops harvested)	Income source, None farm income, Total crop harvested	See do file

Table 8.4: GHS-Panel data set used for designing traditional food security indicators

Traditional food security Indicators	Data Folder
Per capita calorie consumption	• Wave 1-(HH) Post-planting - (section 7b-Households Food Expenditure). • Wave 1-(HH) post-harvest -) section 10b-Food consumption and expenditure
Per capita calorie consumption	Wave 2-(HH) post planting - (section 7b-Households Food and Expenditure)
Coping Strategy Index	Wave 1 (HH) - post planting - (Section 9 - Food security) Wave 1(HH)- post harvest - (Section 12-Food security)
Food consumption score	Wave 1-(HH) Post Harvest - (section 10c -Aggregate food consumption

Qualitative research questionnaires

Section 1: Interview guide for Key informant in NGO/Ministries

Date: ________________________

Reference Number: _______________________

Organization: _____________________________

Position: __________________________________

Location/Villa: _________________________

Section A: Institution mapping

1. What is your role?
2. What key activities does this institution/department do in the community?
3. When do your institution give out support to people in terms of their food security?
4. How do you operate this activity?
5. What government initiatives has been provided?
6. How do your institution deal with issues like food price hike, shocks, food poverty in the community?
7. Are there any NGO that you are aware?
8. Ask for any document that would be of assistance.

Section B: Characterisation of households

1. When you are doing activities with people in the community, how do you group people? What characterises these group of people?
2. In terms of food poverty, how do you characterise people who are highly vulnerable (very poor), mildly vulnerable (average), and not vulnerable (not poor)?
3. What socio-economic groupings are there in the community and who belongs to what group?
4. What are local perception of wealth, well-being and inequality?

Section C: Food security questions [7, 1, 2, 3]

1. What are the commonly seen food-related health problems in this community? List by children, adults and women.
2. For each group (children, adults and women) can you rank these health problems according to their importance? *Give ten marks to the most important problem and one mark to the last important problem. Give a mark between 1 and 10 to the remaining problems.*
3. Can you explain why you have given more importance to one problem than to another? (i.e. higher incidence, more severe, etc.)
4. Can you identify those problems that are important for nutrition (i.e. marasmus, kwashiorkor, night blindness, diarrhea, anemia, etc.)?
5. For each of the nutrition-related problems, what do local people see as the causes? (Draw a matrix with the problems, causes, treatment)

6. What do local people in general do to treat these problems?
7. Can you identify on the community map those villages that have frequently such nutrition-related problems?

Section 2: Focus group with stakeholders in the community:

Participants: Community Health Worker, Traditional Birth Attendant, Home Agent, Traditional Healer, Teacher, Youth leader, Chief, Religious leader

Date: ____________________________

Reference Number: ________________________

Community: _____________________________

Number of participants: __________________________________

Village: _____________________________

Section A: Community mapping

1. Draw a map of the community (physical boundary) and ask participant to locate resources/infrastructure that are abundant for food production and consumption

2. Using this same map ask participant to mapped households that are in areas/villages having:
   a) nutrition-related problems and those that do not have such problem,
   b) households that are wealthy and those that are poor (*Have the participants discuss on the concept of wealth. Within the context of Food Security and Vulnerability Analysis, it is important to highlight that in a wealthy household all members are expected to have enough food to satisfy members' needs; to live in a hygienic and safe environment and to be able to educate children.*),
   c) households that are male headed and those that are female headed.

Section B: Past problems or shocks

1. What shocks/problems (environmental, economic, social, political) have affected the community during last five years? *Use time line tool*
2. What are the major occupations or livelihoods in the area currently? What were the major occupations/livelihoods 10 years ago?

3. Are there any organizations / institutions that are active in the Community and the service they provide. If yes list them in the table below

Organization name	Type	Services provided

Section C: Wealth ranking

1. Who are the most vulnerable groups in the community? Who are the most vulnerable individuals?
2. What characterises these households. (*Use the wealth ranking table below to group these households. Allow the participant to generate local indicators that characterise households – delete your indicators*)

	Category 1: Highly vulnerable households	Category 2: Less vulnerable households	Category 3: Not vulnerable (well-to-do)

Food/diet, clothing, livestock, education, house structure, bedding, access to water, size of farm, yield from crops, possession (assets), employment, food stocks

3. Where are these households located in the community?
4. Why do you think households are vulnerable? [*problem and solution*]

Section D: Coping strategy

5. With the same amount of money are people able to buy more goods and services now compared to last year? Given N100,000 how much food item can you buy now compared to when Goodluck Jonathan was the president. [*time line tool*]
6. Which months are the leanest times in terms of food and income?
7. What happens to consumption patterns during the lean season? (Adjustment of meals, types of food eaten, etc.)
8. Scarcity of food:
    a) What are substitute foods when food is in short supply?
    b) When food is in short supply, do some family members receive preference in food access? Who and why?
    c) How do you manage getting access to food in times of scarcity?
9. What do you think the food security situation will be in the next 6 months? Is this normal for your community?
10. What are the priorities for your community to improve food security?

Section E: Indicators Validation [*proportional pilling or rating or matrix ranking and scoring*]

1. From the following indicators, identify which is the strongest cause of vulnerability. Rank these indicators, using a score causal diagram. (*Alternatively, in your own view rank the following indicators give a score of 1-10 (lowest to highest)*)

Illness of bread winner	Stunting
Job loss	Child mortality
Theft of crops, cash and livestock/kidnapping/hijacking/robbery/assault	Hunger
Poor rain that caused harvest failure	
Flooding that cause harvest failure	
Increase in price of major food item	

2. In your our view which of these indicators are very important to helping households out of vulnerable situation:

Wealth Index	Infrastructure	Livelihood activities	Education
Household asset	Good roads	Income from jobs	Education
Mobility asset	Nearest market	Income from non-farm enterprise	
Livelihood asset	Water source	Harvest crops	
Housing structure			

Section 3: In-depth interview on households

Date: ____________________________

Reference Number: ___________________________

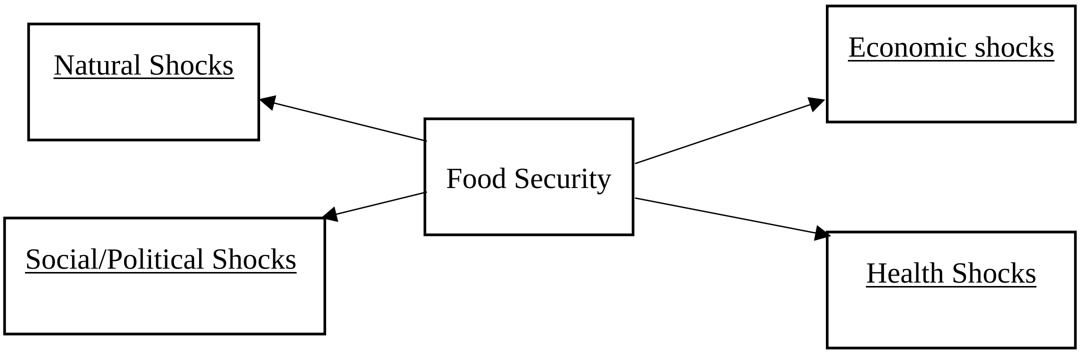
Community: _________________________________

Village: _____________________________________

Household class: ______________________________

Section A: Shocks [*benefit analysis or matrix ranking and scoring*]

1. Can you think about shocks that you have faced over the past 5 years? List all of the natural, social, political, health and economic shocks
2. Put similar shocks in the boxed below:



3. From these shocks you have mentioned, identify 5 most important shocks and rank them from the scale of 1-5 (1 being the shock with the most severe impact).
4. What was the impact of these shocks on household?

1. Shocks	3. Ranking	4. Effect of shocks on household livelihood	5. Response	6.Effectiveness of the response

5. I would like to know what the households did to solve the problem. Please, report all the strategies you have adopted. If you did nothing to solve the problem, I will put "nothing".
6. Using the table below, rank the first 5 strategy that is most frequently used. Report the objective of the coping strategies; if the strategy was effective in solving the problem and if they caused other problems or negative consequences.

