

Analysis of Heterogeneous and Synergistic Effects of Commercialization, Gendered Decision-making, and Climate-smart Practices on Smallholder Horticulture Farmers' Welfare in Jimma, Ethiopia

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Fikadu Asmiro Abeje

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Horticulture Farmers' Welfare in Jimma, Ethiopia**

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DEDICATION

I dedicate this dissertation to:

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THESIS SUMMARY

The welfare of smallholder farmers remains a critical development priority in developing countries, where subsistence farming, weak market linkages, and climate change pose ongoing challenges. To address these multifaceted challenges, Ethiopia has implemented a comprehensive agricultural policy aimed at transforming the agricultural sector into a commercial-oriented farming system, promoting gender empowerment in decision-making, and adopting climate-smart practices. While existing studies have highlighted the individual benefits of commercialization, joint decision-making, and climate-smart practices, their collective impacts on farmers' welfare, whether producing heterogeneous outcomes, synergies, or trade-offs, remain a crucial area of research. Therefore, this study investigates how these essential household-level strategies: commercialization, gendered decision-making, and the adoption of climate-smart practices are collectively associated with farmers' welfare in terms of yield, income, and food security in Jimma zone, Ethiopia. Using the Smallholder Horticulture Empowerment and Promotion (SHEP) intervention as a case study, this research examines the heterogeneous and synergistic effects of these strategies on farmers' welfare. A dual-stage matching technique is employed in this study, with a total of 610 randomly sampled farmers. Initially, nearest-neighbor matching is conducted at the *Kebele* level using GIS data, including slope, elevation, soil properties, distance to the nearest city, distance to rivers, and road networks, to identify comparable counterfactual control groups alongside the treated group. Next, propensity score matching (PSM) and inverse probability weighting (IPW) are applied at the household level to address selection bias.

This study analyzes the heterogeneous effects of factors, including commercialization and gendered decision-making, on income using quantile regression. The results show that the interaction effects between commercialization and SHEP intervention demonstrate positive heterogeneous effects on horticulture income, which are notably more pronounced at equal to or lower than the 50th quantile. Results show that joint decision-making significantly improves farmers' income at the 10th and 25th quantiles. However, the intervention did not provide an added effect through joint decision-making on income. This is because the gender training primarily focuses on behavioral and mindset changes, which can take a longer time to be fully internalized. Proximity to agricultural cooperatives significantly correlates with income at lower quantiles. Thus, for the lower-quantile farmers who are better off, a market-driven extension approach, such as SHEP, is crucial to improving their income.

This study examines the effects of adopting CSH practices on horticultural yield using inverse probability weighting regression adjustment (IPWRA). The findings indicate that adopting CSH practices leads to a 43% increase in aggregate weighted horticultural yield among adopters compared to non-adopters. The regression adjustment via quantile regression reveals that the SHEP intervention has a positive association with yield across all quantiles, regardless of the interaction effects of adopting CSH practices. However, it produces varied results when considering the interaction effects with different CSH practices: the interplay between SHEP and the adoption of disease-resistant crop varieties enhances yield in the upper yield spectrum (75th quantile), serving as a buffer for farmers to stabilize and sustain their horticultural income. In contrast, the interaction between adopting crop diversification and SHEP has a negative association with yield compared

to the pure control group at the 75th and 90th quantiles. This may be due to SHEP's focus extending beyond maximizing yield and instead, prioritizing diversifying market-responsive crops. Farmers in the pure control group may not cultivate market-responsive crops, which might have a higher aggregate weighted yield but are less in demand, leading to lower income. Therefore, the study emphasizes the role of scaling up context-specific CSH practices alongside market-oriented extension services at different yield spectrums.

This study examines the effects of commercialization, joint decision-making, and the adoption of CSH practices on household food security using an extended ordered probit model. The results indicate that the SHEP intervention significantly enhances food security through commercialization, joint decision-making, and the adoption of CSH practices. On average, 80.8% of farmers in the treated group who engaged in commercialization are food secure, compared to only 21.5% in the pure control group, suggesting a synergistic relationship with food security rather than a trade-off. About 82.9% of joint decision-makers in the treated group are food secure, compared to 18.8% in the pure control group. Furthermore, farmers in the treated group who adopt multiple CSH practices are more likely to be food secure than those in the pure control group and those who adopt fewer practices. Furthermore, farmers in the treated group who adopt multiple CSH practices are more likely to be food secure than those in the pure control group and those who adopt fewer practices.

Thus, this study highlights the significant roles of commercialization, joint decision-making, and integrating context-specific CSH practices into a market-oriented agricultural extension program to enhance farmers' welfare in the context of climate change. Moreover, this quasi-experimental methodological innovation using GIS could serve as a valuable reference for future quasi-experimental and impact evaluation studies employing similar approaches in various contexts.

