FOOD SECURITY OUTCOMES OF SMALLHOLDERS' INTEGRATION IN TRADITIONAL AGRICULTURAL VALUE CHAINS IN TANZANIA AND KENYA

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M. A. Luitfred Donacian Kissoly
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Referent:	Prof. Dr. Ulrike Grote Institut für Umweltökonomik und Welthandel Wirtschaftswissenschaftliche Fakultät der Gottfried Wilhelm Leibniz Universität Hannover
Korreferent:	Prof. Dr. Hermann Waibel Institut für Entwicklungs- und Agrarökonomik Wirtschaftswissenschaftliche Fakultät der Gottfried Wilhelm Leibniz Universität Hannover
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Dedication

I dedicate this thesis to my father, the late Donacian Mathias Kissoly, who instilled in me the love of learning and the value of education – MAY GOD GRANT HIM ETERNAL PEACE.

Zusammenfassung

In der Vergangenheit wurde der kleinbäuerlichen Landwirtschaft anhaltende Aufmerksamkeit gewidmet; dies gilt insbesondere für die Ernährungsunsicherheit und Armut der ländlichen Haushalte. Trotz vieler Herausforderungen, wie zum Beispiel niedriger Produktivität, begrenzter Marktzugang, unzureichender Zugang zu Finanzdienstleistungen und schwachen Institutionen zur Unterstützung von kollektivem Handeln, hat die kleinbäuerliche Landwirtschaft das Potenzial, die Ernährungsunsicherheit und Armut in vielen Entwicklungsländern zu reduzieren, vor allem in Sub-Sahara Afrika. Um Einkommen, Ernährungssicherung und allgemeine Wohlfahrt zu steigern, ist die Einbindung der Kleinbauern in wettbewerbsfähige landwirtschaftliche Wertschöpfungsketten (WSK) eine wichtige Strategie. Ein stärkerer Fokus ist dabei bisher jedoch auf moderne WSK gelegt worden, die zum Beispiel Anbauprodukte mit hohem Marktwert für den Export betreffen. Hingegen wurde traditionellen (lokalen) WSK weniger Aufmerksamkeit geschenkt, obwohl an diesen der Großteil der Kleinbauern beteiligt ist.

Die vorliegende Arbeit zielt darauf ab zu evaluieren, wie es um die Beteiligung von Kleinbauern in traditionellen WSK steht, um welche WSK Aktivitäten es geht und welche Wohlfahrtseffekte entstehen, insbesondere im Hinblick auf die Ernährungssicherung. Im Einzelnen sind die Ziele: (1) Art und Ausmaß der Partizipation in traditionellen WSK und die daraus resultierenden Wohlfahrtseffekten, insbesondere in Bezug auf die Ernährungssicherung in Tansania zu untersuchen, (2) die Determinanten der Kommerzialisierungsintensität von Kleinbauern und ihren Einfluss auf die verschiedenen Dimensionen von Ernährungssicherung zu identifizieren, (3) die Bedeutung der kleinbäuerlichen Produktionsvielfalt für die Diversität des Haushaltskonsums (unter Berücksichtigung der verschiedenen agrarökologischen und Markteintrittsbedingungen) zu klären und (4) den Einfluss der kleinbäuerlichen Produktionsvielfalt auf die Nahrungsvielfalt von ländlichen bzw. peri-urbanen Haushalten in Kenia und Tansania vergleichend zu bewerten. Diese Ziele wurden mithilfe von primären Haushaltsdaten aus Kenia und Tansania untersucht.

Die Ergebnisse der Analysen zeigen, dass Kleinbauern in unterschiedlichem Ausmaß an verschiedenen WSK-Aktivitäten wie z.B. Produktion, Bearbeitung nach der Ernte, Lagerung und Marketing partizipieren. Diese Partizipation spielt eine wichtige Rolle bezüglich der Verbesserung der Ernährungssicherung. Letztere ist insbesondere bei Kleinbauern höher,

wenn diese in höherwertigen Produktions- bzw. Marketingstufen der traditionellen WSK integriert sind. Außerdem zeichnen sich Kleinbauern, die in mehreren AVC Aktivitäten involviert sind, durch signifikant marginal bessere Ergebnisse in Bezug auf Ernährungssicherung aus als solche, die nur an einer oder wenigen AVC Aktivitäten teilnehmen.

Bezug nehmend auf die Kommerzialisierung von Kleinbauern und die dazugehörigen Effekten auf die Ernährungssicherung zeigen die Ergebnisse, dass Kleinbauern auf verschiedene Weiser am Markt teilnehmen. Ihre Teilnahme ist abhängig von Haushaltscharakteristika, der Ausstattung mit Eigentum sowie agro-klimatischen und institutionellen Charakteristika. Vor allem zeigen die Ergebnisse, dass die Effekte der Kommerzialisierung von Kleinbauern auf die verschiedenen Dimensionen der Ernährungssicherung nicht homogen sind. Ein geringeres Maß an Kommerzialisierung von Kleinbauern ist verbunden mit einer geringeren Verfügbarkeit an Nahrung, einem beschränkten Zugang sowie geringerer Nutzbarmachung und Stabilität von Nahrung, während eine höhere Intensität der Kommerzialisierung einhergeht mit höherer Nahrungsverfügbarkeit und -zugang, aber nur moderaten Verbesserungen in der Nutzbarmachung und Stabilität der Nahrungsversorgung.

Basierend auf Daten aus zwei ländlichen Regionen in Tansania mit gegensätzlichen agro-ökologischen Charakteristika und Marktzugangsbedingungen, bekräftigen die Ergebnisse außerdem die positive Rolle der Produktionsdiversität auf die Diversität des Nahrungskonsums der Haushalte. Die Ergebnisse deuten jedoch auch auf eine stärkere Rolle der Produktionsdiversität in Regionen mit weniger bevorzugten klimatischen bzw. agro-ökologischen Bedingungen und beschränktem Marktzugang hin, wie z.B. im Distrikt Chamwino. Umgekehrt spielt die Produktionsvielfalt eine geringere Rolle im Falle von besseren agro-ökologischen Bedingungen und Marktzugängen, wie z.B. im Distrikt Kilosa. Im weiterführenden Vergleich von ländlichen bzw. peri-urbanen Regionen in Kenia und Tansania unterstreichen die Ergebnisse, dass Farmproduktionsvielfalt einen positiven und signifikanten Einfluss auf Indikatoren der Ernährungsvielfalt von Haushalten hat. Produktionsdiversität scheint vergleichsweise vorteilhafter für die Nahrungsvielfalt der Haushalte in ländlichen Gegenden mit geringem Marktzugang zu sein als für Haushalte im peri-urbanen Kontext, was die Rolle von Marktzugang betont.

Stichwörter: kleinbäuerliche Landwirtschaft; traditionelle landwirtschaftliche Wertschöpfungsketten; Kommerzialisierungsintensität; Farmproduktionsdiversität; Nahrungsdiversität; Ernährungssicherung

Abstract

Sustained attention has been devoted to smallholder agriculture following the ongoing problems of food insecurity and poverty, especially for most rural households. Despite challenges such as low productivity, limited access to markets, inadequate financial services and weak collective action, smallholder agriculture has the potential to address food insecurity and reduce poverty in most developing economies, especially in Sub-Sahara Africa. Linking smallholders into competitive agricultural value chains (AVCs) is widely promoted as a strategy to enhance smallholder households' incomes, food security and general welfare. However, more focus has been put on modern AVCs, such as those involving high-value and export crops while traditional (local) AVCs have received significantly less attention despite constituting the majority of smallholders.

This thesis aims to evaluate the extent of smallholders' integration in traditional AVCs, the nature of their AVC activities and associated welfare effects, in particular food security. Specifically, the objectives are: (1) to examine the nature and extent of smallholder participation in traditional AVC activities and their associated welfare effects, focusing primarily on food security in Tanzania, (2) to identify the determinants of smallholder commercialization intensity and its influence on different dimensions of food security using the case of smallholders in rural Tanzania, (3) to assess the role of farm production diversity on household consumption diversity using diverse agro-ecological and market access contexts in rural Tanzania, and (4) to comparatively assess the influence of farm production diversity on household dietary diversity using the case of rural and peri-urban households in Kenya and Tanzania. These objectives are pursued using household-level survey data from Kenya and Tanzania.

Findings show that smallholders participate at varying levels in different traditional AVC activities such as production, post-harvest handling, storage and marketing. This participation plays an important role for enhancing food security. Specifically, household food security is higher for smallholders integrated in the productive and marketing stages of traditional AVCs. Additionally, smallholders integrated in multiple activities in AVCs have marginally better food security outcomes than those participating in single – or few – AVC activities.

Concerning smallholders' commercialization and the associated food security effects, findings show that smallholders participate in markets at different levels. This participation is driven by household characteristics, productive assets, agro-climatic and institutional characteristics. Most importantly, findings show that the effects of smallholder commercialization on the different dimensions of food security are not homogenous. Lower levels of smallholder commercialization are associated with lower food availability, access, utilization and stability while at higher intensities of commercialization, smallholders have more food availability and access but modest improvements in food utilization and stability.

In addition, using two regions with contrasting agro-ecological and market access characteristics in rural Tanzania, findings underscore the positive role of farm production diversity on household food consumption diversity. However, results indicate a stronger role in areas with less favorable climatic and agro-ecological characteristics and low market accessibility such as Chamwino district. Conversely, a lesser role of farm production diversity is observed in the presence of better agro-ecological and market access characteristics such as in Kilosa district. Using a broader and more diverse context from rural and peri-urban areas of Kenya and Tanzania, findings further confirm that farm production diversity has positive and significant influence on indicators of household dietary diversity. Again, farm production diversity appears to be comparatively more beneficial for household dietary diversity in rural settings with less market access than in the peri-urban context, thus underscoring the role of market access.

Keywords: Smallholder agriculture; traditional agricultural value chains; commercialization intensity; farm production diversity; dietary diversity; food security

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List of Abbreviations

ASDP	Agricultural Sector Development Program
AVC	Agricultural Value Chains
AIV	African Indigenous Vegetables
BMBF	German Federal Ministry of Education and Research
BMZ	German Federal Ministry for Economic Cooperation and Development
CSI	Coping Strategy Index
DFID	Department for International Development
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FVS	Food Variety Score
HCI	Household Commercialization Index
HDDS	Household Dietary Diversity Score
IFPRI	International Food Policy Research Institute
IFAD	International Food and Agricultural Development
MAHFP	Months of Adequate Household Food Provisioning
MoEVT	Ministry of Education and Vocational Training
PPP	Purchasing Power parity
TAFSIP	Tanzania Food Security Investment Plan
TLU	Tropical Livestock Unit
UNEP	United Nations Environmental Program
USAID	United States Agency for International Development
URT	United Republic of Tanzania

Chapter 1:
Introduction

1.1 Background and Research Problem

Smallholder agriculture remains undoubtedly an important pathway towards sustainable development and poverty reduction (World Bank, 2008). In most developing countries, such as in Sub-Saharan Africa, smallholder agriculture is a lifeline for countless rural households and therefore vital in enhancing food security and other welfare outcomes (Herrero et al., 2010; IFAD and UNEP, 2013). For example, about 62% of the population in Sub-Saharan Africa lives in rural areas where agriculture is a major contributor of food security and employment (World Bank, 2015). However, Sub-Saharan Africa has seen increased challenges of food insecurity and poverty, especially for most rural households. Compared to other regions of the world, for example, Su-Saharan Africa has the highest prevalence of undernourishment among its population (FAO, 2015). Food insecurity in these countries is exacerbated by low agricultural productivity, high population growth, foreign exchange constraints and high transaction costs in terms of domestic and international markets (World Bank, 2008). Consequently, the role of smallholder agriculture has received a recent surge of attention.

To enhance the effectiveness of agriculture in supporting development through sustainable growth and reduction of poverty, the World Bank's World Development Report (2008) outlined four policy objectives: (1) to improve access to markets and establish efficient value chains, (2) to enhance smallholder competitiveness and facilitate market inclusion, (3) to improve livelihoods in sub-subsistence farming and low-skill rural occupations, and (4) to increase employment in agriculture and the rural non-farm economy and enhance skills. In line with these policy directions, effective integration of smallholders in agricultural value chains (AVCs) has been among recent strategies that have been widely promoted in order to enhance smallholders' incomes, food security and general welfare.

Inclusion of smallholders in competitive AVCs is therefore perceived to facilitate increases in productivity and market access while reducing transaction costs (Taylor and Adelman, 2003; Minten and Barrett, 2008; Barrett, 2008, Jaleta et al., 2009). This is especially important given the increasingly transforming agricultural systems, which affect not only smallholders integrated in high-value and export crops value chains but also those linked in traditional AVCs (McCullough et al., 2008; Barrett et al., 2010). Subsequently, participation by smallholders in various AVC activities such as production, post-harvest processing, storage and selling of agricultural produce is seen as a potential pathway to raising smallholders' food security and welfare (Mitchell et al., 2009; Barrett et al., 2010; Bellemare, 2012). This is despite concerns raised on exclusion and exploitative risks that smallholders may be exposed to, when participating in AVCs (Sivramkrishna and Jyotishi, 2008; Wiggins et al., 2010).

With the growing importance of AVCs, recent studies have increasingly focused on how well can smallholder agriculture contribute to household welfare, particularly food security. However, much of this focus has been on modern AVCs, such as those involving high-value and export crops. Traditional (local) AVCs, which constitute majority of smallholders, have, on their part, received much less attention. Takin this into account, this thesis primarily focuses on traditional AVCs to evaluate the extent of smallholders' integration in traditional AVCs, the nature of their AVC activities and associated welfare effects, particularly food security.

In the context of the link between smallholder agriculture and food security, this research therefore aims at contributing to the understanding of the nature and extent of smallholders' integration in various traditional AVC activities and associated food security outcomes. By focusing on traditional AVCs, this study first considers smallholders' participation in a broad spectrum of traditional AVC activities such as input purchases, production, post-harvest handling, storage and selling, and thus generating important insights on the nature and extent of smallholders' integration in different activities along the value chain.

Secondly, out of the various AVC activities, the study draws attention to two particular aspects of AVCs, that is, the nature of farm production and the intensity of smallholder market participation (commercialization). These activities play a substantial role in influencing smallholders' food security outcomes. Increasingly, there is a recent and growing literature on the potential effects of smallholder agricultural diversification and commercialization strategies on different dimensions of food security (Jaleta et al., 2009; Anderman, 2014; Jones et al., 2014; Pellegrini and Tasciotti, 2014; KC et al., 2015; Sibhatu et al., 2015; Muriithi and Matz, 2015). Adding to this literature, this research therefore dwells on the potential role of smallholder farm production diversity and the intensity of commercialization on different aspects of rural households' food security. As is well known, food security is a broader concept. According to the FAO (1996), food security exists "when all people at all times have access to sufficient, safe and nutritious food to maintain a healthy and active life". Thus it encompasses four dimensions namely, availability, access, utilization and stability which are addressed in this study. Emerging findings from these analyses are important in shaping policies geared towards improving smallholder agricultural production and engagement into markets for improved food security outcomes.

1.2 Research Objectives

The overall aim of this thesis is to add to literature on the role of smallholder agriculture on food security of rural households. This objective is implemented by focusing on traditional AVC activities pursued by smallholders using household-level survey data from Tanzania and Kenya[1]. Specifically, this thesis has the following specific objectives:

1) To examine the nature and extent of smallholder participation in traditional AVC activities and their associated welfare effects, focusing primarily on household food security in Tanzania.
2) To identify the determinants of smallholder commercialization intensity and its influence on different dimensions of food security in rural Tanzania.
3) To assess the role of farm production diversity on household consumption diversity using diverse agro-ecological and market access contexts in rural Tanzania.
4) To comparatively assess the influence of farm production diversity on household dietary diversity using the case of Kenya and Tanzania.

1.3 Structure of the Dissertation and Main Findings

This thesis is organized in five chapters. Introduction of the thesis is given in chapter 1 while the selected articles are presented from chapter 2 to 5 (see Figure 1). A summary of the articles included in this thesis is given in Table 1. More specifically, the focus of the chapters is as explained below.

[1] Data for the study was collected in 2014 through the Trans-Sec Project conducted in Tanzania and HORTINLEA project conducted in Kenya. Detailed information of the surveys is available at: http://www.trans-sec.org/ and http://www.hortinlea.org/

Chapter 1 presents the introduction of the present thesis. It provides a focused background on the nature and potential of agriculture in enhancing food security, employment and poverty reduction. In addition, the introduction briefly outlines the major results and highlights the ongoing policy discourse concerning transforming agricultural systems and the relevance of both traditional and modern AVCs for smallholders' welfare. This sets the context of the research problem addressed in this thesis.

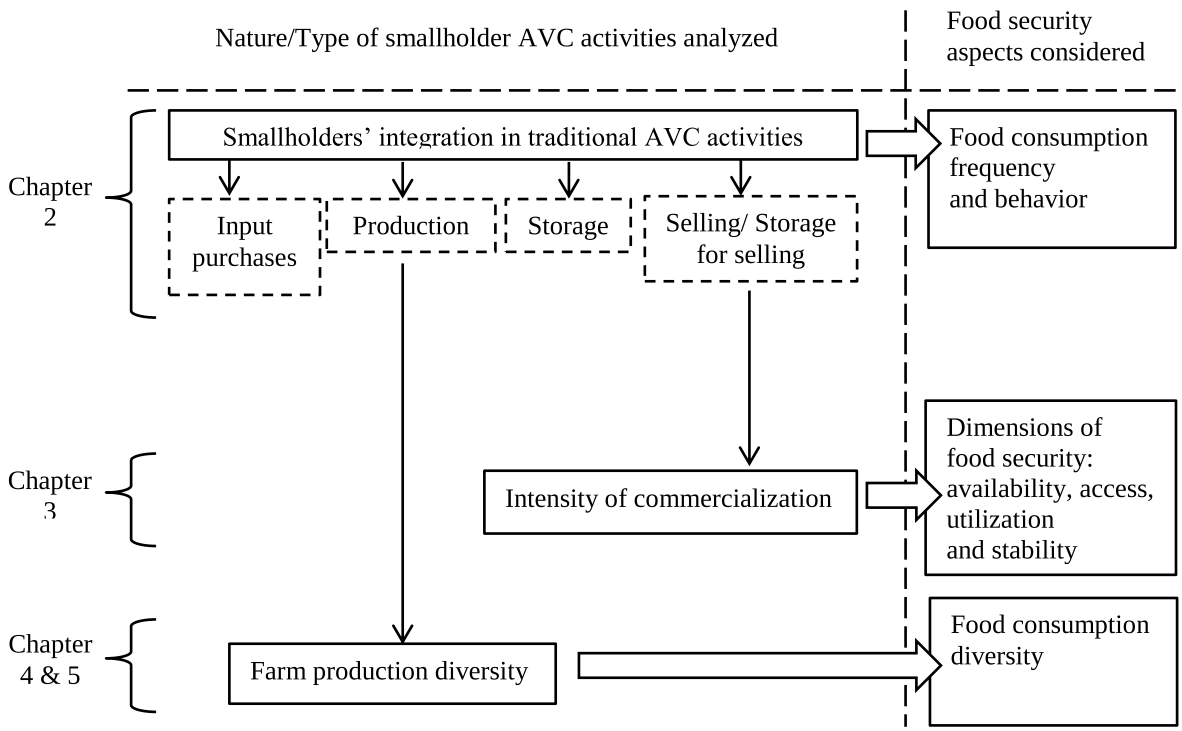

Figure 1: Thesis outline for the analysis of food security outcomes of smallholders' integration in traditional AVC activities (Source: Authors' illustration)

Chapter 2 examines the nature and extent of smallholder participation in traditional AVC activities and their associated welfare effects, focusing primarily on household food security (objectives 1 above). Cluster analysis is used to explore different smallholder livelihood activities and the extent of participation in traditional AVCs while propensity score matching and inverse probability weighted regression adjustment approaches are employed to analyze food security effects of various AVC activities. Results reveal that smallholders participate at varying levels in different AVC activities and their integration in traditional AVCs plays an important role for improving food security. Household food security is higher for smallholders using improved inputs or storing for selling than those not undertaking these activities. Comparing the effects of individual, and combinations of AVC activities, the study reveal that, participating in both, that is, using of improved inputs and storing for selling, translates into marginally higher food security.