Section B: Adaptive capacity

7. Where there any organizations that were present in assisting you to respond to shocks identified above? If so, what type of assistance were rendered and for how long

Event/Risk	Name of organization	Type of organization	Type of assistance	Duration of assistance	Targeted beneficiaries

Section C: Household food security

8. During the last year [*indicate the year*], what have been the problems in the to obtain such an adequate diet (to be food secure)? (Draw a matrix with the problems, the causes, the actions taken by the community and households)

9. In your view, what were the reasons for these problems? What did the community and households do to resolve these problems? (Probe deep enough into the reason for the problem to understand the underlying causes)

10. How are decisions being made within the household regarding achieving food security or responding to problems of attaining food security? Who makes specific decisions? How are resources allocated to achieving food security? How are resources reallocated in case of food insecurity?
11. What measures are taken by households to prevent food security problems from reoccurring?
12. What resources are needed by the community and households to become more successful at preventing food security problems from recurring?

13. Using the seasonal calendar below, identify a time where your household experience the following situation:

Year:

Months												
Season	**Planting Season**						**Harvest Season**					
Food prices (high/low)												
Family income (high/low)												
Family food stocks (high/low)												
Sale own food production (high/low)												
Sale cash crops (high/low)												
Sale animals/products (high/low)												
Wage labour in agriculture (high/low)												
Wage labour in other sectors (high/low)												
Migration out of the village (high/low)												

Participant Information sheet

Group Participant Information Sheet

Reference number:

Project name: Food security and Vulnerability Analysis of Households in South-South Nigeria

I am a PhD student at the University of Reading. As part of my degree thesis I am conducting research into why households are vulnerable to food security.

This research project aims to find out what characterize and influence household's food security and vulnerability. I am interested in exploring what, who and why household in this locality are vulnerable to food security? Therefore, I will like to have a group discussion or exercise to understand these factors. I will be comparing this information with the result of my index, called Food Security and Vulnerability Index.

To undertake this research, I currently contacting the stakeholders in the community or any member of the households that can give me accurate information. I would like to invite you to participate in a focus group discussion taking place at ______________________________ which will take approximately 1 hour of your time. You have been selected as a participant through a stratified random sampling and I am interested in households in this community because my food vulnerability map shows that this area is prone to high vulnerability to food insecurity. You are encouraged to freely express your opinions and please be assured that your views are valued and that there are no right or wrong answers to the questions asked.

As part of this interview, I will not collect any names or any personal details that can be used to discover your identity. In rare cases, should your personal details be collected for the purpose of asking fellow up questions, your identity will not be revealed to anyone other than the researchers conducting this survey. Your anonymity will be held confidentially. Your name and email address will be linked to your original responses by means of a keyed spreadsheet held separately. This spreadsheet and contact details will be password protected and the password known only to me and my supervisor and will not be shared with any third parties. The spreadsheet will be kept on my password protected PC and will be destroyed at the end of my degree in December 2018. Your name and email address will not be published as part of my research. As all data is presented in aggregate format it will not be possible to identify any individuals from their responses.

Participation is entirely voluntary, and you are free to withdraw from this group discussion at any time you feel uncomfortable or unwilling to participate, and you do not have to specify a reason. Any in-part or total contribution can be withdrawn up until the point at which the data is aggregated before 31/03/2018. After 31/03/2018 date it will not be possible to withdraw your contribution from the results of the research. If you wish to withdraw, please contact Mr. Otu Ibok on 08053234895 or with my email, quoting the reference at the top of this page. The reference will only be used to identify your interview transcript and will not reveal any other information about you.

The discussion will be audio recorded if you agree, and the anonymised transcripts of the audio recordings will be used by the students working on the project. Once transcribed the original recording will be deleted. Your anonymity will not be compromised as only the reference number above will be used to identify the transcript.

If at any stage you wish to receive further information about this research project please to not hesitate to contact me using [redacted] or [redacted] before 31/03/2018 date. The findings will be written up into my thesis and included in a report to be published in academic journals. This will not affect your anonymity.

All data I collect will be stored securely electronically on a password-protected computer or in hard copy version in a locked cupboard. The data will be destroyed at the end of the research project and upon completion of analysis/publication no later than 31/03/2019.

By completing this survey, you are acknowledging that you understand the terms and conditions of participation in this study and that you consent to these terms.

This research project has been reviewed according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct.

Thank you very much for taking time to take part in this survey!

Otu Ibok

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Supervisor Contact Details
Name: Dr Henny Osbahr
Phone: [redacted]

E-Mail: [redacted]

Individual Participant Information Sheet

Reference number: ___________________

Project name: Food security and Vulnerability Analysis of Households in South-South Nigeria

I am a PhD student at the University of Reading. As part of my degree I am conducting research into why households are vulnerable to food security.

This research project aims to find out what characterize and influence household's food security and vulnerability. I am interested in exploring answers to the following research questions: what are the causes of household food vulnerability? Who are these vulnerable households? and why households in this locality are vulnerable to food security? Therefore, I will like to have interview with you to get feedbacks from these research questions. I will be comparing this information with the result of my index, called Food Security and Vulnerability Index.

To undertake this research, I am currently contacting the household head or any member of the households that has thorough knowledge of the household. I would like to invite you to participate in an in-depth interview exercise taking place at Akwa Ibom state which will take approximately 1 hour of your time. You have been selected as a participant through a stratified random sampling and I am interested in households in this community because our food vulnerability map shows that this locality is prone to high vulnerability to food insecurity. You are encouraged to freely express your opinions and please be assured that your views are valued and that there are no right or wrong answers to the questions asked.

As part of this interview, we will not collect any names or any personal details that can be used to discover your identity. In rare cases, should your personal details be collected for asking fellow up questions, your identity will not be revealed to anyone other than the researchers conducting this survey. Your anonymity will be held confidentially. Your name and email address will be linked to your original responses by means of a keyed spreadsheet held separately. This spreadsheet and contact details will be password protected and the password known only to me, and will not be shared with any third parties. The spreadsheet will be kept on my password protected PC and will be destroyed at the end of my degree in December 2018. Your name and email address will not be published as part of my research.

As all data is presented in aggregate format it will not be possible to identify any individuals from their responses.
Participation is entirely voluntary and you are free to withdraw from the interview at any time you feel uncomfortable or unwilling to participate, and you do not have to specify a reason. Any in-part or total contribution can be withdrawn up until the point at which the data is aggregated before 31/03/2017. After 31/03/2017 date it will not be possible to withdraw your contribution from the results of the research. If you wish to withdraw, please contact Mr. Otu Ibok on 08053234895 or with my email, quoting the reference at the top of this page. The reference will only be used to identify your interview transcript and will not reveal any other information about you.