Keywords: Adoption of CSH, Commercialization, Food security, Heterogeneous effects, Jimma zone, Joint decision-making, Synergy effects, Ethiopia

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CHAPTER ONE: INTRODUCTION

1.1. Background and Justification

Smallholder Welfare as a Development Priority

The welfare of smallholder farmers remains a critical development priority in developing countries, including Ethiopia, where subsistence farming, weak market linkages, limited access to improved agricultural technology, and climate change pose ongoing challenges (FAO, 2023; Emana et al., 2015; Rapsomanikis, 2025). Smallholder farmers are defined as individuals or households engaged in agricultural production on relatively small land sizes, typically less than two hectares, with an average landholding of 0.9 hectares in Ethiopia (Rapsomanikis, 2015). These farms are primarily managed using family labor and are oriented toward both subsistence and local market sales (Rapsomanikis, 2025). This study conceptualizes welfare as a multidimensional construct comprising three interlinked dimensions: income, yield, and food security (Awotide et al., 2022; FAO, 2021; Tanko et al., 2019). This underscores that farmers' welfare outcomes cannot be fully understood through income or food security alone but must also include agricultural productivity and resilience to climatic and market uncertainties.

Farmers' Welfare Challenges and Household-level Strategic Responses in the Global and African Context

Food security remains a critical global challenge, affecting millions and manifesting as hunger and malnutrition. In response, on September 25, 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, which includes goals such as SDG-1, "no poverty," and SDG-2, "zero hunger," aimed at ensuring everyone has access to safe, adequate, and nutritious food throughout the year (FAO, 2017). Despite these efforts, food security remains a pressing issue, with approximately 29% and 62.8% of the global and Sub-Saharan African populations experiencing moderate or severe food insecurity in 2023, respectively (FAO et al., 2024). Various empirical studies (e.g., Agidew & Singh, 2018; Drammeh et al., 2019; Abafe et al., 2022) have demonstrated that food insecurity is more severe in Africa than in other continents. To address these multifaceted challenges, various household-level strategies have been implemented in different developing countries, such as transforming subsistence farming into commercial-oriented farming (Ogutu & Qaim, 2019), empowering gender in decision-making (Mohammed et al., 2023;

Tadesse et al., 2022), and adapting climate change adaptation strategies (Awotide et al., 2022; Lipper et al., 2014).

Agricultural Commercialization as a Pathway to Farmers' Welfare

In developing countries, agricultural commercialization has become a pivotal catalyst for structural transformation, particularly in contexts where agriculture is central to national GDP and employment, while also supplying food, labor, and capital to other sectors (Etuk & Ayuk, 2021); (Pingali et al., 2019); (von Braun, 1995). Scholars have identified commercialization as a key mechanism to boost agricultural productivity (Ochieng et al., 2016), raise per capita income levels (Ogutu & Qaim, 2019), enhance household welfare (Muriithi & Matz, 2015), and promote the accumulation of productive assets (Tabe-Ojong et al., 2022).

Heterogeneous Effects of Commercialization on Farmers' Income

The existing literature consistently highlights the income-enhancing role of commercialization for smallholder farmers, while often treating these effects as homogeneous or average outcomes (focusing on estimating the uniform impacts of a certain factors across all study units regardless of their background or institutional services differences), failing to account for variations across different farmer types (Carletto et al., 2017; von Braun, 1995). Homogeneous or average treatment effects assume that the impact of an intervention or explanatory factor is constant or uniform across all individuals or groups, without accounting for variations in socioeconomic status, agroecological context, or institutional access. Some studies, however, have begun to show that the impacts of commercialization on income are heterogeneous, reflecting differences in household and farm-level characteristics that lead to varying effects across income distributions (Ogutu & Qaim, 2019; Tabe-Ojong et al., 2022). The concept of heterogeneous effects refers to the assumption that differences in farmers' access to institutional services, resource endowments, socioeconomic characteristics (e.g., education, gender, landholding), and demographic profiles lead to varying effects on income. The concept of heterogeneous effects refers to the assumption that differences in farmers' access to institutional services, resource endowments, socioeconomic characteristics (e.g., education, gender, landholding), and demographic profiles lead to varying effects on income.

Commercialization and Food Security: Synergies and Trade-offs Effects

As highlighted in various empirical studies, commercialization has potential synergy and trade-off effects on food security. From a synergy perspective, commercialization directly enhances farmers' ability to purchase

food, invest in inputs, and access markets (Bolarinwa et al., 2021). From a trade-off perspective, however, the existing studies have shown that commercialization may reduce food availability for household consumption when land is reallocated from subsistence foods to high-value cash crops (Linderhof et al., 2019; Mausch et al., 2020), potentially undermining household food availability and nutrition (Fleuret & Fleuret, 1980).