Chapter 3 focuses on the potential differential effects of smallholder commercialization intensity on the four dimensions of food security (objective 2). Employing Tobit regression, Propensity Score Matching (PSM) and Generalized Propensity Scores (GPS) approaches; the chapter analyzes the determinants of smallholder commercialization intensity and associated food security effects. Results show that, smallholder commercialization has heterogeneous effects on the different dimensions of food security. Specifically, the results reveal that lower levels of commercialization are associated with lower food availability, access, utilization and stability. At higher intensities of commercialization, however, smallholders have more food availability and access but modest improvements in food utilization and stability.

Chapter 4 assesses the relationship between farm production diversity and household food consumption diversity using the two contrasting agro-ecological and market contexts in Chamwino and Kilosa Districts in rural Tanzania (objective 3). Specifically, the chapter uses descriptive and multivariate regression analysis to analyze the relationship between farm production diversity and household food consumption diversity. Results show that, while smallholders maintain a considerable diversity in their production, significant differences exist between the Chamwino and Kilosa districts. Further, the results indicate a stronger role of farm production diversity on food consumption diversity in Chamwino district which has harsh climatic and agro-ecological characteristics and low market accessibility, but a lesser role in presence of better agro-ecological and market access characteristics such as in Kilosa district.

Chapter 5 comparatively assesses the role of farm production diversity on household dietary diversity using the case studies of Kenya and Tanzania (objective 4). This role is analyzed by exploiting diverse smallholder contexts arising from rural and peri-urban settings in the two countries. The chapter uses data from four counties in Kenya (Kisii, Kakamega, Kiambu and Nakuru) and two districts in Tanzania (Kilosa and Chamwino) and employs descriptive and econometric analyses – mainly Poisson and negative binomial regression models. Results reveal that, smallholders in Kenya maintain comparatively higher farm production diversity and have better dietary diversity than their counterparts in Tanzania. In both country cases, however, farm production diversity has a positive and significant influence on indicators of household dietary diversity. In addition, the benefits of farm production diversity appear to be more significant in rural settings with less market access when compared to areas with better access to markets such as in peri-urban counties in Kenya and Kilosa district in Tanzania. Results also demonstrate the role of other factors, beyond farm production diversity, in influencing household dietary diversity.

Table 1: List of articles included in the dissertation

No.	**Tittle**	**Authors**	**Published in/ Submitted to/ presented at**
Article 1 *(elaborated in chapter 2)*	Smallholders' Integration in Agricultural Value Chain Activities and Food Security: Evidence from Rural Tanzania	Luitfred Kissoly, Anja Faße, Ulrike Grote	Published in *Food Security*. DOI: 10.1007/s12571-016-0642-2 Presented at: Development Economics and Policy 2016 (Annual International Conference of the Research Group on Development Economics) held at the University of Heidelberg, June 03-04, Heidelberg. Earlier version of the article was presented and contributed to the Tropentag 2015 "*Management of land use systems for enhanced food security - conflicts, controversies and resolutions*" Humbolt University, September 16-18, Berlin. URL: http://www.tropentag.de/2015/abstracts/full/458.pdf (Small-Scale farmers' Integration in Agricultural Value Chains: The Role for Food Security in Rural Tanzania).
Article 2 *(elaborated in chapter 3)*	Intensity of Commercialization and the Dimensions of Food Security: the Case of Smallholder Farmers in Rural Tanzania	Luitfred Kissoly, Anja Faße, Ulrike Grote	Under review (Journal *Agricultural Economics*)
Article 3 *(elaborated in chapter 4)*	Implications of Farm Production Diversity for Household Food Consumption Diversity in Tanzania: Insights from diverse Agro-ecological and Market Access Contexts	Luitfred Kissoly, Anja Faße, Ulrike Grote	Submitted to the Journal of African Economies
Article 4 *(elaborated in chapter 5)*	Diversity in Farm Production and Household Diets: Comparing Evidence from Smallholders in Kenya and Tanzania	Luitfred Kissoly, Karki Sabina, Ulrike Grote	Submitted to the Canadian Journal of Development Studies

Source: Authors' illustration

The specific contribution of the named authors on the articles outlined above is as follows: For articles 1, 2 and 3, Kissoly contributed on the development of the article's idea, literature review, empirical analysis and writing of articles. Faße provided suggestions on the methodology and comments on improvements of the articles. Grote's contribution included overall guidance and improvements on the ideas and methodologies of the articles together with comprehensive comments on the final versions of the articles. For article 4, Kissoly and Karki collaborated in the shaping of the idea for the article, the literature review, empirical analysis and drafting of the article. Grote contributed on the improvement of the comparative idea of the article, detailed suggestions and review of the final draft.

In the course of the PhD studies, several additional peer-reviewed articles were also co-authored as outlined in Table 2.

Table 2: Additional co-authored peer-reviewed articles

SN	Authors/ Title/ Journal
1	Graef, F., Uckert, G., Fasse, A., Hoffmann, H., Kaburire, L., Kahimba, F.C., Kimaro, A., **Kissoly, L.**, König, H. J., Lambert, C., Mahoo, H.F., Makoko, B., Mbwana, H., Mutabazi, K.D., Mwinuka, L., Saidia, P., Schindler, J., Silayo, V., Sieber, S., Yustas, Y.M. (2016). Expert-based ex-ante assessments of potential social, ecological, and economic impacts of upgrading strategies for improving food security in rural Tanzania using the ScalA-FS approach. Accepted in "Food Security", forthcoming
2	Graef, F., Schneider, I., Fasse, A., Germer, J.U., Gevorgyan, E., Haule, F., Hoffmann, H., Kahimba, F.C., Kashaga, L., **Kissoly, L.**, Lambert, C., Lana, M., Mahoo, H.F., Makoko, B., Mbaga, S.H., Mmbughu, A., Mkangwa, S., Mrosso, L., Mutabazi, K.D., Mwinuka, L., Ngazi, H., Nkonya, E., Reif, C., Said, S., Schaffert, A., Schäfer, M.P., Schindler, J., Sieber, S., Swamila, M., Welp, H.M., William, L., Yustas, Y.M. (2015): Natural resource management and crop production strategies to improve regional food systems in Tanzania. In: Outlook on Agriculture 44(2): 159–167. doi: 10.5367/oa.2015.0206
3	Graef, F., Schneider, I., Fasse, A., Germer, J.U., Gevorgyan, E., Haule, F., Hoffmann, H., Kahimba, F.C., Kashaga, L., **Kissoly, L.**, Lambert, C., Lana, M., Mahoo, H.F., Makoko, B., Mbaga, S.H., Mmbughu, A., Mkangwa, S., Mrosso, L., Mutabazi, K.D., Mwinuka, L., Ngazi, H., Nkonya, E., Said, S., Schaffert, A., Schäfer, M.P., Schindler, J., Sieber, S., Swamila, M., Welp, H.M., William, L., Yustas, Y.M. (2015): Assessment of upgrading strategies to improve regional food systems in Tanzania: Food processing, waste management and bioenergy, and income generation. In: Outlook on Agriculture 44: 179–186. doi: 10.5367/oa.2015.0209

Source: Authors' illustration

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Chapter 2:

Smallholders' Integration in Agricultural Value Chain Activities and Food Security: Evidence from Rural Tanzania

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Chapter 3:

Intensity of Commercialization and the Dimensions of Food Security: The Case of Smallholder Farmers in Rural Tanzania

Abstract

Transformation of smallholder agriculture from subsistence to more commercially-oriented production is one of the strategies advocated for improving rural households' food security and general welfare. Using household data from rural Tanzania, this study focuses on the potential differential effects of smallholder commercialization intensity on the four dimensions of food security. Employing Tobit regression and Generalized Propensity Score (GPS) approaches, we analyze the determinants of smallholder commercialization intensity and associated food security effects. We show that smallholder commercialization has heterogeneous effects on the different dimensions of food security. Specifically, results reveal that lower levels of commercialization are associated with lower food availability, access, utilization and stability. At higher intensities of commercialization, smallholders have higher food availability and access but modest improvements in food utilization and stability. While underscoring the vital role of smallholder commercialization, findings highlight its heterogeneous effects on the multiple aspects of food security. This suggests that heterogeneous effects of commercialization on food security and the multi-dimensional nature of food security are important aspects to consider in the design of strategies to improve smallholder agriculture for enhanced food security and welfare.

Keywords: Commercialization intensity; dimensions of food security; generalized propensity score; Tanzania

3.1 Introduction

Commercialization of smallholder agriculture is recognized as a vital prerequisite for enhanced economic growth and poverty reduction for most developing countries (Von Braun, 1995; World Bank, 2008; Birner and Resnick, 2010). It is also an important driver of food security for most poor agrarian economies (IFAD and UNEP, 2013). In Tanzania, for example, apart from contributing about a third of gross domestic product, smallholder agriculture employs about 67% of rural households (World Bank, 2014). The ongoing efforts to support smallholder agriculture, through raising productivity and enhancing inclusion in markets, among other strategies, imply a gradual transformation of subsistence agriculture to increased commercialization. As a process that involves transformation from subsistence to more market-oriented agriculture (Pingali and Rosegrant, 1995), smallholder commercialization is generally an important strategy towards enhanced food security and welfare, also at the household level (Pingali, 1997; Govereh and Jayne, 2003; Muriithi and Matz, 2015).

There is, however, mixed evidence on the welfare effects of smallholder commercialization on rural farm households. On the one hand, benefits such as improved household income, food security and nutritional status are linked to increased commercialization (von Braun, 1995; Pingali, 1997; Govereh and Jayne, 2003; Hendrick and Msaki, 2009). On the other hand, some empirical evidence raises caution on less desirable welfare implications of commercialization on smallholder households. These include cases such as increased exposure to food market price fluctuations, competing land use for cash and food crops and gender issues over control of crop income (Jayne, 1994; Jaleta et al., 2009; Anderman, 2014).

Focusing on food security, there is limited evidence on how increased intensity of commercialization influences different dimensions of food security. This is important because smallholders participate in markets at different intensities. Also, according to the Food and Agriculture Organization (2002), food security 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. From this definition, food security encompasses multiple facets (i.e. availability, access, utilization and stability). This implies that smallholder commercialization may influence different dimensions of food security differently. Our hypothesis is that different intensities of commercialization may have heterogeneous effects on household food security.

Against this background, this study therefore aims to answer two specific questions: First, what are the determinants of intensity of smallholder commercialization? Second, how does intensity of smallholder commercialization influence different dimensions of food security? In answering these questions, our contribution to literature on smallholder commercialization and food security is twofold: first, we analyze how different levels of smallholder commercialization influence rural households' food security. The aim is to elicit the effects of different intensities of commercialization on different aspects of food security. Second, we consider food security as a multi-dimensional phenomenon and hence disentangle the effects of commercialization on its four dimensions. The analysis is done using unique household-level data from smallholder farmers cultivating staple and food crops in rural Tanzania.

The remainder of the study is structured as follows: the next section presents a brief literature review on smallholder commercialization and multiple dimensions of food security while section 3 describes the data and variables used in the study. The methodology of the study is provided in section 4. Section 5 and 6 present the results and their discussion, respectively. Summary and conclusions are highlighted in section 7.

3.2 Literature Review

3.2.1 Concept and Determinants of Smallholder Commercialization Intensity

Various definitions exist on the concept of smallholder commercialization. From the standpoint of subsistence agriculture, commercialization entails market participation either through increased marketed surplus or increased use of purchased agricultural inputs, or both (von Braun, 1995). Pingali and Rosegrant (1995) define commercialization as market orientation whereby product choices and input use decisions are based on principles of profit maximization. In essence, smallholder commercialization entails both, market orientation and market participation (Gebremedhin and Jaleta, 2010). Owing to this complexity, commercialization can be measured: (1) from input or output side, (2) by the degree of integration into the cash economy, or (3) through other aspects of commercialization such as sales to output and total sales to income ratios, net market position and specialization index (Jaleta et al., 2009)[2].

As a process that involves a gradual transformation from subsistence to a more market-oriented production, smallholder commercialization depends on a complex set of factors that induce or constrain households' decisions to participate in markets. Using farm household models, previous studies focused on how transaction costs and imperfect markets constrained smallholder market participation (de Janvry et al., 1991; Fafchamps, 1992). From empirical studies, a set of external (exogenous) and internal (endogenous) factors has been identified with varying influence on the smallholder commercialization process.

External factors, from a household point of view, include population growth, increased urbanization, rising incomes, changing agro-climatic conditions and overall changes in macro-economic policies, among other factors (von Braun and Kennedy, 1994; Pingali et al., 2005; Jaleta et al., 2009). Focusing on internal factors, smallholder households' resource endowments in natural, physical, financial, social and human capital are considered important internal determinants – those within smallholder's control – of commercialization (von Braun and Kennedy, 1994; Jaleta et al., 2009). For example, human capital in terms of education, skills and experience facilitates smallholder households in commercializing their agricultural production (World Bank, 2008) through engaging in market opportunities and in uptake of improved agricultural technologies. Also, physical assets such as land and farm equipment, together with labor available at the household are vital in enhancing production (Barrett, 2008; Jaleta et al., 2009). These productive assets enable households to produce marketable surplus through better technology and economies of scale thereby increasing commercialization.

In addition, functioning property rights on resources such as land, better legal frameworks for enforcement of contracts and effective financial markets are equally important in the commercialization process. Apart from enabling reduction of transaction costs and risks in production, these institutional aspects facilitate access to credit, inputs and extension services (Pingali and Rosegrant, 1995; Lerman, 2004; Gebremedhin et al., 2009) and thus enhancing smallholder commercialization. However, most smallholders in sub Saharan Africa are constrained by the existing inefficient institutional structures such as insecure land rights,

[2] A detailed discussion on the concept and different measures of smallholder commercialization is given by Jaleta et al. (2009)

inadequate credit access and underdeveloped input markets (Barret et al., 2010). Other determinants of smallholder commercialization identified in the literature include characteristics such as household size, and gender and age of the household head (Jaleta et al., 2009; Muriithi and Matz, 2014; Akinlade et al., 2016). A summary of these determinants, as used in the analysis, is given in Table 2.

3.2.2 Smallholder Commercialization and Food Security

Despite differential welfare impacts of smallholder commercialization on rural households (Jaleta et al., 2009), a wide consensus exists on the important link between commercialization and household food security. This is partly attributed to the fact that subsistence agriculture itself is not viable in ensuring sustainable food security and welfare (Pingali, 1997). However, food security effects of smallholder commercialization depend on the local context, food markets, household preferences and intra-household allocations, among other factors (von Braun, 1995; Paolisso et al., 2001; Jaleta et al., 2009).

Various studies show that commercialization may have positive effects on food security but can also lead to undesirable effects. With regards to positive effects, commercialization is argued to increase household incomes, through increased marketed surplus or increased use of better inputs, which in turn benefits household food security. For example, von Braun (1995) shows that commercialization may have the potential to raise household income and this improves food security and nutrition. In a recent study on smallholder vegetable commercialization in Kenya, Muriithi and Matz (2015) observe an income effect for smallholders supplying to the export market. Commercialization is also able to improve children’s nutrition through the income-consumption link (Babu et al., 2014). Similarly, smallholder commercialization has the potential to increase productivity of other crops. Govereh and Jayne (2003) show that through household level synergies and regional spillover effects, cash cropping can increase productivity of other crops and hence ensure more food production at the household. Pertaining to diversity of diets, Hendrick and Msaki (2009) find that smallholders participating in certified commercial organic farming in South Africa had better nutrient intakes and food diversity compared to nonparticipants.

However, smallholder commercialization is also linked to a number of less desirable outcomes. Despite its comparative advantages over subsistence agriculture, commercial agriculture exposes households to volatile food markets and therefore food insecurity (von

Braun et al., 1994; Dorsey, 1999; Jaleta et al., 2009). This is exacerbated by higher risks and partially integrated and imperfect rural markets. Also, depending on the nature of intra-household allocations, increased income from commercialization is not always dedicated to improving food security at the household (Paolisso et al., 2001). Some empirical literature also shows that tradeoffs may exist between smallholder commercialization and food security. This is mainly attributed to diversion of households' resources from food to cash crop production. For example, Anderman et al. (2014) observes that smallholder commercialization through cash cropping was negatively associated with food security in rural Ghana.

An important, but still under-researched, aspect in the analysis of the effects of smallholder commercialization is the multi-dimensional nature of food security. As noted earlier, food security has four major pillars i.e., food availability, access, utilization and stability. Changes brought by commercialization may influence the food security dimensions differently. For example, commercialization can increase food availability through increased productivity and food production (von Braun et al., 1994; Govereh and Jayne, 2003), but the exposure to volatile food markets (Dorsey, 1999; Jaleta et al., 2009) may not guarantee food stability. Also, although increased household income from commercialization may be instrumental in ensuring food access and utilization –through the income-consumption link – (von Braun et al., 1994: Babu et al., 2014), unfavorable intra-household allocations (such as male household control of crop income) may impair this effect. The eventual effects of smallholder commercialization on different dimensions of food security would therefore ultimately depend on the nature of intermediate changes brought by the shift from subsistence to more market-oriented agriculture. Such changes include the extent of household income, nature of intra-household allocations (such as spousal control of crop income), dependence on food markets and extent of vulnerability to food prices (Anderman et al., 2014).

3.3 Data and Description of Variables

3.3.1 Study Area and Data

This study was conducted in Morogoro and Dodoma regions in Tanzania (Figure 1) in January 2014. Kilosa district in Morogoro and Chamwino district in Dodoma were selected based on climatic, agro-ecological and market access considerations. While Kilosa has a sub-humid climate with 600-800 mm annual rainfall, Chamwino is largely semi-arid with 350-500 mm annual rainfall. Agriculture is an integral part of livelihoods in these study districts. In Kilosa district, maize, sesame, legumes and rice dominate the crop portfolio of most households, whereas in Chamwino district, millet, sorghum, groundnuts and sunflower are the main crops next to a substantial reliance on livestock.

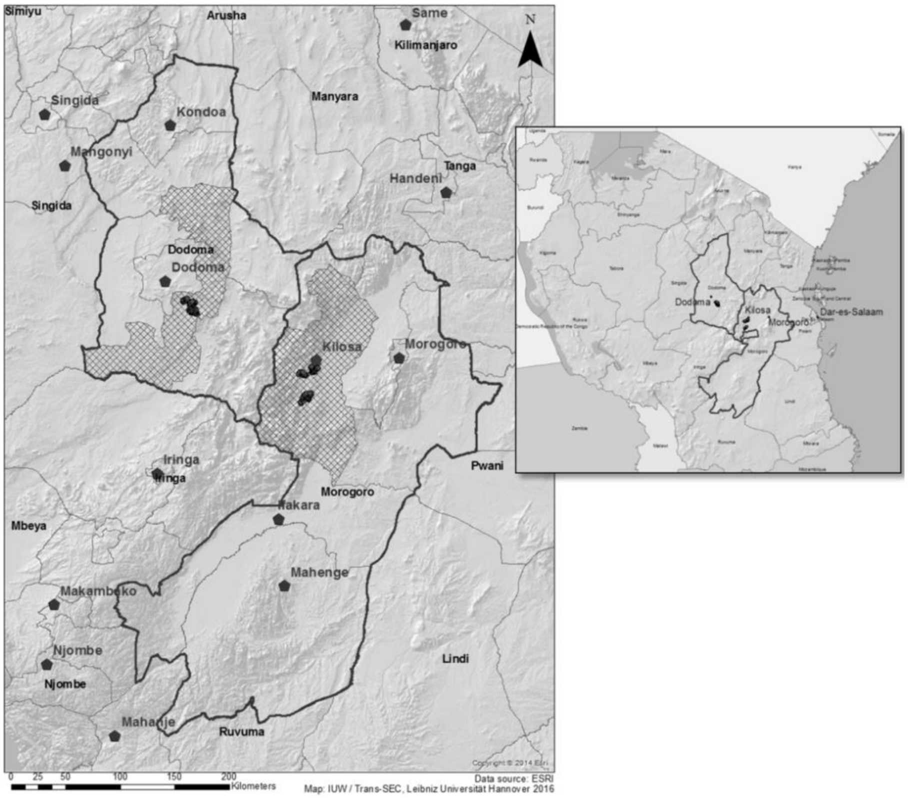

Figure 1: Map showing study regions in rural Tanzania (Source: Trans-Sec 2016).

