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**UNDERSTANDING THE LINK BETWEEN SMALLHOLDER FARM
PRODUCTION DIVERSITY AND MARKET PARTICIPATION IN SHAPING
HOUSEHOLD DIETARY DIVERSITY IN RURAL TIGRAY, NORTHERN
ETHIOPIA**

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for the degree of

Doctor of Philosophy

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Chisholm

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Authority, Ireland, as part of the Walsh Scholarship Program under grant number
2018013.*

March 2025

DECLARATION

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property.

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PUBLICATION AND CONFERENCES

Balcha, T., Lahiff, E., Donnellan, T., & Chisholm, N. (2024). The Joint Influence of Farm Production Diversity and Food Market Visits on Smallholder Household Diets in Northern Ethiopia. *Discover Food, Springer [Manuscript]*

Balcha, T., Lahiff, E., Donnellan, T., & Chisholm, N. (2024). Food on the Plate: The Share of Food Sources on Smallholder Household Diets in Tigray, Northern Ethiopia. *Journal of Social & Economic Development, Springer [Manuscript]*

Balcha, T., Lahiff, E., & Donnellan, T. (2024). The Link Between Smallholder Commercialization and Farm Production Diversity: Evidence from Northern Ethiopia. *Development Studies Research Journal, Tylor and Francis [Manuscript]*.

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Balcha, T., Lahiff, E., Donnellan, T., & Chisholm, N. (2024). The Joint Influence of Farm Production Diversity and Food Market Visits on Smallholder Household Diets in Northern Ethiopia. *The 10th annual Agriculture, Nutrition and Health (ANH) Academy Week 2025 Research Conference, Dar es Salaam, Tanzania. Monday 23 – Thursday 26 June 2025. [Poster accepted]*.

Balcha, T., Lahiff, E., Donnellan, T., & Chisholm, N. (2024). The Joint Influence of Farm Production Diversity and Food Market Visits on Smallholder Household Diets in Northern Ethiopia. *51st Annual Food Science and Technology Conference. Teagasc Food Research Centre. Ashtown, Dublin. December 6th-7th 2023. [Oral, presented]*

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Balcha, T., Lahiff, E., & Donnellan, T. (2024). The Link Between Smallholder Commercialization and Farm Production Diversity: Evidence from Northern Ethiopia. Development Studies Ireland Association (DSAI) Annual Conference 2024. Achieving Just Food Systems in an Era of Global 'Polycrisis'. Nana Nagle Place, Cork City. Thursday, 31st October 2024. [*Oral, presented*]

ABSTRACT

Smallholders have long been the focus of development research for many reasons. They constitute a substantial segment of the population in developing countries, mainly cultivating less than two hectares of land, producing and supplying most of the food to local markets, and consuming a significant portion of their food production. Despite this, food insecurity, malnutrition, and hunger disproportionately affect them. The factors contributing to this include low levels of production, weak market linkages, and limited access to diverse foods.

Increasing farm production diversity and market access have been proposed as crucial strategies to enhance smallholder dietary diversity. In addition, commercialization is recognized as a key strategy to increase smallholder productivity and income, which can also increase availability and accessibility of dietary diversity. Debates persist, however, regarding the effectiveness of the proposed strategies due to the context-specific nature of farm production diversity, market access, and dietary diversity, around the relative importance of farm production diversity versus market access in influencing smallholder dietary diversity, and whether low or high farm production diversity increases smallholder commercialization.

This research aims to contribute to these debates using data from a survey conducted in rural Tigray in northern Ethiopia. Primary data was collected from a cross-sectional household survey of 396 smallholder farmers in Tigray in September–October 2020. Smallholders in Tigray, like others in sub-Saharan Africa, are primarily dependent on agriculture for their livelihood, and they are among the highly deprived populations by all standards of malnutrition. Mixed methods approach used, and data were collected using multistage stratified simple random and purposive sampling methods. The quantitative research used descriptive statistics, Ordinary Least Squares, Poisson, and Structural Equation Modelling econometric methods of analysis, while the qualitative research relied on thematic analysis methods to arrive at the findings.

The findings indicate that both market access and farm production diversity are major influences of smallholder household dietary diversity. Market access and farm production diversity have a complementary non-linear effect on household dietary diversity. The nonlinear effect signals that each unit increases in market access or farm production diversity, or both may not bring an equal increase in household dietary diversity.

Using simultaneous equation analysis, a bidirectional link between commercialization and smallholder farm production diversity is revealed. Farm production diversity influences commercialization, and likewise, commercialization also influences farm production diversity. Social protection programs such as food transfer and PSNP foods contribute notably to dietary diversity, particularly for the poorest households. This highlights the necessity for targeted, sustainable social protection through the establishment and strengthening of public, private, or community-based support systems for the poor, disabled, and marginalized households.

Overall, improving market access through investments in transportation and irrigation smallholder commercialization and household dietary diversity. Promotion of high value short-gestation marketable crops and livestock varieties make a substantial contribution in improving smallholder household dietary diversity, farm productivity, and income in Tigray and similar contexts.

DEDICATION

I dedicate this dissertation to my mom, Fotyen Tella Gebrerufael, and The People of Tigray.

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ABBREVIATIONS

AM	Absence from markets
BoARD	Bureau of Agriculture and Rural Development
CD	Crop Diversity
CFI	Comparative Fit Index
CI	Commercialization Index
CS	Crop Species
EDHS	Ethiopian Demographic Health Survey
EMDHS	Ethiopian Mini-Demographic Health Survey
FAO	Food and Agricultural Organization
FGD	Focus Group Discussions
FMV	Frequency of Market Visits
FPD	Farm Production Diversity
GDP	Gross Domestic Product
HDDS	Household Dietary Diversity Score
ICRAF	International Center for Research on Agroforestry
IFAD	International Fund for Agricultural Development
IMR	Inverse Mills Ratio
KII	Key Informants Interview
LD	Livestock Diversity
LOWESS	Locally Weighted Scatterplot Smoothing
LS	Livestock Species
MLMV	Maximum Likelihood with Missing Values
NGO	Non-Governmental Organizations
OF	Own farm Food
OIM	Observed Information Matrix
OLS	Ordinary Least Squares
PDS	Production Diversity Score

PF	Purchased Food
PH	Potenza Hydrogen
PM	Proximity to Market
PSNP	Productive Safety Net Programme
RMSEA	Root Mean Square Error of Approximation
SDG	Sustainable Development Goals
SE	Socio-economic factors
SEM	Structural Equation Modelling
SSA	Sub-Saharan Africa
SWOT	Strength, Weakness, Opportunity, and Threat
TF	Transfer Foods
TLI	Tucker-Lewis Index
UCC	University College Cork
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children Emergency Fund
US	United States
VIF	Variance Inflation Factor
WFP	World Food Programme
WHO	World Health Organization

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Worldwide, one in eleven people were affected by hunger in 2023, according to the FAO et al. (2024), and undernourishment is worsening in Africa, leaving one out of five people on the continent in hunger. Between 2019 and 2023 alone, about 152 million more people were added to the number categorized as in the state of hunger, and it is anticipated that 53 percent of the world's total hunger in 2030 will come from Africa (FAO et al., 2024). Most affected are smallholders in sub-Saharan Africa (Giller et al., 2021; Ogutu and Qaim, 2019), who are the major producers and suppliers of food in the region (Fan and Rue, 2020; Giller, 2020; Sibhatu and Qaim, 2017). The long-term effects of malnutrition and hunger are expected to significantly harm the future productivity and health of this population.

Productivity loss from undernutrition and micronutrient deficiencies in early childhood are estimated by the World Bank (2024) at US \$1 trillion per year, while an additional US \$2 trillion in economic costs is estimated due to broader nutrition challenges, such as being overweight and obesity. Fan (2014) has indicated that malnutrition results in a significant loss of resources, accounting for a 5% reduction in global GDP, which is equivalent to US \$3.5 trillion per year.

The international community has made a collaborative commitment to eradicate global hunger by 2030 under the Sustainable Development Goals (SDGs). However, with only 5 years left, reports reveal that efforts to end hunger by 2030 may fall short of targets (FAO et al., 2024). Multiple factors have been mentioned as reasons for the shortfall, spanning from conflict and climate change to an unhealthy food environment and lack of access to affordable healthy diets (FAO et al., 2024).

The nature and causes of malnutrition are complex, however, the lack of access to affordable healthy diets remains a critical challenge in developing regions (Burlingame and Dernini, 2012). In Africa, the lack of access to affordable healthy

diets has caused an additional 73.4 million people to fall into hunger in 2022, adding to the already estimated 924.8 million people affected in 2019 (FAO et al., 2024).

Efforts to address access to affordable healthy diets have long been directed towards smallholders, with a view to raising their overall agricultural production (Bellon et al., 2023; Ogotu et al., 2020; Ruel, 2003; Sibhatu and Qaim, 2017). This is because hunger is widespread among rural smallholders, compared to the other sections of society, and raising smallholder productivity is seen as a viable and direct means of addressing the problem (FAO et al., 2024). However, increasing the availability and accessibility of food to smallholders requires increased farm productivity and income (Manikas et al., 2023; Passarelli et al., 2018).

There is a wide range of consensus in the literature that commercialization is key for increasing smallholder farm productivity and income (Mahofa and Sukume, 2022; Newettie et al., 2023; Ogotu et al., 2020; Ogotu and Qaim, 2019; Pamela et al., 2022; Sekyi et al., 2023; Tabe-Ojong et al., 2022; Woldeyohanes et al., 2017). The debate is related to whether a low or high level of farm production diversity increases commercialization. However, increasing farm productivity and income addresses only part of what is required to properly address malnutrition and hunger on smallholders. For this reason, in addition to addressing the debate on commercialization, this research intends to examine how the link between smallholder farm production diversity and markets influences household dietary diversity.

Studies indicate that the contribution of farm production diversity and markets in influencing dietary diversity, however, is inconsistent (Nandi et al., 2021; Sibhatu and Qaim, 2018). This inconsistency triggers debate in the literature between those who advocate farm production diversity-based solutions (i.e., self-provisioning) and those who advocate market-based solutions (i.e., sales and purchases) to smallholder dietary diversity. These grounds are closely linked to the context-specific nature of farm production diversity, market access, and dietary diversity across diverse physical and socioeconomic conditions; the relative importance of farm production diversity or market access in influencing smallholder dietary diversity; and the variations in market access measurements used. A clearer understanding of these major food

insecurity and malnutrition concerns is expected to provide a broader perspective on the efforts to address the challenges.

This research aligns with the latest report on the state of food security and nutrition by FAO et al. (2024), which points out that among other factors, the “...lack of access to and unaffordability of healthy diets... continue to drive food insecurity and malnutrition all over the world.” (p. vii). The report highlights that the global challenge of combating malnutrition and hunger is far from over and requires significant action. Development researchers are striving to create effective and sustainable strategies to address food insecurity and malnutrition. Part of this effort includes researching strategies that increase food security and dietary diversity for the most affected segment of the global community, smallholder farmers. To contribute to this endeavor, we undertake research on smallholder households’ access to diverse diets in Tigray.

The thesis aims to address two gaps: (i) despite the increased evidence of the positive contribution of farm production diversity and market access on smallholder dietary diversity, (Bellon et al., 2023; Sibhatu et al., 2015) debate continues as to the relative effectiveness of each of these approaches, while their joint influence has been given little attention (Nandi et al., 2021); (ii) Though commercialization is widely recognized as a key strategy to increase smallholder productivity and income, and ultimately access to affordable healthy diets (Mahofa and Sukume, 2022; Ogotu and Qaim, 2019), little agreement as to the specific pathways, on whether a low or high farm production diversity, or other factors influence smallholder commercialization (Barrett, 2010; Li et al., 2017; Morrissey et al., 2024; Sekyi et al., 2023).

Therefore, the overall purpose of this research is to better understand the link between farm production diversity and market participation, and how this might contribute to increased availability and accessibility of diverse diets among smallholder households in rural Tigray, northern Ethiopia.

To fulfill this purpose, I take a multifaceted and in-depth approach to investigate the key aspects of the local economy and the factors influencing the challenges facing households looking to improve their agricultural production, generate the necessary

cash income, and securing food and nutrition, under extremely difficult circumstances.

To achieve this purpose, the research intends to respond to how the link between farm production diversity and market participation influences the availability and accessibility of diverse diets among smallholder households in Tigray.

1.2. Research Objectives

The specific objectives of the research are to:

1. Assess the functioning of the market value chain for selected agricultural commodities
2. Identify the sources of smallholder household dietary diversity
3. Examine the joint interplay between farm production diversity and market access in shaping household dietary diversity.
4. Examine the link between farm production diversity and smallholder commercialization.

This thesis is, therefore, based on four independent research papers which, together, provide for a comprehensive understanding of the multifaceted relationships between household-level production strategies and dietary outcomes, as well as a deeper understanding of the potential for interventions by policy makers and development organizations to enhance smallholder dietary diversity in Tigray and similar contexts.

Both quantitative and qualitative information are used for research. Quantitative data was obtained from a cross-sectional household survey of 396 smallholders in the Gergera watershed conducted in September and October 2020. The qualitative survey, on the other hand, was conducted as part of a preliminary rapid value chain assessment conducted in the area in March 2019. This rapid value chain assessment is a policy-oriented market study. While it is not as methodologically complex as the other three papers in this thesis, it nonetheless provides important contextual information for interpretation of the findings of the other three papers that follow it.

1.3. Research Perspective: Dietary Diversity, Markets, and Farm Production Diversity

Across the literature, it is widely argued that the factors influencing smallholder dietary diversity and nutrition are context-specific (Bellon et al., 2016; Jones et al., 2014; Ruel, 2003; Qaim and Sibhatu, 2018). Ruel et al. (2018), for example, emphasize the importance of understanding the local context for the successful implementation of any nutrition-sensitive agricultural programs, stating that “... nutrition-sensitive agricultural programs should continue to be designed carefully, taking into account the specific context in which they are to be implemented and *using formative research* to identify the main constraints that limit household and individual access to healthy diets...” (p. 150). Our perspective on the research questions in this thesis aligns with this nutrition-sensitive agricultural intervention approach. The following section highlights the flow of the research questions as a step-by-step approach to understanding smallholder household dietary diversity.

CHAPTER FOUR - Understanding the Context at household and community levels:

This chapter aims to understand the context of the study area by examining the connection between agriculture and the market. The chapter evaluates the functioning of the value chain for agricultural commodities. Understanding the structures of the food system that determine the interaction of multiple actors influencing smallholder ability to commercialize is crucial for the successful applicability and adaptability of policy instruments (FAO, 2017). Food systems represent “all the people, institutions, and processes by which farm products are produced, processed, and brought to consumers” (FAO, 2017, p. 12). Value chain analysis is one of the mechanisms used to evaluate the performance of the food system. Value chain analysis aids in improving our understanding of how the structure of food systems works in interlinking the multiple actors and activities in the market. It helps to identify the challenges faced during commercialization and the opportunities that can be availed of through an inclusive, resilient, and sustainable integration of farm production with the market.

Knowing the performance of the structure and the interlinkage between the actors and activities of the food system is significant to make the necessary adjustments and corrections for the successful implementation of a project.

CHAPTER FIVE - Identification of Food Sources: - This research aims to identify the major food sources at household level and evaluate their contribution to household dietary diversity. It also evaluates the factors determining household food sources. The 'food sources' refer to how smallholders get physical and economic access to food. The World Food Summit in 1996 defined food security as "a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." (FAO, 2006; Hussein, 2002). However, an adequate supply of food at the national or international level may not necessarily ensure household-level food security and dietary needs (Sen, 1981; Hussein, 2002).

Household food security and dietary quality are guaranteed when individuals have access to diverse food sources based on their entitlement right (Sen, 1981). Amartya Sen's theory of food security links access to food to individuals' entitlement right to own food for themselves and/or their households (Sen, 1981). According to Sen (1981), entitlement rights can be obtained in three forms: Trade-based entitlement- access to food through trade, mainly represented here as foods obtained from the market through purchases; production-based entitlement- access to food through direct self-production, which, in this study, refers to the food sources from own farm production; and inheritance and transfer-based entitlement- access to food by individuals obtained through a voluntary transfer or provision of foods - this entitlement right in this research is related to food sources from private transfers (such as gifts, borrowings, social or community supports) and public transfer sources (such as the Productive Safety Net Program (PSNP) and emergency food, fortified food aids from government and non-government organizations).

In this study, I did not find food sources relating to inheritance. Accordingly, four sources of foods have been identified in the study area: purchased foods, own farm-produced foods, Productive Safety Net Program (PSNP) foods, and transfer foods. Unlike the first two entitlements, the food sources from the inheritance-and-transfer-

based entitlement right are split into two because the PSNP shows consistency in administration compared to the food obtained from transfers. This feature helps make interventions through PSNP easier than the less manageable food transfers.

CHAPTER SIX - Examining the Interactions between the Food Sources: The previous stages of the research identified the local food sources and their contribution to household dietary diversity. This chapter aims to evaluate the interactions among the food sources. It examines the relative and joint effect of the food sources on smallholder household diets. Understanding the interactions among the food sources is important because it helps us understand the aspects of food systems that affect the availability and accessibility of diverse and nutritious foods (FAO, 2012). However, the interaction between food systems is not straightforward; it can be direct or indirect (FAO, 2017). Hence, a proper understanding of how food sources function within food systems is an important task that needs to be addressed contextually. The interaction among multiple food sources might lead to trade-offs or complementarity between alternatives.

CHAPTER SEVEN - Evaluate the Link between Commercialization and Farm Production Diversity: Multiple studies indicate that smallholder commercialization increases farm productivity and farm income (Mahofa and Sukume, 2022; Newettie et al., 2023; Ogutu et al., 2020; Tabe-Ojong et al., 2022). The objective of this chapter is, therefore, to examine the interlink between commercialization and smallholder level of farm production diversity, which is important in designing targeted policy instruments to increase farm productivity and income that have a direct effect on household food sources (households' physical and economic access to diverse diets from their own farms and/or purchases increases).

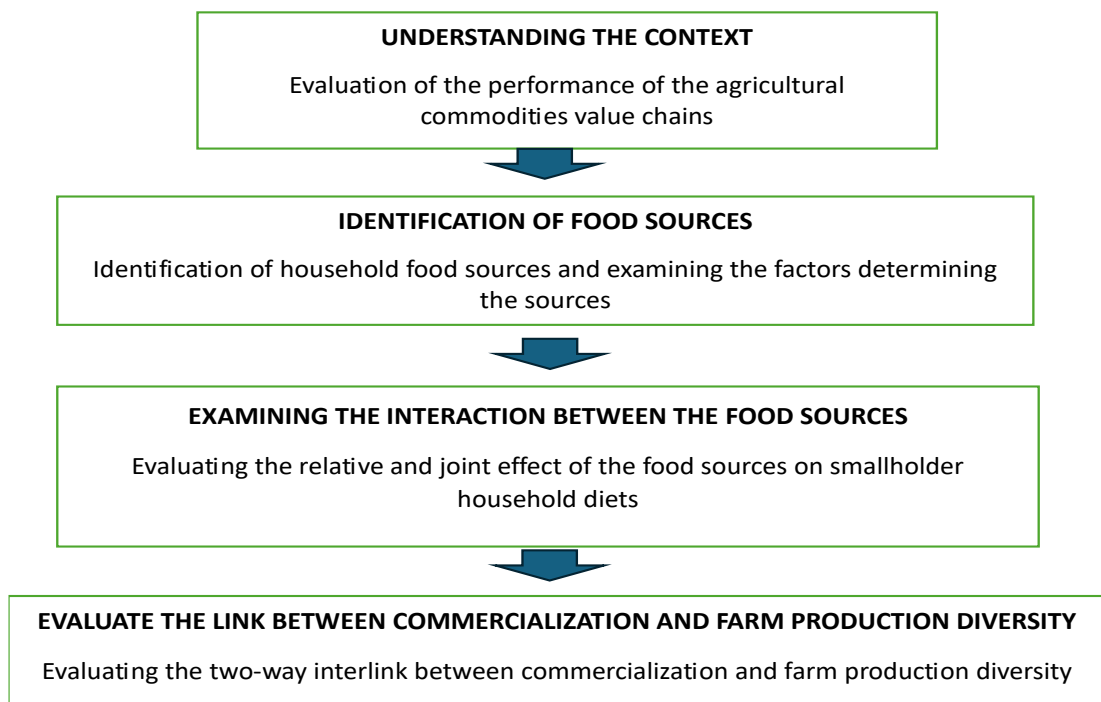


Figure 1 Logical flow of the research on Smallholder Household Dietary Diversity

The boxes in Figure 1 flow from top to bottom. They are designed to illustrate how the research questions of the thesis are constructed for a comprehensive understanding of the relationship between markets and smallholder farm production, on the one hand, and household dietary diversity on the other. The top two boxes relate to the gap in literature in relation to context-specific understanding of the link between the smallholder farm production and the market. This first phase creates a clear understanding of the types of agricultural marketable products, the functioning of the markets for those products, and the challenges and potentials for improvement.

The second box relates to context-specific food systems; it identifies the major food sources and their contribution to the household dietary diversity. This phase of the research provides insights into the factors that determine food sources for households.

The third box relates to the interactions among the food sources identified in the second box. The research in this phase examines the relative and joint interactions between these food sources addresses the gap in the debate over the relative

importance of farm production diversity and markets in shaping smallholder dietary diversity.

The final box relates to the link between smallholder farm production diversity and commercialization. Commercialization is widely recommended to boost smallholder farm productivity and income, which increases the availability and accessibility of diverse diets on households.

This research provides a broader perspective for any planned interventions aimed at enhancing smallholder household dietary diversity in this and similar regions.

The thesis is organized into eight chapters. The first chapter presents a background to the research to introduce the thesis, explain the research questions, the objectives and the structure of the thesis. Chapter two presents the literature review and chapter three familiarizes the reader with the study area, the data types and sources and it briefly introduces the methods by which the four papers in the thesis are produced.

The four independent research papers are presented, beginning with chapter four, which presents the rapid value chain assessment. It is the only qualitative research paper focused on assessing the performance of the value chain on five major marketable agricultural products - vegetables, fruits, dairy, small ruminants, and apiculture production. Chapter five examines the sources of smallholder household dietary diversity in the study area. This paper aims to identify the food varieties and their sources and ranks the contribution to household dietary diversity. Next, in chapter six, the third research paper examines the joint interplay between farm production diversity and market access in shaping smallholder household dietary diversity, in chapter six. The fourth paper, presented in chapter seven, discusses the link between smallholder commercialization and farm production diversity. The final chapter, chapter eight, presents the overall conclusions and derives policy recommendations, along with some reflections on the study. References and appendix sections round out the thesis.

CHAPTER TWO

2. FARM PRODUCTION, MARKET ACCESS, AND SMALLHOLDER

DIETARY DIVERSITY: A REVIEW OF THE LITERATURE

Despite numerous policy proposals and efforts for implementation, the countries of the world are, according to FAO et al. (2024), off track from the commitment to end hunger by 2030, and malnutrition is worsening in most Sub-Saharan African nations. The most affected section of the globe is the rural smallholders in Africa and Asia. The major policy barriers highlighted in this regard include conflicts, extreme climate variability, lack of collaboration among global and national partners, lack of access to affordable healthy diets, and a weak connection between rural producers and the market (FAO et al., 2023). The results reveal that the challenges in combating food insecurity, malnutrition, and hunger are multidimensional and complex, requiring a coordinated commitment from stakeholders at multiple levels. This chapter examines the literature on this topic and analyzes how this development challenge is expressed. It also explains the different policies and strategies that existed and their effectiveness in addressing the challenges of smallholder dietary diversity and nutrition.

2.1. Overview

This review uses a thematic approach to discuss the literature on smallholder food security, dietary diversity, and nutrition, identifying areas of commonality in the literature, areas of difference and potential research gaps. The review starts by defining smallholders and food insecurity/security. It next introduces the concepts of malnutrition and hunger and discusses the links with smallholder farming. It then highlights the use of dietary diversity as an indicator of nutrition and food security. Following this, the review explores the social and economic costs of malnutrition and hunger and then discusses strategies used to combat malnutrition and hunger. Having identified farm diversity and market access as key strategies to combat malnutrition and hunger, it then reviews a range of studies on how the two are associated with smallholder dietary diversity. Empirical evidence on the effects of farm diversity and market access on dietary diversity is then explored, along with the methods used in

such studies. Finally, the range of policy approaches suggested in the literature are discussed, and overall concluding remarks to summarize the key takeaways from the literature review are presented.

2.2. Understanding the Link between Malnutrition and Smallholder Dietary diversity

2.2.1. Understandings of Smallholders

The FAO (2012, p. 2) described smallholders as “small-scale farmers, pastoralists, forest keepers, and fishers who manage areas varying from less than one hectare to 10 hectares”. Similarly, Rapsomanikis (2015) described smallholders as family farm workers operating on less than 2 hectares of land, constrained by limited resources and access to the market and services, and mainly dependent on family labor. Woodhill et al. (2020) point out that although land sizes differ across regions, smallholders are commonly defined in relation to the landholding size, which usually refers to less than two hectares of land. When defining smallholder farmers in Ghana, Chamberlin (2008) indicated the size of holding as the most common attribute of smallholders. Similarly, Rigg et al. (2018) referred to smallholders as farmers with possession of less than or equal to two hectares of land, irrespective of the fertility and productivity of the land.

Apart from the limited size of their farmland, smallholders are described by Kuivanen et al. (2016) as farmers operating on fragmented land yet supplying – on aggregate - a large amount of food to the rural economy. Similarly, Woodhill et al. (2020) described smallholders as producers of a significant proportion of the foods consumed in least developed countries, representing 2 to 3 billion people worldwide and comprising most of the world’s poorest, food insecure, and vulnerable people. Thus, the most common definition of smallholders in the literature generally involves ownership of less than 2 hectares of land operated primarily by family labor.

2.2.2. Understandings of Food Insecurity

FAO (2025) defines food insecurity as “when people lack regular access to enough safe and nutritious food for normal growth and development and an active and healthy life. This may be due to unavailability of food and/or lack of resources to

obtain food”. Looking more specifically at the household level, Coleman-Jensen (2020) described household food insecurity as a condition where a member or members of a household are unable to acquire adequate food at times due to lack of money or other resources. Canali and Slaviero (2010), in their study on food insecurity and risk management among smallholders in Ethiopia, defined food insecurity as “a situation where the conditions of food availability, food access, and food utilization are not satisfied at all times” (p. 1267).

Food security, according to the 1996 World Food Summit, is defined as “a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” (Hussein, 2002, p. 628). This compound definition suggests that food insecurity may arise for numerous reasons, experienced at different levels from the individual to the global, whereby people are unable to achieve food security for a variety of reasons.

2.2.3. The Relationships between Food Insecurity, Malnutrition, and Hunger

The FAO (2025) divides food insecurity into three stages. The first stage is ‘mild’ food insecurity, a condition where people face uncertainty about the sustainability of their access to food; the second stage, the ‘moderate’, is a condition where people experience a shortage of food that forces them to reduce the quantity and/or quality of the food they consume. Malnutrition is usually manifested at this stage. The third stage is ‘severe’, where people are forced to endure a painful situation due to their inability to eat food or dietary energy for one or more days. Hunger usually manifests at this stage (FAO, 2025). The World Bank (2024) indicated that higher levels of malnutrition in all its forms could be found more in some communities and regions compared to others. Malnutrition is widespread in rural areas compared to peri-urban and urban areas, and in women and children compared to adult men (FAO et al., 2024).

2.2.4. Dietary Diversity as an Indicator of Food Security and Nutrition

Dietary diversity is widely recognized in literature as a key indicator of food security and nutrition. Although many authors have described why dietary diversity could be a suitable measure of food security and nutrition, Swindale and Bilinsky's (2006) explanation of the rationale has been widely used. Their explanation is quoted as follows:

“Household dietary diversity - the number of different food groups consumed over a given reference period - is an attractive proxy indicator for the following reasons. (1) A more diversified diet is an important outcome in and of itself; (2) A more diversified diet is associated with a number of improved outcomes in areas such as birth weight, child anthropometric status, and improved hemoglobin concentrations; and (3) A more diversified diet is highly correlated with such factors as caloric and protein adequacy, percentage of protein from animal sources (high-quality protein), and household income. Even in very poor households, increased food expenditure resulting from additional income is associated with increased quantity and quality of the diet.; ...” (pp. 1 – 2).

Similarly, Ruel (2003) argues that dietary diversity is linked to per capita consumption and energy availability in households, which suggests the adequacy of dietary diversity to be used as an indicator of food security. Ruel further states that “dietary diversity is universally recognized as a key component of healthy diets” (p. 3911S). Similarly, Torheim et al. (2004, p. 594), indicated that “dietary diversity is useful as an indicator of nutrient adequacy”. Several other studies, such as Kennedy (2011), Koppmair et al. (2017), Muthini et al. (2020), Sibhatu et al. (2015), and Sibhatu and Qaim (2018a) have used dietary diversity to explain household access to a variety of foods and their nutrient adequacy. Research undertaken in Ethiopia by Herrador et al. (2015) also shows that diversifying diets is an effective strategy to combat malnutrition in school-age children.

Interventions targeting food security have focused on influencing the physical and economic access to sufficient, safe, and nutritious foods for individuals to meet their dietary needs. The ability to influence dietary needs in turn helps people enjoy an

active and healthy life. Conversely, failure to achieve food security limits individuals' access to diverse diets that ultimately lead to malnutrition in different forms, either undernutrition, causing stunting, wasting, and micronutrient deficiency, or overnutrition, causing overweight and obesity.

2.2.5. Economic and Social Cost of Malnutrition and Hunger

Malnutrition is indicated as the primary reason for the deaths of children, greater than deaths caused by natural and human-caused catastrophes (The power of nutrition, 2025). Bain et al. (2013), in their research on malnutrition in Sub-Saharan Africa, showed that malnutrition in all its forms was associated with the death of one third of the worlds and half of the least developed nations' children. The WHO (2022, p. xxi) indicated that "in 2019, more than 9 out of 11 stunted children live in Africa (SSA) or Asia, representing 40 percent and 54 percent of all stunted children in the world, respectively". In 2021 alone, about 4.7 million under-five children died worldwide and the cause for the death of the 2.4 million of those children is linked to child and maternal malnutrition (Ritchie, 2024).

Children affected by stunting at an early age are highly likely to grow-up with a lifetime adverse effect on their physical and cognitive development, which may be revealed during adulthood with negative impacts on their health, education, and income (World Bank, 2024).

The technical brief of the Global Panel on Agriculture and Food Systems for Nutrition (2016, p. 2) indicated that "malnutrition, in all its forms, carries huge direct and indirect costs to individuals, families, and to entire nations. The estimated impact on the global economy could be as high as US\$3.5 trillion per year, or US\$500 per individual". The World Bank (2024) showed that there is a significant cost associated to undernutrition, with an estimated cost of US \$1 trillion a year due to productivity loss caused by undernutrition and micronutrient deficiencies and an additional US \$2 trillion is lost annually due to overweight and obesity. The investment cost to combat and end hunger by 2030, on the other hand, according to the FAO (2025b), was anticipated to be US \$265 billion per year. This suggests that the loss due to malnutrition is higher than the investment cost to fight it (Global Panel, 2016).

The World Bank (2024) indicated that stunting in early childhood results in irreversible damage to human cognitive development, which has a negative impact on the person's education, income, and productivity later in adulthood. The same study indicated that in Malawi, child undernutrition was associated with the death of 23 percent of children, an estimated health care loss of US \$46 million, and an estimated loss of US \$67 million due to adult low productivity associated with stunting in their early childhood (for the year 2012).

Half of the world's countries are reported to be off track to achieve the 2030 nutrition target of 50% reduction in under-five child stunting and 60% off track to address the problem of overweight, according to the FAO et al. (2024), while almost all countries are off track for anemia among women aged 15 to 49 years and adult obesity. These development challenges contribute to a cycle of poverty and need to be addressed urgently. Combating malnutrition in all its forms demands huge financial investment, and studies indicate that the return from this investment is very rewarding. For example, globally, the economic loss of reduced productivity due to undernutrition and micronutrient deficiencies is estimated to be about US \$1 trillion and US \$2 trillion due to obesity and overweight, according World Bank (2024). The additional productivity loss associated with malnutrition due to the burden of COVID-19 according to the World Bank (2024), was anticipated to be US \$29 billion globally in 2022. For this reason, McConville (2021) indicates that it will take about 0.3 percent of the world GDP, which is equivalent to US \$267 billion each year, to eradicate hunger by 2030. The same report indicates that in Ethiopia, the proportion of the GDP loss associated to adults with a history of undernutrition during childhood leading illness, school repetition, school dropout, and reduced productive capacity is estimated to be US \$4.7 billion each year.

The progress and positive achievements in the fight against malnutrition in some countries suggest that the problem is reversible if properly handled and sufficient investments are made. A recent report on the return on investment to fight hunger in 12 African countries by the Global Panel (2016) shows significant reduction in the prevalence rate of child stunting, which would reduce healthcare costs and increase school retention rates, human productivity, and savings (Global Panel, 2016).

Similarly, a report by McConville (2021) showed an estimated positive return of US \$22 in Chad, US \$21 in Senegal, and US \$17 in Niger and Uganda for every US\$1 investment made to fight malnutrition. According to the Global Panel (2016), the estimated return in terms of increased annual savings on a 50 percent reduction in malnutrition in selected countries of Africa is estimated to be US \$3 million in Swaziland, US \$133 million in Egypt, and US \$376 million in Ethiopia.

Overall, the economic and social costs of malnutrition and hunger are multidimensional and have a long-lasting negative effect on people and nations, while the cost of preventing malnutrition is significantly lower. This gives the hope that malnutrition and hunger are preventable and can be eradicated if stakeholders' commitment is properly coordinated. Smallholder dietary diversity could be an important strategy in tackling these problems.

2.2.6. Strategies at Smallholder Level to Combat Malnutrition and Hunger

Smallholders play a major role as both consumers and producers of most of the food supplied in developing countries (Sibhatu and Qaim, 2017). They are, however, disproportionately affected by hunger, malnutrition and food insecurity (FAO et al., 2024). The position of smallholders at the center of this paradox makes them focus on the fight against food insecurity, malnutrition, and hunger consumption (Ruel, 2003). The most common entry point for the fight against food insecurity, malnutrition, and hunger, according to Ruel and Alderman (2013), is promoting nutrition-sensitive agricultural programs.

Nutrition-sensitive agricultural interventions for smallholders have been widely discussed in the literature, with the aim of increasing food security, dietary diversity, and nutrition (Ruel and Alderman, 2013; FAO et al., 2023). Ruel and Alderman (2013) indicated six nutrition-sensitive agriculture-based approaches through which smallholders and their households can improve their food security, dietary diversity, and nutrition wellbeing. These agriculture-to-nutrition pathways are categorized by Ruel et al. (2018, p. 128) as (1) food access from own production; (2) income from the sale of commodities produced; (3) food prices from changes in supply and demand; (4) women's social status and empowerment through increased access to

and control over resources; (5) women's time through participation in agriculture, which can be either positive or negative for their own nutrition and that of their children; and (6) women's health and nutrition through engagement in agriculture, which also can have either positive or negative impacts, depending on exposure to toxic agents and the balance between energy intake and expenditure. The list shows the multiple pathways through which agriculture may contribute to smallholder dietary diversity and nutrition.

Various studies have been undertaken to examine the effectiveness of the pathways and identify the influence of the approaches on smallholder households, women's, and children's nutrition, dietary diversity, and food security status. One of the widely recognized strategies, according to Chamberlin and Schmidt (2011), - which applies Pathway 1- is influencing the nutritional content of smallholders' farm production so that households get access to nutritionally diverse foods from their own farm. Ruel and Alderman (2013) referred to this approach as a nutrition-sensitive agricultural production intervention.

Sibhatu and Qaim (2017) argue that direct consumption from a household's own diversified crops and livestock - Pathway 1 - production contributes to smallholders' diets and nutrition, and that farm production diversity has, therefore, an important role in fighting smallholders' food insecurity, malnutrition, and hunger. A critical review of literature undertaken in low- and middle-income countries by Jones (2017a) identifies farm production diversity as a factor that can contribute to the nutrition and dietary diversity conditions through both subsistence and income-generating pathways. Diverse farm production is also found to positively contribute to diverse household diets in Malawi (Jones et al., 2014). Empirical evidence from studies by Pellegrini and Tasciotti (2014) found that the number of crops grown and the income obtained from the sale of crops positively contributes to dietary diversity, as suggested in the first and second pathways of interventions.

A study on the influence of agricultural diversity on child nutrition in Zambia found a positive contribution of production diversity on dietary diversity among younger children aged 6–23 months and significant positive associations between production diversity and height for age Z-scores and stunting among older children aged 24–59

months (Kumar et al., 2015: 1061). The findings reaffirm the arguments of the above-mentioned authors that farm production diversity plays a crucial role in influencing dietary diversity and nutrition outcomes.

The other widely recognized approach, as indicated in Ruel and Alderman (2013), is to increase productivity and income so that smallholder farmers obtain enough output for self-consumption and sale – Pathway 2. The income is then used to purchase more nutritious foods. Research by Bellon et al. (2020) in Ghana and Do and Nguyen (2024) in rural Thailand and Vietnam indicated that selling a proportion of smallholders' farm production increases smallholder income but also, importantly, its overall productivity. Ogutu et al. (2020, p. 354) summarize the contribution of this approach in the following statement: "commercialization contributes to higher incomes and increased nutrients from purchased foods, without reducing the consumption of nutrients from own-produced foods". The argument stresses the crucial role of agriculture in enhancing dietary quality through direct consumption and income from the sale of farm products.

It can be concluded from this survey of the literature that smallholder agriculture, through its ability to create access to diverse food varieties for direct consumption and incomes from the sale of farm products, has an important role in improving dietary diversity and nutrition.

2.3. Academic Debates on the Role of Farm Production Diversity and Market Access on Smallholder Dietary Diversity

There is a near-consensus in the literature regarding the positive contribution of agricultural production and markets on dietary diversity and nutrition. However, the findings show inconclusive and sometimes conflicting results concerning the relative significance of direct consumption from own farm diversification and from food purchases made with income from sold farm products on dietary diversity (Chegere and Stage, 2020; Sibhatu and Qaim, 2018a). The debate on the relative importance of foods from agricultural diversity and markets in influencing dietary diversity has evolved in literature over time, as empirical findings from various studies either support or challenge the established claims, with few yielding mixed or neutral results.

Several studies have found that the market is more effective in influencing dietary diversity and nutrition than farm production diversification. For example, based on a critical review of 28 research papers from 14 countries, Nandi et al. (2021) summarized that markets provide more diverse diets than farm production due to their ability to create access to more diverse foods produced in various agro-ecological conditions than can be obtained through self-production diversification. A study using nationally representative data from three countries, Bangladesh, Ethiopia, and Kenya, by Sibhatu and Qaim (2018a), concluded that improving market access is an effective strategy to enhance smallholder dietary diversity and nutrition. Multiple studies underscore the effectiveness of markets in shaping smallholder dietary diversity and nutrition compared to farm production diversity (Hirvonen and Hoddinott, 2017; Sibhatu et al., 2015; Sibhatu and Qaim, 2017).

On the other hand, many studies indicate that farm production diversity is an important strategy for improved smallholder dietary diversity and nutrition. Evidence in favor of farm production diversity based on a critical review of research in developing countries, by Jones (2017), indicated that agricultural diversity positively contributes to dietary diversity both through direct consumption and income from sales. Similarly, research undertaken in Nepal showed “overall agricultural yields, specific crop groups, and the consumption of own production as factors correlated with long-term nutrition among children of different age groups” (Shively and Sununtnasuk, 2015, p. 1078). Another study from Tanzania revealed that higher value of crops produced, and ownership of livestock were found to be strongly positively associated with long-term indicators of nutrition among young children’s height for age and short-term indicators among older children’s body mass index for age (Slavchevska, 2015).

Some researchers, however, have found little or no significant effect of farm production diversity on dietary diversity or nutrition. For example, a review of literature from 26 countries Sibhatu and Qaim (2018b) stated that “results may be context-specific; however, there is little evidence to support the assumption that increasing farm production diversity is a[n] ... effective strategy to improve smallholder diets and nutrition” (p. 1). Rajendran et al. (2017), in their examination if

the integration of vegetables into maize-based farming systems in Tanzania, did not find a significant association between farm diversity and dietary diversity. A similar study by Cleghorn (2014) in Tanzania and Lourme-Ruiz et al. (2016) in Burkina Faso also found no significant association to dietary diversity or nutrition.

Apart from the above viewpoints regarding the market versus production diversification, some researchers find mixed results. For instance, a study by Muthini et al. (2020) in Kenya finds that farm production diversity positively contributes to women and household dietary diversity, but not in the case of children. In a study on the effect of cow ownership on child nutrition in rural Ethiopia, Hoddinott et al. (2015) found a positive role of cow ownership in reducing stunting; nonetheless, this effect reduces when households have access to the market, suggesting better market access may substitute for cow ownership. Other studies that examined the influence of agricultural diversity on dietary diversity also found a positive but weak level of influence. A study by Kavitha et al. (2016) on the link between crop diversity and dietary diversity in India showed that crop diversity alone has no effect on household dietary diversity. Koppmair and Qaim (2017) also found that farm production diversity has a positive, but small, effect on dietary diversity.

Bellon et al. (2023, p. 412) defend the importance of farm production diversity, stating that “the argument for prioritizing market access over production diversity for improving diets is often based on a simplistic unidirectional conceptualization of the relationships among production diversity, dietary diversity, and market participation.”

Based on these arguments, it can be concluded that the findings in the literature are mixed, indicating a lack of consensus that reflects the complexity and context specificity of the role of farm production diversity and market access in enhancing dietary diversity and nutrition. Some researchers have provided potential explanations for these inconsistencies. Muthini et al. (2020) observed that the extent of influence varies based on the method used to measure farm production diversity. Other researchers also identified possible factors contributing to the inconsistent findings, which include variation in measurement of dietary diversity (Sibhatu et al., 2015), the context-specific nature of dietary diversity (Ruel et al., 2018; Sibhatu and Qaim, 2018b), and differences in the proxy measures for market access and farm

production diversity used (Chamberlin and Jayne, 2013a; Headey et al., 2019; Zanello et al., 2019).

2.3.1. Measuring Farm Production Diversity, Market Access, and Dietary Diversity

Researchers use different methods to measure dietary diversity, farm production diversity and market access. These measures have been useful in examining the relationships among the variables, arriving at certain conclusions, and providing policy suggestions. Nonetheless, given that each of them has multiple methods of measurement, inconsistencies in the findings have been an issue in the literature (Chegere and Stage, 2020; Muthini et al., 2020; Sibhatu and Qaim, 2018a). The following section briefly discusses the measurement of these variables and the arguments advanced by leading authors in the field.

2.3.1.1. Measuring Dietary Diversity

Sibhatu et al. (2015) indicated that the food variety score (FVS) and the dietary diversity score (DDS) are the most widely used measures of dietary diversity. Kissoly et al. (2020) and Muthini et al. (2020) have argued for a similar approach to measure dietary diversity in their study.

The food variety score (FVS) is a simple count of the various foods consumed during the recording period and is useful to account for the nutritional contribution of the foods consumed (Muthini et al., 2020; Sibhatu et al., 2015). The dietary diversity score (DDS) allocates food items based on their nutritional contributions into 12 food groups (Qaim and Sibhatu, 2018) and is measured based on the number of such food groups consumed during a given recall period (Kissoly et al., 2020; Sibhatu et al., 2015).

The two measures have their limitations, however. One of the limitations of the food variety score (FVS) method, according to Sibhatu et al. (2015), is that it is not suitable for making comparisons between countries due to its subjectivity, related to cultural and social differences across communities. On the other hand, while the dietary diversity score (DDS) overcomes this limitation, it has some other limitations. The first is that it gives equal value to a food group regardless of the quantity consumed

(Sibhatu and Qaim, 2018a); second is that 3 of the 12 food group classifications according to Sibhatu et al. (2015) [sweets and sugars; oils and fats; and spices, condiments, and beverages] “contributes little to the micronutrient density of the diet” (p. 5) and hence some researchers prefer to use only 9 of the 12 food groups, depending on their objectives. For example, Muthini et al. (2020) used 9 food groups to evaluate Women’s Dietary Diversity Score (WDDS) in Kenya, while Chegere and Stage (2020) also used 9 food groups to analyze household dietary diversity score in Tanzania.

In Ethiopia, the dietary diversity score is the most widely used measure of smallholder dietary diversity, being used in studies conducted by multiple researchers such as Headey et al. (2019) and Usman and Callo-Concha (2021).

2.3.1.2. *Measuring Farm Production Diversity*

Different methods of measurement for farm production diversity have been in use in literature. For example, Sibhatu et al. (2015) have used Margalef’s species richness index, a simple, unweighted crop species count, and a farm production diversity score to measure the diversity of the foods produced. Muthini et al. (2020) have used Simpson’s Index, a simple crop and animal species count, and the production diversity score. Similarly, Chegere and Stage (2020) have used Simpson’s Index, agricultural richness score (ARS) and the production diversity score to measure farm production diversity.

All those measures have their respective strengths and weaknesses and are frequently cited as possible reasons for the weak link between farm diversity and dietary diversity (Lourme-Ruiz et al., 2016) and the inconclusive results (Muthini et al., 2020). The most widely used measure of farm production diversity in recent literature, the production diversity score, for example, includes multiple staple crops, such as maize, wheat, and sorghum, as just one food group. A further complication is that different food groups could also be obtained from one product. Sibhatu and Qaim (2018a, p. 50) stated the problem in this way: “The production diversity score counts different species produced on the farm as one when they all belong to the same food group (e.g., maize, wheat, sorghum, potato, cassava that all belong to the

group of starchy staples). On the other hand, the same species can count as two when it delivers products that belong to different food groups (e.g., chicken that deliver eggs and meat)". Acknowledging such limitations, Muthini et al. (2020) have extended the value of farm production diversity score to 16 food groups, independently treating the foods from each the sources. This avoids double the counting which results from counting potential food sources instead of the actual foods produced. Accordingly, each food would be counted as a food group only if it is produced at the specified period. A good example can be a cow, which is usually counted as a provider of three food groups, without regard to its actual production of milk and/or butter. For this reason, Muthini et al. (2020) argued that milk and butter should be counted only if they are produced in the specified production period, otherwise, a cow shall be counted as one food group.

Another limitation regarding the production diversity score is that it is based on potential food sources rather than actual foods obtained from the crops and livestock produced, which may significantly overstate the magnitude of influence of farm production diversity on dietary diversity (Balcha et al., 2024). This is because some livestock varieties may be produced and kept as an asset and may not actually be used for household consumption but are counted as food sources. In addition, industrial or cash crops (Muthini et al., 2020) and some livestock varieties such as donkeys, horses, and camels that are kept as transport animals in parts of Ethiopia may not be meant for household consumption at all (Balcha et al., 2024). Hence, though they directly affect the level of farm production diversity, they are not necessarily linked to dietary diversity.

In summary, there is limited consensus in the literature on the appropriate measurement of farm production diversity. This is due to the lack of a comprehensive measure that accounts for the nutritional contribution, the quantity consumed, and standardization of the production varieties to enable cross-study and cross-country comparisons. This challenge is potentially contributing to differences in results which tend to be context specific.