Gendered Decision-making and Opportunity Costs in Agriculture Farming

Historically, agricultural decision-making in smallholder contexts has been dominated by men, resulting in imbalances in resource allocation and limiting women's roles in farming decisions. Maertens and Swinnen (2010) highlighted that the rapid growth of high-value agriculture has significant gender implications, particularly in terms of resource control within rural households. Thus, recent development interventions and policy frameworks have increasingly promoted joint decision-making as a more equitable and practical approach to managing farm resources and household welfare. Consequently, various studies highlight that gendered decision-making in agriculture further shapes farmers' welfare. As emphasized by Doss (2015), women's involvement in decisions about production, sales, and profit allocation or income use is positively associated with improved household food security. Moreover, evidence suggests that joint¹ decision-making can enhance collaborative resource use and shared goals, leading to better productivity outcomes as well as improved food security (Acosta et al., 2020; Tadesse et al., 2020; Mohammed et al., 2023). However, joint decision-making may increase opportunity costs due to the slowness and delays in making decisions (Acosta et al., 2020; Grabowski et al., 2016). This suggests that missing potential opportunities to adopt improved agricultural technologies may result in trade-offs for household food security. For example, if couples delay deciding how much to sell from their harvests, they may largely miss out on better market prices, and if they take longer to decide on using improved varieties, they may end up with a lower harvest, resulting in lower income gains and implicitly creating trade-offs for their household food security.

¹ Joint decision-making indicates that decisions are made by both couples (husband and wife) within the household instead of focusing solely on the involvement of multiple in decision-making (Mohammed et al., 2023).

Synergies and Constraints in the Adoption of Climate-smart Practices: Implications for Farmers' Welfare

Besides commercialization and gendered decision-making directly influencing farmers' access to markets, income opportunities, and household resource allocation, climate-smart agriculture (CSA) practices also contribute to farmers' welfare. The CSA practices have been widely implemented to mitigate the adverse impacts of climate change, which sustainably transform, reorient, and foster long-term agricultural development for all crops and livestock farming, synergizing to enhance productivity, income, and food security (Hussein, 2024; Kapari et al., 2023; FAO, 2022; Lipper et al., 2014; Zheng et al., 2024; Tabe-Ojong et al., 2023). Recently, the concept of climate-smart horticulture (CSH) practices has been customized from the CSA concept, which shares the definition of CSA. The CSH concept involves adapting and building the resilience of horticulture farming to climate variability (Mwikamba et al., 2024), which helps to increase horticultural crops' productivity and improve household food security. While irrigation is classified as one of the most common CSA practices (Erekalo & Yadda, 2023; Kapari et al., 2023), it is further documented that even within irrigated farming systems, there is a need for tailored climate-smart practices, such as efficient water management, adjusted irrigation scheduling, revised crop calendars, the use of disease-resistant crop varieties, and so forth. The adoption of CSH practices, however, requires a significant financial investment, labor, and technical knowledge (Hussein, 2024; Dougill et al., 2012; Tilahun et al., 2023). Though these studies did not explicitly highlight the trade-off effects on food security, requiring high financial investments and technical knowledge for adoption may implicitly create trade-offs with farmers' welfare, particularly in terms of food security.

Study Rationale and Aim

This dissertation aims to deepen the understanding of how horticultural commercialization, gendered decision-making, and the adoption of climate-smart horticulture practices collectively influence the welfare of smallholder farmers in Ethiopia. By examining these interconnected strategies within the framework of structured interventions like SHEP, the study intends to provide nuanced insights into their heterogeneous and synergistic effects on farmers' welfare, ultimately guiding the development of more inclusive, resilient, and welfare-enhancing agricultural pathways for rural communities.

1.2. Statement of the Problem

Despite a growing body of literature examining agricultural commercialization, gendered decision-making, and adoption of CSA practices in boosting agricultural production, significant gaps remain in understanding

how these household-level strategies influence the farmers' welfare. Notably, existing studies on agricultural commercialization often fail to capture the heterogeneous effects of potential factors across different income groups, limiting the ability to offer tailored support to farmers across various commercialization levels. Moreover, such studies rarely situate their analyses within structured programs, for example, a market-oriented extension intervention as a case study, which captures practical experiences of farming communities. Thus, in our study, we aim to identify how these factors affect different segments such as low-, middle-, and high-income farmers differently, which enables us to suggest more tailored and targeted policy interventions rather than one-size-fits-all solutions.

Similarly, although many studies emphasize the positive association between women's empowerment and household income, there is a lack of evidence on how joint decision-making specifically affects farm income across different household economic levels. This highlights a research gap and indicates a need for further investigation into the nuanced welfare effects of gendered decision-making across diverse farming households.

Most empirical evidence has concentrated on the impact of adopting climate-smart practices on cereal crops and livestock production, with limited focus on horticulture, despite its essential role in enhancing productivity and food security. Studies examining climate-smart horticulture (CSH) practices have primarily focused on adoption patterns and the factors influencing them, rather than directly linking adoption to horticultural yield outcomes. Consequently, there is scant empirical evidence on how the adoption of CSH practices affects horticultural yields among farmers, leaving its potential heterogeneous effects on horticultural yields poorly understood.

Debates remain in the literature about whether these household-level strategies; commercialization, gendered decision-making, and CSH adoption, work synergistically to improve welfare or introduce trade-offs that could undermine household food security. Most existing studies have not integrated these three strategies into a single analytical framework regarding food security outcomes. This is especially true in the context of structured interventions, such as market-oriented extension service provision, where synergies or trade-offs may exhibit differently. Furthermore, most studies fail to account for selection bias and endogeneity, undermining the validity of causal claims regarding the welfare effects of these strategies. Additionally, essential agricultural peculiarities, such as spatial variations in slope, elevation, soil properties, irrigation availability, and road access, are often overlooked, despite their central role in determining farmers' welfare.