The study covered six villages; Nyali, Changarawe and Ilakala in Kilosa district and Ilolo, Ndebwe and Idifu in Chamwino district. For the survey, household lists were prepared in collaboration with village authorities for each of the six villages and households were then randomly selected. A total of 900 households (150 households in each village) were interviewed using a structured questionnaire with detailed sections on household socio-demographics, agriculture, marketing, non-farm activities and food security. In the food security section, detailed information was collected on food consumption, food expenditure and food security related shocks at the household level. A separate village-level questionnaire collected village-related data on institutions and infrastructure. This information is vital in understanding the nature, determinants and extent of smallholder commercialization, as village-level factors play an important role. The final sample used for empirical analysis is 841 due to missing information in several key variables.

3.3.2 Description of variables

In answering the key questions of this study, our variables of interest relate to the two key concepts of smallholder commercialization and food security. With regards to smallholder commercialization, this study uses the output side definition of commercialization following von Braun et al. (1994) and Gebremedhin and Jaleta (2010). This captures the annual household crop output market participation as a ratio of the value of crop sales to total value of crop production. The Household Commercialization Index (HCI) is therefore computed as:

$$HCI = \frac{\sum_{k=1}^{K} \overline{P}_k S_{ik}}{\sum_{k=i}^{K} \overline{P}_k Q_{ik}} \quad (1)$$

where S_{ik} is the quantity of crop output k sold by household i, $\overline{P}_k$ is the village level price and Q_{ik} is the total quantity of output k produced by household i. This index aggregates the value of crops cultivated by the household and crops sold to markets. In the case of total subsistence, the index takes the value of zero. A larger index indicates a higher degree of commercialization.

Regarding food security, a number of indicators are used to capture the four main dimensions (Table 1). Maxwell et al. (2014) argues for the use of a suite of indicators that capture different aspects of food security, because a single measure that adequately captures the complexity of food security is nonexistent. We use the value of agricultural production for food crops (FAO, IFAD and WFP 2013) to proxy for *food availability* at the household, which refers to the amount of food available at the household through own household production. The value of food crops produced is obtained from the quantity of food crops produced and the prevailing village prices for a particular crop[3].

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[3] This variable only gives insights on the level of production at the household but does not capture the entire food availability dimension. The value of food production is widely used to measure food availability at the macro level (FAO et al. 2013).

For *food access*, which entails household's ability to obtain sufficient amounts of food from own stocks or purchases, we use two measures namely the Food Consumption Score (FCS) and value of consumption from own production (in PPP $) in an average week. The FCS, which captures the quantity and quality aspects of food access (Leroy et al. 2015), is calculated from the frequency and type of food consumed by a household (WFP 2008). The value of consumption from own production in a normal week, which is influenced by increased production at the household farm, is used to capture the amount of food accessed by the household through own stocks.

To capture *food utilization* – the uptake of adequate energy and nutrients by individuals – we use the Household Diet Diversity Score (HDDS) and the household consumption of only low quality food. These are used as proxies for diet quality (Moursi et al. 2008; Anderman et al. 2014). The HDDS is calculated by the number of different food groups consumed by a household in a given reference period and is associated with important outcomes such as hemoglobin concentrations and anthropometric status (Swindale and Bilinsky 2006). Household consumption of only low quality food also gives indication of quality and utilization of food in the household. In the survey, households were asked whether there were months in the past year where they could only consume low quality food because of a shock or agricultural seasons.

To account for *food stability*, we use the Months of Adequate Household Food Provisioning (MAHFP) and the household experience of a food shock. MAHFP reflects the ability of households to access food over time and indicates when food is available over the year (Bilinsky and Swindale 2010). Also, household experience of food shock in terms of not having enough food in the reference year signals the level of food stability at the household over time.

Table 1: Food security indicators used with corresponding dimensions

Variable	Source
Availability	
Value of agricultural production (Food crops)	FAO (2013)
Access	
Value of consumption from own production in a week (PPP $)	Own consideration
Food Consumption Score (FCS)	Leroy (2015)
Utilization	
Household Diet Diversity Score (HDDS)	Moursi et al. (2008), Anderman et al. (2014), Coates (2013)
Household consumption of low quality food	Own consideration
Stability	
Months of Adequate Household Food Provisioning (MAHFP)	Coates 2013
Food security shock (Not enough food)	Own consideration

Source: Authors' illustration.

3.4 Methodology

3.4.1 Analyzing Determinants of Intensity of Commercialization

In analyzing factors that influence the intensity of commercialization, a Tobit model is used. The regression model developed by Tobin (1958) is recommended when the dependent variable is censored from below, above or both. In our study, the HCI ranges from 0 to 1, thus rendering Ordinary Least Squares (OLS) inappropriate. The Tobit model is estimated as:

$$v^* = X'\beta + \varepsilon_1 \text{ and } \begin{cases} v = v^* \ \ if \ \ v^* > 0 \\ v = 0 \ \ if \ \ v^* \leq 0 \end{cases} \qquad (2)$$

where, v^* is an unobservable (latent) variable representing the optimal share of value of crop output sold to markets by the household. This value of output is observed if $v^* > 0$ and unobservable otherwise. The vector of independent variables affecting the level of household commercialization is given by X. β is a vector of parameters to be estimated and ε_1 is the disturbance term assumed to be independently and normally distributed.

Table 2 presents the explanatory variables used in equation (2) along with a description, literature source and expected sign. At the level of household head, age is expected to influence commercialization negatively reflecting risk aversion and decreased propensity to adopt new agricultural technologies. However, gender of a household is anticipated to have a positive influence on smallholder commercialization for male head and negative for female head given the disproportionate control male households have on resources such as land, labor and finance. Education of the household may positively influence commercialization through increased skills and ability to use better agricultural technologies, but may also be negatively related to commercialization if household heads with better education pursue alternative income generating activities such as non-farm employment (Muthiiri and Matz, 2014). Productive assets such as land and labor together with access to credit enhance smallholders' ability to produce marketable surplus therefore expected to have a positive influence. However, although livestock is a productive asset, they offer alternative sources of household income thus expected to be negatively influencing commercialization (Gebremedhin and Jaleta, 2010). Mobile phone captures access to information, which is of critical importance in the commercialization process (Omiti et al., 2009; Gebremedhin et al., 2009). Also, access to key services such as transportation and markets is important. Therefore, a long distance to key infrastructure and services is predicted to negatively affect commercialization. Agricultural shocks, which include drought, crop pests and heavy rainfall or flooding of agricultural land, are also expected to affect commercialization negatively. However, availability of rainfall is essential given the rain-fed system of farming that is widely undertaken by smallholders. This is expected to influence commercialization positively.

Table 2: Summary of key variables used in the regressions

Variable	Description	Literature	Expected sign
Age	Number of years of household head	Akinlade et al. (2016)	–
Gender	Gender of household head (Male=1)	Gebremedhin et al. (2009)	+
Household size	Number of household members (n)	Muriithi and Matz (2014)	+/–
Education	Number of school years attended by household head	Gebremedhin et al. (2009), Akinlade et al. (2016)	+/–
Risk	Household preparedness to take risk (scale 1-10)	Jaleta et al. (2009)	+
Land size	Size of agricultural land owned by household (ha)	von Braun and Immik (1994), Akinlade et al. (2016)	+
Livestock	Number of livestock owned by household (Tropical Livestock Units -TLU)	Gebremedhin and Jaleta (2010)	–
Labor	Labor capacity at the household in worker equivalents	von Braun and Immik (1994), Gebremedhin et al. (2009)	+
Mobile phone	Household owns a mobile phone (yes=1)	Omiti et al. (2009), Gebremedhin et al. (2009)	+
Credit access	Household has access to credit (yes=1)	Lerman (2004), Gebremedhin et al. (2009)	+
Distance	Distance to nearest paved road (Km)	De Janvry et al. (1991), Barret (2007), Alene et al. (2008)	–
Agricultural shocks	Household experienced agricultural shocks (yes=1)	Muriithi and Matz (2014)	–
Rainfall	Mean annual rainfall (mm)	Gebremedhin et al. (2009), Muriithi and Matz (2014)	+

Note: Worker equivalents, used to capture labor available at the household, were calculated by weighting household members; less than 9 years=0; 9-15=0.7; 16-49=1 and above 49 years=0.7.

Source: Own calculations based on Trans-Sec household survey 2014.

3.4.2 Modelling the Effects of Commercialization on Food Security

To evaluate the effects of commercialization on different aspects of food security, a typical impact evaluation framework may be employed where commercialization is considered as the 'treatment' while food security is the 'outcome' observed. Commercialization status has been used in the literature to categorize smallholders into commercial and subsistence-oriented households (Strasberg et al., 1999). With this categorization, smallholders with HCI equal to or above 0.5 are classified as commercial while those with HCI below 0.5 are considered subsistence-oriented.

In a simple binary treatment case, the average treatment effects framework (Rosenbaum and Rubin 1983) may be implemented under which the objective is to estimate the treatment effects on the treated, formally given as

$$\tau|_{C=1} = E(\tau|C = 1) = E(O_1|C = 1) - E(O_0|C = 1) \quad (3)$$

where τ is the Average Treatment effect on the Treated households (ATT), C is the dummy variable representing the commercialization status ($C = 1$ for commercially-oriented farmers and $C = 0$ for subsistence-oriented farmers), O_1indicates the outcome when the household commercializes, and O_0 represents the outcome when the household does not commercialize. However, treating commercialization as a binary outcome conceals the true nature of smallholder commercialization. As noted earlier, smallholders commercialize at various levels of intensity. It is thus appropriate to model the potential effects of different levels of commercialization on the various aspects of food security.

Several extensions have emerged in the impact evaluation literature in the analysis of different types of treatments. These include multi-valued treatments (Imbens, 2000; Lechner, 2002) and continuous treatments (Imbens, 2000; Hirano and Imbens, 2004). We therefore analyze the treatment effects of commercialization on food security by employing the GPS approach (Hirano and Imbens, 2004). Through balancing the differences among smallholders of different intensities of commercialization, this approach allows for the estimation of the causal effects of a continuous treatment (in our case HCI) on food security.

Following closely on Hirano and Imbens (2004), the GPS method can be described as follows. Consider a given sample of households represented by $i,$ (where $= 1, \dots, N$). For each household i in the sample, there exists (1) a vector of pre-treatment variables X_i, (2) the actual level of treatment received T_i, and (3) a set of outcome variables associated with the treatment level $O_i = O_i(T_i)$. The ultimate objective is not to show whether or not commercialization enhances different food security outcomes (as in a binary Propensity Score Matching methodology) but rather to estimate a dose-response function (DRF). Formally written as:

$$\theta(t) = E[O_i(t)] \qquad \forall\, t \in \tau \qquad \text{where } \tau = (0, \ldots, 1) \tag{4}$$

where θ denotes the DRF and t represents the treatment level, measured by the commercialization index, HCI. The DRF therefore shows the relationship between the level (or intensity) of commercialization and the post-treatment outcomes in terms of different aspects of food security.

To be able to estimate the DRF, the GPS is estimated and used to adjust for a specified number of observable characteristics. The GPS is defined as the conditional probability of receiving treatment t given observed covariates, X. This is derived from the conditional density of potential treatment intervals given specific covariates, $[r(t,x) = f_{T|x}(t|x)]$. Therefore, the GPS for household i, given as $R_i = r(T_i, X)$, is a balancing score within strata of the same value which is used to remove the bias associated with differences in the covariates and thus used to derive unbiased estimates of the DRF (Hirano and Imbens, 2004). The GPS method presumes the *weak unconfoundedness* where it is assumed that, conditional on the covariates, the treatment assignment (i.e. selection by households into different levels of commercialization) is independent of each potential outcome (Flores et al., 2011).

The implementation of the GPS method follows a series of steps. First, the estimation of the conditional distribution of the treatment (level of commercialization) given observed covariates is estimated. From this estimation, the GPS (as a balancing score) is obtained. Second, using the obtained GPS, the balancing of covariates is evaluated. Third, with sufficient balancing achieved, the conditional expectation of the outcome is calculated as:

$$\gamma(t, r) = E[O_i | T_i = t, R_i = r] \tag{5}$$

From this, the average DRF are estimated at particular levels of treatment as:

$$\theta(t) = E[\gamma(t, r(t, X_i))] \tag{6}$$

In our analysis, we estimate the GPS using the Generalized Linear Model (GLM) with a fractional logit (Flogit) specification because of the nature of the treatment variable (HCI) which ranges from 0 to 1. To obtain unbiased estimates of the DRF, balancing of covariates is done and tests are performed as proposed by Hirano and Imbens (2004). Also, as indicated by Hirano and Imbens (2004) on estimating the conditional expectation of the outcome, we use a flexible polynomial function with quadratic approximations of the treatment variable (HCI) and the GPS, together with interactions terms. For outcome variables, we use OLS and probit regression models given the binary and continuous nature of our outcome variables.

3.5 Results

3.5.1 Descriptive Results

Smallholders in the study area cultivate a variety of crops with predominantly food crops constituting a large share of the crop portfolio (Table 3). Millet, sorghum, groundnuts, bambaranuts and sunflower are mainly grown in semi-arid villages of Chamwino district while maize, sesame, peas and rice are grown in semi-humid villages in Kilosa district. Maize and millet are major subsistence crops produced by most households, 73% and 53%, respectively. A few cash crops are grown by farmers, mainly sesame (38%) and sunflower (20%). With respect to crop groups, cereals are cultivated by all households whereas about 46% of households grow legumes. Regarding participation in markets, most households sell sesame, maize, peas and rice. Unlike other crops, maize is an important food and cash crop and highly traded in most parts of Tanzania.

Table 3: Crops grown and levels of smallholder commercialization

Crop	Households cultivating (number)	Proportion of households cultivating	Households selling to markets (number)	Proportion of Households selling to markets
Specific crops				
Maize	614	73.0%	295	48.0%
Millet	448	53.2%	60	13.3%
Sorghum	194	23.1%	42	21.6%
Sesame	317	37.7%	257	81.1%
Sunflower	171	20.3%	61	35.6%
Groundnuts	329	39.1%	96	29.1%
Bambara nuts	148	17.6%	26	17.5%
Peas (Variety)	123	14.6%	75	60.9%
Rice	70	8.3%	44	62.8%
Crop groups				
Cereals	841	100.0%	372	44.1%
Legumes and nuts	385	45.7%	181	47.0%

Note: Total sample (n) =841.
Proportion of households selling to markets, considers only those cultivating the said crop and not the entire sample.

Source: Own calculations based on Trans-Sec household survey 2014.

Smallholders differ in various characteristics at various commercialization intensities. Table 4 reports selected household characteristics at different intervals of the HCI. Households with higher levels of commercialization have younger household heads with more years of education compared to those at lower levels of commercialization. While households with more land holding have higher levels of commercialization, livestock ownership is lower at higher levels of commercialization. This may suggest existence of more reliance on livestock than crop cultivation especially for the semi-arid areas of Chamwino district in Dodoma. Regarding locational distribution, villages in Kilosa have more households with higher levels of commercialization as compared to those in Chamwino district.

Table 4: Selected household characteristics at varying levels of commercialization

Variables	**Household commercialization index**			
	<0.25	0.25-0.50	0.50-0.75	>0.75
Age of household head (Years)	51.10	49.14	44.17	43.481
Education of household head (School years)	3.79	4.53	5.11	5.85
Land size owned (ha)	1.61	1.61	1.87	1.89
Total number of livestock owned (TLU)	1.27	0.71	0.47	0.26
Household resides in Kilosa (Yes=1)	0.24	0.59	0.86	0.94
Household resides in Chamwino (Yes=1)	0.76	0.41	0.14	0.06
Commercialization level				
Mean HCI	0.04	0.38	0.62	0.85
	n=445	n=138	n=160	n= 98

Note: Total sample (n) =841.
Source: Own calculations based on Trans-Sec household survey 2014.

Table 5 presents unconditional associations between various levels of smallholder commercialization and food security (using various indicators). Without implying causality, results show that overall, household food security is directly related with levels of commercialization. At higher levels of HCI, households have higher value of crop production for food crops, food consumption and diversity and more months of adequate food compared to least commercialized. Also, more households consume only low quality food due to shocks or seasonal variations at lower levels of commercialization as compared to higher levels. The pattern is the same for food security shocks whereas the probability of experiencing food shortage is higher only at lower levels of commercialization.

Table 5: Food security status by commercialization levels

Variables	Household commercialization index			
	<0.25	0.25-0.50	0.50-0.75	>0.75
Value of crop production (Food crops - PPP $)	304.8	608.4	852.2	1393.3
Food consumption score (FCS)	37.2	42.8	46.8	52.6
Value of consumption from own production (PPP $)	10.3	13.3	15.1	13.2
Household diet diversity score (HDDS)	5.8	6.8	7.4	7.7
Household consumption of only low quality food (1=yes)	0.47	0.45	0.35	0.27
Months of adequate household food provisioning (MAHFP)	6.3	6.5	6.7	7.6
Food security shock (Not enough food, 1= yes)	0.73	0.65	0.51	0.36
	n=445	n=138	n=160	n= 98

Note: Total sample (n) =841.
All monetary variables have been converted from local currency Tanzanian Shilling (TZS) to 2010-based purchasing power parity United States Dollars (PPP $).
Source: Own calculations based on Trans-Sec household survey 2014.

3.5.2 Factors Influencing Intensity of Commercialization

Table 6 shows that land size owned, annual rainfall received and the head of household being male have a positive influence on the intensity of smallholder commercialization. On the contrary, age of household head, number of livestock owned and household location are found to have negative and significant influence on the intensity to commercialize.

The probability of commercialization is 4.5% more for smallholders with a male household head, with the proportion of crop output sold being 10% more for this group of farmers. With regards to productive assets, results show that an increase in land size owned by 1 ha results in a 0.9% increase in the probability of commercialization and a 1.7% increase in the intensity of commercialization. As expected, better agro-climatic characteristics as captured by rainfall also increase the probability and the intensity of market participation.

Conversely, an increase in the age of the household by one year decreases the probability of commercialization by 0.2% and the intensity of commercialization by 0.3%. This may reflect risk aversion and the fact that older household heads may be less receptive of new agricultural technologies. Also, a unit increase in livestock ownership by a household lowers the intensity of participating in markets by 0.8%. Livestock keeping offers alternative sources of income thus smallholders keeping more livestock tend to have lower levels of crop output market participation. Residing in areas with less market access also reduces the probability of market participation. This underscores the significance of location characteristics where market access and infrastructural advantages play a key role in smallholder commercialization.

Table 6: Tobit estimates for intensity of smallholder commercialization

Variable	Coefficient	Robust SE	Marginal effects a	Marginal effects b
Age of household head (Years)	-0.0035***	0.001	-0.002	-0.003
Gender of household head (Male=1)	0.0961***	0.033	0.045	0.100
Education of Household head (School years)	0.0030	0.004	0.001	0.003
Household size (Number of households)	-0.0153	0.011	-0.007	-0.015
Household prepared to take risk (Scale: 0-10)	0.0008	0.005	0.000	0.001
Land size owned (ha)	0.0178**	0.007	0.009	0.017
Total number of livestock owned (TLU)	-0.0081**	0.003	-0.004	-0.008
Labor (worker equivalents)	0.0162	0.017	0.008	0.016
Household owns a mobile phone (yes=1)	0.0369	0.027	0.018	0.036
Access to credit (yes=1)	0.0282	0.036	0.014	0.027
Distance to nearest paved road (Km)	-0.0025	0.008	-0.001	-0.003
Agricultural shocks (yes=1)	-0.0105	0.032	-0.005	-0.010
Mean annual rainfall (mm)	0.0034***	0.001	0.002	0.003
Household resides in Ilolo (yes=1)	0. 0656	0.063	0.033	0.060
Household resides in Ndebwe (yes=1)	-0. 2146***	0.049	-0.094	-0.236
Household resides in Nyali (yes=1)	0. 0042	0.038	-0.002	-0.004
Household resides in Changarawe (yes=1)	0. 0607	0.039	-0.028	-0.062
Constant	-1. 4611	0.332		
Sigma	0. 3171	0.010		

F (18, 822) = 37.58
Prob > F = 0.0000
Pseudo R^2 = 0.41
Log pseudo likelihood = -350.24
Observations summary: 304 left-censored, 536 uncensored, 0 right-censored

Note: ***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
'a' and 'b' represent marginal effects at observed censoring rates where: 'a' indicates the marginal effects for the probability of being uncensored ($\Pr(y_i > 0)$, and 'b' represents the marginal effects for the expected value of the dependent variable conditional on being uncensored $E(y_i|y_i > 0)$.

Source: Own calculations based on Trans-Sec household survey 2014.

