Impact of different livelihood strategies on welfare of smallholder farmers: case studies from India, Kenya and Tanzania

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Dedication

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Zusammenfassung

In Entwicklungsländern spielt der Agrarsektor eine wichtige Rolle für die nationale Wirtschaft und Ernährungssicherheit, für die Produktion heimischer Güter, für den Handel und die Beschäftigung. Kleinbäuerliche Landwirtschaft dominiert den Sektor und stellt den Großteil der landwirtschaftlichen Erzeugnisse her. Diese Kleinbauern sind konfrontiert mit verschiedenen Herausforderungen wie geringer Produktivität, volatilen Marktpreisen, Unterernährung, Nahrungsunsicherheit und Armut. Deshalb können Innovationen, die sich auf Produktivitätssteigerung beziehen oder in Richtung alternative Märkte wirken oder die Produktion diversifizieren, u.a., den Kleinbauern helfen sich mit den genannten Herausforderungen auseinanderzusetzen.

Vor diesem Hintergrund ist das übergeordnete Ziel dieser Thesis die Rolle verschiedener Strategien zur Existenzsicherung in Bezug auf die Wohlfahrt (Einkommen und Ernährungssicherheit) von Bauern in Indien, Kenia und Tansania zu verstehen. Genauer gesagt, sind die Ziele folgende: a) die Entscheidung der Bauern zur Teilnahme an „Fair Trade“-Zertifizierung zu analysieren und den Einfluss der Teilnahme auf Wohlfahrt in Form von Einkommen der Kleinproduzenten in Indien, b) die Verknüpfung von Standards mit der heimischen Nahrungsmittelwertschöpfungskette in Subsahara-Afrika mit dem Fallbeispiel Kenia zu beschreiben, c) die Determinanten der technischen Effizienz zu identifizieren und ihren Einfluss auf verschiedene Dimensionen der Ernährungssicherheit in Kenia zu analysieren, d) die Beziehung zwischen Produktions- und Ernährungsvielfalt in ländlichen und stadtnahen Gebieten Kenias zu bewerten, und e) die Beziehung zwischen Produktions- und Nahrungsvielfalt zu vergleichen mithilfe von Fallstudien aus Kenia und Tansania. Die Fallstudien basieren auf in 2014 erhobenen Querschnittsdaten aus Kenia und Tansania und Paneldaten aus Indien, erhoben in 2010 und 2011.

Kapitel 2 und 3 beziehen sich auf „Fair Trade“-Zertifizierung und Nahrungsmittelstandards in Indien und Kenia. In Kapitel 2 wird die Entscheidung der Produzenten, an der Zertifizierung für fair gehandelten Kaffee teilzunehmen, und der Einkommenseffekt durch die Teilnahme an dieser analysiert. Auf Basis der Paneldaten und unter Verwendung der „Endogenous Switching“- bzw. der quantilen Regressionsmethoden bestätigen die Ergebnisse einen positiven Effekt von Fairer-Handel-Zertifizierung auf das Einkommen der Bauern vor allem im unteren Einkommensquantil. Kapitel 3 beschreibt basierend auf Literaturrecherche die Rolle von Standards in der heimischen Nahrungsmittelwertschöpfungskette in Subsahara-

Afrika mit dem Fallbeispiel Kenia. Es befindet, dass der Fokus privater Standards hauptsächlich auf dem heimischen Markt liegt, obwohl sowohl private als auch staatliche Standards in der untersuchten Region eingeführt wurden. Privatstandards sind insbesondere im Gemüsesektor durch die Supermärkte verbreitet und beziehen sich meist auf Qualitätsattribute des Produktes.

Der Einfluss technischer Effizienz auf die Dimensionen der Ernährungssicherheit (Verfügbarkeit, Zugang, Verwertung und Stabilität) der auf indigenes afrikanisches Gemüse spezialisierten Bauern wird in Kapitel 4 mithilfe eines „Cobb-Douglas stochastic frontier model“ und „propensity score matching“ untersucht. Die Ergebnisse weisen auf eine hohe Streuung technischer Effizienz unter den Produzenten des indigenen afrikanischen Gemüses hin. Durch eine bessere Nutzung verfügbarer Ressourcen bei gegebenem Technologiestand, könnte die technische Effizienz der Produzenten gesteigert werden. Eine höhere technische Effizienz bedeutet einen höheren Ernährungsstatus, wie die positiven Effekte der technischen Effizienz auf die Dimensionen der Ernährungssicherheit Verfügbarkeit, Zugang und Verwertung zeigen.

Kapitel 5 und 6 beziehen sich auf die Rolle der Produktionsvielfalt auf die Ernährungsvielfalt der Kleinbauern. Die Assoziation zwischen Produktions- und Ernährungsvielfalt wird in Kapitel 5 mithilfe verschiedener Marktkontexte, wie den ländlichen und den stadtnahen Gebieten Kenias, bewertet. Während ländliche Haushalte eine größere Produktionsvielfalt als stadtnahe Haushalte aufweisen, ist ihre Ernährungsvielfalt jedoch geringer im Vergleich zu stadtnahen Haushalten. Die Ergebnisse der Poisson- und der negativen binomialen Regression deuten auf eine positive Verbindung zwischen Produktions- und Ernährungsvielfalt im ländlichen Kontext. Resultate des „continuous treatment”-Ansatzes lassen erkennen, dass ein höheres Level der Produktionsvielfalt mit einem höheren Level der Ernährungsvielfalt assoziiert ist. Kapitel 6 ist ein vergleichendes Papier über die Assoziation zwischen Produktions- und Ernährungsvielfalt zwischen Kenia und Tansania. Die deskriptive Analyse zeigt signifikante Unterschiede in Bezug auf die Produktions- und Ernährungsvielfalt zwischen den Ländern auf. Kenianische Bauern stehen für eine höhere Produktions- sowie Ernährungsvielfalt als tansanische Bauern. In beiden Ländern zeigt sich eine positive und signifikante Verbindung zwischen Produktions- und Ernährungsvielfalt. Dieser Einfluss ist in beiden Ländern jedoch signifikanter in Regionen mit geringerem Marktzugang. Über die

Produktionsvielfalt hinaus spielen die Märkte also auch eine wichtige Rolle zur Unterstützung der Ernährungsvielfalt der Haushalte.

Stichwörter: Kleinbauern, Kaffee, Fair Trade-Zertifizierung, Lebensmittelstandards, Bauern für indigenes afrikanisches Gemüse, technische Effizienz, Ernährungssicherheit, Produktionsvielfalt, Ernährungsvielfalt, Indien, Kenia, Tansania

Abstract

In developing countries, agriculture sector plays an important role for their national economy and food security, including domestic production, trade and employment. The sector is dominated by small-scale farming which accounts for the majority of total agricultural output. These smallholders are faced with several challenges such as low productivity, volatile market prices, undernourishment, food insecurity and poverty. Therefore, upgrading strategies related to increasing efficiency, working through alternative markets and diversifying farm production, among many others help small-scale farmers to deal with the above mentioned challenges.

Against this background, the overall objective of this thesis is to understand the role of different livelihood strategies on the welfare (income and food security) of farmers in India, Kenya and Tanzania. The specific objectives are as follows: a) to analyze farmers´ decision to participate in coffee fair trade certification and the welfare impacts of participation in terms of income for small-scale producers in India, b) to describe the linkage between standards and the domestic food value chain in Sub-Saharan Africa taking Kenya as a case study region, c) to identify the determining factors of technical efficiency and analyze its influence on different dimensions of food security in Kenya, d) to assess the relationship between production diversity and dietary diversity in rural and peri-urban Kenya, and e) to compare the relationship between production diversity and dietary diversity using case studies from Kenya and Tanzania. The case studies are based on cross-sectional data from Kenya and Tanzania collected in 2014 and panel data from India collected in 2010 and 2011.

Chapters 2 and 3 are related to fair trade certification and food standards in India and Kenya respectively. In chapter 2, participation decision of producers to fair trade coffee certification and the income impact of participation are analyzed. Using panel data and employing endogenous switching and quantile regression methods, the findings confirm a positive effect of fair trade certification on income of farmers with the farmers in the poorer quantiles having the largest income gains. Based on a literature review, chapter 3 describes the role of standards in the domestic food value chains in Sub-Saharan Africa taking Kenya as a case study region. The paper finds that private standards mainly focus on the domestic market, although both private and public standards are implemented in the study region. Private standards particularly for the vegetable sector are driven by supermarkets and these standards mostly relate to quality attributes of the product.

The influence of technical efficiency on the different dimensions of food security (availability, access, utilization and stability) of African Indigenous Vegetable farmers is analyzed using Cobb-Douglas stochastic frontier model and propensity score matching technique in chapter 4. Results reveal a wide variation of technical efficiency among African Indigenous Vegetables producers. Through better use of available resources given the existing technology, the technical efficiency of producers could be increased. Higher technical efficiency improves the food security status as shown by positive impacts of technical efficiency on availability, access and utilization dimensions of food security.

Chapters 5 and 6 are related to the role of production diversity for the dietary diversity of small-scale farmers. In chapter 5 the association between production diversity and dietary diversity is assessed using diverse market contexts such as rural and peri-urban settings in Kenya. While rural households maintained a higher level of production diversity than peri-urban households, their dietary diversity is lower as compared to peri-urban households. Poisson and negative binomial regressions show a positive association between production diversity and dietary diversity in the rural region. Findings from the continuous treatment approach reveal that higher levels of production diversity are associated with higher levels of dietary diversity. Chapter 6 is a comparative paper about the association between production diversity and dietary diversity between Kenya and Tanzania. Descriptive analyses show significant differences in terms of production and dietary diversity between countries. Kenyan farmers maintained higher production diversity and have higher dietary diversity than Tanzanian farmers. In both countries, a positive and significant association between production diversity and dietary diversity is observed. However, the influence is more significant in areas characterized by less market access in Kenya and in Tanzania. Beyond farm production diversity, markets also play important roles in enhancing the dietary diversity of the households.

Keywords: Smallholders, coffee, fair trade certification, food standards, African Indigenous vegetable farmers, technical efficiency, food security, production diversity, dietary diversity, India, Kenya, Tanzania

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List of abbreviations

$	Dollar
AIVs	African Indigenous Vegetables
ATT	Average Treatment Effect on the Treated
CIA	Conditional Independence Assumption
DRF	Dose Response Function
e.g.	For example
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FVS	Food Variety Score
GoK	Government of Kenya
GPS	Generalized Propensity Score
ha	Hectares
HDDS	Household Dietary Diversity Score
HFIAS	Household Food Insecurity Access Scale
HH	Household
IFAD	International Fund for Agricultural Development
km	Kilometers
MAHFP	Months of Adequate Household Food Provisioning
NNM	Nearest Neighbor Matching
PD	Production Diversity
PPP	Purchasing Power Parity
PSM	Propensity Score Matching
TE	Technical Efficiency
TLU	Tropical Livestock Unit
UNEP	United Nations Environment Programme
WFP	World Food Programme

Chapter 1: Introduction

1.1 Background of the study

The agricultural sector is important for most developing countries including Kenya, India and Tanzania because of its contribution to national economy and food security through overall domestic production, trade and employment (World Bank, 2007; Diaz-Bonilla, 2015). For example, in India, agriculture contributed to 16.8% of GDP, constituted 10% of the country´s exports and around 49% of the labor force in 2016. Similarly in 2016, agricultural sector in Kenyan economy accounted for 65% of export earnings, contributed 33% of GDP and employed around 75% of the work force. In Tanzania, agriculture provided 85% of the export earnings, contributed to 25% of its GDP and employed about 65% of the work force (CIA, 2017).

The sector is dominated by small-scale farming which accounts for the majority of these countries’ total agricultural output. Majority of these small-scale farmers have limited access to means of productive assets such as land, labor, tool etc, farming technology and credits and insurance. As a result, small-scale farmers are vulnerable to several challenges including but not limited to low productivity, volatile market prices, credit constraints, supply shocks, and high transaction costs. These challenges accelerate the exclusion of small-scale farmers from remunerative agricultural value chains. In addition, all these problems lead to low income, food insecurity and ultimately poverty. To deal with the above problems, several strategies have been widely advocated such as increasing efficiency, working through alternative market channels and also diversifying farm production. Agriculture has huge importance to alleviate poverty compared to other sectors such as industry and services especially in developing countries. Therefore, increasing the efficiency of agricultural production improves household food and nutrition security and income of smallholders and thus helps to reduce poverty (Bogale, 2012; Ogundari, 2014). Alternative market channels such as fair trade, organic are seen to be favorable for small-scale producers (Raynolds et al., 2007) in response to volatile market prices, credit constraints, and supply shocks. Diverse production systems such as growing crops and raising livestock are assumed to enhance food and nutrition security, and livelihoods of small-scale farmers (Fanzo and Mattei, 2012; IFAD and UNEP, 2013; Herrero et al., 2010) mainly through income obtained from the sale of farm produce and through consumption of food from own production (World Bank, 2007). Particularly, production diversity improves the household dietary diversity through the access of a diverse variety of foods (Fanzo and Mattei, 2012; Berti and Jones, 2013).

Against this background, this thesis aims to examine the role of food standards, technical efficiency and production diversity on welfare and food security aspects of small-scale farmers in India, Kenya and Tanzania. These case studies are unique because of the following reasons: (1) the case study from India is the first one to look at coffee certification and welfare by using the panel data set; (2) with respect to Kenya there are no studies that have empirically analyzed the impact of technical efficiency of African Indigenous Vegetables production on different dimensions of food security; and (3) there is little empirical evidence on the impact of degrees of production diversity on dietary diversity in Kenya, treating production diversity as a continuous variable. Furthermore, the relationship between production diversity and dietary diversity is compared using the cases of Kenya and Tanzania, thus capturing diverse market and agro-ecological contexts.

1.2 Research objectives

The overall objective of this thesis is to understand the impact of different livelihood strategies on the welfare of smallholder farmers in India, Kenya and Tanzania. The specific objectives are the following:

1. To analyze farmers´ decision to participate in fair trade certification and the welfare impacts of participation in terms of income for small-scale producers in India.
2. To describe the linkage between standards and the domestic food value chain in Sub-Saharan Africa taking Kenya as a case study region.
3. To identify the determining factors of technical efficiency and analyze the influence of technical efficiency on different dimensions of food security in Kenya.
4. To assess the relationship between production diversity and dietary diversity in rural and peri-urban Kenya.
5. To compare the relationship between production diversity and dietary diversity using case studies from Kenya and Tanzania.

1.3 Structure of the dissertation and main findings

This thesis is structured into six different chapters. Chapter 1 provides general introduction to the thesis including some background information, stating research problems, highlighting research objectives and providing structural arrangement of the thesis. Chapters 2 to 6 are specific articles from India, Kenya and Tanzania. A summary of the articles included in this thesis is presented in Table 1.1 and each chapter is briefly elaborated below.

Chapter 2 analyzes the participation decision and income impacts of fair trade coffee certification in India. The study employs endogenous switching and quantile regression methods to analyze the panel data collected in 2010 and 2011. Results show that fair trade certification has a positive effect on income of certified farmers. Furthermore, farmers in the poorer quantiles have the largest income gains. This shows that fair trade certification has a "bottom of the pyramid" effect.

Chapter 3 is a review article which explores the role of standards in domestic food value chains in Sub-Saharan Africa specifically focusing on Kenya as a case study region. This article provides information on different kinds of implemented standards, drivers of food standards and impacts of food standards on producers and consumers. Both public and private standards exist in the study region. Private standards, mostly product and to some extent process standards, mainly focus on the domestic market. Particularly for the vegetable sector, supermarkets are identified to be the major driver of private standards, which relate mostly to quality attributes of the product. Supermarkets have especially adopted the standards originated from international markets. Mixed results exist on impact studies of standards on export supply chains, sometimes creating a barrier for producers to participate in the food chain and sometimes acting as a catalyst. Consumers are willing to pay for safer vegetables in Kenya, thus providing incentives to implement safety standards in domestic market.

Chapter 4 presents an article that focuses on the influence of technical efficiency on the different dimensions of food security such as availability, access, utilization and stability. A Cobb-Douglas stochastic frontier model is used to derive the technical efficiency and the determining factors of technical efficiency. The Propensity Score Matching approach is used to analyze the impact of technical efficiency on the four dimensions of food security. Results reveal a mean technical efficiency index of 36%. The results show that through better use of available resources given the existing technology, the technical efficiency of producers could be increased. Likewise, higher technical efficiency improves the food security status as shown by positive impacts of technical efficiency on the availability, access and utilization dimensions of food security.

Chapter 5 evaluates the association between production diversity and dietary diversity using a diverse market context such as rural and peri-urban settings in Kenya. Using Poisson and negative binomial regressions, the study analyzes the factors that determine the production diversity and the association between production diversity and dietary diversity. A continuous treatment approach is used to evaluate the effect of degree of diversification on dietary diversity. Result show that production and dietary diversity differ between rural and peri-urban regions. Rural region have higher production diversity while the peri-urban region have higher dietary diversity. Moreover, a positive association between production diversity and dietary diversity is observed in the rural region. As shown by continuous treatment approach, higher levels of production diversity are associated with higher levels of dietary diversity.

Chapter 6 compares the association between production diversity and dietary diversity from Kenya and Tanzania. The study uses descriptive analysis and Poisson and negative binomial regressions. Differences among Kenya and Tanzania are observed where Kenyan smallholders have higher production diversity as well as dietary diversity than Tanzanian smallholders. Farm production diversity has a positive and significant influence on household dietary diversity in both countries. This influence is more significant in areas characterized by less market access. Results also stress the importance of markets in influencing dietary diversity in addition to farm production diversity.

Table 1.1: List of articles included in the dissertation

S.N.	Name of the article	Authors	Published in/Submitted to/ Presented at
1	Fair Trade Certification and Livelihoods: A Panel Data Analysis of Coffee-growing Households in India (2016)	Sabina Khatri Karki, Pradyot Ranjan Jena, Ulrike Grote	Published in: *Agricultural and Resource Economics Review (ARER)*, 45 (3): 436-458 Sabina Khatri Karki Received the 2017 ARER Young Scholar Award in Washington DC, USA. Earlier version presented and contributed to Tropentag 2013 "Agricultural development within the rural-urban continuum" September 17-19, Stuttgart Hohenheim URL: http://www.tropentag.de/2013/abstracts/links/Khatri_Karki_7bOY9cjv.php

2	The Role of Standards in Domestic Food Value Chains in Sub-Saharan Africa: A Review Article (2016)	Sabina Khatri Karki, Anja Fasse, Ulrike Grote	Published in: *African Journal of Horticulture Science*, 9 :41-54
3	Technical Efficiency and Food Security: Evidence from African Indigenous Vegetable Smallholders in Kenya (2017)	Sabina Khatri Karki, Anja Fasse, Ulrike Grote	Submitted to: *Land Use Policy* (Under Review) Earlier version presented at 2nd Annual International Conference on Poverty and Sustainable Development, December 15-16, 2015 in Colombo, Sri Lanka, Sabina Khatri Karki received the Best Student Presentation Award in Colombo, Sri Lanka. Earlier version presented and contributed to the Tropentag 2015 "Management of land use systems for enhanced food security - conflicts, controversies and resolutions" Humboldt University, September 16-18, Berlin.URL: http://www.tropentag.de/2015/abstracts/links/Khatri_Karki_eR1AGLcb.pdf
4	Farm Production Diversity and Household Dietary Diversity in Rural and Peri-urban Kenya (2017)	Sabina Khatri Karki, Anja Fasse, Ulrike Grote	Submitted to: *Agriculture and Human Values* Earlier version presented during Poverty Reduction, Equity and Growth Network conference, September 11-12, 2017 in Zürich, Switzerland. Earlier version presented during Northeastern Agriculture and Resource Economics Association annual meeting and workshop, June 11-14, 2017 in Washington DC, USA.
5	Diversity in Farm Production and Household Diets:	Luitfred Kissoly, Sabina Khatri Karki, Ulrike Grote	Submitted to: *Studies in Comparative International Development* Earlier version presented during 57th annual

Comparing Evidence from Smallholders in Kenya and Tanzania (2017)	conference of the German Society of Economic and Social Sciences in Agriculture and 27th annual conference of the Austrian Society of Economics, September 13-15, 2017 in Freising-Weihenstephan, Germany

Source: Own illustration

Note: Authors´ contributions to the papers are as follows: For chapter 1, Sabina Khatri Karki participated in collecting the second wave data, performed data cleaning and analysis and wrote the paper. Pradyot Ranjan Jena supervised during data collection, provided suggestions on methodology and revised parts of the paper. For Chapter 2-4, Sabina Khatri Karki generated the idea, involved in collecting data, performed statistical analyses and wrote the papers. Anja Fasse contributed on shaping the ideas, provided the feedback and revised the drafts of the paper. For chapter 5, Sabina Khatri Karki and Luitfred Kissoly generated the idea, performed the analysis and wrote the paper. Ulrike Grote provided suggestions on various aspects during writing and commented and edited the final versions of all the papers.