Taken together, these gaps underscore the need for research that comprehensively examines the collective and heterogeneous impacts of horticultural commercialization, gendered decision-making, and climate-smart practices on farmers' welfare, incorporating Geographical Information System (GIS)² data into the sampling framework. Addressing these knowledge gaps is essential for designing policies and programs that effectively respond to the farmers' challenges and help improve their welfare.

1.3. Conceptual Framework

This study examines the interplay among three pivotal household-level strategies, horticultural commercialization, gendered decision-making, and the adoption of CSH practices; and their collective implications for the welfare of smallholder farmers in the Jimma Zone of Ethiopia. The study explicitly focuses on the heterogeneity and potential synergy or trade-off effects of these strategies on three core welfare outcomes: income, yield, and food security. The conceptual framework (Figure 1.1) illustrates the relationships between these strategies and the intended outcomes. The Smallholder Horticulture Empowerment and Promotion (SHEP) serves as an intervention model, fostering market-oriented horticultural commercialization, promoting joint decision-making, and supporting the adoption of context-specific CSH practices. While these pathways are generally expected to generate positive or synergistic impacts (denoted by “+”) on farmers' welfare, trade-offs (denoted by “–”) may also arise when competing livelihood priorities or resource constraints create conflicts between immediate food availability and income-focused production.

The first aspect of this framework centers on horticultural commercialization, which integrates smallholder farmers into the market to enhance income opportunities. However, its effect may not be uniform among the farmers, potentially due to differences in socioeconomic characteristics and institutional factors, which lead to observed differential incomes among them. In parallel, this study evaluates how gendered decision-making, whether by men or women alone or jointly, on the harvests to sell is associated with farmers' income. While a greater likelihood of women alone and joint decision-making can enhance income, these effects can vary depending on household power dynamics and socioeconomic context. Consequently, this study

² Geographical Information System (GIS) data refers to spatially referenced information, such as elevation, slope, soil type, irrigation access, and proximity to infrastructure that describes the physical and geographical attributes of study areas. In this study, we utilized GIS data to capture agroecological and infrastructural characteristics, identifying comparable counterfactual groups similar to the treated group at the kebele level using spatial matching techniques.

examines the heterogeneity of these decision-making arrangements across different income groups, addressing gaps in prior research that treat the role of gendered decision-making as homogenous.

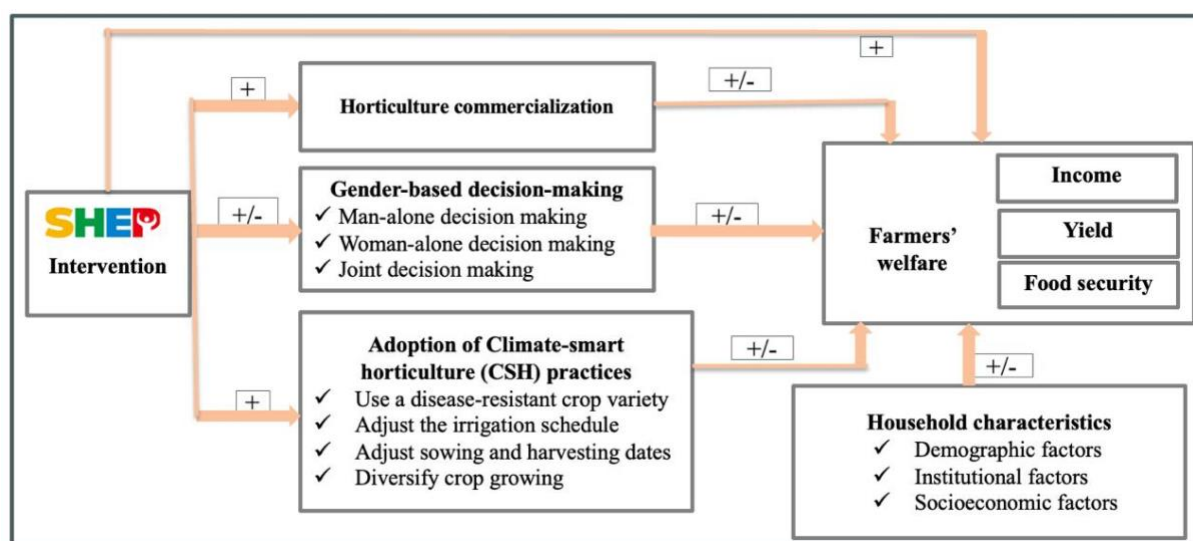


Figure 1-1: Conceptual Framework of the study

1.4. Research objectives and research questions

1.4.1. General research objective

This study aims to examine the impact of commercialization, gendered decision-making, and the adoption of CSH practices on the welfare of farmers in horticulture farming in the Jimma zone of Ethiopia. The dissertation primarily seeks to contribute to current scientific debates on how horticultural commercialization, gendered decision-making, and the adoption of climate-smart practices influence farmers' welfare in terms of income, yield, and food security, by emphasizing their heterogeneous and synergistic effects.