3.5.3 Effects of Intensity of Commercialization on Food Security

To capture the heterogeneous effects of intensity of commercialization on different aspects of food security, the analysis was done with the GPS approach. First, the conditional probability of receiving a specific level of treatment (in our case level of commercialization) given the observed covariates was estimated to obtain the GPS. In this, we use the same set of covariates as those used in determining the intensity of commercialization in equation (2). Estimates of GPS are presented in Appendix 1. Secondly, the treatment variable was divided into four intervals ([0.005, 0.401], [0.402, 0.601], [0.602, 0.799] and [0.803, 1]) and the GPS for each respective interval was computed. The means for all covariates in respective intervals were then used to evaluate balancing among the treatment groups. For each covariate, evaluation of balancing was done by testing the mean differences between one group (interval) and all other groups (intervals) combined. Based on these tests, Table 7 reports the t-statistics before and after adjustment by GPS. Taking example of the first interval, there are 12 variables with a t-statistic above 1.96, in absolute value, before adjustment by GPS but after adjustment this number reduces to 2 variables. Overall, according to a standard two-sided t-test, the balancing property was satisfied at a level lower than 0.01 indicating sufficient covariate balancing after conditioning on the GPS. In the third step, the DRFs (average treatments), for different outcome variables, were obtained at evenly distributed levels of commercialization. The treatment effect functions were also computed.

Table 7: Covariate balancing before and after adjustment by GPS

Variable	Before adjustment by GPS				After adjustment by GPS			
	0.005, 0.401	0.402, 0.601	0.602, 0.799	0.803, 1	0.005, 0.401	0.402, 0.601	0.602, 0.799	0.803, 1
Age of household head (Years)	**4.13**	-0.53	**-2.86**	**-1.98**	**-2.19**	0.75	-0.50	-0.66
Gender of household head (Male=1)	**-3.08**	0.65	1.69	1.57	0.86	-0.99	-0.20	-0.83
Education of Household head (Years)	**-3.88**	-0.11	**2.22**	**3.00**	0.95	0.26	0.40	-1.26
Household size (Number of households)	0.95	1.29	-1.84	-1.01	0.69	-1.79	1.62	0.40
Household prepared to take risk (0-10)	-0.87	-0.25	1.38	0.02	0.42	0.15	-0.72	0.43
Land size owned (ha)	-0.94	**-2.02**	1.67	1.54	1.19	1.12	0.26	0.48
Total number of livestock owned (TLU)	**3.00**	-0.55	**-2.82**	**-2.32**	-0.32	-0.09	1.38	0.99
Labor (worker equivalents)	-0.42	1.71	-1.12	-0.49	0.95	**-2.23**	1.33	0.51
Household owns a mobile phone (Yes=1)	**-3.32**	-0.11	**2.65**	1.67	0.74	-0.26	0.17	-0.62
Access to credit (Yes=1)	0.69	1.37	-1.31	-1.11	1.01	-1.70	1.45	0.91
Distance to nearest paved road (Km)	**11.45**	**-2.42**	**-8.75**	**-7.42**	**-2.28**	1.71	**4.44**	3.22
Agricultural shocks (Yes=1)	**2.34**	**-2.64**	0.06	-0.64	-0.19	1.62	0.20	0.83
Mean annual rainfall (mm)	**-12.84**	**2.11**	**10.94**	**8.81**	1.61	-0.87	**-5.51**	**-3.17**
Household resides in Ilolo (Yes=1)	**4.99**	0.25	**-4.18**	**-2.37**	1.28	-1.46	**2.61**	0.82
Household resides in Ndebwe (Yes=1)	**5.15**	-1.24	**-2.79**	**-2.47**	-0.06	0.66	1.57	1.70
Household resides in Nyali (Yes=1)	**-3.91**	0.62	**3.89**	0.05	0.01	0.13	**-4.28**	0.02
Household resides in Changarawe (Yes=1)	**-3.92**	1.42	1.23	**2.42**	-0.17	-0.73	-0.57	**-2.85**

Note: Values are t-statistics for equality of means for each covariate in the respective interval.
Source: Own calculations based on Trans-Sec household survey 2014.

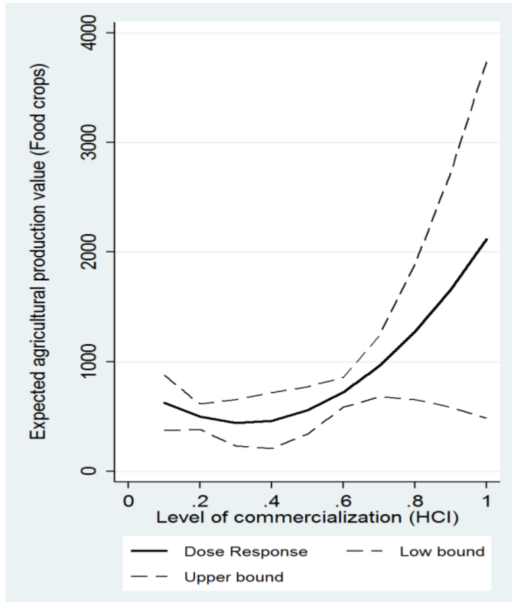
Results show that the intensity of commercialization has heterogeneous effects on the different aspects of food security. Figure 2 presents the GPS adjusted parametric dose response (average treatment) functions on the various food security indicators[4]. The bands represent bootstrapped 95% confidence intervals (bootstrapping with 500 replications).

Regarding food availability, the expected value of agricultural production of food crops is lower at lower levels of commercialization (up to HCI of 0.3) but increases thereafter from

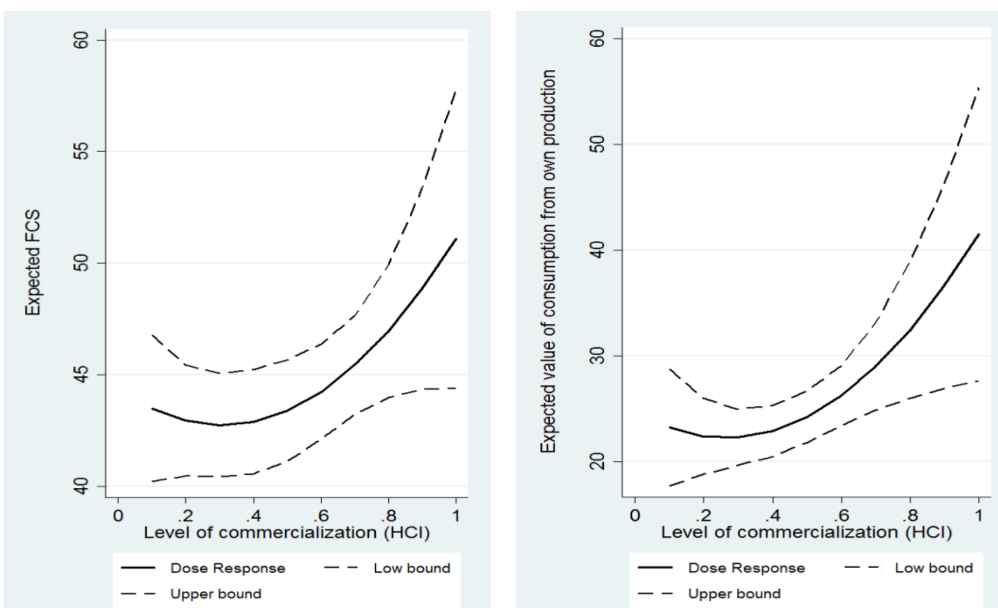
[4] The estimates of the average treatment together with the marginal treatment effects corresponding to the DRFs are presented in Appendix 2.

467 PPP $ to 2100 PPP $ with successive increases in the intensity of commercialization. Similarly, in the indicators for food access, FCS and the value of own production consumed in a normal week are lower at lower levels of smallholder commercialization, but rise as the intensity of commercialization increases. Considering food utilization, the results show that expected HDDS increases as the intensity of commercialization increases but only up to HCI of 0.8. However, higher levels of commercialization, from HCI=0.8, do not translate into increased HDDS. A similar observation can be made for household consumption of only low quality food. The proportion of households accessing only low quality food at certain months of the year increases until an HCI level of 0.6. Subsequently, increased commercialization appears beneficial but, ultimately, there is a negligible reduction at the highest level of commercialization. On food stability, the expected MAHFP depict a modest increase from 6.4 (at HCI of 0.2) to about 7.9 at the highest level of commercialization. The probability of experiencing a food shock is higher at low intensities of commercialization (up to HCI of 0.4) but gradually declines from 63% at 0.4 HCI to 49% at the highest level of commercialization. Despite this decline, the probability of experiencing food shocks is still high at the highest level of HCI.

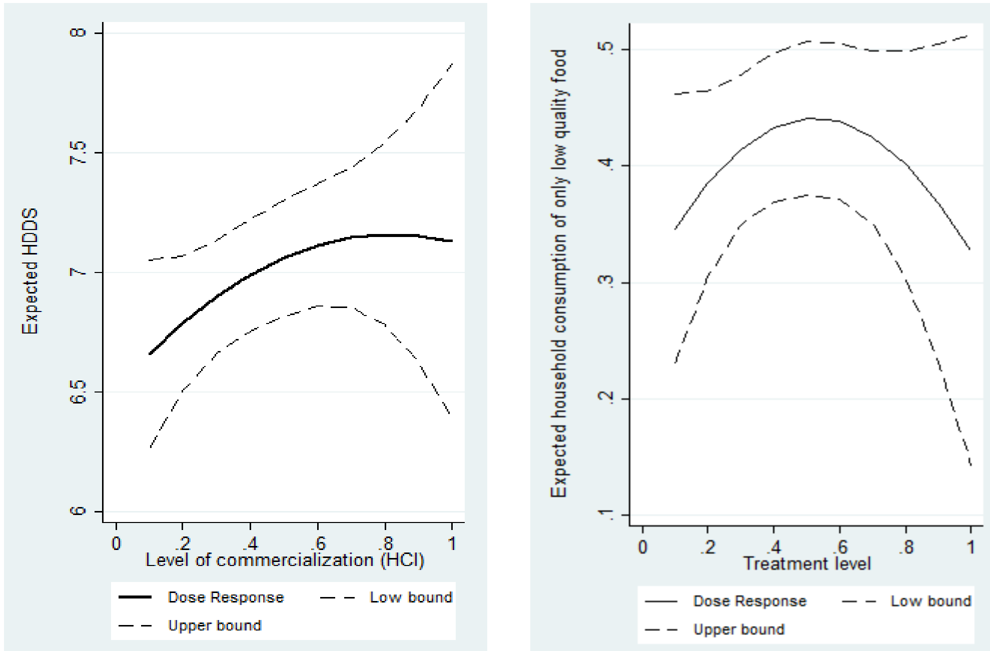
(a) Food availability



(b) Food access



(c) Food utilization



(d) Food stability

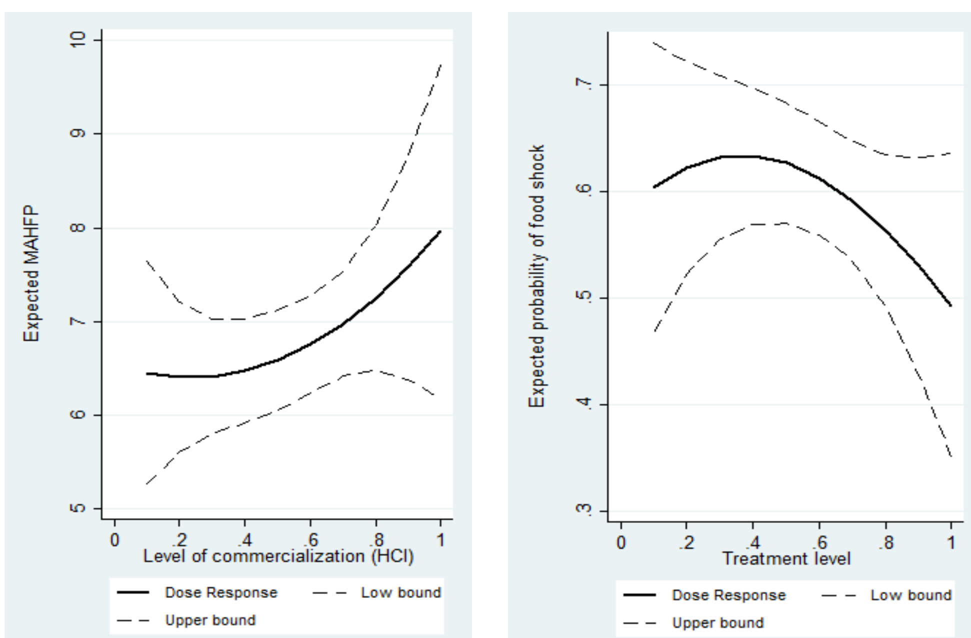


Figure 2 (panel a-d): Average treatment effects functions (DRF) for various food security indicators.

Source: Own calculations based on Trans-Sec household survey 2014.

3.6 Discussion

Smallholder commercialization has become an indispensable outcome of the ongoing gradual transformations in smallholder agriculture. Currently, most smallholders in most low-income countries are neither strictly market-oriented nor subsistence-oriented (Jones et al., 2014). Therefore, the intensity of commercialization among these smallholders varies and this partly depends on the available household endowments. Based on our results, productive assets such as land play an important role in influencing positively the level of commercialization. This may be through increasing advantages of economies of scale and thus the ability of smallholders to produce marketable surplus. In addition, better agro-climatic characteristics, for example availability of rainfall, also enhance commercialization. Pingali and Rosegrant (1995), Barrett et al. (2010) and Akinlade et al. (2016) also observe that households' productive assets (such as land) are instrumental in increasing market participation.

However, other assets such as livestock may divert household resources away from crop production and hence less crop-output market participation. Our descriptive and econometric results show that increased ownership of livestock is associated with lower levels of crop output market participation. This may suggest significant reliance on livestock keeping and subsistence farming over more commercially-oriented farming by households in areas with harsh environments such as in the semi-arid villages of Chamwino district. In these instances, livestock production offers important alternative income for household welfare.

With regards to the consequences of smallholder commercialization, an important finding is that there are heterogeneous effects on different pillars of food security. Different levels of commercialization are associated with different levels of food security. At lower intensities of commercialization, smallholders have lower levels of food security in terms of availability, access, utilization and stability. This may suggest that subsistence levels of production may not be entirely beneficial to smallholders. It also reinforces the concerns on the viability of subsistence agriculture and its potential to contribute to sustainable food security and welfare for majority of resource poor rural households (Pingali, 1997; Hazell et al., 2007). As the level of commercialization increases, findings show that food security is enhanced in largely all dimensions, albeit at varying magnitudes. Other studies also show that food security can benefit from increased commercialization of smallholders mainly through the pathways of increased incomes (von Braun et al., 1994), increased productivity through household level synergies with cash cropping (Govereh and Jayne, 2003) and through the income-consumption link which may also improve nutrition (Babu et al., 2014). Food utilization is also shown to marginally increase as levels of commercialization increase (as shown by the HDDS indicator).

At higher levels of commercialization, results show no improvements in terms of dietary quality and diversity. Two explanations may be plausible for this finding. First, as argued earlier, depending on the nature of intra-household resource allocations, increased incomes from commercialization may not be adequately devoted to improving household food security (Paolisso et al., 2001). For increased incomes to be beneficial to household food security and nutrition, more control of crop income by women is required. Secondly, the nature of the crop portfolio involved in the commercialization process is important. More focus on cash crops may be less beneficial for improved food diversity at the household as compared to a diverse portfolio that includes food crops. Anderman et al. (2014) observe significant negative relationships between cash crop production and the dimensions of food security. Also, there is increasing evidence that more diverse farm production contributes to more diverse diets at the household (Jones et al., 2014). Regarding stability of food at the household level, findings reveal that increased intensity of commercialization translates into positive, but modest improvements in food stability. Evidence from other studies suggests that increased commercialization may lead to less desirable outcomes and has been documented to expose smallholders to volatile food markets (Dorsey, 1999; Jaleta et al., 2009).

3.7 Summary and Conclusion

This study set out to examine the role of intensity of smallholder commercialization on the different aspects of household food security. We analyzed the determinants of intensity of smallholder commercialization and how this intensity influence different dimensions of food security.

Findings confirm the role of household characteristics and productive assets in influencing the level of commercialization for rural smallholders. Also, despite the indisputable relevance of the link between smallholder commercialization and household food security, findings show that the intensity of commercialization also matters. Lower levels of commercialization are associated with poorer food security outcomes in terms of availability, access, utilization and stability. Increased intensity of commercialization is related with steady increases in food availability and access but with modest improvements in food utilization and stability. This suggests that increased commercialization may not necessarily lead to homogeneous improvements in the four dimensions of food security.

The arising policy implications are that, although strategies to promote smallholder commercialization are relevant in ensuring increased productivity, food production and incomes for food security, they need to still take cognizance of the less desirable effects for poorer smallholders. Thus, other strategies to mitigate the negative effects of commercialization are important. Also, and equally important, policies should not only focus on the availability and access to food as outcomes of smallholder commercialization strategies but also take into account food utilization and stability dimensions of food security.

We must point out that while food security is still a complex phenomenon, one that cannot be analyzed easily, so is commercialization. This study has used only one of the many definitions of commercialization. Future research on broader measures of smallholder commercialization (also including livestock commercialization) is suggested. Also, food security dimensions may be influenced by many other aspects and these may vary over time. Further studies are therefore needed to understand the role of smallholder commercialization on the multiple dimensions of food security.

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Appendices

Appendix 1: Estimates of GPS (continuous treatment)

Variable	GPS		
	Coefficient		SE
Age of household head (Years)	-0.009	***	0.002
Gender of household head (Male=1)	0.169		0.112
Education of Household head (School years)	0.012		0.014
Household size (Number of households)	-0.052		0.039
Household prepared to take risk (Scale: 0-10)	-0.010		0.017
Land size owned (ha)	0.081	***	0.022
Total number of livestock owned (TLU)	0.011		0.022
Labor (worker equivalents)	0.060		0.061
Number of crops grown	0.055		0.040
Household owns a mobile phone (yes=1)	0.060		0.092
Access to credit (yes=1)	0.155		0.147
Distance to nearest paved road (Km)	0.014		0.027
Agricultural shocks (yes=1)	0.176		0.106
Mean annual rainfall (mm)	0.011	***	0.002
Household resides in Ilolo (yes=1)	0.138		0.237
Household resides in Ndebwe (yes=1)	-0.183		0.202
Household resides in Nyali (yes=1)	-0.092		0.123
Household resides in Changarawe (yes=1)	-0.087		0.122
Constant	-5.427	***	1.221
Log likelihood	-248.01		
Observations	536		

Note: Dependent variable for GPS: Intensity of commercialization (HCI).
Source: Own calculations based on Trans-Sec household survey 2014

Appendix 2: Estimates of average treatment and marginal treatment effects

	Value of agricultural production (food crops)				Food consumption score (FCS)				Value of consumption from own production			
Treatment level	ATE	t-value	MTE	t-value	ATE	t-value	MTE	t-value	ATE	t-value	MTE	t-value
0.1	648.72	4.82	-134.38	-0.99	43.50	26.05	-0.55	-0.72	23.17	8.22	-0.81	-0.63
0.2	514.34	8.21	-60.46	-0.74	42.96	33.78	-0.20	-0.37	22.36	12.23	-0.10	-0.11
0.3	453.88	4.04	13.46	0.44	42.76	36.31	0.15	0.43	22.26	16.47	0.61	1.00
0.4	467.34	3.46	87.38	2.61	42.90	36.12	0.50	2.01	22.87	18.60	1.32	2.59
0.5	554.72	5.00	161.30	1.90	43.40	37.44	0.84	2.46	24.20	19.47	2.03	2.89
0.6	716.02	10.88	235.22	1.70	44.24	40.66	1.19	2.22	26.23	18.05	2.75	2.64
0.7	951.24	6.49	309.14	1.60	45.43	40.27	1.54	2.03	28.98	13.75	3.46	2.44
0.8	1260.39	3.82	383.06	1.55	46.97	31.01	1.89	1.91	32.43	9.86	4.17	2.30
0.9	1643.45	2.87	456.98	1.52	48.86	21.27	2.23	1.83	36.60	7.39	4.88	2.20
1	2100.43	2.41	530.91	1.49	51.09	15.01	2.58	1.77	41.48	5.87	5.59	2.13
Overall average	931.05	3.66	198.26	1.24	45.21	28.44	1.02	1.41	28.06	10.26	2.39	1.82

	Household diet diversity score (HDDS)				Household consumption of only low quality food				Months of adequate household food provisioning (MAHFP)			
Treatment level	ATE	t-value	MTE	t-value	ATE	t-value	MTE	t-value	ATE	t-value	MTE	t-value
0.1	6.66	33.03	0.13	1.49	0.35	5.83	0.04	1.45	6.45	10.62	-0.05	-0.19
0.2	6.79	47.02	0.11	1.67	0.39	9.45	0.03	1.39	6.40	15.56	0.01	0.03
0.3	6.90	56.88	0.09	1.88	0.41	12.59	0.02	1.27	6.41	20.59	0.06	0.46
0.4	6.99	58.47	0.07	1.84	0.43	13.23	0.01	0.75	6.47	22.93	0.11	1.31
0.5	7.06	57.12	0.05	1.20	0.44	13.07	0.00	-0.25	6.58	24.08	0.17	1.85
0.6	7.11	54.55	0.03	0.56	0.44	12.81	-0.01	-0.80	6.75	25.56	0.22	1.61
0.7	7.15	47.75	0.01	0.17	0.42	11.23	-0.02	-1.04	6.97	24.39	0.28	1.39
0.8	7.16	36.72	-0.01	-0.06	0.40	8.06	-0.03	-1.22	7.25	18.26	0.33	1.25
0.9	7.15	26.29	-0.03	-0.20	0.37	5.25	-0.04	-1.41	7.58	12.39	0.38	1.16
1	7.13	18.77	-0.04	-0.30	0.33	3.46	-0.05	-1.64	7.96	8.70	0.44	1.09
Overall average	7.01	38.15	0.04	0.54	0.40	9.50	-0.01	-0.15	6.88	15.79	0.20	0.94

	Food shock (Not enough food)			
Treatment level	ATE	t-value	MTE	t-value
0.1	0.60	8.71	0.02	0.77
0.2	0.62	12.21	0.01	0.51
0.3	0.63	16.07	0.00	0.09
0.4	0.63	19.38	-0.01	-0.58
0.5	0.63	21.64	-0.01	-1.31
0.6	0.61	22.60	-0.02	-1.65
0.7	0.59	20.73	-0.03	-1.64
0.8	0.56	15.48	-0.03	-1.56
0.9	0.53	10.23	-0.04	-1.51
1	0.49	6.77	-0.04	-1.51
Overall average	0.59	13.49	-0.02	-0.82

Note: ATE = Average treatment effects, MTE = Marginal treatment effects.
Source: Own calculations based on Trans-Sec household survey 2014.