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World Bank (2007). World Development Report 2008: Agriculture for Development. Washington, DC: The World Bank.

Chapter 2: Fair Trade Certification and Livelihoods: A Panel Data Analysis of Coffee-growing Households in India

This chapter is published:

Karki, S.K., Jena, P.R. and Grote, U. (2016). Fair Trade Certification and Livelihoods: A Panel Data Analysis of Coffee-growing Households in India. Agricultural and Resource Economics Review, 45 (3): 436-458. https://doi.org/10.1017/age.2016.3

Download at: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/CCB64D912C7291D6F8E3D33C252C9597/S2372261416000035a.pdf/fair-trade-certification-and-livelihoods-a-panel-data-analysis-of-coffee-growing-households-in-india.pdf

Chapter 3: The Role of Standards in Domestic Food Value Chains in Sub-Saharan Africa: A Review Article

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Karki, S.K., Fasse, A. and Grote, U. (2016). The Role of Standards in Domestic Food Value Chains in Sub-Saharan Africa: A Review Article. African Journal of Horticulture Science, 9: 41-54

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Chapter 4: Technical Efficiency and Food security: Evidence from African Indigenous Vegetable Smallholders in Kenya

Sabina Khatri Karki, Anja Fasse and Ulrike Grote

Abstract

African Indigenous Vegetables (AIVs) are considered to significantly contribute in resource poor households to food and nutrition security. Therefore, increasing productivity and efficiency of these vegetables is one important approach to improve food security of Kenyan smallholders. This study aims to measure the Technical Efficiency (TE) of AIVs and its determinants. Different from existing papers, this study also aims at analyzing the influence of TE on household food security by capturing all four dimensions of food security individually i.e. availability, access, utilization and stability. Based on survey data of 1,042 farming households from Kenya, the study applies the Cobb-Douglas stochastic frontier model to derive TE and its determinants. Results show that the mean TE index of AIV small-scale production is 36%. Location to peri-urban areas, risk attitude, savings, commercialization, and diversification of AIVs are found to significantly increase TE. Empirical evidence from the Propensity Score Matching approach shows that households having higher TE are able to improve their food security status compared to households with lower TE.

Keywords: African indigenous vegetables, food security, Kenya, technical efficiency, propensity score matching

4.1 Introduction

The agricultural sector is important to reduce poverty and attain food security in Africa since it is a principal source of food and livelihoods (Ogundari, 2014; de Graaff, 2011). However, agricultural production achieves only low productivity and efficiency levels in many Sub-Saharan African countries (World Bank, 2008). Thus, food insecurity and poverty remain major problems in Sub Saharan Africa (SSA) until today (Otuska, 2013). Increasing the efficiency of agricultural production, meaning that farmers produce more with the same amount of inputs, is one important approach to improve food security and income of smallholders and therefore help in poverty reduction and secure better food and nutrition

(Bogale, 2012; Ogundari, 2014). Increasing the efficiency in the agricultural sector is also a major objective in Kenya, where about 10 million people, i.e. about 28% of the population, suffered from chronic food insecurity and poor nutrition in 2011 (GoK, 2011). Small-scale agriculture there is characterized by average landholdings of only 0.2-3 hectares accounting for 75% of the total agricultural output in Kenya (GoK, 2010).

African Indigenous Vegetables (AIVs) are important agricultural food crops for households in SSA since they are known to contribute to food and nutrition security (Faber et al., 2010; Oluoch et al., 2009). According to Schippers (2009), “AIVs are those vegetables whose primary or secondary centre of origin is in Africa”. These vegetables are recognized to improve micronutrient deficiency in resource poor households, as they contain proteins, vitamins and iron (Cernansky, 2015). A large number of AIVs are reported to be rich in micronutrients, antioxidants and have health protecting properties and uses (Yang and Keding, 2009). They are also recognized as an important source of income generation and livelihoods for the rural communities, especially for women (Ngugi et al., 2007; Weinberger et al., 2011) and are potential cash crops in the peri-urban areas (Yang and Keding, 2009). In the past, AIVs were mainly viewed as a crop for poor people. In recent years, however, AIVs are increasingly appreciated due to their nutritional values especially by the urban population (Cernansky, 2015). In addition, AIVs were also neglected by seed companies and researchers until few years ago which resulted in low productivity and sometimes poor quality (Cernansky, 2015). Factors such as poor seed quality, poor marketing systems and inadequate infrastructure also contributed to low productivity (Abukutsa-Onyago, 2007).

Kenya is rich in AIVs with an estimated 210 known species (Pasquini et al., 2009). Some of the common indigenous vegetables found in Kenya are African night shade, Amaranthus, cowpeas, spider plant, and Ethiopian kale. Kenyan farmers increased the area planted by 25% between 2011 and 2013 which demonstrates farming communities’ interest towards AIVs (Cernansky, 2015). Also, there is a growing demand of AIVs these days by consumers especially in the urban and peri-urban centers of Kenya. For example, Chelang’a et al. (2013) find that consumers in urban areas in Kenya are willing to pay premium prices for AIVs.

According to the Food and Agriculture Organization (FAO), food security is defined as a “situation that exists when all people, at all times, have physical, social 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). Therefore, food security encompasses four pillars namely availability, access, utilization and stability. Past studies assessed the impact on food security only indirectly through consumption behaviors (Ndirangu et al., 2013) or using a single indicator such as the Food Consumption Score (FCS) or the Household Dietary Diversity Score (HDDS) or Household Food Insecurity Access Scale (HFIAS) (Kennedy et al., 2010, Kimani-Murage et al., 2014; Kabunga et al., 2014, Mason et al., 2015). Multiple indicators can show very different results of the food security level capturing different aspects in terms of food security (Maxwell et al., 2014). Especially nutritional aspects undergo a growing public interest (Heady and Ecker, 2013). In particular, malnutrition covered by the pillar 'utilization' can be reduced through consumption of AIVs (Cernansky, 2015). Therefore, it is essential to analyze the impact on the different pillars individually.

Using data from rural and peri-urban AIVs producing farmers of Kenya, the present study aims to (1) estimate the technical efficiency (TE) of AIV producers, (2) identify the factors explaining TE, and (3) analyze the relationship of TE on food security. To the best of our knowledge, it is the first study to look at the relationship between TE and food security. We contribute to the literature by differentiating between the four different pillars of food security. Furthermore, there are very few studies which looked at the case of vegetables in Kenya (Rao et al., 2012). Kenya is an interesting case because AIVs are receiving attention day by day in the country and there are no studies that have particularly analyzed TE of AIVs.

The reminder of this paper is organized as follows. Section 4.2 reviews the literature on AIVs, technical efficiency and food security. In section 4.3, the study area is described and the data used for estimation is presented. The methodology used in the study is explained in section 4.4. Empirical results are discussed in section 4.5. Section 4.6 finally concludes.

4.2 Literature Review

There are two different strands of relevant literature. Section 4.2.1 reviews the factors which influence the TE. Section 4.2.2 summarizes the relationship between TE and food security.

4.2.1 Technical efficiency and its determinants

Several studies have investigated technical efficiency and the factors that influence technical efficiency of farming households for agricultural products such as rice, wheat, maize, vegetables etc. in general. Specific to vegetables in Kenya, Rao et al. (2012) estimated the TE of vegetable farmers. They found that those supplying their produce to supermarkets and traditional markets have a TE of 0.41 and 0.36, respectively. Although supermarket farmers have higher TE on average, the efficiency levels for farmers in both channels is noted to be relatively low.

There is a well-established literature on the factors that influence technical efficiency of smallholder farming (Table 4.1). While previous studies found education to have a positive influence on technical efficiency (Tan et al., 2010; Liu and Myers, 2009; Ogundari, 2013), findings for age and gender are mixed. For instance, Tan et al. (2010) found that technical efficiency increases with age for rice producers in South-East China. Conversely, Ogada et al. (2014) found that the age of the household head is negatively correlated with technical efficiency of Kenya´s smallholder food crop farmers. Female headed households are found to achieve higher efficiency in Nigeria (Ogundari, 2013) but lower efficiency in Kenya (Liu and Myers, 2009). Female suppliers of vegetables to Kenyan supermarkets are also found to be more efficient than male suppliers (Rao et al., 2012). A longer experience in farming leads to better managerial skills being acquired over the years, thus, resulting in a higher technical efficiency (Bozoğlu and Ceyhan, 2007; Marino et al., 2011; Wollni and Brümmer, 2012). Regarding physical assets, previous empirical studies have shown that size of land holdings and ownership of livestock increases the farm technical efficiency (Tan et al., 2010; Liu and Myers, 2009; Ogada et al., 2014; Okike et al., 2004). Land tenure is another element that affects technical efficiency. Lui and Meyers (2009) show that maize farmers in Kenya are more efficient on rented fields than on their own fields. Technical efficiency can also be affected by access to information and distance to market. For instance, Nyagaka et al. (2010) have reported that in Kenya, households belonging to farmers´ association have high technical efficiency. Similar relationship between technical efficiency and market information has been reported for vegetable farms in Turkey (Bozoğlu and Ceyhan, 2007). Farm households that produce mainly for the market and lie closer to it are also found to have higher technical efficiency in Kenya (Mutoko et al., 2014; Ogada et al., 2014). Crop diversification is found to significantly improve technical efficiency (Coellin and Flemming, 2004; Rahman, 2009). Financial capital such as savings also affects efficiency. Tan et al. (2010) show that savings are positively and significantly related to technical efficiency of rice producers in South-East China. For the Nepalese rice farms, Dungana et al. (2004) found that risk aversion is positively associated with technical efficiency.

Table 4.1: Description of the independent variables in the regression models

Variables	Description of the variables	Influence on TE	References
Household head characteristics			
Age	Age of the household head in years	+ -	Tan et al., 2010 Ogada, 2014
Education	Household head has higher education (Yes=1)	+	Lui and Meyers, 2009; Tan et al., 2010; Ogundari , 2013
Gender	Gender of the household head (1= Male)	- +	Lui and Meyers, 2009 Rao et al., 2012; Ogundari, 2013
Experience	AIVs farming experience in years	+	Bozoğlu and Ceyhan, 2007; Marino et al., 2011; Wollni and Brümmer, 2012
Physical assets			
Land	Land size in hectare	+	Lui and Meyers, 2009; Tan et al., 2010; Ogada, 2014
Owned land	Share of land that is owned	-	Lui and Meyers, 2009
TLU	Livestock measured in tropical livestock units	+	Okike et al., 2004
Shock and risk			
Shock	Households face agricultural shock (1=Yes)	-	Own consideration
Risks	Self-stated risk taking behavior (scale of 0 to 10)	+	Dhungana et al., 2004
Market and groups			
Market share	Proportion of AIVs sold	+	Mutoko et al., 2014
Information	Household has access to market information (Yes=1)	+	Bozoğlu and Ceyhan, 2007
Distance	Distance to nearest market in km	-	Ogada, 2014
Group	Household is a member of farmer group (Yes=1)	+	Nyagaka et al., 2010

Financial capital			
Savings	Households have any savings (Yes=1)	+	Tan et al., 2010
AIV related variables			
No. of AIV	Number of AIVs grown	+	Coelli and Flemming, 2004; Rahman, 2009; Ogundari, 2013
AIV as main crop	Share of land where AIV is grown as main crop	+	Own consideration
Geographic location			
Peri-urban	Household is from peri-urban region (1=yes)	+	Own consideration

Source: Own compilation

4.2.2 Relationship between technical efficiency and food security

Even though AIVs have immense potential and there is a vast literature on technical efficiency, evidence on the welfare impacts of AIVs in general and their technical efficiency in particular is relatively limited. A study conducted in Kenya shows that households involved in production and sale of African leafy vegetables were relatively better off than households who were not involved in production and sale (Gotor and Irungu, 2010). Much less is known about TE and its relationship to food security at household level. Very few available studies from Nigeria examine the relationship between technical efficiency, income and food security based on correlation analyses (Adewumi and Animashaun, 2013; Oyakhilomen et al., 2015). Adewumi and Animashaun (2013) found an inverse relationship of technical efficiency on the HDDS and income implying that HDDS and income decrease as technical efficiency increases. The authors argue that reduced price due to lack of efficient processing and marketing facilities drives the negative relationship between income and technical efficiency. On the contrary, Penda and Asogwa (2011) found a positive correlation between income and efficiency suggesting that efficiency and income tend to rise or fall together. In case of poultry farmers, Oyakhilomen et al. (2015) also found a direct positive relationship between technical efficiency and food security. All of these results mentioned above show only the correlation between income and technical efficiency but not the impact.

The interrelation of different factors (production, household and farm characteristics) influences the TE of AIV producing households and hence the food security. Production factors such as land, seeds, fertilizer, labor, tools and irrigation enter into the production process as inputs. It is expected that proper utilization and management of these resources leads to higher technical efficiency of households. Household and farm characteristics also influence technical efficiency. Technically efficient households are therefore expected to realize improved food security. But the impact is hypothesized to be different along the food security pillars. Increase in efficiency is expected to contribute to food availability at the household level because it is likely to enhance farmers´ opportunities to produce more and also to boost the productivity. While technical efficiency may lead to increased output and productivity, it increases the income of the farmers by selling the surplus production, that affect food purchases and consumption. So, increase in efficiency is hypothesized to ease households' food access. Higher income generated through the sale of agricultural goods, as well as consumption from own production favor a more diversified diet. Diversified diet is associated with greater energy and nutrient intakes thus, improving food utilization. Utilizing resources efficiently increase productivity sustainably and reduce production risks to farmers providing sustained food provisioning. Therefore, increase in efficiency is likely to promote food stability. Therefore, this paper proceeds by exploring how TE influences the different aspects of food security in Kenya.

4.3 Study area and data

Data for this study comes from a household survey that was carried out in 2014 in selected rural and peri-urban areas of Kenya. A multistage sampling technique was employed in selecting the farm households. The first stage involved the purposive sampling of the five counties namely Kisii, Kakamega, Nakuru, Kiambu and Kajiado (Fig 4.1). Kisii and Kakamega are rural counties whereas Nakuru, Kiambu and Kajiado are peri-urban counties. The sampling was purposive because the households within these counties are involved in the production, marketing or consumption of AIVs. In the second stage, sub-counties and divisions were selected based on the information from respective district agricultural offices. The third stage constituted the random selection of locations/wards from each selected division. Finally, in the fourth stage households were randomly selected from these locations. Overall 1,232 households were selected: 800 from rural counties and 432 from peri-urban counties. The final sample size for this study is 1042, as there were missing observations for some variables. The summary statistics of the sample is presented in Appendix 4.1.

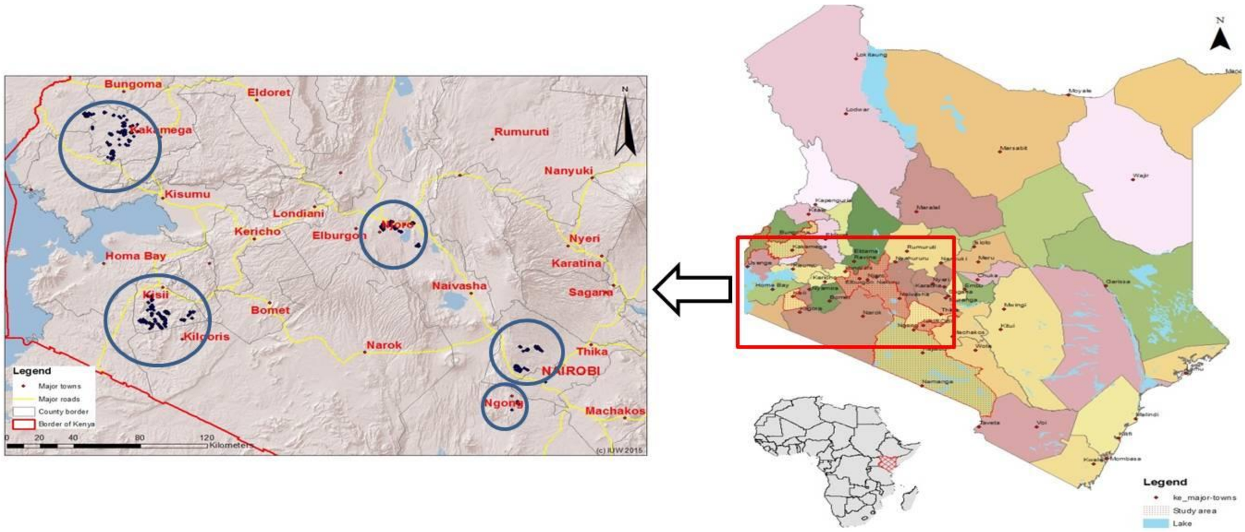

Figure 4.1: Study area showing different counties (HORTINLEA, 2014)

As a survey instrument, pre-tested structured questionnaires were used to collect data through face to face interviews. The data set contains detailed information on production activities, particularly the outputs and inputs of farm activities. It also includes information concerning household and farm characteristics, marketing, savings and credit, and shocks. In addition, the questionnaire asked for extensive information on consumption and food security such as the frequency, amount and the varieties of foods consumed during a normal week and also in a worst week during different seasons and, food sufficiency to meet family's needs for the whole year.

4.4 Methodology

The methodology is conducted in two steps. In the first step, technical efficiency is estimated and the factors explaining technical inefficiency are determined using the Stochastic Frontier Model. Using Propensity Score Matching (PSM), the second step analyzes the impact of technical efficiency on different dimensions of food security such as availability, access, utilization and stability.

4.4.1 Estimating technical efficiency and factors explaining inefficiency

A parametric stochastic frontier approach originated by Meeusen and van den Broeck (1997) and Aigner et al. (1997) is used to estimate a production function and to obtain farm-level technical efficiency estimates. The stochastic frontier model is specified as follows

$$Y_i = f(X_i\beta) + \varepsilon_i \quad (1)$$

Where, Y_i is the output value

X_i is a vector of input used in production

β is a vector of unknown parameters of the production function

$\{ f(X_i\beta)\}$ is the frontier production function that measures the maximum potential output from a vector of inputs. The error term ($\varepsilon_i = v_i - \mu_i$) composed of two independent components v_i and μ_i causes deviation from the frontier. The systematic error component v_i assumed to be identical and independently distributed as $N(0, \sigma_v^2)$ captures random deviations from the frontier caused by factors beyond the farmer´s control. μ_i, a non-negative random error term, independently and identically distributed, as $N(\mu, \sigma_\mu^2)$ is associated with farm-specific technical inefficiency in production.