1.4.2. Specific research objective

- 1) To analyze the heterogeneous factors, including horticultural commercialization and gendered decision-making, that affect smallholder farmers' horticultural income.
- 2) To examine the effects of the adoption of climate-smart practices on horticultural crop yield
- 3) To examine the synergy or trade-off effects of horticulture commercialization, gendered decision-making, and adoption of climate-smart horticulture practices on household food security

1.4.3. Research questions

This study assessed three main research questions such as:

- I. Do commercialization and joint decision-making have heterogeneous effects on income among the smallholder farmers?
- II. Does adopting various CSH practices improve horticulture yield?
- III. Do the collective effects of commercialization, joint decision-making, and the adoption of CSH practices lead to synergistic or trade-off effects on household food security?

1.4.4. Research hypothesis

Based on the above research questions, three main research hypotheses have been tested in this study.

- I. **Research hypothesis 1:** Horticulture commercialization and joint decision-making through SHEP intervention may have a positive and varying effect on the incomes of smallholder farmers across different income quantiles.
- II. **Research Hypothesis 2:** The adoption of CSH practices through the SHEP intervention may have a heterogeneous effect on horticultural crop yield.

- III. **Research hypothesis 3:** Horticulture commercialization, joint decision-making, and adoption of CSH practices will synergize household food security, rather than creating a trade-off.

1.5. Limitations and Significance of the Study

This study provides valuable insights into how horticultural commercialization, gendered decision-making, and climate-smart practices collectively impact smallholder farmers' welfare, encompassing income, yield, and food security. By analyzing these three strategies within a single empirical framework, it adds important nuance to the debate on whether they have heterogeneous or synergistic effects on farmers' welfare. The findings contribute critical evidence for shaping inclusive and context-specific agricultural interventions that integrate market-oriented, gender-responsive, and climate-resilient approaches. However, the limitations have to be elaborated. First, the study is used cross-sectional data, which constrains our ability to observe long-term or dynamic welfare impacts over time. Second, because of the cross-sectional nature of the data, the spillover effects of the SHEP intervention are not measured, thus, being cautious and avoiding overstating the impact is crucial. Third, while the analysis reveals a positive association between livestock holding and horticulture income, this study did not examine causality; which could be an areas of future study to explore the causality between livestock holding and income. As a result, future research could address this issue by employing panel data, which would enable the estimation of the causal pathways, control for time-invariant household characteristics, and provide a deeper understanding of how these strategies ultimately shape long-term farmers' welfare.

1.6. Organizations of the Dissertation

This dissertation is organized into seven main chapters, including this introductory chapter. Chapter two reviews the relevant literature. Chapter three describes the research site, the sampling process, and the data, along with an overview of the case study, "*SHEP intervention*." Chapter four examines the heterogeneous effects of commercialization and gendered decision-making on horticulture income. Chapter five discusses the impact of adopting CSH practices on horticultural crop yield. Chapter six explores how commercialization, gendered decision-making, and adopting CSH practices influence food security. Finally, chapter seven summarizes the conclusions and policy implications of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1. Agricultural Commercialization and Farmers' Welfare

Agricultural commercialization is defined as the shift from subsistence to market-oriented farming and is widely recognized as a catalyst for economic growth and poverty reduction in developing countries (Saha, Wheeler, & Thompson, 2022). However, its effects on income distribution vary among farmers due to demographic factors, socioeconomic conditions, and the availability of institutional services (Minten et al., 2020; Minot et al., 2022). While studies generally confirm the positive impact of commercialization (Barrett, 2007; Carletto et al., 2017; von Braun, 1995), they often focus on the average effect. Some empirical evidence suggests, however, the impact is heterogeneous on income in developing countries (Ogutu & Qaim 2019; Tabe-Ojong et al., 2022). Ogutu & Qaim (2019) found that commercialization benefits farmers' income and reduces poverty, particularly among lower-income farmers. Also, there is similar findings of income variation among smallholder farmers in Malawi (Radchenko et al., 2018), differences in technical efficiency, crop diversification in Ethiopia (Birhanu et al., 2021), and asset accumulation in Vietnam and Ethiopia (Cazzuffi et al., 2020; Tabe-Ojong et al., 2022). Thus, agricultural commercialization provides overall benefits but has varying effects on income distribution, influencing farmers differently based on their resource endowment.