Chapter 4:

Implications of Farm Production Diversity for Household Consumption Diversity in Tanzania: Insights from Diverse Agro-ecological and Market Access Contexts

Abstract

Owing to persistent challenges of food and nutritional insecurity, recent literature has focused on the role diversity of farm production has on food consumption diversity particularly for smallholder households. Yet, the relationship between farm production diversity and household food consumption diversity remains complex and empirical evidence, so far, show mixed results. The present article aims to assess this relationship using two regions with contrasting agro-ecological and market contexts in rural Tanzania. Based on household data from smallholders in Kilosa and Chamwino districts, descriptive and multivariate regression analyses are used to assess the nature and extent of farm production diversity, its determinants and role for household food consumption diversity. Results indicate a positive role of farm production diversity for food consumption diversity in Chamwino district which has relatively harsh climatic and agro-ecological characteristics and poor access to markets. In addition, increased farm production diversity is generally associated with seasonal food consumption diversity. However, results suggest a lesser role of farm production diversity in presence of better agro-ecological and market access characteristics such as in Kilosa district. These findings imply that strategies geared at promoting farm production diversity should consider the existing agro-ecological and market characteristics. In addition, to enhance food consumption diversity, policies should focus not only on smallholder farm production but also aim at addressing other aspects along agricultural value chains such as input systems, processing, storage, marketing and market related institutions.

Keywords: Farm production diversity; food consumption diversity; seasonal food consumption; Tanzania

4.1 Introduction

For most developing countries, smallholder agriculture plays a pivotal role in enhancing rural households' food security and livelihoods (Herrero et al., 2010; IFAD and UNEP, 2013). This is mainly achieved through production of own food and incomes from sales of agricultural produce (World Bank, 2008; Jones et al., 2014). Despite recent significant strides in agricultural production, challenges such as food insecurity, undernutrition and volatile food prices have persistently affected most smallholders (Godfray et al., 2010; Dorward, 2012; IFPRI, 2014). In the wake of these challenges, there has been increased support for diversification of smallholder production as a strategy to enhance rural households' food security through increased food sufficiency and diversity (Burlingame and Dernini, 2012; Pellegrini and Tasciotti, 2014; Jones et al., 2014; Sibhatu et al., 2015; Powell et al., 2015; KC et al., 2015).

At the farm level, production diversity entails smallholders maintaining a variety of species for both plants and animals (Fanzo et al., 2013). The logical argument put forth is that increased diversity of smallholder production (for both crops and livestock) will enhance access to a diverse portfolio of food for consumption at the household level. This, subsequently, improves the dietary diversity of smallholder households. However, the debate on the role of smallholder farm production diversity and household food consumption diversity is far from conclusive. While some recent studies find a positive influence in this relationship (Jones et al., 2014; Pellegrini and Tasciotti, 2014; Kumar et al., 2015), others observe mixed results (KC et al., 2015; Sibhatu et al., 2015). This is due to the fact that, besides smallholder farm production diversity, household food consumption diversity may be influenced by market access and opportunities for off-farm income, among other factors (Jones et al., 2014; Sibhatu et al., 2015). Moreover, the implications of farm production diversity on food consumption of rural households may vary depending on, among other factors, agro-ecological characteristics which determine the cropping systems pursued by smallholders (Ruel, 2003; KC et al., 2015).

Despite the increased promotion of agricultural diversification for smallholders, empirical evidence on its role and implications in different smallholder contexts has lagged behind. In particular, evidence from diverse agro-ecological and market access settings is rare, including in Tanzania. We therefore use household data from diverse agro-ecological and market access contexts in rural Tanzania to answer three questions: (1) what is the nature and extent of farm production diversity among smallholders in the two regions? (2) What determines the observed farm production diversity? and (3) how does farm production diversity influence household food consumption diversity?

This article adds on previous literature in two ways. First, we use data from two distinct agro-ecological and market access contexts to analyze the farm production diversity-food consumption diversity relationship. This is important since the true role of farm production diversity on food consumption diversity may be masked by analyses that use national averages (such as Pellegrini and Tasciotti, 2014). The objective is then to get insights on the nature and role of farm production diversity on food consumption diversity from diverse contexts as smallholder agriculture is inherently heterogeneous. Secondly, we use data on seasonal food consumption to further assess the potential of farm production diversity in contributing to seasonal food consumption diversity. Smallholder households' consumption is inherently seasonal (Vaitla et al., 2009; Bacon et al., 2014) with food insecurity being more prevalent in planting and pre-harvest season. However, farm production diversity may enhance access to a variety of crops in different seasons (Herforth, 2010) and hence improve seasonal food consumption diversity.

The reminder of this article is organized as follows: The next section reviews related literature followed by section three which presents the study area, data and empirical strategy. Results are then presented in section four and a discussion in section five. Section six gives a summary of main findings and draws conclusions.

4.2 Literature review

4.2.1 Farm Production Diversity in Smallholder Agriculture

Smallholder farming systems particularly in Sub-Saharan Africa are characterized by a considerable amount of diversity, owing to heterogeneous biophysical and socio-economic environments (Tittonell et al., 2010). Consequently, smallholders are confronted with multiple constraints and opportunities in their environments, which ultimately shape the diversity of their strategies (Barrett et al., 2001; Tittonell et al., 2010). As argued by Barrett et al. (2001), diversification of assets, activities or incomes by farm households may be due to "push factors” such as land or liquidity constraints and high transaction costs or “pull factors” where new opportunities may provide higher returns and thus enable improvement of livelihoods. Farm production diversity constitutes part of smallholder diversification strategies. Production diversity, which falls within the broader concept of agrobiodiversity, entails not only maintaining a variety of species for both plants and domestic animals but also genetic diversity within each species (Fanzo et al., 2013).

The level of farm diversity maintained by smallholders depends on households’ socio-demographic characteristics (such as age, gender and education) and assets such as land and labor (Benin et al., 2004; Di Falco et al., 2010). Households’ productive assets can be, in particular, important in enhancing the capacity of households to exploit the advantages of production diversity such as through crop-livestock integration. Equally important, agro-ecological characteristics, access to markets and available infrastructure are also instrumental in influencing the level of farm production diversity (Benin et al., 2005; Di Falco et al., 2010). Regarding agro-ecological characteristics, smallholders may be inclined to maintain a high diversity in their production due to presence of climatic and other agricultural risks. With respect to markets and the nature of available infrastructure, smallholders may substantially rely on self-provision of food in less accessible villages due to high costs of accessing markets, thereby maintaining a higher diversity at the farm. Following on the “push factors” argument, farm production diversity can be used as a way of mitigating risks by smallholders, especially in presence of output market imperfections and harsh agro-ecological environments (Hazell, 2009; Pellegrini and Tasciotti, 2014).

4.2.2 Linking Production Diversity to Consumption Diversity

The wider benefits of maintaining diversity of various species both plants and animals by smallholders are well argued in the literature. The contribution of diversity includes enhancing resilience of food production, provision of important nutritional benefits and supporting the overall sustainability of food systems (Fanzo et al., 2013). However, despite these unarguably important benefits, promotion of farm production diversity for improved nutrition has confronted several challenges. An example is the existence of agricultural and food security policies in many developing countries which promote a few cereal staples. This follows decades of implementation of Green Revolution policies, which focused primarily on cereal based systems – involving mainly maize, rice and wheat – to enhance calorie availability

(Fanzo et al., 2013). In addition, Hunter and Fanzo (2013) argue that there is a general lack of empirical evidence that links biodiversity and improved nutrition outcomes such as dietary diversity.

In recent empirical literature, several studies show a positive influence of farm production diversity on household food consumption diversity. For example, in a wide study involving eight developing countries, Pellegrini and Tasciotti (2014) assessed the role of crop diversification and found a positive correlation between the number of crops cultivated and indicators of dietary diversity. Similarly, Oyarzun et al. (2013) observed that on-farm species diversity is positively correlated with household-level dietary diversity in the Ecuadorian rural highlands. Also using a nationally representative sample of farming households in Malawi, Jones et al. (2014) found that farm production diversity is positively associated with dietary diversity. This literature acknowledges that, however, the relationship may be complex given influences of household characteristics, market orientation and the nature of farm diversity. In Tanzania, Herforth (2010) offers first insights into the relationship between farm production diversity and food consumption diversity at the household. Using household data from northern Tanzania and central Kenya, the study found that crop diversity was positively associated with household dietary diversity. However, it does not offer insights on diverse contexts as it was carried out in one part of northern Tanzania which has largely similar agro-ecological and market access characteristics. Also, farm diversity was limited to crop diversity (i.e. the number of crops grown by a household).

Conversely, mixed results have also been documented. Sibhatu et al. (2015) conducted a study using household-level data from Malawi, Kenya, Ethiopia and Indonesia. They observed that on-farm production diversity was not positively associated with dietary diversity in all cases and that this relationship depended on the level of production diversity and the nature of market access. Also KC et al. (2015) observed in three agro-ecological regions of Nepal that crop diversity was more beneficial in enhancing food self-sufficiency for households in low agricultural potential areas and with poor market access compared to those in agro-ecological zones with higher agricultural potential and market access. Other studies find no robust relations between farm diversity and dietary diversity. For instance, Ng'endo et al. (2016) found no strong association between on-farm diversity and dietary diversity among smallholders in western Kenya. Instead, socioeconomic factors such as household wealth and education played a stronger role in influencing dietary diversity.

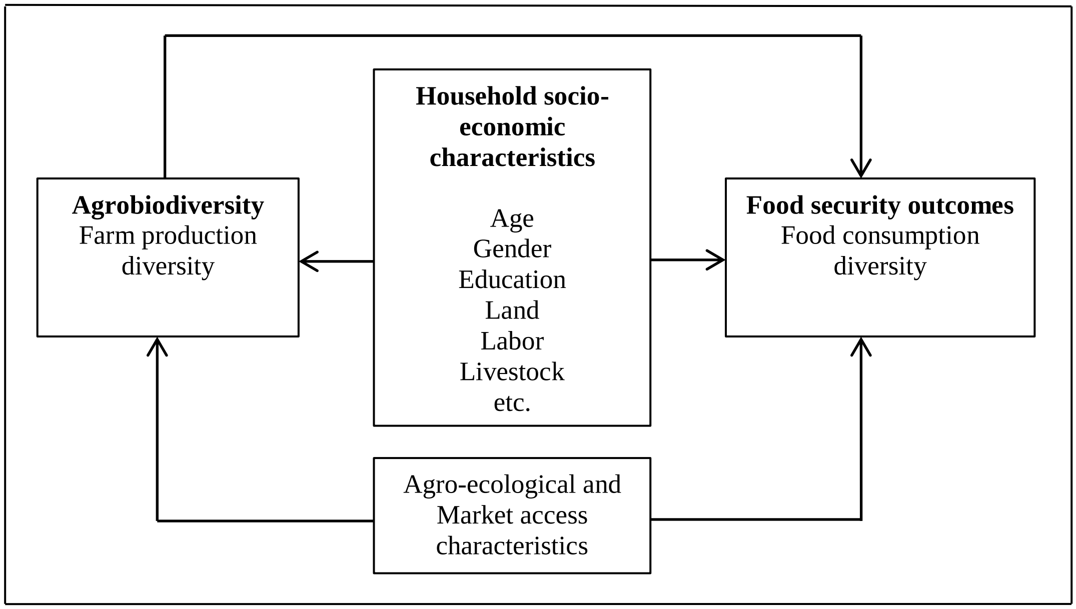

Figure 1: Conceptual framework (Authors' construction based on K.C et al. 2015)

Accordingly, in assessing the links between the nature of farm production diversity and food consumption diversity, an emerging realization is the significant role of opportunities and constraints provided for by household socio-economic factors and the existing market characteristics and agro-ecological environment. The theorized links are summarized in the conceptual framework presented in Figure 1. Food security outcomes (such as food consumption diversity) are assumed to be influenced by the level of agrobiodiversity (represented here by farm production diversity). In addition, farm production diversity and food consumption diversity are also influenced by household socio-economic factors together with the existing agro-ecological and market access characteristics.

4.3 Data and Methodology

4.3.1 Study Area and Data

Tanzania has diverse climatic and ecological zones which support different agricultural systems (URT, 2015). Given the focus of this article, we use data from two regions in Tanzania (Morogoro and Dodoma). These regions are situated in two distinct agro-ecological zones and, in general, represent about 70-80% of the types of farming system found in Tanzania (USAID, 2008). Table 1 provides a summary of main characteristics of the study area in terms of agroecology, agricultural potential, access to major markets, cropping and livestock systems. The two study areas also differ with regards to food security. Morogoro has areas with varying levels of food security while most areas in Dodoma are characterized by high food insecurity.

Table 1: Summary of main characteristics of study area

	Kilosa District (rural)	Chamwino District (rural)
Agro-ecology	Semi-humid (Rainfall 600-800mm)	Semi-arid (Rainfall 350-500mm)
Agricultural potential	Relatively good	Relatively poor
Access to major markets	Relatively good	Relatively poor
Cropping system	Cereals and legumes (Maize, Rice, Peas and Sesame)	Drought resistant cereals, legumes and seeds (Sorghum, Millet, Groundnuts and Sunflower)
Livestock system	Little livestock keeping (poultry, goats)	Heavy integration of livestock (Cattle, goat, poultry)

Source: Environment statistics (2015), National Bureau of Statistics, Tanzania

To enable a comparative analysis, two focus districts were selected from each region namely Kilosa in Morogoro and Chamwino in Dodoma (see Figure 2). In each district, three villages were chosen based on having relatively similar (1) village sizes (800-1500 households), (2) climatic conditions, (3) livestock integration and (4) rain-fed cropping systems. The selected villages were Ilolo, Ndebwe and Idifu for Chamwino district and Changarawe, Nyali and Ilakala for Kilosa district.

A primary household survey was then conducted in the six villages. Using household lists prepared by local agricultural extension officers in collaboration with village heads, 900 households were randomly selected, proportional to sub-village sizes. A total of 150 households were interviewed from each village. A detailed structured questionnaire was used to collect data at the household level. Apart from socio-demographic information, the questionnaire contained comprehensive sections on agriculture, livestock, off-farm employment, non-farm self-employment and food consumption and expenditure. The questionnaire also captured the seasonal aspects of food consumption at the household level.

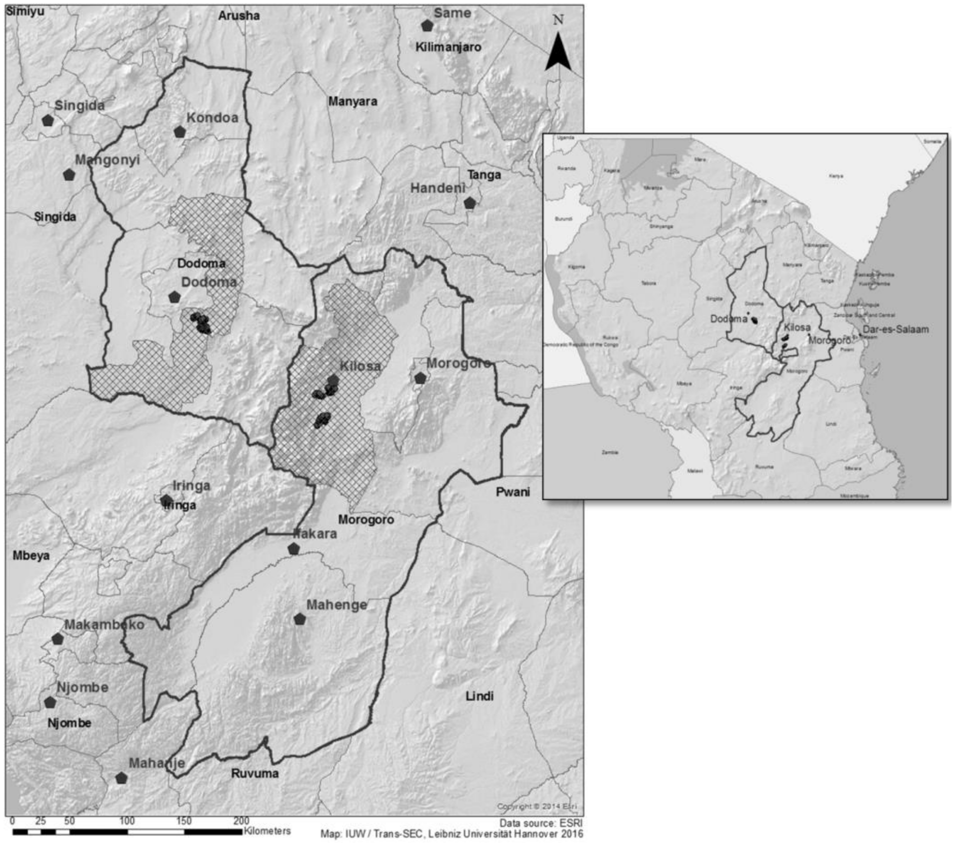

Figure 2: Study sites in Morogoro and Dodoma regions, Tanzania (Source: Trans-Sec 2014)

4.3.2 Measures of Diversity

We use several variables to measure farm production diversity and household food consumption diversity. With respect to farm production diversity, we use two indicators. The first is based on species count for both crops and livestock, as recommended by Last et al. (2014) and used in several recent studies (see, for example, Jones et al., 2014; Pellegrini and Tasciotti, 2014; Sibhatu et al., 2015). From this indicator, for example, a household cultivating three crops (e.g. maize, sorghum and groundnuts) and keeping cattle only will have a crop-livestock count of 4. The second measure uses the number of food groups produced on the farm to generate production diversity scores. Based on our data, we use 9 food groups (cereals; roots, tubers and plantains; pulses, seeds and nuts; fruits; vegetables; fish; meat; eggs; and milk and dairy products). In this case, a household cultivating only maize, rice and sorghum will have a production diversity score of 1, because all crops belong to cereals. Conversely, if a household cultivates maize and groundnuts and keeps goats, the diversity score will be 3, as they fall under different food groups. This indicator addresses the fact that crops and livestock produced on a farm might have different nutritional functions and hence affect household food consumption diversity differently (Berti, 2015; Sibhatu and Qaim, 2016). In general, these indicators are suitable for comparison among farms and regions (Last et al., 2014) and also allow for a comprehensive analysis of a typical smallholder farm production, which, in most cases, integrates crops and livestock[5].