The empirical production function to be estimated is specified as:

$$\ln(Y_i) = \beta_0 + \sum_{k=1}^{7} \beta_k \ln(X_{ki}) + v_i - \mu_i \quad (2)$$

Where, ln (Y_i) is the logarithm of output value of AIVs in Purchasing power parity dollar (PPP$)

$X_{1\text{-}7}$ are input variables such as land measured in ha; expenditures for seeds, tools, irrigation, labor, fertilizer and pesticide measured in PPP$

β_0 is the intercept

β_k are the production function parameters

v_i and μ_i are as defined above

A log linear Cobb-Douglas specification is chosen and the coefficients estimated directly represent elasticity of production. The farm-specific technical efficiency of farmer i is estimated using the expectation of μ_i conditional on the random variable ε_i and is expressed as;

$TE_i = \exp(-\mu_i)$, such that, $0 \leq TE_i \leq 1$. A value of 1 means technically efficient and a value of 0 means technically inefficient.

The inefficiency model is specified as

$$u_i = \delta_0 + \sum_{k=1}^{16} \delta_k Z_k \qquad (3)$$

Where, u_i represents the inefficiency score of each household obtained from equation (2)

Z_k represents variables that may influence farmer´s inefficiency which are summarized in Table 4.1.

Following Wang and Schmidt (2002), equation 2 and 3 are estimated simultaneously by maximum likelihood. By doing so, efficient and consistent parameter estimates are produced for both functions.

4.4.2 Estimating the effect of technical efficiency on household food security

Different food security indicators such as value of agricultural production in PPP dollars, household food consumption expenditure per week in PPP dollars, monthly per capita income in PPP dollars, FCS, HDDS, and Months of Adequate Household Food Provisioning (MAHFP) are used as outcome indicators in the study. These indicators reflect four pillars of food security such as availability, access, utilization and stability (Table 4.2). It is well documented that no single indicator can capture all dimensions of food security (Maxwell, 2014); therefore, we have used several indicators. In this study, food availability is measured with agricultural production value (FAO, IFAD and WFP, 2013). It is calculated based on crop production in physical terms multiplied by output prices. To capture the access dimension, household food consumption expenditure per week and per capita income is used (Magrini and Vigani, 2016; Lovon and Mathiasen, 2014). FCS and HDDS are used as proxy indicators for utilization dimension of food security (Anderman et al., 2014). Both of these indicators are qualitative measures of household food consumption and emphasize dietary diversity (Kennedy et al., 2010; Jones et al., 2013). FCS is a composite score which captures three aspects namely dietary diversity, frequency and nutritional importance of food groups. It is calculated using the frequency of consumption of eight food groups (main staples, pulses, vegetables, fruit, meat and fish, milk, sugar, and oil) consumed by a household in a seven days reference period. All of these food groups are weighted based on their nutrient density. Since FCS captures the nutritional value of food in addition to the frequency, it depicts a measure of the quality of household diet (Lovon and Mathiassen, 2014). The HDDS is the sum of equally weighted response data on food groups consumed by the household during the reference period and captures dietary diversity but without frequency. It is based on 11 different food groups (i.e. staples, roots and tubers, vegetables, fruits, meat, eggs, fish, pulses and nuts, dairy products, oils and fats and sugar) and ranges from 0 to 11 (Kennedy et al., 2011; WFP, 2008; Maxwell et al., 2014). Since the HDDS covers a large number of food groups, it allows for more disaggregated analyses of dietary patterns (Kennedy et al., 2010). Higher numbers of food groups are associated with higher access to calories. Following Coates (2013), the MAHFP is used as a proxy indicator for the stability dimension of food security. It measures the number of months during which households have sufficient food provisioning capturing the temporal dimension of food insecurity and it ranges from 0 to 12 (Battersby, 2011; Bilinsky and Swindale, 2007).

Table 4.2: Food security dimensions and indicators

Food security dimensions	**Food security indicators**	**References**
Availability	Value of agricultural production	FAO, IFAD and WFP, 2013
Access	Per capita income per month	Magrini and Vigani, 2016
	Household food consumption expenditure per week	Lovon and Mathiasen, 2014
Utilization	Food Consumption Score	Own consideration
	Household Dietary Diversity Score	Anderman et al., 2014; Magrini and Vigani, 2016
Stability	Months of adequate household food provisioning	Coates, 2013

Source: Own compilation

To measure the impact of TE on different food security indicators, we use the technical efficiency score to define our treatment variable. We expect heterogeneous effects of our treatment variable on the above mentioned indicators. To capture this, households are divided into a pair of treatment and control groups based on the level of the technical efficiency score, as illustrated in Table 4.3.

Table 4.3: Treatment and control groups based on technical efficiency scores

Treatment	**N**	**Percent**	**Control**	**N**	**Percent**
Households with TE $\geq 75^{th}$ percentile of TE scores (≥ 0.52)	260	25	Households with TE $<75^{th}$ percentile of TE scores (<0.52)	781	75

Source: Own compilation

Households that belong to the above specified treatment and control groups may differ from each other with respect to observable and unobservable characteristics. These characteristics may play an important role in attaining specific levels of technical efficiency. So, if a comparison of the mean outcome between these groups is made without taking into consideration the group differences, it leads to biased estimates. In order to deal with this problem, a counterfactual group is created using the PSM technique (Caliendo and Kopeinig, 2008). Apart from being used in the impact evaluation of the particular program, PSM is also used in other contexts such as migration (Sauer et al., 2015), certification (Jena et al., 2012), agricultural value chain activities (Kissoly et al., 2017) etc. Empirically, PSM is carried out in two steps. In the first step, a binary probit model is used to generate the propensity score p (x_i) that measures the tendency of each farmer to be in the treated group given observed characteristics x_i as specified in equation 4 and summarized in Table 4.1.

$$P_i(X) = Pr(T_i = 1 \backslash X_i) \tag{4}$$

The propensity score generated from the first stage is then used to form two balanced groups. In the second stage, as shown by equation 5, the Average Treatment Effect on the Treated (ATT) is calculated using two matching estimators, namely Nearest Neighbor Matching (NNM) and Radius matching. NNM matches each treated farmer with a control farmer based on their propensity scores. We use five nearest neighbors with a caliper of 0.01 to match each treated farmer. Based on a pre-defined radius, radius matching involves matching of all control farmers to the treated farmer within that radius.

$$ATT = E(Y_1 \backslash T = 1, X) - E(Y_0 \backslash T = 1, X) \tag{5}$$

Since PSM is based on Conditional Independence Assumption (CIA), this method only measures the welfare of treated and control groups based on observed characteristics (Rosenbaum and Rubin, 1983). However, unobserved characteristics might simultaneously affect treatment and outcomes leading to a problem of hidden bias to which the matching estimators are not robust. Therefore, sensitivity analysis using Rosenbaum bounds is performed in order to test whether unobserved confounding variables affect our ATT (Rosenbaum, 2002).

4.5 Result and discussion

4.5.1 Production function estimates

Table 4.4 presents the results of the maximum likelihood estimates of the Cobb-Douglas function. The coefficients represent elasticities because all variables (dependent and input variables) are log transformed. Input variable such as irrigation is statistically significant. The coefficient of this variable is positive, denoting that a 1% increase in expenditure on irrigation leads to increases of about 0.26% in gross income of AIVs. Likewise, labor cost is significant indicating that a unit increases in the expenditure of labor increases the income of AIVs by 0.06%. The positive relationship between inputs factors (such as labor and irrigation) and output produced has been reported in other studies as well (Koirala et al., 2016; Nguyen et al., 2017). Another significant variable is pesticide cost. The findings indicate that a 1% increase in pesticide cost increases the income for AIVs by 0.16%. The land variable, aimed at capturing the effect of scale production, turns out to be insignificant. Expenditure on other input variables such as tools, and fertilizer does not lead to any significant increase in the gross revenue of AIV producers in the area as shown by their statistically insignificant coefficients.

Table 4.4: Production function estimates

Production function	Coef.	Std. Err.
Dependent variable: AIV gross income (log)		
Land	-0.11	0.08
Tools	-0.02	0.12
Seed	-0.08	0.05
Irrigation	0.26***	0.09
Labor	0.06*	0.04
Fertilizer	-0.01	0.04
Pesticide	0.16***	0.05
Constant	3.63***	0.44
N	1042	

Source: Own calculations

4.5.2 Distribution of technical efficiency scores

Results of efficiency analysis reported in Table 4.5 reveal that efficiency scores vary across the AIVs producing farmers. Frequency analysis shows that none of the farmers have a technical efficiency of 1, indicating that farmers are producing AIVs below the maximum efficiency frontier. The most efficient producer has an efficiency score of 0.80 and the least efficient has a score of 0.01.The mean value of TE is 0.36 implying that there is substantial technical inefficiency and in principle, farmers could achieve 64% higher production on average using the same mix of production inputs.

Table 4.5: Distribution of technical efficiency scores

Frequency distribution		
Efficiency	Freq	%
≤ 0.10	115	11
0.11 to 0.20	151	14
0.21 to 0.30	140	13
0.31 to 0.40	172	14
0.41 to 0.50	154	17
0.51 to 0.60	153	15
> 0.60	157	16
Total	1042	100
Mean efficiency	0.36	
Min	0.01	
Max	0.80	

Source: Own calculations

4.5.3 Factors influencing technical efficiency

Table 4.6 represents the estimation results of technical efficiency effects. It is to be noted that a negative sign on a coefficient means that variables have a positive effect on technical efficiency. Several factors such as peri-urban, market share, age, land, experience, savings, risk, livestock ownership, AIV as main crop and number of AIVs are found to be the influential factor in explaining technical efficiency.

Contrary to the finding of Dhungana et al. (2004), risk attitude is negatively associated with technical inefficiency. It indicates that those who take higher risks are the more technically efficient farmers**.** One possible reason could be that risk taking farmers search for more options to earn and invest in their farming activities**.** Furthermore, savings increase the technical efficiency of AIV producing farmers. A possible explanation is savings reduce the monetary constraint of purchasing inputs on time**.** This confirms the finding of Tan et al. (2010) that savings increased TE in one-season rice farming in South-East China. Likewise, the peri-urban area has a negative influence on technical inefficiency for AIV producers. The significant and negative coefficient show that AIV producers residing in peri-urban areas are more efficient compared to those living in rural areas. This underscores that a peri-urban region provides farmers with a better access to input and output markets, which again motivates them to better use and manage their resources. Farmers producing a higher number of AIVs are found to be more technically efficient than their counterparts. This result is consistent with the findings reported by Coelli and Fleming (2004) and Rahman (2009) and Ogundari (2013) of a positive relationship between crop diversification and technical efficiency in Papua New Guinea, Bangladesh and Nigeria, respectively. The results show that the higher the proportion of AIVs sold, the lower is the technical inefficiency showing that the level of commercialization has a positive and significant effect on technical efficiency. Similar result have been reported by Mutuko et al. (2014) and Ebers et al. (2017) who argue that access to market information, competitive pressure and price incentives of market participation motivate farmers to produce efficiently. Higher livestock ownership increases technical efficiency of AIV producers. A similar finding has been reported by Okike et al. (2004) in West Africa who argue that an increase in TE is linked to a direct contribution of sales of livestock and livestock products and indirect crop-livestock interactions. As expected, efficiency increases with experience in AIVs farming. This could be attributed to better managerial skills obtained through a learning process over time. Positive correlation between technical inefficiency and age indicates that younger farmers are more efficient than the older ones as observed by Ogada et al. (2014) in Kenya. This might be due to their willingness to improve their farming knowledge and being active in the agricultural activity. Land size has a positive effect in increasing technical efficiency. This result is similar to the findings of Lui and Meyers, 2009, Ogada et al., 2014, and of Tan et al., 2010. But, farmers allocating a higher share of land to grow AIVs as main crop were found to be less efficient.

Table 4.6: Factors influencing technical inefficiency

	Coeff.	Std. Err.
Peri-urban	-0.77**	0.38
Market share	-0.97**	0.38
Gender	-0.05	0.31
Age	0.02**	0.01
Land	-2.11*	1.11
Group	0.16	0.29
Experience	-0.03**	0.01
Information	-0.23	0.28
Education	-0.45	0.39
Savings	-0.97***	0.33
Risk	-0.09*	0.05
Distance	-0.001	0.05
TLU	-0.26*	0.13
Shock	0.30	0.33
Owned land	-0.20	0.39
AIV main	0.52*	0.30
No. of AIV	-0.48***	0.17
Constant	4.13***	0.82
N	1042	

Statistical significance *** at 1%, ** at 5% and * at 10% level

Source: Own calculations

4.5.4 Relationship of technical efficiency on food security

PSM was used to ascertain the impact of technical efficiency on different food security indicators. Propensity scores generated by the probit model are presented in Appendix 4.2. Figure in the Appendix 4.3 shows the distribution of propensity scores and common support for treated and control groups. Several methods are used to test the matching quality. The matching quality indicators before and after matching are shown in Appendix 4.4. The matching result shows a substantial reduction of standardized bias in the range of 84 to 87%. The pseudo-R^2 which was about 17% before matching also dropped significantly to about 0.6% after matching. Similarly, the p-value of the likelihood ratio test is insignificant after matching. The low pseudo-R^2, low mean standardized bias, insignificant likelihood ratio test and high total bias reduction suggest that the matching procedure is successful in balancing the distribution of covariates between two groups. These results, therefore, allow us to continue to estimate the ATT.

Table 4.7 reports the estimates of average treatment effects of technical efficiency on household food security indicators. The comparison of treated and control groups show that a higher technical efficiency has a positive and significant impact on utilization but also on availability and access. We find that the value of agricultural production is significantly higher in a range of 115.05 to 115.76 PPP$ for treated group. The access dimension of food security measured by household food consumption expenditure per week and per capita income per month is also positively impacted by higher technical efficiency. Those households having higher technical efficiency have on average higher food expenditure and higher per capita income than those with lower efficiency. Results show that higher technical efficiency significantly increases the FCS in a range of 4.76 to 5.15. Similarly, HDDS is increased in a range of 0.28 to 0.31 for farmers having higher technical efficiency. One possible explanation for a positive impact of technical efficiency on food utilization indicators can be through higher productivity and income. Finally, higher technical efficiency did not show any significant effect on MAHFP measuring the stability dimension. This shows that having food availability, access to food and utilization does not necessarily promote food stability. Therefore, our results show that higher technical efficiency has a significant impact on most of the food security indicators explaining different pillars of food security.

Table 4.7: Average treatment effect using nearest neighbor matching and radius matching algorithm

	NNM		**Radius**		**Critical level of hidden bias**
Category	**ATT**	**S.E**	**ATT**	**S.E**	
HHs with TE ≥ 0.52 vs HHs with TE < 0.52					
Availability					
Agricultural production value (PPP$)	115.76***	12.94	115.05***	12.02	2
Access					
Household food consumption expenditure per week	1.91*	1.14	2.21**	1.11	1.2
Per capita income (PPP$)	78.75***	14.95	77.38***	15.35	2
Utilization					
FCS	4.76**	2.18	5.15**	2.36	1.5
HDDS	0.28*	0.15	0.31**	0.12	1.5
Stability					
MAHFP	-0.42	0.34	-0.07	0.33	-

Note: ATT: average treatment effect on the treated; S.E: bootstrapped standard error

Statistical significance *** at 1%, ** at 5% and * at 10% level

Source: Own calculations

The Rosenbaum bounds calculated to check the robustness of PSM against hidden bias is presented in the last column of Table 4.7. The results concerning households with TE≥0.52 versus households with TE<0.52 show that the effect of TE is insensitive even if hidden bias increases by up to 2 for value of agricultural production and per capita income, 1.5 for FCS and HDDS, 1.2 for household food consumption expenditure. This result confirms that the ATT estimates of PSM are robust to possible hidden bias.

4.6 Conclusion and policy implications

To improve households' food security situation, resources need to be utilized properly either through conserving it or through increasing the efficiency. This article a) estimated the technical efficiency of AIV producers in Kenya, b) determined the factors influencing technical efficiency and c) analyzed the influence of technical efficiency on different food security indicators applying one stage stochastic production frontier estimation and PSM.

Econometric results reveal a wide variation of technical efficiency among AIV producers. The mean technical efficiency is 36%. Factors such as savings, land, livestock, risk attitude, experience, peri-urban region, commercialization, and number of AIVs grown positively influenced technical efficiency, while age and AIVs as main crop show negative relationship with efficiency. In addition, the study shows that higher technical efficiency leads to a higher value of agricultural production, higher per capita income and higher food consumption expenditure. Moreover, higher technical efficiency leads to higher FCS and HDDS showing that technical efficiency impacts the availability, access and utilization dimension of food security positively. But the impact is insignificant on MAHFP.

The implication of this study is that technical efficiency of AIV producers could be increased by 64% through better use of available resources given the existing technology. This can be achieved through improved farmer-specific efficiency factors such as savings, commercialization, diversification etc. The result supports the notion that increasing technical efficiency can make a positive contribution to improve household food security especially utilization which diminish malnutrition. Based on these results, policies should be directed towards providing farm management skills through extension activities and also educating farmers to diversify into different AIVs. Importance should be given to transform subsistence production into commercial one and public investment in physical infrastructure such as roads may facilitate easy market access. Trustworthy formal and informal financial institutions should be put in place to have the potential to ease the constraints in obtaining timely inputs.