The agricultural sector, particularly in Sub-Saharan Africa (SSA), presents conflicting evidence on the impact of commercialization on food security. The sector operates under a subsistence-oriented agricultural system, which, despite its crucial role in mitigating household food shortages, has been criticized for hindering economic development in the region (Gollin & Rogerson, 2014). The shift towards a commercial agriculture system, characterized by increased participation in input and output markets, is essential for accelerating economic growth in SSA (Haggblade, 2011; Woldemichael et al., 2017; Linderhof et al., 2019). Thus, many studies suggest that agricultural commercialization improves productivity, income, and food security (Pingali, 1997; Carletto et al., 2017; Fikadu et al., 2025). Furthermore, agricultural commercialization has been recognized as a strategy for enhancing household food security and reducing poverty, leading to synergistic effects in African rural communities (Muriithi & Matz, 2015). On the other hand, commercial-oriented farming, particularly the cultivation of cash crops, is negatively associated with household food security, as it reduces dietary diversity and food availability (Linderhof et al., 2019). It is also often associated with a decline in food self-sufficiency and lower dietary diversity, as farmers tend to prioritize higher-value crops

for market purposes over more nutritious crops intended for household consumption (Mausch et al., 2020). Additionally, the emphasis on cash crop production can reallocate land and resources away from food crops, further undermining food availability for household needs (Fleuret & Fleuret, 1980; Gollin & Rogerson, 2014). These dual dynamic highlights the complex impact of commercialization on food security, underscoring the need for further empirical research to determine whether it produces synergies or trade-offs for farmers' welfare, particularly on household food security.

2.2. Gendered Decision-Making and Farmers' Welfare

The predominance of men has long characterized gendered decision-making in smallholder farming systems, with men often serving as sole decision-makers within households. This pattern has often led to the marginalization of women's voices and the undervaluation of their crucial contributions to decision-making on agricultural and household welfare. Recognizing these disparities, numerous development initiatives worldwide have sought to promote women's empowerment, aiming to amplify women's participation in farm and household decision-making. However, these interventions have frequently yielded limited impacts on actual decision-making dynamics within households (Mwololo et al., 2022). The possible reason for this gap could be the insufficient involvement of men in these empowerment efforts. This oversight may lead men to not fully understand what their wives manage in both productive and reproductive tasks within the household. For better household welfare, the men must recognize the overwhelming nature of their wives' responsibilities, which include fieldwork, household chores, family care, meal preparation, fetching water over long distances, washing clothes, feeding children, and overseeing the entire family. This often results in women sleeping late and waking up early as part of their routine. Despite this, their contributions are frequently overlooked or marginalized, with husbands remaining the ultimate and exclusive decision-makers for every activity. Thus, recent interventions have begun to shift from an exclusive focus on women's empowerment toward a broader emphasis on gender empowerment or joint decision-making, which seeks to transform the attitudes and behaviors of both men and women, fostering mutual understanding and appreciation of one another's workloads and contributions. Joint decision-making facilitates more equitable household dialogue and negotiation, enabling couples to develop shared knowledge and schedules, voice their ideas, and reach consensus on agricultural and household decisions. Agricultural gendered decision-making refers to the active participation and consensus-building between couples within the household regarding farm activities, including cultivating crop types, selecting farming inputs, determining the quantity

of horticultural harvest to consume and sell, and allocating profits (Fikadu, et al., 2025). As noted by Acosta et al. (2020), Tadesse et al. (2020), and Mohammed et al. (2023), joint decision-making enhances household welfare, reflecting that couples collectively determine how to utilize improved resources, how much to sell, and what to consume by openly assessing their family's consumption. However, joint decision-making can be a source of disagreement and may involve lengthy negotiations to reach a consensus, especially when spouses have different preferences. As highlighted by Acosta et al. (2020) and Grabowski et al. (2016), prolonged negotiations in joint decision-making can delay timely agricultural decisions, for example, planting, weeding, or selling harvests. Thus, it may create a trade-off in farmers' welfare.

2.3. Climate-Smart Horticulture (CSH) Practices: Implications for Yield and Food Security

Climate change poses a significant threat to agricultural production, particularly in developing nations, where agriculture sustains the livelihoods of over 2.5 billion people (Goli et al., 2023). As a result, climate-smart agriculture (CSA) practices have been widely practiced in crops and livestock farming, which sustainably transform, reorient, and create long-term agricultural development, acting as buffers against the adverse impacts of severe weather events on reducing greenhouse gas emissions and improving farm production and food security (Zheng et al., 2024; Tabe-Ojong et al., 2023; Di Falco & Veronesi 2013; FAO 2022; Lipper et al. 2014). CSA practices are tailored to the local context of each country, including sustainable land management practices (soil and water conservation, intercropping, irrigation schedule adjustment, minimum tillage, and so forth), agrochemicals (fertilizers, herbicides, and pesticides), agronomic practices (improved varieties of crops and animals, disease-resistant crop varieties, optimizing planting and harvesting periods, crop diversification, and among others (FAO 2022; Lipper et al. 2014; Zheng et al., 2024). Moreover, Bello et al. (2024) highlighted that climate-smart agricultural practices provide synergy effects for farm productivity, thereby increasing farmers' income. The concept of climate-smart horticulture (CSH) practices has been adapted from the broader definition of CSA practices. These practices focus on enhancing horticulture's resilience to climate variability, increasing productivity, and improving household food security (Mwikamba et al., 2024). However, the adoption of climate-smart practices often requires significant investments in labor, technical knowledge, and financial resources (Hussein, 2024; Dougill et al., 2012), which leads to heterogeneity in yields among farmers and might create trade-offs in food security.