2.3.1.3. Measuring Market Access

Smallholders fill the need for diverse foods by purchasing from markets (Mulenga et al., 2021). Moreover, markets help smallholders obtain income through selling farm products, and facilitate the purchase of diverse foods, two distinct roles for markets in improving smallholders' dietary diversity as argued by Usman and Callo-Concha (2021).

However, quantifying the contribution of markets to smallholder dietary diversity is not straightforward. For this reason, researchers use different proxies to measure the effect of market access on smallholder diet and nutrition. Some of the most widely used proxies for market access are physical distance to the nearest market center (Sibhatu et al., 2015; Hirvonen et al., 2017), travel time to the market (Jones, 2017; Koppmair et al., 2017), degree of market participation (Abay et al, 2016; Bellon, et al, 2023), various measures of commercialization (Ogutú et al., 2020), the cost of transportation (Zanello et al., 2019), and others, such as, Headey et al. (2019) used a mix of two or more of those measures at a time.

Despite the widespread use of those proxies, researchers question the effectiveness of these measures in explaining the role of markets on dietary diversity. Bellon et al. (2023, p. 412) expressed their concern in this way: "markets have been treated as a 'black box'... and market access and participation have been mainly measured in overly simplified ways".

In line with this argument, Chamberlin and Jayne (2013) have raised concern that these proxies are too weak to be used as measures of farmers' access to the market. Similarly, Headey et al. (2019, p. 1312) highlighted the limitation as "these types of proxies for market access may be very poor indicators of the latent quality of a market, particularly the nutritional dimensions of market quality". In Balcha et al. (2024), on the other hand, I have explained that 'the limitation in most of the proxies is that they focus on exogenous factors in addressing farmers' access to the market, giving little attention to the endogenous factors such as the ability, willingness, and preference of people to engage in markets.'

A systematic review of literature by Nandi et al. (2021) identified the use of self-reported travel time, distance to the nearest market, time taken, and cost to reach the nearest market as the measure of market access used in most of the published studies. They questioned these measures, arguing that “these may not accurately measure the construct of market access and also may not necessarily equate to market participation” (p. 11). Other researchers such as Usman and Haile (2022) argue that the proxy measures neglect the households’ social, economic, cultural, and other factors that may influence a decision to engage in market transactions. It can thus be concluded that there is a lack of consensus in the literature on the appropriate measurement of market access. This makes it challenging to make cross study comparisons, potentially contributing to differences in results.

Overall, it can be argued that there is no consensus in literature arising from the lack of standard measures of market access to appropriately explain the effect of market access on dietary diversity and nutrition. Moreover, this lack of a standard measure of market access limits comparisons across studies, regions, and countries.

2.4. Policy Alternatives and Barriers for Implementation

It is widely argued in the literature that production of both crops and livestock should be promoted among smallholder farmers. Mulenga et al. (2021: 10), for instance, suggested that “from a food and nutrition security perspective, agricultural interventions need to promote a broader food group diversification strategy that includes crops and livestock as opposed to focusing on crop-centric diversification approaches”. A similar policy direction was given by Khandoker et al. (2022), recommending policies and programs to promote multiple varieties of crop and livestock diversification.

According to Bellon, Kotu, et al. (2020), depending on the context, farm production diversity can play a vital role in providing nutritious and diverse diets for smallholders, both through self-consumption and cash income generation, and should therefore be promoted by policy makers. Likewise, Nandi et al. (2021) recommend for nutrition-sensitive agricultural programs that promote effective market integration through farm diversification.

Muthini et al. (2020), on the other hand, recommend creating better access to the market for smallholders to trade their farm produce, thereby promoting diverse household diets. Similarly, Headey et al. (2019) advise that establishing or creating better access to well-functioning markets is more important than promoting farm production, even for farmers with relatively high dependence on agriculture. Sibhatu and Qaim (2018b) similarly recommend that improving markets and technologies would increase the diversification of food systems without the need to diversify farm production among smallholders. Thus, the literature demonstrates a strong tension between the diversification of production, in order to directly increase dietary diversity, and the development of market access to indirectly achieve the same objective.

In between these policy perspectives, Chegere and Kauky (2022) suggested that neither farm production diversity nor market access may be effective unless smallholders' income and nutrition knowledge are also improved. Therefore, policies should focus on improving smallholders' income – from all available sources - and their overall nutritional knowledge. Similarly, the FAO et al. (2024) stress that nutrition of poor and vulnerable individuals must be emphasized and recommend that it could be best addressed through a mixed on-farm and off-farm measures, such as social protection, bio-fortification, and climate-resilient nutrition-sensitive agricultural intervention programs, with due consideration to gender equality.

2.5. Concluding Remarks

The literature review focused on debates around the effect of agriculture and market on smallholder dietary diversity and nutrition, and appropriate development interventions. Much of the reported research focuses on farm production diversity as a basis for agriculture's greater contribution to dietary diversity; others on the importance of well-functioning markets as a contribution to smallholder dietary diversity and nutrition through creating opportunities for farmers to sell their farm and purchase nutritionally diverse foods in return.

Beyond this dichotomy, much of the debate has focused on quantifying the relative influence of these two factors and, while most protagonists acknowledge the contribution of both, their conclusions and recommendations are generally either in

favor of farm diversification or markets or some combination of the two. Looking across the literature, farm production diversity and market access can have a negative, zero, or positive relationship with dietary diversity and their degree of influence is also inconclusive. The lack of standardization in measurement also creates uncertainty and hinders cross study, cross-country or even cross-region comparisons. The major reasons for the inconclusive results identified in the literature are the context-specific nature of agriculture, markets, and dietary diversity (Ruel, 2003; Sibhatu and Qaim, 2018a), the way farm production diversity, market access, and dietary diversity are measured (Muthini et al., 2020), and the complexity of the link between the three variables (Bellon et al., 2023).

Based on these findings, the literature is divided between two competing policy alternatives: strengthening markets or promoting diversified farm production. However, some authors recommend improving overall income and nutrition knowledge (Chegere and Kauky, 2022) and social protection programs for the poor and vulnerable sections of the people (FAO et al., 2024).

In an important development, a few recent studies have reported a positive effect of the complementarity between farm diversity and market access on smallholder dietary diversity (Bergau et al., 2022; Morrissey et al., 2024 ; Mulenga et al., 2021). These studies suggest a tailored complementary approach, through integrating farm diversity with/for greater market participation. However, there is limited exploration of how farm production diversity and market access interact with each other since most studies look at these separately. Given the uncertainty and context-specificity of the relationships examined in most studies to date, the divergent findings on the relative influence of farm production diversity and market access, and the limited attention to their potential complementarity, there remains an important gap in the literature which this study from rural Tigray seeks to address. By considering both farm diversity and market access in an integrated framework, this study aims to provide a better understanding of their combined effects on smallholder dietary diversity. This approach will help generate more context-relevant insights that can inform policies and interventions tailored to the region's unique agricultural and market conditions.

The Theoretical Framework of the Literature Review

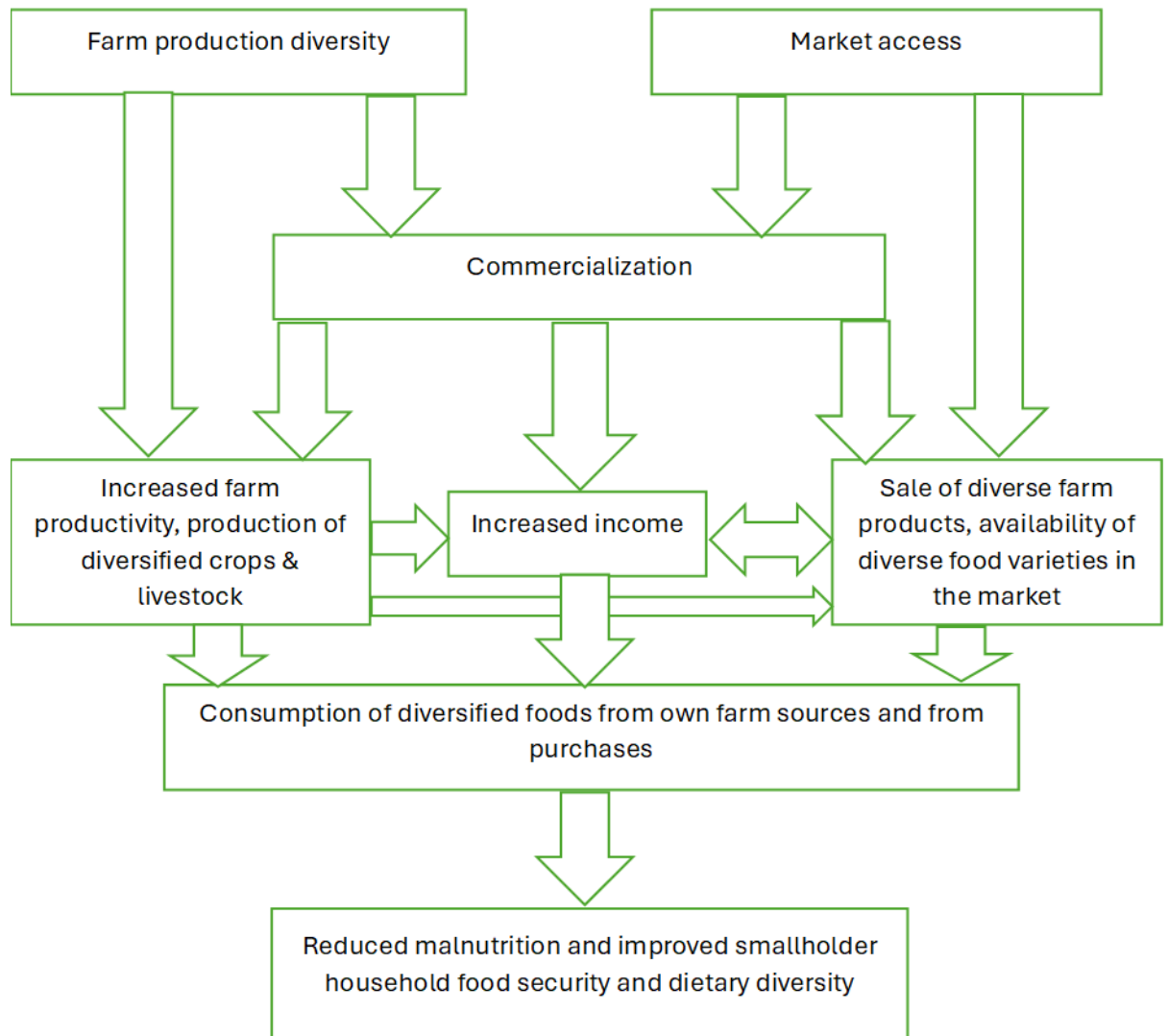


Diagram 1 Theoretical framework depicting the thematic presentation of the review of literature in this thesis.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

This section briefly discusses the different methodological approaches used to produce the four independent papers included in this thesis. The first paper discussed in Chapter 4 is a policy-oriented rapid value chain assessment that was conducted in 2019. The aim was to undertake a preliminary market value chain assessment on some selected agricultural commodities: honey, dairy, fruits, vegetables, and sheep and goats in Gergera Watershed, Tigray. The paper is based on qualitative data, and it used thematic analysis. These products are selected because they are the widely produced agricultural commodities for commercialization purposes.

In Chapter 5 I identified the sources of smallholder household dietary diversity. This research aims to examine the food sources and their shares of household dietary diversity. Moreover, it intended to investigate the factors determining the food sources for households. This paper uses pairwise graphical analysis to examine the shares of each food source in dietary diversity and econometric analysis to analyze the determinants of each food source in the smallholder household.

Chapter 6 of the thesis evaluates the combined effect of farm production diversity and market access on smallholder household dietary diversity in Tigray. The research uses the pairwise scatterplot and Poisson estimation econometric methods to analyze the data.

The final paper, discussed in Chapter 7, examines the bidirectional link between commercialization and farm production diversity, which aimed at contributing to the debate on whether smallholder commercialization increases through low or high levels of farm production diversity. I use a Structural Equation Model (SEM) in a two-pathway simultaneous equation approach to analyze the relationship.

The following sections explain the study area description, the sources of the data used in all the papers, and the instruments applied to gather the information. In

addition, it presents the type of data, the sampling methods used, and the varied methods of data analysis applied in the research papers in the chapters that follow.

3.2. Research Design

This thesis aims to evaluate the effect of the link between farm production and markets in enhancing smallholder household dietary diversity in Tigray, northern Ethiopia. A cross-sectional household survey was conducted in the Gergera Watershed, in Tigray, in September-October 2020. Quantitative and qualitative data was gathered using multistage stratified simple random sampling and purposive sampling, respectively. I collected primary data from 396 smallholder households. This sample size is robust with around 4% margin of error at 95% confidence. Secondary data was also consulted from published literature and unpublished official government reports. Mixed descriptive and econometric methods for the quantitative and the thematic method for qualitative data were employed to analyze the collected data. Three of the four research papers are based on quantitative data, while the fourth paper assesses the performance of the value chains for five selected agricultural commodities in the Gergera watershed and is based on the qualitative data.

3.3. Study Area and Population

Primary data was collected from a cross-sectional household survey in District Hayelom, in Tigray, northern Ethiopia (Figure 2). Hayelom district is a rural administrative zone in the Eastern Zone of Tigray. The center of this research is the Gergera Watershed. The watershed encompasses 143.9 square kilometers and is divided into four sub-districts (locally known as *kushets*) namely: Geter Haiki-Mesihal, Damaino, Gergera, and Degaabur. A kushet is the lower governance structure in the hierarchy of the public administration levels in Tigray, the largest being the Region, followed by Zone, *Wereda*, *Tabia* (also known as Peasant Association), *Kushet* and *Goot* (a subdivision of a kushet).

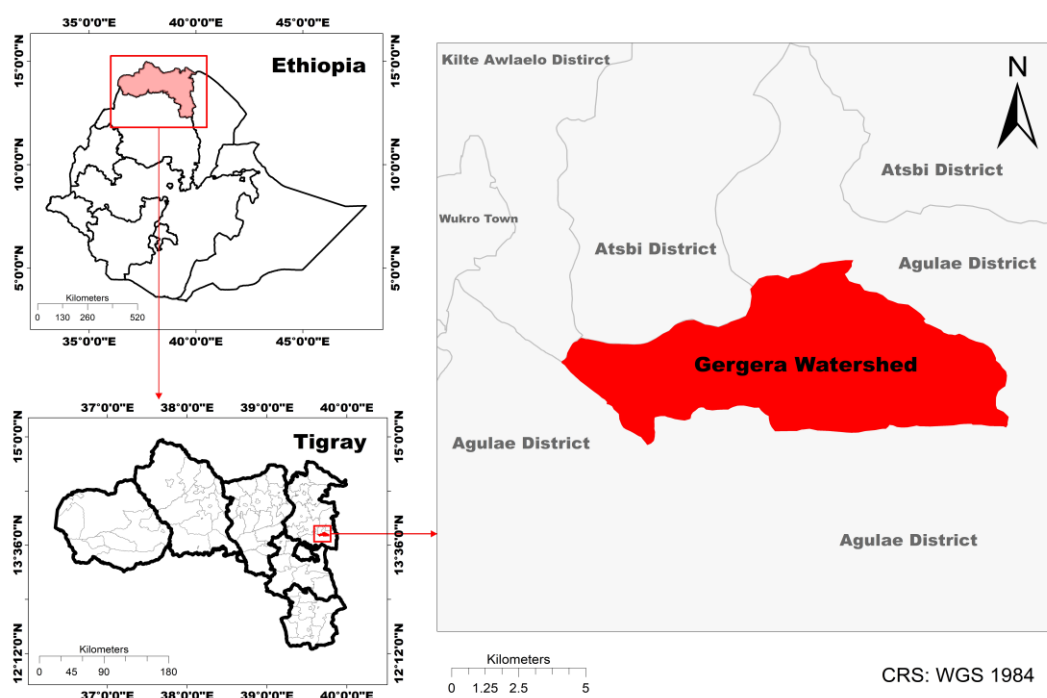
The watershed is ecologically classified between highland and lowland. It is located between 13.043 and 13.046N latitude and 39.040 to 39.045E longitude, at an elevation between 2,066 and 2,505 meters above sea level. The area experiences

bimodal annual rainfall of 450mm to 600mm. The average annual temperature in the watershed is between 15 and 25 degrees Celsius (ICRAF, 2018).

Morphologically, the Gergera watershed is marked by several cliffs surrounded by steep and undulating terrain. The flat regions and enclosures are mostly utilized for producing fodder grass and beekeeping. The soil texture is primarily silt-loam and loam, with a pH neutral to low alkaline content (Woldewahid G. et al., 2012).

Mixed crop-livestock farming is the most common farming technique in the area. The most widely grown cereal crops are barley, wheat, maize, teff (*Eragrostis tef*) and sorghum. Pulses, including beans, peas, and lentils are also grown. Some households along the banks of the Gergera river practice small-scale irrigation, cultivating crops such as tomatoes, potatoes, onion, cabbage, spinach and lettuce.

Figure 2 Map of the Gergera Watershed, Tigray Region, Ethiopia



Fruit tree species such as guava, avocado, papaya, and oranges flourish. The main livestock produced are cattle, sheep, goats, and poultry. Donkeys, horses, and mules are commonly utilized to transport commodities and farm products (Meaza, 2010).

3.4. Sampling Strategy

This section briefly presents the sources, and the types of data used in the four papers. It also introduces sampling methods and instruments. The stratified random sampling method is applied to select the survey participants from the target population.

3.4.1. Sampling Methods

3.4.1.1. Probability Sampling

This study uses primary data acquired through a cross-sectional survey of 396 households from four sub-districts (*kushets*) of the Gergera watershed in Tigray. A multi-stage stratified sampling procedure was used. At the first stage an implicit selection of all the four sub-districts of the watershed was made. The stratum is preferred because the four sub-districts of the watershed exhibit distinct agroecological characteristics which may have an impact on the farm production and market access of the residents. In the second stage a systematic sampling method is used to select the 405 households from the total of 1056 in the watershed. The sample size was proportional to the size number of households in each sub district, of the sampling frame, at 38%.

3.4.1.2. Purposive Sampling

The purposive sampling method is used to collect qualitative data for the value chain assessment described in Chapter 4. Smallholder households engaged in the production of major marketable agricultural commodities were identified by the agriculture and rural development office of the district. The office identified five major marketable agricultural commodities in the area. These were vegetables, fruits, dairy, small ruminants, and apiculture productions. The smallholders were then categorized according to their major production items and asked to participate in a focus group discussion (FGD).

The focus group discussions (FGD) conducted with agricultural producers, farmer cooperatives, and wholesalers, as well as key informant interviews (KII) with market experts and reports from tabia and wereda agricultural and rural development

offices. As I used purposive sampling method for the qualitative data, Degaabur is not included in this qualitative survey for its limited access to irrigation and low productivity of vegetables, fruits, dairy and honey.

3.5. Data Collection Methods

3.5.1. Primary Data Collection

The primary data was collected from the four sub-districts of Hayelom, named Geter Haiki-Mesihal, Gergera, Damino, and Degaabur. Using the stratified sampling method, 118 households were chosen from the subdistrict Geter Haiki Mesihal, 120 from Damaino, 78 from Gergera, and 89 from Degaabur, giving a total of 405 households. The questioned households were 293 male-headed and 112 female-headed households. Of the total sample size of 405 households, 9 have been excluded due to absence, or unreliable, inconsistent, and outlier data. The final sample size is 396 with 290 male-headed and 106 female-headed households.

A team of experienced enumerators received training on the questionnaire and a digital data-gathering platform, Kobo toolbox. The questionnaire was translated into the local language (Tigrinya), and two pilot surveys with 6 household heads at each survey were conducted. The questionnaire was designed to be consistent with the cultural norms of the areas regarding farm production, consumption, and marketing behaviors. The actual data collection took place between September and October 2020.

There were four components to the questionnaire (see Appendix C). The first section discusses the households' demographic and socioeconomic features; the second section is on household food consumption data; the third on household farm production; and the fourth on household market interaction. Crop and livestock production statistics for one agricultural year were collected, spanning September 2019 to August 2020. The research on the three quantitative papers is based on this data.

3.5.1.1. Focus Group Discussion (FGD)

Rich qualitative data was gathered through Focus Group Discussions (FGD) March 2019. Purposive sampling was utilized to pick farmers for the groups, with one group

of six farmers for each of the five selected farm products, namely vegetables, fruits, dairy products, small ruminants, and apiculture from targeted Tabias/sub-district - Geter Haiki Mesihal, Gergera, and Damaino. The farmers were purposely selected from each of the producers of the identified agricultural commodities. The reason is that those producers are expected to have better knowledge, experience, and understanding of the challenges in the production and commercialization of their respective products.

This data supports the value chain analysis for the five agricultural commodities produced in the three sub-districts. The voice record of the FGD data for a total of 142 farmers (74 male and 68 female) was collected.

3.5.1.2. Key Informant Interview (KII)

The Key Informant Interviews (KII) were intended to gather qualitative data (behavior, values, and attitudes) on the scale of production, the characteristics of the production system, the nature of the value chain, the main markets for commodities, and information on prices and seasonal price fluctuations. Five informants were selected purposively from knowledgeable local officers, market experts in the wereda, agricultural extension workers, and tabia and kushet level administrators, all with a strong grasp and experience of the Gergera market. The key informants consulted were, the wereda agricultural and irrigation expert, the wereda cooperatives, and market expert, the tabia chairperson, the tabia office of agricultural and rural development head, and transport service provider.

3.5.2. Secondary Data Sources

3.5.2.1. Document Review

Secondary data from official reports and published (Gessesse, 2016; Meaza, 2010; Woldewahid G. et al., 2012) and unpublished (ICRAF, 2018) research outputs were reviewed. Agriculture and rural development offices at the wereda and tabia levels provided access to official reports, but these did not generally include kushet-specific details needed to address our research questions. As a result, the study relied more on official reports obtained from the district and sub-district's Agriculture and Rural Development offices.

3.6. Measurement and Variable Construction

The key variables selected for the analysis and each measurement method used for the variables are described in this section.

3.6.1. Key Variables and Indicators

The following are the key variables of interest used in the quantitative aspects of the research:

3.6.1.1. Household Dietary Diversity

The household dietary diversity score (hereafter HDDS) is used to measure the diversity of household access to food, using 24-hours and 7 days recall periods (Swindale and Bilinsky, 2006; FAO, 2007; Sibhatu and Qaim, 2018; Admasu et al., 2011). The 24-hour and 7-day recall are established approaches, and both are used in this thesis to account for any significant difference between the two approaches. According to the Swindale and Bilinsky (2006) Food Access Indicator Guide, food items are classified into 12 food groups, based on their nutritional contribution, to compute the HDDS. The 12 food group are the following: 1. Cereals; 2. White tubers and roots; 3. Vegetables; 4. Fruits; 5. Meat; 6. Eggs; 7. Fish and other seafood; 8. Legumes, nuts, and seeds; 9. Milk and milk products; 10. Oils and fats; 11. Sweets and honey and, 12. Spices, condiments, and beverages (Swindale and Bilinsky, 2006). Each group is counted just once, if it is consumed by anyone in the household at least once within the time period.

3.6.1.2. Household Food Sources

The four main sources of food for consumption in households were classified as personal production, purchased foods, the Productive Safety Net Program/PSNP, and other public and private food transfers (including gifts). The relative contribution of each of these to household dietary diversity is calculated by assigning each food category consumed to one or more of these sources for a given week. This assessment provides a mechanism of capturing the source of foods in rural households by measuring all the foods consumed directly, hence minimizing the limits of traditional (indirect, or imputed) methods based on farm production diversity and market access.

3.6.1.3. Own Farm Produced Foods (OF)

Home farm production is the main source of food for rural smallholders in Ethiopia and other low-income nations (Argyropoulou, 2016; Bellon et al., 2016; Kumar et al., 2015; Rajendran et al., 2017). The contribution of farm-produced foods to household dietary variety is quantified in terms of the percentage of all the food groups consumed in the household rather than a simple count of the foods produced in the farm, as all produced foods may not end up consumed in the household.

3.6.1.4. Purchased Food (PF)

The foods that a household purchases can have a significant impact on its dietary diversity. In this study, the contribution of purchased foods to family diet is calculated using the percentage share of purchased foods in weekly home meals, tallied according to the food groups. Matita et al. (2021a) employed a similar technique, referring to it as a "food purchases diversity score". I once again calculated the contribution of purchased food in terms of the food groups contributing to household consumption during the seven-day recall period. As with the other sources utilized in this study, I did not account for the absolute quantity of purchased items consumed.

3.6.1.5. Productive Safety Net Program (PSNP)

The Productive Safety Net programmed (PSNP), a national welfare program that supports very poor households with employment, cash, and/or food, is another potential food supply for smallholder rural households in the research region. Following a similar trace-back technique, the PSNP's contribution to household dietary variety is calculated based on the food types consumed by the household throughout a week, broken down by origin. In Ethiopia, studies have produced mixed results about the PSNP's influence on household nutrition and food security (Gebrehiwot and Castilla, 2019; Hoddinott et al., 2015; Welteji et al., 2017).

3.6.1.6. Transfer Food (TF)

This source includes foods consumed by the household received in the form of assistance from various public and private sources, presents from friends, family, or neighbors, borrowings, bartering, and so on. Zhou and Hendriks (2017) shown that such payments can improve food diversity in low-income households. The

contribution of transfer foods is calculated by their percentage share of overall consumption in terms of food groups.

3.6.1.7. Farm Production Diversity

There are several approaches to quantifying agricultural production variety. In this study, I used the production diversity score (PDS), which is determined as the number of food groups produced by households in the preceding agricultural year (September 2019–August 2020). The PDS divides crops and animals into 12 food groups, which are nearly identical to the HDDS outlined above (Chegere and Stage, 2020; Koppmair et al., 2017a; Sibhatu and Qaim, 2018b). Food groups are those that may be expected to be produced by smallholders in the region.

3.6.1.8. Measuring Households' Access to Market

The research uses three different market access measures. The first market access metric is the number of times a household visits a food market in 30 days, also known as the Frequency of Food Market Visits. The second measure of market access applied here is the number of days since households last visited a market, or absence from the market (AM). The third measure is a proxy measure, the households' proximity to the markets (PM), measured in walking minutes, an established metric for market access (Bergau et al., 2022; Koppmair et al., 2017).

3.6.1.9. Smallholder Commercialization

Another variable of interest is smallholder commercialization, (defined in terms of the proportion by value of agricultural goods (crops and/or livestock) sold during a certain harvest season (Do and Nguyen, 2024). In this study, I use a Commercialization Index (CI), which is defined as the ratio of the value of all farm products (crops and livestock) sold to the total value of farm output produced by the household from September 2019 to September 2020, multiplied by 100 (Li et al., 2017; Mulenga et al., 2021; Ogutu and Qaim, 2019). Mathematically, this may be expressed as follows:

$$CI = \frac{\text{total value of all farm output sold}}{\text{total value of all farm output produced}} \times 100\% \dots\dots\dots (3.1)$$

The Commercialization Index (*CI*) is a continuous variable which ranges from 0% to 100%, where the minimum (0%) indicates no sales while the maximum (100%) indicates sale of all produce (Sekyi, Quaidoo, et al., 2023).

3.6.1.10. Farm Production Strategies

In smallholder agricultural research, farms are often described as having a high or low level of farm production variety (Bellon et al., 2020; Timmer, 1997; Omamo, 1998). More product variety implies a more diverse agricultural production strategy, whereas a lower level of diversity indicates a more specialized (or restricted) approach. The level of diversity is measured using a simple crop and livestock species count method, which is the number of distinct crop and livestock species produced in one harvest season, expressed as a continuous variable ranging from 0 to the maximum number of crop and livestock species produced in the study area (Islam et al., 2018; Jones et al., 2014); Linderhof et al., 2016).

Farm Production Diversity (FPD_i) measures the overall diversity level expressed as sum of crop diversity (CD_i) and livestock diversity (LD_i) produced in the harvest season (September 2019 to September 2020), which represents the total farm production diversity level.

$$FPD_i = CD_i + LD_i \dots\dots\dots (3.2)$$

Where CD_i represents the varieties of the crop species planted and harvested, numbered from 1 to k; LD_i is the varieties of livestock species reared, numbered from 1 to j, and FPD_i is the overall farm production diversity level in the harvest season.

3.7. Data Analysis Techniques

The three quantitative research papers were analyzed using simple descriptive statistics, graphical analysis and advanced econometric estimation methods. STATA-19 Standard Edition (SE) is used to analyze the quantitative data in this thesis.

3.7.1. Descriptive Analysis

Inferential statistics such as histograms and scatter plots are used to show the pairwise association between selected variables during the analysis. The percentage

shares, the trends, and associations between the variables are discussed based on this inferential statistics technique.

3.7.2. Econometric and Statistical Models

A variety of econometric estimation methods were used in the papers included in this thesis.

3.7.2.1. Ordinary Least Squares (OLS) Estimation

The ordinary least squares (OLS) estimation methodology is used to investigate what influences household choice of the various food sources (see Chapter 4). The model assesses how certain families and socioeconomic parameters impact household food sources. The equations for the models are as follows:

$$OF_i = \beta_0 + \beta_1 SE_i + \varepsilon_i \dots\dots\dots (3.3)$$

$$PF_i = \beta_0 + \beta_1 SE_i + \varepsilon_i \dots\dots\dots (3.4)$$

$$PSNP_i = \beta_0 + \beta_1 SE_i + \varepsilon_i \dots\dots\dots (3.5)$$

$$TF_i = \beta_0 + \beta_1 SE_i + \varepsilon_i \dots\dots\dots (3.6)$$

- where PF_i refers to the number of food group varieties purchased from the market and served at the households plate within the week under consideration; OF_i represents to the own farm-produced crop and livestock varieties classified into their respective food groups which are served and consumed at the given week; PF_i refers to food groups consumed during the week sourced from transfers. The transfer foods include foods from Aid and other public and private sources, gifts from friends, relatives or neighbors, borrowings, barter, and so on; and the $PSNP_i$ refers to the food groups consumed during the week sourced from the Productive Safety Net Program.

SE_i is a vector of socioeconomic characteristics that includes the head's age, gender, marital status, family size, level of education, sub-district in which the household is located, rainfed land holding size, irrigated land holding size, and household proximity to the market centre. The β_i s are vector parameters that indicate the quantity or degree of effect the explanatory factors have on the dependent variables, which are

the food sources. The ε_i is an error term that represents the impact of other unobserved factors on household i's food supply.

3.7.2.2. *The Poisson Estimation*

The Poisson regression equation was used in chapter 7 based on HDDS count outputs. The count outcomes of HDDS are assumed to follow the Poisson probability distribution function. This distribution function is shown by the occurrence of non-negative discrete outcomes at a set interval of time, each of which is independent of the others (Wooldridge, 2013). The Poisson regression equation is used to estimate the probability of a family consuming a certain number of food categories in 24 hours based on household and socioeconomic data (Sibhatu et al., 2015). The Poisson regression equation is mathematically represented as follows:

$$P(HDDS_i) = \beta_0 + \beta_1 PDS_i + \beta_2 FMV_i + \beta_3 AM_i + \beta_4 PM_i + \beta_5 PDS_i \times FMV_i + \beta_6 PDS_i \times AM_i + \beta_7 PDS_i \times PM_i + \beta_8 Marital\ status_i + \beta_9 Sub\ district_i + \beta_{10} Gender_i + \beta_{11} Age_i + \beta_{12} Family\ size_i + \beta_{13} Rainfed\ farmland\ size_i + \beta_{14} Irrigated\ farmland\ size_i + \varepsilon_i \dots\dots\dots (3.7)$$

In the regression models, the dependent variable $HDDS_i$ represents the HDDS over 24 hours. The explanatory variables are the farm production diversity score (PDS_i) and market access. Market access is further explained by the household i's frequency of food market visits (FMV_i), absence from the market (AM_i), and proximity to the market centre (PM_i). The interaction between $PDS_i \times FMV_i$, $PDS_i \times AM_i$, and $PDS_i \times PM_i$ is used to examine the simultaneous interaction of PDS and market access on HDDS. I hypothesise that PDS_i and FMV_i are positively associated with HDDS, whereas AM_i and PM_i are negatively associated with $HDDS_i$.

3.7.2.3. *Structural Equation Modeling (SEM)*

The Structural Equation Modelling (SEM) approach is used to investigate the possible two-way relationships between commercialization and farm production diversity (see Chapter 6). The detailed model definition of the two-pathway simultaneous equation is shown as follows:

Two Equations Simultaneous Path Model

1. Equation for commercialization:

$$\text{Commercialization Index}_i = \alpha_0 + \alpha_1(\text{Farm production diversity}) + \alpha_2(\text{Age}) + \alpha_3(\text{Additional income source}) + \alpha_4(\text{Education}) + \alpha_5(\text{Rainfed farmland size}) + \alpha_6(\text{Irrigated farmland size}) + \alpha_7(\text{Time to the market}) + \varepsilon_i \dots\dots (3.8)$$

2. Equation for farm production diversity:

$$\text{Farm production diversity}_i = \beta_0 + \beta_1(\text{Commercialization Index}) + \beta_2(\text{Gender}) + \beta_3(\text{Age}) + \beta_4(\text{Family size}) + \beta_5(\text{Education}) + \beta_6(\text{Rainfed farmland size}) + \beta_7(\text{Irrigated farmland size}) + \omega_i \dots\dots (3.9)$$

Where the Commercialization Index and farm production diversity are the key outcome variables, and ε_i and ω_i are the structural error terms. α_0 and β_0 represent the intercepts, while $\alpha_1 - \alpha_7$ and $\beta_1 - \beta_7$ are the sets of parameters for the exogenous variables in the first and second structural equations, respectively.

3.7.2.4. Thematic Analysis

Thematic approach is used to analyze our qualitative data (Castleberry and Nolen, 2018; Kiger and Varpio, 2020; Lochmiller, 2021). The information collected through the FGD and KII has been transcribed and coded according to selected topics. The selected topics were agricultural production diversity, access to transport services, agricultural commodity price, seasonal production and market influencing factors, and government and private sectors' role across agricultural commodity value chains. The interpretation and narration of the refined themes were made, and results are discussed (see Chapter 7).

3.8. Ethical Considerations

This research work got an ethical approval before commencing data collection from the research ethics committee at the College of Business and Economics, Mekelle University (MU) in Tigray, Ethiopia. The letter was referenced as CBE/4019/T-38, dated August 25/2020.

Since the research required human participation, the first step in undertaking the survey was to describe the research to participants identified for the sample, request

voluntary participation, and ensure their willingness to sign an informed consent document before commencing each interview.

The consent form stated the full right of the participants to withdraw from the research at any time and for any reason and (where relevant) omit questionnaire items or questions to which they do not wish to respond. In addition, it was made clear that the researchers are legally obliged to treat the collected data with full confidentiality and anonymity in compliance with the UCC and MU data protection policy.

Moreover, the participants were made aware that the information collected would be securely held for a minimum period of ten years after the completion of the research project. Participants were also informed that the results would highly likely be published in open access journals, presented in conferences, published as book chapters, or published as working papers or other forms of information dissemination technologies while properly maintaining the confidentiality and anonymity of the participants.

3.9. Limitations

The main household survey evaluated the food consumed by any member of the family over a period of 24 hours and 7 days, but foods consumed outside the home by any family member were excluded. This omission may result in an underestimation of the total household dietary diversity score (HDDS), especially for households with members who often eat out or attend social events and ceremonies where food is provided. However, considering that this is mostly a rural area with few big towns nearby, any such miscalculation is unlikely to be significant. Furthermore, the one-time data collected through the cross-sectional survey does not appropriately capture the dynamics in the consumption pattern of the households over time.

Self-reporting bias linked to correctly recalling the complete list of food items consumed in households over the past 24 hours or 7 days may result in data inaccuracies. Another potential limitation is that data collection took place after COVID-19 restrictions were lifted in Tigray. The negative effects of the COVID-19 pandemic on the income, market access, production, and consumption of smallholders might introduce errors that could alter the results. Furthermore, the

limitations of the cross-sectional nature of the data fail to capture any possible seasonal variations that could have reduced the extent of error in the data. The PDS has several identified drawbacks due to the possibility of double counting of specific food groups, notably animal items (Berti, 2015; Kissoly et al., 2020). A PDS value of two is reported for a chicken-keeping household since it may generate both meat and eggs. Similarly, a cow may provide three distinct food groups: meat, milk, and butter (oil food group). An ox, on the other hand, receives a score of one regardless of whether or not it is slaughtered in the given year. PDS is thus viewed as a tally of prospective food supplies from self-produced sources rather than an account of actual consumption.

Muthini et al. (2020) eliminated non-food crops from the PDS count. Although no non-food crops were identified in this study, I followed this example and excluded animals such as donkeys, horses, mules, and camels, since these are working animals and are not considered foods in the local culture.

These are the main materials and methods used to produce the four papers of the thesis. Specific details are presented in each paper in the following chapters.

CHAPTER FOUR

4. RAPID VALUE CHAIN ASSESSMENT IN GERGERA WATERSHED, TIGRAY, ETHIOPIA

4.1. Introduction

The Ethiopian economy is heavily dependent on smallholder agriculture that accounts for 85 % of the total agricultural output (Woldewahid G., 2010). Therefore, commercialization of smallholder agriculture is one of the strategies that have been given priority in the government's development plans. The National Regional State of Tigray, Northern Ethiopia, is characterized by smallholder agriculture with an average household land holding size of about 0.5 ha (Admasu et al., 2011). The people of the region have been engaged in prolonged and successive soil and water conservation activities through the direct involvement of the community, NGOs, donors and government agencies with the aim of improving the welfare of the smallholder farmers (Bachmann, 2009; ICRAF, 2018; Woldewahid G., 2010).

Irish Aid is one of the donors that have been engaged in soil and water conservation and irrigation development programs in the regional state of Tigray. The Gergera watershed project has been an intervention area for soil and water conservation initiatives of the Irish Aid Development Program since 1998 (Bachmann, 2009). The project site is in the Eastern zone of the National Regional State of Tigray. The watershed is found in Hayelom, a rural village district, which includes Gergera, Geter-Haiki-Mesihal and some parts of Damaino upper catchment.

Gergera watershed is found in Atsbi Wemberta, one of the 34 rural weredas of Tigray, located in the eastern zone about 65 km northeast of the regional capital, Mekelle, off the main road to the east departing at the town of Agula'e. The total area of the wereda is estimated at 1223 sq. kms with 16 peasant associations (tabias) and two town dwellers. Gergera Watershed is located within one of the 16 tabias, Hayelom and one of the town dwellers, Haikimeshal. The size of tabia Hayelom is about 90.2 sq. kms and Haiki-Mesihal 1.02 sq. kms (ICRAF, 2018). The wereda in general receives bimodal rainfall: *belg* (short rains) from November to March and *meher* (long rains)

from June to September. The short rains are not reliable enough for crop production except for growing short duration barley (locally known as *Sae'sa'a*), land preparation for the main rainy season and grass for livestock. The long rains are relatively more reliable than the short rains even though they could also fail due to climatic changes. Nearly all the cereals and legumes are planted during the main rains. The soil type of the wereda is highly dominated by Lithic Leptosols except for some Regosols, Cambisols and Fluvisols (Admasu et al., 2011). The average land holding size in the wereda is 0.5 hectare. The maximum holding size of households in the area does not exceed 1 hectare (Woldewahid G., 2010).

In Gergera watershed, there is huge potential for agriculture with the dominant crops being barley and wheat, and important marketable crops such as pulses like faba bean, field pea and lentils. Currently, due to the significant rehabilitation and soil and water conservation works in the village, irrigation schemes are being developed. With the development and increase in the number of irrigation schemes, vegetables, like lettuce, potato, tomato, spinach, cabbages and pepper; and tropical fruits like mango, papaya, avocado and orange are growing around the water ponds. Livestock rearing is an integral part of the farming practices in the area, including sheep and goats fattening, dairy, oxen and cow rearing. In addition to this, the enclosures on the conserved areas create better conditions for controlled fodder collection and integrated honey production (Gessesse, 2016; Gebremedhin Woldewahid et al., 2011; Meaza, 2010).

Despite the existing agricultural potential in Gergera, smallholder farmers struggle to commercialize their produce to get enough benefit from the growing urbanization in surrounding areas. They are facing constraints including lack of information, coordination, finance, and risks that ultimately impede their market participation and their income (Bachmann, 2009).

The potential to improve the livelihoods in Gergera through increased market orientation justifies a greater focus on developing value chains which meet consumer needs while providing real benefits to producers. The value chain analysis, however, requires a detailed examination of the market. Market chain analysis identifies and describes all points in the chain (producers, traders, transporters, processors,

consumers), prices in and out at each point, functions performed and the features of the market, and the constraints and opportunities for the products (Hobbs, 2000).

This research is, therefore, aimed at conducting a rapid market assessment, with the intention to provide a preliminary analysis of the value chain of some selected agricultural commodities produced in Gergera Watershed, namely: honey, dairy, fruits, vegetables, sheep and goats. This preliminary study aims to provide some initial information for the detailed value chain study planned to be carried out. The assessment is designed to provide reliable estimates of the current scale of production, particular features of the products, the actors and prices in the market (including focusing on seasonality and which groups are particularly involved), a summary description of the nature of the value chain (i.e. short- or long-value chains), the potential for increase and deliver multiple benefits (such as, improvements in nutrition and women's empowerment).

4.1.1. General Objective

The general objective of this study is to undertake a preliminary market value chain assessment of some selected agricultural commodities: honey, dairy, fruits, vegetables, sheep and goats in Gergera Watershed, Tigray.

4.1.2. Specific Objectives

The specific objectives of the assessment are to:

- ✓ Assess the nature of the value chain for the selected agricultural commodities produced in Gergera Watershed
- ✓ Examine the existing scale of production of the selected agricultural commodities
- ✓ Analyze the typical features of the commodities, the actors and the prices in response to seasonal variations
- ✓ Identify current constraints to further development of the value chains

- ✓ Identify the potential for improving the quantity, quality and benefits of the commodities, including a focus on the potential to deliver multiple benefits (such as, women's economic empowerment, improved nutrition).

4.2. Methodology

4.2.1. Description of the Study Area

Gergera watershed (Figure 1) is located in the Eastern zone of the National Regional State of Tigray, Northern Ethiopia. The watershed is found in a village district known as Hayelom. It includes Gergera, Geter-Haiki-Mesihal and some parts of Damaino upper catchment. Geographically, Gergera watershed is located between 13.043 and 13.046N latitude, and 39.040 and 39.045E longitude, and covers an area of 2,302 hectares. The watershed drains into the Birki /Agula River with a stream length, from the outlet of Gergera, of 149 km (Woldewahid G., 2010). A watershed is a surrounding where different river streams drain into specific junction of an outlet of land or water body, regardless of the size of the territory (Wolter, 2017). Watershed development is therefore an intervention in such geographically delineated areas, with the aim of ensuring a sustainable use of resources through preserving ecosystems and biodiversity, optimizing resource productivity and improving human livelihoods and well-being (Wolter, 2017).

Watershed development can be a "Targeted Approach"- specifically aimed at improving water resources and hydrologic outcomes or an "Integrated Approach"- with broader goals and objectives, such as sustainable land and natural resources management, poverty reduction, and rural development (Smyle J., 2014). The watershed development intervention in Gergera can be an example of an integrated approach targeting to achieve some of the Sustainable Development Goals (SDGs) (FAO, 2017), through protecting and restoring terrestrial ecosystems (SDG 15), combating climate change and its impacts (SDG 13), ensuring sustainable water management (SDG 6), ending poverty (SDG 1) and achieving food security, improved nutrition and sustainable agriculture (SDG 2) (ICRAF, 2018).

Climate: According to the local agro-ecological classification, the climatic zone of Gergera watershed lies in *Dega* (highlands) and *Woyyna- Dega* (middle lands) areas,

with an altitude ranging between 2,066 and 2,505 meters above sea level. The climate is characterized as semi-arid, with temperatures ranging from 15°C to 25°C. The mean annual rainfall of the watershed varies between 450 and 600mm, with one rainy season in summer months stretching from June to September (ICRAF, 2018).

Population: The total population size of Hayelom districts is estimated to be 8,660 according to the Ethiopian population estimation of 2018. The watershed is dominated by female residents, accounting for about 5,375 compared to 3,285 for their male counterpart. Of the total population living in the district of Hayelom, 6,640 are believed to be the inhabitants of the watershed area. The male population here is 2,635 compared to 4,005 females. There are about 837 male, and 541 (39%) female headed households in the watershed (ICRAF, 2018).

Economy: There were 2,137 Holstein Freisian (American, given local name), 3,103 local and 37 Begait, local breed, cows; 674 honeybee colonies in the modern hive and 490 honeybee colonies in the traditional hive; and of the total cultivated area of 7,405 ha, only 608 hectares was under irrigation in Tabia Hayelom in 2006 (ICRAF, 2018). More than 3,000 improved/grafted avocado seedlings, 600 guava and 400 papaya fruit trees were planted in cluster bases in 100 farmers' fields (20 Female and 80 Male household heads) (ICRAF, 2018).

4.2.2. Commodity Selection

This study conducts a rapid value chain assessment of the following selected commodities: honey, dairy, fruits, vegetables, sheep and goats. Summary details on the agricultural commodities selected for the study are presented in Table 1 below.

Table 1 Summary of the selected agricultural commodities, by product group

Study Site	Vegetable group	Fruit Group	Dairy Group	Honey	Small Ruminant group
Gergera Watershed	Tomato	Orange	Milk	Honey	Sheep
	Spinach	Banana	Butter		Goat
	Lettuce	Avocado	Cheese		
	Green chill	Apple			

	Onion	Papaya			
	Garlic				
	Potato				
	Cabbage				

4.2.3. Description of the Value Chain Actors

Table 2 below establishes the sample representation of the market actors for each of the agricultural commodities selected for the study. Non-probabilistic sampling was used to collect data from a total of 205 market actors in the project area. To have a good representation of the community, quota sampling was used. The producers and wholesalers of the selected commodities were represented from the three village districts. 180 farmers and 20 wholesalers of the selected agricultural products were included in the study.

Table 2 Description and sample size of the value chain actors and service providers in Gergera Watershed

S/N	Commodity	Actors				
		Farmers	#	# Tabias	Wholesalers	#
1	Vegetables	Smallholder farmers	12	3	big stores/cooperatives	5
2	Fruits	Farmers	12	3	Big Stores/cooperatives	5
3	Dairy	Private/ cooperative dairy producers	12	3	Cooperatives	5
4	Honey	Private/cooperative Bee	12	3	Cooperatives	5
5	Sheep and Goats	Animal rearing household	12	3	Local traders	5
	Total		180			25

The information collected from those market actors was helpful to analyze the scale of production, the features of the production system, the nature of the value chain, the main markets for the commodities and the information on prices and seasonal price fluctuations in Gergera Watershed.

4.2.4. Data Sources

The sources of data used to carry out the study include documents of various types, focus group discussions with the agricultural producers, farmer's cooperatives and wholesalers, and key informant interview with market experts and local government officials.

4.2.4.1. Literature/Document Review

Reports from the wereda and tabia level agriculture and rural development offices were collected and reviewed. Secondary data from plans, reports, and published and unpublished research outputs on the project activities were consulted. The reports and secondary documents collected from the wereda were not detailed, since they were compiled reports about tabia Hayelom in total and did not give kushet¹-specific pictures. Therefore, the study was highly dependent on the reports and secondary documents collected from the tabia office of Agriculture and Rural Development. Even so, there are major contradictions regarding the data on the scale of production in each kushet in the watershed. Data at the lower level of public administration is more realistic than at the top. It is likely that numbers are inflated as reports go up through the hierarchy. Therefore, in this study I was forced to take the average numbers, while computing the scale of production and productivity of the selected commodities.