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Appendices

Appendix 4.1: Descriptive statistics of the variables used in the model

Variables	Description	Mean	Std. Dev
Variables used in Production function			
Gross income	Gross income from AIVs (PPP$)	66.43	246.71
Land	Land measured in hectare	0.19	0.39
Tools	Expenditure on tools (PPP$)	0.61	5.31
Seed	Expenditure on seeds (PPP$)	6.06	12.64
Irrigation	Expenditure on irrigation (PPP$)	0.96	7.62
Labor	Expenditure on labor (PPP$)	27.22	107.06
Fertilizer	Expenditure on fertilizer (PPP$)	10.77	30.46
Pesticide	Expenditure on pesticides (PPP$)	6.83	23.72
Variables used in inefficiency function and probit estimation			
Peri-urban	Household is from peri-urban region (1=yes)	0.34	0.47
Gender	Gender of the household head (1= Male)	0.80	0.39
Age	Age of the household head in years	50	12.68
Education	Household head has higher education (Yes=1)	0.17	0.37
Experience	AIVs farming experience in years	20	13.28
Total land	Land size in hectare	0.83	0.82
Owned land	Share of owned land	0.16	0.35
AIV as main crop	Share of land where AIV is grown as main crop	0.49	0.46
Number of AIVs	Number of AIVs grown	2	1.11
Market share	Proportion of AIVs sold	0.51	0.39
Distance	Distance to nearest market in km	2.3	2.46
Group	Household is member of a farmer group (Yes=1)	0.36	0.48
Information	Household has access to market information (Yes=1)	0.38	0.48
Tropical livestock unit	Livestock measured in tropical livestock units	1.64	2.49
Shock	Households face agricultural shock (1=Yes)	0.79	0.40
Savings	Households have any savings (Yes=1)	0.47	0.49
Risks	Self-stated risk taking behavior (scale of 0 to 10)	5.5	2.50
Outcome variables			
Income	Per capita income (PPP$)	94.17	136.22
Consumption expenditure	Household food consumption expenditure per week (PPP$)	37.25	11.56
FCS	Food consumption score during pre-harvest season	59.78	22.76
HDDS	Household dietary diversity score	8.16	1.63
MAHFP	Months of adequate household food provisioning	9.51	3.72
Production value	Value of agricultural production (PPP$)	2384.38	5043.66

Treatment variable			
Efficiency	Technical efficiency score	0.36	0.20

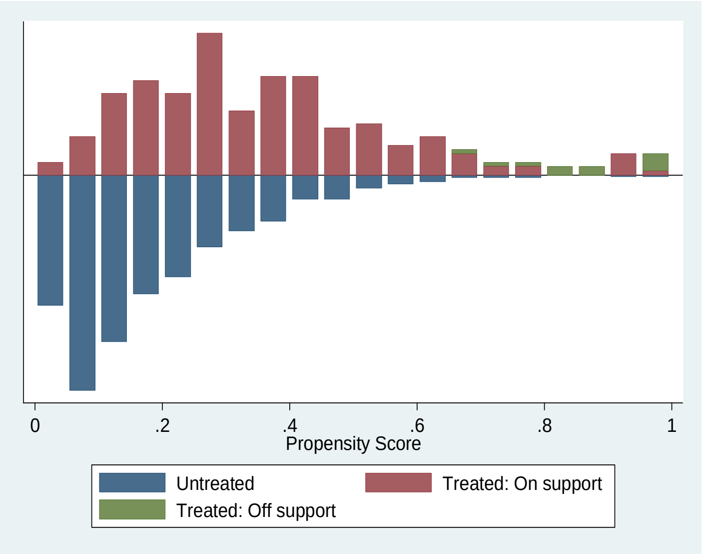
Source: Own compilation

Appendix 4.2: Probit estimation of propensity scores

	HHs with TE>=0.52 vs HHs with TE<0.52		
	Coef.	**Std. Err.**	**P>z**
Peri-urban	0.278	0.132	0.035
Market share	0.355	0.128	0.006
Gender	0.203	0.129	0.116
Age	0.007	0.004	0.057
Group	0.234	0.109	0.032
Education	0.116	0.101	0.249
Risk	0.064	0.020	0.001
Information	0.200	0.100	0.044
Distance	0.016	0.018	0.354
TLU	0.213	0.026	0.000
Shock	-0.183	0.116	0.117
AIV as main crop	-0.462	0.110	0.000
Number of AIVs	0.304	0.047	0.000
Constant	-3.009	0.333	0.000
Pseudo R^2		0.17	
N		1002	

Source: Own calculations

Appendix 4.3: Histogram of propensity scores and common support for treated and control groups



Appendix 4.4: Propensity score matching quality indicators before and after matching

	Pseudo R^2 before matching	Pseudo R^2 after matching	LR X^2 (p-value) before matching	LR X^2 (p-value) after matching	Mean standardized bias before matching	Mean standardized bias after matching	Median bias reduction before matching	Median bias reduction after matching	Total % mean bias reduction	Total % median bias reduction
Nearest neighbor matching										
HHs with TE>=0.52 vs HHs with TE<0.52	0.174	0.006	188.25 (0.000)	3.46 (0.996)	22.5	3.6	22	2.4	0.84	0.89
Radius matching										
HHs with TE>=0.52 vs HHs with TE<0.52	0.174	0.006	188.25 (0.000)	3.46 (0.996)	22.5	3.6	22	2.4	0.87	0.87

Source: Own calculations

Chapter 5: Farm Production Diversity and Household Dietary Diversity in Rural and Peri-urban Kenya

Sabina Khatri Karki, Anja Fasse, Ulrike Grote

Abstract

The empirical relationship between production diversity and dietary diversity is still limited in Africa. This study therefore addresses the following research questions: a) What determines households' production diversity? b) Does production diversity influence dietary diversity in general and also seasonal dietary diversity in particular? and c) How does the level of production diversity influence dietary diversity? Using data of 1184 farm households from rural and peri-urban Kenya, the Poisson regression shows that age, education, land, labor, access to off-farm employment, market information and distance to market influence the production diversity. Further, regression results show a significant positive relationship between production diversity and dietary diversity in a rural region even after controlling for other covariates. This relationship is also observed for planting and post-harvest seasons. Results from the continuous treatment approach reveal that different levels of diversified production influence households' dietary diversity differently. These results suggest that increasing production diversity contributes to greater household dietary diversity.

Keywords: Farm production diversity, household dietary diversity, Kenya, continuous treatment approach, small-scale farmers

5.1 Introduction

Africa has diverse climate, soil and agro-ecological features which support diverse agricultural production systems such as growing a wide range of crops and keeping livestock. Diverse production systems are assumed to enhance food security, nutrition and livelihoods of small-scale farmers (Fanzo and Mattei 2013; IFAD and UNEP 2013; Herrero et al. 2010). This is achieved mainly through income obtained from the sale of farm produce and through consumption of food from own production (World Bank 2007). In particular, production diversity has the potential to improve the household dietary diversity through the access to a variety of foods (Berti and Jones 2013). Dietary diversity has a great nutritional value. Studies have shown that consumption of higher numbers of food varieties or food groups are associated with greater energy and nutrient intakes (Kant 2004; Rose et al. 2002), dietary adequacy (Steyn et al. 2006) and positive anthropometric outcomes (Arimond and Ruel 2004; Rah et al. 2010).

There is however mixed evidence on the role of production diversity on dietary diversity of smallholders. On the one hand, maintaining higher production diversity improves the dietary diversity of households via food sufficiency and enhanced diversity (Kumar et al. 2015; Pellegrini and Tasciotti 2014; Jones et al. 2014). On the other hand, beyond production diversity there are other factors such as market-related ones that have an important role in the household diet diversity. Therefore, production diversity alone does not necessarily improve dietary diversity (Ng'endo et al. 2016; KC et al. 2015; Sibhatu et al. 2015). The above mentioned studies that have looked at production diversity-dietary diversity relationships have considered national representative data (Pellegrini and Tasciotti 2014; Sibhatu et al. 2015). There are only few studies that have analyzed the relationship between production diversity and dietary diversity based on sub-national data (Jones et al. 2014; Herforth 2010). Despite of using sub-national data, these studies are limited in comparing diverse market context. Therefore, using data from rural and peri-urban Kenya, this paper aims at studying the disaggregated production diversity-dietary diversity relationship based on following research questions: a) What determines households' production diversity? b) Does production diversity influence dietary diversity in general and also seasonal dietary diversity in particular? and c) How does the level of production diversity influence dietary diversity? We hypothesize that production diversity matters more in rural settings. This paper is among the first to provide empirical evidence on the impact of production diversity on dietary diversity using household-level data in Kenya. We assume different levels of production diversity impact on dietary diversity differently. Although studies have shown the potential benefits of production diversity on seasonal dietary diversity of smallholders (Ng'endo et al. 2016; Herforth 2010), the empirical evidence is limited. Therefore, we also assess the role of production diversity on seasonal dietary diversity. We assume that agricultural seasons influence food availability over the year, therefore households experience seasonal food insecurity.

The paper is organized as follows. An overview of related literature is provided in section 5.2. Section 5.3 presents the data and description of production diversity and dietary diversity variables. The conceptual framework and estimation strategy are described in section 5.4.

Results and discussion are presented in section 5.5. In the final section, the summary is given and conclusions are drawn.

5.2 Literature review

5.2.1 Determinants of farm production diversity

A number of studies have revealed that farm production diversity is determined by a variety of factors. These include socioeconomic and farm characteristics, climatic factor, market characteristics, location-specific variables, income sources, access to information and credit, and risks and shocks (Benin et al. 2004; Di Falco et al. 2010; Bezabih 2008; Nagarajan et al. 2007; van Dusen and Taylor 2005). Demographic characteristics (age, gender, education) of the farm households and wealth (asset holdings) fall under the category of socioeconomic characteristics. Households with larger availability of land and labor maintain higher production diversity (Di Falco et al. 2010; van Dusen and Taylor 2005). Households' production choices can be constrained by climatic factors. Therefore, farmers tend to expand their diversity portfolio in response to climatic risk (Di Falco et al. 2010, van Dusen and Taylor 2005). Likewise, farmers face high transaction costs when they are located far from the market. Therefore, they are likely to depend on their own production to meet their consumption needs, thus tend to diversify their production (Nagarajan et al. 2007). Production diversity increases with different sources of income by facilitating the cash constraint faced by households (Nagarajan et al. 2007). Access to information improves marketing opportunities of farm products, hence encouraging farmers to diversify their production. Location-specific variables capture the differences in cultural and physical environments across regions or counties.

5.2.2 Farm production diversity and dietary diversity: how are they related?

The literature on farm production diversity and dietary diversity is quite mixed. Some reported a positive association, others a mixed association while some reported no association. Pellegrini and Tasciotti (2014) estimated the effects of crop diversification on dietary diversity using household surveys from eight developing and transition countries. Their results show that the higher the number of crops cultivated, the higher is the number of food consumed in all the countries. This highlights a positive relationship between crop diversity and dietary diversity of the rural households. In Malawi as well, all indicators of farm production diversity are positively associated with dietary diversity (Jones et al. 2014).

However, association between production diversity and dietary diversity differed depending on gender and wealth status of the household. Woman-headed households and wealthier households experienced a greater positive association compared to male-headed and poorer households. Growing a higher crop variety leads to consumption of a higher level of food diversity by smallholder households in two East African countries, namely Kenya and Tanzania (Herforth 2010).

Mixed results have been documented from some African and Asian countries. Sibhatu et al. (2015) found that production diversity is positively associated with dietary diversity in Indonesia and Malawi, whereas no significant association is observed in Kenya and Ethiopia. This highlights the fact that the association is context-specific and depends also on other factors such as market access. Similar findings have been reported by a study conducted in three districts of Nepal (KC et al. 2015). In the mountainous and plain district, greater crop diversity resulted in more self-sufficiency. In contrast, households in the hilly district did not benefit from additional crop diversity. Authors also come to the same conclusion as Sibhatu et al. (2015) that other factors are also responsible for household dietary diversity such as accessibility of farm and access to markets.

Remans et al. (2011) did not find any significant correlations between functional diversity of crops grown and household food consumption indicators in Malawi, Kenya and Uganda. But the number and value of food items bought and sold on the local markets are significantly correlated with the household food indicators emphasizing the importance of local markets in dietary diversity. The relationship between production diversity and seasonal dietary diversity i.e. for pre-harvest, planting and post-harvest seasons is also captured in our study. The intensity of production diversity also matters, which is not documented at all in the literature. Therefore, in order to fill this literature gap, our study goes beyond estimating the impact of production diversity intensity on household dietary diversity treating our production diversity indicator as a continuous variable.

5.3 Data and variables

5.3.1 Data

The study uses data from the household survey that was conducted in Kenya in 2014 from four different counties namely Kisii, Kakamega, Nakuru and Kiambu (Fig 5.1). Based on the proximity to the main urban centers, these counties were grouped into rural and peri-urban counties. Rural counties consist of Kisii and Kakamega, while Nakuru and Kiambu belong to the peri-urban counties. Sampling was done in multi stages. The above mentioned counties were selected purposively in the first stage because of the fact that households were involved in production, marketing and consumption of African Indigenous Vegetables. Based on the information from agricultural offices from the respective counties, sub-counties and divisions with high prevalence of vegetable production were selected. Then from each division, locations/wards were randomly selected. Finally, 800 households from rural counties and 432 from peri-urban counties were randomly surveyed resulting in a total sample size of 1,232 households. Variables with missing values are not included, therefore the final sample size is 1184 households.

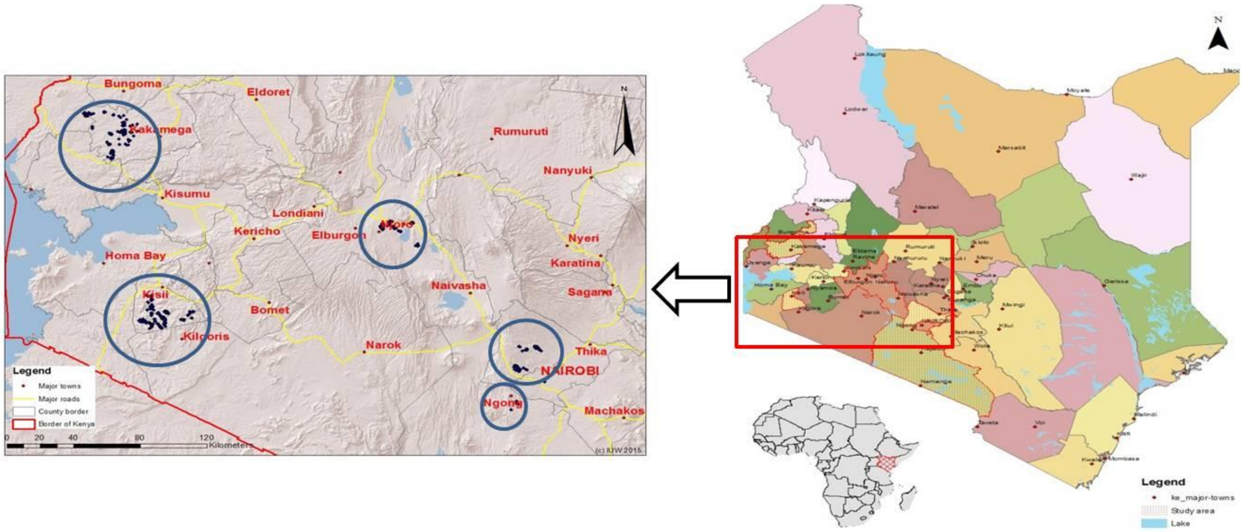


Figure 5.1: Map of study area

Data was collected using structured questionnaires and following a face to face interview method. Detailed information on agricultural production activities including crops and livestock, household and farm characteristics, and marketing aspects was collected. In addition, the questionnaire includes information related to food consumption during the past week.

5.3.2 Description of diversity variables

5.3.2.1 Farm production diversity

Production diversity is measured by nine different food groups produced by the household. These nine food groups correspond to those groups used in the household dietary diversity score calculation (Table 5.1). This takes into account the production of food from crops as well as livestock. Out of the nine food groups, five are from crop production and four are from livestock production. Food groups from crop production include cereals, roots and tubers, vegetables, fruits and pulses, seeds and nuts. Eggs, fish, meat and dairy are the food groups from livestock production.

5.3.2.2 Dietary diversity

The Household Dietary Diversity Score (HDDS) and the Food Variety Score (FVS) are used for measuring the dietary diversity of the household. HDDS is calculated using response data on consumption of different food items over the reference period of the previous week. These food items are grouped into nine food groups (Table 5.1) similar to the ones as used to derive farm production diversity. Each food group receives an equal weight if consumed by the household. Therefore, the HDDS ranges from 0 to 9. The FVS is a simple count of different food items consumed during a reference period of the previous seven days (Table 5.1).

Table 5.1: List of different food items within nine different food groups

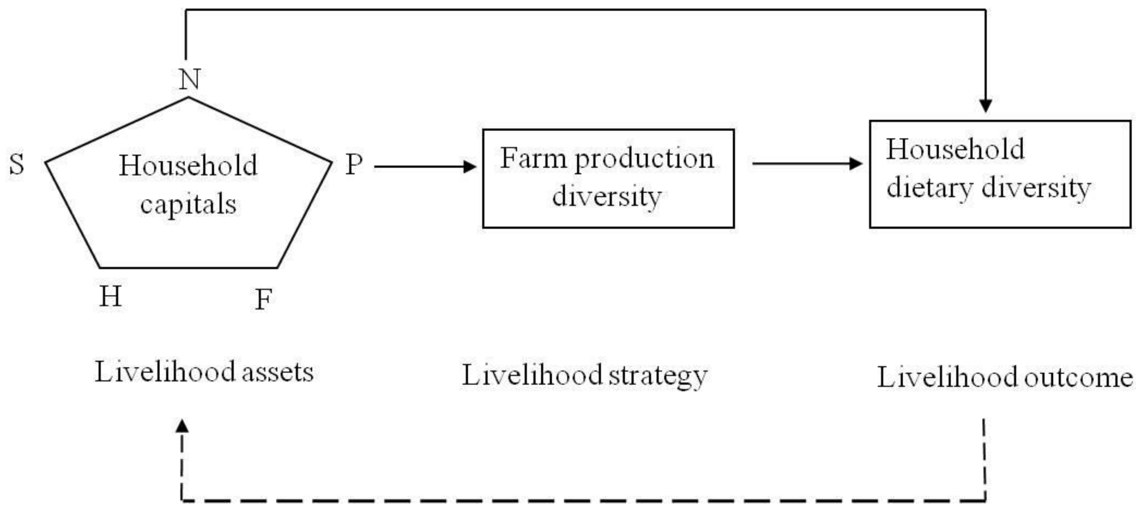
Food group	Food items within group
Crop based	
Cereals	Millet, Maize, Rice, Sorghum
Roots and tubers	Cassava, Sweet potatoes, Irish potatoes
Vegetables	Onion, Cabbages, Carrots, Tomatoes, Spinach, Capsicum, Cucumber, Lettuce, Cauliflower, Pumpkins, Coriander leaves, Amaranthus, Cowpeas, African night shade, Spider plant, Ethiopian Kale, Miroo, Murenda, Sukuma wiki
Fruits	Avocado, Banana, Mango, Pears, Sugarcane
Pulses, seeds and nuts	Beans, Green gram, Groundnuts, Pigeon peas, Sun flower
Animal based	
Milk and milk products	Milk from cows and goats
Meat	Duck, Chicken, Quails, Guinea fowl, Dove, Bulls, Cow, Goat, Pig, Sheep, Turkey, Rabbit
Eggs	Eggs from chicken, duck, dove, guinea fowl and quails
Fish and fish products	Fish

Source: Own compilation based on HORTINLEA survey data 2014

5.4 Conceptual framework and estimation strategy

5.4.1 Conceptual framework

In order to assess the relationship between production diversity and dietary diversity, a conceptual framework as depicted in the figure below is used. The framework displays the interlinkages between livelihood assets, livelihood strategy and livelihood outcomes. Production diversity, regarded as the livelihood strategy and dietary diversity, i.e. livelihood outcome is determined by livelihood assets (Scoones 1998; Barrett et al. 2001). These assets consist of natural capital (e.g. land), human capital (e.g. education and labor), social capital (e.g. information networks), financial capital (e.g. access to credit) and physical capital (e.g. farm equipment and assets). Dietary diversity is also influenced by the level of farm production diversity.



N= Natural capital; S= Social capital; P= Physical capital; H= Human capital; F= Financial capital

Figure 5.2: Conceptual framework (Authors' construction based on Scoones 1998)

5.4.2 Estimation strategy

5.4.2.1 Analyzing the determinants of farm production diversity

The level of farm production diversity is influenced by different types of household capital such as natural, social, physical, human and financial. Other factors such as risk and shocks also influence production diversity. Therefore, the influence of above mentioned factors is estimated using a regression model as outlined in equation (1).

$$Y_i = \beta X_i + \mu_i \quad (1)$$

Where, the dependent variable Y_i is the farm production diversity as measured by the number of food groups produced by the household.

X_i is the vector of explanatory variables (Table 5.2)

μ_i is the error term

5.4.2.2 Analyzing the relationship between production diversity and dietary diversity

The association between production diversity and dietary diversity is analyzed by estimating equation (2)

$$Y_i = \beta X_i + PD_i + \mu_i \quad (2)$$

Where, the dependent variable Y_i is the dietary diversity as measured by HDDS and FVS

PD is the production diversity and is a variable of major interest

X_i is the vector of explanatory variables (Table 5.2)

μ_i is the error term

Equation 2 is further estimated by using HDDS for different seasons such as pre-harvest, planting and post-harvest separately.