For household food consumption diversity, we also use two indicators. These are the Household Dietary Diversity Score (HDDS) and the Food Variety Score (FVS). Following Swindale and Bilinsky (2006), HDDS is constructed from the number of different food groups consumed by a household in a specified reference period, in our case a 7 day period. We use 9 food groups as those used in the indicator for production diversity above. We also extend the HDDS indicator to capture household dietary patterns during planting, pre-harvest and post-harvest seasons. For this, households were asked how many days in a normal week they would eat a particular food group for each season in the past year. The FVS records the number of different food items eaten during a specified reference period (Hartley et al., 1998). A 7 day recall period is also used based on the previous normal week.

4.3.3 Empirical Strategy

In assessing the relationship between farm production diversity and household food consumption diversity, we first examine determinants of farm production diversity and then analyze how this diversity is associated with household food consumption diversity outcomes.

Analyzing the Determinants of Farm Production Diversity

Observed farm production diversity may be influenced by different household, farm, institutional and locational characteristics. To examine how these factors determine farm production diversity, we use the following model specification:

$$PD_i = \delta X_i + u_i \qquad (1)$$

where PD_i indicates the farm production diversity for household i, Farm production diversity is represented as a score for both diversity indicators i.e. crop-livestock count and for

[5] Alternative indicators include (1) the Simpson's Index, which measures species diversity and accounts for both, species richness and evenness and (2) the modified Margalef species richness index (Di Falco and Chavas, 2009; Last et al., 2014). However, the use these indicators in the present analysis would limit the scope to crops only as both measures require land area in their computation.

the number of food groups produced. X_i represents a vector of explanatory variables. δ is a vector of parameters to be estimated and u_i is the error term.

Drawing from literature on farm production diversity, the predicting variables include household, farm and locational characteristics. Household socio-demographic characteristics such as age, gender are important in influencing the skills, experiences, risk attitude, willingness and ability to maintain different levels of diversity in their production (Benin et al., 2004). These may influence farm production diversity either positively or negatively. For example, while older household heads may be less able and eager to maintain higher diversity especially for new crop or livestock varieties as compared to younger ones, the accumulated skills and experience in farm production may influence farm production positively. Also, depending on the level of control of household productive assets such as land, labor and equipment, female headed households may maintain more or less diversity at the farm. However, education is expected to influence farm production diversity positively as it enhances skills and use of information for maintaining different varieties of crops and livestock (Benin et al., 2004). Household productive assets such as land and labor are expected to have a positive influence on farm production diversity (Benin et al., 2004; Di Falco et al., 2010). Locational factors are equally important. As distances to key services and markets increase, transaction costs increase thus compelling households to allocate land to more diverse production to cater for expected consumption (Benin et al., 2004; Pellegrini and Tasciotti, 2014).

Analyzing the Influence of Farm Production Diversity on Consumption Diversity

Regarding the link between farm production diversity and household food consumption diversity, we analyze this relationship by a model specified as follows:

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

where CD_i represents household food consumption diversity for each individual household i. This is a score based on HDDS and FVS. Food consumption diversity is influenced by farm production diversity PD_i and a vector of other explanatory variables X_i. β and δ are parameters to be estimated and u_i is the error term.

As already noted, household food consumption diversity is influenced by factors beyond farm production diversity. These include household socio-economic characteristics (such as age, gender and education) and market related factors. For example, gender may determine the control of household resources and how they are allocated (Jones et al., 2014). Household income in female-headed household may be spent more on quality diets than that of male-headed households. Household productive assets such as land, labor and livestock may also enhance household's production capacity and thus influencing food consumption diversity positively. Household wealth is expected to play a strong positive role in enhancing food consumption diversity because it increases the ability of households to afford diverse diets (Jones et al., 2014). Households with higher consumption expenditure are therefore expected to have higher food consumption diversity. Equally important is the fact that food consumption diversity may also be influenced by market access (Sibhatu et al., 2015). Proximity to markets and purchasing power to access different food items are expected to raise household food consumption diversity. Proximity to markets enables market-oriented smallholders to take advantage of lucrative product markets thereby enhancing incomes which may be spent on accessing diverse diets (Jones et al., 2014). In addition, income from non-farm self-employment and other sources is essential in raising household's purchasing power, thus expected to enhance food consumption diversity.

In both equations (1) and (2), and depending on the nature of the dependent variable, we use Poisson and negative binomial regression models because both diversity indicator variables consist of count data. Poisson regression assumes *equi-dispersion* (that is, the conditional mean of the dependent variable is equal to its variance), while the negative binomial regression can be used in case of over-dispersed count data. We test for potential collinearity among independent variables and also use robust standard errors to address problems of heteroscedasticity in the estimates. Given the cross-sectional nature of the data, our analysis is restricted to potential relationships between key explanatory factors and food consumption diversity. Thus results should not be interpreted as causal but rather correlational.

4.4 Results

Table 2 presents the characteristics of the sample at household and farm-level. In the two districts, farm level characteristics show important differences. In particular, households in Chamwino district possess more land and livestock. In addition, these households have more cultivated plots and crops grown, on average, as compared to those in Kilosa district. Levels of self-provision of food seem to also be higher in Chamwino evidenced by higher share of home consumption from total output. Similarly, greater distance to paved roads indicates poor access to markets and key services. This is not the case for Kilosa which has a better proximity to markets and households have relatively more food and non-food expenditure.

Table 2: Selected household and farm characteristics

Variable	**Kilosa district – Semi humid with better market access (n=450)**	**Chamwino district – Semi arid with poor market access (n=449)**	**Pooled sample**
	Mean (SD)	Mean (SD)	Mean (SD)
Household characteristics			
Age of HH head (years)	48.20(17.28)	49.10(16.94)	48.65(17.11)
Gender of HH head (Male=1)	0.81(0.39)	0.77(0.42)	0.79(0.41)
Education of HH head (School years)	4.89(3.30)	3.96(3.48)	4.42(3.42)
Labor (Worker equivalents)	2.84(1.43)	3.19(1.49)	3.01(1.47)
Access to off-farm employment (Yes=1)	0.20(0.40)	0.47(0.50)	0.33(0.47)
Access to non-farm self-employment (Yes=1)	0.16(0.37)	0.35(0.48)	0.25(0.44)
Non-food expenditure (Per capita/month-PPP $)	34.11(34.97)	23.49(20.31)	28.81(29.07)
Food expenditure (Per capita/ month PPP $)	13.65(19.18)	9.94(11.33)	11.81(15.86)
Share of home consumption from total output	0.45(0.38)	0.68(0.42)	0.57(0.42)
Distance to nearest paved road (Km)	1.94(1.16)	10.18(2.74)	6.15(4.72)
Farm characteristics			
Land size owned (ha)	1.47(1.56)	1.95(1.91)	1.71(1.76)
Number of plots cultivated	2.2(0.7)	3.2(1.3)	2.6(1.11)
Livestock owned (Tropical Livestock Unit)	0.53(6.06)	1.26(2.70)	0.90(4.71)
Number of crops cultivated	2.66(1.28)	4.47(1.80)	3.56(1.81)

Note: Worker equivalents, used to capture labor available at the household, were calculated by weighting household members; less than 9 years=0; 9-15=0.7; 16-49=1 and above 49 years=0.7.
All monetary variables have been converted from local currency Tanzanian Shilling (TZS) to 2010-based purchasing power parity United States Dollars (PPP $).

Source: Own calculations based on Trans-Sec household survey 2014.

4.4.1 Comparison of Farm Production Diversity by Agro-ecology and Market Access

Table 3 provides a comparison of farm production diversity indicators based on agro-ecological and market access characteristics in Kilosa and Chamwino districts, and also for the pooled sample. Overall, significant differences in farm production diversity can be observed between the two districts. Compared to Chamwino, Kilosa has low farm production diversity in terms of both, crop-livestock count and the number of food groups produced. Specifically, diversity based on crop-livestock count is significantly lower for Kilosa compared to that of Chamwino. Similarly, diversity based on the number of food groups produced show the same pattern.

Table 3: Comparison of farm production diversity by agro-ecology and market access in Kilosa and Chamwino districts

Diversity indicator	**Kilosa district – Semi humid with better market access (n=450)**	**Chamwino district – Semi arid with poor market access (n=449)**		**Pooled Sample**
	Mean(SD)	Mean(SD)	Z statistics	
Farm production diversity (based on crop-livestock count)	3.40(1.62)	5.82(2.49)	15.30***	4.61(2.42)
Farm production diversity (based on number of food groups produced)	3.01(1.35)	3.81(1.33)	8.40***	3.41(1.40)

Note: *, ** and *** represent significant differences at 10%, 5% and 1%, respectively. Wilcoxon-Mann-Whitney non parametric two-sample test identifies differences between Kilosa and Chamwino.

Source: Own calculations based on Trans-Sec household survey 2014.

4.4.2 Comparison of Food Consumption Diversity in Kilosa and Chamwino Districts

Food consumption diversity is higher for households in Kilosa district, compared to those in Chamwino (see Figure 3). This is despite the low farm production diversity observed in Kilosa. Notwithstanding the high farm production diversity in Chamwino, the household food consumption diversity is relatively low compared to Kilosa, consistently for both measures of food consumption diversity (HDDS and FVS) and for the planting, pre-harvest and post-harvest agricultural seasons.

We also compare food consumption diversity based on low and high farm production diversity of households (Table 4). To achieve a simplified comparison, the threshold for high and low diversity is determined by median values of the crop-livestock diversity indicator. Households with crop-livestock diversity above the median are classified as having high production diversity while those below the median are considered to have low production diversity. For Kilosa district, crop-livestock diversity ranges from 1 to 12 with the median value of 3. For the case of Chamwino district, the median crop-livestock diversity is 4 with diversity ranging from 1 to 14. Consistently, the results show that households with high production diversity have higher food consumption diversity based on HDDS and FVS in both districts, though this difference is not significant in a few cases. In Chamwino, the difference is far more significant and thus suggesting a stronger role of farm production diversity.

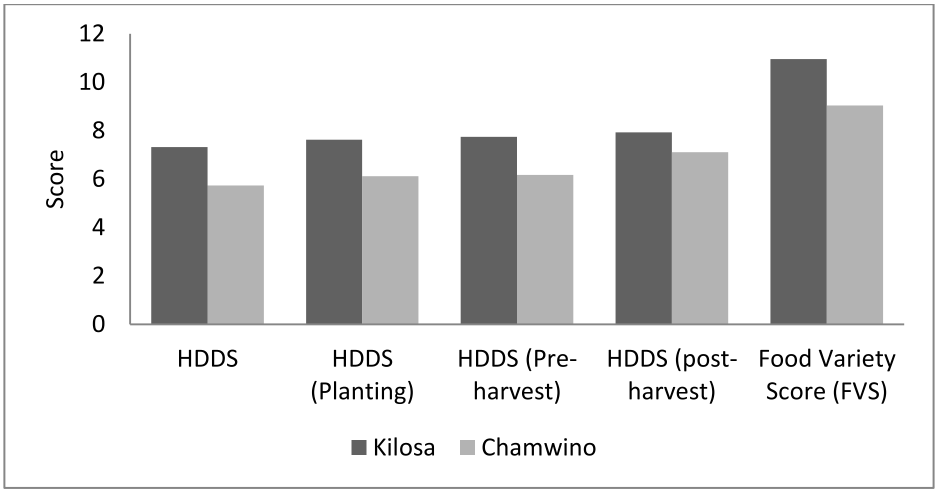

Figure 3: Mean household food consumption diversity in Kilosa and Chamwino districts

Source: Own calculations based on Trans-Sec household survey 2014

Table 4: Comparison of food consumption diversity based on crop-livestock diversity

	Kilosa				Chamwino			
	Low production diversity (n=133)		High production diversity (n=317)		Low production diversity (n=213)		High production diversity (236)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HDDS	7.32	1.94	7.32	1.78	5.15	1.79	6.25***	1.73
HDDS (Planting)	7.41	1.66	7.71***	1.41	5.59	1.97	6.54***	1.79
HDDS (Pre-harvest)	7.53	1.63	7.82***	1.41	5.71	2.01	6.57***	1.66
HDDS (post-harvest)	7.82	1.44	7.95**	1.29	6.77	1.76	7.38***	1.53
Food Variety Score (FVS)	10.81	3.45	11.00	3.36	7.80	3.61	10.14***	3.68

Note: *, ** and ***: Significant difference at 10%, 5% and 1% respectively.
Wilcoxon-Mann-Whitney non parametric two-sample test used to test the differences between low and high production diversity.

Source: Own calculations based on Trans-Sec household survey 2014.

4.4.3 Determinants of Farm Production Diversity

In the analysis of factors determining the observed farm production diversity, we present results based on crop-livestock count and the number of food groups produced – our primary indicators of farm production diversity – as dependent variables. Despite a few differences, the results from the two indicators of diversity provide a similar picture. Here we interpret the regression results based on crop-livestock count for both regions and the pooled sample (Table 5).

Table 5: Regression results of determinants of farm production diversity

Variable	(1) Kilosa		(2) Chamwino		(3) Pooled	
	Crop-livestock Count	Number of food groups produced	Crop-livestock Count	Number of food groups produced	Crop-livestock Count	Number of food groups produced
Age of HH head (years)	0.003*	0.002	0.002*	0.001	0.002***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	0.057	0.087	0.088*	0.037	0.087**	0.066*
	(0.062)	(0.064)	(0.047)	(0.040)	(0.038)	(0.035)
Education of HH head (School years)	0.012*	0.008	0.003	0.005	0.006	0.007
	(0.007)	(0.007)	(0.006)	(0.005)	(0.004)	(0.004)
Risk attitude (scale: 1-10)	0.001	-0.004	0.019***	0.010**	0.015***	0.005
	(0.010)	(0.009)	(0.006)	(0.005)	(0.005)	(0.004)
Land size owned (ha)	0.027	0.011	0.059***	0.038***	0.051***	0.028***
	(0.019)	(0.016)	(0.008)	(0.006)	(0.007)	(0.006)
Labor (Worker equivalents)	0.040***	0.028*	0.038***	0.033***	0.038***	0.030***
	(0.013)	(0.014)	(0.011)	(0.010)	(0.009)	(0.008)
Access to off-farm employment (Yes=1)	-0.085	-0.043	0.045	0.042	0.004	0.005
	(0.056)	(0.059)	(0.037)	(0.031)	(0.030)	(0.028)
Access to non-farm self-employment (Yes=1)	0.105*	0.136**	0.049	0.042	0.068**	0.076***
	(0.058)	(0.056)	(0.037)	(0.031)	(0.032)	(0.028)
Distance to nearest paved road (Km)	0.024*	0.032**	0.000	0.011	0.012	0.025***
	(0.014)	(0.014)	(0.013)	(0.011)	(0.010)	(0.009)
Access to credit (Yes=1)	0.144*	0.132**	0.165***	0.109***	0.150***	0.103***
	(0.074)	(0.061)	(0.045)	(0.041)	(0.037)	(0.033)
Access to market information (Yes=1)	0.005	0.002	0.000	0.002	0.001	0.002
	(0.004)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
Agricultural shocks (Yes=1)	-0.110*	-0.177***	-0.047	-0.027	-0.067**	-0.072**
	(0.058)	(0.068)	(0.037)	(0.032)	(0.031)	(0.029)
Household asset holding (asset 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)
Household resides in Ilolo village			0.075	0.031	0.124**	0.086
			(0.077)	(0.068)	(0.063)	(0.058)
Household resides in Ndebwe village			0.001	-0.009	0.009	0.005
			(0.042)	(0.037)	(0.042)	(0.037)
Household resides in Changarawe village	-0.102*	-0.047			-0.376***	0.036
	(0.055)	(0.050)			(0.114)	(0.105)
Household resides in Ilakala village					-0.291***	0.074
					(0.110)	(0.102)
Household resides in Nyali village	-0.150***	-0.176***			-0.403***	-0.073
	(0.056)	(0.056)			(0.095)	(0.089)
Constant	0.854***	0.817***	1.127***	0.800***	1.041***	0.681***
	(0.142)	(0.134)	(0.166)	(0.156)	(0.130)	(0.128)
Observations	450	450	449	449	899	899
Wald chi2	80.79	49.70	201.86	135.46	690.71	239.01
Probability > chi2	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.023	0.016	0.060	0.024	0.107	0.030

Note: ***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
Values shown in parentheses are standard errors.

Source: Own calculations based on Trans-Sec household survey 2014.

Results show that farm production diversity is positively and significantly influenced by age of household head, availability of labor in the household and access to credit, for both Kilosa and Chamwino districts. For Kilosa, column (1), education of the household head and access to non-farm self-employment are also significantly and positively associated with increased farm production diversity. Interestingly, increased distance to nearest paved road has a significant positive influence on production diversity only for Kilosa with better market access suggesting increased role of self-sufficiency for households far from market opportunities. However, for Kilosa and the pooled sample, agricultural shocks are negatively associated with farm production diversity. The implication may be that resource-constrained households opt for few highly resistant crops and livestock after the experience of agricultural shock. In addition, the onset of an agricultural shock (such as drought, crop pests or unusually heavy rainfall) may have severe and negative impacts which may further reduce their agricultural production including its diversity. For Chamwino, the preparedness of a household to undertake risk, availability of land and other assets are significant in raising farm production diversity. Locational dummies also confirm the pattern observed in descriptive analysis, where residing in villages in Kilosa is negatively related to farm production diversity, unlike in Chamwino.

4.4.4 The Role of Farm Production Diversity on Household Food Consumption Diversity

In the analysis of the role of farm production diversity on food consumption diversity of households, we used several regression models. As pointed out earlier, the aim is to assess this relationship based on the two regions with distinct agro-ecological and market access characteristics. Also, to ascertain whether farm production diversity plays a role in influencing seasonal food consumption diversity. For farm production diversity, we used crop-livestock count and the number of food groups. To get insights on food consumption diversity and its seasonal nature, the dependent variables were HDDS and FVS, and HDDS (planting), HDDS (pre-harvest) and HDDS (post-harvest) respectively. All regression models were estimated with Poisson regression except for FVS in Chamwino and Pooled sample which were estimated with negative binomial regressions.

Table 6 summarizes these results showing only the estimates of farm production diversity indicators for all dependent variables. While results show almost consistent positive effects of farm production diversity on household food consumption diversity for Chamwino district, the same effects are not observed for Kilosa, except for HDDS (planting). The magnitudes of effects are also consistently higher for the former than the later. Implicitly, the results suggest that the role of farm production diversity is more pronounced in Chamwino, which has relatively poor market access and agricultural potential as compared to Kilosa district with better market access. This observation holds also for seasonal food consumption diversity. Looking at the results from the pooled sample, farm production diversity has an overall positive and significant influence on household food consumption diversity.

Table 6: Summary of results for effects of farm production diversity on household food consumption diversity

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Chamwino					
Crop-livestock count	0.032***	0.016***	0.018***	0.011**	0.051***
	(0.006)	(0.006)	(0.006)	(0.005)	(0.009)
Number of food groups produced	0.048***	0.015	0.030**	0.014	0.061***
	(0.013)	(0.014)	(0.014)	(0.012)	(0.016)
Kilosa					
Crop-livestock count	0.001	0.016**	0.008	0.006	0.008
	(0.007)	(0.005)	(0.005)	(0.005)	(0.008)
Number of food groups produced	0.009	0.014	0.006	0.004	0.015
	(0.009)	(0.010)	(0.010)	(0.009)	(0.011)
Pooled sample					
Crop-livestock count	0.022***	0.019***	0.015***	0.010***	0.037***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.006)
Number of food groups produced	0.030***	0.025***	0.023***	0.012*	0.041***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.009)

Note: ***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
Values shown in parentheses are standard errors.
Source: Own calculations based on Trans-Sec household survey 2014.

Going beyond farm production diversity, results also show that household food consumption diversity is also influenced by market access characteristics. These results are summarized in Table 7 and Table 8. The results with all explanatory variables are given in Appendix 1 to 6. For Kilosa district, access to market information and income from non-farm self-employment is significantly associated with increased food consumption diversity. Similarly, per capita food expenditure per month is positively related to food consumption diversity indicating that sourcing of different varieties of food from markets seems to be a relevant factor. Distance to nearest paved road is also negatively related to food consumption diversity suggesting that market access is plays an important role. However, for Chamwino, the role of market access is less pronounced. Despite a significant influence of access to market information on food consumption diversity, distance to nearest paved road and access to income from non-farm self-employment (except for HDDS for post-harvest) are insignificant. However, there is still a significant positive association between per capita food expenditure per month and household food consumption diversity.