The discussion will be audio recorded if you agree, and the anonymised transcripts of the audio recordings will be used by the students working on the project. Once transcribed the original recording will be deleted. Your anonymity will not be compromised as only the reference number above will be used to identify the transcript.
If at any stage you wish to receive further information about this research project please to not hesitate to contact me using [redacted] or [redacted] before 31/03/2018. The findings will be written up into my thesis and included in a report to be published in academic journals. This will not affect your anonymity.
All data I collect will be stored securely electronically on a password-protected computer or in hard copy version in a locked cupboard. The data will be destroyed at the end of the research project and upon completion of analysis/publication no later than 31/03/2019.
By completing this survey, you are acknowledging that you understand the terms and conditions of participation in this study and that you consent to these terms.
This research project has been reviewed according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct.
Thank you very much for taking time to take part in this survey!
Otu Ibok

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Supervisor Contact Details

Name: Dr Henny Osbahr
Phone: [redacted]
E-Mail: [redacted]

Do files sections

COPING STRATEGY INDEX

****CPI for post planting 2010

```
gen limit_foods_eaten = 3 * s9q1b
gen limit_meal_size = 4 * s9q1c
gen reduce_meals_eaten = 3 * s9q1d
gen restrict_consumptn_children = 4 * s9q1e
gen borrow_food = 2 * s9q1f
gen no_food_hh = 4 * s9q1g
gen sleep_night_hungry = 4 * s9q1h
gen  wholeday_without_eating = 4 * s9q1i
egen cpi = rowtotal ( less_preferred_foods limit_foods_eaten limit_meal_size reduce_meals_eaten restrict_consumptn_children borrow_food no_food_hh sleep_night_hungry wholeday_without_eating), missing

gen cpi_pp_category = 1 if cpi_ppw1 <=2
replace cpi_pp_category =2 if cpi_ppw1 >=3 & cpi_ppw1<=12
replace cpi_pp_category =3 if cpi_ppw1 >=13 & cpi_ppw1 <=40
replace cpi_pp_category =4 if cpi_ppw1 >40
label var cpi_pp_category "category for cpi_pp 1=foodsecure 2=mildly foodsecure 3=mderately foodsecure 4=severly foodsecure"

****CPI for Post Harvest 2010
gen less_preferred_foods = 1*s12q1a
gen limit_foods_eaten = 3 * s12q1b
gen limit_meal_size = 4 * s12q1c
gen reduce_meals_eaten = 3 * s12q1d
gen restrict_consumptn_children = 4 * s12q1e
gen borrow_food = 2 * s12q1f
gen no_food_hh = 4 * s12q1g
gen sleep_night_hungry = 4 * s12q1h
gen  wholeday_without_eating = 4 * s12q1i
egen cpi_ph2010 = rowtotal ( less_preferred_foods limit_foods_eaten limit_meal_size reduce_meals_eaten restrict_consumptn_children borrow_food no_food_hh sleep_night_hungry wholeday_without_eating), missing

gen cpi_ph_category = 1 if cpi_phw1 <=2
replace cpi_ph_category =2 if cpi_phw1 >=3 & cpi_phw1 <=12
replace cpi_ph_category =3 if cpi_phw1 >=13 & cpi_phw1 <=40
replace cpi_ph_category =4 if cpi_phw1 >40
```

FOOD CONSUMPTION SCORE

```
**FCS using Post Harvest data w1
**multiplying by weight
by hhid item_cd: gen fcs = 2 * s10cq7 if item_cd==1
replace fcs = 2 * s10cq7 if item_cd==2
replace fcs = 3 * s10cq7 if item_cd==3
replace fcs = 1 * s10cq7 if item_cd==4
replace fcs = 4 * s10cq7 if item_cd==5
replace fcs = 1 * s10cq7 if item_cd==7
replace fcs = 4 * s10cq7 if item_cd==8
```

```
replace fcs = 0.5 * s10cq7 if item_cd==9
replace fcs = 0.5 * s10cq7 if item_cd==10
replace fcs = 0 * s10cq7 if item_cd==11

*generating the fcs
by hhid: egen fcs_w1 = total ( fcs)

preserve
collapse (mean) foodconscore_w1= fcs_w1, by (hhid)
restore

** Generating FCS threshold
gen fcs_thresholdgroup =1 if foodconscore_w1 <=28
replace fcs_thresholdgroup =3 if foodconscore_w1 >42
```