In the models 1 and 2 as specified above, the dependent variable is a count data. Depending on the nature of dispersion of the data, either a Poisson regression or negative binomial regression is used for the estimation. A Poisson model is appropriate when the count data is equally dispersed while a negative binomial model is appropriate in cases of over dispersed count data. Performing goodness of fit tests, we check whether the Poisson distribution is a good choice.

Furthermore, the level of production diversity is hypothesized to affect dietary diversity differently. Therefore, to assess the relationship between the level of production diversity and dietary diversity, we employ a continuous treatment approach following Hirano and Imbens (2004). This approach is based on Generalized Propensity Score (GPS), which is used to balance the differences among households of different diversity levels. Once the balancing property is fulfilled, it estimates the entire dose-response function (DRF) relating the treatment levels (production diversity) and outcomes (dietary diversity). The GPS method is described briefly as follows: Let us consider a random sample of N individuals, where i= 1 …N. For each individual i, there is a set of potential outcomes $\{Y_i (t)\}$ for $t \in \Gamma$, where t is the treatment, Γ is the treatment interval (t_0, t_1) and $\{Y_i (t)\}$ is the individual-level dose-response function. We observe a) a vector of pre-treatment variables X_i, b) the level of treatment received, T_i, and c) the outcome associated with the treatment level $Y_i= Y_i (t_i)$ for each individual. The focus is on the average dose-response function for households which is the function of the average potential outcomes over all possible treatment levels and is given by $\mu (t) = E [Y_i (t)]$.

An important assumption in estimating a dose response function is the weak unconfoundedness assumption which implies that individuals select into specific treatment levels based on observable characteristics and is independent of each potential outcome. To adjust for a multitude of factors influencing the treatment, Hirano and Imbens (2004) suggest to use GPS which is the conditional density of actual treatment given the observed covariates and is given by $R_i=r (T_i, X)$.

GPS is empirically carried out in three steps. The first step estimates the conditional probability of receiving a particular level of treatment given observed covariates resulting in a balancing score, the GPS. In the second step, balancing of the covariates is tested using the estimated GPS. Finally, the dose response functions i.e. the conditional expectation of the outcome is estimated.

5.5 Results and discussion

5.5.1 Summary statistics of the sample

Table 5.2 presents the characteristics of the sample included in the analysis disaggregated by rural and peri-urban regions. Most of the households are headed by men in both regions. Household heads from peri-urban regions are on average older than household heads from rural region. While 50% of the household head has received secondary education in peri-urban regions, only 38% of the household head has received in rural regions. Rural households have higher labor capacity than peri-urban households.

On average, rural households possess larger land and receive higher amounts of rainfall than peri-urban households. Rural households hold higher assets and are far from the nearest major markets as compared to peri-urban households. Households residing in peri-urban region have greater access to credit facilities and market information as compared to households in rural areas. Also, a larger proportion of peri-urban households have access to employment opportunities such as off-farm employment than rural households. Peri-urban households spend higher amount for food than rural households. They face less agricultural shocks and are also more risk taking than rural households.

Table 5.2: Summary statistics of the variables disaggregated by rural and peri-urban regions

Variables	Description of the variables	Pooled	Rural	Peri-urban
Human capital				
Age (years)	Age of the household head	49.63	49.27	50.35
		(12.56)	(12.45)	(12.76)
Gender (Male=1)	Gender of the household head	0.80	0.82	0.76
		(0.39)	(0.38)	(0.42)
Education (Secondary=1)	Household head has secondary education	0.42	0.38	0.51
		(0.49)	(0.48)	(0.50)
Labor (Worker equivalents)	Labor capacity	4.11	4.48	3.37
		(1.92)	(1.97)	(1.59)
Natural capital				
Land (ha)	Total land	0.82	0.89	0.67
		(0.81)	(0.77)	(0.87)
Rainfall (mm)	Mean annual rainfall	1405.18	1621.61	981
		(339.69)	(123.56)	(199.34)
Physical capital				
Distance (km)	Distance to the nearest major markets	2.49	3.11	2.18
		(2.49)	(2.85)	(2.22)
Assets (Score)	Household asset holding	63.50	65.48	59.64
		(86.37)	(100.81)	(49.71)
Social capital				
Market information (Yes=1)	Access to market information	0.38	0.32	0.49
		(0.48)	(0.46)	(0.50)
Financial capital				
Off-farm employment (Yes=1)	Access to off-farm employment	0.31	0.25	0.34
		(0.46)	(0.43)	(0.47)
Non-farm self –employment (Yes=1)	Access to nonfarm self-employment	0.18	0.17	0.18
		(0.38)	(0.38)	(0.38)

Credit access (Yes=1)	Access to credit	0.19	0.17	0.22
		(0.39)	(0.37)	(0.41)
Others				
Risk attitude (Scale: 1-10)	Risk attitude	5.51	5.47	5.58
		(2.45)	(2.21)	(2.87)
Shocks (Yes=1)	Household faces agricultural shocks	0.79	0.84	0.70
		(0.40)	(0.36)	(0.45)
Food expenditure (PPP$)	Food expenditure per capita per month	32.07	27.72	40.59
		(21.01)	(17.77)	(24.07)
Location variables				
Region (Peri-urban=1)	Household belongs to peri-urban region	0.33		
		(0.47)		
County (Kissi=1)	Household belongs to Kissi county		0.50	
			(0.50)	
County (Nakuru=1)	Household belongs to Nakuru county			0.54
				(0.49)
Observations		1184	784	400

Values shown in parentheses are standard deviations

Source: Own calculations based on HORTINLEA household survey 2014

5.5.2 Production diversity and dietary diversity

Table 5.3 shows the production diversity and dietary diversity found in rural and peri-urban regions of Kenya. Overall, households produce around 5 different kinds of food groups and consume around 17 food items. Differences between rural and peri-urban regions are observed in terms of production and dietary diversity. Rural households have significantly higher production diversity than the peri-urban households. Despite the fact that rural households produce more food groups, their dietary diversity in terms of both HDDS and FVS is significantly lower compared to the households residing in peri-urban regions. This signifies that peri-urban households acquire their diverse diets from markets in addition to their own production (HatlØy et al. 1999). Seasonal variation for dietary diversity is also observed between rural and peri-urban regions where rural households have significantly lower HDDS for all seasons i.e. planting, pre-harvest and post-harvest compared to peri-urban households.

Table 5.3: Comparison of production diversity and dietary diversity in rural and peri-urban Kenya

Diversity indices	Pooled	Peri-urban	Rural
Production diversity	4.95	4.34***	5.26
	(1.49)	(1.51)	(1.38)
Dietary diversity			
HDDS	6.41	6.78***	6.23
	(1.48)	(1.30)	(1.45)
HDDS (Pre-harvest)	8.19	8.65***	7.96
	(1.33)	(0.69)	(1.53)
HDDS (Planting)	8.28	8.59***	8.12
	(1.05)	(0.77)	(1.14)
HDDS (Post-harvest)	8.41	8.68***	8.27
	(1.01)	(0.69)	(1.11)
FVS	16.52	18.46***	15.53
	(4.84)	(5.30)	(4.27)
Observations	1184	400	784

*** indicate a significance level of 1% using a two-sample Wilcoxon rank-sum test

Values shown in parentheses are standard deviations.

Source: Own calculations based on HORTINLEA household survey 2014

5.5.3 Determinants of production diversity

Table 5.4 reports the determining factors of production diversity for the pooled and the rural and peri-urban samples. Results show that land and labor have a positive and significant influence on production diversity for the pooled sample as well as for the rural and peri-urban samples. This implies that households having more land and more labor force diversify their production portfolio. This result is supported by studies from Benin et al. (2004); van Dusen and Taylor (2005) and di Falco et al. (2010).

In the peri-urban region, household head characteristics such as age and gender influence production diversity. Female-headed households have higher production diversity. Benin et al. (2004) also found a similar result in Ethiopia. This is plausible considering that male-headed households might be involved in other income generating activities which provide less time for them in the farm production activity. Households with older household heads maintain higher production diversity because they are more experienced in engaging in multiple activities (van Dusen and Taylor 2005). Households having different employment opportunities (such as non-farm self-employment and off-farm employment) and higher asset holdings have significantly higher farm production diversity. Employment opportunities provide additional cash income for households to invest and enlarge their production activities. Furthermore, households can also better cope when they face production risk. Assets are important as they can be sold to increase households' liquidity and they can protect farmers from risks. Those households residing in Nakuru county maintain lower production diversity compared to households from Kiambu county.

For the rural region, the distance to market, access to credit and access to market information increases production diversity, whereas the risk attitude decreases production diversity. Households far away from markets maintain higher production diversity, because they need to cover their consumption demand by their own production (Whitney et al.2017; van Dusen and Taylor 2005). Credit facilities provide the possibility to the rural households to invest in required inputs and diversify their farming activities. Access to market information helps households to be informed about various inputs and technologies, and reduce marketing costs. This enables and encourages farmers to participate in markets by diversifying their production according to the market needs. Households' preparedness to take risk is negatively associated with production diversity implying that risk taking households would specialize in production rather than diversify.

Table 5.4: Determinants of farm production diversity

	Pooled	Peri-urban	Rural
	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)
Age of HH head	0.000	0.004***	-0.001
	(0.00)	(0.001)	(0.001)
Gender of HH head	-0.027	-0.105**	-0.013
	(0.021)	(0.041)	(0.025)
Education of HH head	0.013	0.019	0.007
	(0.017)	(0.034)	(0.020)
Risk attitude	-0.004	0.006	-0.012***
	(0.003)	(0.006)	(0.004)
Land size owned	0.068***	0.067***	0.063***
	(0.009)	(0.015)	(0.011)
Labor	0.013***	0.046***	0.009*
	(0.004)	(0.011)	(0.004)
Access to off-farm employment	0.036**	0.091**	0.022
	(0.017)	(0.040)	(0.020)

Access to non-farm self-employment	0.018	0.077*	-0.013
	(0.019)	(0.040)	(0.022)
Distance to nearest market	0.004	0.004	0.005*
	(0.002)	(0.006)	(0.003)
Access to credit	0.038**	0.039	0.040*
	(0.018)	(0.035)	(0.021)
Access to market information	0.052***	-0.048	0.087***
	(0.016)	(0.033)	(0.018)
Agricultural shocks	0.041**	0.037	0.040
	(0.020)	(0.036)	(0.025)
Household asset holding	0.000	0.001**	0.000
	(0.000)	(0.000)	(0.000)
Rainfall	0.000		
	(0.000)		
Region (Peri-urban=1)	-0.143***		
	(0.043)		
County (Nakuru=1)		-0.083**	
		(0.036)	
County (Kisii=1)			0.000
			(0.019)
Constant	1.396***	1.044***	1.601***
	(0.105)	(0.090)	(0.056)
N	1184	400	784
chi2	226.60	119.44	85.83
P	0.000	0.000	0.000

***, ** and * indicate a significance level of 1%, 5% and 10% respectively

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

5.5.4 Association between production diversity and dietary diversity

The results of Poisson and negative binomial models are presented in Table 5.5 for the pooled, rural and peri-urban samples. Results reveal that production diversity is significantly associated with dietary diversity for the pooled sample as well as for rural one. These are consistent for both measures of dietary diversity, i.e. HDDS and FVS, and suggest that production diversity plays a major role in enhancing dietary diversity for rural households. A similar observation has been reported for Haiti by Pauze et al. (2016) where HDDS and accessibility of location are also positively associated. The argument behind this is that rural households, characterized by having a low access to markets depend more on their own production to fulfill their diet requirements and may have greater access to food throughout the season (Anzid et al. 2009; Jones et al. 2014). In addition to production diversity, the key variables explaining dietary diversity are age, gender, labor, assets, livestock, food consumption expenditure and market-related factors such as distance and off-farm employment. Labor, food consumption expenditure and assets are positively associated with both indicators of dietary diversity in both rural and peri-urban regions. Jones et al. (2014) also observed a positive association between food consumption expenditure and dietary diversity in Malawi. Age of the household head has a negative association with dietary diversity, suggesting that households with young heads have higher dietary diversity (Jones et al. 2014). Male-headed households of peri-urban regions experience a higher HDDS than female-headed households. This result is consistent with a study from Bangladesh (Rashid et al. 2011). They argue about differences in knowledge, preferences and limited mobility to be the associated factors for the lower dietary diversity of households headed by women. Similarly, livestock asset endowments are positively and significantly associated with dietary diversity implying that households who keep more livestock have higher dietary diversity (Pellegrini and Tasciotti 2014; KC et al. 2015). Two explanations are possible for this positive association. First, livestock serve as a critical input in the farms providing draught power and manure to grow more crops adding to the diversity. Second, households consume meat and dairy products from their own production so that it is an important source of food for them, thus improving diet quality. Indicators used to capture market access (off-farm employment and distance to market) have an influence on the dietary diversity. The effect of these factors is pronounced in peri-urban Kenya. While having off-farm employment has a positive and significant association with dietary diversity (Jones et al. 2014, Sibhatu et al. 2015), distance to market has a negative association (Sibhatu et al. 2015; Koppmair et al. 2016). This implies that households closer to the market and participating in off-farm activities experience higher dietary diversity.

Table 5.5: Regression results on the effect of farm production diversity on dietary diversity

	Pooled		Peri-urban		Rural	
	HDDS	FVS	HDDS	FVS	HDDS	FVS
Diversity (based on number of food groups produced)	0.022^{***}	0.036^{***}	0.006	0.009	0.028^{***}	0.046^{***}
	(0.005)	(0.006)	(0.007)	(0.010)	(0.006)	(0.007)
Age of HH head	-0.002^{***}	-0.003^{***}	-0.002^{**}	-0.002^{*}	-0.003^{***}	-0.003^{***}
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Gender of HH head	0.046***	0.020	0.046**	0.001	0.022	-0.006
	(0.016)	(0.020)	(0.025)	(0.035)	(0.021)	(0.024)
Education of HH head	0.008	0.017	0.020	0.027	0.007	0.014
	(0.014)	(0.016)	(0.018)	(0.027)	(0.019)	(0.019)
Land size owned	0.011	-0.002	-0.005	-0.028*	0.016	0.005
	(0.008)	(0.010)	(0.010)	(0.016)	(0.012)	(0.014)
Livestock owned	0.000	0.005*	0.008**	0.015**	-0.003	0.001
	(0.002)	(0.003)	(0.003)	(0.006)	(0.002)	(0.002)
Labor	0.018***	0.024***	0.032***	0.047***	0.016***	0.021***
	(0.005)	(0.006)	(0.008)	(0.011)	(0.006)	(0.006)
Food consumption expenditure	0.003***	0.004***	0.003***	0.004***	0.003***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Distance to nearest market	-0.004	-0.006*	-0.006*	-0.008*	-0.003	-0.001
	(0.003)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Access to off-farm employment	0.002	-0.002	0.024	0.061**	-0.014	-0.046*
	(0.014)	(0.017)	(0.020)	(0.031)	(0.018)	(0.020)
Household asset holding	0.000**	0.000***	0.001***	0.001***	0.000**	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Region dummy (Peri-urban=1)	0.095***	0.187***				
	(0.014)	(0.018)				
County dummy (Nakuru=1)			-0.014	0.002		
			(0.019)	(0.029)		
County dummy (Kissi=1)					-0.039***	-0.036*
					(0.017)	(0.019)
Constant	1.587***	2.413***	1.653***	2.570***	1.636***	2.431***
	(0.044)	(0.061)	(0.074)	(0.106)	(0.057)	(0.065)
N	1184	1184	400	400	784	784
r2_p	0.01	0.06	0.01	0.04	0.01	0.04
chi2	165.51	241.87	72.22	100.33	82.98	137.29
P	0.000	0.000	0.000	0.000	0.000	0.000
Ln alpha				-4.552***		
Constant				(0.453)		

***, ** and * indicate a significance level of 1%, 5% and 10%, respectively

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

5.5.5 Association between production diversity and seasonal HDDS

Table 5.6 provides the result of the association between production diversity and seasonal dietary diversity (pre-harvest, planting and post-harvest) for the pooled, peri-urban and rural samples, respectively. The full model is shown in Appendix 5.1-5.3. For the pooled and the rural sample, production diversity has a significant influence on dietary diversity for two seasons i.e. planting and post-harvest. Agricultural production cycle influences the prices and the food availability. One possible explanation is that agricultural seasons such as planting and post-harvest are characterized by better food availability, whereas there is a decrease in food availability during the pre-harvest season and shifts in food prices. However, for the peri-urban region which has lower farm production diversity, this relationship is not observed.

Table 5.6: Association between farm production diversity and seasonal HDDS

	HDDS (Pre-harvest)	HDDS (Planting)	HDDS (Post-harvest)
Pooled			
Diversity (based on number of food groups produced)	0.003 (0.004)	0.007*** (0.003)	0.016*** (0.003)
Rural			
Diversity (based on number of food groups produced)	0.008 (0.006)	0.015*** (0.004)	0.026*** (0.004)
Peri-urban			
Diversity (based on number of food groups produced)	-0.002 (0.003)	-0.004 (0.004)	-0.000 (0.003)

*** indicate a significance level of 1%

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

5.5.6 Impact of the level of production diversity on dietary diversity

Using the continuous treatment effects model, the heterogeneous impacts of production diversity on household dietary diversity is estimated. In the first step, the conditional distribution of maintaining a particular level of diversity given observed covariates is estimated using maximum likelihood estimation. This estimates the GPS (Appendix 5.4). Since the treatment variable i.e. production diversity indicator needs to be normally distributed, we check the distribution of the production diversity indicator, i.e. the number of food groups produced. As can be seen from Figure 5.3, the production diversity variable (number of food groups produced) is highly skewed. To make it normally distributed, we use zero skewness Box Cox transformation.

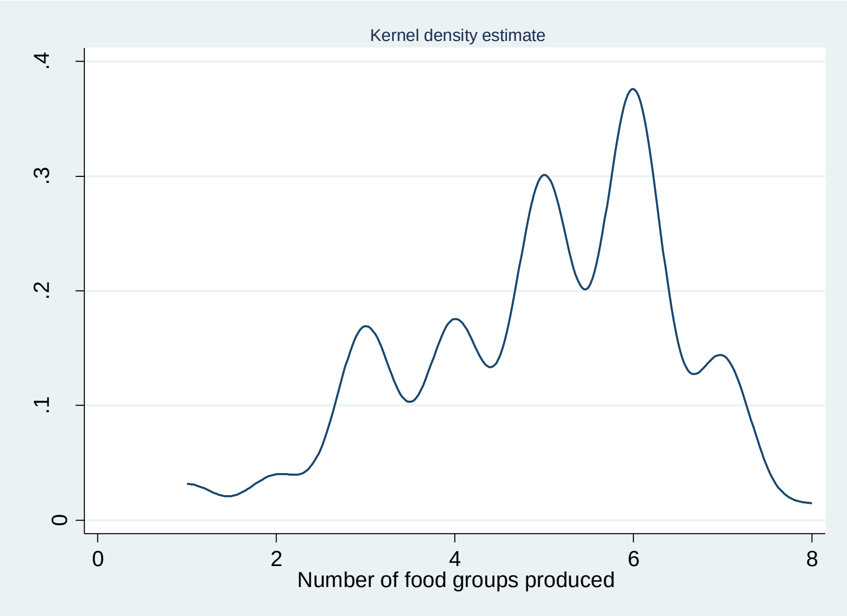


Figure 5.3: Density of number of food groups produced

In the second step, the estimated GPS is used to check for the balancing of the covariates. To do so, the sample is divided into three groups based on the distribution of the treatment variable. Group 1 includes households with a treatment level between 1 and 4; households with a treatment level 5 and 6 fall under group 2, and group 3 has households with treatment level 7 and 8. The balancing of each of the covariates used is done by testing whether the mean in one of the three groups is different from the mean of the other two groups combined. Table 5.7 shows the results of the balancing test which reports the t-statistics for each of the covariates and each of the three groups before and after adjustment of the GPS. Referring to Table 5.7, 16 variables had t-statistics above 1.96 in absolute value which reduced to three variables after adjustment by GPS. This shows a sufficient balancing whereby overall covariate imbalance was reduced by 81.25%.