4.2.4.2. Focus Group Discussion (FGD)

Primary data was collected using Focus Group Discussions (FGD). Convenience sampling was used to select farmers for discussion. A focus group discussion of six farmers for each of the selected agricultural products was held in the three tabias. It was planned to contact a total of 180 producers from the three village districts for the five selected commodities (6x2x3x5), but ultimately, only 142 farmers (74 male and 68) were contacted. A total of 18 women headed households could not be contacted as planned because there were no women involved in the production of honey, either in a cooperative association or as private producers. The remaining 20

¹ Kushet is the lower governance structure in the hierarchy of the public administration levels in Tigray. The largest governance structure being the Region, followed by Zone, Wereda, Tabia (or Peasant Association), Kushet and finally Goot.

household heads missed the discussion due to absence or late arrival in the group discussion. Except for the honey producers both men and women producers for all the remaining selected agricultural products were contacted. In addition, it was planned to hold a focus group discussion with groups of wholesalers for each of the selected agricultural commodities comprised of 5 traders (25 in total for the 5 selected commodities) in the local markets, however, it couldn't be conducted due to repeated cancellation and inability to fix a common convenient date.

4.2.4.3. Key Informant Interview (KII)

The KII help to collect data about the scale of production, the features of the production system, the nature of the value chain, the main markets for the commodities and the information on prices and seasonal price fluctuations from local officers, market experts in the wereda, development agents and tabia and kushet level administrators. Five key informants, comprising local government officials and market experts with understanding and experience about the market in Gergera, were selected by convenience method and included in the survey. The selected key informants contacted were the wereda agriculture and irrigation expert, the wereda cooperatives and market expert, the tabia chairperson, the tabia office of agriculture and rural development head, and a transport service provider (owner and driver of Isuzu truck).

4.2.5. Data Analysis

4.2.5.1. Thematic Analysis

I employ a thematic method to analyze our qualitative data (Castleberry and Nolen, 2018; Kiger and Varpio, 2020; Lochmiller, 2021). The material gathered through the FGD and KII has been transcribed and coded based on certain subjects. The selected themes were agricultural production variety, access to transportation services, agricultural commodity prices, seasonal production and market affecting variables, and the involvement of the government and private sectors in agricultural commodity value chains. The refined concepts were interpreted and narrated, with the outcomes debated.

4.3. Findings and Discussions

The findings of the assessment and detailed discussions are presented below for each of the selected agricultural commodities.

4.3.1. Fruits Market Value Chain

4.3.1.1. Introduction

Growing fruit trees has long been practiced in tabia Haylem. However, there were very few individuals involved growing one or two fruit trees mainly for household consumption. Mass production of fruits started in 1991 to 1995 with the introduction of irrigation schemes (Bachmann, 2009). The development of irrigation and soil and water conservation activities, with the support from government and non-government organizations, encouraged farmers to participate in fruit production and intensified agriculture for commercialization. Initially, the government and non-government organizations through the BoARD² were disseminating different types of fruits seedlings to the farmers. The farmers lack knowledge and experience towards the challenges and the benefits that could be obtained from fruit production. Hence, the decision to allocate 0.5 to 2 tsimads³ of land (0.125 to 0.5 hectare), for about 2-6 years till the fruit trees began production couldn't be easy. Most of the farmers were also worried about the unknown future of the planted fruits trees, for example in relation to quality, market availability etc. These, and other reasons, meant it took longer for most farmers to start to engage in fruit production. Many farmers have no fruit and others have just introduced a few trees (Meaza, 2010).

4.3.1.2. Characteristics of Fruits and Fruit Producers

Currently, the farmers have adopted two methods for irrigation: river diversion and using motor pumps from rivers, springs and wells. The second scheme of irrigation is the most common technique in the watershed. Different types of fruits grow in Gergera watershed using the irrigation methods. The most common fruits growing are guava, papaya, mango, avocado and orange. Of those fruits, guava, is the dominant one. The farmers prefer guava because it has short gestation period, bigger

²Bureau of Agriculture and Rural Development

³Tsimad is equivalent to 0.25 Hectare of land

and more frequent harvest (at least twice a year, whereas all the other fruits mentioned here can be harvested once a year), familiarity and high demand in the local market, and its disease and drought resistance ability are also other reasons for guava production. There are some papayas producing farmers in Gergera and very few mango and avocado producers in Geter-Haiki-Mesihal and Damaino. Both the grafted and non-grafted fruits of avocado have also been introduced.

Avocado has better demand in Wukro and Mekelle while guava has a better market in Haiki-Mesihal, Atsibi and Agulae towns. The people in these local markets are not familiar with avocado and mango fruits and there is therefore lower demand. Even so, some farmers prefer producing avocado more than guava, as it is sold at higher price in other markets, understands the higher demand in big towns, while it can be stored for up to two weeks after harvest; whereas guava cannot be stored if ripe enough; guava also has lower market price due to excess supply in local markets and lower demand in big towns. Orange fruit growing in the watershed is very limited and is of lower quality. The low quality of the fruit is due to the wrongly grafted or inappropriate seedlings given to the peasants, as they mentioned in the group discussion.

Most commonly, guava has two harvesting seasons per annum, September to November and March to May; avocado and papaya are harvested in the summer season, June to August.

Though there is no clear gender-based classification of duties for fruit production in the watershed, there is a slight gender-based division of labor particularly in male headed households. According to this division, the women are expected to retail the fruits in the local market, whenever necessary, while the men are involved in farming, harvesting and wholesaling in the big markets, outside the wereda⁴.

⁴Wereda is the third major administrative level in the regional states. The highest is the region, the second the zone, the third is the Wereda, followed by Tabia, Kshet and the lowest political (public) administrative unit is the goot.

4.3.1.3. Scale of Fruits Production

The potential for fruit production in the watershed is believed by the farmers and the BoARD to be as much as twice or three times the current production level. The potential in Damaino, in particular, is said to be very high. According to the data from the tabia office of Agriculture and Rural Development, currently the watershed is producing more than 7,500 quintals of guava and 3,100 quintals of avocado in a single harvest. However, there are other fruits that are planted but not yet producing fruits.

Table 3 below depicts the current scale of fruit production in the Gergera watershed.

Table 3 Fruit Production Scale in Gergera Watershed Classified based on Fruit Varieties and Sub-districts

S/N	Type of Fruit	Kushet/Sub village name	Number of fruit trees	Male producer	Female producer	Fruit Production per tree (quintals)	Total Production scale (quintals)
1	Avocado	Damaino	367	36	3	4	1468
		Geter-Haiki-Mesihal	409	40	8	4	1636
		Gergera	11	0	3	4	44
2	Guava	Damaino	268	24	2	15	4020
		Geter-Haiki-Mesihal	230	33	3	15	3450
		Gergera	15	3	0	15	225
3	Mango	Damaino	0	0	0	0	0
		Geter-Haiki-Mesihal	5	1	0	5	25
		Gergera	0	0	0	0	0
4	Papaya	Damaino	0	0	0	0	0
		Geter-Haiki-Mesihal	20	1	0	-	-
		Gergera	425	38	16	-	-
5	Apple	Damaino	20	24	2	-	-
		Geter-Haiki-Mesihal	0	0	0	0	0
		Gergera	0	0	0	0	0

Source: Tabia Agriculture and Rural Development Office; March 2019

Of this fruit production capacity, 53% of guava and 47% of the avocado production is obtained from kushet Damaino. At this stage these two types of fruits are reported to be the dominant and output bearing fruits in the watershed.

4.3.1.4. Fruits Markets

The farmers use different markets to sell their fruit. The most common markets for the producers are: Haiki-Mesihal town (Haiko, according to its residents' naming), Atsibi (particularly, for Gergera producers), Agulae (particularly, for Damaino farmers), Wukro, Mekelle and sometimes Des'a. These locations have different market days during the week; therefore, it provides an opportunity for producers to have access and look for better demand and prices for their output. The market day in Haiki-Mesihal town is on Saturday (and mini market on Monday), Atsibi on Saturday, Wukro on Thursday, Agulae on Wednesday (mini on Saturday) and Mekelle on Monday. However, most of the guava fruits are sold in Haiki-Mesihal town on both market days (Saturday and Monday) due to shortage of transport, lower market demand in other markets and saving time. When there is higher demand wholesalers and retailers come to Haiki-Mesihal town (even to the farmland) to buy fruits; whereas when demand is lower and prices fall, the farmers are forced to sell at an unfairly lower price and/or retail their fruits to consumers, all by themselves.

4.3.1.5. Fruits Prices

Prices of the fruits produced in the watershed show seasonal variation across the production year. The price of guava declines significantly in October to November due to the higher supply and the limited market in Haiki-Mesihal. On the other hand, its price increases in March and April due to lower supply and higher demand on account of the biggest Ethiopian Orthodox Church fasting period⁵. The price of guava per kg falls as low as 3 ETB⁶ and rises as high as 12 ETB. Avocado and papaya prices do not

⁵The Ethiopian Orthodox Church celebrates its biggest fasting period starting from Mid-February to Mid-April, for 55 days, every year. At this time the followers of the religion forbid themselves from consuming meat, milk, egg and their respective products. Instead, the people consume vegetables, fruits, cereals and their respective products. This has the biggest impact in households' consumption decision making and significantly influences demand and prices of commodities.

⁶ ETB refers to Ethiopian Birr. Birr is the official name of the Ethiopian currency. All currency values are expressed in Ethiopian Birr (ETB).

show much price fluctuation, because the productivity and the supply are still at the lowest level, as compared to the demand in the big markets.

Most of the time, farmers sell their fruits to the retailers in Haiki-Mesihal town. They carry their output using Wood crate⁷ (a kind of ventilated box made of wood which can contain 45-50 kg of fruits). The average selling price of guava per wood crate is 400 ETB and its retail price is around 600 ETB; the average selling price of Avocado is 700 ETB /wood crate, and the retail price is 1000 ETB /wood crate.

The seasonal price variation has its own positive and negative effects on the market challenges and particularly on transport, as explained by the farmers. When demand for fruit is higher in the market in general, traders (wholesalers and retailers) come as deep as the farmland, harvest by themselves and this gives the producers a better position to bargain, solve all the costs and the nasty transport challenges, eliminates the risk of damage and losses during loading (unloading) and transport. By contrast, the opposite holds true when there is excess supply and lower demand and prices in the market, with adverse implications for logistics and the level of losses.

4.3.1.6. Communications and Contracts

The terms and conditions of transactions of fruits are verbal and mostly based on mutual trust. The trading partners communicate on the quantity and price of exchange using mobile phones and face to face communications. However, the main communication channel with the traders and transport service providers and to assess market prices is using phone calls. Since there is no permanent fruit purchaser in any of the markets, there is no contractual agreement on terms and conditions of exchange.

4.3.1.7. Transportation

Harvest and transportation of fruits from the farmland to the market starts on the eve of the market days. The most common means of transport from the farmland to the local market, Haiki-Mesihal town, is using donkeys, human labor and carts, ranked respectively. The route may take four different forms: 1. traders may directly come

⁷ Wood crate is a ventilated box made of wood most commonly 50 cm long, 40 cm wide, and 30 cm high. It contains 45-50 kg of fruits and vegetables like banana and tomatoes.

along with their vehicles to the farm land (or to the nearest possible area of the farm land, as most of the farm lands are not accessible to vehicle transport) and take the produce to Mekelle and sometimes Wukro; or 2. carts may be used to transport the harvested fruits to Haiki-Mesihal town to be sold there or to be transported to other markets (Wukro and Mekelle), 3. Donkeys may be used to transport the fruits directly to be sold in Haiki-Mesihal town/Atsibi (particularly from Gergera kushet) or to make ready for further transport to Mekelle and Wukro, 4. Human labor (owner, including his/her children, relatives or hired) may be used for the same purpose.

The charge for cart and human transport from the farmland to Haiki-Mesihal is 5 ETB to 10 per wood crate (distance and ease of access determines the cost). Vehicle (Isuzu truck) transportation to Wukro costs 10-15 ETB per Wood crate and 20-25 ETB to Mekelle. The farmers pay 10 ETB per person to Wukro and 25 ETB to Mekelle, on public buses. However, this price increases as much as twice the average on market days.

4.3.1.8. Challenges

The biggest challenge in the watershed in relation to the fruits market is access to easy and safe transport, which emanates from the rough, dusty and unrepaired or unpaved roads. Most of the transport service providers do not want to go to Haiki-Mesihal. Thus, there are very few vehicles providing transport in the town, mostly owned by residents of the Haiki-Mesihal town. This limited access to transport gets worse during harvesting seasons. The harvest season for most fruits overlaps and every producer wants to get his/her fruits sold fresh. This creates greater demand for transport services and hence puts further pressure on the limited service.

There are times when producers are forced to stay as long as three days, along with their harvested fruits, to wait for transport services. They carry their fruits to the roadside every morning and bring it back to a nearby relative's or friend's house in the evening. This exposes the fruits to day-long sunshine and dust in addition to the frequent loading and unloading to and from the house, resulting in spoilage. This problem is severe in kushet Damaino, even though it applies to all the kushets. This is because kushet Damaino is the dominant fruit and vegetable producer, but it has

no bus or vehicle station. People must travel to Haiki-Mesihal (and back) to get the cars and come by through Damaino to go to Agulae, Wukro and Mekelle. The Isuzus and other vehicles are willing to load fruits from Damaino if they couldn't get a full load in Haiki-Mesihal town. The problem, serious and is costing much to the producers.

There are three-wheel vehicles (locally named as *Bajaj* and *Mehandra*) that wait in Birki, the last asphalt road from Agulae to depart to tabia Hayelom, 16 km from Haiki-Mesihal and 7 km from Damaino. The farmers sometimes must bring their fruits on the back of donkeys or use a cart to get access to the asphalt road and to get this transport service. Following this route means targeting to sell their fruits in Agulae and to do so they have to start the journey getting up as early as 3:00 am, otherwise they may not get the right price for their products because the market might already be supplied with enough of that commodity. The long-distance use of donkeys may also damage the quality of the fruits, due to the shaking along the ups and downs in the gravel road; this, hence, significantly influences the price of the fruits in the market. A similar case is that of the Gergera kushet producers when following the direct route to Atsibi town, on Saturdays. Fruit producers must travel as far as 20 kms on foot and they are forced to travel as long as the whole night to get to the market as early as possible. When transporting the fruits on the back of their donkeys they usually try to minimize the damage by using different leaves, clothes, and sacks for protection, but guava fruits are not very safe even using this method.

The other challenge mentioned by the farmers is related to the volatility of fruits prices. Prices are not only variable across seasons, but also within hours on the same market day. Participants mentioned “... *for unknown reasons...and even due to fake rumors... prices keep changing in relation to other markets such as Mekelle, in particular, in minutes on phone communications. There are market agents who are actively involved in such activities*”. Many in the discussion also indicated that “*the agents sometimes cheat and harass the farmers unreasonably. This particularly happens when the farmers try to sell their products by themselves (as street vendors) in Mekelle and Wukro to avoid selling their fruits at unreasonably lower prices. This harassment and violation of the rights by individuals (especially, agents) is made on*

the basis that farmers have no right to sell their product in an area where they did not pay tax for the government.” The participants indicated that these and other inconveniences force the farmers to sell their fruit at an unfairly low price.

The other issue is that, once the fruits are ready to be harvested, they have to go to an everyday market rather than weekly or bi-weekly ones. Fruits are demanded fresh. However, there is a lower probability of selling the fruits from the watershed as fresh. This in turn reduces the quality and the prices of the fruit and ultimately reduces the benefit to the producers. One method to reduce this challenge may be by adopting new technology for processing fruits. This may include training and awareness creation about the care and protection that should be provided during the growth, harvest and post-harvest to optimize the quality and durability of the fruits. Moreover, the introduction of fruit processing technologies for example guava juice, guava jam and toffee are some important products that can be produced using light machinery (Kumari, 2017).

The following are some of the experiences and incidents mentioned by the farmers during the Focus Group Discussions (FGDs) in Gergera Watershed

There is one typical incident raised during our discussion with Damaino’s male fruit producers. “I am a farmer from Damaino, I went to Mekelle to sell 27 wood crate (around 14 quintal) of guava. Unfortunately, by the time I arrived there, the price was too low to accept. Hence, I decided to leave all my fruits with my loyal wholesaling customer in an agreement to get some money if the fruits were sold and I went back to his village. After a week, I went back to Mekelle to collect the money from the wholesaler. Very sadly, the wholesaler told me that he owed me 60 ETB, for he has paid that amount of money to dispose of the spoiled fruits from his store”.

Another experience was that “A trader used to buy some boxes of fruits from different farmers on loan, in the name of a loyal customer. But ultimately, he denied them all. The case went to the court, the trader was forced to pay, but he managed to pay only part of the amount he took from some of the farmers and denied the others.”

A farmer from Geter-Haiki-Mesihal said this “Even though we had lots of issues in relation to the violation of our rights and breaking of promises, we couldn’t sue them in the courts, for fear of losing even these unhealthy trade relations.”

“There are also times when we are forced to distribute the harvested guava fruits to the students in Damaino elementary school and sometimes we give the fruits to our cattle. This happens either due to the shortage of transport or due to the excessive price reduction. For the fear of such incidents, we just want to sell our products at whatever price is determined in our local market” said a women fruit producer from Damaino.

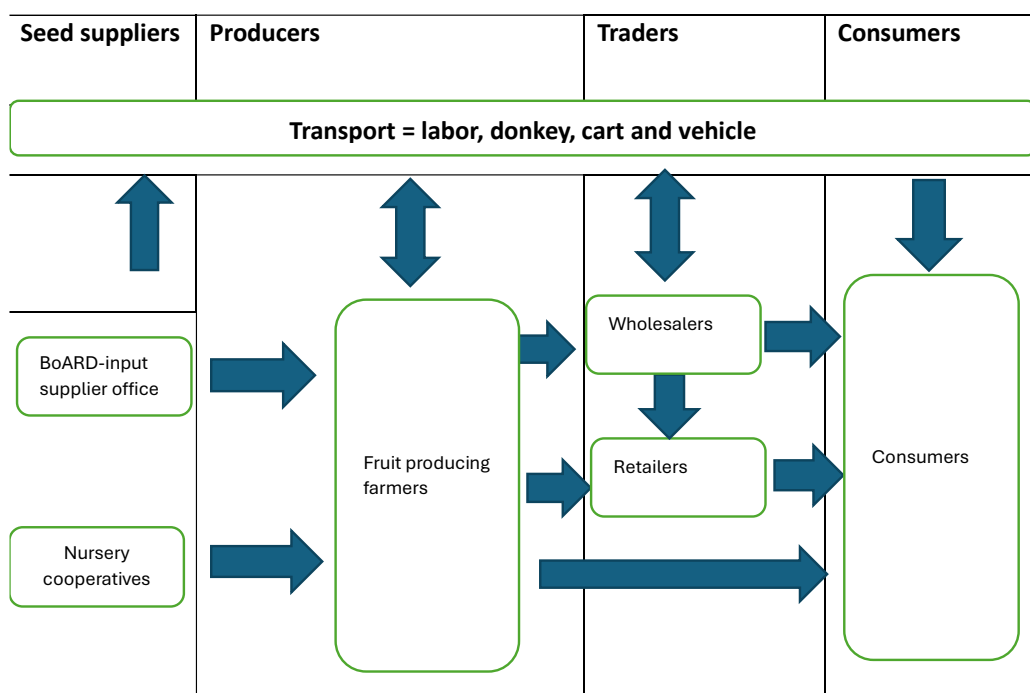
The other typical and serious problem raised in Geter-Haiki-Mesihal is that of the destruction of fruits and vegetables by apes and monkeys. *“These wild animals” said a farmer, “are severely attacking not only our fruits and vegetables but also the newly born sheep and goats. An estimated area of 50 tsimad/12.5 hectare of irrigable land in Katun, Geter-Haiki-Mesihal, is abandoned from cultivation for fear of these wild animal attacks.”*

The public institutions run by the BoARD such as the agricultural office, input suppliers and the agricultural extension workers contribute to the promotion of fruit farming, provision of fruit seedlings, and on planting and harvesting.

4.3.1.9. Recommendations for the Fruit Sector

The main challenge in fruit production is access to a suitable market. This problem is due to the limited access to the market (transaction is possible only on the market day, once or twice a week), poor roads, and limited transport service. To address these problems, a few recommendations can be considered, but all would require detailed feasibility study. These include the upgrade of roads to Gergera; establishment of a farmer-run fruit purchasing union to coordinate supply to the market, in appropriate volumes; development of agro-processing facilities on a cooperative or private-investor basis; introduction of a fruit-transporting truck on a cooperative or private-investor basis that would specifically serve for producers in Gergera area.

Figure 3 The Fruits Market Value Chain Map



4.3.2. Vegetables Market Value Chain

4.3.2.1. Introduction

Commercialization of vegetables in the Gergera watershed started in 1992/93 (Bachmann, 2009). The farmers used to water their vegetables by fetching water from rivers and springs before the diversions were built. The sole purpose of the production was household consumption. Currently, many households in the watershed produce vegetables for commercial purposes. The common vegetables grown in Gergera watershed are tomato, green chill, cabbage, kale, lettuce, onion and garlic. Apart from those vegetables, the farmers in the watershed also use their irrigable land to plant maize/corn interchangeably. Corn is categorized as one of the cash crops (to be sold raw) and believed by the farmers to be equally beneficial as

vegetables. The farmers cultivate multiple types of vegetables at a time on the existing limited tsimad of land with the objective of diversifying risks related to price changes. In vegetable production there are no clear gender-specific duties, however, more male headed than female headed households are engaged in this production.

4.3.2.2. *Characteristics of Vegetables and Vegetable Producers*

Most of the time vegetables are harvested twice a year 1) January to March and 2) June to September. These two harvesting seasons have their own specific characteristics. The first period is a lean/fasting season for Orthodox Christian Church religious followers. Given the suitability of the weather conditions and the expected excess demand for vegetables in the first season, every farmer wants to produce and sell at these times. Thus, there is mass production and stronger demand, hence average prices are recorded in the market. On the other hand, the second season (June to September) is not convenient for vegetable production, because it is rather suitable for the reproduction of insects and pests that can destroy the entire vegetables planted. Thus, it is hard for the producers to get a significant harvest, and relatively few farmers take the risk to produce at these times to benefit from the limited supply and higher market prices.

There are typical vegetable seed varieties that the local farmers prefer more than others, for example small green chill variety (locally known as mitmita) and a small sized onion variety (Kesela onion) are preferred more than the ordinary ones. Nonetheless, farmers raise serious concern about how to switch from the production of tomatoes to other vegetables due to the risk of being affected by a 'dangerous weed' locally named *Meselem*, which can significantly destroy tomato plants before it gives any output. The farmers call *Meselem* 'a plant cancer', that, according to the explanation of the farmers from Damaino, "replicates itself multiple times whenever one cuts it at a time. It grows on the roots and sticks on the tomatoes' tree". The peasants said that "they have repeatedly reported it to the BoARD but could not get a real solution" while the office responded that 'they are aware and have reported it to the wereda, though there is little practical response'.

The farmers also prefer spinach/kale, green chill, and onion because they can be stored for as long as two weeks after the harvest. Women headed households on the other hand prefer spinach/kale, cabbage, lettuce, and green chili, as these vegetables demand comparatively low labor; spinach and green chill can be re-harvested up to three times once planted; cabbage is drought- and disease- resistant and can be stored till the market price revives; lettuce has shorter gestation period, it needs 1-2 months to grow and it has good market demand, tomatoes need 6 months to grow, spinach 3-4 months, green chili 5-6 months, and cabbage 6 months). Maize/corn is a substitute for vegetables in the irrigation sites in Gergera watershed.

Though the irrigable land holding size of the households in Gergera watershed ranges from 0.5 – 2 tsimads of land, the maximum irrigable land holding size for women headed households is 1 tsimad, which is equivalent to $\frac{1}{4}$ of a hectare. Using this land, on average it is possible for the farmers to harvest about 5 quintal of vegetables per tsimad per harvest.

According to the farmers who participated in the group discussions, they purchase vegetables seeds from supermarkets and/or they themselves preserve them from their own or their neighbors' better vegetable seeds. The BoARD has a variety of vegetable seeds at its stores, but farmers reported a very bureaucratic process in buying even a handful of seeds. Moreover, the quality of the seeds provided by the office is said to be low, their price is relatively high and the varieties not the ones preferred by the farmers.

4.3.2.3. Scale of Vegetable Production

The scale of vegetable production in Gergera Watershed is increasing over time, according to the farmers' observation. The most common vegetables growing in the watershed are onion, garlic, spinach, lettuce, cabbage, tomato and green chili. Damaino, Geter-Haiki-Mesihal and Gergera kushets are ranked respectively in their order of potential for vegetable production. In the year 2018 more than 16,500 quintals of vegetables were harvested in a single season. More than 40% or 6,690 quintals of the production in the watershed was tomato. Kushet Damaino's share of

vegetable production in the harvesting season was about 39% of the total vegetable production in the watershed.

The details of the scale of production from a sample of the 2018 harvesting season (January to March) are presented in Table 4 below.

Table 4 Scale of Vegetable Production in Gergera Watershed Classified Based on Vegetable Varieties and Sub-districts

S/ N	Type of vegetable	Kushet/Sub village name	Tsimad of land covered by the vegetable	Male produc er	Female produc er	Estimated Vegetable Production per tsimad (quintals)	Total Production scale (quintals)
1	Green chill	Damaino	36.25	136	15	59	2138.75
		Geter-Haiki-Mesihal	9.5	27	4	59	560.5
		Gergera	9.5	24	1	59	560.5
2	lettuce	Damaino	0.75	3	0	37.5	28.75
		Geter-Haiki-Mesihal	10.25	35	5	37.5	384.37
		Gergera	7.125	18	11	37.5	267.18
3	Onion	Damaino	27.125	78	4	42.5	1152.81
		Geter-Haiki-Mesihal	7.5	22	1	42.5	318.75
		Gergera	5.5	13	2	42.5	233.75
4	Tomato	Damaino	36.875	141	17	67.5	2489.06
		Geter-Haiki-Mesihal	27.125	134	16	67.5	1830.93
		Gergera	35.125	148	15	67.5	2370.95
5	Spinach	Damaino	1.5	10	1	62.5	93.75
		Geter-Haiki-Mesihal	13.75	41	2	62.5	859.37
		Gergera	8.75	11	5	62.5	546.87
6	Garlic	Damaino	6.5	22	3	15	97.5
		Geter-Haiki-Mesihal	0.875	7	0	15	13.12

		Gergera	3.25	11	5	15	48.75
7	Cabbage	Damaino	3.25	36	5	62.5	515.62
		Geter-Haiki-Mesihal	21.025	59	3	62.5	1343.75
		Gergera	11.25	29	13	62.5	703.12

Source: Tabia Agriculture and Rural Development Office; March 2019.

4.3.2.4. Vegetable Markets

The vegetable producing farmers sell their output to wholesalers coming from Mekelle, Adigrat and Wukro; retailers in Haiki-mesihal town, Agulae and Atsibi; and consumers in Haiki-Mesihal, Atsibi, and Agulae. Most of the time prices are determined by the wholesalers and the retailers. Given the relatively higher production and shorter gestation period of vegetables, producers are better off than fruit producers. Moreover, the short growth period of vegetables provides an opportunity to switch production to the preferred marketable commodity.

The vegetable producers in the three kushets have their own preference regarding the market for their products. The farmers in Gergera prefer to go to Atsbi for wholesale and they go to Hayko, (Haiki-Mesihal town) only for retail because they believe that the price is not attractive as compared to Atsbi's. Hayko is the most preferred market for Geter-Haiki-Mesihal producers for its ease of access in short distance. Damaino farmers on the other hand prefer to go to Agulae for greater market benefit. However, the center for all the three districts of the watershed is Hayko, Haiki-Mesihal town, and all the farmers trade in this town, although with varying degrees.

In general, the majority of the farmers' products are sold while the remaining small part is used for household consumption. More sales and less household consumption are undertaken when prices are higher and vice versa.

4.3.2.5. Vegetables Prices

Prices for vegetables are higher in the summer season, June to September, average in the fasting period February to April and cheap in the remaining months. This is because the summer season is very harsh for vegetable production; hence the supply of vegetables is lower in the market, while the second highest prices are in the fasting

period, with more demand plus more supply creating an average price; for the later periods there is moderate supply in the watershed but more in other areas and demand is not as high as the other seasons, thus price is lower.

In general, average vegetable prices for the farmers range from 5-7 ETB when it is cheap and 16-18 ETB when it is expensive; while the average retail price of the same vegetables is 8-10 ETB when it is cheap and 20- 22 ETB when it is expensive. Given the efforts exerted by the farmers, they believe that the traders and most importantly wholesalers enjoy most of the benefit from the market chain.

Prices for vegetables are highly volatile with seasonal supply variation. This variation strongly influences the returns on investment costs made by the farmers. For example, it is difficult to preserve or store tomatoes if they are ripe enough. For this reason, the farmers harvest on the eve of the market day, regardless of the market price. Thus, the price of tomatoes per wood crate (a box that can contain 45-50 kg of tomatoes) reaches as low as 20 - 40 ETB from as high as 480-580 ETB per Wood crate, during the expensive periods. A women participant from Gergera explained the situation this way and said, *"Sometimes we even beg the traders to take our products at any price they want rather than carrying it back home"*. Another woman participant from Damaino said, *"After such repeated experiences I began to think if it is better to start to produce spices and leave vegetable cultivation."* *"A farmer had been forced to make the worst decision..."* said a participant in the FGD from Geter-Haiki-Mesihal, *"he sold his tomatoes for only 0.10 ETB (10 Cents) per kg in Mekelle rather than taking it back home at a higher transport cost or even paying high disposing cost for the municipality"*.

The average prices of the most common vegetables growing in Gergera watershed per kilogram range from: spinach 3-5 ETB, green chili 25-36 ETB, tomatoes 10-15 ETB, onion 8-15 ETB, garlic 30-40 ETB and cabbage 5-8 ETB.

4.3.2.6. Communication and Contracts

Communication on the quantity and price, be it among the farmers themselves, the farmers and the traders or the farmers and transporters, is usually by mobile phone. The interaction among the different parties is based on trust and there are no formal

contractual agreements made on the terms and conditions of the transactions. However, there are a few cases that end up in court for breaking promises. On the other hand, the agricultural extension workers give advice, support, guidance, and marketing strategies regarding vegetable production though the commitment is not as it should be. The support from the agricultural extension workers in the tabia is more or less similar to all the selected commodities. Three things can be mentioned as possible reasons for this; 1. The number of experts compared to the size of the tabia is very few (only one natural resource, one irrigation, and one livestock development experts cover the entire tabia) 2. There is little capacity building training and practical skills 3. There are different overlapping and complex public duties and assignments. Overall, these factors have limited the efficiency of agricultural productivity in the area.

4.3.2.7. Transport Services

The most common means of transport in the watershed are donkeys and human labor, particularly from the farmland to the main street and sometimes to the local market also. However, every household does not possess donkeys. *“For example,”* said a woman from Damaino, *“I don’t have donkeys, but Hiwot (the name of a participant in the group) has; if we didn’t harvest vegetables on the same day, she lends me her donkeys. But if we harvest on the same day, as mostly do, because we harvest on market days, I must carry it by myself to transport to the main road or the market. Here you can guess how inefficient the mode of transport can be.”*

The transport problem influences the market access for all the selected agricultural products in Gergera Watershed. Similar issues were repeatedly raised by vegetable and fruit producers in the three kushets.

The three kushets in the watershed have access to transport through Damaino to Hayko to Gergera on a rough road. The farmers should provide their vegetables to the roadside or to Haiki-Mesihal town to get transport access. The farmers in Kushet Damaino pay 10 ETB per wood crate to Agulae, 20 ETB to Wukro and 10 ETB to Haiki-Mesihal town. A donkey-load of cabbage, spinach and lettuce costs 20 ETB to transport to Agulae or Haiki-Mesihal (twice the price of a wood crate). Those prices

are average transport costs charged in normal situations, however, there is no standard transport cost for any of the products to be transported. The cost of transport services depends on the number of people and the quantity of commodities ready to be transported rather than a tariff. In the market days and peak harvesting days in particular, the transport cost doubles for all commodities and people.

The vehicles with smaller carrying capacity, known as Mehandra and Bajaj, are preferred by the farmers in Damaino, because it has small carrying capacity and provides the service even for a single person with small quantity unlike the bus or Isuzu. Other small vehicles that can fit the small-scale production capacity of the producers do not usually come to the watershed, for fear of the rough road and its associated risk of damage on the vehicles. The main reason for the farmers' preference for the small sized vehicles, however, is that the Isuzu trucks (Isuzu are the sole transport service provider for vegetables and fruits) do not provide a service, unless there is a full load ready to be transported at a time. Neighboring farmers and friends need to communicate and collect a full truck load (50 quintals) of products before they can get the transport service of an Isuzu on nonmarket days. Given the farmers' limited scale of production, it is usually hard to get full of a lorry load harvest. A farmer may need to wait until his products get ready for a harvest while the harvest period for others' products has passed. Apart from this, the farmers need to pay double the ordinary transport cost to get the service if they want the service on nonmarket day, i.e., they need to pay double the price considering a full trip (going to and coming back from the market).

4.3.2.8. Challenges

The biggest challenge in vegetable production is related to access to transport and the resulting impacts on the quality and price reduction. There are times when there is not enough demand in the local market, nor transport access to other market centers on the harvest date. During those times the farmers gave the vegetables to cattle, particularly spinach, lettuce and cabbage. Most of the time farmers use donkey and human labor for transporting to roadside or to the nearest market, another rough road will follow if one wants to use vehicles: these stages of transport make the

farmers face a great deal of losses due to broken leaves (spinach and lettuce) and damaged or spoiled (tomatoes). This shortage of transport service, most of the time, forces the farmers to sell their products in Hayki-Meshal town, though they know that there is a significant price difference in other markets.

Carrying to the main road by itself is not a guarantee for getting transport service, the farmers need to wait on the roadside to get the service. After long hours' delay, one must be lucky enough to get the service. There is no certainty about getting it, particularly for the Kushet Damaino and Gergera producers. This is because there is no station for cars and they only pass through, to and from Haiki-Mesihal town. The farmers living there get the service if the vehicles are not fully loaded at Haiki-Mesihal town.

This problem of access to transport, along with the higher price for the service, limits the farmers' ability to compete with other producers in the market, be it in the quality or in the price aspect. For example, vegetable producers from Birki have easy access to fast and cheap transport services, hence, there is less damage to the vegetables during transport, and lower transportation cost. For this reason, it is less possible to compete with those producers. This problem makes the farmers in the watershed disadvantaged compared to other suppliers with better access to transport.

The other critical problem repeatedly mentioned during the discussion with the farmers is rust, a frost-like condition that devastates agricultural products of all types. The farmers said there is no method for prevention or for curing this problem. It destroys vegetables, fruits, crops, bee farming and even the fertility of cows, according to the farmers. For this reason, there is no guarantee of producing output if *rust* and powdery mildew are developed on the crops and grasses. Most of the time *rust* and powdery mildew are seen two times a year. It appears in October and January.

4.3.2.9. Recommendations to the Vegetable Sub-Sector

Better access to transport is a critical issue to consider in trying to solve challenges existing in the vegetable market chain. This may take a long time, but the problems can potentially be minimized through introduction of light technologies for vegetable

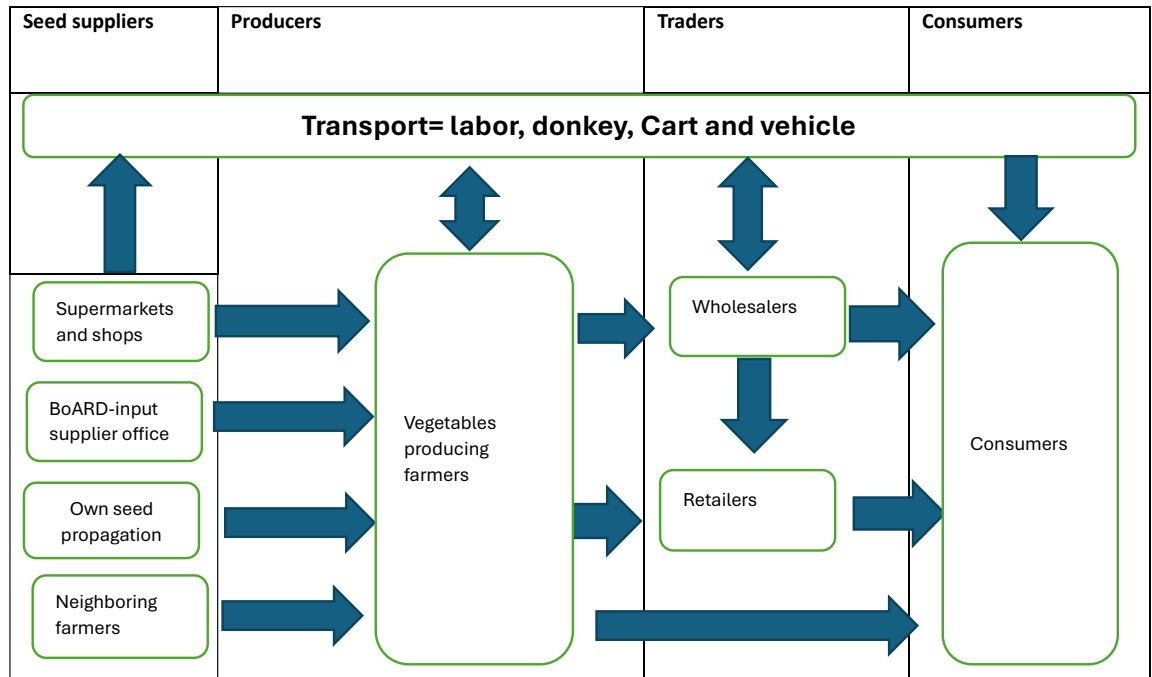
processing, possibly by establishing cooperative associations in collaboration with the BoARD and NGOs working in the area. The two adjacent weredas (Atsbi Wemberta and Kilte Awlalelo) are important producers of vegetables. Most of the producers in both weredas face similar market challenges, however, access to transport for the producers in different tabias is different. Some are better and others have equal or worse access than Gergera. Nevertheless, mass and guided production between the two adjacent weredas may create an enabling environment for sustainable production. Tomatoes, for example, are under mass production in both weredas. Big and sustainable production also creates a conducive environment for a tomato processing factory in Agulae or Wukro. A factory can produce tomato sauce, puree, juice, ketchup, and so on. The production process is not complex and can be done using simple machinery. Tomato processing is regarded as a very profitable agro-based business idea.

A range of options, involving farmers' cooperatives, private investors, and the state agencies, should consider this opportunity.

As with fruit, collective storage, transportation, and marketing of vegetables, possibly through the establishment of a producers' union or cooperative association could assist farmers in overcoming the many obstacles they face in marketing their produce, especially in the areas of logistics and market information, and thereby reduce the losses caused by price fluctuation and damage during transportation.

Finally, the BoARD should work to improve its efforts in distributing vegetable seeds, revise the price it charges, provide better quality (preferred) seeds and monitor and evaluate the implementation with greater commitment. It should increase the number of agricultural extension workers and train its staff with practical skills, support, guide and strengthen its follow-up in all production and marketing stages.

Figure 4 The Vegetable Market Value Chain Map



4.3.3. Honey Market Value Chain

4.3.3.1. Introduction

Bee farming is long established in tabia Hayelom, though there were only a few farmers with traditional beehives. Mass production of honey started in 1993, with the introduction of modern beehives by the BoARD through establishing cooperative associations and encouraging model farmers to adopt it (Bachmann, 2009).

4.3.3.2. Characteristics of Honey production and Honey Producers

Currently, both modern and traditional beehives are used by farmers, though the modern hives dominate. The two types of beehives have their own advantages and disadvantages identified by the bee farmers. The farmers' said that the traditional beehive is better for bees, allowing them to live longer because it enables them to produce wax. However, the traditional hive results in a lower production volume

compared to the modern hive. On the other hand, the modern hive gives more honey products per beehive, but the beehive lives for a shorter period because the bees cannot produce wax in this beehive. The farmers prefer the modern one for its productivity and try to minimize the shortage of wax by buying from the market and the BoARD. However, since most farmers are now adopting modern beehives, there is a severe shortage of wax, and the bees are dying prematurely. Thus, the farmers are trying to minimize the shortage of wax by adopting one or two traditional beehives to produce wax for their modern beehives.

There are three different bee species identified as being kept by farmers in the watershed. The three of them have their typical characteristics

1. Black bees- are drought resistant, but are low in honey production (live for longer)
2. Red bees - produce more honey, but are not drought resistant
3. Brown bees - do not produce honey, but it produces bees.

Many farmers prefer the black bee species for its ability to resist drought. Frequent drought is their biggest threat as explained by the farmers in the watershed. The brown bee is not meant to be kept, but it is the type of bee that the producers encounter when they first bought it from the market. The lack of information about brown bees led the farmers to buy them by mistake.

The honey produced in the watershed is also classified into different types based on its color. There are four different types of honey products. These are

1. Extra white honey
2. White honey
3. Yellow honey and
4. Red honey

The difference in the color of honey originates from the color of the flowers that the bees pollinate in different seasons. Different types of flowers with different colors

grow in different seasons. Thus, the same bee colony in the same beehive can produce different types of honey in different seasons.

Honey can be harvested in three different seasons in the watershed. However, there is no exact common season as to which color of honey is to be harvested for all the kushets. This is because there are some differences in the plant types that grow in different seasons in the three kushets. Nonetheless white honey is harvested in November and December, red honey in May and July, and yellow in September and October. Of all the different colors of honey, the dominant one in the watershed is the white honey, both extra white and white honey types.

The honey production is highly dependent on rainwater in the watershed. This is because most beehive farming sites are on the top of the mountain, which is far away from the rivers, springs, and diversions. Even so, the farmers use traditional means of providing water and food during the dry seasons to sustain the productivity and survival of the colonies. The farmers provide them with Shiro powder (Shiro is a traditional spicy powder prepared from roasted and milled beans, peas or chickpeas primarily prepared for human consumption as “Shiro-wett”), sugar and water in an open container.

In general, a bee colony can be harvested two to three times a year, but there are also times when the farmers cannot get any harvest throughout the year, especially if drought or *rust* and powdery mildew exists. A colony in a modern beehive can give 12-20 kilograms of honey at a time, while a colony in a traditional beehive gives 6-10 kg of honey.

Damaino’s honey is white but somewhat unique from the other kushets’ white honey in that it cannot be stored for longer. This is because the honey produced in this kushet dries and changes into hard solid material, like compacted sand. When consumed at this time it sounds like a gentle crash of biscuit. For this reason, there is lower demand in the market and the farmers need to sell it fresh. In contrast the farmers in the other two kushets of the watershed prefer to store their honey.

4.3.3.3. Scale of Honey Production

There are three honey producing cooperatives in the watershed, one in each kushet. There are also individual households who own as much as 64 bee colonies in the watershed, as in the case of Mr. Resom in Geter-Haiki- Mesihal. Apart from this there are exclosures (nature reserves) in the mountains in Gergera and Damaino which have been given to honey processing investors that are currently involved in bee farming (Dima Honey Processing and Mehari Honey Processing PLCs.) in the watershed.

Compared to the other selected agricultural products under study, honey production is more profitable and less risky. Honey is a highly valued, nonperishable, (of course they say that it gets better when stored for longer years) easy to transport, has limited waste, relatively low operational cost, and high market demand with little price fluctuation. These qualities of honey make producers more successful when producing in a group or individually.

The 2017/18 (September to August) report from the office of the Agriculture and Rural Development of Tabia Hayelom, showed that there were more than 858 bee colonies owned by cooperative associations and individual households. These bee colonies produced 195 quintals of different types of honey. This report does not include the number of bee colonies owned by the honey processing factories (Dima and Mehari) which are believed to have 100 bee colonies each in the mountain terrains of the watershed.

Table 5 Scale of Honey Production in Gergera Watershed classified based on Beehive Varieties and Sub-districts

S/N	Type of beehive	Kushet/Sub village name	Number of beehives	Male producer	Female producer	Honey Production per beehive per harvest (kilograms)	Total annual Production of honey (kilograms)
1	Modern	Damaino	233	47	0	21	4893
		Geter-Haiki-Mesihal	200	40	0	25	5000
		Gergera	401	81	0	23	9223
2	Traditional	Damaino	4	1	0	18	72

		Geter-Haiki-Mesihal	10	1	0	18	180
		Gergera	10	1	0	20	200
Total			858				19,568

Source: Tabia Agriculture and Rural Development Office; March 2019.

4.3.3.4. Honey Markets

The major customers of the honey produced in the watershed are the Dima Honey Processing Factory in Adigrat, Meles Honey Union in Agulae, and the newly established Honey Processing Factory in Haiki-Mesihal owned by Mr. Mehari Abrha. Apart from those wholesalers the farmers also sell their honey to retailers and to individual consumers. Nowadays, many customers come from Mekelle, Wukro, Adigrat, and Agulae to Haiki-Mesihal to buy honey and there is no need for the farmers to go to other markets to sell their products.

Honey is produced in different seasons and can be stored for as many years as one wants (if the necessary hygiene standard is maintained). Therefore, the farmers sell their products any time they want, thus the selling of honey depends on the financial need of the household and the price level in the market. Most of the time honey is sold during September (the first month in the Ethiopian calendar). This is because of the high household spending requirements for the New Year festivity and for children's educational expenses (the beginning of the school year).

4.3.3.5. Honey Prices

The price of honey differs based on its color. The extra white is the most expensive, the next most expensive are the white, the yellow, and the red respectively. Accordingly, the price of extra white honey was on average 350-450 ETB per kg, White 300-350 ETB per kg, Yellow 250 – 300 ETB per kg; Red 180 -230 ETB per kg in the year 2017/18.

There is no clear seasonal variation in the price of honey identified by the farmers. Therefore, some say it gets expensive in September to November and prices drop in January to March, but others believe that the opposite is true. However, they agreed on the fact that there is more honey supply in September (due to the above-mentioned reasons) and more demand, too. In September more wholesalers and

honey processing factory representatives come to Haiki-Mesihal to purchase honey, and the price is generally good. The price of honey is mainly determined by the agro-processing factories because they are the mass purchasers of honey in the market.

Nevertheless, there is no significant purchase price difference among the agro-processing factories and the Meles Honey Union. For example: the March 2017/18 average purchasing price of honey by the union for extra white was 300 ETB per kg and for the White 270 ETB. On the other hand, the union sells the extra white for 350 ETB per kg and the white for 300 ETB per kg. The purchasing price by the union, the processing factories and consumers is mainly dependent on the color of honey (the union only buys extra white and white honey) and the purchasing price is determined by the price in the local market on the market day. Hence, Saturday's purchase price is determined by the same product's price in Agulae, and Thursday's purchase price in Wukro.

4.3.3.6. *Communications and Contracts*

Information on market price is disseminated using phone calls and personal communications. The farmers communicate with the buyers on the quantity and price using mobile phones. The term of exchange is only in cash, whether it is sold to the union or to other traders or consumers.

There is a written contractual agreement when the farmers sell their honey to Meles Honey Union but not when exchange is made with other traders and consumers.