HOUSEHOLD CALORIE CONSUMPTION EQUIVALENT

```
list hhid item_cd s7bq2a s7bq2b s7bq2c if hhid==30001
list hhid item_cd s7bq2a s7bq2b s7bq2c if hhid==30002
list hhid item_cd s7bq2a s7bq2b s7bq2c if hhid==30003

/* Converting raw food data from local unit to standardize metrics */
** Converting all KG to Gramms (because this is the comon unit to convert to grams)
 labellist s7bq2b
        1 kilogram
        2 grams
        3 litre
        4 millilitre
        5 pieces
        6 other (pecify

gen foodqty_grams = s7bq2a * 1000 if s7bq2b==1
replace foodqty_grams = s7bq2a * 1 if s7bq2b==2
replace foodqty_grams = s7bq2a * 1 * 1000 if s7bq2b==3
replace foodqty_grams = s7bq2a * 1 if s7bq2b==4

browse hhid item_cd s7bq2a s7bq2b s7bq2c foodqty_grams
tab item_cd  if s7bq2b==5
labellist item_cd

***Converting all food items calibrates as "PIECES" to grams
*Bread
replace foodqty_grams = s7bq2a * 433.3 if item_cd==15 & s7bq2b==5
browse hhid item_cd s7bq2a s7bq2b foodqty_grams if item_cd==15

*Millet
replace foodqty_grams = s7bq2a * 78.57 if item_cd==11 & s7bq2b==5
*maize
replace foodqty_grams = s7bq2a * 300 if item_cd== 12& s7bq2b==5
*rice-imported
```

```
replace foodqty_grams = s7bq2a *168.7 if item_cd==14 & s7bq2b==5
*maize flour
replace foodqty_grams = s7bq2a *56.25  if item_cd==16 & s7bq2b==5
*wheat flour
replace foodqty_grams = s7bq2a * 25.565 if item_cd==19 & s7bq2b==5
*other grains flour
replace foodqty_grams = s7bq2a * 150 if item_cd==20 & s7bq2b==5
*Cassava-roots
replace foodqty_grams = s7bq2a * 1250 if item_cd==30 & s7bq2b==5
*yam-root
replace foodqty_grams = s7bq2a * 3560 if item_cd==31 & s7bq2b==5
*garri white
replace foodqty_grams = s7bq2a *206.25  if item_cd==32 & s7bq2b==5
* garri yellow
replace foodqty_grams = s7bq2a * 180 if item_cd==33 & s7bq2b==5
* Cocoyam
replace foodqty_grams = s7bq2a * 140 if item_cd==34 & s7bq2b==5
* Plantains
replace foodqty_grams = s7bq2a * 59.165 if item_cd==35 & s7bq2b==5
* Sweet potatoes
replace foodqty_grams = s7bq2a * 450 if item_cd==36 & s7bq2b==5
* Potatoes
replace foodqty_grams = s7bq2a *110  if item_cd==37 & s7bq2b==5
* Other roots and tuber
replace foodqty_grams = s7bq2a *118.3  if item_cd==38 & s7bq2b==5
* Brown beans
replace foodqty_grams = s7bq2a * 72.5 if item_cd==41 & s7bq2b==5
* White beans
replace foodqty_grams = s7bq2a * 72.5 if item_cd==42 & s7bq2b==5
* Groundnuts
replace foodqty_grams = s7bq2a * 1250 if item_cd==43 & s7bq2b==5
* Other nuts/seeds/pulses
replace foodqty_grams = s7bq2a * 1250  if item_cd==44 & s7bq2b==5
* Palm oil
replace foodqty_grams = s7bq2a * 79.5 if item_cd==50 & s7bq2b==5
* Groundnut oil
replace foodqty_grams = s7bq2a * 79.5 if item_cd==52 & s7bq2b==5
* Other oils and fats
replace foodqty_grams = s7bq2a * 159 if item_cd==53 & s7bq2b==5
* Bananas
replace foodqty_grams = s7bq2a * 2150 if item_cd==60 & s7bq2b==5
* Organe/tangerine
replace foodqty_grams = s7bq2a * 400 if item_cd==61 & s7bq2b==5
* Avocado pear
replace foodqty_grams = s7bq2a * 237 if item_cd== 63 & s7bq2b==5
*Pineapples
replace foodqty_grams = s7bq2a * 2200 if item_cd==64  & s7bq2b==5
* Tomatoes
replace foodqty_grams = s7bq2a * 50 if item_cd==70 & s7bq2b==5
```

```
* Tomato puree (canned)
replace foodqty_grams = s7bq2a * 2100 if item_cd==71 & s7bq2b==5
* Onions
replace foodqty_grams = s7bq2a * 145  if item_cd==72 & s7bq2b==5
* Garden eggs/egg plant
replace foodqty_grams = s7bq2a * 97.5 if item_cd==73 & s7bq2b==5
* Okra - fresh
replace foodqty_grams = s7bq2a * 210 if item_cd==74 & s7bq2b==5
* Okra - dried
replace foodqty_grams = s7bq2a * 32.5 if item_cd==75 & s7bq2b==5
* Pepper
replace foodqty_grams = s7bq2a * 1010 if item_cd==76 & s7bq2b==5
* Leaves (cocoyam, spinach, etc.)
replace foodqty_grams = s7bq2a * 100 if item_cd==77 & s7bq2b==5
* Other vegetables (fresh or canned)
replace foodqty_grams = s7bq2a * 100 if item_cd==78 & s7bq2b==5
* Agricultural eggs
replace foodqty_grams = s7bq2a * 50 if item_cd== 83& s7bq2b==5
* Local eggs
replace foodqty_grams = s7bq2a * 50 if item_cd==84 & s7bq2b==5
* Other eggs (not chicken)
replace foodqty_grams = s7bq2a * 40 if item_cd==85 & s7bq2b==5
* Beef
replace foodqty_grams = s7bq2a * 10000 if item_cd==90 & s7bq2b==5
* Mutton
replace foodqty_grams = s7bq2a *10000  if item_cd==91 & s7bq2b==5
* Fish - fresh
replace foodqty_grams = s7bq2a *190  if item_cd==100 & s7bq2b==5
* Fish - frozen
replace foodqty_grams = s7bq2a *190  if item_cd== 101& s7bq2b==5
* Fish - smoked
replace foodqty_grams = s7bq2a *190  if item_cd== 102& s7bq2b==5
* Fish - dried
replace foodqty_grams = s7bq2a *190 if item_cd==103 & s7bq2b==5
* Snails
replace foodqty_grams = s7bq2a * 2000 if item_cd==104 & s7bq2b==5
* Milk powder
replace foodqty_grams = s7bq2a * 38 if item_cd==111 & s7bq2b==5
* Baby milk powder
replace foodqty_grams = s7bq2a * 20000 if item_cd==112 & s7bq2b==5
* Milk tinned (unsweetened)
replace foodqty_grams = s7bq2a * 15 if item_cd== 113& s7bq2b==5
* Coffee
replace foodqty_grams = s7bq2a * 20 if item_cd==120 & s7bq2b==5
* Chocolate drinks (including Milo)
replace foodqty_grams = s7bq2a * 200 if item_cd==121 & s7bq2b==5
* Tea
replace foodqty_grams = s7bq2a * 200 if item_cd==122 & s7bq2b==5
* Sugar
```

```
replace foodqty_grams = s7bq2a * 88 if item_cd==130 & s7bq2b==5
* Honey
replace foodqty_grams = s7bq2a *15  if item_cd==132 & s7bq2b==5
* Condiments (salt, spices, pepper, etc)
replace foodqty_grams = s7bq2a * 225 if item_cd==140 & s7bq2b==5
* Bottled water
replace foodqty_grams = s7bq2a * 15 if item_cd==150 & s7bq2b==5
* Sachet water
replace foodqty_grams = s7bq2a * 72 if item_cd==151 & s7bq2b==5
* Malt drinks
replace foodqty_grams = s7bq2a * 22  if item_cd==152 & s7bq2b==5

***Converting all food items calibrates as "Other unit" to grams
*starting with all food items measure in "CUPS"
browse hhid item_cd s7bq2a s7bq2b foodqty_grams if s7bq2b==6
browse hhid item_cd s7bq2a s7bq2c foodqty_grams if s7bq2c=="CUP"

**conversion of food items measure in CUPS to grams
replace foodqty_grams = s7bq2a *150  if item_cd==10 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *157.14  if item_cd==11 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 187.5  if item_cd==12 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 168.7  if item_cd==13 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 168.75 if item_cd==14 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 112.5 if item_cd==16 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *103.13  if item_cd==17 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *100  if item_cd==19 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *150 if item_cd==20 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *240  if item_cd==30 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *240  if item_cd==31 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *137.5  if item_cd==32 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 120 if item_cd==33 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 155 if item_cd==34 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 118.33 if item_cd==35 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 326 if item_cd==36 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 130 if item_cd==37 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 118.33 if item_cd== 38& s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 147.5 if item_cd==40 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *145  if item_cd==41 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 145 if item_cd==42 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a * 100 if item_cd==43 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *100  if item_cd==44 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15.9*10  if item_cd==50 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15.9*10  if item_cd==52 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15.9*10  if item_cd==53 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *283  if item_cd==73 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *65 if item_cd==74 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *65 if item_cd==75 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *25 if item_cd==76 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *100 if item_cd==77 & s7bq2b==6 & s7bq2c=="CUP"
```

```
replace foodqty_grams = s7bq2a *100  if item_cd==78 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *75  if item_cd==103 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==110 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *76  if item_cd==111 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==113 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *2*10  if item_cd==120 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *20*10  if item_cd==121 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *2*10  if item_cd==122 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *176  if item_cd==130 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==132 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *225  if item_cd==140 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==150 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==160 & s7bq2b==6 & s7bq2c=="CUP"
replace foodqty_grams = s7bq2a *15  if item_cd==161 & s7bq2b==6 & s7bq2c=="CUP"

***Converting some food items measured in BOTTLES into grams
**Bottle
browse hhid item_cd s7bq2a s7bq2c foodqty_grams if s7bq2c=="BOTTLE"
tab  item_cd  if s7bq2c=="BOTTLE"