Table 7: Role of food consumption expenditure and related market factors on food consumption diversity – Kilosa district

Variable	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Food consumption expenditure quintile					
Per capita per month: Low-middle	0.051	-0.041	-0.025	-0.019	0.092*
	(0.042)	(0.035)	(0.037)	(0.030)	(0.053)
Per capita per month: Middle	0.097**	0.020	0.057*	0.036	0.135***
	(0.039)	(0.030)	(0.030)	(0.026)	(0.051)
Per capita per month: High-middle	0.117***	-0.010	0.028	0.016	0.167***
	(0.038)	(0.030)	(0.029)	(0.025)	(0.049)
Per capita per month: High	0.154***	0.040	0.053**	0.038*	0.192***
	(0.034)	(0.028)	(0.027)	(0.022)	(0.044)
Access to market information (Yes=1)	0.063**	0.039*	0.024	0.038*	0.071**
	(0.027)	(0.023)	(0.023)	(0.021)	(0.033)
Distance to nearest paved road (Km)	-0.033***	-0.015**	-0.009	-0.013**	-0.042***
	(0.007)	(0.006)	(0.006)	(0.005)	(0.009)
Access to non-farm self-emp.(Yes=1)	0.051*	0.027	0.044**	0.039**	0.075**
	(0.026)	(0.021)	(0.019)	(0.017)	(0.034)
Observations	450	450	450	450	450

Note: Crop-livestock count used as indicator for production diversity.
***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
Values shown in parentheses are standard errors.

Source: Own calculations based on Trans-Sec household survey 2014.

Table 8: Role of food consumption expenditure and related market factors on food consumption diversity – Chamwino district

Variable	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Food consumption expenditure quintile					
Per capita per month: Low-middle	0.025	0.051	0.002	0.003	0.021
	(0.040)	(0.049)	(0.043)	(0.033)	(0.054)
Per capita per month: Middle	0.020	0.163***	0.075*	0.033	0.041
	(0.045)	(0.049)	(0.044)	(0.034)	(0.057)
Per capita per month: High-middle	0.124***	0.209***	0.124***	0.075**	0.157***
	(0.044)	(0.046)	(0.044)	(0.033)	(0.055)
Per capita per month: High	0.114**	0.225***	0.147***	0.073**	0.161**
	(0.048)	(0.052)	(0.052)	(0.036)	(0.066)
Access to market information (Yes=1)	0.123***	0.124***	0.147***	0.079***	0.131***
	(0.029)	(0.029)	(0.029)	(0.023)	(0.037)
Distance to nearest paved road (Km)	0.000	-0.005	0.003	-0.005	0.003
	(0.009)	(0.009)	(0.009)	(0.008)	(0.012)
Access to non-farm self-emp. (Yes=1)	0.044	0.039	0.014	0.056***	0.031
	(0.028)	(0.027)	(0.027)	(0.020)	(0.038)
Observations	449	449	449	449	449

Note: Crop-livestock count used as indicator for production diversity
***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
Values shown in parentheses are standard errors.

Source: Own calculations based on Trans-Sec household survey 2014.

4.5 Discussion

4.5.1 The Nature and Drivers of Farm Production Diversity

Typical to smallholder farming systems, our results show that households' farm production is rather diverse constituting of a variety of crops and livestock species. Farm production diversity is substantially higher in Chamwino district which has a semi-arid agro-ecology with less agricultural potential and market access compared to Kilosa district. The agro-ecology of Chamwino district supports a 'pastoralist/agro-pastoralist' farming system (Mnenwa and Maliti, 2010). This partly contributes to the observed higher levels of farm production diversity. In addition, unlike in Kilosa, the semi-arid nature of Chamwino implies that households may experience more frequent periods of food insecurity and other shocks such as drought. In areas with fragile agro-ecologies farm production diversity has been argued as an important strategy. Thus, smallholders may diversify their agricultural production as a risk mitigation strategy from negative effects of weather shocks and other agro-ecological conditions (Di Falco and Chavas, 2009).

Regarding determinants of farm production diversity within the two agro-ecological regions, results suggest that households' socio-economic characteristics and endowments in terms of land and labor play an important role. These results are also in line with the results of Benin et al. (2004) and Di Falco et al. (2010). In addition to age and education, households' preparedness to undertake risk was correlated with increased farm production diversity especially in Chamwino district which has a relatively fragile agro-ecology. Farm production diversity was also significantly associated with access to land and labor, together with other agricultural assets. As observed by Benin et al. (2004), our results also underscore the role of locational factors including agro-ecological conditions and proximity to markets. Households in villages which are least accessible to markets have higher farm production diversity, even within the same agro-ecological region.

4.5.2 The Influence of Farm Production Diversity on Food Consumption Diversity

Agriculture has long been considered influential in improving food consumption especially for smallholder rural households (World Bank, 2008). Results from our analysis reveal that this role is largely dependent on agro-ecological characteristics and market considerations. While farm production diversity plays a significant and positive role for household food consumption diversity in Chamwino district, this role is rather mute in Kilosa district. This is observed for both indicators of food consumption diversity, that is, HDDs and FVS. The significant role of farm production diversity in Chamwino may be partly attributed to the challenging agro-ecological characteristics and low market access. In these contexts, households resort to subsistence production to cater for food consumption needs. KC et al. (2015) also observes the same pattern in a study in Nepal, where the role of crop diversity on food self-sufficiency is stronger in agro-ecological regions which are less accessible and with low market access. Similarly, Di Falco (2010) finds that the benefits of crop biodiversity are more pronounced in ecologically fragile agricultural systems. Kilosa, on the other hand, has relatively better agro-ecology and subsequently a higher agricultural potential. However, the region has far less diversity of production with mainly maize-legume cropping system with little livestock integration.

4.5.3 The Role of Market Access in Food Consumption Diversity

Recent studies have also shown that food consumption diversity for smallholder households may be influenced by factors beyond farm production. In essence, most smallholders are neither strictly subsistence-oriented nor market-oriented (Jones et al., 2014). As noted earlier, our analysis shows that household food consumption expenditure is positively associated with food consumption diversity. This partly suggests that households with higher food consumption expenditure spend on more diverse food items that are available in food markets. In Kilosa district where the contribution of farm production diversity is largely insignificant, access to markets, both for selling of agricultural produce and purchases of food, appears to play a significant role in influencing household food consumption diversity. Descriptive analysis shows that despite low farm production diversity, households in Kilosa have higher food consumption diversity compared to those in Chamwino. This may be associated with better agricultural potential and market access in Kilosa as compared to Chamwino. As noted by Sibhatu et al. (2015), increased market transactions tend to lower the role of farm production diversity on food consumption. They note that better access to markets enable households to not only purchase diverse foods but also use their comparative advantage to produce and sell food and cash crops and hence generate higher agricultural incomes.

4.5.4 Farm Production Diversity and Seasonal Food Consumption

As aforementioned, farm production diversification has received increased attention due to its potential for enhancing seasonal food consumption. As Herforth (2010) argues, for example, different crops may grow at different agricultural seasons and consequently increased farm production diversity may be beneficial in cases of seasonal food insecurity. Results from our regression models show that both farm production diversity indicators are positively associated with increased food consumption diversity in the planting, pre-harvest and post-harvest seasons. Specifically, results show that in Chamwino, where the role of markets is low and production is oriented towards food crops and livestock, farm production diversity has a significant positive role in seasonal food consumption diversity. However, with an exception for the planting season, this relationship is not significant for Kilosa which has lower farm production diversity. Nevertheless, the results from Chamwino and the pooled sample offer insights on the potential positive role of farm production diversity can play in enhancing food consumption diversity.

4.5.5 Limitations

A number of potential limitations can be highlighted. First, the link between farm production diversity and household food consumption diversity is a complex one. As Jones et al. (2014) observes, this relationship is influenced by many factors. While we attempted to include the major relevant aspects in line with the literature and the focus of the present article, these factors may not be entirely exhaustive. For example, cultural values may influence consumption of particular food items but this may be difficult to capture in the analysis. Second, HDDS is an indicator that is based on household recall of food consumption in the previous 24 hours or 7 days. Given the cost and time limitations for collecting data on seasonal food consumption in each agricultural season, we rely on recall also for seasonal food consumption diversity. Therefore, our modified HDDS for planting, pre-harvest and post-harvest relies on relatively long recall periods. Apart from this, however, the indicator provides a similar pattern of food security in our sample as other indicators used such as the normal HDDS and FVS. Despite these potential limitations, the analysis provides unique empirical insights on the smallholder households' production-consumption link using two distinct agro-ecological and market access contexts.

4.6 Summary and Conclusion

This article assessed how farm production diversity influences household food consumption diversity in two districts (Kilosa and Chamwino) with distinct agro-ecological and market access contexts in rural Tanzania. Specifically, (1) it examined the nature and extent of farm production diversity, and its determinants and (2) analyzed the role of farm production diversity on household food consumption diversity.

Findings reveal that smallholder households maintain a considerable diversity in their production, both for crops and livestock. However, significant differences exist between the two agro-ecological regions with regards to farm production diversity and food consumption diversity. While low farm production diversity is observed in Kilosa district, households in Chamwino districts have significantly higher farm production diversity in terms of crops and livestock. Regarding the role of farm production diversity in household food consumption diversity, our results underscore findings from earlier studies that this relationship is largely dependent on agro-ecological characteristics and market contexts, among other factors.

Results show that, while farm production diversity is significantly associated with increased food consumption diversity in Chamwino, the same relationship is not observed in Kilosa. This influence is also observed for seasonal food consumption diversity, particularly in Chamwino which suggests additional benefits for smallholder farm production diversification. These observations suggest a stronger role of farm production diversity on food consumption diversity in areas with challenging agro-ecological characteristics and low market accessibility such as Chamwino, and a lesser role in presence of better agro-ecological and market access characteristics such as in Kilosa.

These findings imply that, strategies geared at promoting farm production diversity should consider the existing agro-ecological and market characteristics. In challenging agro-ecologic settings and less accessible rural communities, farm production diversity can be more beneficial in enhancing food security and, most importantly, seasonal food consumption diversity. However, agricultural diversification strategies should go hand in hand with strengthening of other core aspects along agricultural value chains such as input systems, processing, storage and marketing. In addition, to achieve increased food consumption diversity in farm households, the focus of policy should not only be on smallholder farm production diversity but also aim at improvements in infrastructure and market related institutions.

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Appendices

Appendix 1: Determinants of food consumption diversity in Chamwino (Production diversity indicator used: crop-livestock count)

Variable	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Crop-livestock count	0.032***	0.016***	0.018***	0.011**	0.051***
	(0.006)	(0.006)	(0.006)	(0.005)	(0.009)
Age of HH head (years)	-0.004***	-0.003***	-0.003***	-0.002***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	-0.022	0.044	-0.039	-0.027	-0.030
	(0.035)	(0.036)	(0.033)	(0.027)	(0.045)
Education of HH head (School years)	0.003	-0.005	0.001	0.001	0.004
	(0.004)	(0.004)	(0.004)	(0.003)	(0.006)
Land size owned (ha.)	0.001	0.008	0.005	-0.001	-0.003
	(0.008)	(0.006)	(0.006)	(0.005)	(0.010)
Livestock owned (TLU)	0.005	0.011***	0.007*	0.007**	0.003
	(0.004)	(0.004)	(0.004)	(0.003)	(0.007)
Labor (Worker equivalents)	-0.001	0.000	-0.001	0.008	0.009
	(0.009)	(0.009)	(0.010)	(0.007)	(0.013)
Per capita per month: Low-middle	0.025	0.051	0.002	0.003	0.021
	(0.040)	(0.049)	(0.043)	(0.033)	(0.054)
Per capita per month: Middle	0.020	0.163***	0.075*	0.033	0.041
	(0.045)	(0.049)	(0.044)	(0.034)	(0.057)
Per capita per month: High-middle	0.124***	0.209***	0.124***	0.075**	0.157***
	(0.044)	(0.046)	(0.044)	(0.033)	(0.055)
Per capita per month: High	0.114**	0.225***	0.147***	0.073**	0.161**
	(0.048)	(0.052)	(0.052)	(0.036)	(0.066)
Share of home consumption	-0.006	-0.007	0.008	-0.001	-0.002
	(0.033)	(0.034)	(0.033)	(0.026)	(0.043)
Access to market information (Yes=1)	0.123***	0.124***	0.147***	0.079***	0.131***
	(0.029)	(0.029)	(0.029)	(0.023)	(0.037)
Distance to nearest paved road	0.000	-0.005	0.003	-0.005	0.003
	(0.009)	(0.009)	(0.009)	(0.008)	(0.012)
Access to off-farm employment (Yes=1)	-0.012	0.044	-0.005	-0.006	0.005
	(0.029)	(0.029)	(0.028)	(0.022)	(0.038)
Access to non-farm self-employment (Yes=1)	0.044	0.039	0.014	0.056***	0.031
	(0.028)	(0.027)	(0.027)	(0.020)	(0.038)
Household asset holding (asset score)	0.000***	0.000**	0.000**	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilolo village	0.048	-0.001	0.059	-0.024	0.065
	(0.054)	(0.055)	(0.054)	(0.047)	(0.078)
Household resides in Ndebwe village	0.035	0.026	0.082**	0.023	0.045
	(0.035)	(0.036)	(0.034)	(0.028)	(0.045)
Constant	1.556***	1.597***	1.605***	1.934***	1.908***
	(0.132)	(0.132)	(0.126)	(0.104)	(0.175)
ln(alpha)					-3.673***
					(0.369)
Observations	449	449	449	449	449
Wald chi2	166.31	130.43	117.44	72.48	127.74
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.034	0.032	0.027	0.013	0.052

Source: Own calculations based on Trans-Sec household survey 2014.

Appendix 2: Determinants of food consumption diversity in Chamwino (Production diversity indicator used: Number of food groups produced)

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Number of food groups produced	0.048***	0.015	0.030**	0.014	0.061***
	(0.013)	(0.014)	(0.014)	(0.012)	(0.016)
Age of HH head (years)	-0.004***	-0.003***	-0.002*	-0.002**	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	0.001	0.068	-0.025	-0.025	-0.026
	(0.036)	(0.043)	(0.041)	(0.034)	(0.046)
Education of HH head (School years)	0.001	-0.006	0.001	0.003	0.003
	(0.004)	(0.005)	(0.005)	(0.004)	(0.006)
Land size owned (ha.)	0.007	0.016*	0.011	0.001	0.010
	(0.007)	(0.008)	(0.008)	(0.007)	(0.010)
Livestock owned (TLU)	0.007	0.021***	0.015***	0.013***	0.007
	(0.006)	(0.005)	(0.005)	(0.004)	(0.007)
Labor (Worker equivalents)	-0.004	-0.005	-0.012	0.010	0.013
	(0.009)	(0.011)	(0.012)	(0.009)	(0.013)
Per capita per month: Low-middle	-0.004	0.027	-0.024	0.012	0.034
	(0.041)	(0.054)	(0.052)	(0.040)	(0.055)
Per capita per month: Middle	0.042	0.171***	0.081	0.054	0.060
	(0.045)	(0.055)	(0.052)	(0.042)	(0.058)
Per capita per month: High-middle	0.124***	0.211***	0.143***	0.112***	0.167***
	(0.045)	(0.054)	(0.054)	(0.042)	(0.056)
Per capita per month: High	0.116**	0.239***	0.166***	0.100**	0.197***
	(0.050)	(0.060)	(0.064)	(0.047)	(0.068)
Share of home consumption	-0.001	-0.050	-0.003	-0.029	-0.023
	(0.033)	(0.040)	(0.040)	(0.032)	(0.044)
Access to market information (Yes=1)	0.125***	0.169***	0.177***	0.093***	0.141***
	(0.030)	(0.035)	(0.035)	(0.028)	(0.038)
Distance to nearest paved road	-0.006	-0.012	-0.004	-0.013	-0.000
	(0.009)	(0.010)	(0.011)	(0.010)	(0.013)
Access to off-farm employment (Yes=1)	-0.000	0.067*	0.009	-0.012	0.014
	(0.030)	(0.035)	(0.035)	(0.028)	(0.039)
Access to non-farm self-employment (Yes=1)	0.038	0.028	-0.003	0.073***	0.034
	(0.030)	(0.033)	(0.034)	(0.027)	(0.039)
Household asset holding (asset score)	0.000***	0.000***	0.000***	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilolo village	0.048	-0.073	0.014	-0.086	0.081
	(0.055)	(0.066)	(0.069)	(0.057)	(0.079)
Household resides in Ndebwe village	0.055	-0.016	0.061	0.007	0.046
	(0.035)	(0.042)	(0.042)	(0.035)	(0.046)
Constant	1.286***	1.489***	1.407***	1.785***	1.933***
	(0.136)	(0.160)	(0.163)	(0.129)	(0.181)
ln(alpha)					-3.447***
					(0.308)
Observations	449	449	449	449	449
Wald chi2	139.84	162.66	135.11	86.41	107.96
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.027	0.038	0.031	0.017	0.044

Source: Own calculations based on Trans-Sec household survey 2014.

Appendix 3: Determinants of food consumption diversity in Kilosa (Production diversity indicator used: crop-livestock count)

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Crop-livestock count	0.001	0.016**	0.008	0.006	0.008
	(0.007)	(0.005)	(0.005)	(0.005)	(0.008)
Age of HH head (years)	-0.002**	-0.001	-0.000	-0.000	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	0.008	0.007	-0.001	-0.023	0.015
	(0.032)	(0.029)	(0.028)	(0.024)	(0.039)
Education of HH head (School years)	0.003	0.002	0.004	0.004	0.001
	(0.004)	(0.003)	(0.003)	(0.003)	(0.005)
Land size owned (ha.)	0.008	0.014***	0.010**	0.012***	0.007
	(0.007)	(0.005)	(0.005)	(0.004)	(0.008)
Livestock owned (TLU)	-0.002	0.000	0.000	0.000	-0.004**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)
Labor (Worker equivalents)	0.007	-0.001	0.005	0.006	0.012
	(0.009)	(0.008)	(0.006)	(0.005)	(0.011)
Per capita per month: Low-middle	0.051	-0.041	-0.025	-0.019	0.092*
	(0.042)	(0.035)	(0.037)	(0.030)	(0.053)
Per capita per month: Middle	0.097**	0.020	0.057*	0.036	0.135***
	(0.039)	(0.030)	(0.030)	(0.026)	(0.051)
Per capita per month: High-middle	0.117***	-0.010	0.028	0.016	0.167***
	(0.038)	(0.030)	(0.029)	(0.025)	(0.049)
Per capita per month: High	0.154***	0.040	0.053**	0.038*	0.192***
	(0.034)	(0.028)	(0.027)	(0.022)	(0.044)
Share of home consumption	-0.036	-0.036	-0.028	-0.034	-0.048
	(0.031)	(0.026)	(0.027)	(0.023)	(0.039)
Access to market information (Yes=1)	0.063**	0.039*	0.024	0.038*	0.071**
	(0.027)	(0.023)	(0.023)	(0.021)	(0.033)
Distance to nearest paved road	-0.033***	-0.015**	-0.009	-0.013**	-0.042***
	(0.007)	(0.006)	(0.006)	(0.005)	(0.009)
Access to off-farm employment (Yes=1)	-0.065**	-0.051**	-0.029	0.017	-0.102***
	(0.029)	(0.024)	(0.024)	(0.018)	(0.036)
Access to non-farm self-employment (Yes=1)	0.051*	0.027	0.044**	0.039**	0.075**
	(0.026)	(0.021)	(0.019)	(0.017)	(0.034)
Household asset holding (asset score)	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilakala village	-0.013	0.004	0.010	-0.012	-0.018
	(0.028)	(0.024)	(0.024)	(0.022)	(0.033)
Household resides in Nyali village	0.007	0.064***	0.049**	0.040*	0.036
	(0.030)	(0.025)	(0.025)	(0.023)	(0.037)
Constant	1.970***	1.983***	1.951***	2.010***	2.335***
	(0.077)	(0.072)	(0.069)	(0.063)	(0.099)
Observations	450	450	450	450	450
Wald chi2	119.35	56.28	45.14	48.03	119.33
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.021	0.009	0.006	0.005	0.039

Source: Own calculations based on Trans-Sec household survey 2014.