4.3.3.7. *Transport*

The means of transport depends on the quantity of honey to be sold and the distance to the market. The farmers use donkeys and human labor to transport their honey to the market. Retailers, the union, and the agro-processing factories use vehicles to transport honey to other areas. There is less incidence of wastage due to transport. This is because the honey produced in the watershed is almost entirely sold in Haiki-Mesihal town. Though transport was a critical problem for fruit and vegetable producers, it is not a serious concern for honey producers in the Gergera watershed.

4.3.3.8. Challenges

Honey production in the watershed faces some challenges. The most common problems are *rust* and powdery mildew and the existence of insects and butterflies.

Another challenge is the weedkiller sprays used by the local farmers in the watershed. Traditionally, the farmers used to spray their crops early in the morning and this time is when bees go to the field for pollination. The weedkiller then sticks to the body of the worker bees. As one of the participants explained, *"...as the worker bees come with strange smell, soldier bees prevent them from entering back to their hives, they fight among themselves, and the soldiers attack the workers and finally kill them"*. Though the BoARD has ordered such anti-insect and anti-weed sprays be used only in the evening, later than 6:00 pm, most farmers do not abide by the rule, due to the lack of enforcement.

The other challenge is related to the relationship between the farmers and the Meles Honey Union. The Union accepts honey from the cooperative associations, but it does not have a quality testing lab or machine, but only a refractor meter, used to measure the moisture content of the honey. Thus, the union depends on the more traditional means of testing the quality of honey, which involves keeping the honey in its store for at least six months (after the purchase is made on cash) with the name of the producer written on the packing container. This has become the source of disagreements between the two parties. The farmers explained that method has some serious defects: for example, it takes a long time to test; even after the 6 month, the method can't help to identify the source of the quality problem, whether or not the problem is from honey or the packing material; and the union demands back its money after six months if any problem is recorded on the farmers' honey. As an example, a farmer from Geter-Haiki-Mesihal was forced to pay 32,000 ETB back to the union after six months, due to the contractual agreement made with the supplier farmers and the union. Many farmers are not able to pay back the money because they have already spent it. As a result, some of the honey producers have now withdrawn from selling their products to the union.

Another challenge in this sector is the limited knowledge and expertise of the agricultural extension workers in the tabia. The experts as well as the producers have limited knowledge of bee farming. Therefore, there is a need for capacity building in this area. A shortage of wax and a lack of awareness on how to handle the honey neatly, lack of appropriate shortage of harvested honey and a lack of distillation machines, are other critical challenges that significantly limit the production of honey. Most of the time farmers are forced to wait for longer days to get the harvesting machine from the BoARD. If the weather changes (cloud cover increases) while waiting for the harvesting machine, the bees start to consume the honey in the beehive and production therefore reduces.

4.3.3.9. *Recommendations to the Honey Sub-Sector*

Urgent and coordinated approach is needed to halt the prevalence of rust and powdery mildew on crops and grasses and/or effectively treat it. This serious problem has been raised very frequently. According to the farmers it negatively and significantly influences agricultural production of all types, plants or animals. Thus, a serious focus on rust and powdery mildew problem needs to be made.

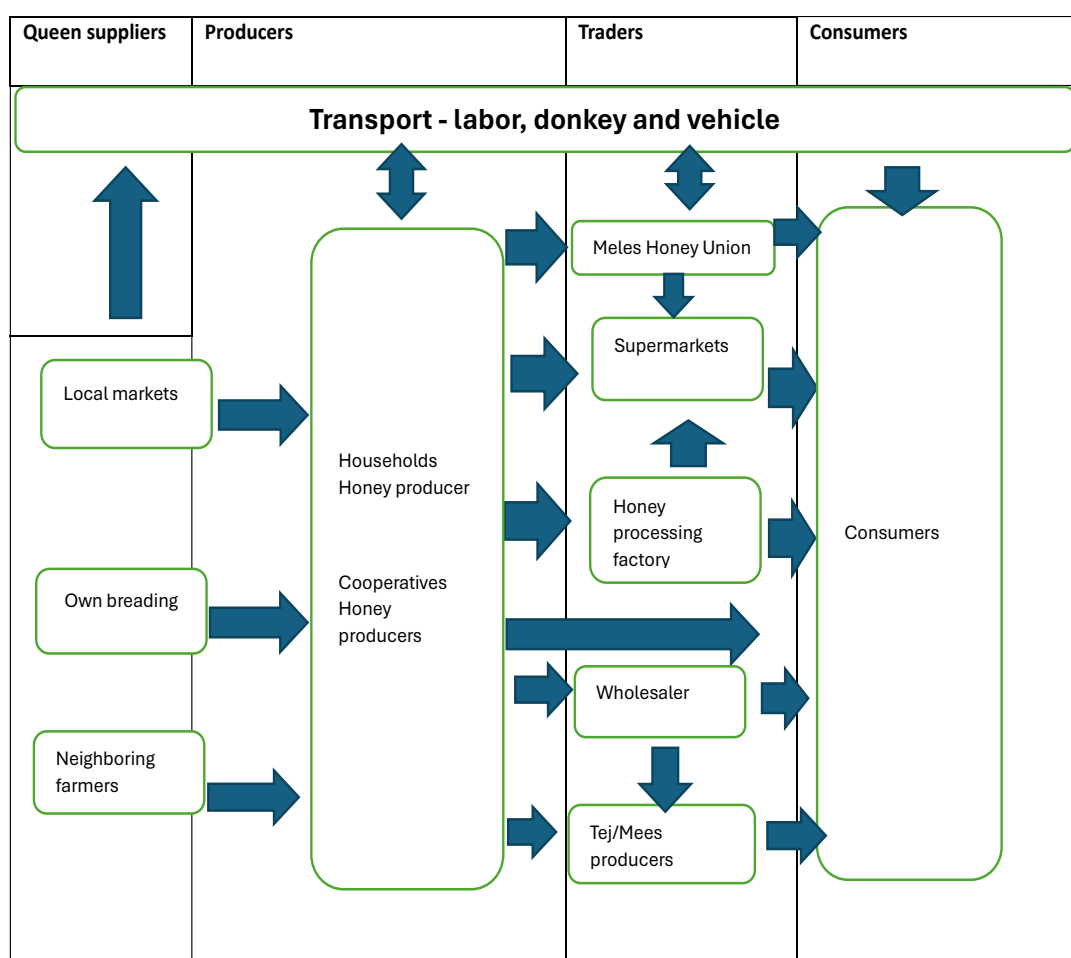
The BoARD needs to strengthen the expertise of its staffs through providing short- and long-term trainings, with tailored technical skills for efficient agricultural support. A shortage of the harvesting machinery and wax are also issues that should be seriously addressed. Investigating how to switch to artificial wax by undertaking research and development works in collaboration with Tigray Institute of Agricultural Technology, Mekelle University and other National and International organizations working in agriculture, could be another possibility for the long run.

Strict law along with its enforcement mechanisms should be developed, by the BoARD, to avoid the spraying of anti-weed and anti-insects in the wrong hours of the day, to safeguard the lives of bees.

The Meles Union should find ways to resolve the existing tension among the two parties around quality testing of honey. The lack of appropriate testing equipment in its laboratory put the suppliers at unacceptable risk and needs to be addressed by the Union.

Research on the special behavior of Damaino's honey products should be made to bring the quality of the honey into the common texture with the other kushets, or to minimize the degree of difference in its content and quality.

Figure 5 Honey Market Value Chain Map



4.3.4. Dairy Market Value Chain

4.3.4.1. Introduction

There are three most common species of cows in the dairy production in the watershed: the local cow breed, the Holstein-Friesian (American as it is locally known), and the Begait, local breed. Dairy farming using the Holstein-Friesian and Begait cow species was started in 1998/99. The dairy production for commercial purpose was also introduced by the BoARD at this time by providing modern hybrid and crossbreed cows to volunteer farmers on long term credit.

4.3.4.2. Characteristics of Dairy Production and Dairy Producers

Currently, many people are taking up dairy farming by buying calves from preferred dairy farmers amongst their neighbors. The number of farmers involved in dairy production in the watershed is, therefore, growing from time to time. Having access to irrigation creates fertile conditions for dairy production, by easing the availability of forage. Some women-headed households are opting for dairy production because the stall-fed system can fit with women's traditional role of home working environment. This is because dairy production in the watershed is mainly developing using crossbred cows in a stall-fed system. The most dominant business in dairy production in the watershed is milk production, followed by butter and the sale of calves and young bulls. On the other hand, the preferred cow species are the Holstein-Friesian followed by the Begait and the local cow species. Though the productivity of the cows is highly dependent on the quantity and the quality of the feeding, there is a difference in productivity among the species given the same feeding. There are two types of Holstein-Friesian cows, those for milk only and those for milk and butter. Those used for milk only provide very little butter, which is of low quality and lower value in the market.

4.3.4.3. Scale of Dairy Production

Table 6 Scale of Dairy Production in Gergera Watershed Classified Based Cow Varieties and Sub-districts

S/ N	Type of cow	Kushet/Sub village name	Numbe r of cows	Male produc er	Female producer	Estimated Milk Production per cow (liters) per day	Estimated Total Milk Production per kushet (liters) per day
1	Modern hybrid and cross breed cows (Holstein-Friesian and Begait, local breed)	Damaino	416	213	4	10	4160
		Geter-Haiki- Mesihal	612	354	3	10	6120
		Gergera	558	271	0	10	5580
2	Local cows	Damaino	693	126	15	3	2079
		Geter-Haiki- Mesihal	900	137	13	3	2700
		Gergera	1110	240	11	3	3330
	Total		4289	1341	46		23,696

Source: Tabia Agriculture and Rural Development Office; March 2019

There were 4,289 cows in the three kushets of the watershed. With this number of cows, the three kushets of the watershed can produce about 23,696 liters of milk per day. The number of modern hybrid and crossbreed cows (Holstein-Friesian and Begait) is 1,586 and their estimated production is 15,860 liters of milk per day, which is 66% of the total milk production of the watershed.

A Holstein-Friesian cow gives 6-12 liters, a Begait gives 4-6 liters, and a local variety produces 1-5 liters of milk per day. The productivity depends on the species of the cow and the amount of food. Most farmers prefer to sell fresh milk, but when milk prices fall during the fasting season (February to April) the farmers switch their production to butter for better prices in the Easter holidays.

4.3.4.4. Dairy Markets

Most of the milk produced in the three kushets is sold inside the watershed. Farmers from Kushets Gergera) and Geter-Haiki-Mesihal sell most of their milk in Hayo, Haiki-Mesihal town; all the milk produced in Damaino is consumed inside the Kushet, Damaino. The major consumers of milk are civil servants and the cafes and hotels.

Most of the dairy producers have regular customers who buy milk every day - they name such transactions as a 'contract', though there is no written contractual agreement. Every transaction here is made based on verbal agreements, on price as well as on quantity. The market is exclusively for fresh milk, as the producers do not have any capacity to store milk. There is no production of cheese in the watershed.

The consumers who buy on contract in Damaino and Geter-Haiki-Mesihal (those near Haiko town) collect milk and butter from the farmers' houses. On the other hand, the dairy farmers themselves provide door-to-door delivery services to the bigger purchasers, such as the hotels and cafes. Hence, wastage and transport were not raised as concerns in this sector. Most of the time, butter is sold in the market rather than at home. The kushet Gergera dairy farmers store their products to sell fresh and/or skimmed milk on market days (Saturdays) in Haiko and Atsbi. Sometimes, guests who come to the town of Haiki-Mesihal buy milk and butter. Apart from this, a significant quantity of milk and butter is used for household consumption by the producers. The participants indicated that almost every household sells its milk and butter only after satisfying its own needs. Two Milk Cooperative Unions exist in Agulae (Daero and Selam Milk Cooperative Unions), which simply collect fresh milk from their members for marketing in Mekelle; they do not have any milk processing or preserving technologies. The dairy farmers in the watershed did not have any link with these Cooperatives, because the cooperatives collect the milk only from their members. The members of the cooperatives own 1 to 45 Holstein-Friesian cows per person using a stall-feeding method. The cooperatives collect mainly from its members. However, when the market demand for milk increases the cooperatives may collect from other non-member producers.

4.3.4.5. Dairy Prices

The price of milk does not show much variation across seasons. The cheapest is 15 ETB, while the most expensive is 20 ETB per liter. The slight reduction in price takes place during fasting and in the summer season, while the small increase occurs on holidays. On the other hand, the price of butter is more volatile across seasons; its price ranges from 280 ETB per kg on lean/fasting seasons to 360 ETB on holidays. The dairy farmers in the watershed primarily sell their milk and butter in Haiki-Mesihal

town, because demand for milk and butter in the local market are relatively better compared to the other farm products. Even if there is a slight price difference in other big markets as compared to that of Haiki-Mesihal's, going to another market to sell the product at a higher price does not compensate for the additional transportation cost.

4.3.4.6. Market Information and Contracts

Market information is usually obtained through personal communications, with friends, families and neighbors. Every transaction here is made based on verbal agreements, on price as well as on quantity.

4.3.4.7. Challenges

Fresh milk and, to a lesser extent, butter, is a highly perishable commodity, and can easily be spoiled. The fluctuation in demand for those products therefore creates a challenge in this sector. The nonexistence of milk cooperatives in the watershed to process milk and butter or provide a channel to the major markets during such periods may limit the growth of the sector.

The other pressing challenge is the shortage of forage for the cows, and the very limited support from the agricultural extension workers and veterinary services provided by the BoARD. The capacity and knowledge of agricultural extension workers and veterinary professionals is limited (according to the report by the farmers in the discussion), particularly in relation to the medication, feeding, reproduction, and caring of livestock. The service from the BoARD was said to be better in the past but has deteriorated over time for unknown reasons.

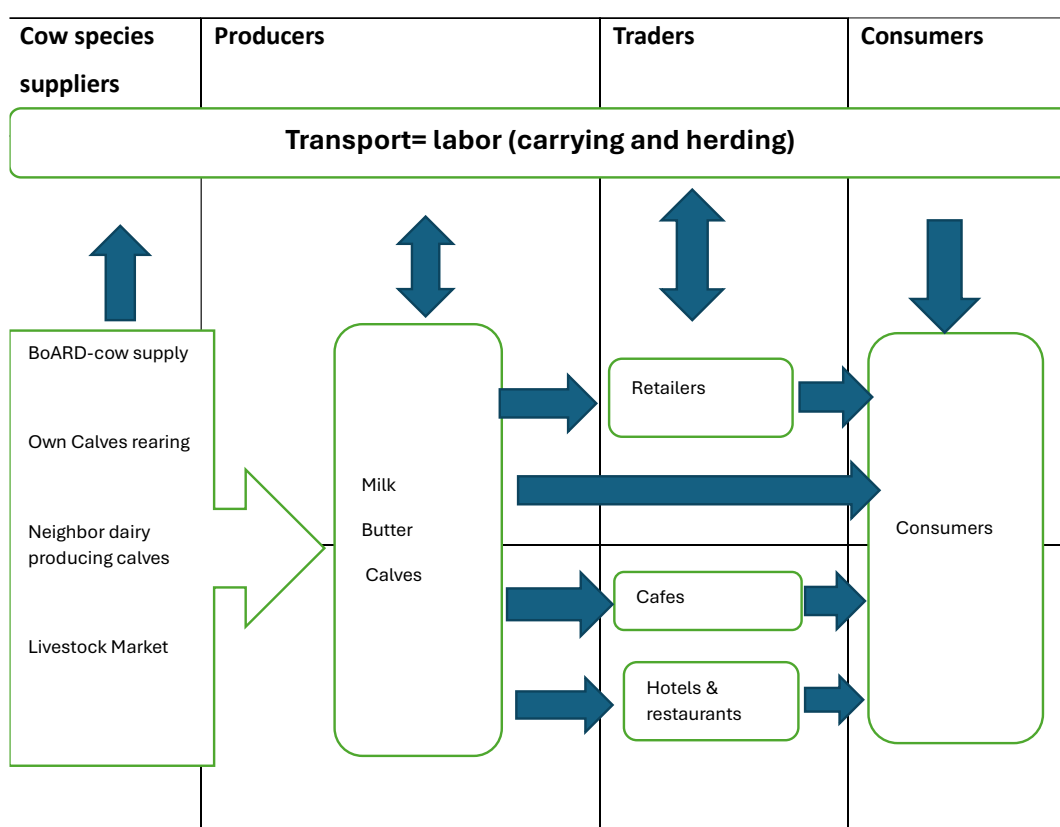
Women-headed households in the watershed are responsible for most household level duties, such as cooking, childcare, fetching water and firewood collection, going to market for different household transactions, and milling. Therefore, they lack time to participate in a series of meetings or short-term training on dairy farming given by experts from the wereda or the regional offices. Hence, they lack significant skill and knowledge in efficiently working dairy farming. This problem mainly exists in young women-headed households which tend to look after infants and children.

4.3.4.8. Recommendations for the Dairy Sub-Sector

Building a sustainable market for the dairy sector is a priority issue. This requires collective efforts in the collection, transportation, and marketing of fresh milk and butter, and neighboring areas have shown that this can be accomplished through the formation of producer cooperatives.

Improving the capacity of agricultural extension workers and veterinary professionals in the BoARD is recommended, to deliver better services, education, and training to dairy farmers. The support from the BoARD needs to come with special interventions to support women-headed households and in particular, households headed by young households. In such cases, the BoARD should consider door-to-door information provision or training methods, either as a campaign run over a short period or over an extended period.

Figure 6 The Dairy Market Value Chain Map



4.3.5. Sheep and Goats Market Value Chain

4.3.5.1. Introduction

Traditionally sheep and goats rearing has been the culture of the people in Tabia Hayelom. The number of goats and sheep owned has long been the indicator of the inhabitants' wealth status. Though measures of status are evolving, sheep and goats are still believed to be potential stores of wealth and a key area of investment for smallholder households. The BoARD used to provide sheep and goats for poor households, especially, women-headed households. This type of support was terminated 10 years ago; hence the farmers are forced to find other means of acquiring small ruminants. Nowadays, small ruminant rearing is the preferred means of livelihood diversification for women-headed households. This is because of the ease in management, reproduction, feeding/grazing need, and herding, relative to cattle.

4.3.5.2. Characteristics of Sheep and Goats Production and the producers

Recently, there were a few farmers who rear small ruminants for commercial purposes, particularly through fattening. The other purpose of rearing goats and sheep, according to the farmers' explanation, is that the animals themselves are assets; they can be sold, reproduced and give milk and butter (though in small quantity). Especially, the butter from goats is believed to be good for traditional medical purposes and is highly demanded in the watershed. A ½ kg of goats' butter is sold at 180 ETB, at minimum. The production of sheep and goats is dominated by male headed households. This is because the feeding method is free grazing in non-enclosure fields and mountain terrains which requires a full day out of home care and herding duty. Women headed households are less likely to participate, particularly those headed by young women and with childcaring responsibilities.

Households rearing small ruminants may also be producers of vegetables, fruits, or bees. It is not common to specialize in a specific livelihood strategy, most farmers in the watershed have a diversified means of livelihood. As a result, most of the households rearing sheep and goats are also active in irrigation works. The participants of the survey indicated that irrigation and rearing are highly integrated activities. For example, weeds, dried vegetables and fruit leaves are used as forages

for the ruminants, and the ruminants' waste is used for fertilizer on the farms, and so on. For this reason, there are households with as many as 60 ruminants in addition to their irrigation and honey production activities in the watershed.

There are no specific species of sheep and goats named by the participants. However, they try to breed from those sheep and goats who give birth to multiple offspring at a time. The farmers collect information on which sheep and goats gave multiple birth and multiple offspring in the village and to from those variety. This way, they try to rear the "best species" of ruminants in the watershed. If the households are unable to buy the preferred species, they alternatively use traditional cross breeding method.

4.3.5.3. Scale of Sheep and Goats Production

The watershed is a potential area for goat production; out of the total 8450 small ruminants reared in the watershed 6,643 or 78% of them are goats. The farmers in the watershed prefer to rear goats to sheep. This is because, the mountainous topography, the trees species, and the weather condition are convenient for goat production.

Table 7 Scale of Sheep and Goats Production in Gergera Watershed Classified Based Livestock Varieties and Sub-districts

Sheep	Damaino	Geter-Haiki-Mesihal	Gergera	Watershed Total
Number of Sheep in each kushet	472	580	755	1807
Number of Goats in each kushet	2868	3380	395	6643
Male producer	215	158	72	445
Female producer	17	15	5	37

Source: Tabia Agriculture and Rural Development Office; March 2019

4.3.5.4. Sheep and Goats Markets

The market demand for small ruminants increases substantially in holiday periods. The preferred market for sheep and goats in the watershed is Hayko, (Haiki-Mesihal town) for most of the kushets' producers. However, there are other alternative markets in Agulae for Damaino, and Atsbi for Gergera farmers. The market demand for sheep and goats shows significant seasonal variations.

4.3.5.5. Sheep and Goats Prices

The farmers indicated that the price of sheep and goats show variability across seasons, across weeks, and even within hours on a given market day. The biggest marketing demand comes along with the Ethiopian Orthodox Christian Church holidays, and the best of these are St. John (kidus Yohannes), on the New Year, Easter (Fasika) and Ethiopian Christmas (Lidet). Thus, most farmers prefer to sell sheep and goats on these occasions, unless there is no urgent financial need for the household. At these times, there is high demand for small ruminants, and the price tends to be high.

During the Ethiopian Orthodox Christian Church holidays the best male sheep are sold for 2500-3000 ETB; best female sheep 1500-2000 ETB; the best /castrated male goats are sold as high as 5000 ETB, while uncastrated male goats are 2000-2500 ETB. The average sheep and goats are sold in the range between 1500-2000 ETB. The price of these animals on the other hand, is cheap during the Ethiopian Orthodox Church fasting/lean period, February to April. In this period, though the price of the animals depends on their size, it is generally lower, and the average animal can be sold for as low as 800 ETB. The main purchasers of small ruminants are retailers (coming from neighboring cities and towns including Adigrat, Mekelle, and Wukro), consumers and hotels and restaurants are respectively ranked according to their volume of purchase.

4.3.5.6. Challenges

The main challenge with this production type relates to the lack of adequate veterinary service and capable and sufficient professionals in the BoARD. As a result, many small ruminants are dying due to various diseases. For example, according to informants, in January 2018 a farmer (Mr. Negash) from Damaino, was herding 15 of his sick goats to the veterinary clinic in Agulae, but because of the long distance they traveled, many of them died before they reached the clinic. The informant who raised this incident as an example had lost five of his own goats in February 2019 due to a disease, explaining how they die and its symptoms as *“the goats continuously release mucus from their nose; their skin hair erects and finally they die”*. He added that *“They had already been vaccinated in November, the same year and the sick goats got injected; the treatment couldn’t be a cure for some of them, but it worked for others.”*

Another farmer from Gergera said that *“I, too, have lost two sheep from a swollen pancreas... they couldn’t be cured by the existing veterinary staff”*. The participants added that there are so many unknown diseases in the tabia, that couldn’t get cured by the existing veterinary personnel. A man from Geter-Haiki-Mesihal stated the condition from his personal experience saying that *“the veterinary staff couldn’t identify or cure the type of disease my goats are affected by. Thus, they couldn’t help, as a result I have lost 35 of my goats with that unknown disease, and with the mercy of God it stopped by itself before all my belongings vanished”*. It appears that those veterinary experts either didn’t report the case to senior veterinary professionals in the wereda or the region, or the senior professionals were not willing to give an urgent response to the reported cases.

The other challenge regarding the medical service for livestock in the watershed is that there is critical shortage of medicines in the veterinary drug store, and this resulted in delay for treatment after the checkup. For example: anti-flea medicine is not available in the store, moreover, it is late to be provided from the regional or wereda level drug store after the request is made. The farmers indicated that, the issue with the staff of the veterinary professionals in the tabia is not about commitment but about their capacity to treat the different diseases.

The main means of transporting small ruminants to the market is by herding them. There is no transport service for animals. Farmers may walk herding their animals as far as Mekelle, which is more than 65 km away.

4.3.5.7. Market information and Contractual agreements

Information about the market and the prices is most obtained by farmers from personal communication with neighbors who visited the market and/or phone communication for an immediate decision making if a farmer had a plan to buy or sell sheep or goats.

There is no formal contractual agreement in buying and selling the sheep and goats, however, the farmers indicated that they did not face any conflict while buying and selling sheep and goats. Most transactions are made in cash and prices in the market

are mostly determined by the quantity of sheep and goats demanded and supplied to the market day.

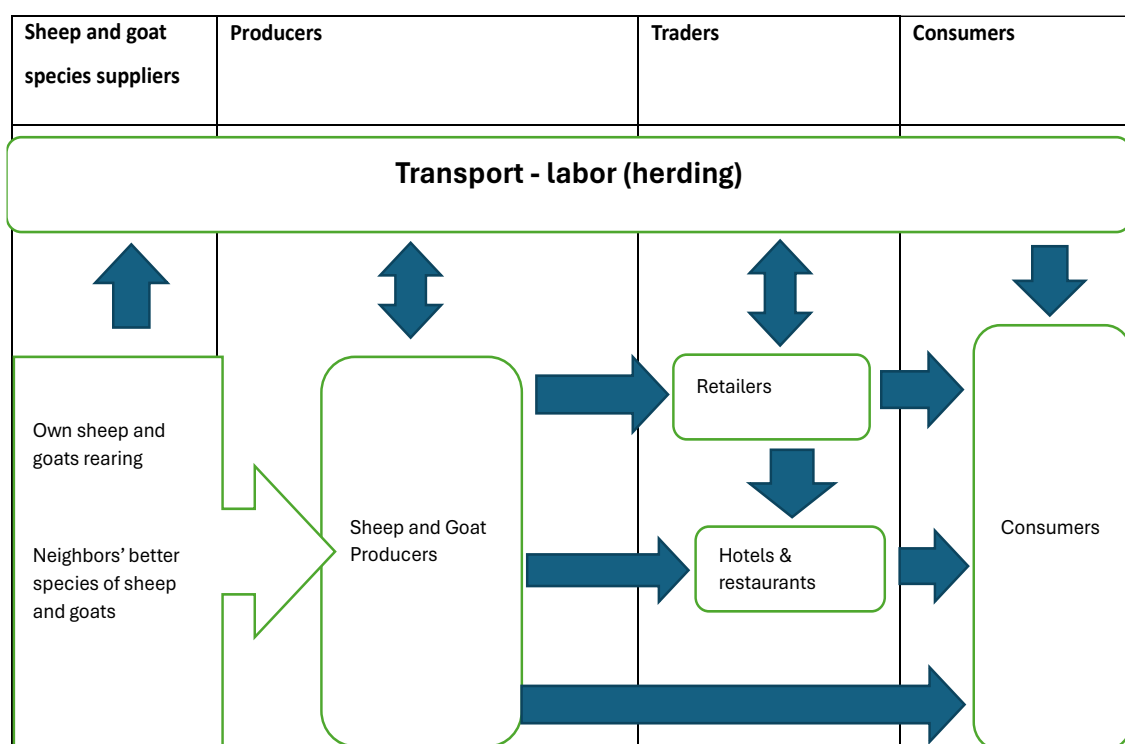
4.3.5.8. Recommendations to the Sheep and Goats Sub-Sector

Additional resources and continuous capacity building are needed for the veterinary personnel in the tabia to update on the skill and knowledge of the existing and newly emerging diseases of the animals in the watershed and their means of prevention and curing/treatment.

There is a critical shortage of medicine and delay in the distribution of the medicines. Therefore, sufficient medicine should be distributed on time to the posts, taking into consideration the numbers of animals and the incidence of livestock diseases in the watershed.

Sufficient capable veterinary professionals should be placed in each kushet along with sufficient medical equipment for better care and prevention.

Figure 7 The Sheep and Goats Market Value Chain Map



4.4. Conclusions

The rapid value chain assessment was conducted with a main objective to undertake a preliminary market value chain assessment on five selected agricultural commodities - honey, dairy, fruits, vegetables, sheep and goats-in Gergera Watershed, Tigray, Ethiopia. The watershed includes three kushets: Gergera, Geter-Haiki-Mesihal and part of Damaino's upper catchment. Qualitative data from 142 farm households was collected using focus group discussions and key informant interviews.

Findings of the assessment indicated that market-oriented production of the selected agricultural commodities began in the 1990s, with the introduction of irrigation schemes in the village by Irish Aid project. The watershed is endowed with a strong potential for irrigation and commercialization of agriculture. Markets for the agricultural commodities produced in the watershed include Haiki-Mesihal, Agulae, Atsibi, Wukro, Mekelle, and Adigrat.

Despite the existence of those markets, farmers struggle to obtain a reasonable return for their produce, especially from perishable commodities such as fruit, vegetables, and milk. High-value durable commodities such as honey and livestock generally do better. Producers have limited knowledge of markets, and information about prevailing prices, and often find themselves selling goods at a loss.

Institutional arrangements that could build the capacity of farmers and strengthen their relative bargaining power in the market – such as through cooperatives – are notably lacking in the area although similar cooperatives have been successfully established in neighboring districts. Moreover, support from state agencies was found to be weak in key areas, particularly veterinary services and the provision of seeds. Technical support is also required to deal with the problem of rust and powdery mildew which is affecting crops and grass in the watershed.

The most pressing challenge facing farmers who want to expand or engage in the marketing of agricultural commodities is the very poor transport links to local markets. This is due to the mountainous topography, poor condition of existing roads, and limited and expensive transport services. This imposes severe costs and risks on

producers and acts as a major deterrent for further expansion of production in the area. Except for honey, there is no agro-processing or other value-adding activities operating in the watershed. Further investigation is required to establish the viability of small-scale processing of fruit and milk, whether on a private or a cooperative basis.

4.5. Policy Implications

The rapid value chain analysis was a policy-oriented assessment. This section, therefore, discusses the detailed policy intervention suggested.

The rapid value chain assessment identified that most of the challenges in the agricultural commodity value chain emanate from inefficiencies in markets, institutions, and limited infrastructures. These challenges require three major policy interventions: Market-oriented policy, institutional structure-related policy, and infrastructure-related policy interventions.

Market-oriented policies: the findings indicated that smallholders face two major issues when selling their farm production. The first is related to the low prices of the commodities and the low returns from sales, particularly with perishable products. The second is related to limited market information or information asymmetry. These challenges can be addressed using market-oriented interventions, such as through better market regulation to control price volatility and provision of market price information for farmers to avoid shortage or asymmetry of information.

Institutional structure-related policies: The most frequently mentioned challenge was linked to institutional inefficiencies mainly related to the damage to crops and grass due to rust and powdery mildew. Other major challenges reported were related to the limited agricultural extension and professional support, lack of sufficient input supply such as selected seeds, pesticides, weedicides, and veterinary services. These challenges can be addressed through maximizing extension, technical, and professional support services and increasing the availability of farm input through subsidies and provision of improved veterinary services. Another pressing challenge reported was the weak bargaining power of farmers during agricultural commodity transactions. This problem may be addressed by establishing agri-business

cooperatives that collect farm products from smallholders and distribute them to retailers and wholesalers in different markets.

Institutions also need inclusive and sustainable interventions to succeed in such drought-prone and low-productivity areas. For this reason, organizing women in cooperatives and empowering productivity and market participation through providing business training tailored to their living circumstances may support gender equality in agricultural markets. In addition, expansion of irrigation infrastructures and promotion of climate-resilient farming practices can help in mitigating climate risks and improve environmental sustainability.

Infrastructure-related policies: the assessment underscores lack of access to transport and technologies as one of the critical challenges that increases post-harvest losses, particularly for perishable farm products. Therefore, investments in upgrading, expanding, and constructing all-weather roads could be a positive approach to halt the losses. Provision of a farm product collecting track in an arranged loan or subsidizing for farmers cooperatives can be another way to minimize lack of transport service. On the other hand, promoting basic vegetable processing and storage techniques for preservation and subsidizing agro-processing investments may contribute to reducing the losses.

CHAPTER FIVE

5. FOOD ON THE PLATE: THE SHARE OF FOOD SOURCES ON SMALLHOLDER HOUSEHOLD DIETS IN TIGRAY, NORTHERN ETHIOPIA

Abstract

Estimating smallholder household dietary diversity through farm production diversity and market access may either overstate or understate the results. Therefore, auditing the primary sources of smallholder household dietary diversity from the households' plate is crucial for effective policymaking. This research is based on cross-sectional data collected from 396 smallholder households selected using a multistage stratified random sampling method. Four primary food sources for smallholder households were identified by tracing back to the origins of the foods served on their plates. The food sources include purchased foods, own farm produced foods, Productive Safety Net Program (PSNP) foods, and transferred foods. Graphical and descriptive statistics revealed that purchased and own farm produced foods contribute the most to household dietary diversity. PSNP and transferred foods have a relatively smaller contribution to overall dietary diversity, though their impact is notably higher in poorer households. Socioeconomic factors, such as the size of irrigated farmland holdings size, marital status, and the gender of the household head, influence access to specific food sources to varying degrees. This study enhances the understanding of household dietary diversity dynamics in rural areas of Ethiopia and offers valuable insights for policymakers and future research aimed at addressing ongoing food security and nutrition challenges.

Key Words: Foods on the plate, household food sources, own farm foods, purchased foods, smallholders' dietary diversity, Tigray, Ethiopia.

5.1. Introduction

In sub-Saharan Africa, the achievement of the Sustainable Development Goals is challenged by the prevalence of high food insecurity, which is manifested by hunger and malnutrition (UNDP, 2012). Household food insecurity leads to the consumption of less diverse diets, while the lack of diverse diets, in turn, results in micronutrient malnutrition (Argaw et al., 2021). Studies from many countries, using a range of econometrics methodologies, have shown a positive influence of farm production

diversity and market access on household dietary diversity (Bellon et al., 2016; Koppmair et al., 2017), but this influence is often of relatively small magnitude (Chegere and Stage, 2020; Headey et al., 2019; Jones, 2017; Sibhatu and Qaim, 2018; Usman and Haile, 2022). Some researchers, such as Sibhatu and Qaim (2017) have associated this with the constraints faced in smallholder farmers' agriculture, such as limited crop choice and seasonal availability, while others, such as Ruel et al. (2018) have reasoned that the small influence of market access on dietary diversity may be due to long distances to market, high transport costs, and seasonality factors. While these factors may have an impact on the extent of the influence of farm production diversity and market access on dietary diversity, Muthini et al. (2020), argued that the way farm production diversity and market access are measured may also be a reason for the smaller predicted magnitude of influence on household dietary diversity.

Despite these issues, many studies have used farm production diversity (crops and livestock) to measure the influence of own produced foods on dietary diversity. However, this method may overstate or understate the level of influence own food production on household dietary diversity and nutrition as, in some countries, including Ethiopia, livestock are mainly considered as assets by smallholders rather than as direct food sources and may not directly reflect household consumption (Tegebu et al., 2012; Wodajo et al., 2020). Some crop varieties may also be produced for the market rather than for consumption. Similarly, proxy measures of market access such as distance and cost of travelling to the market may also be flawed as such measures may suggest an opportunity to purchase food from the market but do not capture what is actually purchased or consumed. Purchase of diverse foods may also be influenced by households' information and knowledge of nutrition. Thus, while farm production diversity and market access may show an association with dietary diversity, they may not be strong predictors of the share of a particular food source on household dietary diversity.

Identifying the share of the food sources on households' dietary diversity is crucial in designing targeted nutrition policies and interventions, particularly when there is a requirement to prioritize and optimize scarce resources.

A better way to explore the relationship between food sources and dietary diversity may be by assessing the actual food consumption variety from the households' plate and back tracing the origins of the served foods. This paper, therefore, evaluates the weekly consumption of smallholder households based on an established method of food categorization (Ruel, 2003) which has, however, been little utilized in examining the topic.

The approach used to measure dietary diversity in this paper follows that developed by Swindale and Bilinsky (2006). This first involved creating a list of food sources in the study area collected through informal discussions with local agriculture and health experts and modified through successive pilot surveys. All foods consumed within the household over a seven-day period were then categorized into one of twelve food groups and then into one (or more) of four possible food sources: 1. Purchased foods, 2. Own farm-produced foods, 3. Productive Safety Net Program (PSNP) foods (food welfare program), and 4. Transfer foods.

The aims of this paper are to evaluate the contribution of the various food sources to overall household dietary diversity and examine the factors determining access to each of the different food sources at the smallholder households. I hypothesize that purchased and own farm-produced foods have high share to household dietary diversity. This analysis will contribute to a better understanding of the factors shaping rural smallholder household dietary diversity in the Ethiopian context. To our knowledge, to date, there is an absence of literature examining the share of food sources on rural smallholder household dietary diversity using a complete list of the food sources as presented here. Identifying the extent of share from each food source is crucial for policy and resource priority purposes.

5.2. Materials and Methods

5.2.1. Description of the study area

This research is based on smallholder households in Gergera watershed, Eastern Tigray in Northern Ethiopia. The watershed covers 143.9 km² and has four sub-districts (locally known as kushets), namely, Geter Haiki-Mesihal, Damaino, Gergera, and Degaabur. Ecologically, the watershed is classified between highland and

lowland. The study site lies in a latitude range between 13.043 and 13.046N and a longitude of 39.040 to 39.045E, situated between 2,066 and 2,505 meters above sea level. The district has a bimodal annual rainfall of 450mm to 600mms. The average annual temperature in the watershed fluctuates between 15 C° and 25 C° (ICRAF, 2018).

Morphologically, the Gergera watershed is characterized by many cliffs, surrounded by rugged and undulation terrains. The flat areas and enclosures on the hillsides are mostly used for growing fodder grass and beekeeping activities. The soil texture is predominantly silt-loam and loam with the soil acidity classified as pH neutral to minimum alkaline content (Woldewahid et al., 2012).

Mixed crop-livestock farming is the predominant farming practice in the area. The most common cereal crops are barley, wheat, maize, teff, and sorghum. Pulses such as beans, peas, and lentils are also widely grown. Small scale irrigation is practiced by some households living along the banks of the Gergera river, growing varieties of vegetables including tomatoes, potatoes, onion, cabbage, spinach, and lettuce. Some fruit trees species including guava, avocado, papaya, and oranges grow, and livestock such as cattle, sheep, goats, and chickens are reared. Donkeys, horses, and mules, are mainly used for transporting materials and farm products (Meaza, 2010).

5.2.2. Data Sources and Sampling

This study utilizes primary data collected through a cross-sectional survey from 396 sampled households across the four sub-districts of the Gergera watershed, Tigray. A multistage stratified random sampling technique was employed to select the participants proportional to the population size in each of the sub-districts. The residents' list was obtained from the local administrative office. A team of experienced enumerators took training on the questionnaire and the use of the Kobo toolbox, a digital data collection platform. The questionnaire was translated into the local language (Tigrinya) and pilot surveys were undertaken in the study area. The main data collection was carried out in the period September to October 2020.

The questionnaire had four parts. The first part focused on household demographic and socioeconomic characteristics; the second focused on food consumption

patterns over a specified period, and the sources of the food; the third collected data on land holdings and the types and quantities of crops and livestock produced; the fourth captured information about the households' access to market and food purchases.

5.2.3. Definition and Measurement of Key Variables

The study focuses on five key variables of interest which are as follows:

5.2.3.1. Household Dietary Diversity Score (HDDS)

Household dietary diversity score is defined as the number of food groups consumed by the participating households over a recall period of the past seven days Muthini et al. (2020); Sibhatu and Qaim (2017). Household dietary diversity score (HDDS) classifies food items based on their nutritional characteristics into 12 food groups, namely cereals, white tubers and roots, vegetables, fruits, meat, eggs, fish and other seafood, legumes, nuts and seeds, milk and milk products, oils and fats, sweets, and spices, condiments, and beverages (Swindale and Bilinsky, 2006). However, this paper accounts for 11 food groups as there is no fish and other sea foods consumption recorded in the study area. Food group consumption measured over a 7-day period is preferred to 24-hour recall accounting for potential variations in daily food intake (Lele et al., 2016; Jones et al., 2014; Sibhatu and Qaim, 2018).

5.2.3.2. Household Food Sources

I have identified four major food sources in the study area. The sources identified are classified as own farm produced foods, purchased foods, Productive Safety Net Program/PSNP foods, and Transfer foods (other public and private food transfers, borrowings, and gifts). I have counted the food group contribution from each of the food sources to the household dietary diversity over the past seven days. The identification of the food sources is made by counting the diverse food groups served in a household's food plate and tracing back to their origins. This approach provides an advantage to make an exhaustive list of the food groups consumed and their respective sources, thereby minimizing the limitations of the conventional (indirect) methods based on farm production diversity and market access.

Own Farm Produced Foods (OF): Household own farm production is widely reported to be the primary source of food for the rural smallholders in Ethiopia and other low-income countries (Argyropoulou 2016; Bellon et al. 2016; Kumar et al. 2015; Rajendran et al. 2017). The contribution of the own farm-produced foods to household dietary diversity is directly measured as the number of the food groups included in the food actually served in the household's plate rather than the crop and livestock varieties produced in the farm.

Purchased Food (PF): A household's dietary diversity is also influenced by the foods purchased by the household (Headey et al., 2019). In this study, the contribution of purchased foods to household dietary diversity is computed based on the number of purchased food groups served in the household's meals in seven days. Matita et al. (2021), have used the number of purchased food groups as a dependent variable referring it as "food purchases diversity score". Here I counted food groups served in the household's plate over the seven days from purchased food sources.

Productive Safety Net Program (PSNP): Another food source identified in smallholder rural households in our study area is the Productive Safety Net Program (PSNP), a national welfare program that provides poor households with access to work for food and/or cash. Following a similar trace-back approach, the contribution of the PSNP foods to household dietary diversity is obtained by counting the in-kind food groups contributed to the household consumption over a week. Some studies have examined the contribution of the PSNP to household dietary diversity and food security in Ethiopia with varying results regarding its impact on household diet and food security (Gebrehiwot and Castilla, 2019; Hoddinott et al., 2015; Welteji et al., 2017).

Transfer Food (TF): Other sources of household foods in the study area include food aid from other public and private sources, gifts from friends, relatives or neighbors, borrowings, barter, and so on, collectively named here as transfer foods. Zhou and Hendriks (2017) showed that such transfers can make a positive contribution to dietary diversity in poor households. Like the other food sources described above, the contribution of transfer foods to household dietary diversity is computed by

counting the number of the food groups served in the household's plate over the week originating from these sources.

5.2.4. Econometric Analysis

This study uses Ordinary Least Squares methods to estimate the factors determining households' access to specific food sources. The detailed specification of each food source is presented below.

5.2.4.1. Ordinary Least Squares (OLS) Estimation

The ordinary least squares (OLS) estimation model evaluates how households' access to the food sources may be influenced by household and socioeconomic factors. The equations for the models are represented as follows:

$$PF_i = \alpha_0 + \alpha_1 SE_i + v_i \dots\dots\dots (5.1)$$

$$OF_i = \beta_0 + \beta_1 SE_i + \varepsilon_i \dots\dots\dots (5.2)$$

$$TF_i = \pi_0 + \pi_1 SE_i + \omega_i \dots\dots\dots (5.3)$$

$$PSNP_i = \mu_0 + \mu_1 SE_i + e_i \dots\dots\dots (5.4)$$

- where PF_i refers to the number of food group varieties purchased from the market and served at the households plate within the week under consideration; OF_i represents to the own farm-produced crop and livestock varieties classified into their respective food groups which are served and consumed at the given week; PF_i refers to food groups consumed during the week sourced from transfers. The transfer foods include foods from Aid and other public and private sources, gifts from friends, relatives or neighbors, borrowings, barter, and so on; and the $PSNP_i$ refers to the food groups consumed during the week sourced from the Productive Safety Net Program.

SE_i is the vector of socioeconomic characteristics including the age of the head, sex of the head, marital status, family size, level of education, sub-district in which the household is located, rainfed land holding size, irrigated land holding size, and household proximity to the market centre. The α_i , β_i , π_i , and μ_i are the vector parameters indicating the magnitude influence of the corresponding explanatory

variables on the dependent variables, the food sources. ν_i , ε_i , ω_i , and e_i are the error term representing the influence of other unobserved variables on household i 's food sources.

5.3. Results and Discussions

5.3.1. Descriptive Statistics

Table 8 below presents summary statistics for the 396 surveyed households of which 106 were female-headed and 290 were male-headed. The average age of the household heads was 54 years, and their average family size was 5 per household. Their education level ranges from zero to 15 years of schooling, with an average of 1 year.

The household dietary diversity score ranges from 1 to 11 food groups, with an average of 6.25 food groups over the week. In a comparable study based on a 7-day recall period for farm households in Ethiopia, Sibhatu and Qaim (2018) found an average HDDS of 6.00 food groups, which is close to our data. The average food group contribution of the four identified food sources was 6.91, which is higher than the average HDDS, 6.25. This is because the same food group can be obtained from more than one source.⁸ Of the average 6.25 HDDS, food purchases contribution is 5.32 food groups showing a higher dominance, followed by 1.24 food contribution from own farm-produced foods over the week, the PSNP contributes 0.12 and transfer foods 0.30. There were some households who consumed as many as ten food groups. Even though I found households with zero consumption from own farms production, every household has consumed at least one food group from purchased sources during the week.

Table 8 also showed that the total number of households with rainfed land was 382 and the average rainfed land size was 1.2 tsimad⁹ (or 1.18 tsimad across the entire

⁸ For instance, *injera*, or bread, though made from different cereal crops, and therefore belonging to the same food group, can be sourced from purchased, own farm produced, the PSNP, or received as transfers.

⁹ *Tsimad* is a local unit of land measurement and represents the amount of land that can typically be ploughed by a man in one day, using a pair of oxen. The equivalent of one tsimad is one-quarter of a hectare [$1.2 * \frac{1}{4} = 0.30$ ha].

sample). The total number of households possessing irrigated farmland was 242, and the average irrigated land holding size was 0.48 tsimad (or 0.29 tsimad across the entire sample). The overall average land holding size for all households was 1.47 tsimad, (rainfed and irrigated land holdings summed).

Table 8 Descriptive statistics on key data variables

		HDDS	Purchase	Own	PSNP	Transfer	Age	Family size	Education	PDS	Rainfed Land size (in tsimad)	Irrigated land size (in tsimad)	Proximity to market (in walking minutes)
GENDER													
	Female: N	106	106	106	106	106	106	106	106	106	106	106	106
	Mean	5.92	5.17	0.97	0.16	0.29	51.58	3.42	0.37	2.9	0.77	0.22	75.75
	Male: N	290	290	290	290	290	290	290	290	290	290	290	290
	Mean	6.38	5.38	1.34	0.11	0.30	54.96	5.73	1.54	3.7	1.33	0.32	71.8
MARITAL STATUS													
	Divorced: N	46	46	46	46	46	46	46	46	46	46	46	46
	Mean	6.3	5.54	1.09	0.11	0.37	50.07	2.87	0.37	2.96	0.74	0.2	62.93
	Married: N	287	287	287	287	287	287	287	287	287	287	287	287
	Mean	6.33	5.35	1.32	0.11	0.31	54.3	5.81	1.6	3.71	1.32	0.33	72.46
	Single: N	2	2	2	2	2	2	2	2	2	2	2	2
	Mean	5.5	5.5	0	0.5	0	25	3	0	2	0.5	0.12	120
	Widowed: N	61	61	61	61	61	61	61	61	61	61	61	61
	Mean	5.85	5.02	1.05	0.2	0.2	56.85	3.57	0.16	2.87	0.86	0.23	80.66
SUB-DISTRICTS													
	Geter Haki Mesihal: N	116	116	116	116	116	116	116	116	116	116	116	116
	Mean	6.83	5.66	1.56	0.07	0.25	56.49	5.26	1.66	3.69	1.23	0.3	27.17
	Damaino N:	120	120	120	120	120	120	120	120	120	120	120	120
	Mean	6.61	5.64	1.35	0.14	0.28	49.76	5.08	1.11	3.42	1.26	0.46	82.42
	Gegera N:	76	76	76	76	76	76	76	76	76	76	76	76
	Mean	6.22	5.13	1.25	0.16	0.49	57.92	5.24	1.49	3.82	1.03	0.35	42.37
	Degaabur N	84	84	84	84	84	84	84	84	84	84	84	84
	Mean	4.98	4.58	0.64	0.14	0.24	53.32	4.82	0.56	3	1.11	0	149.88
	TOTAL: N	396	396	396	396	396	396	396	396	396	396	396	396
	Mean	6.25	5.32	1.24	0.12	0.30	54.05	5.11	1.23	3.48	1.18	0.3	72.86

Source: Authors' calculations from survey data collected Sep. to Oct. 2020.