replace foodqty_grams = s7bq2a * 35.775*10 if item_cd==50 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a *15  if item_cd==51 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a *35.775 *10  if item_cd==52 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a *15.9 * 10  if item_cd==53 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a *171  if item_cd==111 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a *20 *10  if item_cd==121 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 396 if item_cd==130 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 506.25 if item_cd==140 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 33 if item_cd==150 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 75 if item_cd==151 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 18 if item_cd==152 & s7bq2b==6 & s7bq2c=="BOTTLE"
replace foodqty_grams = s7bq2a * 100 if item_cd==161 & s7bq2b==6 & s7bq2c=="BOTTLE"

**Bag/Sack
tab  item_cd  if s7bq2c=="BAG/SACK"
replace foodqty_grams = s7bq2a * 3881.25 if item_cd==14 & s7bq2b==6 & s7bq2c=="BAG/SACK"
replace foodqty_grams = s7bq2a * 200  if item_cd==122 & s7bq2b==6 & s7bq2c=="BAG/SACK"
replace foodqty_grams = s7bq2a * 50  if item_cd==151 & s7bq2b==6 & s7bq2c=="BAG/SACK"
replace foodqty_grams = s7bq2a * 18  if item_cd==152 & s7bq2b==6 & s7bq2c=="BAG/SACK"

**Ball
tab  item_cd  if s7bq2c=="BALL"
replace foodqty_grams = s7bq2a *220  if item_cd==64 & s7bq2b==6 & s7bq2c=="BALL"
replace foodqty_grams = s7bq2a * 50 if item_cd==70 & s7bq2b==6 & s7bq2c=="BALL"
replace foodqty_grams = s7bq2a * 210 *10 if item_cd==71 & s7bq2b==6 & s7bq2c=="BALL"
replace foodqty_grams = s7bq2a * 145 if item_cd==72 & s7bq2b==6 & s7bq2c=="BALL"
replace foodqty_grams = s7bq2a *32.5  if item_cd==74 & s7bq2b==6 & s7bq2c=="BALL"

**Basin
```

```
tab  item_cd  if s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1200  if item_cd==10 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1250  if item_cd==12 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *800  if item_cd==20 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1920  if item_cd==30 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1100  if item_cd==32 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *960  if item_cd==33 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1240  if item_cd==34 & s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *1160  if item_cd== 42& s7bq2b==6 & s7bq2c=="BASIN"
replace foodqty_grams = s7bq2a *2264  if item_cd==73 & s7bq2b==6 & s7bq2c=="BASIN"

**Basket
tab  item_cd  if s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a *1518.75  if item_cd==14 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a * 2160 if item_cd==18 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a *1080  if item_cd==33 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a * 1064.97 if item_cd==35 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a * 1305 if item_cd==42 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a * 1100 * 10 if item_cd==70 & s7bq2b==6 & s7bq2c=="BASKET"
replace foodqty_grams = s7bq2a * 585 if item_cd==74 & s7bq2b==6 & s7bq2c=="BASKET"

**Bowl/Bucket
tab  item_cd  if s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1414.26 if item_cd==11 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1518.75 if item_cd==14 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *900  if item_cd==20 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *2160  if item_cd==30 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *2160  if item_cd==31 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1237.5 if item_cd==32 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 1080 if item_cd==33 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1064.97 if item_cd==35 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1305  if item_cd==41 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *1305  if item_cd==42 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a *900 *10 if item_cd==43 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 1100 if item_cd==70 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 720 *10 if item_cd==71 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 840 * 10 if item_cd==72 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 585 if item_cd==74 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
replace foodqty_grams = s7bq2a * 1000 *10 if item_cd==90 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"
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replace foodqty_grams = s7bq2a * 1000 *10 if item_cd==91 & s7bq2b==6 & s7bq2c=="BOWL/BUCKET"

**Bunch
tab item_cd if s7bq2c=="BUNCH"
replace foodqty_grams = s7bq2a *59.165 if item_cd==35 & s7bq2b==6 & s7bq2c=="BUNCH"
replace foodqty_grams = s7bq2a *2150 if item_cd==60 & s7bq2b==6 & s7bq2c=="BUNCH"
replace foodqty_grams = s7bq2a *50 if item_cd==77 & s7bq2b==6 & s7bq2c=="BUNCH"
replace foodqty_grams = s7bq2a * 100 if item_cd==78 & s7bq2b==6 & s7bq2c=="BUNCH"

**Bundle
tab item_cd if s7bq2c=="BUNDLE"
**Cube
tab item_cd if s7bq2c=="CUBE"
**Heap
tab item_cd if s7bq2c=="HEAP"
**Kongo
tab item_cd if s7bq2c=="KONGO"
replace foodqty_grams = s7bq2a *1305 if item_cd==42 & s7bq2b==6 & s7bq2c=="KONGO"
**Mudu
tab item_cd if s7bq2c=="MUDU"
replace foodqty_grams = s7bq2a *1920 if item_cd==31 & s7bq2b==6 & s7bq2c=="MUDU"
replace foodqty_grams = s7bq2a *960 if item_cd==33 & s7bq2b==6 & s7bq2c=="MUDU"

**Pack
tab item_cd if s7bq2c=="PACK"
**Paint
tab item_cd if s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a *3880.1 if item_cd==13 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a *3881.25 if item_cd==14 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a *2587.5 if item_cd==16 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 2371.99 if item_cd==17 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 5520 if item_cd==30 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 5520 if item_cd==31 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 3162.5 if item_cd==32 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 2760 if item_cd==33 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 3565 if item_cd==34 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 3335 if item_cd==41 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 3335 if item_cd==42 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 3000 * 10 if item_cd==70 & s7bq2b==6 & s7bq2c=="PAINT"
replace foodqty_grams = s7bq2a * 1495 if item_cd==74 & s7bq2b==6 & s7bq2c=="PAINT"

**Rubber
tab item_cd if s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 3450 if item_cd==10 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 4312.5 if item_cd==12 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 2300 if item_cd==18 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 5520 if item_cd==31 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 3162.5 if item_cd==32 & s7bq2b==6 & s7bq2c=="RUBBER"
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```
replace foodqty_grams = s7bq2a * 2760 if item_cd==33 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 3335 if item_cd==41 & s7bq2b==6 & s7bq2c=="RUBBER"
replace foodqty_grams = s7bq2a * 3335 if item_cd==42 & s7bq2b==6 & s7bq2c=="RUBBER"

**Satchet
tab  item_cd  if s7bq2c=="SATCHET"

**TIN
tab  item_cd  if s7bq2c=="TIN"
replace foodqty_grams = s7bq2a *120  if item_cd==33 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a *145  if item_cd==41 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a *100 * 10  if item_cd==44 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a *15.9 * 10  if item_cd==50 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 15 if item_cd==51 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a *15.9  if item_cd==52 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 90 *10 if item_cd==70 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 90 * 10 if item_cd==71 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 85 * 10  if item_cd==72 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 283 if item_cd==73 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 25 if item_cd==76 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 15 if item_cd==110 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 76 if item_cd==111 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 2000 * 10 if item_cd==112 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 15 if item_cd==113 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 20 * 10 if item_cd==120 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 20 * 10 if item_cd==121 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 2 * 10 if item_cd==122 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 176 if item_cd==130 & s7bq2b==6 & s7bq2c=="TIN"
replace foodqty_grams = s7bq2a * 225 if item_cd== 140& s7bq2b==6 & s7bq2c=="TIN"

**Tuber
tab  item_cd  if s7bq2c=="TUBER"
replace foodqty_grams = s7bq2a *3560  if item_cd==31 & s7bq2b==6 & s7bq2c=="TUBER"
replace foodqty_grams = s7bq2a *140  if item_cd==34 & s7bq2b==6 & s7bq2c=="TUBER"
replace foodqty_grams = s7bq2a *450  if item_cd==36 & s7bq2b==6 & s7bq2c=="TUBER"
replace foodqty_grams = s7bq2a *110  if item_cd==37 & s7bq2b==6 & s7bq2c=="TUBER"

**Commands for crutinizing all the food items with missing grams
**Cross checking before conversion  to energy equivalent.
tab foodqty_grams if foodqty_grams==.
browse hhid item_cd foodqty_grams if foodqty_grams==.
tab item_cd if foodqty_grams==.