CHAPTER THREE: STUDY CONTEXT AND DATA

3.1. Horticulture Production in Ethiopia: A Contextual Analysis

In Ethiopia, agriculture accounts for 37.6% of the country's GDP and 67% of its employment (World Bank, 2023). Horticulture farming also plays a vital role in rural livelihoods, nutrition, and income diversification in the country (Emana et al., 2015; Wendimu, 2021). Despite the ongoing challenges posed by climate change, Ethiopia benefits from a diverse array of climatic conditions and soil types, which support the cultivation of a wide range of horticultural crops for both domestic consumption and export markets (Ashinie & Tefera, 2019). Based on the Ethiopian Central Statistical Agency report, vegetable crops are lettuce, head cabbage, Ethiopian cabbage, tomato, green pepper, red pepper, and swiss chard, while the root crops are includes beetroot, carrot, onion, potato, yam/boye, garlic, taro/goder, and sweet potato (Ethiopian Centra Statistical Agency [ECSA], 2021). The analysis of horticultural production trends in Ethiopia from 2005 to 2021 reveals a gradual yet uneven growth trajectory for both vegetable and root crop production (Figure 3.1).

The vegetable production, reflected in the number of producers, cultivated area, and total output, demonstrates a slow but steady increase over the years. The vegetable production shows a modest but consistent rise in both the number of producers and the area under cultivation. The production volume (measured in millions of quintals (qt)³) also displays a slight upward trajectory, indicating an incremental production growth.

Root crop production, initially stable, showed a sharp increase from around 2012 to 2015. Fluctuations in production levels were more pronounced than in area expansion. This spike may reflect the intensified promotion of root crops as climate-resilient staples, along with improved market opportunities and diversification of farming systems. The number of root crop producers and the area under cultivation increased steadily, peaking around 2015–2016, while a noticeable decline was observed in horticulture production after 2019.

The overall growth of the horticulture sector has been constrained by limited access to improved seed varieties, inadequate irrigation systems, post-harvest losses, climate-related risks, including pest and disease,

³ Quintal is the local measurement unit in Ethiopia (1 quintal = 100 kilogram).

market disruptions, and policy shifts⁴ (EMoA, 2023; Tadesse and Bekele, 2022; Ashinie & Tefera, 2019; Rahiel et al., 2018; Emanu et al., 2015). Thus, the decline in horticulture production highlights the need for targeted interventions, such as SHEP’s market-oriented training and climate-adaptive practices, to maintain resilience and productivity.

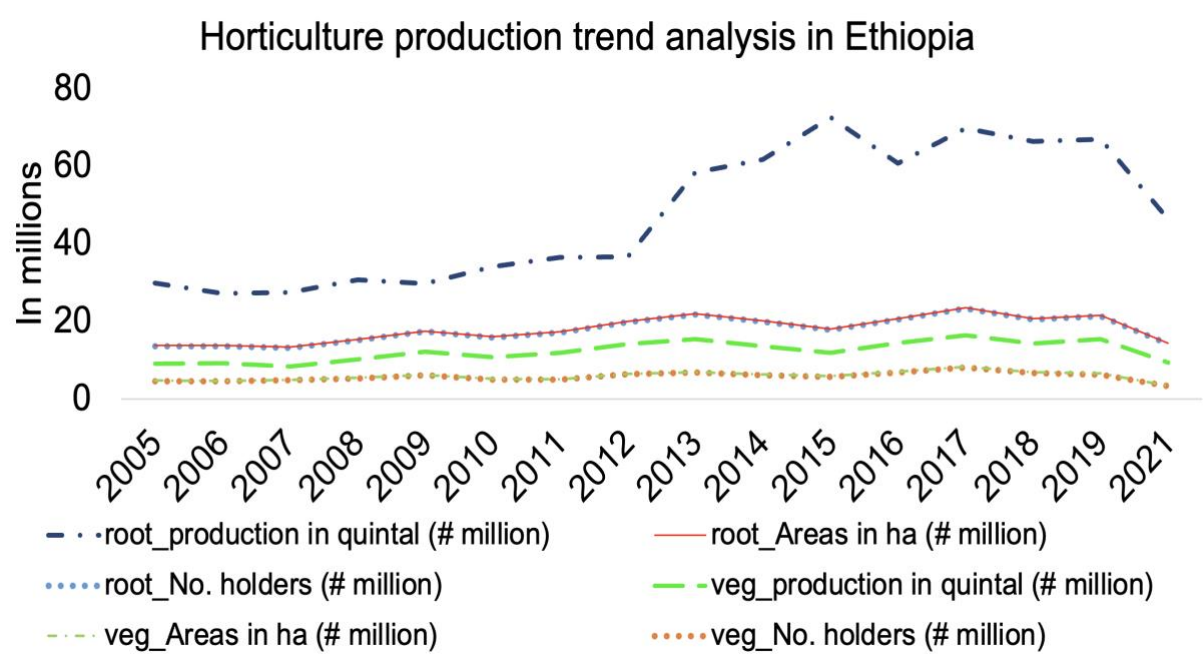


Figure 3-1: Horticulture production trend analysis in Ethiopia

Source: Authors’ computation based on the Ethiopian Central Statistical Agency (ECSA) data