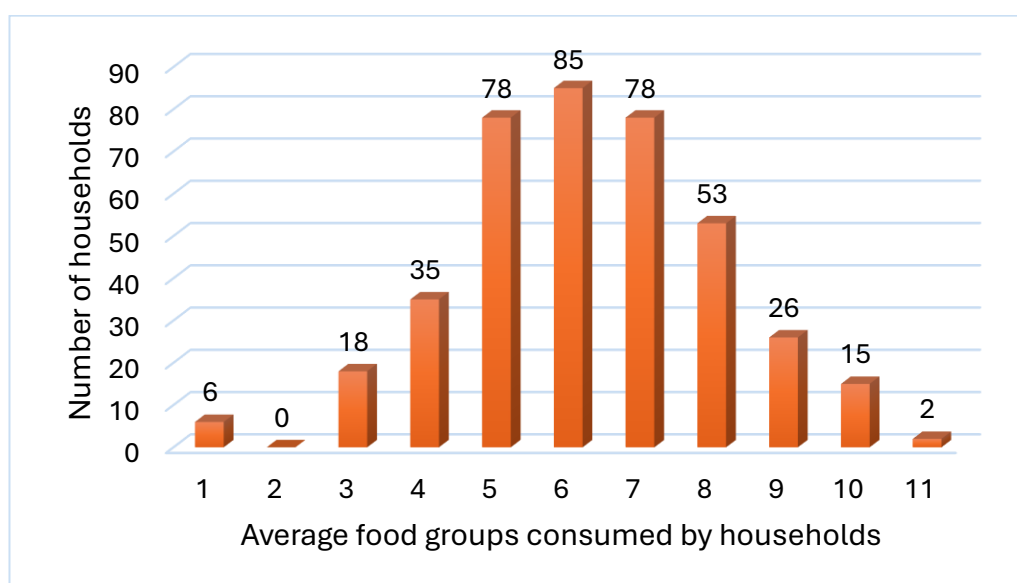
5.3.2. Sources of Household Dietary Diversity

The following section presents the statistical relationship between food sources and household dietary diversity in the Gergera watershed. I have used bar graphs to show the distribution of the number of food groups consumed across households (Figure 8) and the contribution of the various food sources to household dietary diversity (Figures 9A and 9B).

5.3.2.1. Distribution of dietary diversity in the study area

Figure 8 presents the number of households at an average weekly food group consumption, ranging from one to eleven. As no fish was consumed, the total number of food groups observed was reduced from 12 to 11.

Figure 8 Distribution of households at each level of food group diversity



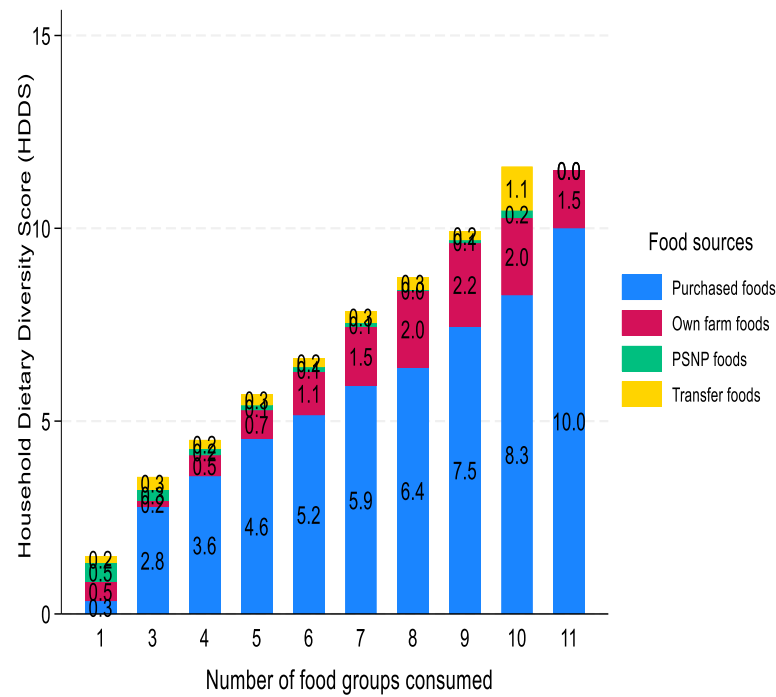
Source: Authors' computation from survey data collected Sep. to Oct. 2020.

Note also that no household reported an average consumption of two food groups per week in the study period. The shape of the bar graph resembles that of a normal distribution, with most of the households lying closer to the average. 241 (60.85%) of the households consumed between 5 and 7 food groups in seven days, 59 (14.89%) consumed below average, 1-4 food groups, and the remaining 96 (24.24%) consumed above average, 8-11 food groups.

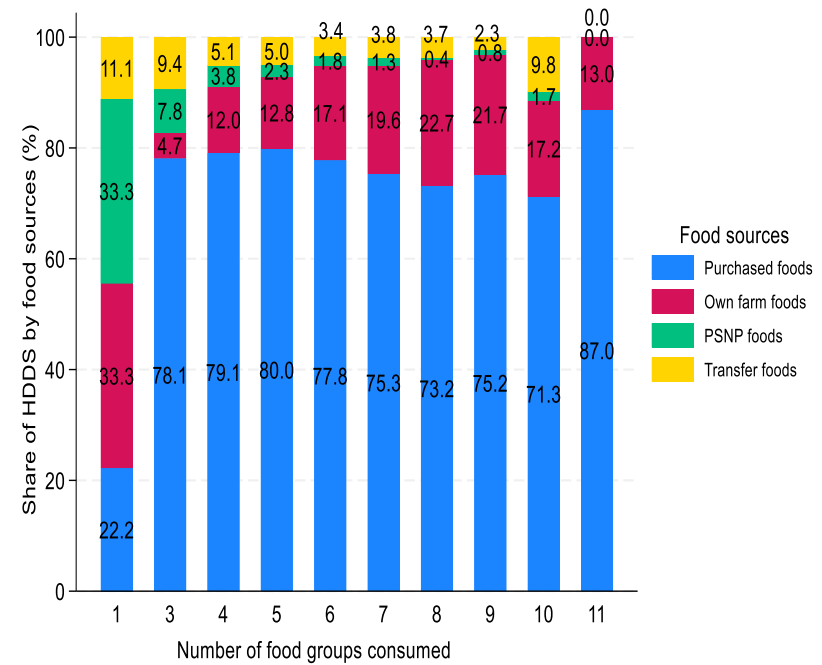
In Figures 9A and 9B, I present the absolute and relative shares of the food sources to household dietary diversity over seven days in the Gergera Watershed. Figure 9A shows that purchased foods significantly contribute to household dietary diversity across various levels of food group consumption in absolute terms. This finding aligns with the assertion made by Sibhatu and Qaim (2017) in their study in Ethiopia, where they found over 80% of the food diversity comes from purchased food sources, and they stated that ‘food purchases dominate in contributing more to dietary diversity than subsistence production.’ Consistent with this result, Zanello et al. (2019) indicated that markets provide the bulk of dietary diversity to households. A study conducted in Tanzania by Rajendran et al. (2017) also found that smallholders who spend more to purchase foods show a consistent increase in their household dietary diversity score. For instance, households consuming a single food group purchase an average of 0.3 food groups, while the variety of food group purchases steadily increases to 10 for households consuming 11 food groups. This association suggests that greater dietary diversity may be linked to increased food purchases.

Looking at the contribution of purchased foods relative to total consumption (Figure 9B), I see that purchased food groups remain important across all consumption categories. Except for the households consuming only one food group, food purchases make up more than 70% of all levels of the 3 to 11 HDDS categories. This association is not, however, in a strictly linear manner.

The second major food source in the study area was own farm-produced foods. The mean contribution of own farm foods to household dietary diversity reveals a clear trend, increasing from 0.5 food groups at the 1st food group consumption level to 2.2 food groups at the 9-food group consumption level and then back to 1.5 foods at the 11-food group consuming households. Again, the notable exception is the lowest HDDS – 1 food group- in which households, on average, obtain one-third of their food from own production.



(A) Absolute share of food sources (numbers)



(B) Relative share of food source (%)

Figure 9 Share of food source to household dietary diversity

Source: Authors' computation from survey data collected Sep. to Oct. 2020.

The average contribution of own farm foods showed a trend in relative terms; as a percentage of the total, the importance of own produced foods increases steadily from HDDS category 3 to category 8 (Fig. 9B) with a decline in the three highest categories.

Overall, with the increase in the consumption of purchased and own farm-produced foods, household dietary diversity increases. The association also signals that there appears to be no substitution between purchased and own farm foods: as households increase their consumption of one source, they also increase their consumption of the other.

The trend in the contribution of the transfer and PSNP foods to household dietary diversity is more visible at the bottom of the scale, among those households with a HDDS of 1. This suggests effective targeting of the PSNP to poorer households may support dietary diversity.

5.3.3. Econometric Analysis

In the previous section, I examined the share of food sources to household dietary diversity. This section uses the Ordinary Least Squares (OLS) estimation method to evaluate the factors determining households' access to the different food sources.

5.3.3.1. Determinants of Household Food Sources

This section presents the factors determining household access to specific food sources among rural smallholders in the Gergera watershed. Table 9 shows the OLS regression result of the socioeconomic factors determining access and contains four models for the four food sources: purchased foods, own farm-produced foods, PSNP foods, and transfer foods. The food sources are the dependent variables in the equation to be explained by the different socio-economic variables selected.

Accordingly, the regression results in Table 9, Column 1, revealed that only irrigated farmland is found to significantly influence household access to purchased foods. This implies that as a household's irrigated land holding size increases by one tsimad, its consumption of purchased foods grows by an average of 0.463 food groups, at a $P < 0.05$

level of significance (keeping all other factors constant). This could be because many of the irrigated crops sold in the market generate income enabling smallholders to buy other foods used for household consumption.

The findings in Table 9, Column 2, indicate that residential sub-district, marital status, and the gender of the household head determine households' consumption of own farm-produced foods. The regression output for the sub-district uses "Geter Haiki Mesihal" as the reference category. The output reveals that residents of Damaino and Degaabur consume, on average, 0.397 and 1.255 fewer food groups from their own farm-produced foods compared to households in Geter Haiki Mesihal, holding other factors constant. These findings are significant at $P < 0.05$ for Damaino and $P < 0.001$ for Degaabur (Table 9, Column 2). It takes an average of 27.17 walking minutes from Geter-Haiki Mesihal to the local market; this is much closer compared to the 82.42 walking minutes distance from Damaino and 149.88 walking minutes from Degaabur sub-districts (see the summary statistics in Table 8). Despite being the third and fourth most remote areas from the local market, households in these sub-districts consume less diverse foods from their own farms compared to those in Geter Haiki-Mesihal, the closest sub-district. This may suggest that the purchase of diverse food and diverse food production could complement market access and the relative advantage of access to nutritional information.

Another factor influencing household consumption of home-produced foods is marital status. With "Divorced head" as the reference category, Table 9, Column 2, indicates that single-headed households consume 1.288 fewer food groups from their own farm sources compared to divorced-headed households. The single-headed households in our survey have the smallest average rainfed and irrigated farmland sizes in this category (see the summary statistics in Table 8); therefore, the interpretation of the results may be questionable. Another important household characteristic affecting the consumption of home-produced food sources in Column 2 is the gender of the household head. Male-headed households consume 0.778 more food groups from their own farms than those headed by females, which is significant at the $P < 0.001$ level.

Table 9 Determinants of Household Food Sources (OLS Estimations)

	(1)	(2)	(3)	(4)
	Purchased foods	Own farm foods	Transfer foods	PSNP foods
Food sources				
Sub-districts				
Geter Haki Mesihal	(.)	(.)	(.)	(.)
Damaino	0.191 (0.277)	-0.397** (0.197)	-0.149 (0.116)	0.033 (0.055)
Gegera	-0.469 (0.248)	-0.311 (0.163)	0.183 (0.127)	0.090 (0.049)
Degaabur	-0.310 (0.440)	-1.255*** (0.280)	-0.351 (0.181)	-0.064 (0.092)
Gender of the household head				
Female	(.)	(.)	(.)	(.)
Male	0.492 (0.432)	0.778*** (0.218)	-0.084 (0.109)	0.031 (0.053)
Marital status				
Divorced	(.)	(.)	(.)	(.)
Married	-0.437 (0.485)	-0.466 (0.268)	0.039 (0.144)	0.030 (0.067)
unmarried	0.069 (0.664)	-1.288** (0.573)	-0.346** (0.153)	0.316 (0.335)
Widowed	-0.375 (0.350)	0.100 (0.207)	-0.155 (0.138)	0.120 (0.071)
Other socioeconomic variables				
Age of the head	0.002 (0.007)	-0.006 (0.005)	-0.002 (0.002)	-0.002 (0.001)
Family size	-0.070 (0.044)	0.004 (0.032)	0.013 (0.017)	-0.009 (0.009)
Education level	0.005 (0.037)	0.010 (0.028)	-0.012 (0.014)	-0.007 (0.006)
Rainfed farmland size (in tsimad = 0.25 hectare)	-0.072 (0.088)	0.024 (0.058)	-0.047 (0.028)	0.008 (0.015)
Irrigated land size (in tsimad = 0.25 hectare)	0.463* (0.217)	0.015 (0.146)	0.027 (0.076)	-0.106*** (0.030)
Proximity to market (in walking minutes)	-0.005 (0.003)	0.003 (0.002)	0.003 (0.002)	0.001 (0.001)
Constant	5.964*** (0.490)	1.479*** (0.372)	0.326 (0.217)	0.203* (0.087)
Observations	396	396	396	396

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

The dependent variables in the model are the household food sources, based on the 11 food groups. The model was estimated by using OLS regression. The coefficient estimates are shown along with the robust standard errors in brackets. *Source: authors' own computation from survey data collected in Sep. – Oct. 2020.*

The relatively lower reliance of female-headed households on home-produced foods can be attributed to their smaller average sizes of rainfed farmland holdings (0.77 tsimad for female-headed households compared to 1.33 tsimad for male-headed households) and irrigated landholdings (0.22 against 0.32 tsimad) (see Table 8). This may be because female-headed households are at least one labour resource short on the household and the farm.

Table 9, Column 3, suggests that being a unmarried head of household reduces the possibility of consuming food from transfers by an average of 0.346 food groups, significant at $P < 0.05$ level, however, this interpretation needs caution due to the small number of unmarried headed households. Table 9, Column 4, indicates that households with larger irrigated farmland size have relatively lower access to PSNP foods, on average. This result was expected because the qualifying criteria for the PSNP is to fall below a certain level of poverty by the local administration's measures, and ownership of a larger irrigated farmland would reduce the chance of being selected as a beneficiary of the PSNP foods.

Overall, our study finds that residential sub-districts, marital status, gender, and size of irrigated land are the important factors influencing households' access to a particular food source in the Gergera watershed.

5.4. Conclusion

The study traced the origin of smallholder dietary sources from the households' plates and identified four major sources: purchased foods, own farm-produced foods, Productive Safety Net Program (PSNP) foods, and transfer foods. The paper then examines the share of these food sources to dietary diversity and the factors determining access to a particular food source by farm households in Tigray, northern Ethiopia.

The findings indicate that purchased and own farm foods are the primary contributors to household dietary diversity across all income levels. No substitution between purchased and own farm foods is observed, instead, households' increased consumption of one food source, is linked to increased consumption of the other.

PSNP and Transfer foods show the least contribution to overall household dietary diversity relative to purchased and own farm foods. However, the individual effect of PSNP and Transfer foods is relatively higher in poor households. The results suggest that interventions aiming to improve smallholder household dietary diversity may need to focus on increasing the diversity of food purchases through increasing or shifting to high value short gestation crop and livestock varieties to increase income from sales and diverse consumption from own-farm productions in smallholder households while making the PSNP and public transfers nutritionally diverse foods to targeted poor households.

The findings also show that the size of irrigated farmland contributes to increased consumption of purchased foods, while it limits the households' access to PSNP foods. Male-headed households enjoy a greater share of own farm-produced foods. Overall, the residential sub-districts, marital status, gender, and size of irrigated farmland are important factors determining households' access to a particular food source in the study area.

The findings highlight the complementary nature of purchased and own farm-produced foods in improving household dietary diversity, emphasizing the need for targeted interventions, and tailored agricultural extension programs. Activities such as small ruminant rearing, poultry farming, dairy production, and apiculture are suggested as income-generating activities that would enhance purchasing power without compromising own consumption, particularly for female-headed households facing labor and resource constraints.

Future research focused on the socio-cultural dimensions influencing household dietary diversity dynamics among rural smallholders is advised to provide a holistic view of the complexities surrounding dietary choices and may uncover hidden determinants of food

consumption patterns. Further use of foods on the plate to assess the origin and the contribution of various food sources to dietary diversity and nutrition should also be considered. This study focused on the Gergera watershed alone. Hence, any wider interpretation and generalization of the findings should be taken with caution.

CHAPTER SIX

6. THE JOINT INFLUENCE OF FARM PRODUCTION DIVERSITY AND FOOD MARKET VISITS ON SMALLHOLDER HOUSEHOLD DIETS IN NORTHERN ETHIOPIA

Abstract

Consumption of nutritionally poor and monotonous diets causes many smallholders in low-income countries to suffer from micronutrient malnutrition. Although empirical evidence is mixed, increasing farm production diversity and improving smallholder market access, defined in this paper as the frequency of food market visits, have been widely reported as effective approaches to address the situation. Various studies have examined the relative influence of farm production diversity and market access on household dietary diversity. However, only a few have empirically investigated the joint interplay in shaping smallholder household diets. This research addresses this gap based on cross-sectional data from 396 smallholder households in rural Tigray in Northern Ethiopia. In the analysis, a graphical interpretation of the relationship between farm production diversity and three different market access measures is applied, followed by a deeper investigation using Poisson estimation methods. Household frequency of food market visits is rigorously tested for stability and compared with alternative market access measures. Our findings reveal that farm production diversity and the frequency of food market visits, jointly and independently, have a positive and significant nonlinear influence on the dietary diversity of rural smallholder households. The right mix of farm production diversity and smallholder households' frequency of food market visits increases rural household dietary diversity. Measuring market access in walking proximity reveals that market accessibility thresholds influence household dietary diversity in a non-linear, rather than simple linear, manner. The implication is that different market accessibility thresholds require different policy approaches for effective dietary influences.

Keywords: Household dietary diversity, Market access, Farm production diversity, Smallholder households, Frequency of food market visits, Proximity to market, Ethiopia.

6.1. Introduction

A report from a group of United Nations organizations anticipated that there will be 582 million people chronically undernourished globally in 2030 and that 53 percent of those facing hunger will be in Africa (FAO et al., 2024). Studies indicate that food insecurity in sub-Saharan Africa is a contributor to less diverse diets, and the lack of diverse diets results in micronutrient malnutrition (Argaw et al., 2021). Smallholder farmers are the most affected, characterized by low levels of daily energy consumption, poor nutritional quality, and monotonous diets (Dorosh and Minten, 2020). This situation leaves poor households prone to short-run diseases and long-run cognitive problems (Eckhardt, 2006).

Numerous studies, however, show that smallholder household dietary diversity can be achieved by increasing farm production diversity and improving market access (Ruel, 2003, Ruel, and Alderman, 2016, Sibhatu and Qaim, 2017). Farm production diversity allows smallholder households to consume fresh and nutritious foods from their farm (Appiah-Twumasi and Asale, 2024). It also improves the supply of fresh and nutritious foods in rural markets and may induce local demand for the products (Weatherspoon et al., 2021). Similarly, there is a wide range of consensus on the positive contribution of market access to smallholders' dietary quality and nutrition. However, a challenge persists in precisely indicating the pathways shaping smallholder household dietary diversity due to mixed findings of various studies (Nandi et al., 2021; Sibhatu and Qaim, 2018).

The way market access is measured has been suggested as a potential reason for the inconsistency in findings (Muthini et al., 2020). Researchers have recently begun to question the robustness of the traditional measures of market access in explaining the

role of markets in modelling household dietary diversity and nutrition (Bonuedi et al., 2022; Matita et al., 2021). After a systematic review of the literature on the subject, Nandi et al. (2021b) criticized the use of self-reported travel time, distance to the nearest market, and costs to reach the nearest market as inadequate means to indicate the participation aspect of market access. Market access measures, such as distance to nearest market centers and distance to road infrastructures have been criticized by Chamberlin and Jayne (2013) for their weakness as measures of farmers' access to the market. A similar argument against those measures, by Headey et al. (2019) states that such proxies lack strength in explaining markets' nutritional contributions.

To address the above-mentioned limitations of market access measures, this paper used an alternative metric, the frequency of food market visits. The use of this measure of market access intends to integrate the endogenous and exogenous factors influencing households' decisions to interact in food markets. The frequency of food market visits combines the concepts of market access and market participation in a single measure.

Apart from this, most previous research has been examining the relative influence of farm production diversity and market access on dietary diversity. Some studies have underlined the greater influence of farm production diversity on dietary diversity (Jones, 2017; Kumar et al., 2015; Muthini et al., 2020; Romeo et al., 2016; Tesfaye and Tirivayi, 2020). Others have emphasized the greater influence of market access (Bellon et al., 2020; Bonuedi et al., 2022; Kihui and Amuakwa-Mensah, 2021; Koppmair et al., 2017; Sibhatu and Qaim, 2017; Usman and Haile, 2022). However, there are relatively few empirical studies on the joint interplay between farm production diversity and market access in shaping smallholder household dietary diversity.

To our knowledge to date, Zanello et al. (2019) in Afghanistan, Mulenga et al. (2021) in Zambia, and Morrissey et al. (2024) in Uganda have examined the interplay between farm production diversity and market access on smallholder household dietary diversity,

using panel data. This study, therefore, aims to evaluate the joint interplay between farm production diversity and frequency of food market visits in shaping household dietary diversity using a cross-sectional data from Tigray, Northern Ethiopia.

The remaining parts of the paper are set out as follows: Section 2 introduces the study area, the techniques of data collection, the information collected, and the method used to analyze the data. Section 3 then discusses the graphical presentations and econometric findings followed by the conclusions in Section 4.

6.2. Materials and Methods

6.2.1. Description of the Gergera Watershed in Tigray, Ethiopia

This research was conducted in the Gergera watershed, located in the rural administrative area of Hayelom Tabia in the regional state of Tigray, northern Ethiopia (See Figure 2). Geographically, the Gergera watershed is situated in the Eastern zone of Tigray, at a latitude of 13.043 and 13.046N and a longitude of 39.040 to 39.045E. The watershed covers a land area of 2,302 hectares. The average daily temperature ranges from 15°C to 25°C (ICRAF, 2018). According to the local agroecological classification, the Gergera watershed lies within highlands (dega) and mid-land (woyna dega) areas, with an altitude ranging between 2,066 and 2,505 meters above sea level. The weather is characterized as semi-arid, with a bimodal annual rainfall regime between 450mm and 600mm. The main rainfall occurs in the summer season from mid-June to early September, and this is the main season for crop cultivation. There is another short rainy season between March and April which the farmers usually use for cropland preparation.

Morphologically, the Gergera watershed is characterized by an undulating terrain with rugged topographic features. The soil texture is mainly silt-loam and loam with neutral PH and very little alkaline (Woldewahid G. et al., 2012). Mixed crops and livestock are the dominant farming practice in the watershed. The main crops grown are cereals, such as barley, wheat, teff, maize, and sorghum; and pulses, including beans, peas, and lentils (Deribe, 2008). There are some irrigation activities in the lower areas of the valley around

the outlet of the watershed. Vegetables, such as tomato, onion, cabbage, and spices, and fruits such as guava, avocado, papaya, and orange are some of the major products of the irrigable fields (Gebremedhin Woldewahid et al., 2011). The livestock in the area includes cattle, sheep, goats, donkeys, horses, and chickens (Gessesse, 2016). The flat areas and enclosures on the hillsides are usually reserved for fodder grass collection and beekeeping (Meaza, 2010).

6.2.2. Data Sources and Sampling

Primary data was collected using a cross-sectional survey conducted with rural smallholder households from the four sub-districts (*kushets*¹⁰) of the Gergera watershed, namely Geter Haiki Mesihal, Damaino, Gergera, and Degaabur. The data collection was executed by experienced enumerators, who were provided with training on the translated questionnaire and underwent two rounds of pilots to evaluate the suitability of the survey. The data were collected between September and October 2020.

A multistage stratified simple random sampling method was applied. In the first stage, a stratified sampling technique was used to determine the size of each stratum based on the sub-districts' population size. In the second stage, a systematic random sampling technique was used to select each participating household from a list of 1,056 residents provided by the local administrative office. Accordingly, 116 households were selected from the sub-district Geter Haiki Mesihal, 120 from Damaino, 76 from Gergera, and 84 from Degaabur. A total of 396 households were selected. Based on gender, the surveyed households consist of 290 male-headed and 106 female-headed households.

The questionnaire was comprised of four parts. The first part deals with the households' demographic and socioeconomic characteristics; the second focuses on household food consumption data; the third on the household farm production diversity; and the fourth on households' market interaction. Crop and livestock production data for one

¹⁰ Kushet is the lowest or seventh governmental administrative level in Ethiopian rural governance structure next to Tabia.

agricultural year was captured, covering the period from September 2019 to August 2020.

This survey assessed food consumed by any member of the household inside the household within 24 hours. Foods consumed outside the home by any member of the household are not included in the 24-hour consumption data in this study. This exclusion may cause an underestimation of the overall household dietary diversity score, particularly for households with members regularly eating outside the home and participating in social events and ceremonies where food is served. However, any such underestimation is likely to be small given that this is a predominantly rural area not close to any large towns.

6.2.3. Measurement of Key Variables

6.2.3.1. Measuring Household Dietary Diversity

The household dietary diversity score (hereafter HDDS) is used to measure the diversity of household access to food, using a 24-hours recall period (Swindale and Bilinsky, 2006; FAO, 2007; Sibhatu and Qaim, 2018; Admasu et al., 2011). According to the Swindale and Bilinsky (2006) Food Access Indicator Guide, food items can be classified into 12 food groups, based on their nutritional contribution, to compute the HDDS. The 12 food group classifications are as follows: 1. Cereals; 2. White tubers and roots; 3. Vegetables; 4. Fruits; 5. Meat; 6. Eggs; 7. Fish and other seafood; 8. Legumes, nuts, and seeds; 9. Milk and milk products; 10. Oils and fats; 11. Sweets and honey and, 12. Spices, condiments, and beverages (Swindale and Bilinsky, 2006). From this list of food groups, households were asked to identify any food item they consumed in the previous 24 hours. The enumerators recorded '1' if the household had consumed an item from a food group or '0' otherwise.

The sum of the number of food groups consumed in the 24 hours gives the total value of the HDDS for the household, which may range from a minimum of 0, if no food at all was consumed in the 24-hours, to a maximum of 12, if the household consumed something from all 12 food groups. Only 1 point is recorded if a household consumes from a

particular food group within 24 hours, regardless of the quantity or the frequency of the consumption within that time, or the number of people who consumed it. For example, a household would likely consume injera¹¹ (the local staple food) for up to four meals a day. According to the HDDS, however, the repeated consumption of injera is counted as 1 (being part of the cereal food group). Following the HDDS methodology, food consumed outside the home, such as in markets, public events, or at neighbors' homes, is not counted as part of the household diet. The computation of HDDS can be presented as follows:

$$HDDS_i = \sum_1^{12} FG \text{ consumed by the } HH_i \text{ in 24 hrs} \dots\dots\dots (6.1)$$

6.2.3.2. Measuring Farm Production Diversity

Different methods are available for measuring farm production diversity. In this study, I have adopted the production diversity score (PDS) to measure the farm production diversity, calculated in terms of the number of food groups produced by households in the previous agricultural year (September 2019 to August 2020). The PDS classifies crops and livestock into 12 food groups, effectively the same as for the HDDS discussed above (Chegere and Stage, 2020; Koppmair et al., 2017; Sibhatu and Qaim, 2018). The data for the PDS was based on the 12 food groups that may be produced at a smallholder household level. The list of food groups is previously presented in section 6.2.3.1. in this paper.

The application of the PDS has some limitations arising from possible multiple counting of certain food groups, particularly animal products (Berti, 2015; Kissoly et al., 2020). The PDS value of 2 is recorded for household keeping chickens, because chickens may produce 2 different food groups, meat and eggs. Similarly, a cow can be a source of 3 different food groups: meat, milk and butter (oil food group). On the other hand, an ox

¹¹ Injera is a pancake made of teff, a cereal crop and Ethiopia's staple crop. Almost every meal in Ethiopian family has injera made of teff, or sometimes made of wheat, maize, sorghum or a mixture of those cereal crops.

is given a score of 1, whether it is consumed in the given year or not. PDS is therefore seen as a count of potential food sources, rather than a record of actual consumption from own-produced sources.

Muthini et al. (2020b) have excluded non-food crops from the PDS count. Similarly, this study excluded animals such as donkeys, horses, mules, and camels, since these are working animals and are not considered foods in the local culture.

6.2.3.3. *Measuring Households' Access to Market*

Market access for smallholders has been assessed in various studies using proxy measures, such as distance to the market, distance to roads or other public infrastructures, travel time, and cost of transportation to the market (Hoddinott et al., 2015; Jones et al., 2014; Sibhatu et al., 2015; Koppmair et al., 2017; Muthini et al., 2020; Zanello et al., 2019). However, those conventional proxy measures have faced criticism for their weakness in explaining the influence of markets in shaping smallholder diets and nutrition (Bonuedi et al., 2022; Chamberlin and Jayne, 2013; Headey et al., 2019; Matita et al., 2021; Nandi et al., 2021). A key limitation lies in their focus on the exogenous factors (Usman and Haile, 2022), neglecting the social, environmental, economic, and cultural contexts which influence households' decisions to engage in market transactions.

To address this limitation, this paper uses an alternative proxy for market access which is based on household decisions that implicitly integrate the internal and external factors influencing their market engagement. This measure of market access is *the households' frequency of food market visits in 30 days* or the Frequency of food Market Visits (FMV). The FMV can reflect the physical proximity to the market and the households' preferences, willingness, and ability to engage in markets. For example, the FMV is preferred to the distance in kilometres approaches because: (i) it considers market access as an outcome of households' decision to transact in a market; (ii) the decision made is related to food purchases, which has a direct influence on the households' dietary diversity; (iii) it is flexible in response to various factors including environmental, social,

economic, cultural, and political factors affecting households decision to participate in market transactions in a specific period. The selection of the 30-day window is to give space for a range of variations among household market engagements because there is a single main market day, on Saturdays, for households to make major market transactions. This period is, therefore, a relatively well-remembered range of time.

For comparison, the length of days since households' last market visit or absence from the market (AM) is used as an alternative measure of market access. Examination of the length of days of absence from the food markets facilitates the evaluation of how households' level of dietary diversity is impacted if they refrain from visiting markets for an extended period. This measure of market access captures the difference in HDDS on market days and non-market days. A third proxy measure used for comparison is the households' proximity to the food markets (PM), measured in walking minutes, an established metric of market access (Bergau et al., 2022; Koppmair et al., 2017).

6.2.4. Data Analysis

6.2.4.1. *Pairwise Analysis of the PDS, HDDS, and Market Access*

A scatterplot is applied to visualize the pairwise relationship between PDS, HDDS, and the three market access measures. Linear fit, a parametric regression method, along with LOWESS (Locally Weighted Scatterplot Smoothing) fit, a non-parametric regression method, is used. Both approaches fit a smooth curve through a scatterplot of data. However, while the linear fit shows the linear relationship between the dependent and the explanatory variable, the LOWESS fit adapts to the data. It helps capture more complex and nonlinear relationships between pairs of variables with much flexibility in their shape. The LOWESS fit is also helpful in identifying changes in trends and thresholds. Another benefit of this approach is detecting the linearity and non-linearity of the relationships in a pairwise scatterplot analysis between the variables. I used the collapsed deciles (10 quantiles - each quantile containing approximately 10% of the observation) of the key variables of interest: the HDDS, PDS, FMV, AM, and PM as data points in the scatterplots.

Collapsing the data into quantiles helps to group similar observations into data points, making it easier to visualize the patterns and trends of the pairwise relationships. The process reduces the influence of outliers and the complexity of large datasets. However, since this method aggregates information into groups, individual-level variability within groups may remain unobserved. To address this limitation and undertake individual household-level observations, an econometric analysis, Poisson estimation, is also applied.

6.2.4.2. Poisson Regression Analysis

The Poisson regression equation is based on the count outcomes of the HDDS. The count outcomes of HDDS are assumed to have the characteristics of a Poisson probability distribution function. This distribution function is revealed by the occurrence of non-negative discrete outcomes at a fixed interval of time, where each event is independent of one another (Wooldridge, 2013). The Poisson regression equation is used to model the probability that a household consumes a fixed number of food groups in 24 hours, given their household and socioeconomic characteristics (Sibhatu et al., 2015a). Mathematically, the Poisson regression equation takes the form:

$$P(HDDS_i) = \beta_0 + \beta_1 PDS_i + \beta_2 FMV_i + \beta_3 AM_i + \beta_4 PM_i + \beta_5 PDS_i \times FMV_i + \beta_6 PDS_i \times AM_i + \beta_7 PDS_i \times PM_i + \beta_8 Marital\ status_i + \beta_9 Sub\ district_i + \beta_{10} Gender_i + \beta_{11} Age_i + \beta_{12} Family\ size_i + \beta_{13} Rainfed\ farmland\ size_i + \beta_{14} Irrigated\ farmland\ size_i + \varepsilon_i \dots\dots\dots (6.2)$$

In the regression models, the dependent variable $HDDS_i$ represents the HDDS in the 24 hours. The explanatory variables are the farm production diversity score PDS_i and market access. Market access is alternatively explained by the household i 's frequency of food market visits, FMV_i , Absence from the market, AM_i , and household i 's Proximity to the market center, PM_i . For the analysis of the joint interplay between PDS and market access on HDDS, the interaction between $PDS_i \times FMV_i$, $PDS_i \times AM_i$, and $PDS_i \times PM_i$ is used. I hypothesized that both PDS_i and FMV_i have a positive association with HDDS, while AM_i and PM_i have negative correlations with $HDDS_i$.

After estimating the influence of the PDS and FMV on HDDS separately, I regressed them together with socioeconomic characteristics using Poisson estimation. The estimation helps to identify other influencing factors that might have been omitted during the pairwise estimations. Moreover, it helps to test the robustness and stability of the key explanatory variables throughout the estimation. The socioeconomic characteristics of the household included the marital status of the head, household residential sub-district (kushet), gender of the head, level of education in years of schooling, age of the head in years, family size in number, owned rainfed farmland holding size in tsimad¹² (1 tsimad =1/4 of a hectare), and irrigable land holding size in tsimad. These socioeconomic factors are selected because they are repeatedly mentioned in literature as influencers of smallholder dietary diversity (Bellon et al., 2016; Ogutu et al., 2020; Koppmair et al., 2017; Sibhatu and Qaim, 2017).

The statistical analysis integrates the findings obtained from a pairwise analysis of variable relationships and the econometric estimations. This approach increases the dependability of the results and highlights the robustness of our research framework.

6.3. Results and Discussions

6.3.1. Descriptive Statistics

Table 10 presents the summary statistics for the selected socioeconomic variables in the study area. It compares the mean differences of the variables across gender, marital status, and sub-districts. This comparison displays whether the socioeconomic variables have significant differences within gender, marital status, and geographic locations in the study area.

The summary statistics in Table 10 indicate that male-headed households are relatively older, with a mean age of 55 years, and have a larger family size of 6 compared to female-headed households, which have a mean age of 52 years and a family size of 3. Both differences are statistically significant at the 5% and 1% levels, respectively. Family size

¹² Tsimad is a local measure of farmland size in the study area, which is approximately equal to ¼ of a hectare.

may play a crucial role in smallholder farm production since farm activities in low-income countries primarily depend on family labor (Asfaw et al., 2019; FAO, 2012; Rapsomanikis, 2015). Similarly, male-headed households have a larger area of rainfed farmland, with a mean of 1.326 tsimad, and irrigated farmland, with a mean of 0.325 tsimad. In contrast, female-headed households possess a mean of 0.774 tsimad of rainfed farmland, which is significant at the 1% level, and a mean of 0.218 tsimad of irrigated farmland, significant at the 5% level.

The summary statistics in Table 10 indicate that the gender of the household head creates a statistically significant difference in HDDS. Male-headed households reported a higher mean HDDS of 5.986 food groups compared to female-headed households, which consumed an average of 5.528 food groups in 24 hours, significant at the 1% level (Table 10).

The statistics also reveal that differences in marital status and sub-district can contribute to variations in HDDS. Married households, which account for 72.5% of the sampled households, have a mean HDDS of 6 food groups, followed by single (unmarried) headed households, which consume a mean HDDS of 6.500 food groups. The lowest mean HDDS in this category was 5.475 food groups, recorded by widowed heads. Caution is needed when interpreting the data for single (unmarried) headed households because (1) single-headed households consist of only two people in our data, and (2) the classification is based on marital status, indicating no partner and never married, rather than having just one family member in the household. Those household heads could be guardians of their orphan siblings or relatives caring for orphans in a household.

A higher PDS has been recorded in male-headed households, averaging 3.700 food groups with various crops and livestock produced during the year, compared to female-headed households, which average 2.896 food groups. This gender difference in PDS is statistically significant at the 1% level. Similarly, Table 10 indicates a significant difference in PDS across marital status at the 1% level. Married households produced 3.711 diverse food groups, followed by divorced households with 2.957 food groups, widowed

households with 2.869 food groups, and single household heads with 2.000 food groups. Differences in PDS are also observed among the four sub-districts. Gergera sub-district ranked first at a mean PDS of 3.816 food groups followed by Geter Haiki-Mesihal at 3.690 food groups, Damaino at 3.417 food groups, and Degaabur at 3.000 food groups. This variation in PDS across the sub-districts is statistically significant at the 5% level, suggesting that geographic differences can result in disparities in smallholder PDS levels.

The three market access measures showed statistically significant differences, at the 1% level, across the four sub-districts. Market access measured by PM, from the closest to the farthest sub-district, is ranked as follows: Geter Haiki-Mesihal has the lowest mean walking time of 27.172 minutes, followed by Gergera at 42.368 minutes, Damaino at 82.417 minutes, and Degaabur at 149.881 minutes away from the market (Table 10). Using the FMV, the summary statistics in Table 10 demonstrate a similar order, with Geter Haiki-Mesihal leading at a mean of 3.629 visits, followed by Gergera at 3.421 visits, Damaino at 2.842 visits, and Degaabur at 2.131 visits over 30 days. However, the results indicate that AM shows mixed relationships with PM. Gergera, ranked second in PM, exhibited the lowest AM with a mean of 4.289 days of absence, whereas Geter Haiki-Mesihal, the closest in PM, had the next lowest with a mean of 4.767 days of AM (Table 10). The third and fourth sub-districts, Damaino and Degaabur, also align with PM, displaying 7.758 and 9.143 days of AM, respectively (Table 10).

Table 10 Summary statistics for selected socioeconomic characteristics.

	Gender				Marital Status					Sub-District				
	Total	Female	Male	t-test	Divorced	Married	Single	Widowed	t-test	G.H. Mesihal	Damaino	Gergera	Degaabur	t-test
N	396 (100.0%)	106 (26.8%)	290 (73.2%)		46 (11.6%)	287 (72.5%)	2 (0.5%)	61 (15.4%)		116 (29.3%)	120 (30.3%)	76 (19.2%)	84 (21.2%)	
HDDS (food groups)	5.864 (1.285)	5.528 (1.181)	5.986 (1.302)	0.002	5.500 (1.378)	6.000 (1.282)	6.500 (0.707)	5.475 (1.120)	0.004	6.060 (1.307)	5.817 (1.223)	6.026 (1.423)	5.512 (1.146)	0.015
PDS (food groups)	3.485 (1.725)	2.896 (1.579)	3.700 (1.728)	<0.001	2.957 (1.813)	3.711 (1.745)	2.000 (1.414)	2.869 (1.284)	<0.001	3.690 (1.931)	3.417 (1.510)	3.816 (1.655)	3.000 (1.686)	0.010
FMV (number)	3.033 (1.148)	2.755 (1.094)	3.134 (1.152)	0.003	2.978 (1.183)	3.146 (1.137)	1.500 (0.707)	2.590 (1.055)	0.001	3.629 (1.092)	2.842 (0.944)	3.421 (0.983)	2.131 (0.979)	<0.001
AM (days)	6.510 (4.658)	7.198 (4.831)	6.259 (4.576)	0.076	7.022 (5.702)	6.118 (4.333)	9.000 (1.414)	7.885 (5.086)	0.037	4.767 (2.944)	7.758 (4.890)	4.289 (3.769)	9.143 (5.109)	<0.001
PM (minutes)	72.859 (54.256)	75.755 (58.305)	71.800 (52.766)	0.521	62.935 (47.147)	72.463 (53.479)	120.000 (42.426)	80.656 (61.951)	0.229	27.172 (19.827)	82.417 (33.663)	42.368 (23.144)	149.881 (38.102)	<0.001
Education (year of schooling)	1.227 (2.464)	0.368 (1.463)	1.541 (2.674)	<0.001	0.370 (1.218)	1.599 (2.732)	0.000 (0.000)	0.164 (0.916)	<0.001	1.664 (2.690)	1.108 (2.456)	1.487 (2.778)	0.560 (1.563)	0.012
Age (years)	54.053 (14.339)	51.585 (12.583)	54.955 (14.847)	0.038	50.065 (12.639)	54.300 (14.579)	25.000 (0.000)	56.852 (13.115)	0.002	56.491 (14.188)	49.758 (12.928)	57.921 (13.280)	53.321 (15.853)	<0.001
Family size (number)	5.109 (2.247)	3.415 (1.830)	5.728 (2.061)	<0.001	2.870 (1.439)	5.808 (2.011)	3.000 (1.414)	3.574 (1.910)	<0.001	5.259 (2.106)	5.083 (2.310)	5.237 (2.226)	4.821 (2.370)	0.543
Rainfed farmland (in tsimad 1/4 of hectare)	1.178 (0.998)	0.774 (0.639)	1.326 (1.064)	<0.001	0.739 (0.611)	1.320 (1.063)	0.500 (0.354)	0.863 (0.733)	<0.001	1.234 (1.088)	1.264 (1.074)	1.031 (0.800)	1.112 (0.911)	0.354
Irrigable land size (tsimad)	0.296 (0.404)	0.218 (0.340)	0.325 (0.422)	0.020	0.196 (0.237)	0.328 (0.434)	0.125 (0.177)	0.228 (0.342)	0.079	0.303 (0.361)	0.460 (0.501)	0.350 (0.347)	0.004 (0.018)	<0.001

Note: Standard Deviation (SD) in parenthesis.

Gender-wise evaluation of the summary statistics in Table 10 demonstrates that male household heads have a higher average age, compared to female- heads, at 54.96 and 51.58 years, respectively; higher family size, at 5.73 to 3.42 persons; more years of schoolings, at 1.54 to 0.37; there is a significant, at 1% level, difference in farm landholding size between male and female heads with an average of 1.326 and 0.325 tsimad of rainfed and irrigation for males against 0.774 farmland and 0.218 irrigated tsimad for females, respectively. Overall, these results show a dominance of male heads of households in all the parameters examined in Table 10.

6.3.2. Pairwise Explanatory Variables Analysis

6.3.2.1. *Pairwise Relationship between Farm Production Diversity and Household Dietary Diversity*

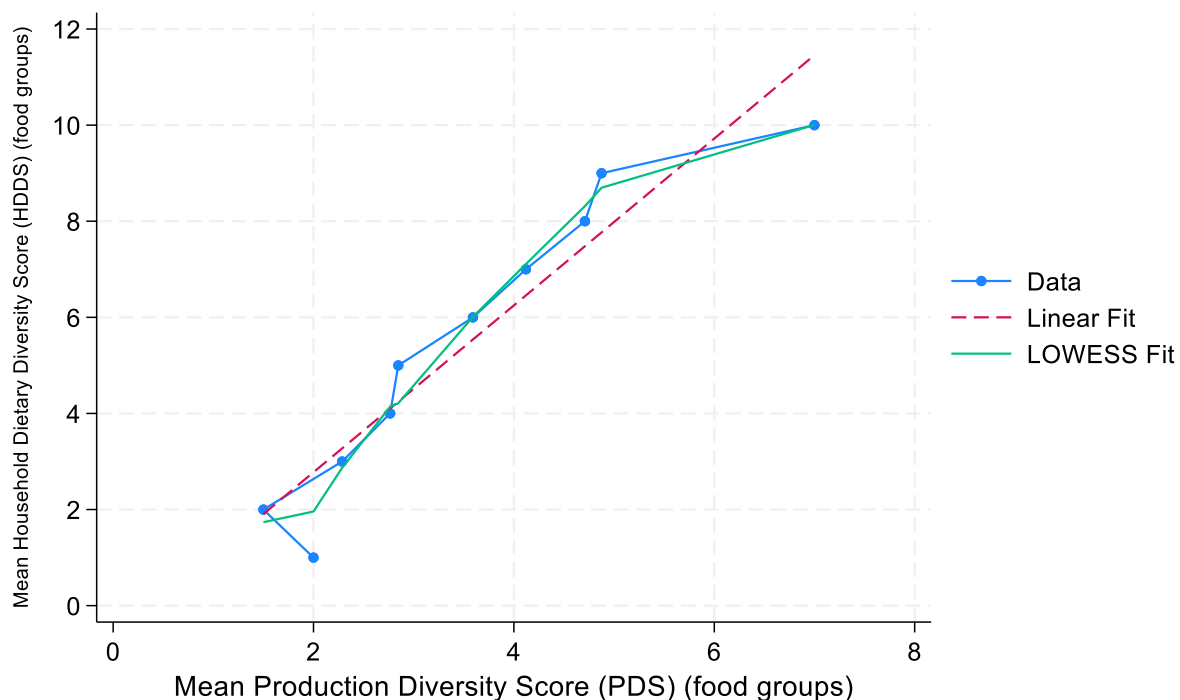
The analysis of the pairwise influence between PDS, FMV, AM, PM, and HDDS is visualized in the following figures.