tab s7bq2c if item_cd==15 & foodqty_grams==.
browse s7bq2c if item_cd==15 & foodqty_grams==.
browse s7bq2c item_cd foodqty_grams if item_cd==15 & foodqty_grams==.
browse s7bq2b s7bq2c item_cd foodqty_grams if item_cd==15 & foodqty_grams==.

*Missing Bread compuation
replace foodqty_grams = s7bq2a * 433.3 if item_cd==15 & s7bq2c=="LOAF" & foodqty_grams==.
```

```
browse s7bq2c if item_cd==140 & foodqty_grams==.
browse s7bq2c item_cd if item_cd==140 & foodqty_grams==.
browse s7bq2c item_cd if item_cd==130 & foodqty_grams==.
browse s7bq2c item_cd s7bq2a if item_cd==130 & foodqty_grams==.
browse s7bq2c item_cd s7bq2a if item_cd==122 & foodqty_grams==.
browse s7bq2c item_cd s7bq2a if item_cd==160 & foodqty_grams==.
browse s7bq2c item_cd s7bq2a if item_cd==121 & foodqty_grams==.
browse s7bq2c item_cd s7bq2a if item_cd==105 & foodqty_grams==.

***Computing food energy equivalent
**food qtyin weeks and day
lab var foodqty_grams " food qty in grams per week"
gen foodqty_g_d = foodqty_grams/7
browse foodqty_grams foodqty_g_d
lab var foodqty_g_d "food qty in grams per day"
**Dropping food items with no food energy conversion factor
drop item_cd if item_cd==65 |item_cd ==66 |item_cd ==75 |item_cd ==81 |item_cd ==94 |item_cd==104 |item_cd==133 |item_cd==150 |item_cd==151 |item_cd==152 |item_cd ==153 |item_cd ==155 |item_cd ==162 |item_cd ==163 |item_cd ==164

*Calaculating energy equivalent per food item
gen food_kcal= foodqty_g_d * 1 * (344/100) if item_cd==10
lab var food_kcal "Energy equivalent per food item"

replace food_kcal= foodqty_g_d * 1 * (348/100) if item_cd==11
replace food_kcal= foodqty_g_d * 1 * (349/100) if item_cd==12
replace food_kcal= foodqty_g_d * 1 * (349/100) if item_cd==13
replace food_kcal= foodqty_g_d * 1 * (352/100) if item_cd==14
replace food_kcal= foodqty_g_d * 1 * (249/100) if item_cd==15
replace food_kcal= foodqty_g_d * 1 * (354/100) if item_cd==16
replace food_kcal= foodqty_g_d * 1 * (312/100) if item_cd==17
replace food_kcal= foodqty_g_d * 1 * (335/100) if item_cd==18
replace food_kcal= foodqty_g_d * 1 * (351/100) if item_cd==19
notreplace food_kcal= foodqty_g_d *1 * (345/100) if item_cd==20
replace food_kcal= foodqty_g_d * 1 * (347/100) if item_cd==30
replace food_kcal= foodqty_g_d * 0.81 * (141/100) if item_cd==31
replace food_kcal= foodqty_g_d * 1 * (351/100) if item_cd==32
replace food_kcal= foodqty_g_d * 1 * (351/100) if item_cd==33
replace food_kcal= foodqty_g_d *1  * (136/100) if item_cd==34
replace food_kcal= foodqty_g_d *0.65  * (140/100) if item_cd==35
replace food_kcal= foodqty_g_d * 1 * (115/100) if item_cd==36
replace food_kcal= foodqty_g_d * 1 * (80/100) if item_cd==37
replace food_kcal= foodqty_g_d * 1 * (137/100) if item_cd==38
replace food_kcal= foodqty_g_d * 1 * (410/100) if item_cd==40
replace food_kcal= foodqty_g_d * 1 * (318/100) if item_cd==41
replace food_kcal= foodqty_g_d * 1* (335/100) if item_cd==42
replace food_kcal= foodqty_g_d * 1* (578/100) if item_cd==43
replace food_kcal= foodqty_g_d * 0.37 * (593/100) if item_cd==44
```

```
replace food_kcal= foodqty_g_d * 1 * (900/100) if item_cd==50
replace food_kcal= foodqty_g_d *  1* (730/100) if item_cd==51
replace food_kcal= foodqty_g_d *  1* (900/100) if item_cd==52
replace food_kcal= foodqty_g_d *  1* (900/100) if item_cd==53
replace food_kcal= foodqty_g_d * 0.64 * (106/100) if item_cd==60
replace food_kcal= foodqty_g_d * 0.73 * (45/100) if item_cd==61
replace food_kcal= foodqty_g_d * 0.71 * (76/100) if item_cd==62
replace food_kcal= foodqty_g_d * 0.74 * (154/100) if item_cd==63
replace food_kcal= foodqty_g_d *0.51  * (54/100) if item_cd==64
replace food_kcal= foodqty_g_d * 0.91 * (22/100) if item_cd==70
replace food_kcal= foodqty_g_d * 1 * (20/100) if item_cd==71
replace food_kcal= foodqty_g_d * 0.91 * (33/100) if item_cd==72
replace food_kcal= foodqty_g_d * 0.81 * (30/100) if item_cd==73
replace food_kcal= foodqty_g_d * 0.86 * (33/100) if item_cd==74
replace food_kcal= foodqty_g_d * 0.73 * (45/100) if item_cd==76
replace food_kcal= foodqty_g_d * 0.80 * (42/100) if item_cd==77
replace food_kcal= foodqty_g_d *0.80  * (42/100) if item_cd==78
replace food_kcal= foodqty_g_d * 0.66 * (218/100) if item_cd==80
replace food_kcal= foodqty_g_d * 0.65 * (232/100) if item_cd==82
replace food_kcal= foodqty_g_d * 0.88 * (139/100) if item_cd==83
replace food_kcal= foodqty_g_d * 0.88 * (139/100) if item_cd==84
replace food_kcal= foodqty_g_d * 0.88 * (139/100) if item_cd==85
replace food_kcal= foodqty_g_d * 1 * (126/100) if item_cd==90
replace food_kcal= foodqty_g_d * 0.82 * (257/100) if item_cd==91
replace food_kcal= foodqty_g_d * 1 * (265/100) if item_cd==92
replace food_kcal= foodqty_g_d *0.74  * (165/100) if item_cd==93
replace food_kcal= foodqty_g_d * 1 * (243/100) if item_cd==95
replace food_kcal= foodqty_g_d *0.76  * (127/100) if item_cd==96
replace food_kcal= foodqty_g_d * 0.71 * (124/100) if item_cd==100
replace food_kcal= foodqty_g_d * 0.71 * (124/100) if item_cd==101
replace food_kcal= foodqty_g_d * 0.64 * (151/100) if item_cd==102
replace food_kcal= foodqty_g_d * 0.64 * (151/100) if item_cd==103
replace food_kcal= foodqty_g_d * 0.54 * (119/100) if item_cd==105
replace food_kcal= foodqty_g_d * 1 * (220/100) if item_cd==106
replace food_kcal= foodqty_g_d * 0.55 * (126/100) if item_cd==107
replace food_kcal= foodqty_g_d * 1 * (65/100) if item_cd==110
replace food_kcal= foodqty_g_d * 1 * (495/100) if item_cd==111
replace food_kcal= foodqty_g_d * 1 * (519/100) if item_cd==112
replace food_kcal= foodqty_g_d * 1 * (135/100) if item_cd==113
replace food_kcal= foodqty_g_d * 1 * (73/100) if item_cd==114
replace food_kcal= foodqty_g_d * 1 * (354/100) if item_cd==120
replace food_kcal= foodqty_g_d * 1 * (386/100) if item_cd==121
replace food_kcal= foodqty_g_d * 1 * (0/100) if item_cd==122
replace food_kcal= foodqty_g_d * 1 * (400/100) if item_cd==130
replace food_kcal= foodqty_g_d * 1 * (326/100) if item_cd==132
replace food_kcal= foodqty_g_d *1  * (348/100) if item_cd==140
replace food_kcal= foodqty_g_d * 1 * (44/100) if item_cd==154
replace food_kcal= foodqty_g_d * 1 * (35/100) if item_cd==160
replace food_kcal= foodqty_g_d * 1 * (34/100) if item_cd==161
```

```
**Age-sex adult equivalent factor computation
keep zone state lga sector ea hhid indiv s1q2 s1q3 s1q4 s1q5_day s1q5_month s1q5_year
gen age_sex_AE = 0.27  if s1q4<=1
lab var age_sex_AE "Age-sex adult equivalent factor for post planting HH wave 1"
replace age_sex_AE = 0.45 if s1q4>1 & s1q4<=3
replace age_sex_AE = 0.61 if s1q4>3 & s1q4<=6
replace age_sex_AE = 0.73 if s1q4>6 & s1q4<=9
replace age_sex_AE = 0.86 if s1q4>9 & s1q4<=12 & s1q2==1
replace age_sex_AE = 0.78 if s1q4>9 & s1q4<=12 & s1q2==2
replace age_sex_AE = 0.96 if s1q4>12 & s1q4<=15 & s1q2==1
replace age_sex_AE = 0.83 if s1q4>12 & s1q4<=15 & s1q2==2
replace age_sex_AE = 1.02 if s1q4>15 & s1q4<=19 & s1q2==1
replace age_sex_AE = 0.77 if s1q4>15 & s1q4<=19 & s1q2==2
replace age_sex_AE = 1.00 if s1q4>=20 & s1q2==1
replace age_sex_AE = 0.73 if s1q4>=20 & s1q2==2

**Calculating Total Adult Equivalent per  household
egen HH_AE = sum (age_sex_AE), by(hhid)
lab var HH_AE "Household Adult Equivalent Factor"

preserve
collapse (sum) Household_AE=age_sex_AE, by(hhid)
lab var Household_AE "Total Adult Equivalent factor for each PPW1_HH"

**Calculating calories consumption per household
egen HH_food_Kcal = sum (food_kcal), by(hhid)
drop HH_food_Kcal

preserve
collapse (sum) HH_food_Kcal=food_kcal, by(hhid)
lab var HH_food_Kcal "kilocalories consumption per household per day"
save collapse_calories_consumption

mmerge hhid using "collapse_AdultEquivalent_HH.dta",  type (spread) ukeep (Household_AE)
save collapse_calories_consumption_AE

** calculating DAILY ENERGY ACQUISITION PER ADULT EQUIVALENT
gen kcal_AE_PPW1= HH_food_Kcal/ Household_AE
lab var kcal_AE_PPW1 "AE_Kcal consumption per day for postplanting household"

***Estimating calorie consumption per adult equivalent for HH with missing observations
** First imputation command - regressing with only two independent variable
misstable summarize HH_food_Kcal Household_AE kcal_AE HHsize
mi set mlong
mi register imputed HH_food_Kcal
mi register regular HHsize
mi register regular Household_AE
```

```
mi impute regress HH_food_Kcal HHsize Household_AE, add(1)
** Second imputation command
mmerge hhid using "educationPP.dta",  type (spread) ukeep (sector s1q4 literacy s1q2)
drop _merge
mi set mlong
mi register imputed HH_food_Kcal
mi register regular Household_AE
mi register regular HHsize sector s1q2 s1q4 literacy
mi impute regress HH_food_Kcal Household_AE HHsize sector s1q2 s1q4 literacy, add(1)

**Replace the missing values
replace HH_food_Kcal = 7511.683 in 594
replace HH_food_Kcal = -4466.452 in 150
drop in 801/802
replace kcal_AE= HH_food_Kcal/ Household_AE
replace kca_PC=HH_food_Kcal/HHsize

***Calculating TOTAL HOUSEHOLD ENERGY CONSUMPTION PER CAPITA
mmerge hhid using "HHsize.dta",  type (spread) ukeep (HHsize )
gen kca_PC=HH_food_Kcal/HHsize
lab var kca_PC "Total HH calories consumption per capita"]


**Quartile Calculation
        **for  Kcal consumption per Adult Equivalent per day
xtile kcal_AE_quartile= kcal_AE [pweight= wt_wave1], nq(4)
lab var kcal_AE_quartile "4 quartile for daily kilocalories consumption per adult equivalent "
        **For calories consumption per capita
xtile kca_PC_quartile= kca_PC [pweight= wt_wave1], nq(4)
lab var kca_PCquartile "4 quartile for total HH calories consumption per capita for PPW1 households"
```