Table 5.7: Covariate balancing before and after adjustment by GPS

Variable	Before adjustment by GPS			After adjustment by GPS		
	1, 4	5, 6	7,8	1, 4	5, 6	7,8
Age of household head	2.21	-0.27	-1.46	0.47	-0.00	0.24
Gender of household head	1.75	-1.03	-0.41	-0.36	0.19	-0.21
Education of Household head	-0.48	-0.71	1.03	-0.14	0.18	-0.76
Risk	1.09	-0.66	-0.38	-0.00	-0.57	0.54
Land	8.27	4.28	-9.11	2.84	-1.36	-0.99

Worker equivalent	6.68	2.47	-6.99	-0.46	0.17	-0.63
Off farm employment	3.95	0.95	-3.69	0.44	-0.26	-0.84
Self-employment	0.76	-1.32	0.61	-0.00	-0.55	0.57
distance to market	0.70	-0.86	0.30	0.58	-0.96	0.78
Credit access	0.91	0.31	-0.99	-0.21	-0.42	0.84
Market information	1.11	1.73	-2.46	0.05	0.62	-0.28
Rainfall	9.61	0.69	-8.78	-0.22	0.61	-2.60
Shocks	1.85	0.91	-2.37	-0.08	0.06	-1.40
Peri-urban	-9.16	-1.84	9.20	-0.23	-0.32	2.83
Asset score	0.32	1.48	-1.47	1.27	-0.43	-1.31

Note: Values are t-statistics for equality of means for each covariate in the respective interval

Source: Own calculations based on HORTINLEA household survey 2014

Finally, the DRFs as shown in Figure 5.3 are estimated for the dietary diversity indicators HDDS and FVS. The level of production diversity as given by number of food groups is represented by the horizontal axis, and dietary diversity indicators are shown along the vertical axis. The bootstrapping approach is used to obtain the standard errors. Results show that FVS and HDDS increase as the number of food groups produced increases. For example, as production diversity increases from 1 to 8, the HDDS increases from 5.89 to 7.16 while the FVS increases from 13.74 to 19.59. Overall, producing different food groups improves HDDS by 6.17 and FVS by 15.62 on average (Appendix 5.5). This result indicates that production diversity delivers varieties of food groups and food items to the households which could be one of the reasons for the effect of production diversity to dietary diversity of households.

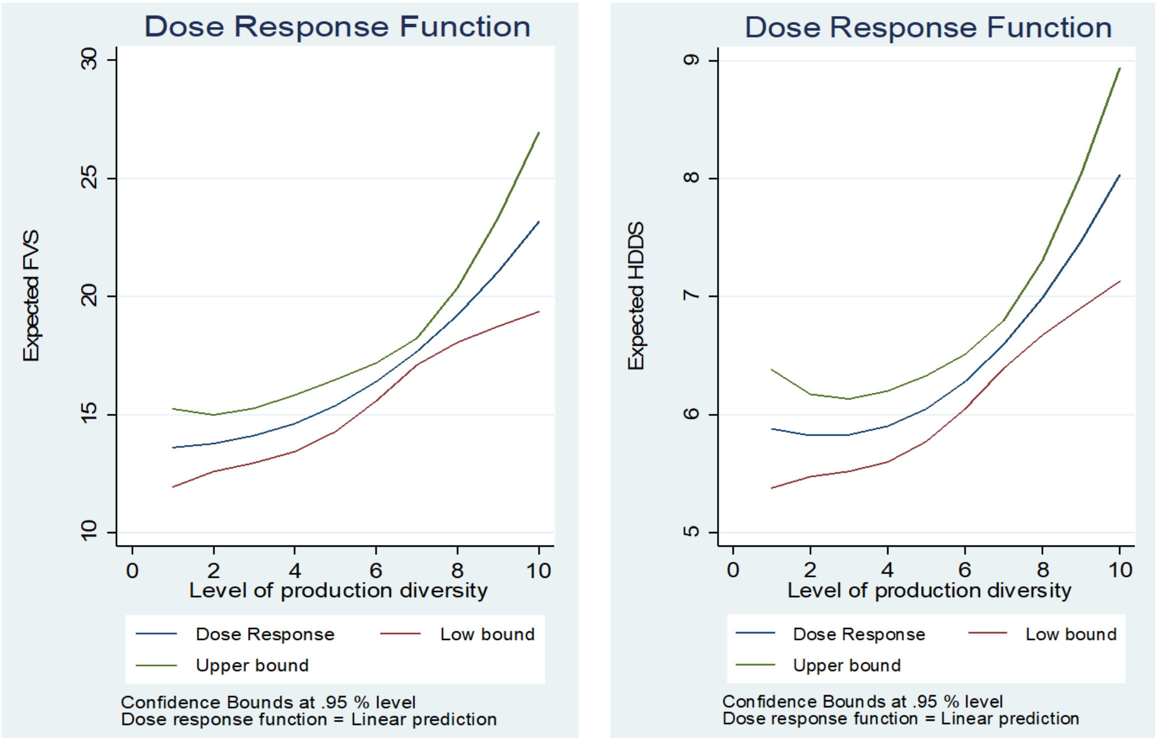


Figure 5.4: Estimated dose response (average treatment) functions for FVS and HDDS

5.6 Summary and conclusion

Using disaggregated information from rural and peri-urban Kenya, we have investigated the links between production diversity and household dietary diversity by addressing the following three research questions. First, what determines households´ production diversity? Second, does production diversity influence dietary diversity in general and also seasonal dietary diversity in particular? Third, how does the level of production diversity influence dietary diversity? Differences in production diversity and dietary diversity are observed in these regions. The descriptive analysis indicates that rural households have higher production diversity but lower dietary diversity. On the other hand, peri-urban households who maintain lower production diversity have higher dietary diversity. Households' choice to maintain diversity in farm production is influenced by several factors such as land and labor, employment opportunities, asset holdings, market access, credit and information. By estimating the Poisson and negative binomial regression models, we find a positive association between production diversity and dietary diversity for the rural households in Kenya. A significant role of production diversity is also observed for planting and post-harvest seasons in rural region. Production diversity is neither associated with households´ overall dietary diversity nor with seasonal dietary diversity in peri-urban region. Considering production diversity as a continuous treatment, results show the heterogeneous effects of production diversity on dietary diversity with higher level of production diversity resulting into higher dietary diversity.

These analyses show that the role of production diversity on dietary diversity is context-specific. In low market access region, production diversity has a critical role in enhancing the dietary diversity of the household. In regions with better market access, markets determine household dietary diversity by providing an opportunity to sell their agricultural products and at the same time to buy varieties of food. Therefore, policy focus on improving smallholders´ dietary diversity also needs context-specific strategies. For example, in rural contexts, production related challenges should be addressed. While, focus should be on improving market institutions and infrastructure in peri-urban settings.

Our study gives insights into the role of different levels of production diversity on dietary diversity using the average dose response functions. It should be noted, however, that our analysis is based upon cross-sectional data. This prevented us from addressing issues related to dynamics of production diversity and dietary diversity and also to control for unobserved specific heterogeneity. Since, our HDDS indicator for agricultural seasons is recall data, data on each seasons can be collected to capture the real time situation.

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Appendices

Appendix 5.1: Relationship between farm production diversity and seasonal HDDS (Pooled)

	HDDS (Pre-harvest)	HDDS (Planting)	HDDS (Post-harvest)
Diversity (based on number of food groups produced)	0.003	0.007***	0.016***
	(0.004)	(0.003)	(0.003)
Age of HH head	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Gender of HH head	0.002	0.004	0.002
	(0.013)	(0.011)	(0.009)
Education of HH head	0.015	0.014*	0.002
	(0.010)	(0.008)	(0.007)
Land size owned	0.006	-0.004	-0.002
	(0.005)	(0.005)	(0.004)
Livestock owned	0.002*	0.003**	0.003**
	(0.001)	(0.001)	(0.001)
Labor	0.000	-0.005**	-0.002
	(0.003)	(0.002)	(0.002)
Food consumption expenditure	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)
Access to market information	-0.003	0.005	0.019***
	(0.011)	(0.008)	(0.007)
Distance to nearest market	-0.003*	-0.004**	0.000
	(0.002)	(0.002)	(0.001)
Access to off-farm employment	0.024***	0.004	-0.010
	(0.009)	(0.008)	(0.008)
County dummy (Peri-urban=1)	0.090***	0.059***	0.059***
	(0.009)	(0.008)	(0.008)
Household asset holding	0.000	0.000**	0.000**
	(0.000)	(0.000)	(0.000)
Constant	2.015***	2.059***	2.039***
	(0.028)	(0.024)	(0.024)
N	1184	1184	1184
chi2	146.35	104.33	95.10
P	0.000	0.000	0.000

***, ** and * indicate a significance level of 1%, 5% and 10%, respectively

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

Appendix 5.2: Relationship between farm production diversity and seasonal HDDS (Peri-urban)

	HDDS (Pre-harvest)	HDDS (Planting)	HDDS (Post-harvest)
Diversity (based on number of food groups produced)	-0.002	-0.004	-0.000
	(0.003)	(0.004)	(0.003)
Age of HH head	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Gender of HH head	-0.006	-0.007	-0.009
	(0.009)	(0.011)	(0.009)
Education of HH head	0.008	0.011	0.004
	(0.008)	(0.009)	(0.008)
Land size owned	-0.001	-0.001	-0.004
	(0.005)	(0.006)	(0.005)
Livestock owned	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)
Labor	0.002	-0.002	0.004
	(0.004)	(0.004)	(0.003)
Food consumption expenditure	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Access to market information	-0.012	-0.026***	-0.005
	(0.008)	(0.009)	(0.008)
Distance to nearest market	-0.003*	-0.006**	-0.002
	(0.002)	(0.002)	(0.002)
Access to off-farm employment	0.009	0.016*	0.001
	(0.009)	(0.010)	(0.010)
Household asset holding	0.000***	0.000**	0.000
	(0.000)	(0.000)	(0.000)
County dummy (Nakuru=1)	-0.008	-0.009	-0.001
	(0.008)	(0.009)	(0.009)
Constant	2.145***	2.155***	2.150***
	(0.021)	(0.025)	(0.019)
N	400	400	400
chi2	21.01	25.55	11.96
P	0.050	0.012	0.449

***, ** and * indicate a significance level of 1%, 5% and 10%, respectively

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

Appendix 5.3: Relationship between farm production diversity and seasonal HDDS (Rural)

	HDDS (Pre-harvest)	HDDS (Planting)	HDDS (Post-harvest)
Diversity (based on number of food groups produced)	0.008	0.015***	0.026***
	(0.006)	(0.004)	(0.004)
Age of HH head	0.000	0.000	-0.000
	(0.001)	(0.000)	(0.000)
Gender of HH head	-0.005	0.001	-0.004
	(0.020)	(0.016)	(0.014)
Education of HH head	0.032**	0.023**	0.010
	(0.015)	(0.011)	(0.011)
Land size owned	0.007	-0.007	-0.004
	(0.008)	(0.008)	(0.006)
Livestock owned	0.003	0.003*	0.003*
	(0.002)	(0.002)	(0.002)
Labor	-0.000	-0.006**	-0.003
	(0.004)	(0.003)	(0.003)
Food consumption expenditure	-0.000	-0.001	-0.000
	(0.000)	(0.000)	(0.000)
Distance to nearest market	-0.004	-0.003	0.001
	(0.003)	(0.003)	(0.001)
Access to off-farm employment	0.032**	0.000	-0.014
	(0.013)	(0.010)	(0.010)
Household asset holding	0.000	0.000**	0.000*
	(0.000)	(0.000)	(0.000)
County dummy (Kissi=1)	-0.080***	-0.042***	-0.053***
	(0.014)	(0.010)	(0.010)
Constant	2.049***	2.062***	2.033***
	(0.045)	(0.037)	(0.036)
N	784	784	784
chi2	57.64	44.84	78.88
P	0.000	0.000	0.000

***, ** and * indicate a significance level of 1%, 5% and 10%, respectively

Values shown in parentheses are standard errors

Source: Own calculations based on HORTINLEA household survey 2014

Appendix 5.4: Estimates of GPS (continuous treatment)

	GPS	
	Coefficient	SE
Age of household head	0.006	.012
Gender of household head	-0.450	0.368
Education of Household head	0.120	0.307
Risk	-0.091	0.058
Land	1.293***	0.184
Worker equivalent	0.229***	0.080
Off farm employment	0.602*	0.315
Self-employment	0.179	0.366
distance to market	0.056	0.057
Credit access	0.563	0.368
Market information	0.892***	0.298
Rainfall	0.000	0.000
Shocks	0.654*	0.362
Peri-urban	-2.646***	0.704
Asset score	0.002	0.001
Constant	7.714***	1.716
Log likelihood	-3427.576	
Observations	1184	

Note: Dependent variable for GPS: Number of food groups produced

***, ** and * indicate a significance level of 1%, 5% and 10%, respectively

Source: Own calculations based on HORTINLEA household survey 2014

Appendix 5.5: Estimates of average treatment and marginal treatment effects

	Food Variety Score (FVS)				Household Dietary Diversity Score (HDDS)			
Treatment level	ATE	t-value	MTE	t-value	ATE	t-value	MTE	t-value
1	13.745	-4.09	0.043	-2.11	5.894	-3.39	-0.100	-3.11
2	13.789	-6.04	0.205	-2.72	5.794	-4.92	-0.027	-3.79
3	13.994	-5.34	0.470	-3.67	5.766	-4.69	0.066	-4.74
4	14.465	-3.95	0.777	-3.99	5.833	-3.89	0.169	-4.14
5	15.242	-2.88	1.105	-0.94	6.002	-3.10	0.276	-1.00
6	16.348	-1.46	1.448	0.22	6.279	-1.84	0.386	0.37
7	17.796	2.34	1.799	0.70	6.665	1.08	0.497	0.97
8	19.595	3.36	2.156	0.96	7.163	2.98	0.610	1.29
Overall	15.622		1.000		6.174		0.234	

Note: ATE = Average treatment effects, MTE = Marginal treatment effects

Source: Own calculations based on HORTINLEA household survey 2014

Chapter 6: Diversity in Farm Production and Household Diets: Comparing Evidence from Smallholders in Kenya and Tanzania

Luitfred Kissoly, Sabina Khatri Karki, Ulrike Grote

Abstract

Farm production diversity is widely promoted as a strategy for enhancing smallholders' food and nutrition security. However, empirical evidence from the rural smallholder context is still limited and mixed. This study, therefore, compares the nature, determinants and influence of farm production diversity on household dietary diversity in rural and peri-urban settings in Kenya and Tanzania. Descriptive and econometric analyses are employed using household-level survey data from four counties in Kenya (n=1150) and two districts in Tanzania (n=899). Results show that smallholders in Kenya generally maintain a higher diversity in farm production and have more diverse diets compared to Tanzania. In addition, for peri-urban and rural areas with better market access, production diversity is generally lower and dietary diversity higher. Nonetheless, farm production diversity has a positive and significant influence on indicators of household dietary diversity for both countries. This role is especially important for households in remote rural settings. The arising implication is that, apart from farm production diversity, factors such as access to off-farm income opportunities and market access are equally important in improving household dietary diversity. This calls for strengthening of context specific production and market-related aspects of smallholder agriculture for enhanced dietary diversity.

Keywords: Farm production diversity, dietary diversity, smallholders, rural, peri-urban, Kenya, Tanzania

6.1 Introduction

Enhancing smallholder farm production diversity has recently gained increased attention owing to its potential to enhance rural households' food and nutrition security (Berti and Jones, 2013). This comes against the backdrop of persistent undernourishment and increasing vulnerability of rural households, particularly in developing countries, due to climate change and weather related shocks (Grote, 2014; FAO, IFAD and WFP, 2014). Despite the fact that challenges of food and nutrition security are global in nature, the magnitude of the problem is immense in Sub-Saharan Africa. For example, prevalence of undernourishment is the highest where about one in every four people remains undernourished (FAO, IFAD and WFP, 2014). In Kenya and Tanzania, in particular, the proportion of undernourishment in total population is about 21% and 32%, respectively. In rural areas, undernourishment is generally more pronounced than in urban settings.

Agricultural diversification has been among several strategies being widely advocated to address the above challenges (KC et al., 2015; Powell et al. 2015; Pellegrini and Tasciotti, 2014; Fanzo and Mattei, 2012). For smallholders, agriculture plays an important role in their food security and livelihood outcomes (IFAD and UNEP, 2013; Herrero et al., 2010). In fact, smallholder agriculture provides a lifeline for rural households through direct consumption of food from own production and also through incomes obtained from sale of farm produce which is used for purchases of food (World Bank, 2007). From this, agricultural diversification is seen as a potential strategy for improving smallholders' food and nutritional outcomes, and in particular household dietary diversity, among other benefits. Farm production diversity, which entails a variety of plant and animal species maintained at the farm, is therefore assumed to enhance smallholders' access to a diversity of food products (Fanzo et al., 2013; Burlingame and Dernini, 2012).

However, various recent studies acknowledge that the relationship between farm production diversity and dietary diversity is still complex and inherently confounded by numerous other factors such as market access (Sibhatu et al., 2015; Jones et al., 2014). Indeed, empirical literature on this relationship reveals mixed results. On the one hand, several studies find that smallholder farm production diversity is positively related to household dietary diversity (Kumar et al., 2015; Pellegrini and Tasciotti, 2014; Jones et al., 2014). From this strand of literature, increased dietary diversity is linked to farm production diversity mainly through direct subsistence consumption of own farm produce and through purchase of food from markets using farm income obtained from selling part of their agriculture produce. On the other hand, studies show that farm production diversity is not always associated with dietary diversity (Ng'endo et al., 2016; KC et al., 2015; Sibhatu et al., 2015). Beyond production diversity, they argue that markets play a major role in enhancing dietary diversity. Essentially markets offer opportunities for selling their farm produce as well as purchases of different food varieties.

The present study contributes to this literature by comparatively assessing the nature, determinants and role of farm production diversity on household dietary diversity using the cases of Kenya and Tanzania. So far, there are only a few studies looking at the relationship between farm production diversity and dietary diversity at sub-national levels (Jones et al., 2014; Herforth, 2010). Despite important insights generated, these studies are limited in terms of representing diverse market and agro-ecological contexts. Other existing comparative studies mainly refer to country averages (Sibhatu et al., 2015; Pellegrini and Tasciotti, 2014). We use survey data from smallholder households conducted in various regions in Kenya and Tanzania, hence capturing diverse market and agro-ecological contexts. For Tanzania, these include villages in (1) Kilosa district which poses semi-humid agro-ecology and relatively better market access and (2) Chamwino district which has less market access with semi-arid agro-ecological characteristics. For the case of Kenya, the survey covered Kiambu and Nakuru counties – representing peri-urban characteristics – and Kisii and Kakamega representing a rural context. In addition, we analyze the role of farm production diversity on seasonal dietary diversity of smallholders. Recent studies on agricultural diversification have also focused on the potential benefits of farm production diversity on seasonal dietary diversity of smallholder households (Ng'endo et al., 2016; Herforth, 2010). However, empirical evidence on this potential is still limited. We therefore use dietary diversity indicators capturing planting, pre-harvest and post-harvest agricultural seasons. This is especially important given the seasonal food insecurity experienced by most rural households (Bacon et al., 2014; Vaitla et al., 2009).