In Figure 10 mean PDS is graphed on the X-axis, and the average values of HDDS on the Y-axis. The graph shows pairwise relationship between the two variables. At the lower level of the scatterplot in Figure 10, the data points did not show a clear pattern, perhaps suggesting a weak relationship between PDS and HDDS for poor households. The visualization indicates that there is a positive non-linear relationship between PDS and HDDS which can be divided into two stages of returns. The linear and LOWESS fit confirm that there is a positive return in the early stages of increasing PDS, followed by diminishing returns to each additional unit of PDS in the intermediate and later stages.

A closer look at Figure 10 illustrates that at the initial stage, additional food group production, until about 4.5 PDS, leads to a greater increase in HDDS. At the intermediate stage, beyond 4.5 PDS, the rate of increase in HDDS diminishes for every additional PDS level; and gets flatter at later stages up to about 7 PDS levels. The result may suggest that smallholders' preferred food range is narrow, possibly confined to traditional staple foods. Hence, households may increase their consumption of the diverse but locally

common food group varieties at the initial stages. At later stages, further production diversification may be targeted more for sale.

Figure 10 Pairwise Relationship between Farm Production Diversity and Household Dietary Diversity



6.3.2.2. Pairwise Relationship between Market Access and Household Dietary Diversity

In Figure 11 (A-C) a set of graphs are presented to examine the independent influence of market access on HDDS. The three different graphs are used to examine the results and compare if there are significant differences when the various measures of market access are used.

Figure 11A shows a distinct relationship between households' FMV and their level of HDDS. The HDDS is treated as a dependent variable, on the Y-axis, and the FMV, on the X-axis. The graph shows that every additional FMV positively contributes to the HDDS. Contrary to the pattern I observed on the PDS, the FMV shows a smaller rate of additions to the HDDS at the initial stages, and the rate of contribution increases with more FMV.

A closer observation of the graph suggests that a certain level of FMV can achieve the maximum HDDS, beyond which each marginal FMV brings little or no addition to HDDS, but without turning negative – meaning they may continue to buy the same kinds of food groups.

Figure 11B depicts that lower AM brings diverse foods to rural smallholder households. Market-day diets are more diverse than other days. HDDS diminishes as the number of days of AM increases. This is a factor for most of the surveyed households who live in rural areas, where there is limited electricity coverage and hence limited food preservation technologies. Households may purchase perishable foods that need to be consumed fresh, such as meat, milk, vegetables, and fruits.

Another interesting phenomenon revealed in Figure 11B is that when households attend food markets regularly (when AM is low), they enjoy higher HDDS levels. However, a longer AM leads to lower but not zero HDDS: other food sources (for most households, primarily own-production) fill the gap in the absence of food purchases.

Figure 11C presents another measure of market access, PM measured in walking minutes. Average PM is on the X-axis and average HDDS on the Y-axis. The graph indicates an inverse relationship between HDDS and PM: longer walking minutes adversely impact HDDS. Following the LOWESS fit, Figure 11C also has its own unique features. Close PM is associated with higher HDDS but there is little difference among households living within 50 walking minutes radius. The downward trend in the middle of the graph shows that the remote residents suffer from lower HDDS levels. The horizontal line at the end of the graph (bottom right, which is visible in LOWESS fit) signals that after a certain remote distance, the negative influence of remoteness on HDDS will be negligible. Accordingly, little or no change in HDDS is expected due to further increased distances if the households reside beyond 95 walking minutes from the food markets.

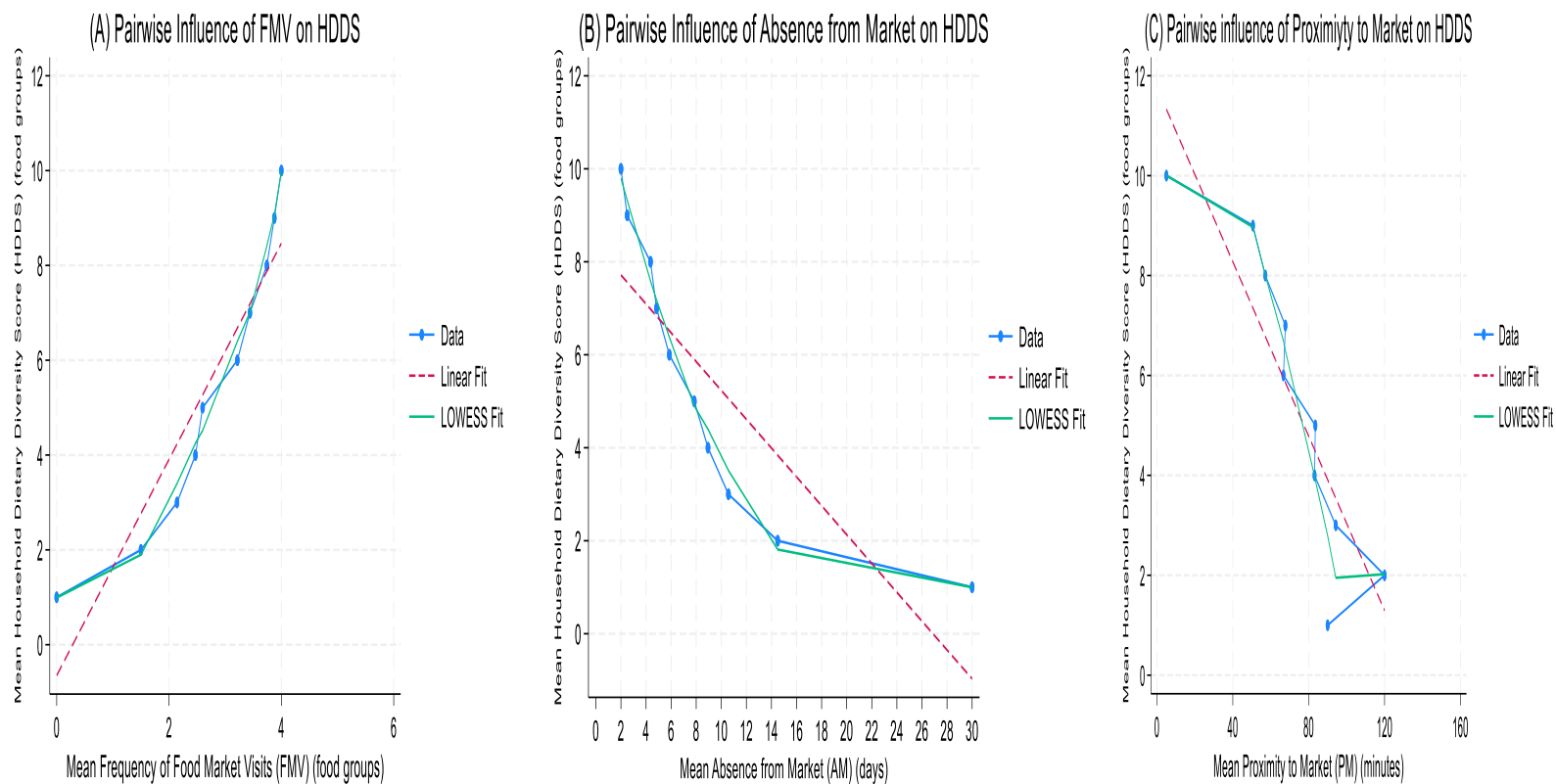


Figure 11 Pairwise Relationship between Market Access and Household Dietary Diversity

Following the LOWESS fit, the pairwise relationship shows a “Z” curve suggesting that the influence of PM on HDDS is non-linearly explained by market accessibility thresholds rather than by linear distances. For example, households living within a 5-minute walking distance from the market enjoy a uniformly high level of HDDS as those living within 10, 30, or 50 walking minutes. Conversely, beyond 95 minutes of walking distance, the marginal negative effect of distance on HDDS becomes zero. This indicates that households living farther away than this threshold are significantly isolated from the influence of the market. They might be adapted to subsistence living and informal markets or bartering. Hence, households are forced to consume a limited variety of what they grow, or some varieties of non-perishable food stock purchased during their infrequent market visits. Smallholders living between 50 to 95 minutes of walking distance experience a linear type of influence from PM on their HDDS. That is, every additional walking minute leads to a reduced level of HDDS in smallholders living within this range of PM.

According to the findings, difference in market accessibility thresholds may significantly impact policy approaches. The policies for those within the 50-minute radius of the market can be targeted at influencing the supply and quality of food varieties in the market. On the other hand, those beyond the market accessibility threshold of 95 minutes may be better approached through investments in improving transport infrastructures, arranging satellite markets, and/or establishing community-based agrifood business cooperatives. Smallholders between 50 to 90 minutes walking range may need investments in transport infrastructures to reduce the negative effect of remoteness on HDDS.

6.3.2.3. *Pairwise Relationship between Market Access and Farm Production Diversity*

The joint interplay between PDS and market access in influencing HDDS is graphically examined in Figures 12A-C which graphs PDS against the three market access measures used in this study.

Figure 12A shows that there is a strong positive association between PDS and FMV but only up to a certain optimal point. As is depicted in Figure 12A, at the initial stage, an increase in PDS by 3 food groups (from 1.5 to 4.5) is associated with an increase in FMV by 2.3 visits (from 1.5 to 3.8). However, at a later stage, a 2.5 food group increase in PDS is associated with only a 0.2 increase in FMV (from 3.8 to 4). This implies that a further increase in PDS will lead to a smaller FMV. This indicates the existence of a positive nonlinear complementarity between FMV and PDS, either induced by high PDS or influenced by positive market signals due to FMV. However, in both cases, further PDS may reduce the surplus in output and the benefits per unit of diversification. This may be due to increased costs, time, and inputs for farm diversification, which negatively affect income and the time to visit markets, particularly for most rural households. The loss of income and time may also force households to consume their production instead of purchasing food, which in turn reduces FMV.

Figure 12B graphs PDS (x-axis) against days of AM (y-axis), and not surprisingly shows an inverse relationship compared with Figure 12A. This figure shows that more AM is associated with lower PDS levels. However, there is little association beyond PDS levels of 5 or above. This suggests that farmers with less PDS, such as those producing staple crops, may have high AM. This could be because they mainly visit the market during harvesting, or when the households need cash, and this leads to a significant AM outside of such circumstances.

The final comparison, Figure 12C, shows the association between households' PM and their level of PDS. PDS is higher in households closer to the markets than in remote areas. The relationship implies that lower travel time or low PM encourages households to pursue more PDS, while remoteness (high PM) discourages PDS. This may mean that markets can create economic incentives for farmers to produce multiple varieties, possibly by easing access to production inputs, such as seeds and fertilizers and/or providing greater market access advantages and benefits to the closest smallholders compared to those in remote areas. In addition, there is an issue of perishability of farm products during transportation.

The findings suggest a strong positive interconnection between market access and PDS in smallholder households. The interlink may be crucial in determining smallholders' production and market engagement decisions which in turn may influence the HDDS status. The positive interlinks between market access and PDS in the findings are contrary to expectations. This could be because households in remote areas were expected to diversify to compensate for their inability to make frequent food purchases due to limited access to the market (Sibhatu and Qaim, 2018).

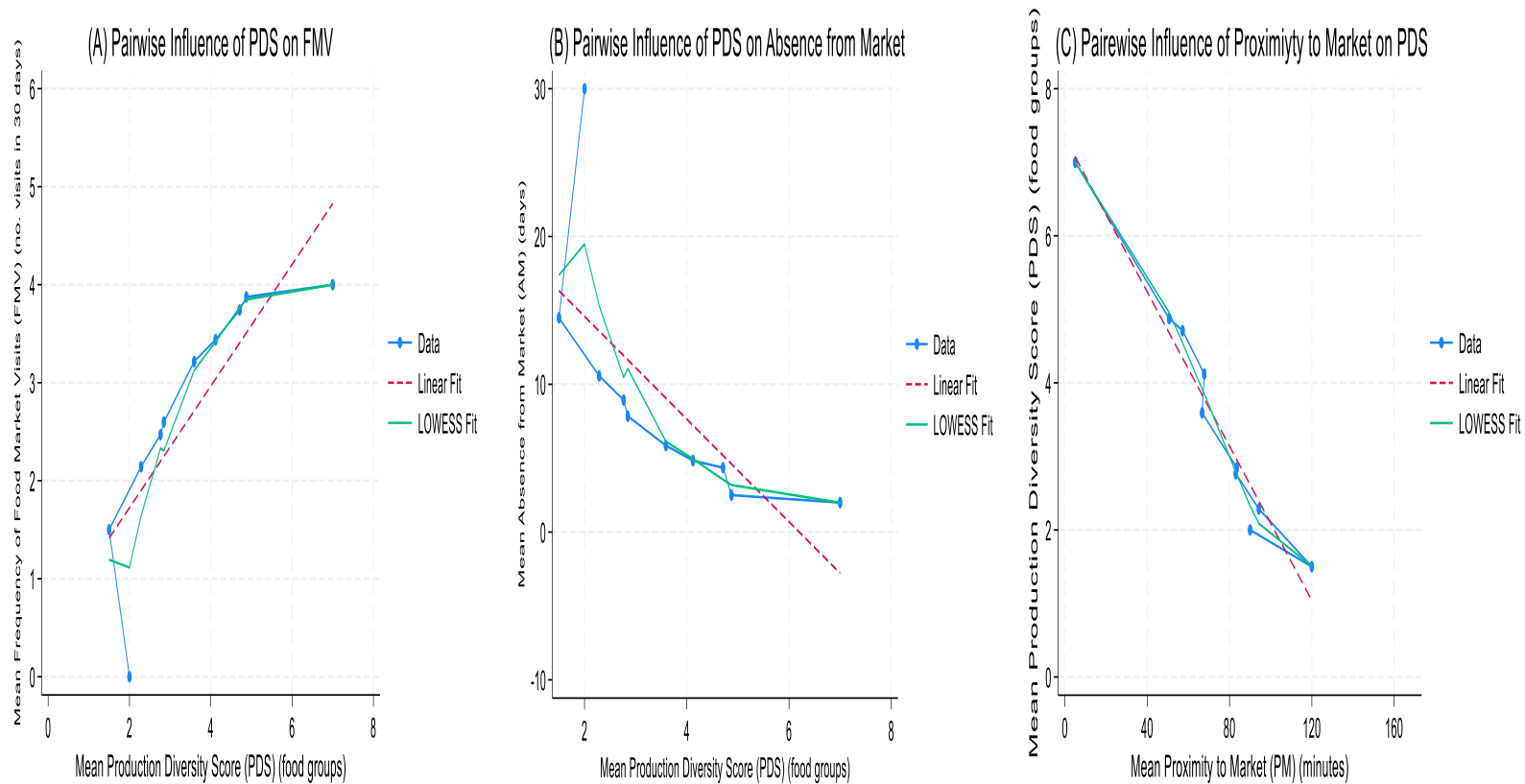


Figure 12 Pairwise Relationship between Farm Production Diversity and Market Access

6.3.3. Econometrics Results

6.3.3.1. Estimation of PDS and Market Access Alongside Control Variables

The pairwise and joint relationship between HDDS, PDS, and the three market access measures is analyzed using Poisson estimation in the following sections. Examining the pairwise and joint effects between PDS and market access among smallholders is relevant for a comprehensive understanding of their possible synergy and trade-offs. It helps identify which strategy is most impactful in addressing the dietary diversity and nutrition challenges faced by smallholders.

The estimation results presented in Table 11 divide the output into two sets of findings. The first set indicated in (Columns 1 – 4) independently estimates the influence of PDS and the different market access measures on HDDS. The second presented in (Columns 5 – 10) presents the combined influence of PDS and the three alternative market access measures on HDDS.

6.3.3.1.1. The Pairwise Influence of Farm Production Diversity and Market Access on HDDS

The output in Table 11 Column 1 shows that the pairwise influence of PDS on HDDS is positive and significant (see Pearson correlation coefficient in Appendix 6.1A for robustness check). This result is similar to previous findings based on various approaches such as Kumar et al. (2015); Jones et al. (2014); Romeo et al. (2016); Tesfaye and Tirivayi (2020); Muthini et al. (2020). The addition of a food group into the PDS increases HDDS by 0.285 food groups, significant at a 1% level. This may indicate that though an increase in PDS increases HDDS levels, only a portion of the PDS is translated to HDDS through direct consumption or income effects. The possible reason could be that many diverse products are livestock varieties counted as additional PDSs but are usually considered asset portfolios rather than food varieties by the households, particularly in our study area. Another reason could be that households may prefer to sell some varieties for their cash needs, such as high-value fruits, vegetables, and livestock species.

Pairwise evaluation of the three market access measures on HDDS is examined in Table 11 Columns 2 to 4. All three market access measures show a highly significant association with HDDS at a 1% level. However, the magnitude and direction of their influence is different. The FMV has a positive and higher magnitude of influence, compared to the remaining two market access measures. Every additional FMV increases HDDS by an average of 0.452 food groups, (Column 2). This finding is similar to the results obtained using panel data from Uganda by Morrissey et al. (2024).

Households' AM and PM show negative influence with magnitudes of -0.011 for AM, (Column 3) and -0.004 for PM, (Column 4). The results indicate that household dietary diversity declines by an average of 0.11 food groups if the household is AM for 10 days. The effect of AM is small, possibly because rural smallholder households tend to buy most of their food on market days, which usually occur once a week. For example, in our study area, Haiki-Mesihal town's main market day is on Saturdays.

Likewise, every additional 10 walking minutes farther from the market leads to a reduction of 0.04 food groups by households thus lowering levels of HDDS.

Table 11 Marginal effect after Poisson estimation of the influence of farm production diversity (PDS) and market access on HDDS

Model Estimations										
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PDS	0.285*** (0.037)				0.205*** (0.038)	0.223*** (0.038)	0.271*** (0.037)			
FMV		0.452*** (0.058)			0.338*** (0.059)					
AM (In number of days)			-0.011** (0.004)			-0.088*** (0.015)				
PM (Walking minutes)				-0.004*** (0.001)			-0.003*** (0.001)			
PDS X FMV								0.070*** (0.007)		
PDS X AM									-0.012** (0.004)	
PDS X PM										0.000 (0.000)
Observations	396	396	396	396	396	396	396	396	396	396

Table 2 presents the marginal effects after Poisson estimation. The dependent variable is the household dietary diversity score, based on the 12 food groups. The models were estimated using Poisson model. The marginal effects are shown in model estimations (1) to (10), robust standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The Dependent variable for model estimation 1-10 is household dietary diversity (HDDS). The independent variables are Production diversity Score (PDS), Frequency of Market Visits (FMV), Absence from Markets (AM), and Proximity to Market (PM). PDS X FMV, PDS X AM, PDS X PM – stands for the interaction between PDS and the three market access measures. X represents the interaction (multiplication) between the variables.

6.3.3.1.2. *The Joint Influence of Farm Production Diversity and Market Access on HDDS*

The other gap intended to be addressed in this study is to examine the joint interplay between farm production diversity and market access on rural smallholder household dietary diversity. The output for the joint treatment of the variables is presented in Table 11, (Columns 5 to 10). The joint influences are estimated in two categories of models. The first category (Columns 5 to 7) evaluates the PDS pairing with each of the three market access measures. The second category (Columns 8 to 10) examines the interaction (multiplication) between the PDS and each of the three market access measures.

The joint estimation of PDS and AM in Table 11 (Column 6) indicates a lower magnitude of the PDS, 0.223, compared to the 0.285 (Column 1) and a higher negative influence of AM, -0.088, on HDDS, compared to -0.011 (Column 3), all at significant 1% levels. Conversely, the household's PM shows a 0.001 improvement from -0.004 in (Column 4) compared to its -0.003 points in (Column 7) in influencing HDDS. Bergau et al. (2022) have also found a -0.001 magnitude of farmers' travel time on HDDS in Ethiopia, which is close to this finding. The magnitude of the impact of PDS on HDDS in Table 11 has reduced from 0.285 (Column 1) to 0.271 (Column 7). This is possibly due to the negative effect of remoteness on PDS. The result is also supported by the visualization presented in Figure 4C above.

One important point observed in Table 11 is that the magnitude of influence of market access measured in the FMV is higher than when measured in PM. This indicates that the way in which market access is measured affects the magnitude of influence (Muthini et al., 2020) and the search for a stable measure of market access requires further attention.

Table 11 (Columns 8 to 10) depicts the interaction (multiplication) between the PDS and the three market access measures. In Table 11 (Column 8), the magnitude of the interaction between PDS and FMV becomes 0.070, which is positive and significant at

the 1% level. The results indicate (1) a positive association between PDS and HDDS, (2) a positive association between FMV and HDDS, and (3) a positive association between the interaction of FMV x PDS and HDDS. This value suggests a positive interaction between the two. The high magnitude of the coefficients of the FMV in Table 11 models 2 and 5 indicate that the joint effect is altered by the households' FMV. This implies that by keeping all other factors constant, where PDS and FMV are in operation, the FMV determines the level of HDDS. The results reaffirm that the joint interplay between the FMV and PDS enhances smallholder HDDS.

The interaction between PDS and AM is found to be negative (-0.012), and significant at a 1% level, (Column 9). The results in Table 11 indicate (1) a positive association between PDS and HDDS (Column 1), (2) a negative association between AM and HDDS (Column 3), and (3) a negative association between the interaction of AM x PDS and HDDS (Column 9). The negative and significant interaction shows that the effect of PDS and AM on HDDS is joint and not independent. Hence, with low food market attendance rate, the positive effect of PDS on HDDS is likely to be less.

Table 11 (Column 10) shows the interaction between PDS and household PM. The relationship indicates that the interaction between PDS and PM is highly significant, at 1% level, but has a coefficient close to zero. This result suggests that the effect of PM on HDDS through PDS may be complex, non-linear, or threshold-based, as previously observed in the graphical relationships. The findings signal the need for further research into the interplay between PDS and market access.

Examination of the joint interplay between PDS and FMV reveals that FMV combined with greater PDS, reinforces one another in improving HDDS. A recent study conducted in Uganda comes to a similar conclusion, stating that “there are benefits to smallholders that come from a combination of crop diversity and market engagement” (Morrissey et al., 2024).

6.3.3.1.3. *Estimation of the PDS and Market Access Alongside Control Variables*

Table 12 examines the influence of other socioeconomic variables on smallholder HDDS. It shows the marginal effects of the variables after Poisson estimation in 6 models (Columns 1 – 6). Columns 1 to 3 show the joint interplay among the PDS, the three alternative market access measures, and other selected socioeconomic variables. Columns 4 to 6 show the interaction of the PDS with the three market access measures and the control variables.

Table 12 Marginal effects after Poisson estimation: The influence of farm production diversity, market access, and control variables on household dietary diversity

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Marital status = 2, Married	0.256 (0.436)	-0.004 (0.377)	0.243 (0.469)	0.232 (0.466)	0.178 (0.470)	0.188 (0.492)
Marital status = 3, Single	1.759*** (0.373)	1.367*** (0.324)	1.436*** (0.384)	1.486*** (0.425)	1.198** (0.530)	1.383*** (0.385)
Marital status = 4, Widowed	0.117 (0.264)	0.036 (0.263)	0.032 (0.263)	0.100 (0.265)	-0.060 (0.271)	-0.014 (0.271)
Kushet/sub district = 2, Damaino	0.020 (0.156)	-0.001 (0.142)	-0.083 (0.196)	-0.045 (0.151)	-0.247 (0.162)	-0.629*** (0.183)
Kushet/sub district = 3, Gergera	0.027 (0.180)	-0.113 (0.171)	-0.011 (0.183)	0.029 (0.180)	-0.062 (0.189)	-0.142 (0.197)
Kushet/sub district = 4, Degaabur	0.173 (0.185)	0.165 (0.172)	0.167 (0.298)	0.027 (0.175)	-0.222 (0.188)	-0.836*** (0.223)
Gender = 2, Male	-0.061 (0.367)	0.109 (0.300)	-0.070 (0.395)	-0.030 (0.396)	0.029 (0.395)	0.029 (0.417)
Education (year of schooling)	0.040* (0.022)	0.031 (0.022)	0.042* (0.023)	0.043* (0.023)	0.038 (0.025)	0.042* (0.024)
Age (years)	-0.003 (0.005)	-0.003 (0.005)	-0.005 (0.005)	-0.004 (0.005)	0.000 (0.005)	-0.004 (0.005)
Family size (number)	0.008 (0.032)	0.024 (0.032)	0.020 (0.033)	0.018 (0.032)	0.067** (0.032)	0.036 (0.032)
Irrigable farmland size (in tsimad 1/4 of hectare)	0.266* (0.138)	0.497*** (0.135)	0.442*** (0.136)	0.313** (0.135)	0.598*** (0.152)	0.610*** (0.149)
PDS (food groups)	0.201*** (0.037)	0.198*** (0.037)	0.253*** (0.037)			
FMV (number)	0.322*** (0.068)					
AM (days)		-0.095*** (0.017)				
PM (minutes)			-0.003 (0.002)			
PDS X FMV				0.064*** (0.008)		
PDS X AM					-0.009* (0.005)	
PDS X PM						0.001*** (0.000)
Observations	396	396	396	396	396	396

Table 3 presents the marginal effects after Poisson estimation. The dependent variable is the Household Dietary Diversity Score (HDDS), based on the 12 food groups. The models were estimated using Poisson model. The marginal effects are shown in model estimations (1) to (6), robust standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The Dependent variable for model estimation 1-10 is household dietary diversity (HDDS). PDS stands for Production diversity Score; FMV - Frequency of food Market Visits; AM - Absence from Markets; and PM - Proximity to Market. The X in PDS X FMV, PDS X AM, PDS X PM – stands for the interaction (multiplication) between PDS and the three market access measures.

The results in Table 12 show that the PDS regressed with selected control variables positively and significantly influences HDDS, ranging from 0.198 to 0.253 food groups. There are small changes in coefficient values compared with Table 11 which could be associated with the compensating effects of the included control variables: nonetheless, the direction and level of significance observed in Table 11 is sustained. Similarly, the FMV with an estimated coefficient of influence of 0.332, and that of AM, -0.095, show only minor differences compared to their respective magnitude in Table 11, and the direction and level of significance are still maintained. However, although PM has the same magnitude of influence as was observed in Table 11, it is not significant in Table 12. Again, this could be another indicator for PM's weak predictive power compared to the other two measures examined in this paper.

The results for the interaction variables in Table 12 also exhibit similar features to those reported in Table 11. An exception to this is the coefficient of the interaction between PDS and PM, which becomes significant at the 1% level in Table 12. This again suggests that there is an issue of stability in using PM as a measure of market access compared to the alternative market access measures examined.

Our study highlights the importance of considering the FMV as an alternative measure of market access in understanding HDDS. This is because the FMV has shown higher magnitudes of influence in Table 11 Models 2 and 5 (Table 11 Columns 2 and 5) and Table 12 Model 1 (Column 1) and in all interactions at a consistently high significance level, 1%, compared to PM and AM measures.

The Poisson estimation result in Table 12 explores some statistically significant household and socioeconomic variables influencing HDDS. The findings show that households identified as single in their marital status have high HDDS levels, though caution should be applied to the interpretation of this result due to the very small number of single-headed households in our data (see Table 10). Another socioeconomic variable, education level (years of schooling) of the household head is marginally significant, at the 10% level.

Irrigated farmland sizes show a significant positive association at the 1% level across models 1-4 and at the 10% level in models 5-6 in Table 12. The result was anticipated, which is why this paper treated irrigated and rainfed farmlands differently. Households with access to irrigation in the study area can grow diverse crops multiple times using the year-round flowing river, Gergera, and a few spring water sources. Irrigated farmlands are mainly planted with different vegetable and fruit varieties (See Section 6.1) usually for commercial benefits. Studies undertaken in Tigray, such as Gebrehiwot and Mesfin (2015) and Tesfay (2021), show that participation in irrigation improves household welfare through increased consumption, crop income, and asset accumulation. This indicates that households with larger irrigated farmland sizes may enjoy greater HDDS either directly from self-consumption or indirectly through income effects compared to what is obtained from rainfed farmlands. An important point is that HDDS is primarily influenced by the variety of crops grown rather than the size of farmland among smallholders. The summary statistics in Table 10 show that the average size of irrigated farmland is about a quarter, at 0.296 tsimad, compared to the size of rainfed farmland, which is 1.178 tsimad. However, the contribution to HDDS is significantly higher for households with access to irrigated farmland than those with rainfed farmland.

Significant differences in HDDS between the sub-districts is observed. For example, in comparison to Geter Haiki Mesihal, the reference category, Damaino residents consume 0.621 food groups less diverse diets, significant at 1%. Similarly, households who live in Degaabur consume 0.819 food groups lower dietary diversity compared to Geter Haiki Mesihal residents at a 1% level of significance.

Rainfed farmland, the age of the household head, and family size are found statistically insignificant in influencing HDDS (Table 12). The explanation could be because, in most cases, regardless of its size, rainfed farmlands are primarily used to grow staple crops, usually cereals, in our study area. This is because rainfed farmland depends mainly on seasonal rainfall and are vulnerable to rainfall variability. Therefore, monotonous food group production in rainfed farmland compared to irrigated farmland is expected. This

difference may limit the contribution of crops grown in rainfed farmlands to HDDS, and so does the size. Given the less diverse food group production on rainfed farmlands, the finding might signal that diversity in livestock and through irrigation could be more effective in influencing smallholder HDDS, either due to direct consumption or income effects.

The types of crops grown in rainfed versus irrigated farmlands are generally different in the study area, and their contribution to HDDS is anticipated to be different. The multicollinearity test and model estimations, first excluding rainfed farmland and then irrigated farmland sizes for model stability, show that multicollinearity between the variables does not create a statistically significant change in the model outputs (see the multicollinearity test result with mean VIF = 2.680 in Appendix 6.3A).

Age has a statistically insignificant effect on HDDS, which may indicate that age differences among heads have a limited effect on HDDS because of the community's strong attachment to traditional feeding habits.

Although large family size may lead to food shortages, the finding does not show a negative influence on HDDS. This could be because a large family size may offset resource constraints and food shortages due to possible multiple labor resources, which may provide various income that will help the household purchase diverse foods. Hence, the trade-off may ultimately neutralize the negative effect of large family size on HDDS.

6.4. Conclusion

To evaluate the joint influence of farm production diversity (PDS) and market access on HDDS, this paper uses three different measures of market access. These are the household's frequency of food market visits (FMV), absence from food markets (AM), and proximity to the market (PM). Graphical presentation and Poisson econometrics estimation methods are used to analyze the primary data collected from 396 smallholders in a cross-sectional household survey in Tigray, northern Ethiopia.

The findings indicate there is a joint and individual nonlinear complementary relationship between PDS and the three market access measures in influencing HDDS, though the direction differs according to the measure employed. I find that PDS has a positive relationship with FMV and a negative relationship with AM and PM. Household FMV significantly increases smallholder HDDS while longer AM from markets negatively influences HDDS. Market access measured in walking minutes, PM, shows that the impact of market access on HDDS is threshold-based and nonlinear. Our visualization analysis indicates that the influence of market access on the level of HDDS for smallholders living within a 50-minute walking radius is quite similar. The negative impact of market influence on HDDS starts to be seen for households living beyond the 50-minute walking threshold. Conversely, market access' influence on HDDS for smallholders living beyond 95 walking minutes is negligible.

Regarding socioeconomic factors, I find that the size of irrigable farmland significantly contributes to HDDS, while rainfed farmland has a statistically insignificant influence. On the other hand, the household head's education level can marginally influence HDDS.

Several possible policy implications arise from these findings. Policies could focus on creating livelihood opportunities and promoting more frequent market visits through improved access to transport, or by encouraging more market-oriented agricultural production such as short gestation marketable vegetables and small ruminants in backyards so that farmers would make more frequent visits to sell their products. In addition, I conclude that differences in market accessibility thresholds should be taken into consideration by policymakers. Interventions targeting smallholders within a certain threshold (identified in this study as approximately a 50-minute radius) need to address the quantity, supply, quality, and diversities of the food varieties in the market. Those beyond the market accessibility threshold of 95 minutes may be better approached through investments in improving transport infrastructures, arranging satellite markets, or establishing community-based agrifood business cooperatives to address household dietary diversity. For those smallholders living between 50 to 95 minutes walking threshold, the focus should be on the improvement and construction of transport

infrastructures so that the negative influence of remoteness on households' access to the market is minimized.

CHAPTER SEVEN

7.1. THE LINK BETWEEN SMALLHOLDER COMMERCIALIZATION AND FARM PRODUCTION DIVERSITY: EVIDENCE FROM NORTHERN ETHIOPIA

Abstract

Studies indicate commercialization increases smallholder farm productivity and income. However, the debate on whether a specific farm production diversity level or other factors influence smallholder commercialization is not yet settled and the pathways remain unclear in the literature. This paper examines the bidirectional link between commercialization and farm production strategies. The research is based on cross-sectional data collected from randomly selected 396 smallholder households in Tigray, northern Ethiopia. A structural equation modelling (SEM) method is used to simultaneously assess the relationship between smallholder commercialization and farming strategies. The findings indicate a complex bidirectional link between commercialization and smallholder farm production diversity. Low farm production diversity positively influences commercialization. Conversely, commercialization slightly and positively influences high farm production diversity. Both relationships, however, are strongly influenced by other socioeconomic and household characteristics: the size of irrigable farmland and market access have a stronger positive influence on commercialization than specialization. Family size, gender, age, and education level of the household head have a strong positive influence on farm production diversity. On the contrary these household factors have little significance in shaping smallholder commercialization.

Key words: *Smallholders, Commercialization, Farm production strategies, Farm production diversity, Tigray, Ethiopia.*

7.1. Introduction

On average, around 733 million people, representing approximately 8.5 percent of the global population, may have faced hunger in 2023 (FAO et al., 2024). The same report notes that this figure reflects an additional 152 million malnourished individuals compared to 2019. The highest percentage of the population affected is in Africa, where nearly 20 percent are affected. The distribution of hunger is notably severe and consistently widespread in rural areas compared to urban and peri-urban locations (FAO et al., 2024). This indicates that smallholder farmers, who make up a significant portion of the rural population, are suffering from hunger.

Numerous studies indicate that increasing smallholder productivity and income is a vital strategy for addressing hunger and food insecurity (Ogutu et al., 2020; Ruel and Alderman, 2013; Sibhatu and Qaim, 2017). However, enhancing the productivity and income of smallholders is a complex challenge due to factors related to limited farmland, climate change, conflicts, and inefficient market linkages (Bagheramiri and Keshvarz Shaal, 2020; FAO et al., 2024; Rapsomanikis, 2015).

Multiple studies have therefore been conducted and show the importance of smallholder commercialization through the sale of a portion of their farm products (Do and Nguyen, 2024) an approach to increase smallholder productivity and income (Mahofa and Sukume, 2022; Mulenga et al., 2021; Newettie et al., 2023; Ogutu and Qaim, 2019a; Pamela et al., 2022; Tabe-Ojong et al., 2022; Usman and Haile, 2022; Woldeyohanes et al., 2017).

None the less, many of these studies associate improved smallholder commercialization with a specific level of farm production diversity, favoring either a low farm production diversity (i.e. specialization) or a high farm production diversity (i.e. diversification). As a result, some studies by Barrett, (2010); Ogutu et al. (2020); Kuma et al. (2019); Sibhatu et al. (2015); Timmer, (1997); Wickramasinghe, (2015). suggest smallholders reduce their level of farm production diversity to one or a few crops or livestock variety to commercialize. Li et al. (2017) and Sekyi, Quaidoo, et al. (2023) extended this argument into the existence of a synergic two-way interrelationship between specialization and commercialization.

Conversely, researches by Bellon, Kotu, et al. (2020); Kissoly et al. (2020); McCord et al. (2015), Michler and Josephson (2017); Morrissey et al. (2024); Mulenga et al. (2021); Rajendran et al. (2017a); and Tesfaye and Tirivayi (2020) indicated that high farm production diversity drives smallholder commercialization by enabling households to sell multiple high-value crops and livestock varieties.

The literature on the subject shows the existence of an ongoing debate about the degree of farm production diversity influencing smallholder commercialization. In addition, little attention has been paid to the reverse relationship - the effect of commercialization on the degree of farm production diversity. This paper, therefore, aims to contribute to the literature by responding to the following three questions,

1. What level of farm production diversity influence smallholder commercialization?
2. What are the specific pathways to influence smallholder commercialization? And
3. How does commercialization influence the level of smallholder farm production diversity?

The answer to the first question is crucial in the identification of the policies, resources, and forms of interventions needed to increase smallholder commercialization – and farm productivity and income. The second question is important in understanding the specific pathways influencing smallholder commercialization and guides policies for interventions. The third question gives insights on the effect of commercialization on smallholders' choice of farming strategies, their ability to respond to market forces, and identifying opportunities for sustainable agricultural development and food security interventions.

Examination of these relationships demand simultaneous treatment of the variables. This study, therefore, uses Structural Equation Modelling (SEM) method to simultaneously evaluate the bidirectional interdependence between smallholder commercialization and their farm production strategies.

This analysis is based on empirical data from a cross-sectional household survey in Tigray, northern Ethiopia. This paper uses the United Nations Food and Agriculture Organization definition of smallholders, farmers possessing less than 2 hectares of land (Rapsomanikis, 2015). The study site- with a national average farm landholding

size of 1.18 hectares (Tesfay, 2021) - rests within the subset. Agricultural production is also based on family labor matching the definitions of smallholders given by the FAO (Chavas and Di Falco, 2012; FAO, 2017; Tabe-Ojong et al., 2022; Tesfay, 2020), suitable for this research.

Unlike most previous studies that focused on specific crop or livestock production such as Bellon, et al. (2020); BIRTHAL and Hazrana (2019); Islam et al. (2018); Michler and Josephson (2017); Sekyi, Adom, et al. (2023), Wu et al. (2022), this study uses a combination of both crop and livestock species produced by smallholders, which represents the most common method of farming in Ethiopia (Chavas and Di Falco, 2012; Rapsomanikis, 2015; Tabe Ojong et al., 2022). The findings from this study are expected to provide valuable insights into the relationship between commercialization and smallholder farm production strategies and suggest policy options for improved commercialization that would influence smallholder income and productivity (Bergau et al., 2022).

7.2. Materials and Methods

7.2.1. Data Source and Sampling Method

The information used in this study is primary data collected from a cross-sectional household survey in rural Tigray, northern Ethiopia. The survey was conducted among smallholders in the Gergera Watershed, in the Eastern zone of Tigray, from September to October 2020. A multistage stratified random sampling technique was used to select 396 households from the list held in the rural district administration office.

The actual data collection was conducted after two pilot surveys were carried out to validate the dependability of the questionnaire. The questionnaire was translated into the local language, Tigrigna. It was designed to be compatible with the cultural norms of the areas as related to farming, consumption and marketing behaviors, and had four sections: questions on demographic and socioeconomic characteristics; questions on farm production activities; questions on marketing; and questions related to consumption behavior. The Kobo Toolbox digital data collection platform was used to gather and save the survey data.

7.2.2. Measurement of Key Variables

7.2.2.1. Measurement of Smallholder Commercialization

Smallholder commercialization is an outcome variable of this research and is described in the literature as the sale of a proportion of farm products (Do and Nguyen, 2024). Commercialization is typically measured in terms of the proportion by value of the farm products (crops and/or livestock) sold in a specific harvest season (Bellon et al., 2020; Omamo, 1998; Timmer, 1997).

In this paper, I use a Commercialization Index (CI), defined as the ratio of the value of all farm products (crops and livestock) sold to the total value of the farm output produced by the household in the harvest season September 2019 to September 2020, multiplied by 100 (Li et al., 2017; Mulenga et al., 2021; Ogutu and Qaim, 2019).

Mathematically

$$CI = \frac{\text{total value of all farm output sold}}{\text{total value of all farm output produced}} \times 100\% \dots\dots\dots (7.1)$$

The Commercialization Index (*CI*) is a continuous variable which ranges from 0% to 100%, where the minimum (0%) indicates no sales (complete self-consumption) while the maximum (100%) indicates sale of all produce (Sekyi, Quaidoo, et al., 2023).

The total production of crops and livestock by the household in the harvest year was multiplied by the average local market price over four weeks (coinciding with data collection) to arrive at the monetary value of farm output. Price information was gathered from local markets at the time of the survey. Standardized valuation of the farm products using actual (real-time) market prices is preferred to household-specific prices because recalling prices can be difficult, particularly when small quantities of multiple varieties were sold at different times, and there was considerable price volatility due to COVID-19 (on top of the expected seasonal agricultural commodity price fluctuations) (Asfaw et al., 2019). Hence, average crop and livestock producer existing prices in the local markets were used to calculate the value of the individual farm output (Ogutu and Qaim, 2019).

7.2.2.2. *Smallholder Farm Production Strategies*

In studies of smallholder agriculture, farm production strategies are typically understood as a high or a low level of farm production diversity (Bellon et al., 2020; Timmer, 1997; Omamo, 1998). A higher product diversity reflects a more diversified farm production strategy, while a lower level of diversity indicates a specialized farm production strategy. The level of diversity is measured using a simple crop and livestock species count method, that is, the number of distinct crop and livestock species produced in one harvest season, expressed as a continuous variable from 1 up to the maximum number of crop and livestock species produced in the study area (Islam et al., 2018; Jones et al., 2014; Linderhof et al., 2016; Sibhatu et al., 2015; Swindale and Bilinsky, 2006).

The simple crop and livestock species count method is as follows:

Crop Diversity (CD_i) count is used to measure the crop species varieties (CS_i) of different staple crops, vegetables, and fruit species planted and harvested throughout the farming season (September 2019 to September 2020).

$$\sum_1^k CS_i = CD_i \dots\dots\dots (7.2)$$

Livestock Diversity (LD_i) is measured by counting the different livestock species (LS_i) varieties reared in the harvest season (September 2019 to September 2020) – it includes poultry and apiculture.

$$\sum_1^j LS_i = LD_i \dots\dots\dots (7.3)$$

Farm Production Diversity (FPD_i) measures the overall diversity level expressed as sum of crop diversity (CD_i) and livestock diversity (LD_i) produced in the harvest season (September 2019 to September 2020), which represents the total farm production diversity level.

$$FPD_i = CD_i + LD_i \dots\dots\dots (7.4)$$

Where CD_i represents the varieties of the crop species planted and harvested, numbered from 1 to k; LD_i is the varieties of livestock species reared,

numbered from 1 to j, and FPD_i is the overall farm production diversity level in the harvest season.

7.2.3. Data Analysis

The objective of this research is to evaluate the bidirectional links between smallholder commercialization and farm production diversity and identify other factors influencing commercialization. Simultaneous estimation using the Structural Equation Modelling (SEM) method is applied to examine the potential links between the two outcome variables, commercialization and farm production diversity.

The detailed model specification of the two-pathway simultaneous equation is represented as follows:

Two Equations Simultaneous Path Model

1. Equation for commercialization:

$$\text{Commercialization Index}_i = \alpha_0 + \alpha_1(\text{Farm production diversity}) + \alpha_2(\text{Age}) + \alpha_3(\text{Additional income source}) + \alpha_4(\text{Education}) + \alpha_5(\text{Rainfed farmland size}) + \alpha_6(\text{Irrigated farmland size}) + \alpha_7(\text{Time to the market}) + \varepsilon_i \dots\dots (7.5)$$

2. Equation for farm production diversity:

$$\text{Farm production diversity}_i = \beta_0 + \beta_1(\text{Commercialization Index}) + \beta_2(\text{Gender}) + \beta_3(\text{Age}) + \beta_4(\text{Family size}) + \beta_5(\text{Education}) + \beta_6(\text{Rainfed farmland size}) + \beta_7(\text{Irrigated farmland size}) + \omega_i \dots\dots (7.6)$$

Where Commercialization Index and farm production diversity are the key outcome variables, and ε_i and ω_i are the structural error terms. α_0 and β_0 represent the intercepts, while α_1 – α_7 and β_1 – β_7 are the sets of parameters for the exogenous variables in the first and second structural equations, respectively.

Equations (1) and (2) differ in the exogenous variables used to impose an exclusion restriction in our model (Wooldridge, 2013). The exclusion restriction in a two-way simultaneous equations model ensures the necessary and sufficient conditions for identification, namely the rank and order conditions. These conditions require that at least one exogenous variable with a non-zero coefficient be excluded from one

equation and included in the other (Wooldridge, 2013, pp. 560-570). Accordingly, family size is excluded from the first equation and included in the second, while additional income source is excluded from the second and included in the first.

7.2.4. Definitions of Variables

The following section defines all the variables included in the econometrics model. In addition, it presents the hypothesis for the expected signs of influence for each explanatory variable and the two outcome variables - commercialization and farm production diversity.

Smallholder commercialization is an outcome variable in the first model of the simultaneous equation. It is also used to explain farm production diversity in the second model. Smallholder commercialization is a continuous variable ranging from 0% to 100%, indicating the percentage of the value of the products sold in the market. As an explanatory variable, smallholder commercialization is expected to have a negative influence on farm production diversity. This is because less diverse farm production enables the production of a surplus of specific marketable crops or livestock, compared to a more diverse farm production.

Farm production diversity is the outcome variable in the second model but is also treated as an explanatory variable in the first model. Farm production diversity is a continuous variable, representing the scale of diversity in the number of crop and/or livestock species produced in one farming season. Given the small average land size of the farms in the study area, a more diverse farm production diversity is expected to reduce the surplus of any output available for sale. Hence, as an explanatory variable, a higher farm production diversity is expected to have a negative effect on commercialization.

The other explanatory variables are presented as follows:

Age of the household head is a continuous variable measured in years, representing the number of years since the household head was born. Because younger people are more likely to take risks and more likely to have non-farm income, I expect they will be more interested in selling their farm output than older people. The expected relationship between age and commercialization is therefore negative, while the

expected relationship between age and farm production diversity is expected to be positive. This is because it can be challenging for older people to actively engage in markets and incur the risks of specialization. Instead, older people may prefer a diverse portfolio of production to guard against losses caused by climate and market price volatility.

Gender of the household head is a categorical variable expected to influence commercialization and farm production diversity. Compared with female-headed households in the study area, male-headed households have an advantage in having additional farm labor resources that enable them to produce more diverse products and more surplus for sale. Therefore, male-headed households are expected to affect commercialization and farm production diversity positively. In addition, physical, religious, and cultural factors could limit female-headed households' participation in producing excess output.

Education level of the household head is a continuous variable representing the number of years of schooling. Educated people may have better access to market price information and alternative income sources, such as off-farm and non-farm incomes. This may help educated people purchase diverse foods rather than rely on diverse farm production. Hence, education level is expected to influence commercialization positively but farm production diversity negatively.

Family size counts the number of people living in and recognizes as part of the household membership. Large family size is associated with higher household consumption needs, leaving less surplus for sale. Therefore, family size is expected to impact commercialization negatively. It may, however, positively affect farm production diversity by providing more labor resources to handle diverse farming activities.

Additional income source is a binary variable where 1 indicates the presence of an additional (non-farm) income source for the household and 0 otherwise. The additional sources of income identified during the survey include remittance, PSNP, casual labor, salary, masonry, carpentry, pottery, craftwork, hairdressing and other informal income-generating activities. The expected sign of additional income in

commercialization is negative because households can trade using other income sources and thereby reduce the sale of their farm products. Additional income sources are also expected to negatively influence farm production diversity because households may prefer to produce less diverse varieties and purchase what is missing in the household using their additional income.

Size of rainfed farmland is a measure of the farmland owned by the household that relies on seasonal rainfall for agricultural production. Farmland is measured in tsimad, a local measure of equivalent to $\frac{1}{4}$ of a hectare. The size of rainfed farmland is expected to have a positive effect on commercialization, as it may enable higher levels of production, while also having a positive effect on farm production diversity by giving farmers a chance to diversify more compared to those with less rainfed farmland.