Data cleaning for calorie consumption

```
use "C:\Users\Otu Ibok\Google Drive\NGA_2012_LSMS_v03\DATA\Calorie_consumption_W2\Kcal_PPW2\HHfood_kcal_PPW2.dta"
list hhid HHfood_kcal_PPW2 foodkcal_AE if foodkcal_AE >10000 & foodkcal_AE~=.

**CHECKIN ERROR CAUSED BY MY IMPUTATION
*** Converting all food calibrated in centiliter (*Mistaked this to be militer) to grams
replace foodqty_grams_PPW2 = s7bq2a * 10 if s7bq2b==4

*HHid==90019 (found that beef was wronly computed)
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if hhid ==90019
*Meat-beef
replace foodqty_grams_PPW2 = s7bq2a * 1 in 4344
        *HHid==90095
Did not find any problem. Although cassava consumption was high
```

*HHid==90098
Did not find any problem
HHid=90122
change qaunty (item_cd=50 -cassava root) from 150kg to 15kg
replace s7bq2a = 15 in 5762
(1 real change made)
. replace foodqty_grams_PPW2 = 15000 in 5762
(1 real change made)

*HHid==90130
changed cocoyam quantity(item_cd==30) from 20kg to 2.0kg
replace s7bq2a = 2.0 in 5861
(1 real change made)
. replace foodqty_grams_PPW2 = 2000 in 5861
(1 real change made)

CHECKING ERROR CAUSED by NBS DATA ENTRY ERROR
*FOR item_cd==36 (sweet potatoe) & s7bq2b==1
sum s7bq2a if s7bq2b==1 & item_cd==36

. sum s7bq2a if s7bq2b==1 & item_cd==36, det

*HHid==90121
changed sweet potatoe quantity from 30kg to 3.0kg
replace s7bq2a = 3 in 5748
. replace foodqty_grams_PPW2 = 3000 in 5748
*HHid==90122
Changed sweet potatoe from 20kg to 2kg
replace s7bq2a = 2 in 5765
. replace foodqty_grams_PPW2 = 2000 in 5765

*HHid==90130
sweet potatoe from 20kg to 2kg
replace s7bq2a = 2 in 5862
(1 real change made)
. replace foodqty_grams_PPW2 = 2000 in 5862
(1 real change made)

*FOR item_cd==30 (cassava) & s7bq2b==1
. sum s7bq2a if s7bq2b==1 & item_cd==30
. sum s7bq2a if s7bq2b==1 & item_cd==30, det
*HHid=30002
change from 100kg cassava to 50kg cassava
replace foodqty_grams_PPW2 = 50000 in 23
replace s7bq2a = 50 in 23

*HHid=90063
change from 100kg cassava to 50kg cassava

replace foodqty_grams_PPW2 = 50000 in 4982
replace s7bq2a = 50 in 4982

*HHid=90067
change from 100kg cassava to 50kg cassava
replace foodqty_grams_PPW2 = 50000 in 5040
replace s7bq2a = 50 in 5040

*HHid=90113
change from 100kg cassava to 50kg cassava
replace foodqty_grams_PPW2 = 50000 in 5667
replace s7bq2a = 50 in 5667

*FOR item_cd==33 (Garri -Yellow) & s7bq2b==1 (Kg)
sum s7bq2a if s7bq2b==1 & item_cd==33
. sum s7bq2a if s7bq2b==1 & item_cd==33, det
*HHid=100076
change 100kg to 10kg
replace foodqty_grams_PPW2 = 10000 in 7086
replace s7bq2a = 10 in 7086

*HHid==100113
change sugar(item_cd=130) qty from 100kg to 10kg
replace foodqty_grams_PPW2 = 10000 in 7684
replace s7bq2a = 10 in 7684

*HHid==100113
Changed condiment(item_cd =140) qty from 250kg to 2.5kg
replace foodqty_grams_PPW2 = 2500 in 7685
replace s7bq2a = 2.5 in 7685

*HHid==320080
Changed condiment(item_cd =140) qty from 200kg to 2.0kg
replace foodqty_grams_PPW2 = 2000 in 11301
replace s7bq2a = 2 in 11301

*HHid==120036
Changed maize-unshelled (item_cd=20) qty from 900 mudu to 9 mudu
replace s7bq2a = 9 in 8842
replace foodqty_grams_PPW2 = 13500 in 8842

*HHid==320191
changed palm oil (item_cd=50) qty from 75 litre to 0.75 litre
replace s7bq2a = 0.75 in 13099
replace foodqty_grams_PPW2 = 750 in 13099

*HHid==100119
changed palm oil (item_cd=50) qty from 100 litre to 1 litre
replace foodqty_grams_PPW2 = 1000 in 7783

replace s7bq2a = 1 in 7783

*HHid==320204
changed bread (item_cd=25) qty from 800kg to 8kg
replace foodqty_grams_PPW2 = 8000 in 13271
replace s7bq2a = 8 in 13271
sum s7bq2a if s7bq2b==1 & item_cd==25, det

. sum s7bq2a if s7bq2b==1 & item_cd==25

*frequently use commands
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if item_cd==30 & s7bq2b==1
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if hhid==320204
sum s7bq2a if s7bq2b==1 & item_cd==25
sum s7bq2a if s7bq2b==1 & item_cd==25, det

**SECOND stage of cleaning data for hh with foodkcal_AE between 5,000kcal and 10,000 kcal
. list hhid HHfood_kcal_PPW2 foodkcal_AE if foodkcal_AE >5000 & foodkcal_AE <=10000 & foodkcal_AE~=.