Against this background, this comparative study intends (1) to examine the nature and determinants of farm production diversity and (2) to analyze the influence of farm production diversity on household dietary diversity using the cases of Kenya and Tanzania. The rest of the study is organized as follows. The next section describes the study areas and data, while section 6.3 elaborates on the conceptual framework and methodology used in this study. Results and discussion are presented in section 6.4. Section 6.5 summarizes the main results and gives concluding remarks.

6.2 Study areas and data

This study uses household-level survey data from Kenya and Tanzania collected in 2014. For Kenya, the data was collected from four counties namely Kisii, Kakamega, Kiambu and Nakuru (Figure 6.1). These counties were classified into rural and peri-urban based on the proximity to the main urban centers. Kisii and Kakamega counties represent a rural context while Kiambu and Nakuru counties can be classified as peri-urban. From respective counties, sub-counties and divisions were selected based on the information from district agricultural offices. Then locations/wards were selected randomly from each selected divisions. Finally, households were randomly selected from these locations resulting into a total sample size of 1,150 households where 766 households belong to rural counties and 384 households are from peri-urban counties.

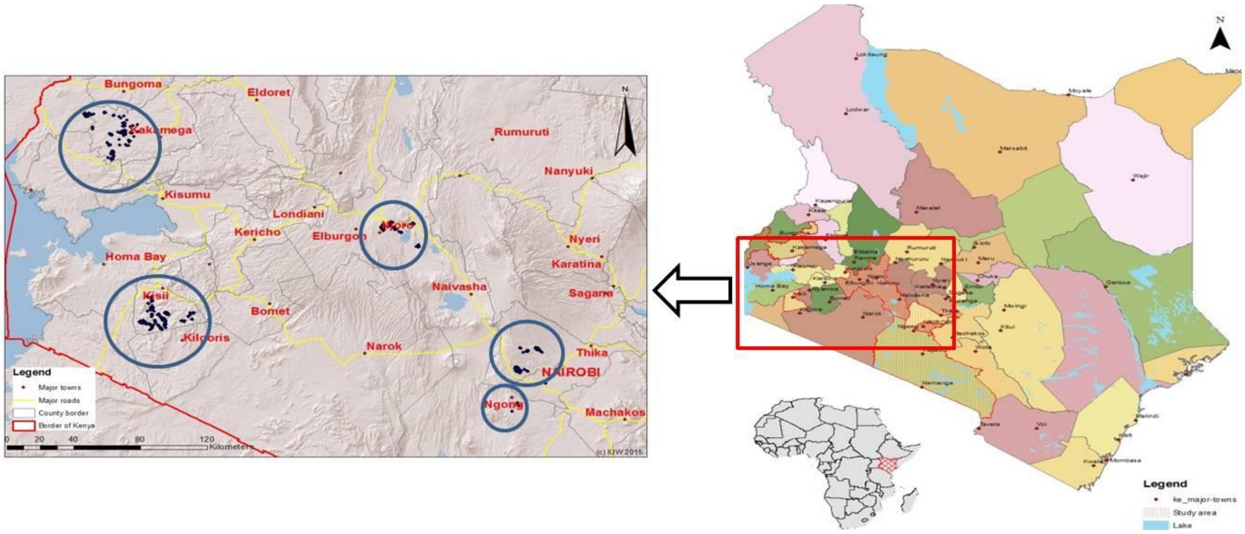


Figure 6.1: Map of study area-Kenya

In Tanzania, data was collected from smallholders in two districts, Kilosa and Chamwino (Figure 6.2). Three villages were selected from each district based on several criteria. These included having (1) rain-fed cropping systems, (2) livestock integration in the production system, (3) similar climate by district, (4) different market access characteristics and (5) village size between 800-1500 households. The villages include Changarawe, Nyali and Ilakala in Kilosa district and Ilolo, Ndebwe and Idifu in Chamwino district. Household lists were prepared covering all households in the respective villages. From these lists, 150 households were randomly selected to participate in the survey with distribution within each village being proportional to sub-village sizes. In total 900 households were interviewed.

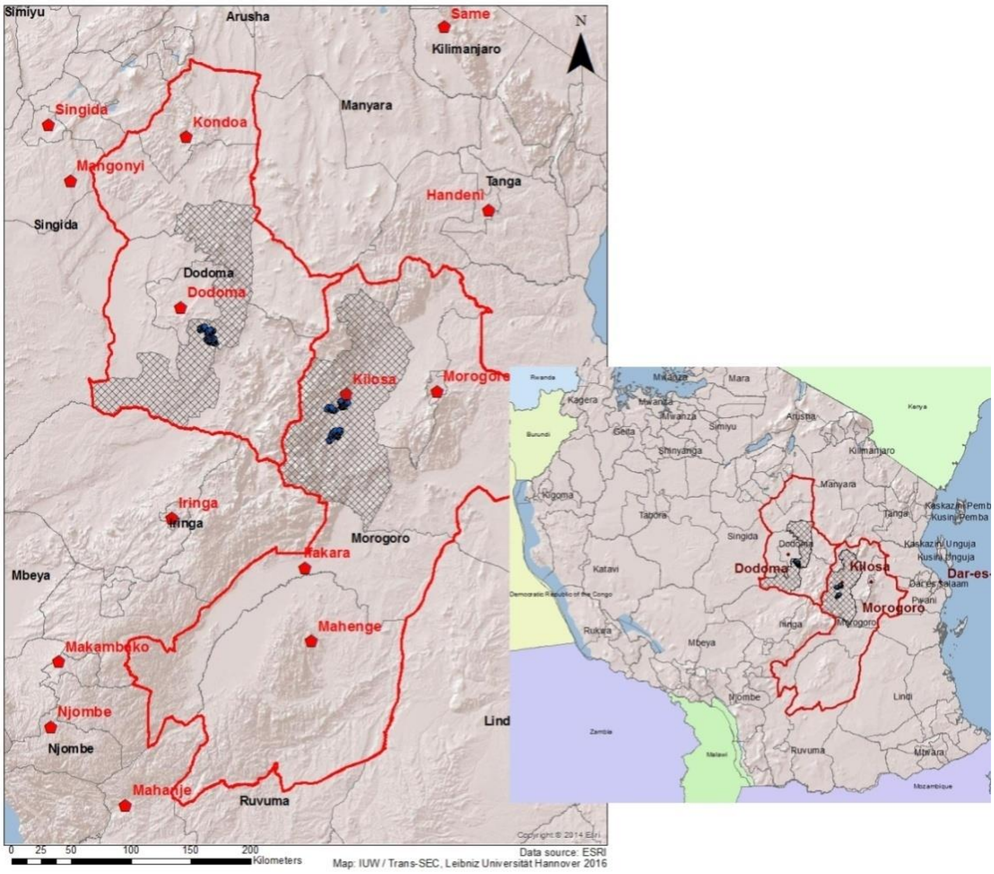


Figure 6.2: Map of study area-Tanzania

A summary of key characteristics of the study areas is provided in Table 6.1 while a map of the study sites is presented in Figure 6.1 and 6.2. In both Kenya and Tanzania, structured household and village questionnaires were used as key survey instruments. The household-level questionnaire contains detailed sections to capture data on household demographic, social, economic and food security characteristics. The village-level questionnaires were administered to village authorities to acquire important information at village-level such as on infrastructure, economic profiles and other key services.

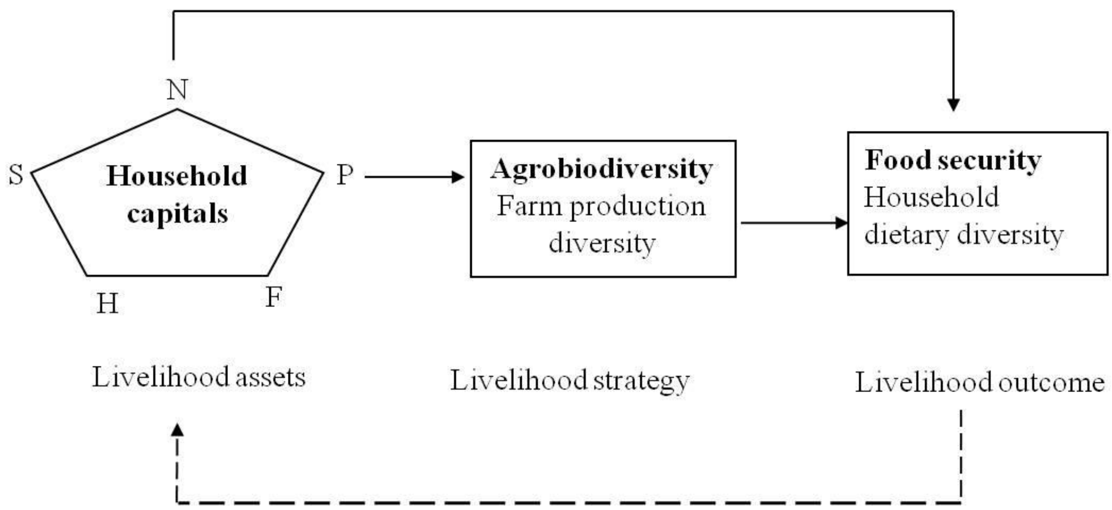
Table 6.1: Summary of main characteristics of study area

	Kenya		Tanzania	
County/ District	Kiambu, Nakuru (peri-urban)	Kisii, Kakamega (rural)	Kilosa (rural)	Chamwino (rural)
Climate	Semi-humid	Semi-humid	Semi-humid	Semi-arid
Agricultural potential	Relatively good	Relatively good	Relatively good	Relatively poor
Access to major markets	Relatively good	Relatively poor	Relatively good	Relatively poor
Major crops Food crops	Maize, potatoes, vegetables	Maize, vegetables	Maize, rice, peas	Sorghum, millet, groundnuts
Cash crops	Tea, coffee, pyrethrum	Tea, coffee, sugarcane	Sesame, cotton	Sunflower, sesame
Livestock	Dairy cattle, sheep	Dairy cattle	Little livestock keeping (poultry, goats)	Heavy integration of livestock (Cattle, goat, poultry)

Source: Trans-Sec Survey, 2014; Hortinlea Survey, 2014

6.3 Conceptual framework and methodology

In assessing and comparing the role of farm production diversity on household dietary diversity in Kenya and Tanzania, we conceptualize key relationships as follows. Smallholder choices of livelihood strategies (such as diversity in farm production) and the resultant livelihood outcomes (such as household dietary diversity) are likely to depend largely on livelihood assets (Scoones, 1998; Barrett et al., 2001). These are in terms of natural (e.g. land), physical (e.g. farm equipment or assets), social (e.g. information networks), human (e.g. education and labor) and financial (e.g. access to credit) capitals owned. From the Sustainable Livelihoods Approach, farm production diversity can be viewed as a livelihood strategy which is influenced by household capitals. For households' livelihood outcomes, we assume that dietary diversity is influenced by farm production diversity as well as the existing household capitals in terms of socio-economic characteristics and market and agro-ecological characteristics. Likewise, livelihood outcomes determine livelihood assets. The conceptual framework is presented in Figure 6.3.



N= Natural capital; S= Social capital; P= Physical capital; H= Human capital; F= Financial capital

Figure 6.3: Conceptual framework (Authors' construction based on Scoones, 1998)

6.3.1 Measurement of farm production diversity and dietary diversity

Several studies have proposed and used various measures of farm production diversity and dietary diversity. Starting with farm production diversity, different measures have evolved from previous studies that focused on assessing genetic diversity at the farm and on biodiversity (Meng et al., 2010). In general, these measures capture species diversity and different nutritional functions of crops and livestock species produced (Last et al., 2014; Berti, 2015). Among the widely used are count indicators which are constructed as simple count variables capturing both crop produced and livestock species kept at the farm. However, these do not capture the different nutritional functions of the crops and livestock under consideration (Berti, 2015). This study therefore uses the number of food groups produced on the farm to ascertain the level of production diversity[1]. Based on our data, and to aid comparison between Kenya and Tanzania, we construct a diversity score based on 9 food groups. These are cereals; roots, tubers and plantains; pulses, seeds and nuts; fruits; vegetables; fish; meat; eggs; and milk and dairy products. From this production diversity score we are then able to capture the different nutritional functions of crop and livestock produced by smallholder as proposed by Berti (2015). Therefore, a household cultivating rice, groundnuts and in addition keeping chicken will have a production diversity score of 4 as they come from 4 different food groups i.e. cereals; pulses, seeds and nuts; meat; and eggs.

[1]The Simpson's Index and the modified Margalef species richness index would have been alternative indicators but these are able to suitably capture only crop diversity (Di Falco and Chavas 2009; Last et al. 2014).

Conversely, for a household cultivating rice, millet and maize and also keeping cattle the production diversity score will be 3 i.e. cereals; meat; and milk and dairy products.

Regarding dietary diversity we use two indicators. The first is the Household Dietary Diversity Score (HDDS). HDDS is a good proxy indicator for diet quality and is documented to correlate well with important nutrition outcomes such as anthropometric status (Swindale and Bilinsky, 2006; Moursi et al., 2008). Following Swindale and Bilinsky (2006), we construct the HDDS from 9 different food groups consumed by a household in the previous normal week. The 9 food groups correspond to the classification used in the farm production diversity indicator above. The HDDS is also calculated for different agricultural seasons in the year based on how many days in a normal week households ate a particular food group in each season i.e. planting, pre-harvest and post-harvest seasons. Despite involving long recall periods, this indicator gives essential insights into the levels of dietary diversity for various agricultural seasons. The second dietary indicator is the Food Variety Score (FVS) which captures the number of different food items consumed by a household in a given reference period (HatlØy et al., 1998). We also use the previous normal week as a recall period. Unlike HDDS which captures different food groups, FVS counts all single foods consumed.

6.3.2 Assessing determinants of farm production diversity

Deriving from the conceptual framework, farm production diversity is influenced by various livelihood assets such as human, natural, social, physical and financial capital. We therefore assess the determinants of farm production diversity using a regression model specified as:

$$PD_i = \delta \mathrm{X}_i + u_i \qquad (1)$$

Where, PD_i represents the farm production diversity for household i. This is a score capturing the number of food groups produced by the household. X_i represents a vector of explanatory variables while δ is a vector of parameters to be estimated and u_i is the error term. As presented in the conceptual framework, variables predicting household farm production diversity constitute human capital (e.g. age, gender, education and labor), natural capital (e.g. land and rainfall), physical capital (e.g. distance and assets), social capital (e.g. market information), financial capital (e.g. credit access, off-farm and non-farm employment) and other factors such as risk attitude and shocks.

6.3.3 Evaluating the relationship between farm production diversity and dietary diversity

Household dietary diversity is assumed to be influenced by farm production diversity among other factors. To specifically analyze this relationship for Kenya and Tanzania, we also specify a regression model in which household dietary diversity is determined by farm production diversity and other important control variables. This is given as follows:

$$CD_i = \beta PD_i + \delta X_i + u_i \quad (2)$$

Where, CD_i captures household dietary diversity for each individual household, i as measured by the HDDS and FVS. For seasonal dietary diversity, the HDDS indicators for planting, pre-harvest and post-harvest are used. PD_i is the farm production diversity, our main determinant of interest. X_i represents a vector of other important independent variables influencing dietary diversity. β and δ are parameters to be estimated, while u_i represents the error term.

Apart from farm production diversity, household dietary diversity can be influenced by household socio-economic characteristics such as age and gender of the household head which may determine households' dietary preferences and allocation of household resources towards food consumption (Jones et al., 2014). Also, household ownership of productive assets such as labor and land may play an important role in improving dietary diversity through enhanced agricultural production and farm incomes. Off-farm incomes are also vital in enhancing dietary diversity through increased household food consumption expenditure and access to diverse food items from markets (Jones et al., 2014; Sibhatu et al., 2015). This implies that, market access is an essential element in achieving household dietary diversity. Proximity to markets is thus expected to positively influence dietary diversity as it improves households' access to a diversified food portfolio as well as income generating opportunities.

Both specified relationships above in Eq. (1) and Eq. (2) are estimated with count data models i.e. Poisson and negative binomial regression models owing to the nature of our diversity indicators. We first carry out over-dispersion tests in our dependent variables to ascertain the need for employing a Poisson or negative binomial regression. For equi-dispersion, Poisson regression is used while the negative binomial regression is used in case of over-dispersed count data. Also, potential collinearity among explanatory variables is tested. As the present study rely on cross-section data, it must be pointed out that the results enable us to only assess potential associations between our variables of interest. Therefore, caution should be taken when interpreting the results as they may not necessarily imply causation.

6.4 Results and discussion

6.4.1 Household and farm characteristics in Kenya and Tanzania

Descriptive statistics in Table 6.2 show that notable differences exist in key characteristics at household and farm level. In terms of human capital, results show that household heads in Kenya are, on average, older but with more labor capacity at the household level compared to their counterparts in Tanzania. Moreover, these households have a higher proportion of educated and male-headed households. Regarding natural capital, smallholders in Kenya possess less land but receive substantially higher average annual rainfall. On the contrary, smallholders in Tanzania own about twice the amount of land compared to those in Kenya but receive much less average annual rainfall. For Tanzania, large parts of Chamwino district are sparsely populated and characterized by a 'pastoralist/agro-pastoralist' farming system which requires on average large areas of land (Mnenwa and Maliti, 2010). With regards to physical and social capital, while asset holding is relatively the same in both countries, households in Kenya are closer to markets compared to those in Tanzania. However, a smaller proportion has access to market information in Kenya. Concerning financial capital, households in Tanzania are more enterprising with a larger proportion having access to non-farm self-employment compared to those in Kenya. Similarly, off-farm employment is higher in Tanzania than in Kenya suggesting that a greater proportion of household members resort to casual work off their farms. However, households in Kenya have far better access to credit compared to Tanzania. This may be attributed to the peri-urban proximity to key services for the case of Kenya.

Table 6.2: Descriptive statistics of key household and farm characteristics in Kenya and Tanzania

	Description of the variables	**Kenya**	**Tanzania**
Human capital			
Age (years)	Age of the household head	49.71	48.64
		(12.49)	(17.10)
Gender (Male=1)	Gender of the household head	0.80	0.78
		(0.39)	(0.40)
Education (Formal=1)	Household head has formal education	0.73	0.67
		(0.44)	(0.47)
Labor (Worker equivalents)	Labor capacity	4.11	3.02
		(1.92)	(1.47)
Natural capital			
Land (ha)	Total land	0.82	1.71

		(0.80)	(1.76)
Rainfall (mm)	Mean annual rainfall	1408.4	473.23
		(339.06)	(78.69)
Physical capital			
Distance (km)	Distance to the nearest major markets	2.46	6.06
		(2.48)	(4.71)
Assets (Score)	Household asset holding	64.87	64.01
		(87.19)	(190.27)
Social capital			
Market information (Yes=1)	Access to market information	0.38	0.45
		(0.48)	(0.47)
Financial capital			
Off-farm employment (Yes=1)	Access to off-farm employment	0.31	0.33
		(0.46)	(0.47)
Non-farm self –employment (Yes=1)	Access to nonfarm self-employment	0.18	0.25
		(0.38)	(0.43)
Credit access (Yes=1)	Access to credit	0.18	0.09
		(0.39)	(0.29)
Observations		1150	899

Values shown in parentheses are standard deviations

6.4.2 Comparison of farm production diversity and dietary diversity

In terms of diversity, results from Table 6.3 show that, overall, smallholders in Kenya maintain a higher diversity of farm production compared to those in Tanzania. Similarly, household dietary diversity in Kenya, both in terms of HDDS and FVS is higher compared to that of Tanzania. However, diversity within the two countries reveals interesting results. In Kenya, farm production diversity is significantly lower for the peri-urban counties of Nakuru and Kiambu as compared to the rural counties of Kisii and Kakamega. Similarly, for the case of Tanzania, Kilosa district (with better agricultural potential and better market access) has significantly lower farm production diversity compared to Chamwino district. However, in both countries dietary diversity is significantly higher for the areas with lower farm production diversity, i.e. Nakuru/ Kiambu counties in Kenya and Kilosa district in Tanzania. This underscores the argument that farm production diversity is only one among several factors influencing dietary diversity.