Size of irrigated farmland is a measure of irrigated farmland owned by the household. Both irrigated and rainfed farmland sizes are treated as continuous variables but a separate treatment is needed due to the difference in the crop species produced on each land type (McCord et al., 2015; Zimmerer, 2014). Rainfed farmlands depend on seasonal rainfall for production while irrigated farmlands use diverse water sources such as rivers, diverted canals, springs, and wells. Staple crops are usually grown on rainfed lands in the study area while irrigated farmlands are used to grow vegetables and fruits. Access to irrigable farmland creates opportunities for frequent harvests. The quantity of production is expected to be proportional to the size of farmland, keeping other factors constant. Hence, irrigated farmland size is also hypothesized to have a positive effect on commercialization and farm production diversity- due to the ability to produce crops two to three times per year.

Time to the market is an indicator of household access to the market. The study uses an estimate of the walking time in minutes to the nearest market center, as reported by the survey participants. Given the diverse topography in the study area, I chose to measure market access in time instead of kilometers to better capture the farmers' challenges in accessing the market. Longer walking time might discourage smallholders from frequent market visits or from trading large volumes of products at a given time. Hence, I expect travel time to market to have a negative influence on

smallholder commercialization. On the other hand, greater distance from the market is expected to positively influence farm production diversity, as farmers may diversify their production to compensate for limited access to market-bought goods.

7.3. Results and Discussions

7.3.1. Descriptive Statistics

Smallholder commercialization is the first of the two outcome variables of the paper. The proportion of agricultural output sold, commercialization, ranges from 0 to 100%, the average being 11.96% (see Table 13). This wide range indicates the extent of heterogeneity among the smallholders. It is also manifested by the 12.56 standard deviation, which is greater than the average.

Table 13 Summary statistics of the variables of interest

Variable	Obs	Mean	Std. Dev.	Min	Max
Commercialization	396	11.961	12.561	0	100
Farm production diversity	396	6.485	3.346	0	16
Age of the hh head	396	54.053	14.339	20	100
Education level	396	1.227	2.464	0	15
Size of Irrigated land	396	.296	.404	0	2
Size of rainfed land	396	1.178	.998	0	5
Time to the market	396	72.859	54.256	2	240
Family size	396	5.109	2.247	1	11
Gender	396	Frequency	Percentage		
Female		106	26.76		
Male		290	73.23		
Additional income source	396				
Yes		209	52.78		
No		187	47.22		

Source: own computation from the survey data collected Sep. to Oct. 2020.

The second outcome variable is smallholder farm production strategy.¹³ The minimum farm diversity level recorded was 1 species, while the maximum was 16 species. The average farm production diversity in the study area was 6.485 crop and livestock species, and the data is approximately normally distributed around the mean, with a standard deviation of 3.346.

¹³ Only four households, or 1% of those surveyed, reported zero production. The Maximum Likelihood with Missing Values (MLMV) method is used in our structural equation model (SEM) econometric analysis to handle missing data and ensure the efficiency and robustness of the findings.

The factors expected to influence commercialization and farm production diversity in the study area include the size of irrigated farmland, the size of rainfed farmland, access to the market, gender, age and education of the household head, family size, and additional sources of income.

The summary statistics for these explanatory variables are presented in Table 13, showing that the average irrigated farmland size was 0.296 tsimad, while the average rainfed farmland size was 1.178 tsimad. The minimum distance to the market recorded in our survey was 2 walking minutes while the maximum was 240 minutes (4 hours): the average walking time to the market was 72 minutes. Looking at the demographic characteristics, male-headed households accounted for 73.23% of the surveyed households and female for 26.76%. The average age of household heads was 54.5 years, and their average years of schooling was 1.23 years. The average family size of the households surveyed was 5.1, which ranged from 1 to 11 family members.

7.3.2. Econometrics Results

This study aims to evaluate the links between smallholder commercialization and farm production diversity in Gergera Watershed, while also examining other factors influencing the two outcome variables. The dependent variables are commercialization and farm production diversity. I use a Structural Equation Model (SEM) in a two-pathway simultaneous equation approach to analyze the relationship between the two outcomes and their explanatory variables. The theoretical hypothesis is that many literatures link commercialization with low farm production diversity (Barrett, 2010; Ogutu et al. 2020; Kuma et al. 2019; Sibhatu et al. 2015; Timmer, 1997; Wickramasinghe, 2015); while others with a high farm production diversity (Bellon, Kotu, et al. 2020; Kissoly et al. 2020; McCord et al. 2015, Michler and Josephson 2017; Morrissey et al. 2024; Mulenga et al. 2021; Rajendran et al. 2017; and Tesfaye and Tirivayi 2020). Multiple other studies also suggest a two-way link between commercialization and low farm production diversity (Sekyi, et al., 2023; Li et al., 2017). The existing mixed findings in the literature regarding the direction of influence between smallholder commercialization and farming diversity creates a

strong theoretical and logical foundation to examine the bidirectional link between the two outcome variables.

The analysis executed three stages of rigorous model tests: pre-estimation, during estimation, and post-estimation. In the pre-estimation stage, despite using a stratified random sampling method during data collection, I applied the Heckman correction method to address unobserved potential selection bias. I find a statistically insignificant value ($p = 0.596$) for the coefficient of the Inverse Mills Ratio (IMR), indicating that selection bias is not a concern for the model. Additionally, the Durbin-Wu-Hausman test was conducted to check for endogeneity. The test result suggests that the variables in the model are not correlated with the error term and are exogenous.

During estimation, the Maximum Likelihood for Missing Values (MLMV) method was used to account for any missing data ensuring an efficient and unbiased estimate of the bidirectional relationship between commercialization and farm production diversity.

A post-estimation model fit test using Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were also conducted (see appendix 7.4B). In all the test results our estimated model is a good fit. Moreover, the Variance Inflation Factor (VIF) test for possible multicollinearity between the variables indicates no significant concern with the model.

Consequently, the estimation of the simultaneous equations in SEM was conducted jointly. The estimation enables the analysis of direct, indirect, and total effects between the explanatory and the two outcome variables (commercialization and farm production diversity) within the structural models. In line with the main objective - evaluating the links between smallholder commercialization and farm production diversity - discussions of the findings are based on the total effect of the SEM estimation. The following sections discuss the direct effect results of the SEM estimation.

7.3.2.1. Total Effect

7.3.2.1.1. The Two-Pathway Links Between Smallholder Commercialization and Farming Diversity

The results presented in Table 14 show a bidirectional link between smallholder commercialization and farming diversity in the study area. In the first structural model, commercialization is the dependent variable and farm production diversity is an explanatory variable. The SEM estimation results indicate that high diversity has a negative influence on smallholder commercialization. The magnitude of influence shows that a unit increase in crop or livestock species diversity leads to a 1.062 percentage points reduction in commercialization at a 5% level of significance. The reason for this may be that increased farm production diversity on a relatively small plot of land leaves households with limited surplus products to be traded. In general, the finding reveals that smallholder commercialization is strongly associated with a low-diversity farm production diversity.

In the second model, farm production diversity is presented as the dependent variable and commercialization as an explanatory variable. The estimation results indicate that commercialization positively but only marginally (at a 10% level) affects smallholder farm production diversity. The results indicate that a 0.067 percent increase in smallholder commercialization leads to an increased farm production diversity by one additional crop or livestock species. The finding suggests that increased commercialization may slightly encourage higher production diversity, possibly in response to perceived market benefits.

The overall finding suggests the existence of a bidirectional link with a modest feedback loop between commercialization and farm production diversity. The relationship is expressed as a strong negative influence of farm production diversity on smallholder commercialization, on one hand, and a weak positive influence of commercialization on farm production diversity on the other.

Table 14 Result: The Joint Estimation of Simultaneous Equations in Structural Equation Modelling (SEM)

Model 1- Dependent variable: Commercialization

Model 2 - Dependent variable: Farm Production Diversity

	Total OIM	effects				
	Coef.	std. err.	z	P>z	[95% conf.	interval]
Commercialization						
Commercialization	-0.077	0.083	-0.930	0.352	-0.239	0.085
Farm diversity	-1.062	0.519	-2.050	0.041**	-2.079	-0.045
Additional income	-2.299	1.178	-1.950	0.051*	-4.608	0.010
Age of the head	-0.010	0.045	-0.230	0.820	-0.098	0.078
Level of education	0.198	0.269	0.740	0.462	-0.329	0.725
Size of irrigated land	5.062	1.584	3.190	0.001***	1.956	8.167
Size of the rainfed land	1.142	0.649	1.760	0.078*	-0.130	2.414
Time to the market	-0.029	0.012	-2.420	0.016***	-0.052	-0.005
Family size	-0.242	0.142	-1.700	0.089*	-0.520	0.037
Gender (female head)	1.802	1.129	1.600	0.110	-0.410	4.015
Farm diversity						
Farm diversity	0.067	0.034	1.940	0.052*	-0.001	0.134
Commercialization	-0.077	0.083	-0.930	0.352	-0.239	0.085
Additional income	-0.166	0.127	-1.310	0.189	-0.414	0.082
Age of the head	0.038	0.012	3.260	0.001***	0.015	0.061
Level of education	0.135	0.067	2.000	0.046**	0.002	0.267
Size of irrigated land	0.590	0.397	1.480	0.138	-0.189	1.369
Size of the rainfed land	0.295	0.163	1.820	0.069*	-0.024	0.614
Time to the market	-0.004	0.003	-1.230	0.219	-0.009	0.002
Family size	0.210	0.080	2.630	0.008***	0.054	0.366
Gender (female head)	-1.567	0.395	-3.970	0.000***	-2.341	-0.792
var (e.commercialization)	158.3***	(8.81)				
var (e.farmdiversity)	9.930***	(8.57)				
LR test of model vs. saturated: X^2 (2) = 2.24 Prob > X^2 = 0.3264						
Observations 396						
t-statistics in parentheses						
* $p<0.10$, ** $p<0.05$, *** $p<0.01$						

Source: Computed from own survey collected September to October 2020.

The following section discusses the findings shown in Table 14, the influence of the socioeconomic and household characteristics of smallholders on commercialization and farm production diversity. The table presents the analysis of the total effect of the variables on commercialization (structural model 1) and farm production diversity (structural model 2).

Robustness and Model Fit Tests of the SEM model

Pre-Estimation Robustness Tests

In the pre-estimation stage, despite using a stratified random sampling method for data collection, I applied the Heckman correction method to address potential undetected selection bias. I include the Inverse Mills Ratio (IMR) in the main SEM estimation. The coefficient of the IMR is found to be statistically insignificant ($p = 0.596$), indicating that selection bias is not a concern for the model. Thus, the findings from the SEM model are deemed unbiased and reliable.

Tests of endogeneity

The Durbin-Wu-Hausman test was also conducted to check for endogeneity. The results show a p-values of 0.5923 for the Durbin (score) test and 0.5972 for Wu-Hausman test, suggesting that the variables in the model are not correlated with the error term and are exogenous.

H0: Variables are exogenous

Durbin (score) $\chi^2(1) = 0.286793$ ($p = 0.5923$)

Wu-Hausman $F(1,386) = 0.279754$ ($p = 0.5972$)

Our model shows that the p-value = 0.5923 for Durbin score and p-value=0.5972 for Wu-Hausman tests are higher than the acceptable levels of significance (0.01, 0.05, and 0.10). Hence, I accept the null hypothesis that there is no evidence of endogeneity.

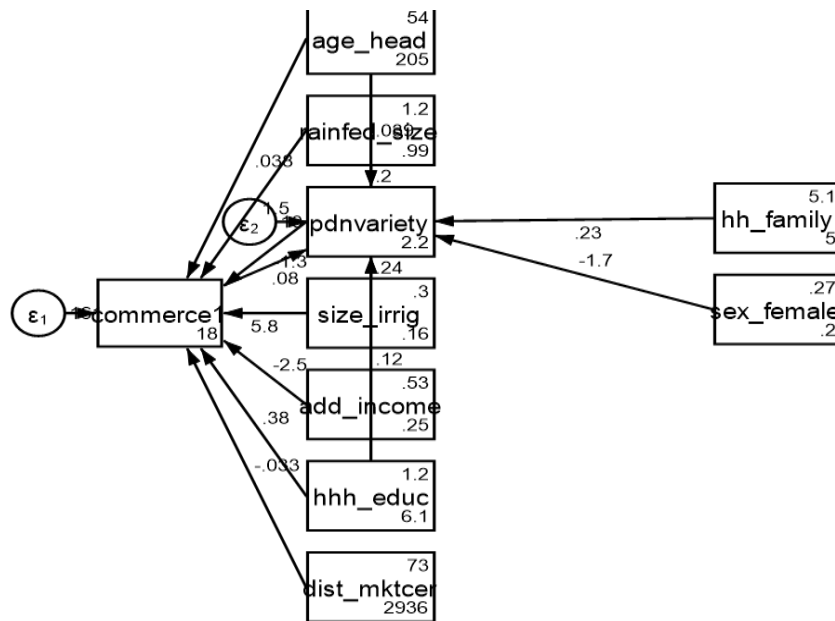
Post-Estimation Model Fit Tests

Post estimation model fit test shows a Chi-square value of 0.3264, which is statistically insignificant. This indicates that our estimated model does not significantly differ from the saturated model (a model that perfectly fits the data), suggesting a good model fit.

Other model fit tests conducted include:

- i) The **RMSEA** value ranges from 0 to 1, with lower values indicating a better fit.
 - $RMSEA < 0.05$: Indicates good fit.
 - $0.05 < RMSEA < 0.08$: Suggests a reasonable fit.
 - $RMSEA > 0.10$: Indicates poor fit.
- ii) **CFI** values range from 0 to 1, with values closer to 1 indicating a better fit.
 - $CFI \geq 0.95$: Indicates a good fit.
 - $0.90 \leq CFI < 0.95$: Indicates an acceptable fit.
 - $CFI < 0.90$: Suggests poor fit.
- iii) **TLI** values also range from 0 to 1, with higher values indicating better fit.
 - $TLI \geq 0.95$: Indicates a good fit.
 - $0.90 \leq TLI < 0.95$: Indicates an acceptable fit.
 - $TLI < 0.90$: Suggests poor fit.

SEM Path diagram for the link between commercialization and farm production diversity at smallholder households in the Gergera Watershed



Source: Author's graph created with Stata 16 statistical software.

7.3.2.1.2. Structural Model 1: Determinants of commercialization

In this model commercialization is the dependent variable. The total effects of the statistically significant explanatory variables on commercialization are discussed.

- **Additional source of income:** the findings indicate that the existence of additional income has a negative influence on smallholder commercialization, at a 10% significance level. Farmers with additional income sources sell a lower proportion of their farm production: 2.299 percentage points lower compared to those with no alternative income source. This may be because smallholders with additional sources of income have access to cash for making purchases compared to those who need to sell their farm products to get cash.
- **Size of Irrigated Land:** the size of irrigated land has a strong positive effect on smallholder commercialization with a coefficient value of 5.062, at a 1% level of significance. The result indicates that an additional one tsimad of irrigated land

increases commercialization by 5%. The direction of influence is as expected, since larger irrigated farmland creates opportunities to produce more marketable products and thereby boosts commercialization.

- ***Size of rainfed farmland:*** the size of rainfed farmland has a modest positive effect on household commercialization. I find that a one tsmad increase in rainfed farmland size increases smallholder commercialization by about 1.142 percentage points, significant at a 10% level. The result is expected as greater farmland creates opportunities for farmers to produce surplus crops and livestock that can be traded.
- ***Time to the market:*** another factor that strongly influences smallholder commercialization is travel time to the market, which has a negative influence on smallholders' commercialization. I find that every additional walking minute reduces commercialization by about 0.028 points, at a 1% level of significance. This result is expected as higher transportation costs and the associated challenge of accessing the market are likely to impede commercialization.
- ***Family size:*** the total effect result indicates that family size has a slight negative influence on commercialization with 0.242 percentage points, significant at the 10% level. In terms of direct effect, the number of household members has no statistically significant effect on smallholder commercialization but, indirectly, it influences commercialization in a negative way maybe due to the effect on farm production diversity. This result can be considered as one of the strengths of the SEM estimation, identifying the implicit effects of some explanatory variables. The total effect of family size on commercialization is, therefore, indirect, mild and negative.

7.3.2.1.3. Structural Model 2: Determinants of farm production diversity

In the second model, farm production diversity is the dependent variable. This section presents the total effect results of the statistically significant explanatory variables on smallholder farm production diversity.

- **Age:** the age of the household head has a positive influence on farm production diversity. Each additional year is associated with a 0.038 increase in crop and livestock diversity, significant at a 1% level.
- **Education level:** every additional year of schooling is linked to a 0.134 increase in crop and livestock diversity, statistically significant at a 5% level. This is unexpected and it may perhaps be explained by the tendency of educated heads to engage in a more diverse production, based on a knowledge of nutrition and preference to consume a greater variety of foods.
- **Family size:** family size showed a strong positive association with farm production diversity. An additional family member contributes to an increase of 0.210 in crop and livestock diversity, significant at a 1% level. This result is expected, and it implies that larger family size is endowed with relatively more labor that can contribute to the production of a greater variety of crops and livestock compared to those with smaller family size.
- **Gender:** Our findings indicate that households headed by women produce 1.567 less crop and livestock species compared to male-headed households, significant at a 1% level. The result is expected because of the availability of at least one male worker in male-headed households. Differences in risk preferences between men and women may also contribute to the difference in the level of farm production diversity between male and female headed households.
- **Rainfed farmland size:** The SEM estimation result indicates that an additional tsimad of rainfed farmland increases farm production diversity by 0.295, significant at the 10% level. Rainfed farmland size, though a key resource in smallholder production, is found statistically insignificant in terms of the direct and indirect effect results, but it is marginally significant in the total effect in influencing smallholder farm production diversity. This suggests that smallholder farm production diversity is more influenced by other socioeconomic and household factors, such as the variables discussed above, than the size of land held by the household.

7.3.2.2. Direct Effect

Most of the statistically significant variables obtained in the direct effect results maintain a similar level of statistical significance in the total effect model (see Appendix 7.1A). There were exceptions, however, namely the effects of family size and gender on commercialization, and the effect of additional income sources on farm production diversity. Family size and gender showed zero direct effect on smallholder commercialization, but each showed some influence in the total effect model. Additional income sources showed zero direct effect on farm production diversity and commercialization, but a negative total effect on commercialization only. Obtaining a different result for the same variable in its direct and indirect effect on a dependent variable can be considered as one of the strengths of using the SEM in analyzing such complex relationships.

7.3.2.3. Indirect Effect

The indirect effect captures the influence of the independent variables on the outcome variables through their interaction with other mediating variables. The indirect effects of most of the explanatory variables are found to be statistically insignificant, except for family size. Family size has a statistically insignificant influence on smallholder commercialization in a direct way. However, family size showed a slight significant negative indirect effect on commercialization through its influence on farm production diversity. Hence, an additional family member leads to a 0.24% reduction in commercialization, in an indirect way, significant at a 10% level. This implies that the positive contribution of family labor to farm production diversity leads – indirectly - to a slight negative impact on commercialization.

7.4. Discussions and Policy Recommendations

Extensive research indicates that enhancing commercialization is a key strategy to improve smallholder income and productivity in developing countries, but findings on whether specialized or more diverse farm production have the greater influence on commercialization remain inconclusive. Moreover, the inverse relationship - the

influence of commercialization on farm production diversity, which can shape the market integration of smallholders - has been largely overlooked. This study, therefore, uses the Structural Equation Modelling (SEM) method to simultaneously examine the complex bidirectional interdependence between smallholder commercialization and farm production strategy.

The average farm production diversity in the sample was found to be 6.485 crop and livestock species. Farm production diversity is symmetric, with most households having a level of farm production diversity close to the average. The average rate of commercialization in our study area was found to be 11%, with rates ranging widely from 0% (no sales) to 100% (sale of total production).

The findings indicate that a lower farm production diversity increases smallholder commercialization. Smallholders with a lower diversity are more likely to produce a surplus in each category, thereby enhancing the likelihood of having a surplus to sell. In contrast, a more diverse production strategy often means little, or no excess output is available from each product for sale, meaning relatively little cash available for food purchases and a higher level of direct consumption. Socioeconomic factors such as larger irrigable farmland and proximity to the market are predominantly crucial in increasing smallholder commercialization.

The findings on the inverse relationship indicate that commercialization positively influences farm production diversity, albeit to a minimal extent. These results suggest commercialization encourages more diverse crop and livestock species production. Smallholders may react to anticipated benefits from commercialization by diversifying their farm production. Even so, the small degree of influence can be related to farmers' perceptions of risks associated with the market and the resource constraints they face in terms of the required land, labor and knowledge necessary for market-oriented production.

While farm production diversity is slightly influenced by commercialization, household factors such as family size, gender, and age of the household head are the major influencers of diversity, which is in line with the findings of Sekyi, Quaidoo, et

al. (2023) and Rapsomanikis (2015). These results suggests that households with large family sizes, headed by men, older people or those with higher education levels, are likely to have higher farm production diversity. This can be related to the availability of more family labor, limited ability to purchase diverse foods by older heads (who are less likely to work off-farm), and better knowledge of nutrition and price information by better-educated heads. It can also be related to the more risk-averse nature of older people with regard to climate change and market price fluctuations. Socioeconomic factors such as the size of rainfed farmland also have a positive influence on smallholder farm production diversity at 10% level of significance.

The evidence indicates that while low farm production diversity, or specialization, contributes positively to commercialization, there are other alternative ways that smallholders can commercialize. Smallholder commercialization in the study area is mainly achieved through ownership of larger irrigated farmland and better access to the market. Most household factors have no significant influence on commercialization, except for the indirect negative effect of family size.

Given these findings, investments in the construction and expansion of irrigation and transportation infrastructures may be crucial measures to increase smallholder commercialization in the study area. A targeted strategy of specialization may also be appropriate for households with larger irrigable land and better access to markets. Support for higher production diversity should also be considered based on specific household factors - for example, targeting households with large family size and male headed households as those households have extra labor resources advantages.

7.5. Conclusions

This study explores the bidirectional relationship between smallholder commercialization and farm production diversity. It is based on a cross-sectional data from 396 households in the Gergera Watershed, Tigray, northern Ethiopia. Simultaneous estimation in a structural equation model (SEM) was applied to account for the bidirectional relationship.

The results indicate a complex bidirectional link between commercialization and smallholder farm production diversity. Low farm production diversity positively influences commercialization. Conversely, commercialization slightly and positively influences high farm production diversity. Both commercialization and farm production diversity, however, are strongly influenced by other socioeconomic and household characteristics: the size of irrigable farmland and market access have a stronger positive influence on commercialization than specialization, while family size, gender, age, and education level of the head have a stronger positive influence on farm production diversity. On the contrary these household factors have little significance in shaping smallholder commercialization.

The findings show that the size of irrigable land and market access are important factors influencing smallholder commercialization. This suggests that the extent to which smallholder commercialization is viewed only in conjunction with a particular level farm production diversity may be exaggerated. The assertion could be sidelining other important policy variables influencing smallholder commercialization. The implication is that improving access to irrigable land and markets is crucial for increasing commercialization. Smallholders' alteration of their farm production strategies in response to price signals or anticipated market benefits may be another factor influencing commercialization. Additional findings are that commercialization doesn't appear to be significantly affected by specific social factors like gender, age, family size, or education level. This suggests that commercialization may be equally accessible despite some demographic and social differences in the study area.

CHAPTER EIGHT

8. DISCUSSION, CONCLUSIONS, AND POLICY RECOMMENDATIONS

8.1. Discussion

Food insecurity continues to be a livelihood threat for millions of people worldwide, particularly for smallholders in developing countries. The global commitment to end hunger by 2030 under the Sustainable Development Goals (SDGs) has led to progress in some regions, but falls short of the targets in many areas, with only five years left. The challenge of rural hunger and poverty, therefore, remains one of the top concerns for the development community, including policy makers and researchers.

Extensive research has explored this issue from multiple perspectives and has proposed policy responses to combat food insecurity and malnutrition in all its forms. Nutrition-sensitive agriculture, based on increasing farm production diversity and strengthening the link between agriculture and markets has emerged as some of the key recommendations for enhancing smallholder food security, dietary diversity, and nutrition. Empirical evidence on the effect of farm production diversity and market on dietary diversity and nutrition is, however, mixed, or inconclusive, and sometimes contradictory. Most researchers have tended to examine the relative contribution of either farm production diversity or markets on dietary diversity and nutrition, but rarely the interaction of the two. Some studies find farm production diversity to be an important contributor to smallholder dietary diversity and nutrition, while others revealed stronger effects of markets, as shown in Chapter 2 (above). Others also find neutral or negative outcomes from farm production diversity or markets. Researchers tend to explain these inconsistencies in terms of context-specific factors or variations in the measurement method of farm production diversity, market access or dietary diversity.

The need for the present research emerges from these gaps in the literature, with the specific objective of understanding the links between smallholder farm production diversity and market participation and how these might enhance households' access to diverse diets in the context of rural Tigray in northern Ethiopia. This objective is

organized into four research questions that lead to four independent, yet thematically connected papers. The responses to these questions provide evidence-based policy suggestions that aim to influence smallholder household food security, dietary diversity, and nutrition in the Gergera Watershed and similar contexts.

The key variables in this research are smallholder household dietary diversity, farm production diversity, market access, and commercialization, and all of these are points of debate in literature. The debate is often linked to the limitations in the standardization of the methods used to measure these variables.

The research employed arguably original alternative approaches to minimize the effects of these limitations on the findings. For example, I addressed the limitations associated with multiple counting of the production diversity score measure by excluding varieties that are not considered edible in the study area, such as donkeys, horses, and camels. These livestock varieties serve as important pack and transport animals, however, ownership of any of these animals can indirectly contribute positively to dietary diversity through the wealth effect, the income effect in reducing transport costs, and facilitating market access, which I didn't control for.

Market access has featured prominently in the literature due to the limitations in measurement methods associated with it. Some researchers indicate that the existing methods are unstandardized, focusing on external factors, such as distance to market. I approached this limitation by introducing an alternative measure of market access, which is the frequency of food market visits (FMV). This measure has some merits compared to many established measures of market access in that it accounts for both endogenous and exogenous factors influencing smallholder households' decision to engage in market transactions. Those factors are related to households' preference, ability, and willingness to transact in markets. The introduction of the frequency of food market visits (FMV) as an alternative measure of market access is arguably an original contribution that addresses important limitations in previous studies and could better facilitate cross-country and cross-region comparisons. However, this new method has a limitation in that I did not account for whether the visits actually ended up resulting in the purchase of food or identifying what type of food was purchased. This would be an interesting piece for future research on household food purchase

and consumption decisions. Apart from these methodological innovations, many important findings are presented in each of the chapters above.

The first paper of the thesis (see Chapter 4) is a policy-oriented rapid value chain assessment. The result from the preliminary market value chain assessment of five selected agricultural commodities- honey, dairy, fruits, vegetables, sheep and goats- in the Gergera Watershed indicated that market-oriented production of these agricultural commodities is a recently introduced practice in the district which began in the 1990s with the introduction of irrigation schemes in the village by the Irish Aid project. The assessment report indicates that the watershed is endowed with the potential for irrigation and trading of agricultural products at a reasonable geographic distance, which includes Haiki-Mesihal, Agulae, Atsibi, Wukro, Mekelle, and Adigrat.

However, despite the existence of these markets, farmers struggle to obtain a fair share of returns from markets, especially for perishable commodities such as fruit, vegetables and milk. The production of high-value durable commodities such as honey and livestock, on the other hand, generally lead to better outcomes for farmers. Smallholder farmers have reported that they have limited access to markets due to inadequate transport services, limited market information, and high price volatility in markets, and consequently experience weak bargaining power during market transaction. They also have shortages of farm inputs, including seed, fertilizers, pesticides, and limited veterinary services.

The paper in Chapter 5 traces the sources of smallholder dietary diversity, using pairwise graphical visualization to examine the shares of each food source contributing to dietary diversity as well as econometrics method to evaluate the determinants of access to each food source. The findings reveal four major food sources: purchased foods, own farm-produced foods, Productive Safety Net Program (PSNP) foods, and transfer foods. Purchased and own farm foods are the primary contributors to household dietary diversity, ranked in order, across all income levels in the Gergera Watershed. No substitution between purchased and own farm foods was observed. Instead, households' increased consumption of one food source (purchased/own farm foods) is linked to increased consumption of the other (own farm/purchased foods). The remaining two food sources, PSNP foods and transfer

foods, showed the least contribution to overall household dietary diversity relative to purchased and own farm foods. Nonetheless, the individual effect of the PSNP and transfer foods was observed to be relatively higher in poor households. Examining the determinants of access to the food sources for smallholder households, I

found that ownership of irrigated farmland contributes to increased consumption of purchased foods, while it limits the households' access to PSNP foods. Male-headed households enjoy a greater share of own farm-produced foods. Residential sub-districts, marital status, gender, and size of irrigated farmland were all found to be important factors determining access to a particular food source for households in the study area.

Chapter 6 contains new and policy-relevant findings. Differences in market access measures are found to cause significant differences in the level of influence of market access on household dietary diversity, which may have significant policy implications. For example, when using proximity to market measured in walking minutes, the effect of market access on HDDS becomes threshold-based and nonlinear. This indicates that proximity to the market affects households in three different ways, reflecting the categorization of the households into three-distance segments. The first segment is related to the smallholder households living within a 50-minute walking distance from the nearest market; the second segment refers to smallholders between 50 and 95-minutes walking distances; and the third segment refers to the smallholders living beyond 95 minutes walking distance.

Based on this segmentation, the effect of proximity to the market on HDDS is nearly zero for all smallholders living within the 50-minute walking distance from the nearest market. The policy implication is that distance to the market is less of an issue for the level of dietary diversity of those smallholders. Hence, increasing the supply, sustainability, and diversity of foods in the market may be effective to improve HDDS, while investment in infrastructure might not bring a significant effect. On the other hand, smallholders living within 50-to-95-minutes, walking distance leads to a linear negative effect on their level of HDDS. This shows that distance matters for those

households and implies that, unlike the households in the first segment, the HDDS of those smallholders significantly decreases when there are additional walking minutes distance from the market. The policy implication would be to consider measures to improve access to the market through reduced transport costs and increased investment in transport infrastructure.

The third segment, smallholders living beyond the 95-minute walking threshold, are far away from the impact (negative or positive) of the market. Thus, a different approach to improve their access to diverse foods must be envisaged. For example, encouraging smallholders to grow a more diverse range of foods, establishing food-based agribusiness cooperatives in their locality to facilitate local food exchanges, facilitating regular satellite food markets in the village and, over the longer term, investing in transport infrastructure.

Other measurement methods show a nonlinear effect on household dietary diversity. When examining the effect of the frequency of food market visits (FMV) on HDDS, I find a positive and nonlinear effect, implying that every additional market visit brings improvement to smallholder HDDS.

Another important finding in Chapter 6 is that farmland types have important dietary diversity implications. I treated irrigated and rainfed farmland separately and our results indicate that HDDS is more influenced by the variety of crops grown in each farmland type than by the overall size of the farmland. This was observed in that households with irrigable farmland enjoy high HDDS even though the average size of the irrigated farmland is about a quarter, at 0.296 tsimad, of the average size of rainfed farmland, which is 1.178 tsimad. Irrigated farmland size thus shows a significant positive association with household dietary diversity, while rainfed farmland is found to be insignificant. This could be because households with access to irrigated farmlands grow diverse crops, usually vegetable and fruit varieties targeted for sale, while in most cases, regardless of their size, rainfed farmlands are primarily used to grow staple crops, usually cereals, for domestic consumption. The implication is that access to irrigated farmland improves HDDS by creating opportunities to grow diverse food varieties either for direct self-consumption or indirectly through income effects compared to rainfed farmland. Given the low

diversity of the food group production on rainfed farmlands, the policy implication is that greater diversity in livestock products (meat, milk, eggs) could support smallholder HDDS where irrigation is not feasible. The key takeaway from the findings is that it is diversity rather than the quantity of crops and livestock production that most influences household dietary diversity.

The question of whether a low or high level of farm production diversity increases smallholder commercialization is another topic in the literature that I aim to address. I therefore employed a simultaneous equation approach using a structural equation modelling (SEM) method to analyze our data to address this point (see Chapter 7). The findings of the analysis revealed the existence of a bidirectional link between commercialization and smallholder farm production diversity. That is commercialization affects farm production diversity, and that farm production diversity affects commercialization. While low farm production diversity (i.e. specialization) often encourages commercialization. High farm production diversity can sometimes be encouraged by commercialization, but to the lowest extent. This implies that market participation may encourage smallholders to further diversify when there is high demand for certain varieties of farm products, which is diversifying in response to market price signals.

On the other hand, market access and irrigation are found to be important factors influencing commercialization to a greater extent. Household-level factors, such as family size, gender, age, and education level of the head, have a strong positive influence on farm production diversity. On the other hand, these household-level factors have little significance in shaping smallholder commercialization. This suggests that smallholder commercialization can potentially be adopted by any member of society regardless of their socioeconomic status.

8.2. Policy Recommendations

Here, I discuss the policy implications arising from each of the four papers presented above.

Policy Oriented Value Chain Assessment: Chapter 4 is a rapid value chain analysis for the study region which provides a policy-oriented assessment of the challenges for smallholders and how they might be resolved. Numerous challenges in the agricultural commodity value chain were identified in this assessment. However, it is possible to categorize these into three broad areas, namely: inefficiencies in local markets, deficiencies in local institutional supports, and inadequacies in local infrastructure. In turn, these challenges require dedicated measures, which can similarly be categorized into three groups, namely, market-oriented policy solutions, institutional structure-related policy solutions, and infrastructure-related policy solutions. Table 15 summarizes these challenges and proposes associated interventions.

Table 15 Challenges and policy proposals arising from Chapter 4

Category	Challenge	Proposed Solution
Market-oriented	Low market prices, especially for perishable goods	Market regulation to limit market price volatility
Market-oriented	Limited market information and information asymmetry between sellers and buyers	Provision of market price information to farmers
Institutional structure-related	Farmers require more and better technical support	Maximizing extension, technical, and professional support services
Institutional structure-related	Limited assistance for farmers in response to diseases affecting yield and quality.	Provision of improved veterinary services
Institutional structure-related	Gender inequality in the delivery of support	Organizing women in cooperatives and empowering increased farm productivity and market participation through dedicated business and technical training tailored to women's living circumstances
Institutional structure-related	Insufficient supply of inputs (seeds, pesticides, herbicides, veterinary services)	Subsidies for inputs
Institutional structure-related	Weak bargaining power of farmers	Establishing institutions that allow farmers to act collectively, such as agri-business cooperatives
Institutional structure-related	Smallholders need inclusive and sustainable interventions to succeed in drought-prone and low-productivity areas	Promotion of climate-resilient farming practices
Infrastructure-related	Lack of access to transport, storage, and processing technologies, leading to increased post-harvest losses	Investment in upgrading, expanding and constructing better roads
Infrastructure-related	Lack of farm product collection services or centers	Provision of a farm product collection route through arranged loans or farmer cooperatives
Infrastructure-related	Post-harvest losses	Promoting basic vegetable processing and storage techniques for preservation, and subsidizing agro-processing investments
Infrastructure-related	Low production levels	Expansion of irrigation infrastructure

These challenges and intervention are next discussed in turn.

Market-oriented challenges and policy solutions

Challenges: The findings in the value chain assessment indicate that smallholders are faced with two major issues when selling their farm production. The first is low market prices, which imply low returns from the goods they are selling. This was particularly evident with respect to perishable products which need to be sold immediately after harvest. The second critical issue for smallholders is the limited amount of market information they have or more precisely the information asymmetry between sellers (smallholders) and buyers in the market.

Solutions: These two market-related challenges can be addressed using market-oriented interventions. Market regulation could limit the extent of price volatility and provision of market price information to farmers would address the informational asymmetry between them and intermediaries in the market.

Institutional structure-related challenges and policy solutions

Challenges: The value chain assessment indicated that farmers require more and better technical support. Institutional inefficiencies are evident in the limited assistance farmers receive in response to diseases which reduced yield and quality, such as damage to crops and grass due to rust and powdery mildew. Other major challenges relating to limited agricultural extension and professional support were also reported. Gender inequality is also a consideration in the delivery of support. There is also an insufficient supply of inputs, such as selected seeds, pesticides, herbicides and veterinary services. Another pressing challenge reported was the weak bargaining power of farmers during agricultural commodity transactions. Smallholder households also need inclusive and sustainable interventions to succeed in drought-prone and low-productivity areas.

Solutions: Inadequate technical support can be addressed by maximizing extension, technical, and professional support services and by providing improved veterinary services. The shortage of inputs can be addressed through the provision of input subsidies. Weak bargaining power may be addressed by establishing institutional

structures that allow farmers to act collectively, such as agri-business cooperatives that collect farm products from smallholders and distribute them to retailers and wholesalers in different markets. Organizing women in cooperatives could empower them to increase farm productivity and market participation. By providing dedicated business and technical training tailored to women's living circumstances, this could lead to better gender equality in agricultural markets. In addition, the promotion of climate-resilient farming practices could help to mitigate climate risks and improve environmental sustainability.

Infrastructure-related challenges and policy solutions

Challenges: The value chain assessment highlights the lack of access to transport, storage and processing technologies as critical challenges that lead to increased post-harvest losses, particularly for perishable farm products.

Solutions: Investment in upgrading, expanding, and constructing better roads could limit post-harvest losses. Provision of a farm product collection route through an arranged loan or by making it more affordable through farmer cooperatives could be another way to address the lack of transport service. On the other hand, promoting basic vegetable processing and storage techniques for preservation or subsidizing agri-food processing investments may limit post-harvest losses. The expansion of irrigation infrastructure could also support higher levels of production (see chapter 4).

The other three papers in the thesis are reported in Chapter 5, Chapter 6, and Chapter 7 and each also has produced implications for policy makers. Based on the findings from the other three papers, the following policy interventions emerge. These aim to enhance smallholder household dietary diversity in Gergera and other similar settings. They are first summarized in Table 16.

Table 16 Challenges and policy solutions arising from Chapters 5, 6, and 7.

Challenge	Proposed Policy Solution
<p>Limited dietary diversity in smallholder households.</p> <p>Reliance on monotonous diets, leading to micronutrient deficiencies.</p>	<p>Promote frequent market visits, increase farm production diversity, and improve access to diverse food sources.</p>
<p>Limited market access due to distance and infrastructure constraints.</p> <p>Many smallholders live far from markets, making it difficult to purchase diverse foods.</p>	<p>Improve roads and transport services and establish alternative food distribution points (e.g., satellite markets and agrifood cooperatives).</p>
<p>Gender disparities in household dietary diversity.</p> <p>Female-headed households have lower farm production diversity and market engagement.</p>	<p>Provide targeted support, such as agricultural training to enhance female farmers' productivity and market participation.</p>
<p>Dependence on purchased foods with limited own-farm production contribution.</p> <p>Heavy reliance on purchased food rather than their own production, making smallholders vulnerable to price fluctuations.</p>	<p>Encourage diversified farm production through farm advisory support, promote high-value short-cycle crops and livestock and promote education around the role of nutrition.</p>
<p>Limited irrigation and rainfed farming constraints</p> <p>Households with irrigated land have better dietary diversity, while this is less often the case with those relying on rainfed agriculture.</p>	<p>Expand irrigation schemes and promote climate-resilient farming practices to increase year-round production and dietary diversity.</p>
<p>Low frequency of market visits</p> <p>Smallholders who rarely visit markets have less access to diverse foods.</p>	<p>Improve transport options, develop cooperative purchasing models and incentivize regular market visits through targeted programs.</p>
<p>Post-Harvest losses and poor storage facilities</p> <p>Perishable farm products often become inedible before they can be sold or consumed, limiting dietary diversity.</p>	<p>Invest in food storage and preservation technologies, subsidize food-processing efforts and support farmer cooperatives in collective marketing and storage.</p>
<p>Lack of targeted policies based on market proximity.</p> <p>Policies may fail to differentiate between households with different levels of market access.</p>	<p>Develop differentiated policy interventions based on market distance and accessibility, ensuring tailored solutions for different household needs.</p>

Influence of low farm production diversity on commercialization	Focus on factors like irrigable farmland size and market access to enhance commercialization, alongside specialization.
Influence of socioeconomic and household characteristics on farm production diversity	Recognize the importance of factors like family size, gender, age, and education level in shaping farm production diversity.

These proposals are next discussed in more detail.

Increasing smallholder food purchase ability and farm production diversification

The findings from the research in Chapter 5 highlight the complementarity between purchased and own farm-produced foods in improving household dietary diversity. Improved smallholder household dietary diversity could be achieved by prioritizing interventions that simultaneously increase smallholder household income and the ability of those households to purchase foods and diversify own-farm productions for household consumption. Strategies that observe one or other of these objectives could also be pursued where the achievement of both is not feasible.

Other smallholder support mechanisms remain important for food provision:

Where smallholder households are not able to obtain food from either of the above two sources or where progress in this regard is slow, then instead, as a short-term solution, social protection programs, such as the transfer and PSNP foods, may be used to provide nutritionally diverse foods to retain dietary diversity.

Tailored agricultural extension programs: The findings in chapter 5 suggest that tailored agricultural extension programs, such as small ruminant rearing, poultry, dairy, and apiculture farm production could be considered. These practices increase both the diversity in farming and income-generating sources that would enhance smallholders' purchasing power, without compromising consumption from their own farms. This is also important for female-headed households which may have labor and resource constraints.

Turning to chapter 6 and the limited research on the combined effect of farm production diversity and market access in improving smallholder household dietary diversity is investigated. Our research suggests that farm production diversity and

market access are almost equally important in influencing smallholder dietary diversity. However, differences in market access measurement methods exist and this may influence research outcomes, which in turn may contribute to the observed difference in findings in literature.

Transport to facilitate market access: The policy implication arising in Chapter 6 is to focus on creating livelihood opportunities and promotion of more frequent market visits through improved access to transport.

More market-oriented production to increase market access: This would involve encouraging more market-oriented agricultural production, such as short gestation marketable vegetables and the rearing of small ruminants, so that farmers would make more frequent market visits to sell their products.

Distance to market may determine the choice of intervention: Differences in market accessibility should be taken into consideration by policymakers. The research suggests that it is possible to group households into three categories, defined by their distance to market. The first smallholder category, identified in this study as smallholders within approximately a 50-minute walking radius of the market, could benefit from interventions targeting the quantity, supply, quality, and diversity of food varieties in the market. At the other extreme, there is a householder category in excess of 95 minutes walking distance to the market, who may be better assisted through investments in improving transport infrastructures, arranging satellite markets, or establishing community-based agri-food business cooperatives to address household dietary diversity. For the third category, those smallholders living at an intermediate walking distance of 50 to 95 minutes from the market, the focus should be on the construction and improvement of transport infrastructures, so that the negative influence of remoteness on households' access to the market is minimized.

Turning to chapter 7, the literature widely acknowledges the positive role of commercialization in increasing smallholder income and productivity. I recommend

that improving access to irrigable land and markets is crucial for increasing commercialization. This gives rise to an array of potential interventions.

Specialization in production as a route to commercialization: Where market access is not an issue and the return from farm products sales are positive, smallholders producing a few high-value crops and livestock may find that this encourages commercialization.

Diversification in production as a route to commercialization: On the other hand, where market price volatility is high, diversifying crops and livestock varieties may increase smallholder commercialization and income. In addition, in remote areas, where commercialization is less feasible or nonexistent, smallholder households that are married, male-headed, and have large family sizes may benefit from diversifying their farm production to improve their food security and dietary diversity.

Commercialization may be a versatile solution: Another important policy implication is that, given that commercialization is less affected by specific social factors, such as gender, age, family size, or education level, it could be a versatile solution, equally applicable to a range of smallholders irrespective of their demographic or social status.

Improvements to markets can make it easier for farmers to sell their produce and buy what they need. Stronger support from institutions, such as cooperatives, credit services and extension programs, can also help smallholders succeed. Investing in better roads, storage and processing capacity would also bring benefits.

To improve farm incomes and food security, farmers need more buying power and also need to consider growing a wider variety of crops. Some will benefit from specializing in the production of a few profitable products, while others may do better by diversifying what they grow and sell.

Smallholders' circumstances are not all the same, so policies must consider where they are located, how much they can produce, and other challenges unique to them. Tailored solutions will ensure that support matches smallholders' needs.

8.3. Limitations of the Research

Our data is based on food consumed by any member of the family over a period of 24 hours and 7 days, but foods consumed outside the home by any family member were excluded. This omission may understate the total household dietary diversity score (HDDS), especially for households with members who often eat out or attend social events and ceremonies where food is provided. However, considering that this is mostly a rural area with few big towns nearby, any such miscalculation is unlikely to be significant.

Furthermore, the one-time data collected through the cross-sectional survey cannot appropriately capture the dynamics in the consumption pattern of the households over time. Furthermore, the limitations of the cross-sectional nature of the data fail to capture any possible seasonal variations that could have reduced the extent of error in the data.

Self-reporting bias linked to correctly recalling the complete list of food items consumed in households over the past 24 hours or 7 days may result in data inaccuracies.

Another potential limitation is that data collection took place after COVID-19 restrictions were lifted in Tigray. The negative effects of the COVID-19 pandemic on the income, market access, production, and consumption of smallholders might introduce errors that could alter the results.

The PDS has several identified drawbacks due to the possibility of double counting of specific food groups, notably animal items (Berti, 2015; Kissoly et al., 2020). A PDS value of two is reported for a chicken-keeping household since it may generate both meat and eggs. Similarly, a cow may provide three distinct food groups: meat, milk, and butter (oil food group). An ox, on the other hand, receives a score of one regardless of whether it is slaughtered in the given year. PDS is thus viewed as a tally of prospective food supplies from self-produced sources rather than an account of actual consumption. Muthini et al. (2020) eliminated non-food crops from the PDS

count. Although no non-food crops were identified in this study, we followed this example and excluded animals such as donkeys, horses, mules, and camels, as indicators of PDS since these are working animals and are not considered foods in the local culture.

This study focused on the Gergera watershed alone. Hence, any wider interpretation and generalization of the findings should be taken with caution.

8.4. Potential for Future Research

Future research focused on the socio-cultural dimensions influencing household dietary diversity dynamics among rural smallholders is advised to provide a holistic view of the complexities surrounding dietary choices and may uncover hidden determinants of food consumption patterns. Another area for research is that there is a limited focus on household decision-making and gender roles regarding smallholder household consumption, farm production, and food purchases, which may have crucial impact on the household's dietary diversity. Research is also needed on developing standardized measures of market access for smallholders to enable cross-area comparisons.

8.5. Conclusion

The thesis is based on research conducted in Tigray, in northern Ethiopia. Primary data was collected through a cross-sectional household survey of 396 smallholders. A multistage stratified simple random sampling method was employed to select the participants. The research received an ethical approval from Mekelle University (MU), Tigray, Ethiopia. Both qualitative and quantitative methods were used to analyze the collected data. The goal of the thesis was to evaluate the link between smallholder farm production diversity and market participation in enhancing the availability and accessibility of diverse diets in rural households in Tigray. The thesis is composed of four independent yet interconnected research papers.