*HHid==90062
Changed orange/tangerine (item_cd==61) from 120kg to 12.0kg
replace foodqty_grams_PPW2 = 12000 in 4973
replace s7bq2a = 12 in 4973
. sum s7bq2a if s7bq2b==1 & item_cd==61

. sum s7bq2a if s7bq2b==1 & item_cd==61, det

USING item_cd TO CLEAN DATA
* I summarize the variable (foodqty_grams_PPW2) whic food quantity in grams per week.
* This help me to identify food items with extreem values

by item_cd, sort: sum foodqty_grams_PPW2

*command mostly used for data cleaning using "summarize" and "item_cd"
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if foodqty_grams_PPW2==147000
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if item_cd==71
browse hhid item_cd item_desc s7bq2a s7bq2b conv g_cl foodqty_grams_PPW2 foodqty_g_d_PPW2 food_kcal_PPW2 if item_cd==71 & s7bq2b==11

*hhid=100090
changed tomatoe puree (item_cd==71) from 70 small derica (s7bq2b==11) to 7 small derica
replace s7bq2a = 7 in 6362
replace foodqty_grams_PPW2 = 7350 in 6362

*hhid=100088
changed tomatoe puree (item_cd==71) from 140 small derica (s7bq2b==11) to 14 small derica
replace s7bq2a = 14 in 6389
replace foodqty_grams_PPW2 = 14700 in 6389

*hhid=100089
changed tomatoe puree (item_cd==71) from 70 small derica (s7bq2b==11) to 7 small derica
replace s7bq2a = 7 in 6293
replace foodqty_grams_PPW2 = 7350 in 6293

*hhid=90118
changed cassava root (item_cd=30) from 14 paint rubber (s7bq2b=8) to 1.4 paint rubber
replace s7bq2a = 1.4 in 1810
replace foodqty_grams_PPW2 = 7728 in 1810

*hhid=90062
changed yam root(item_cd=31) for 60kg to 50kg
replace s7bq2a = 50 in 2130
replace foodqty_grams_PPW2 = 50000 in 2130

*hhid=90057
changed yam root(item_cd=31) for 70kg to 50kg
replace s7bq2a = 50 in 2249
replace foodqty_grams_PPW2 = 50000 in 2249

*hhid=30047
changed plantain(item_cd=35) from 50kg to 5kg
replace s7bq2a = 5 in 3234
replace foodqty_grams_PPW2 = 5 * 1000 in 3234

*hhid=100132
changed groundnut (item_cd=43) unit from 1 paint rubber(s7bq2b==8) to kg (s7bq2b==1)
replace s7bq2b = 1 in 4326
replace foodqty_grams_PPW2 = 1000 in 4326

*hhid=100130
change pineapple (item_cd=64) from 350kg to 3.5kg
replace foodqty_grams_PPW2 = 3500 in 5900
replace s7bq2a = 3.5 in 5900

*hhid=90083
changed onion (item_cd=72) from 300kg to 3kg
replace foodqty_grams_PPW2 = 3000 in 6925
replace s7bq2a = 3 in 6925

*hhid=320094
changed onion (item_cd=72)from 700kg to 7kg
replace s7bq2a = 7 in 7362
replace foodqty_grams_PPW2 = 7000 in 7362

*hhid =320072
changed garden egg(item_cd=73) from 65.4kg to 0.65kg
replace s7bq2a = .65400002 in 7423
replace foodqty_grams_PPW2 = 654 in 7423

*hhid=100113
changed sugar (item_cd=130)from 10kg to 0.1kg
replace s7bq2a = 0.1 in 11660
replace foodqty_grams_PPW2 = 100 in 11660

*hhid=320056
change honey(item_cd=132) from 20 litre (s7bq2b=3) to 2 litre
replace s7bq2a = 2 in 11842
replace foodqty_grams_PPW2 = 2000 in 11842

*hhid=60020
change condiment (item_cd=140) from 24 litre (s7bq2b=3) to 24 grams
replace s7bq2b = 2 in 12360
replace foodqty_grams_PPW2 = 24 in 12360

*DROPPING food item_cd that do not have energy equivalent
tab item_cd if food_kcal_PPW2==.

CLEANING DATA BY CHECKING food-enegry and edible portion coversion factor
* HHid =90043
Cassava-root (item_cd=30), reduce enegy content from 347 to 160 (source: USDA)
palm oil (item_cd=50), from 900 to 884

*Cassava-root
replace foodenergy=159 if item_cd==30
(161 real changes made)

*Gari-white
replace foodenergy=330 if item_cd==32
(219 real changes made)

*Garri-Yellow
replace foodenergy=330 if item_cd==33
(478 real changes made)

*G/oil
replace foodenergy=884 if item_cd==52
(216 real changes made)

*G/nut
replace foodenergy=567 if item_cd==43
(234 real changes made)

```
*Palm oil
replace foodenergy=884 if item_cd==50
(709 real changes made)

*Rice-local
replace foodenergy= if item_cd==

*Rice-imported
replace foodenergy= if item_cd==

*Yam-root
replace foodenergy= if item_cd==

* recalculating kilocalorie consumption
replace food_kcal_PPW2 = foodqty_g_d_PPW2 * edibleportion * (foodenergy/100)
(2017 real changes made)

*Summing food consumption in kcal by HH
egen HHfood_kcal_PPW2 = sum ( food_kcal_PPW2), by (hhid)
lab var HHfood_kcal_PPW2 " Household food consumption in kcal for PPW2"
```

USING FAO & USDA FOOD CONVERSION FACTOR TO CORRECT FOR CALORIE CONSUMPTION

```
use "C:\Users\Otu Ibok\Google Drive\NGA_2012_LSMS_v03\DATA\Calorie_consumption_W2\Kcal_PPW2\backup_Calorie_W2\sect7b_plantingw2 - BackupCopy.dta"

mmerge item_cd using "C:\Users\Otu Ibok\Google Drive\NGA_2012_LSMS_v03\DATA\Calorie_consumption_W2\USDA_FAO_foodenergy_ppw2.dta", type (spread) ukeep(foodenergy_faousda edibleportion_faousda)

*calculating food energy using FAO & USDA food conversion factor
gen foodkcal2_PPW2 = foodqty_g_d_PPW2 * edibleportion_faousda * (foodenergy_faousda/100)
lab var food_kcal_PPW2 "kcal food consumption per day FAO_USDA"
(306 missing values generated)

*CORRECTING ADULT EQUVALENCE SCALE
* The previous AE scale was estimating per capital consumption per adult male. In otherwords it look at what the consumption of HH will be if these HH consist of only male. Howevere, am looking for the actual consumption and not the requirement.
gen age_AE2_PPW2 = 0.27  if s1q6<=1
lab var age_AE2_PPW2 "Actual adult equivalent factor for post planting HH wave 2"
replace age_AE2_PPW2 = 0.45 if s1q6>1 & s1q6<=3
replace age_AE2_PPW2 = 0.61 if s1q6>3 & s1q6<=6
replace age_AE2_PPW2 = 0.73 if s1q6>6 & s1q6<=9
replace age_AE2_PPW2 = 0.86 if s1q6>9 & s1q6<=12 & s1q2==1
replace age_AE2_PPW2 = 0.78 if s1q6>9 & s1q6<=12 & s1q2==2
```

```
replace age_AE2_PPW2 = 0.96 if s1q6>12 & s1q6<=15 & s1q2==1
replace age_AE2_PPW2 = 0.83 if s1q6>12 & s1q6<=15 & s1q2==2
replace age_AE2_PPW2 = 1.00 if s1q6>15 & s1q6<=19 & s1q2==1
replace age_AE2_PPW2 = 1.00 if s1q6>15 & s1q6<=19 & s1q2==2
replace age_AE2_PPW2 = 1.00 if s1q6>=20 & s1q2==1
replace age_AE2_PPW2 = 1.00 if s1q6>=20 & s1q2==2

** computing HH size adjusted for adult equivalent according hhid
egen HHsize_AE2 = sum (age_AE2_PPW2), by(hhid)
lab var HHsize_AE2 "AE household size after correcting for adult equivalent"
**Collapse
preserve
collapse (sum) HHsize_AE2_PPW2 = age_AE2_PPW2, by (hhid)
lab var HHsize_AE2_PPW2 "AE household size after correcting for adult equivalent"
```

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