Appendix 4: Determinants of food consumption diversity in Kilosa (Production diversity indicator used: Number of food groups produced)

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Number of food groups produced	0.009	0.014	0.006	0.004	0.015
	(0.009)	(0.010)	(0.010)	(0.009)	(0.011)
Age of HH head (years)	-0.002**	-0.001	-0.001	-0.000	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	0.012	0.021	0.003	-0.028	0.013
	(0.035)	(0.036)	(0.035)	(0.031)	(0.040)
Education of HH head (School years)	0.003	0.003	0.006	0.005	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Land size owned (ha.)	0.009	0.018**	0.013*	0.016***	0.008
	(0.008)	(0.007)	(0.007)	(0.006)	(0.010)
Livestock owned (TLU)	-0.002*	0.002**	0.001*	0.001**	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)
Labor (Worker equivalents)	0.000	-0.007	0.001	0.001	0.012
	(0.010)	(0.011)	(0.009)	(0.008)	(0.011)
Per capita per month: Low-middle	0.084*	-0.035	-0.003	-0.003	0.091*
	(0.046)	(0.045)	(0.046)	(0.040)	(0.053)
Per capita per month: Middle	0.120***	0.037	0.088**	0.056	0.135***
	(0.044)	(0.041)	(0.041)	(0.036)	(0.050)
Per capita per month: High-middle	0.147***	-0.024	0.030	0.015	0.167***
	(0.045)	(0.043)	(0.040)	(0.037)	(0.050)
Per capita per month: High	0.172***	0.049	0.064*	0.040	0.192***
	(0.040)	(0.040)	(0.038)	(0.034)	(0.048)
Share of home consumption	-0.025	-0.071**	-0.053	-0.065**	-0.053
	(0.034)	(0.036)	(0.035)	(0.031)	(0.039)
Access to market information (Yes=1)	0.047	0.048	0.034	0.050*	0.074**
	(0.030)	(0.031)	(0.030)	(0.028)	(0.034)
Distance to nearest paved road	-0.029***	-0.021**	-0.014*	-0.020***	-0.043***
	(0.009)	(0.008)	(0.008)	(0.007)	(0.010)
Access to off-farm employment (Yes=1)	-0.082**	-0.082**	-0.038	0.014	-0.102***
	(0.034)	(0.032)	(0.032)	(0.026)	(0.039)
Access to non-farm self-employment (Yes=1)	0.041	0.038	0.061**	0.067***	0.072*
	(0.029)	(0.030)	(0.029)	(0.026)	(0.040)
Household asset holding (asset score)	0.000	0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilakala village	-0.035	-0.007	0.004	-0.026	-0.018
	(0.031)	(0.033)	(0.032)	(0.029)	(0.037)
Household resides in Nyali village	-0.041	0.079**	0.063*	0.047	0.040
	(0.034)	(0.034)	(0.035)	(0.032)	(0.041)
Constant	1.638***	1.793***	1.757***	1.826***	2.321***
	(0.084)	(0.093)	(0.090)	(0.082)	(0.096)
Observations	450	450	450	450	450
Wald chi2	104.02	59.67	48.72	56.58	93.54
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.019	0.013	0.009	0.009	0.040

Source: Own calculations based on Trans-Sec household survey 2014.

Appendix 5: Determinants of food consumption diversity, Pooled sample (Production diversity indicator used: crop-livestock count)

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Crop-livestock count	0.022***	0.019***	0.015***	0.010***	0.037***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.006)
Age of HH head (years)	-0.002***	-0.002***	-0.001**	-0.001***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Gender of HH head (Male=1)	-0.003	0.033	-0.012	-0.024	-0.001
	(0.024)	(0.023)	(0.022)	(0.018)	(0.029)
Education of HH head (School years)	0.004	-0.001	0.003	0.002	0.004
	(0.003)	(0.003)	(0.003)	(0.002)	(0.004)
Land size owned (ha.)	0.006	0.010**	0.006	0.006	0.004
	(0.005)	(0.004)	(0.004)	(0.003)	(0.007)
Livestock owned (TLU)	-0.001	0.001	0.001	0.001	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)
Labor (Worker equivalents)	0.002	-0.001	0.001	0.008*	0.009
	(0.006)	(0.006)	(0.006)	(0.004)	(0.008)
Per capita per month: Low-middle	0.044	0.010	-0.008	-0.005	0.062*
	(0.029)	(0.030)	(0.029)	(0.022)	(0.037)
Per capita per month: Middle	0.063**	0.094***	0.072***	0.038*	0.088**
	(0.029)	(0.028)	(0.026)	(0.021)	(0.036)
Per capita per month: High-middle	0.118***	0.098***	0.075***	0.046**	0.158***
	(0.029)	(0.028)	(0.026)	(0.021)	(0.036)
Per capita per month: High	0.142***	0.126***	0.095***	0.054***	0.179***
	(0.028)	(0.027)	(0.026)	(0.020)	(0.037)
Share of home consumption	-0.031	-0.018	-0.016	-0.015	-0.030
	(0.022)	(0.021)	(0.020)	(0.017)	(0.028)
Access to market information (Yes=1)	0.101***	0.084***	0.095***	0.062***	0.108***
	(0.020)	(0.019)	(0.018)	(0.015)	(0.024)
Distance to nearest paved road	-0.027***	-0.021***	-0.021***	-0.012***	-0.027***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.004)
Access to off-farm employment (Yes=1)	-0.036*	-0.006	-0.024	-0.000	-0.039
	(0.020)	(0.019)	(0.019)	(0.015)	(0.026)
Access to non-farm self-employment (Yes=1)	0.046**	0.033*	0.022	0.047***	0.049*
	(0.020)	(0.018)	(0.018)	(0.014)	(0.026)
Household asset holding (asset score)	0.000	0.000	0.000*	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilakala village	-0.018	0.026	0.032	-0.006	-0.037
	(0.026)	(0.023)	(0.023)	(0.020)	(0.036)
Household resides in Nyali village	0.010	0.102***	0.097***	0.044**	0.023
	(0.026)	(0.022)	(0.022)	(0.018)	(0.035)
Household resides in Ilolo village	-0.100***	-0.090***	-0.079***	-0.054**	-0.089**
	(0.028)	(0.028)	(0.029)	(0.022)	(0.036)
Household resides in Ndebwe village	0.021	0.012	0.052*	0.019	0.043
	(0.034)	(0.034)	(0.032)	(0.027)	(0.039)
Constant	1.903***	1.864***	1.903***	2.004***	2.256***
	(0.060)	(0.057)	(0.055)	(0.046)	(0.072)
ln(alpha)					-4.945***
					(0.726)
Observations	899	899	899	899	899
Wald chi2	456.17	338.94	321.60	153.50	250.30
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.044	0.035	0.032	0.013	0.051

Appendix 6: Determinants of food consumption diversity, Pooled sample (Production diversity indicator used: Number of food groups produced)

	HDDS	HDDS (Planting)	HDDS (Pre-harvest)	HDDS (Post-harvest)	FVS
Number of food groups produced	0.030***	0.025***	0.023***	0.012*	0.041***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.009)
Age of HH head (years)	-0.002***	-0.002**	-0.001*	-0.001*	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender of HH head (Male=1)	0.011	0.053*	-0.002	-0.027	-0.002
	(0.026)	(0.029)	(0.027)	(0.023)	(0.030)
Education of HH head (School years)	0.003	-0.001	0.005	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Land size owned (ha.)	0.010*	0.018***	0.012**	0.009*	0.012*
	(0.005)	(0.006)	(0.005)	(0.005)	(0.007)
Livestock owned (TLU)	-0.001	0.003*	0.003*	0.003*	-0.002
	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
Labor (Worker equivalents)	-0.002	-0.007	-0.005	0.007	0.011
	(0.007)	(0.008)	(0.007)	(0.006)	(0.008)
Per capita per month: Low-middle	0.044	-0.001	-0.014	0.004	0.068*
	(0.030)	(0.036)	(0.035)	(0.028)	(0.037)
Per capita per month: Middle	0.086***	0.105***	0.092***	0.058**	0.099***
	(0.031)	(0.034)	(0.033)	(0.027)	(0.037)
Per capita per month: High-middle	0.135***	0.090**	0.084**	0.063**	0.166***
	(0.032)	(0.035)	(0.034)	(0.028)	(0.036)
Per capita per month: High	0.151***	0.134***	0.105***	0.066**	0.192***
	(0.031)	(0.035)	(0.034)	(0.027)	(0.038)
Share of home consumption	-0.024	-0.054**	-0.035	-0.042*	-0.043
	(0.023)	(0.026)	(0.026)	(0.022)	(0.028)
Access to market information (Yes=1)	0.094***	0.108***	0.116***	0.074***	0.114***
	(0.021)	(0.024)	(0.023)	(0.020)	(0.024)
Distance to nearest paved road	-0.027***	-0.020***	-0.022***	-0.013***	-0.023***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Access to off-farm employment (Yes=1)	-0.041*	-0.016	-0.027	-0.009	-0.038
	(0.022)	(0.024)	(0.024)	(0.020)	(0.026)
Access to non-farm self-employment (Yes=1)	0.036*	0.032	0.020	0.069***	0.050*
	(0.022)	(0.024)	(0.023)	(0.019)	(0.027)
Household asset holding (asset score)	0.000**	0.000**	0.000**	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Household resides in Ilakala village	-0.040	-0.004	0.013	-0.030	-0.042
	(0.029)	(0.031)	(0.031)	(0.027)	(0.036)
Household resides in Nyali village	-0.027	0.097***	0.101***	0.035	0.020
	(0.029)	(0.029)	(0.028)	(0.025)	(0.035)
Household resides in Ilolo village	-0.074**	-0.102***	-0.088***	-0.067**	-0.041
	(0.030)	(0.033)	(0.033)	(0.028)	(0.035)
Household resides in Ndebwe village	0.043	-0.015	0.035	0.012	0.052
	(0.034)	(0.040)	(0.039)	(0.033)	(0.039)
Constant	1.570***	1.642***	1.665***	1.789***	2.225***
	(0.065)	(0.073)	(0.071)	(0.060)	(0.074)
ln(alpha)					-4.697***
					(0.579)
Observations	899	899	899	899	899
Wald chi2	411.99	337.48	311.61	151.31	231.70
Probability > chi2	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.035	0.039	0.037	0.016	0.047

Chapter 5:

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

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=1212) 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. For both countries, results further show that, farm production diversity has a positive and significant influence on indicators of household dietary diversity. This is especially of importance to households in remote rural settings. In peri-urban and rural areas with better market access, production diversity is generally lower and dietary diversity higher. Findings imply that production diversity remains an important factor in ensuring enhanced household dietary diversity. This calls for strengthening of context specific production and market-related aspects of smallholder agriculture.

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

5.1 Introduction

Enhancing smallholder farm production diversity has recently gained increased attention owing to its potential to enhance rural households' food and nutrition security (Fanzo et al., 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; Burlingame and Dernini, 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 (e.g. Jones et al., 2014; Herforth, 2010). Despite important insights generated, these studies are limited in terms of representing diverse market and agro-ecologic contexts. Other existing comparative studies mainly refer to country averages (e.g. 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 (see for example 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 three elaborates on the conceptual framework and methodology used in this study. Results and discussion are presented in section four. Section five summarizes the main results and gives concluding remarks.

5.2 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 (See Figure 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.

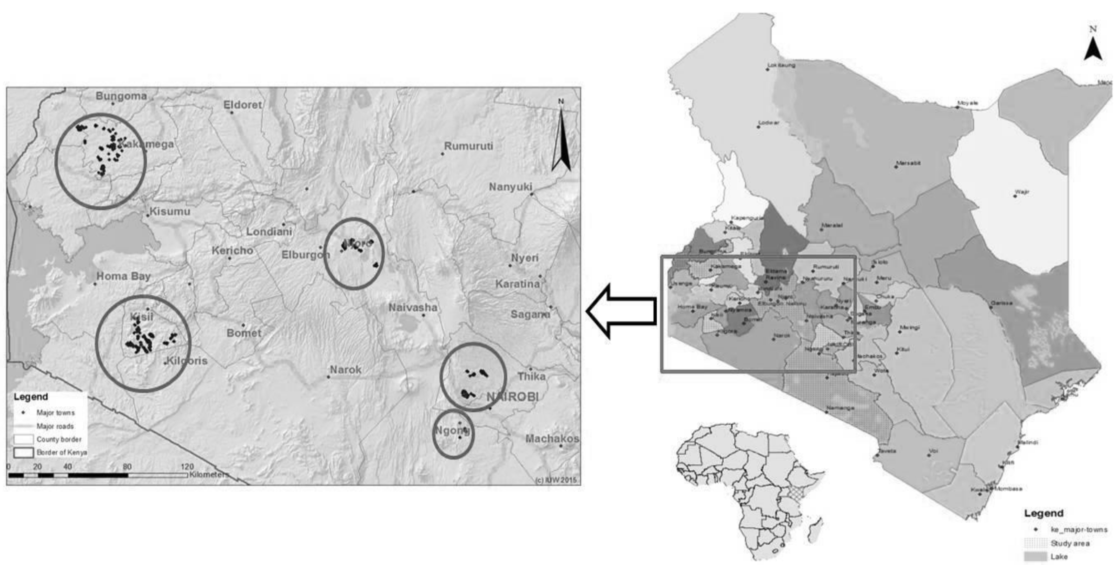


Figure 1: Map of study area-Kenya

Source: HORTINLEA survey, 2014.

In Tanzania, data was collected from smallholders in two districts, Kilosa and Chamwino (See Figure 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.

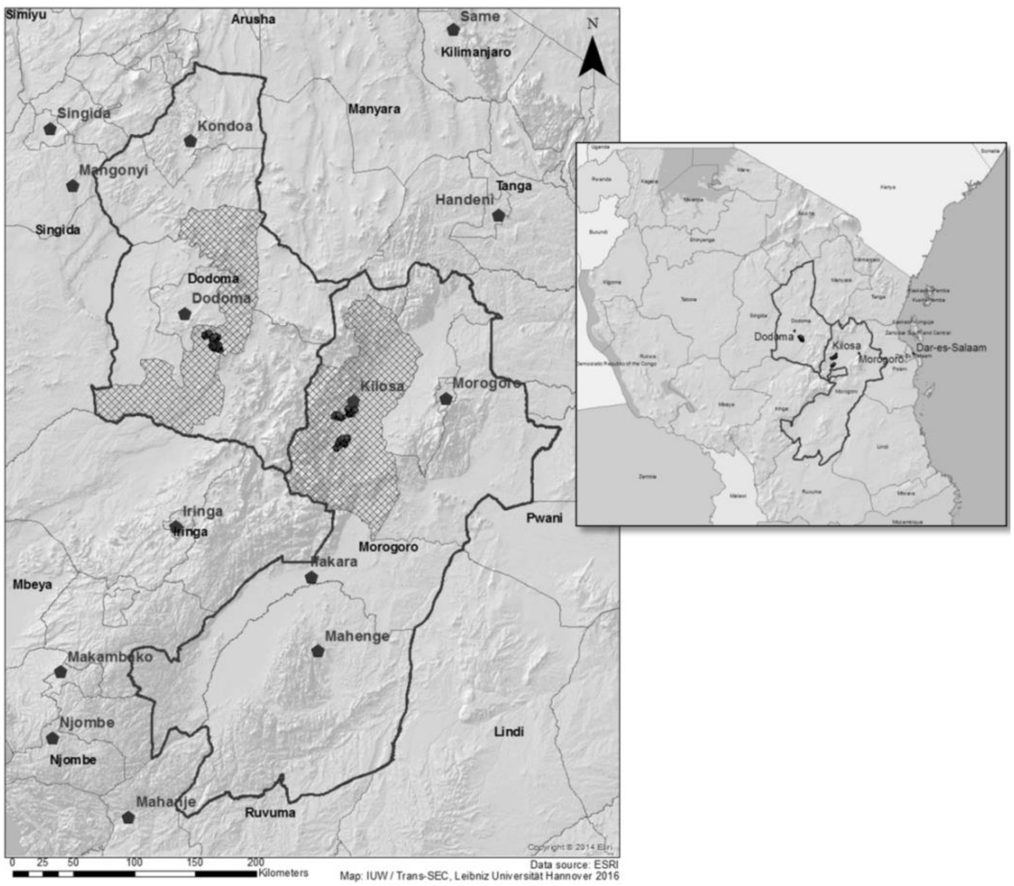


Figure 2: Map of study area -Tanzania

Source: Trans-Sec survey, 2014.

A summary of key characteristics of the study areas is provided in Table 1 while maps of the study sites for Kenya and Tanzania are presented in Figure 1 and 2, respectively. In both Kenya and Tanzania, structured household and village questionnaires were used as key survey instruments. The household-level questionnaires contained 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.

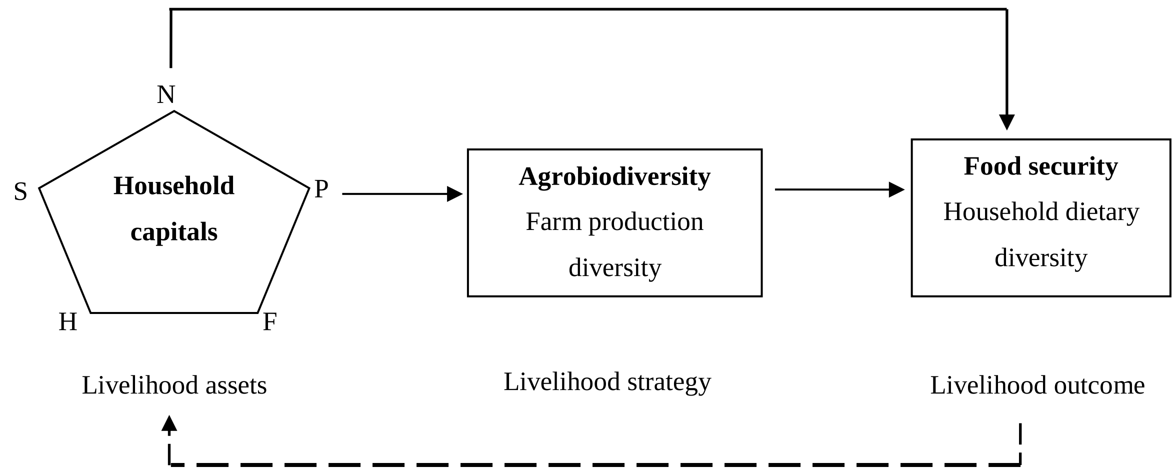
Table 1: Summary of main characteristics of study area

	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

5.3 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 (SLA), 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 3.



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

Figure 3: Conceptual framework (Authors' construction based on Scoones 1998)

5.3.1 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; Hawksworth, 1995). 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[6]. 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;

[6] 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).

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. 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 (Hartley 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 food items consumed.

5.3.2 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.

5.3.3 Evaluating the Relationship between Farm Production Diversity and Dietary Diversity

Household dietary diversity is assumed to be influenced by farm production 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 equations (1) and (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.

5.4 Results and Discussion

5.4.1 Household and Farm Characteristics in Kenya and Tanzania

Descriptive statistics in Table 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 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

Note: Values shown in parentheses are standard deviations.
Source: Own calculations based on Trans-Sec Survey, 2014 and Hortinlea Survey, 2014.

5.4.2 Comparison of Farm Production Diversity and Dietary diversity

In terms of diversity, results from Table 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 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

Note: *** indicate a significance level of 1%
Values shown in parentheses are standard deviations.
Source: Own calculations based on Trans-Sec Survey, 2014 and Hortinlea Survey, 2014.

5.4.3 Determinants of Farm Production Diversity

Table 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 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

Note: ***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively. Values shown in parentheses are standard errors.
Source: Own calculations based on Trans-Sec Survey, 2014 and Hortinlea Survey, 2014.

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 affecting farm production diversity.

5.4.4 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 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 reinforces the argument 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 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

Note: 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.

Source: Own calculations based on Trans-Sec Survey, 2014 and Hortinlea Survey, 2014.

5.4.5 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.

5.4.6 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. 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: 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	-0.000	0.000	0.000	0.001***	0.001***	0.001***
(PPP$)	(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

Note: ***, ** and * indicate a significance level of 1%, 5%, and 10%, respectively.
Values shown in parentheses are standard errors.

Source: Own calculations based on Trans-Sec Survey, 2014 and Hortinlea Survey, 2014.

5.5 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 that 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 capitals are found to be important factors influencing the level of farm production diversity.

Concerning 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, as 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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