Table 6.3: Comparison of farm production and dietary diversity in Kenya and Tanzania study areas

	Kenya			Tanzania		
Diversity indices	Rural (Kisii/ Kakamega)	Peri-urban (Nakuru/ Kiambu)	Pooled	Rural (Kilosa)	Rural (Chamwino)	Pooled
Production diversity	5.27 (1.38)	4.34*** (1.52)	4.96	3.01 (1.35)	3.81*** (1.33)	3.41
Dietary diversity						
HDDS	6.28 (1.45)	6.81*** (1.30)	6.46	5.29 (1.46)	4.20*** (1.39)	4.74 (1.52)
FVS	15.66 (4.08)	18.64*** (5.27)	16.66	10.95 (3.38)	9.03 (3.82)	9.99 (3.73)
Observations	766	384	1150	450	448	899

*** indicate a significance level of 1%

Values shown in parentheses are standard deviations

6.4.3 Determinants of farm production diversity

Table 6.4 presents the estimation results for determinants of farm production diversity in Kenya and Tanzania. Overall, the results show that farm production diversity is influenced by numerous human, natural, physical, social, financial and other factors. However, similarities and differences exist in how these factors influence production diversity in the two case study countries.

Table 6.4: Regression results of determinants of production diversity

	Kenya	Tanzania
Human capital		
Age (years)	0.000	0.002**
	(0.001)	(0.001)
Gender (Male=1)	-0.028	0.071**
	(0.022)	(0.036)
Education (Formal=1)	0.003	0.036
	(0.021)	(0.029)
Labor (Worker equivalents)	0.016***	0.031***
	(0.004)	(0.008)
Natural capital		
Land (ha)	0.072***	0.030***

	(0.010)	(0.006)
Rainfall (mm)	0.000***	-0.001**
	(0.000)	(0.000)
Physical capital		
Distance (km)	0.002	0.012**
	(0.003)	(0.005)
Assets (Score)	0.000	0.000
	(0.000)	(0.000)
Social capital		
Market information (Yes=1)	0.044***	0.034
	(0.017)	(0.027)
Financial capital		
Off-farm employment (Yes=1)	0.041**	0.004
	(0.018)	(0.028)
Nonfarm self–employment (Yes=1)	0.021	0.079***
	(0.020)	(0.028)
Credit access (Yes=1)	0.038**	0.112***
	(0.019)	(0.033)
Other control variables		
Risk attitude (Scale: 1-10)	-0.006*	0.005
	(0.004)	(0.005)
Shocks (Yes=1)	0.051**	-0.069**
	(0.021)	(0.029)
Constant	1.125***	1.146***
	(0.068)	(0.205)
Observations	1150	899
Wald chi2	204.20	227.04
Probability>chi2	0.000	0.00
Pseudo R2	0.02	0.028

***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively

Values shown in parentheses are standard errors

In both countries, labor, land and credit access have a positive and significant contribution to farm production diversity. These constitute important household endowments which are critical in influencing the number of crops produced and livestock species kept by a household (Benin et al. 2004). The positive and significant effect of labor on farm production diversity indicates that households with more resources in terms of labor capacity are able to meet the increased labor demand required in maintaining higher farm production diversity.

Labor capacity is especially important in rural farming systems which involve labor-intensive cultivation technologies and are likely to maintain higher levels of biodiversity (Smale, 2006). As noted, results also show that land influences farm production diversity positively. Land is an important determinant as it enhances the capacity of smallholders to exploit returns arising from strategic complementarities in their activities such as crop-livestock integration (Barrett et al., 2001). From our data, smallholders in areas with more land (such as Kisii and Kakamega counties in Kenya and Chamwino district in Tanzania) have, on average, higher farm production diversity. These results are in line with the findings of Benin et al. (2004) and Di Falco et al. (2010) in Ethiopia where land plays an important positive role in enhancing crop diversity. With regards to credit access, farm production diversity is partly enhanced by the availability of important inputs for both, crops and livestock (Smale, 2006). These include seeds and fertilizer for crops and medicine and veterinary services for livestock. Access to credit may be particularly necessary for market-oriented smallholders such as those in peri-urban areas in Kenya.

As aforementioned, country-specific differences exist in how various factors influence farm production diversity. In Kenya, rainfall has a positive and significant effect on farm production diversity. The reason for this may be that, given the existing agro-ecological characteristics, availability of rainfall is likely to increase diversity maintained by smallholders, especially in terms of different crop species (Di Falco et al., 2010). However, for Tanzania, increased rainfall is associated with less farm production diversity. This may be explained by the regional effects where farm production is lower in Kilosa district with relatively higher levels of rainfall unlike in the semi-arid Chamwino district in which smallholders maintain higher levels of farm production diversity. Again, Di Falco et al. (2010) argue that, in presence of harsher environmental conditions, smallholders may produce more diverse crops as a risk mitigation strategy in case of crop loss or other shocks.

Distance to the nearest major markets is significantly associated with increased farm production diversity only in Tanzania. This implies that smallholders in distant and less accessible areas tend to maintain higher levels of diversity in their farm production so as to circumvent higher transaction costs involved in acquiring food from markets (Benin et al., 2004; Pellegrini and Tasciotti, 2014). Social capital, which is captured by households' access to market information, is significant in influencing farm production positively for the case of Kenya. In the rural and peri-urban areas, most farmers are engaged in the cultivation of horticultural crops and widely sell African Indigenous Vegetables. Access to market information appears to play an important role for this category of smallholders. This role is, however, not significant in Tanzania as markets and market transactions are relatively underdeveloped in most villages constituting the sample, especially in Chamwino district.

In terms of household financial capital, off-farm employment and non-farm self-employment are positively and significantly associated with farm production diversity. While off-farm employment is significant only for Kenya, non-farm self-employment is significant for Tanzania. Both are important sources of income to smallholders and they enable financing of various farm production operations such as inputs purchases. In Kenya, off-farm employment mostly takes the form of construction work or wholesale/retail trade. For Tanzania, information from qualitative interviews revealed that off-farm employment is less remunerative as it involves provision of manual labor to different agricultural work such as weeding or harvesting. However, income from non-farm self-employment (such as from petty trading), provide essential sources of finance to smallholders for investing in agriculture.

With regards to other controls, results show that risk attitude plays a vital role in influencing farm production diversity in Kenya. Specifically, preparedness of a household to take risk has a negative and significant influence on farm production diversity. The reason for this may be that, smallholders who are more willing to take risks have a more specialized farm production portfolio as they aim at increasing efficiency and farm incomes. On the contrary, risk-averse smallholders are likely to maintain a more diverse farm production portfolio so as to reduce production risks (Di Falco and Chavas, 2009; Di Falco et al., 2010). Results further show that agricultural shocks have a significant positive influence on farm production diversity in Kenya, but a negative influence for the case of Tanzania. As argued by Di Falco and Chavas (2009), shocks may compel smallholders to maintain a higher diversity in their production as a risk mitigation strategy. However, shocks may also have a negative influence on farm production diversity, as is the case for Tanzania, when resource poor smallholders decide for a few highly resistant crops and livestock following an occurrence of a shock in the household. For most vulnerable smallholders, severe agricultural shocks may substantially reduce farm production capacity of households, thus negatively impacting farm production diversity.

6.4.4 Role of farm production diversity on dietary diversity

Results from the analysis of the relationship between farm production diversity and dietary diversity are presented in Table 6.5. Results summarize the influence of farm production diversity, together with other control variables, on consumption or dietary diversity in Kenya and Tanzania. Starting with farm production diversity, results show that it has a significant positive influence on dietary diversity in both countries. This relationship is observed for both indicators of dietary diversity, i.e. HDDS and FVS. An important implication here is that smallholders maintaining a higher diversity in their farm production portfolio (in both crops and livestock) benefit more in terms of diversity of their diets at the household level. This confirms that for smallholder households, agriculture is indispensable in improving diets either through increased consumption from own production or from markets through increased income from sale of agriculture produce (World Bank, 2007; Jones et al., 2014; Sibhatu et al., 2015).

Table 6.5: Regression results of determinants of food consumption diversity (HDDS and FVS)

	Kenya		**Tanzania**	
	HDDS	FVS	HDDS	FVS
Production diversity	0.022***	0.035***	0.031***	0.040***
	(0.004)	(0.006)	(0.007)	(0.009)
Age (years)	-0.002***	-0.003***	-0.002***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Gender (Male=1)	0.051***	0.029	0.012	0.004
	(0.016)	(0.020)	(0.026)	(0.030)
Education (Formal=1)	-0.009	-0.020	0.030	0.041
	(0.015)	(0.018)	(0.023)	(0.027)
Labor (Worker equivalents)	0.017***	0.023***	-0.005	0.006
	(0.004)	(0.005)	(0.007)	(0.009)
Land (ha)	0.017**	0.003	0.009	0.010
	(0.007)	(0.009)	(0.005)	(0.007)
Distance (km)	-0.003	-0.005	-0.016***	-0.017***
	(0.003)	(0.004)	(0.004)	(0.005)
Assets (Score)	0.000***	0.000***	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Livestock (TLU)	-0.001	0.004	-0.001	-0.002
	(0.002)	(0.003)	(0.001)	(0.003)
Market information (Yes=1)	-0.007	0.008	0.085***	0.105***
	(0.013)	(0.016)	(0.022)	(0.025)

Food consumption expenditure (PPP$)	0.003***	0.004***	0.001***	0.001***
	(0.001)	(0.001)	(0.000)	(0.000)
Off-farm employment (Yes=1)	0.002	-0.001	-0.046**	-0.049*
	(0.013)	(0.016)	(0.023)	(0.026)
Nonfarm self-employment (Yes=1)	0.072***	0.062***	0.043*	0.055**
	(0.014)	(0.018)	(0.022)	(0.027)
Credit access (Yes=1)	0.028*	0.046**	0.042	0.049
	(0.015)	(0.019)	(0.030)	(0.038)
Regional dummy	0.099***	0.193***	0.089**	0.055*
	(0.015)	(0.018)	(0.042)	(0.049)
Constant	1.590***	2.429***	1.492***	2.212***
	(0.044)	(0.061)	(0.076)	(0.083)
Ln(alpha)				-4.336***
				(0.419)
Observations	1150	1150	899	899
Wald chi2	215.32	307.34	350.74	202.02
Probability>chi2	0.000	0.000	0.00	0.00
Pseudo R2	0.01	0.06	0.032	0.041

Regional dummy: Kenya (Peri-urban=1) Tanzania (Kilosa=1)

***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively

Values shown in parentheses are standard errors

6.4.5 Role of other important factors influencing dietary diversity

The relationship between farm production diversity and dietary diversity is complex (Jones et al., 2014). Indeed, dietary diversity is also influenced by other factors beyond farm production diversity. Our results show that household endowments in terms of productive assets (such as land and labor), market related factors (such as distance and market information), access to off-farm and non-farm self-employment and location are important in influencing household dietary diversity. Specifically, land and labor are significantly and positively associated with dietary diversity for Kenya while ownership of assets has a positive influence for both countries. Apart from reflecting household wealth, ownership of assets, especially productive assets such as land and labor, contribute to households' capacity to produce both for home consumption and for sale hence enhancing access to a variety of food items at the household level. More important, smallholders may use their land and labor endowments to grow more varieties of nutrient-dense crops and keep livestock thus improving food self-sufficiency and dietary diversity (Jones et al., 2014; KC et al., 2015).

Market related factors are also important determinants of dietary diversity. Distance to nearest major markets influences dietary diversity negatively for the case of Tanzania. This suggests that, with limited access to markets and other essential services, smallholders are not only constrained in terms of accessing a variety of food items from markets but also lack essential support infrastructure to improve their agricultural production. Dietary diversity is also positively related to access to market information for both countries, Kenya and Tanzania. Similarly, Sibhatu et al. (2015) stress the important role of market access and market transactions in enhancing dietary diversity. The reason is that smallholders rely on markets for generating important income for household food consumption as well as sourcing different food varieties.

Dietary diversity is also significantly influenced by household income. Our results show that food consumption expenditure and access to non-farm self-employment have a positive and significant effect on household dietary diversity for both Kenya and Tanzania. Access to remunerative non-farm self-employment income adds to household incomes and thus raises the households' purchasing power. With increased purchasing power, households may spend on more diverse food and hence improve their dietary diversity. Several studies note the positive role of increased household food consumption expenditure resulting from various income generating activities. For example, Jones et al. (2014) observe that dietary diversity was positively associated with household food expenditure. However, off-farm employment is negatively associated with dietary diversity for the case of Tanzania. As noted earlier, the less remunerative nature of off-farm employment means that it is done by the very poor households and thus its contribution to household dietary diversity is largely marginal.

Location characteristics have also significant influence on household dietary diversity. Being located in peri-urban counties (for Kenya) and those in Kilosa for Tanzania is positively associated with increased dietary diversity. With regards to Kenya, this may reflect the fact that households in peri-urban areas have more opportunities in terms of market access thus being able to sell their produce and also purchase different food items. For Tanzania, Kilosa district has more agricultural potential given its semi-humid agro-ecology and also has better market access thus impacting household dietary diversity positively unlike in Chamwino district which is semi-arid with low market access.

6.4.6 Farm production diversity and seasonal dietary diversity

Results on the analysis of the potential of farm production diversity on the seasonal household dietary diversity are presented in Table 6.6. Overall, the results show that farm production diversity is associated with seasonal dietary diversity in both countries. In Kenya, farm production diversity has a positive and significant influence on dietary diversity during planting and post-harvest seasons. With regards to Tanzania, farm production diversity is consistently positively associated with the indicator of dietary diversity for planting, pre-harvest and post-harvest seasons. These results imply that increased farm production diversity may have additional potential benefits of improving household dietary diversity also across different agricultural seasons. As widely noted, most smallholder households' consumption is highly dependent on agricultural seasons. Seasons before harvest (i.e. planting and pre-harvest) are mainly characterized by sporadic food insecurity when compared to post-harvest season (Vaitla et al., 2009). With farm production diversity, smallholders can therefore access various crops at different periods of the year as different crops mature and are harvested at different seasons of the year (Herforth, 2010). This potential may also be applicable to different livestock species.

Table 6.6: Regression results of determinants of seasonal dietary diversity

	Kenya			**Tanzania**		
	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)
Production diversity	0.007^{***}	0.004	0.016^{***}	0.024^{***}	0.024^{***}	0.011^{*}
	(0.003)	(0.004)	(0.003)	(0.008)	(0.007)	(0.007)
Age (years)	0.000	0.000	-0.000	-0.001^{*}	-0.002^{**}	-0.001^{**}
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Gender (Male=1)	0.005	0.003	0.003	-0.001	0.058^{**}	-0.024
	(0.011)	(0.013)	(0.009)	(0.027)	(0.029)	(0.023)
Education (Formal=1)	0.009	0.017	0.002	0.048^{*}	0.012	0.029
	(0.010)	(0.013)	(0.009)	(0.026)	(0.025)	(0.022)
Labor (Worker equivalents)	-0.005^{*}	0.000	-0.002	-0.007	-0.010	0.006
	(0.003)	(0.003)	(0.002)	(0.007)	(0.008)	(0.006)
Land (ha)	-0.004	0.007	-0.002	0.012^{**}	0.017^{***}	0.009^{*}
	(0.005)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)
Distance (km)	-0.004^{*}	-0.003	0.000	-0.005	-0.007	-0.006
	(0.002)	(0.002)	(0.001)	(0.005)	(0.005)	(0.004)

Assets (Score)	0.000**	0.000*	0.000*	0.000***	0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock (TLU)	0.002*	0.002	0.002*	0.002*	0.003*	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Market information (Yes=1)	0.004	-0.003	0.019***	0.104***	0.098***	0.069***
	(0.008)	(0.010)	(0.007)	(0.023)	(0.024)	(0.020)
Food consumption expenditure (PPP$)	-0.000	0.000	0.000	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Off-farm employment (Yes=1)	0.004	0.027***	-0.010	-0.033	-0.027	-0.014
	(0.008)	(0.010)	(0.008)	(0.024)	(0.024)	(0.019)
Nonfarm self-employment (Yes=1)	-0.003	0.008	0.009	0.018	0.025	0.064***
	(0.009)	(0.012)	(0.008)	(0.023)	(0.024)	(0.019)
Credit access (Yes=1)	0.014*	-0.014	0.001	-0.021	0.005	-0.004
	(0.008)	(0.012)	(0.008)	(0.032)	(0.034)	(0.030)
Regional dummy	0.060***	0.094***	0.057***	0.210***	0.188***	0.081**
	(0.009)	(0.011)	(0.008)	(0.044)	(0.043)	(0.036)
Constant	2.052***	1.999***	2.029***	1.480***	1.471***	1.697***
	(0.027)	(0.031)	(0.025)	(0.075)	(0.077)	(0.065)
Observations	1150	1150	1150	899	899	899
Wald chi2	108.41	151.78	102.86	291.21	304.99	138.23
Probability>chi2	0.000	0.000	0.000	0.00	0.00	0.00
Pseudo R2	0.00	0.00	0.00	0.035	0.036	0.014

***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively

Values shown in parentheses are standard errors

6.5 Summary and conclusions

The present study assessed and compared the nature and determinants of farm production diversity and its influence on household dietary diversity in Kenya and Tanzania.

Comparing the level of farm production diversity in the two countries, results show that smallholders in Kenya have a higher diversity compared to their counterparts in Tanzania. However, in Kenya, smallholders in peri-urban counties which are closer to major markets are far less diverse when compared to those in rural counties. Similarly, in Tanzania, farm production diversity is low in villages with better market access and a higher agricultural potential compared to those with lower market access. Overall, households' endowments in human, natural, physical, social and financial capital are found to be important factors influencing the level of farm production diversity.

With regards to dietary diversity, overall, households in Kenya have significantly higher diversity in their diets when compared to Tanzania. Nevertheless, results demonstrate a significant and positive association between farm production diversity and the indicators of household dietary diversity for both countries. We also find evidence of a positive role of farm production diversity for seasonal dietary diversity. In addition, apart from farm production diversity, factors such as household productive assets, access to off-farm income opportunities and market access are equally important in enhancing household dietary diversity. In particular, market access seems to play a critical role in enhancing dietary diversity.

In light of the above findings, several implications can be drawn from this study. First, maintaining a higher diversity in farm production can be beneficial for household dietary diversity. This may be applicable to diverse rural and peri-urban contexts with varying market access and agricultural potentials. Second, market related factors are equally important. Proximity to markets offer additional benefits for households; they are able to increase their dietary diversity through increased incomes from agriculture and off-farm opportunities and enhanced access to a diversified portfolio of food items from markets. In terms of policy, therefore, interventions geared towards improving smallholder households' dietary diversity should address both production as well as market-related challenges. Specifically, focus should be on addressing production related challenges especially in rural contexts with less market access. In addition, improvement of market institutions and infrastructure is important for enhancing dietary diversity in diverse contexts such as rural and peri-urban settings.

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