The overall findings indicate that both market access and farm production diversity are major influences of smallholder household dietary diversity. Market access and

farm production diversity have a complementary non-linear effect on household dietary diversity. The nonlinear effect signals that every increase in market access or farm production diversity, or both, may not bring an equal increase in household dietary diversity. Using simultaneous equation analysis, a bidirectional link between commercialization and smallholder farm production diversity is revealed. Farm production diversity influences commercialization, and likewise, commercialization also influences farm production diversity. Accordingly, while low farm production diversity (i.e., specialization) often encourages commercialization, commercialization also encourages high farm production diversity, though to a lesser extent, particularly in response to high market demand and positive price signals. On the other hand, smallholder commercialization is strongly influenced by improved market access and irrigation. Farm production diversity is highly influenced by household-level factors, such as family size, gender, and education level, whereas commercialization is not. Social protection programs such as food transfer and PSNP foods contribute notably to dietary diversity, particularly for the poorest households. This highlights the necessity for targeted, sustainable social protection through the establishment and strengthening of public, private, or community-based support systems for the poor, disabled, and marginalized households, which would create a significant impact.

The key takeaway of the study is that the link between smallholder farm production diversity and market participation, if supported by improved market access and irrigation opportunities, can substantially enhance the availability and accessibility of nutritious diets for smallholder households in Tigray and similar contexts.

The policy implication is that improving market access through investments in transportation, expansion and investment in irrigation, and promotion of high market-value farm production diversity tailored to the context could make a substantial contribution to improving smallholder households' dietary diversity, farm productivity, and income, ultimately leading to greater food security and overall welfare.

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APPENDICIES

Appendix A

Appendix 6.1A. Robustness Checks

The robustness of our findings is checked by applying different model fit tests. The first is the Likelihood Ratio (LR) Test, used to compare the fit of the Poisson model against alternative models such as the negative binomial regression to check for overdispersion. The result (LR test alpha = 0: $\chi^2(01) = 0.000$; Prob > = $\chi^2 = 1.000$) indicates that there is no evidence of overdispersion, and the Poisson model used is a good fit. In addition, we run the Pearson goodness of fit to see if our data fits the Poisson regression model. The Pearson test result $\chi^2 = 83.31748$; Prob > $\chi^2(382) = 1.000$, shows that the fitness of the data to our model is good.

Appendix 6.2A. Pairwise Correlation

Pearson correlation coefficients

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) HDDS	1.000								
(2) PDS	0.392 (0.000)	1.000							
(3) FMV	0.401	0.367	1.000						

	(0.000)	(0.000)							
(4) AM	-0.407	-0.287	-0.573	1.000					
	(0.000)	(0.000)	(0.000)						
(5) PM	-0.182	-0.140	-0.471	0.393	1.000				
	(0.000)	(0.005)	(0.000)	(0.000)					
(6) Education level	0.149	0.044	0.140	-0.178	-0.155	1.000			
	(0.003)	(0.379)	(0.005)	(0.000)	(0.002)				
(7) Age	-0.035	0.115	0.012	0.017	-0.069	-0.259	1.000		
	(0.482)	(0.022)	(0.814)	(0.732)	(0.173)	(0.000)			
(8) Family size	0.171	0.250	0.191	-0.120	-0.042	0.165	-0.146	1.000	
	(0.001)	(0.000)	(0.000)	(0.017)	(0.409)	(0.001)	(0.003)		
(9) Rainfed land size	0.115	0.304	0.222	-0.019	-0.008	-0.079	0.166	0.198	1.000
	(0.023)	(0.000)	(0.000)	(0.704)	(0.880)	(0.118)	(0.001)	(0.000)	
(10) Irrigated land size	0.212	0.145	0.327	-0.080	-0.267	0.041	-0.012	0.050	0.138
	(0.000)	(0.004)	(0.000)	(0.114)	(0.000)	(0.418)	(0.809)	(0.321)	(0.006)

Appendix 6.3A. Multicollinearity' test

	VIF	1/VIF
Marital status		
2, Married	7.540	0.133
3, Single	1.110	0.902
4, Widowed	2.070	0.482
Sub-districts		
2, Damaino	2.390	0.419
3, Gergera	1.410	0.711
4, Degaabur	4.560	0.219
Gender		
2, Male	6.050	0.165
Education level	1.220	0.817
Age	1.380	0.725
Family size	1.510	0.664
PDS	1.260	0.794
FMV	1.880	0.533
AM	1.650	0.607
PM	3.540	0.282
Mean VIF	2.680	

Appendix B

Appendix 7.1B. Pre-Estimation Test

The Structural Equation Model (SEM) Main Estimation Output

Maximum Likelihood with Missing Values (MLMV) Method

Endogenous variables

Observed: commercialization farm diversity

Exogenous variables

Observed: add-income age_head education size_irrig siz_rainfed travel time to the market family_size gender_female

Fitting target model:

Iteration 0: Log likelihood = -9261.5132

Iteration 1: Log likelihood = -9260.4477

Iteration 2: Log likelihood = -9260.0507
Iteration 3: Log likelihood = -9260.0366
Iteration 4: Log likelihood = -9260.0365
Structural equation model
Estimation method: mlmv
Log likelihood = -9260.0365

Number of obs = 396

OIM (Observed Information Matrix)						
	Coefficient	std. err.	z	P>z	[95% conf. interval]	
Structural						
Commercialization						
Farm diversity	-1.150	0.663	-1.730	0.083	-2.450	0.150
Additional income	-2.490	1.279	-1.950	0.052	-4.997	0.017
Age of the head	0.033	0.054	0.620	0.533	-0.072	0.138
Level of education	0.353	0.313	1.130	0.260	-0.261	0.967
Size of irrigated ld	5.740	1.718	3.340	0.001	2.372	9.108
Size of the rainfed	1.482	0.752	1.970	0.049	0.009	2.955
Time to the market	-0.033	0.013	-2.620	0.009	-0.058	-0.008
_cons	17.452	3.902	4.470	0.000	9.804	25.100
Farm diversity						
Commercialization	0.072	0.044	1.660	0.097	-0.013	0.158
Age of the head	0.039	0.012	3.190	0.001	0.015	0.062
Level of education	0.120	0.071	1.690	0.091	-0.019	0.260
Size of irrigated land	0.224	0.469	0.480	0.633	-0.696	1.144
Size of the rainfed	0.213	0.177	1.200	0.228	-0.133	0.559
Time to the market	-0.002	0.003	-0.480	0.632	-0.008	0.005
Family size	0.228	0.082	2.760	0.006	0.066	0.389
Gender (female head)	-1.697	0.453	-3.740	0.000	-2.586	-0.808
_cons	2.474	1.080	2.290	0.022	0.357	4.591
var(e.commercailization)	158.283		17.973	126.702	197.737	
var(e.farmdiversity)	9.930		1.159	7.899	12.482	

LR test of model vs. saturated: chi2(2) = 2.24

Prob > chi2 = 0.3264

Direct effects
OIM

	Coefficient	std. err.	z	P>z	[95% conf. interval]	
Commercialization						
Commercialization	0		(no			
Farm diversity	-1.150	0.663	-1.730	0.083	-2.450	0.150
Additional income	-2.490	1.279	-1.950	0.052	-4.997	0.017
Age of the head	0.033	0.054	0.620	0.533	-0.072	0.138
Level of education	0.353	0.313	1.130	0.260	-0.261	0.967
Size of irrigated land	5.740	1.718	3.340	0.001	2.372	9.108
Size of the rainfed	1.482	0.752	1.970	0.049	0.009	2.955
Time to the market	-0.033	0.013	-2.620	0.009	-0.058	-0.008
Family size	0		(no			
Gender (female head)	0		(no			
Farm diversity						
Commercialization	0.072	0.044	1.660	0.097	-0.013	0.158
Farm diversity	0		(no			
Additional income	0		(no			
Age of the head	0.039	0.012	3.190	0.001	0.015	0.062
Level of education	0.120	0.071	1.690	0.091	-0.019	0.260
Size of irrigated land	0.224	0.469	0.480	0.633	-0.696	1.144
Size of the rainfed	0.213	0.177	1.200	0.228	-0.133	0.559
Time to the market	-0.002	0.003	-0.480	0.632	-0.008	0.005

Family size	0.228	0.082	2.760	0.006	0.066	0.389
Gender (female head)	-1.697	0.453	-3.740	0.000	-2.586	-0.808

Indirect effects OIM						
	Coefficient	std. err.	z	P>z	[95% conf. interval]	
Commercialization						
Commercialization	-0.077	0.083	-0.930	0.352	-0.239	0.085
Farm diversity	0.088	0.145	0.610	0.544	-0.197	0.373
Additional income	0.191	0.237	0.810	0.419	-0.272	0.655
Age of the head	-0.044	0.028	-1.560	0.118	-0.098	0.011
Level of education	-0.155	0.120	-1.290	0.198	-0.391	0.081
Size of irrigated land	-0.679	0.606	-1.120	0.263	-1.867	0.510
Size of the rainfed	-0.340	0.281	-1.210	0.226	-0.890	0.210
Time to the market	0.004	0.004	0.990	0.322	-0.004	0.013
Family size	-0.242	0.142	-1.700	0.089*	-0.520	0.037
Gender (female head)	1.802	1.129	1.600	0.110	-0.410	4.015
Farm diversity						
Commercialization	-0.006	0.009	-0.600	0.550	-0.024	0.013
Farm diversity	-0.077	0.083	-0.930	0.352	-0.239	0.085
Additional income	-0.166	0.127	-1.310	0.189	-0.414	0.082
Age of the head	-0.001	0.003	-0.230	0.821	-0.007	0.006
Level of education	0.014	0.023	0.620	0.534	-0.031	0.059
Size of irrigated land	0.366	0.254	1.440	0.150	-0.133	0.865
Size of the rainfed	0.083	0.076	1.080	0.279	-0.067	0.232
Time to the market	-0.002	0.002	-1.380	0.166	-0.005	0.001
Family size	-0.017	0.019	-0.900	0.367	-0.055	0.021
Gender (female head)	0.130	0.155	0.840	0.401	-0.174	0.434

During estimation, the maximum likelihood for missing values method (MLMV) is used to account for any missing data ensuring more efficient and unbiased estimates of the bidirectional relationship between commercialization and farm production diversity.

Appendix 7.2B. SEM Regression with Heckman Correction Model

- Endogenous variables
Observed: commercialization farm diversity
- Exogenous variables
Observed: add-income age_head education size_irrig siz_rainfed travel time to markets family_size gender_female inverse_mills_ratio hh_family sex_male
- Fitting target model:
Iteration 0: Log likelihood = -8246.9126
Iteration 1: Log likelihood = -8246.8951
Iteration 2: Log likelihood = -8246.7147
Iteration 3: Log likelihood = -8246.7142
Structural equation model
Estimation method: mlmv
Log likelihood = -8246.7142

Number of obs = 396

OIM						
	Coef.	std. err.	z	P>z	[95% conf. interval]	
Structural						

Commercialization						
Farm diversity	-0.682	1.081	-0.630	0.528	-2.800	1.436
Additional income	-0.230	4.434	-0.050	0.959	-8.921	8.460
Age of the head	-0.014	0.102	-0.130	0.894	-0.214	0.187
Level of education	0.210	0.404	0.520	0.602	-0.581	1.002
Size of irrigated land	2.886	5.621	0.510	0.608	-8.131	13.904
Size of the rainfed	0.122	2.657	0.050	0.963	-5.086	5.329
Time to the market	0.001	0.065	0.020	0.986	-0.127	0.129
Inverse mill ratio	-11.605	21.866	-0.530	0.596	-54.462	31.252
_cons	27.392	19.162	1.430	0.153	-10.164	64.948
Farm diversity						
Commercialization	0.043	0.069	0.630	0.531	-0.092	0.178
Age of the head	0.039	0.012	3.290	0.001	0.016	0.062
Level of education	0.128	0.071	1.810	0.071	-0.011	0.266
Size of irrigated land	0.373	0.534	0.700	0.485	-0.673	1.418
Size of the rainfed	0.247	0.183	1.350	0.178	-0.112	0.606
Time to the market	-0.002	0.004	-0.670	0.504	-0.009	0.005
Family size	0.232	0.081	2.870	0.004	0.073	0.390
Gender (female head)	-1.595	0.480	-3.320	0.001	-2.537	-0.654
_cons	2.728	1.153	2.370	0.018	0.468	4.988
var(e.commercialization)	150.286	17.280	119.963	188.273		
var(e.farmdiversity)	9.438	1.090	7.526	11.836		

LR test of model vs. saturated: $\chi^2(3) = 3.23$ Prob > $\chi^2 = 0.3578$

Source: Computed from Own survey collected September to October 2020.

In the pre-estimation stage, despite using a stratified random sampling method for data collection, we apply the Heckman correction method to address potential undetected selection bias. We include the Inverse Mills Ratio (IMR) in the main SEM estimation. The coefficient of the IMR is found to be statistically insignificant ($p = 0.596$), indicating that selection bias is not a concern for the model. Thus, the findings from the SEM model are deemed unbiased and reliable.

Appendix 7.3B. Tests of endogeneity

The Durbin-Wu-Hausman test was also conducted to check for endogeneity. The results show a p-values of 0.5923 for the Durbin (score) test and 0.5972 for Wu-Hausman test, suggesting that the variables in the model are not correlated with the error term and are exogenous.

H0: Variables are exogenous

Durbin (score) $\chi^2(1) = 0.286793$ ($p = 0.5923$)

Wu-Hausman $F(1,386) = 0.279754$ ($p = 0.5972$)

Our model shows that the p-value = 0.5923 for Durbin score and p-value=0.5972 for Wu-Hausman tests are higher than the acceptable levels of significance (0.01, 0.05, and 0.10). Hence, I accept the null hypothesis that there is no evidence of

endogeneity.

Appendix 7.4B. Post-Estimation Model Fit Tests

Post estimation model fit test shows a Chi-square value of 0.3264, which is statistically insignificant. This indicates that our estimated model does not significantly differ from the saturated model (a model that perfectly fits the data), suggesting a good model fit.

Other model fit tests conducted include:

- iv) The **RMSEA** value ranges from 0 to 1, with lower values indicating a better fit.
 - $RMSEA < 0.05$: Indicates good fit.
 - $0.05 < RMSEA < 0.08$: Suggests a reasonable fit.
 - $RMSEA > 0.10$: Indicates poor fit.

- v) **CFI** values range from 0 to 1, with values closer to 1 indicating a better fit.
 - $CFI \geq 0.95$: Indicates a good fit.
 - $0.90 \leq CFI < 0.95$: Indicates an acceptable fit.
 - $CFI < 0.90$: Suggests poor fit.

- vi) **TLI** values also range from 0 to 1, with higher values indicating better fit.
 - $TLI \geq 0.95$: Indicates a good fit.
 - $0.90 \leq TLI < 0.95$: Indicates an acceptable fit.
 - $TLI < 0.90$: Suggests poor fit.

Goodness-of-fit statistics including Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI).

Fit statistic	Value	Description
Likelihood ratio		
chi2_ms(2)	2.239	model vs. saturated
p > chi2	0.326	
chi2_bs(17)	109.839	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.017	Root mean squared error of approximation
90% CI, lower bound	0.000	
upper bound	0.103	
pclose	0.615	Probability RMSEA <= 0.05
Information criteria		
AIC	18558.073	Akaike's information criterion
BIC	18633.720	Bayesian information criterion
Baseline comparison		
CFI	0.997	Comparative fit index
TLI	0.978	Tucker-Lewis index
Size of residuals		
SRMR	0.007	Standardized root mean squared residual
CD	0.105	Coefficient of determination

Source: Computed from Own survey collected September to October 2020.

Appendix 7.5B. Multicollinearity

Variance inflation factor

	VIF	1/VIF
Gender female head	1.472	.679
Family size	1.392	.718
Age of the head	1.233	.811
Farm diversity	1.22	.82
Level of education	1.208	.828
Size of rainfed farmland	1.149	.87
Time to the market	1.132	.883
Size of irrigated land	1.122	.892
Additional income source	1.014	.987
Mean VIF	1.216	.

Source: Computed from Own survey collected September to October 2020.

Post estimation test for multicollinearity using the Variance Inflation Factor (VIF) show an overall mean VIF of 1.216, indicating no significant multicollinearity.

Appendix C

Questionnaire and Ethical Approval Letter

Rural Household Diet_Gergera

Section-A: General Household Information

Please, address every question

Household Information

Household Form ID

Name of Household Head

Age of the household head

Total family size of the household

Gender of Household Head

- ☐ Male
- ☐ Female

Educational level of the household head

Marital status of the household head

- ☐ Married
- ☐ Single

Income sources of the household

- ☐ Farm only
- ☐ Non-farm employment only
- ☐ Remittance
- ☐ Public support & PSNP

What type of off farm and non farm activities do your household involved at?

Please, record if any one of the members of the household has involved in any of the given alternative economic activities at any times.

- ☐ Trade of agricultural and non agricultural product markets
- ☐ Agricultural and non agricultural casual labor
- ☐ Masonry and other construction works
- ☐ Transport services

Name of Respondent

If respondent is different from the household head: Respondent should best be household head. If head is not around, the respondent should be wife/husband of household head or the most educated adult.

Kushet

- ☐ Gergera
- ☐ Geter Haiki Mesihal
- ☐ Damaino

Interview Date and Time

yyyy-mm-dd

hh:mm

Name of the Interviewer

Section-B: Now I will ask you about the household's market related information

Please, address every question

Market Related information**Where is your primary market?**

Primary market is a market where the household most frequently visit for most of its transaction.

- ☐ Haiki Mesihal
- ☐ Atsibi
- ☐ Agulae

Where is your secondary market?

Secondary market is a market where the household sometimes visit for some of its transaction.

- ☐ Atsibi
- ☐ Agulae
- ☐ Wukro
- ☐ Haiki Mesihal

Where is your tertiary market?

Tertiary market is a market where the household occasionally visit for few of its transaction.

- ☐ Wukro
- ☐ Mekelle
- ☐ Atsibi
- ☐ Agulae

Distance to the household's primary market

in hours (on foot)

Distance to the household's primary market

in kilometres

Distance to the household's secondary market

in hours (on foot)

Distance to the household's secondary market

in kilometres

Distance to the household's tertiary market

in hours (on bus)

Distance to the household's tertiary market

in kilometres

Over all how many times did you go to the market in the last 30 days only?

- ☐ None
- ☐ Once
- ☐ Two times
- ☐ Three times
- ☐ Four times
- ☐ More than four times

When did you go to the market for the last time recently?

yyyy-mm-dd

calculate the difference in the number of days between the last market day and today (the interview date)

What type of items did your household sell in the last 12 months in all markets?

Hint: List every item the household has sold in the last 12 months in all of the market.

what are the total quantity of the items sold in kilograms or litters?

what are the total price of the items sold ?

What type of items did your household buy in the last 30 days from all market?

Hint: List every item purchased by the household in the last 30 days in all the markets.

What is the total quantity of items bought in kilogram or litters?

How much money did you spend to buy in your last visit to the market?

Section-C: Household Dietary Diversity

Please, address every question

Household Dietary Diversity

Now I would like to ask you about the types of foods that you or anyone else in your household ate yesterday during the day and at night.

CEREALS: foods made of cereals: Injera, tihlo, beso/fraro, Tihni, geat, qicha, kolo, mugo, bread, rice noodles (endomi), pasta, Makaroni, biscuits, or any other foods made from teff, millet, sorghum, barley, maize, rice, wheat, dagusha, mishela, ares?

☐ Yes

☐ No

Did you consume cereals for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of the cereals ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of cereals have you consumed in the last 24 hours?

PUMPKINS: carrots, squash, or sweet potatoes that are yellow or orange inside?

- ☐ Yes
- ☐ No

Did you consume foods made from pumpkin, carrots, squash, or sweet potatoes for breakfast, lunch, dinner or snack?

- ☐ Break fast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of the pumpkin, carrots, squash, or sweet potatoes foods ?

- ☐ Own Production
- ☐ Purchased
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of have you consumed in the last 24 hours?

ROOTS AND TUBERS: foods made from white potatoes, white yams, manioc, cassava beets (Qeyih sur), ginger,

☐ Yes

☐ No

Did you consume any food prepared from ROOTS AND TUBERS for breakfast, lunch, dinner or snack?

☐ Breakfast

☐ Lunch

☐ Dinner

☐ Snack

☐ None

What was the source of the food prepared ROOTS AND TUBERS ?

☐ Own production

☐ Purchased food

☐ PSNP

☐ Transfers and gifts

☐ None

How many kilogram of food prepared from ROOTS AND TUBERS have you consumed in the last 24 hours?

VITAMIN A RICH VEGETABLES: dark, green, leafy vegetables such as cassava leaves, bean leaves, kale, spinach, pepper leaves, taro leaves, and amaranth leaves, kale (Etirtir hamli), collard greens (qotsal selata), sweet pepper

☐ Yes

☐ No

Did you consume VITAMIN A RICH VEGETABLES for breakfast, lunch, dinner or snack?

☐ Breakfast

☐ Lunch

☐ Dinner

☐ Snack

☐ None

What was the source of the food prepared from VITAMIN A RICH VEGETABLES ?

- ☐ Own Production
- ☐ Purchased foods
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of food prepared from VITAMIN A RICH VEGETABLES have you consumed in the last 24 hours?

ANY OTHER VEGETABLES: food prepared from any other vegetables cabbage, lettuce, tomatoes, onion, garlic, green chill, etc or other vegetables

- ☐ Yes
- ☐ No

Did you consume food prepared from other vegetables, Cabbage, Lettuce, tomatoes, onion, garlic, green chill, etc for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of food prepared from other vegetables, Cabbage, Lettuce, tomatoes, onion, garlic, green chill, etc ?

- ☐ Own production
- ☐ Purchased foods
- ☐ PSNP
- ☐ Transfers and gifts
- ☐ None

How many kilogram of food prepared from other vegetables, Cabbage, Lettuce, tomatoes, onion, garlic, green chill, etc have you consumed in the last 24 hours?

VITAMIN A RICH FRUITS: ripe mango, ripe papaya, grape, dried peach, apricot (kuk), and 100% fruit juice made from these fruits?

- ☐ Yes
- ☐ No

Did you consume foods prepared from VITAMIN A RICH FRUITS like ripe mangoes, ripe papayas, etc for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of the VITAMIN A RICH FRUITS like ripe mangoes, ripe papayas, etc ?

- ☐ Own Production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of VITAMIN A RICH FRUITS like ripe mangoes, ripe papayas, etc have you consumed in the last 24 hours?

OTHER FRUITS: any fruit or foods made from guava, avocado, orange, banana, beles/cactus, lemon, tringo, including wild fruits and 100% fruit juice made from these other fruits like Guava, avocado, mango, papaya, orange, beles/cactus, grape, lemon, tringo, etc

- ☐ Yes
- ☐ No

Did you consume foods made from OTHER FRUITS like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of foods made from OTHER FRUITS like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of foods made from OTHER FRUITS like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc have you consumed in the last 24 hours?

FLESH MEATS: any food made from beef, pork, lamb, goat, rabbit wild game, chicken, or other? Tsebhi siga, tibsi, qiqil, kitfo, Tire siga, etc.meat: beef, lamb, goat, wild animal, chicken, liver, kidney, heart, or other organ meats? Tsebhi siga, tibsi, qiqil, kitfo, Tire siga, etc.

☐ Yes

☐ No

Did you consume food made from FLESH MEATS: beef, lamb, goat, wild animal, chicken for breakfast, lunch, dinner or snack?

☐ Breakfast

☐ Lunch

☐ Dinner

☐ Snack

☐ None

What was the source of food made from FLESH MEATS: beef, lamb, goat, wild animal, chicken ?

☐ Own production

☐ Purchased food

☐ PSNP

☐ Transfer and gifts

☐ None

How many kilogram of food made from FLESH MEATS: beef, lamb, goat, wild animal, chicken have you consumed?

ORGAN MEAT: liver, kidney, heart, or other organ meats liver, kidney, heart or other organ meats or blood-based foods

☐ Yes

☐ No

Did you consume food made from ORGAN MEAT: liver, kidney, heart, or other organ meats liver, kidney, heart or other organ meats or blood-based foods for breakfast, lunch, dinner or snack?

☐ Breakfast

☐ Lunch

☐ Dinner

☐ Snack

☐ None

What was the source of food made from ORGAN MEAT: liver, kidney, heart, etc ?

- ☐ Own production
- ☐ Purchased
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many kilogram of food made from ORGAN MEAT: liver, kidney, heart, etc have you consumed?

EGG: Foods made from eggs? Enququho silsi, zebesele, firfir, etc?

- ☐ Yes
- ☐ No

Did you consume foods made from EGG for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of foods made from EGG ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How many EGG have you consumed?

FISH AND SEAFOOD: Any food prepared from fresh or dried fish or shellfish?

- ☐ Yes
- ☐ No

Did you consume food prepared from FISH AND SEAFOOD or shellfish for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of the food prepared from FISH AND SEAFOOD or shellfish ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How much kilogram of food prepared from FISH AND SEAFOOD or shellfish have you consumed?

LEGUMES, NUTS AND SEEDS: Any foods made from beans, peas, chickpeas, haricot beans, lentils, or nuts? Shiro, dekokko, quaya, shimbira, tegamino, timtimo, ful, ocholoni, etc Any foods made from beans, peas, chickpeas, haricot beans, lentils, or nuts? Shiro, dekokko, quaya, shimbira, tegamino, timtimo, ful, etc

- ☐ Yes
- ☐ No

Did you consume foods made from LEGUMES, NUTS AND SEEDS like beans, peas, chickpeas, haricot beans, lentils, or nuts for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of foods made from LEGUMES, NUTS AND SEEDS like beans, peas, chickpeas, haricot beans, lentils, or nuts ?

- ☐ Own Production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How much kilogram of foods made from LEGUMES, NUTS AND SEEDS like beans, peas, chickpeas, haricot beans, lentils, or nuts have you consumed?

MILK AND MILK PRODUCTS: Any milk and milk products like cheese, yogurt, hiquan, mancheba, ajbo, Any milk and milk products like cheese, yogurt, hiquan, mancheba, ajbo,

- ☐ Yes
☐ No

Did you consume MILK AND MILK PRODUCTS like cheese, yogurt, hiquan, mancheba, ajbo, etc for breakfast, lunch, dinner or snack?

- ☐ Breakfast
☐ Lunch
☐ Dinner
☐ Snack
☐ None

What was the source of MILK AND MILK PRODUCTS like cheese, yogurt, hiquan, mancheba, ajbo ?

- ☐ Own Production
☐ Purchased food
☐ PSNP
☐ Transfer and gifts
☐ None

How much litters of MILK AND MILK PRODUCTS like cheese, yogurt, hiquan, mancheba, ajbo have you consumed?

OILS AND FATS: Any foods made with oil, fat, or butter? oil, fats or butter added to food or used for cooking Any foods prepared using oil, fat, or butter? litters of oil used to prepare the food

- ☐ Yes
☐ No

Did you consume foods prepared using OILS AND FATS like oil, fat, or butter for breakfast, lunch, dinner or snack?

- ☐ Breakfast
☐ Lunch
☐ Dinner
☐ Snack
☐ None

What was the source of the OILS AND FATS like oil, fat, or butter ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How much litters of OILS AND FATS like oil, fat, or butter have you consumed?

Hint: ask how much liters they consume per month and divide it to 30 to get the average daily oil consumption.

SWEETS: any sweets or foods prepared using sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes ?

- ☐ Yes
- ☐ No

Did you consume food or drink using SWEETS like sugar or honey for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of the SWEETS like sugar or honey ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How much kilograms of SWEETS like sugar or honey have you consumed?

Hint: ask how much liters they consume per month and divide it to 30 to get the average daily sweet consumption.

SPICES, CONDIMENTS, BEVERAGES: Any food prepared using condiments, hazo, salsa/silsi, awaze, dilik, (entatie, selit, nihug, shio,) dirtso, hlibet, coffee, tea? Abd beverages mes, birzi, siwa, local or industrial beer, etc.

- ☐ Yes
- ☐ No

Did you consume food prepared using condiments, hazo, salsa/silsi, awaze, dilik, etc for breakfast, lunch, dinner or snack?

- ☐ Breakfast
- ☐ Lunch
- ☐ Dinner
- ☐ Snack
- ☐ None

What was the source of food prepared using SPICES, CONDIMENTS, BEVERAGES like hazo, salsa/silsi, awaze, dilik ?

- ☐ Own production
- ☐ Purchased food
- ☐ PSNP
- ☐ Transfer and gifts
- ☐ None

How much kilograms of food prepared using SPICES, CONDIMENTS, BEVERAGES like hazo, salsa/silsi, awaze, dilik have you consumed?

Hint: ask how much liters they consume per month and divide it to 30 to get the average daily SPICES, CONDIMENTS, BEVERAGES consumption.

Do the household prepare different food for children under the age of five?

Hint: this means the family cook special food for the children only and for the rest of the family another one. It doesn't mean giving the child a food in a different plate from what is prepared for the whole family.

- ☐ Yes we prepare separate food for children always
- ☐ No special food but they are provided with additional food
- ☐ No the household share the same food together always
- ☐ No children of this age in the household

Do the household prepare different food for women and adolescent girls?

Hint: this means the family cook special food for the women & adolescent girls only and for the rest of the family another one. It doesn't mean giving the women & adolescent girls a food in a different plate from what is prepared for the whole family.

- ☐ Yes we prepare separate food for women and adolescent girls always
- ☐ No the household share the same food together always
- ☐ No special food but they are provided with lower quantity of food
- ☐ No special food but they are provided with lower quality of food

Does your household ever made a decision of the following activities aiming to diversify its family diet? 1. Diversifying farm production (crop cultivation) 2. Purchase diverse foods by selling own produced crops/livestock 3. Involve in off and non farm activities to get income and purchase what is not produced in your farm

- ☐ Yes
- ☐ No

If YES, what was the decision you made related to diversifying household diet?

- ☐ Diversify agricultural production to get dietary foods from own farm land
- ☐ Specialize in a crop and actively participate in a market to buy dietary foods
- ☐ Engage in off farm & non farm income generating to be able to buy quality foods
- ☐ Attend nutrition and diet related education and apply it for own household

What motivate you (why do you decide) to diversify your household diet this way?

- ☐ Shortage of farm land
- ☐ the variety can not grow in our farm land
- ☐ we don't have enough water supply through irrigation or rain fall
- ☐ we give priority to our staple foods
- ☐ buying is cheaper than production
- ☐ The varieties could not be found in our local markets
- ☐ The market price of the varieties is expensive
- ☐ we have sufficient water to cultivate them in our farm land
- ☐ we don't know any thing about the benefit of dietary diversity
- ☐ we have sufficient land to grow the variety
- ☐ we can only buy from our income because we don't have farm land

If NO, why don't you ever decide to diversify your household diet?

- ☐ We don't think it is necessary to diversify
- ☐ We are already consuming diverse foods
- ☐ We can't afford to consume diverse foods
- ☐ We don't know the benefit of diversifying household diet

Section-D: Farm Production Diversity

Household Production Diversity

Now I like to ask you about the type of crops, vegetables, fruits and livestock your household produced in the last 12 months.

Have you produced any, cereal crop: Teff, barley, wheat, millet, sorghum, maize, rice, dagusha, meshela, ares, etc in the last 12 months?

- ☐ Yes
- ☐ No

What was the purpose of producing cereal crops ?

- ☐ Household Consumption
- ☐ For the Market
- ☐ For both Consumption and Market

How much cereal crop did you produce in the last 12 months in total? in kg

Have you produced PUMPKINS: carrots, squash, or sweet potatoes that are yellow or orange inside in the last 12 months? in kg

- ☐ Yes
- ☐ No

What was the purpose of producing PUMPKINS, squash, etc ?

- ☐ Household Consumption
- ☐ For the market
- ☐ For both Consumption and market

How much PUMPKINS, squash, etc did you produce in the last 12 months in total? in kg

Have you produced ROOTS AND TUBERS: foods made from white potatoes, white yams, manioc, cassava beets (Qeyih sur), ginger in the last 12 months, in kg?

- ☐ Yes
- ☐ No

What was the purpose of producing ROOTS AND TUBERS like white potatoes, white yams, manioc, etc ?

- ☐ Consumption
- ☐ Market
- ☐ Both

How much ROOTS AND TUBERS like white potatoes, white yams, manioc did you produce in the last 12 months in total? in kg

Have you produced VITAMIN A RICH VEGETABLES: dark, green, leafy vegetables such as cassava leaves, bean leaves, kale, spinach, pepper leaves, taro leaves, and amaranth leaves, kale (Etirtir hamli), collard greens (qotsal selata), sweet pepper in the last 12 months??

- ☐ Yes
- ☐ No

What was the purpose of producing VITAMIN A RICH VEGETABLES like dark, green, leafy vegetables ?

- ☐ Consumption
- ☐ Market
- ☐ Both

How much VITAMIN A RICH VEGETABLES like dark, green, leafy vegetables did you produce in the last 12 months in total? in kg

Have you produced ANY OTHER VEGETABLES like cabbage, lettuce, tomatoes, onion, garlic, green chill, etc in the last 12 months?

- ☐ Yes
- ☐ No

What was the purpose of producing the OTHER VEGETABLES like Cabbage, Lettuce, tomatoes, onion, garlic, green chill, etc ?

- ☐ Consumption
- ☐ Market
- ☐ Both

How much OTHER VEGETABLES like Cabbage, Lettuce, tomatoes, onion, garlic, green chill, etc did you produce in the last 12 months in total? (in kg)

Have you produced VITAMIN A RICH FRUITS like ripe mango, ripe papaya, grape, dried peach, apricot (kuk), etc in the last 12 months?

- ☐ Yes
- ☐ No

What was the purpose of producing VITAMIN A RICH FRUITS like mangoes, papayas, etc ?

- ☐ Consumption
- ☐ Market
- ☐ Both

How much VITAMIN A RICH FRUITS like ripe mangoes and ripe papayas did you produce in the last 12 months in total? (in kg)

Have you produced ANY OTHER FRUITS like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc in the last 12 months?

- ☐ Yes
☐ No

What was the purpose of producing ANY OTHER FRUITS like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc ?

- ☐ Consumption
☐ Market
☐ Both

How much OTHER VEGETABLES like guava, avocado, orange, banana, beles/cactus, lemon, tringo, etc producing fruit trees do you have in the last 12 months in total?

Have you produced livestock like, cattle, sheep, goats, chicken, etc.

- ☐ Yes
☐ No

What was the purpose of producing livestock like, cattle, sheep, goats, chicken ?

- ☐ Consumption
☐ Market
☐ Both

How many oxen did you have?

How many cows do you have?

How many calves and bulls do you have?

How many sheep do you have?

How many goats do you have?

How many chicken do you have?

Do have egg laying chicken?

☐ Yes

☐ No

What do you do with the produced eggs ?

☐ Consumption

☐ Market

☐ Both

How many egg laying chicken do you have?

Does the household has any access to fish catching?

☐ Yes

☐ No

What was the purpose of the fish catching ?

☐ Consumption

☐ Market

☐ Both

How many fish do you catch in the last 12 months?

Do you produce any beans, peas, chickpeas, haricot beans, lentils, or nuts, etc in the last 12 months?

☐ Yes

☐ No

What was the purpose of producing beans, peas, chickpeas, haricot beans, lentils, or nuts, etc ?

☐ Consumption

☐ Market

☐ Both

How many kg of beans, peas, chickpeas, haricot beans, lentils, or nuts, etc did you produce in the last 12 months?

Do you have milk cows, sheep or goats?

- ☐ Yes
☐ No

What was the purpose of having the cow milk ?

- ☐ Consumption
☐ Market
☐ Both

How many milk cows do you have?

How much litters of cow milk per day do you get now ?

How many milk sheep do you have now?

How much litters of sheep milk per day do you get now ?

What was the purpose of rearing sheep ?

- ☐ Consumption
☐ Market
☐ Both

How many milk goats do you have now?

How much litters of goat milk per day do you get now ?

What was the purpose of rearing goats ?

- ☐ Consumption
☐ Market
☐ Both

Do you produce butter from cow, sheep or goat milks?

- ☐ Yes
☐ No

What was the purpose of producing the butter ?

- ☐ Consumption
☐ Market
☐ Both

How many kilogram of butter per week do you get now ?

Do you have bee hives?

- ☐ Yes
☐ No

What was the purpose of producing the ?

- ☐ Consumption
☐ Market
☐ Both

How many kilogram of honey do you get in the last 12 months ?

Do your household prepare or produce condiments, hazo, salsa/silsi, awaze, dilik, (entatie, selit, nihug, shio,) dirtso, hilbet, coffee, tea? Abd beverages mes, birzi, siwa, local or industrial beer, etc.

- ☐ Yes
☐ No

What is the purpose of preparing or producing condiments, hazo, salsa/silsi, awaze, dilik ?

- ☐ Consumption
☐ Market
☐ Both

How many kilogram of hilbet, dilik, etc do you prepare per month ?

How many liters of siwa, tea, coffe, etc do you prepare per month?

Section-E: Nutrition Awareness

Now I like to ask you about your general knowledge about nutrition and healthy feeding habits.

Household Nutrition Knowledge

Now I like to ask you about your general knowledge about nutrition and healthy feeding habits.

While asking those question DO NOT READ THE ALTERNATIVE CHOICE OF ANSWERS TO THE RESPONDENT. If he/she did not understand the question read the question again and again for him/her

Have you ever decided to diversify your production for the purpose of diversifying your household diet?

- ☐ Yes
- ☐ No

Do you think your household should eat variety of food every day?

- ☐ Yes
- ☐ No
- ☐ I don't know

Do you know what will happen to your family if you can't diversify your household diet?

- ☐ Nothing
- ☐ Health benefit
- ☐ Health problem
- ☐ I don't know

How do you know about the benefit of household dietary diversity?

- ☐ Health professionals
- ☐ formal education
- ☐ Media
- ☐ Others
- ☐ I don't know

Which of the following diseases do you think come due to nutrient deficiency/dietary problem?

Here, read the alternatives answers listed for the respondent: Multiple response is possible

- ☐ Goitre
- ☐ Headache
- ☐ Blood pressure
- ☐ Diabetes
- ☐ Diarrhea
- ☐ Stunting
- ☐ Wasting
- ☐ Overweight
- ☐ None

Section-F: Agriculture Value Chain

Agricultural Product Value Chains in Local Markets**Does your household produce any of the following agricultural commodities**

- ☐ Vegetables
- ☐ Fruits
- ☐ Milk and Dairy
- ☐ Honey
- ☐ None

Where did you get the seed (seedling) of those plants?

- ☐ Government agriculture office
- ☐ Cooperatives nurseries
- ☐ Private nurseries
- ☐ Market
- ☐ Own preparation

How do you rate the quality of those seedling ?

- ☐ High
- ☐ Medium
- ☐ Poor

what are the challenges you face when using those seedlings ?

- ☐ Poor quality
- ☐ Not find in time
- ☐ Expensive
- ☐ limited skill on how to use/misuse

Has your household produce vegetables in the last 12 months?

- ☐ yes
- ☐ no

Rank the major vegetable products of your household in the last 12 months

1st choice

- | | | |
|-----------------------------------|------------------------------|-------------------------------|
| ☐ Tomato | ☐ Onion | ☐ Spinach |
| ☐ Lettuce | ☐ Garlic | ☐ Potato |
| ☐ Green chill | | |

2nd choice

- | | | |
|-----------------------------------|------------------------------|-------------------------------|
| ☐ Tomato | ☐ Onion | ☐ Spinach |
| ☐ Lettuce | ☐ Garlic | ☐ Potato |
| ☐ Green chill | | |

3rd choice

- | | | |
|-----------------------------------|------------------------------|-------------------------------|
| ☐ Tomato | ☐ Onion | ☐ Spinach |
| ☐ Lettuce | ☐ Garlic | ☐ Potato |
| ☐ Green chill | | |

Which are the top best markets for your vegetables?

1st choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

2nd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

3rd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

Rank the top three main buyers of your vegetable

1st choice

- | | | |
|--|---|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkts | ☐ Consumers in other mkts | ☐ wholesaler in other mkts |
| ☐ Hotel cafe restaurants etc | | |

2nd choice

- | | | |
|--|---|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkts | ☐ Consumers in other mkts | ☐ wholesaler in other mkts |
| ☐ Hotel cafe restaurants etc | | |

3rd choice

- | | | |
|--|---|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkts | ☐ Consumers in other mkts | ☐ wholesaler in other mkts |
| ☐ Hotel cafe restaurants etc | | |

Has your household produce fruits in the last 12 months?

- ☐ yes
- ☐ no

Rank the major fruit products of your household in the last 12 months

1st choice

- | | | |
|-----------------------------|------------------------------|-------------------------------|
| ☐ Guava | ☐ Orange | ☐ Avocado |
| ☐ Mango | ☐ Papaya | ☐ Apple |
| ☐ Banan | | |

2nd choice

- | | | |
|-----------------------------|------------------------------|-------------------------------|
| ☐ Guava | ☐ Orange | ☐ Avocado |
| ☐ Mango | ☐ Papaya | ☐ Apple |
| ☐ Banan | | |

3rd choice

- | | | |
|-----------------------------|------------------------------|-------------------------------|
| ☐ Guava | ☐ Orange | ☐ Avocado |
| ☐ Mango | ☐ Papaya | ☐ Apple |
| ☐ Banan | | |

Which are the top best markets for your fruits?

1st choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

2nd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

3rd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

Rank the top three main buyers of your fruits

1st choice

- | | | |
|---|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailer in other mkt | ☐ Consumers in other mkt | ☐ Wholesalers in other mkt |
| ☐ Hotel cafe restaurant etc | | |

2nd choice

- | | | |
|---|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailer in other mkt | ☐ Consumers in other mkt | ☐ Wholesalers in other mkt |
| ☐ Hotel cafe restaurant etc | | |

3rd choice

- | | | |
|---|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailer in other mkt | ☐ Consumers in other mkt | ☐ Wholesalers in other mkt |
| ☐ Hotel cafe restaurant etc | | |

Has your household produce milk in the last 12 months?

- ☐ yes
- ☐ no

Rank the major milk and dairy products of your household in the last 12 months

1st choice

- | | | |
|---|---|------------------------------------|
| ☐ Fresh Milk Tsalta | ☐ Skimmed milk Huquan | ☐ Butter Tesmi |
| ☐ Yogurt Rigio | ☐ Cheese Ajibo | |

2nd choice

- | | | |
|---|---|------------------------------------|
| ☐ Fresh Milk Tsalta | ☐ Skimmed milk Huquan | ☐ Butter Tesmi |
| ☐ Yogurt Rigio | ☐ Cheese Ajibo | |

3rd choice

- | | | |
|---|---|------------------------------------|
| ☐ Fresh Milk Tsalta | ☐ Skimmed milk Huquan | ☐ Butter Tesmi |
| ☐ Yogurt Rigio | ☐ Cheese Ajibo | |

Which are the top best markets for your milk and dairy products?

1st choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

2nd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

3rd choice

- | | | |
|-------------------------------------|-------------------------------|------------------------------|
| ☐ Haiki Mesihal | ☐ Atsibi | ☐ Agulae |
| ☐ Wukro | ☐ Mekelle | |

Rank the top three main buyers of your milk and diary products

1st choice

- | | | |
|--|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkt | ☐ Consumers in other mkt | ☐ wholesalers in other mkt |
| ☐ Hotel cafe restaurant | | |

2nd choice

- | | | |
|--|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkt | ☐ Consumers in other mkt | ☐ wholesalers in other mkt |
| ☐ Hotel cafe restaurant | | |

3rd choice

- | | | |
|--|--|--|
| ☐ Retailers in Hayko | ☐ Consumers in Hayko | ☐ Wholesalers in Hayko |
| ☐ Retailers in other mkt | ☐ Consumers in other mkt | ☐ wholesalers in other mkt |
| ☐ Hotel cafe restaurant | | |

Has your household produce honey in the last 12 months?

- ☐ yes
- ☐ no

Rank the major Honey products of your household in the last 12 months

1st choice

- | | |
|----------------------------------|---------------------------|
| ☐ Honey | ☐ Wax |
| ☐ Bee colony | |

2nd choice

- ☐ Honey
 ☐ Wax
☐ Bee colony

3rd choice

- ☐ Honey
 ☐ Wax
☐ Bee colony

Which are the top best markets for your honey?

1st choice

- ☐ Haiki Meshal
 ☐ Atsibi
 ☐ Agulae
☐ Wukro
 ☐ Mekelle

2nd choice

- ☐ Haiki Meshal
 ☐ Atsibi
 ☐ Agulae
☐ Wukro
 ☐ Mekelle

3rd choice

- ☐ Haiki Meshal
 ☐ Atsibi
 ☐ Agulae
☐ Wukro
 ☐ Mekelle

Rank the top three main buyers of your honey

1st choice

- ☐ retailers in Hayo
 ☐ consumers in Hayko
 ☐ Wholesalers in Hayko
☐ Retailer in other mkt
 ☐ Consumers in other mkt
 ☐ Wholesalers in other mkt
☐ Cooperative and unions

2nd choice

- ☐ retailers in Hayo
 ☐ consumers in Hayko
 ☐ Wholesalers in Hayko
☐ Retailer in other mkt
 ☐ Consumers in other mkt
 ☐ Wholesalers in other mkt
☐ Cooperative and unions

3rd choice

- ☐ retailers in Hayo
 ☐ consumers in Hayko
 ☐ Wholesalers in Hayko
☐ Retailer in other mkt
 ☐ Consumers in other mkt
 ☐ Wholesalers in other mkt
☐ Cooperative and unions

how do you get information about the demand and price of your products?

- ☐ mobile
- ☐ friend
- ☐ agriculture office
- ☐ meddle men
- ☐ buyers call

how do you feel about the meddle men during your transaction?

- ☐ helpful
- ☐ useless
- ☐ dishonest
- ☐ abusive
- ☐ never know any

How many mobile phones are there in your household-----?

Please, count the member of households with own mobile phones.

Ethical Approval Letter

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 **Mekelle University**

ኪህነድና ኢኮኖሚክስ ኮሌጅ
College of Business and Economics
Mekelle – Ethiopia

Mail @ 451 Dial @ 40 76 00/ 40 76 09/4076 08 E-mail: cbemudean@gmail.com

ቁጥር/Ref.No. CBE/4019/17-38 ቀን/Date: August 25/2020

To: Mr. Tsegay Balcha Gashie
Principal Investigator
Mekelle

Re: Notification of Research Ethics Approval
Protocol: Explore the Effect of Integrating Farm Diversification and Market Engagement on Smallholder Household Diets in Tigray, Ethiopia.

Dear PI

This is your notification that your above referenced study has received research approval on 20/08/2020.

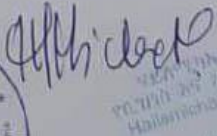
The research study cited above has been reviewed by Mekelle University College of Business and Economics (MU-CBE) Research and Community Services Office and has been determined that it meets the social science research conducts and ethics policies criteria for the research to be undertaken.

The PI should comply with national and international scientific and ethical guidelines. Any reportable event (adverse events, breaches of confidentiality, protocol deviation or protocol violation) or issues resulting from this study should be immediately reported to the MU-CBE Research and Community Services Office. Any amendments (changes to any portion of this research protocol including but not limited to protocol or informed consent changes) must have the offices approval before being implemented.

All correspondences and inquiries concerning this research protocol must include this letters reference number, the name of the PI and the title of the protocol.

Best Regards,

CC:
☐ College of Business and Economics
☐ Department of Economics

 
Hailu Michael Tesfaye Gese
Dean,
College of Business & Economics

We Really Care!