Nationally, Ethiopia produced approximately 9 million quintals of vegetable crops and over 56.2 million quintals of root crops in the 2021 production season. Oromia leads in vegetable crop production with 3.7 million quintals, followed by SNNP and Amhara. For root crops, SNNP is the leading producer, reporting over 30.8 million quintals, while Oromia ranks second with 17.5 million quintals. In contrast, regions like Tigray and Benishangul-Gumuz have notably lower production volumes (ECSA, 2021). It is noted that the

⁴ The Ethiopian government has implemented the National Wheat Flagship Program (NWFP) to achieve self-sufficiency in wheat production. This ambitious initiative aims to enhance domestic wheat production and reduce the country's reliance on imports. As part of the NWFP, the government plans to expand and promote irrigated wheat cultivation across an area of one million hectares in the 2022/23 agricultural season, with subsequent annual expansion targets of 5% to 10% (Ethiopian Ministry of Agriculture [EMoA] 2023). This policy shift is, as a result, negatively influence the horticulture production (Nomura et al., 2024).

Ethiopian regional administration has recently undergone changes, but there are no horticulture production data available for the current new regions separately.

Figure 3.2 illustrates horticultural crop production across different zones of the Oromia region during the 2021 production season. There is a consistent trend of higher production of root crops compared to vegetable crops in nearly all zones of the Oromia region, including the Jimma zone. The East Harerge zone records the highest root crop production in 2021, followed by the West Arsi zone. In contrast, the Jimma zone has the highest production of vegetable crops, exceeding 478 thousand quintals, followed by the West Arsi zone. In the Jimma zone, root crops are also produced in quantities exceeding 1.5 million quintals. This pattern indicates that, while the Jimma zone has a vibrant vegetable sector, root crops dominate the production landscape, potentially reflecting both climatic suitability and market demand factors.

Descriptively, the Jimma zone has a more balanced representation of both vegetable and root crops compared to other zones in the Oromia region, highlighting its diverse horticultural portfolio. This diversity may have significant implications for food security and income-generation strategies among smallholder farmers in the Jimma zone.

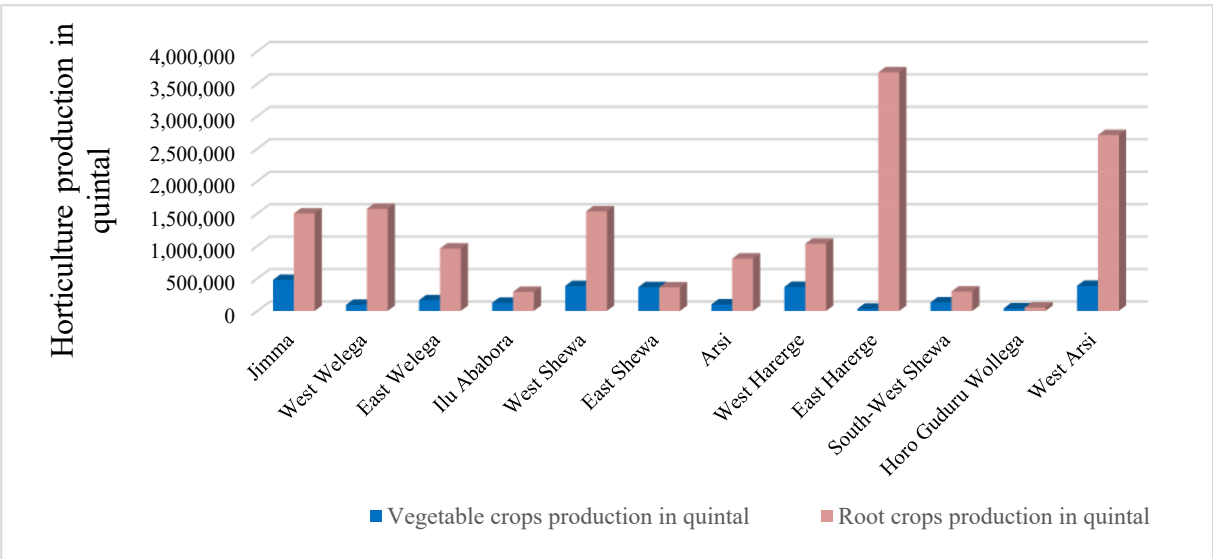


Figure 3-2: Horticulture production in quintal across zones in the Oromia region in Ethiopia

Source: Authors’ computation using ECSA (2021) data

3.2. Horticulture Productivity in Ethiopia- Global Context

Globally, horticultural crops, including vegetable and root crops, serve as a cornerstone of diversified farming systems and are crucial for household nutrition and food security (FAO, 2023). In Ethiopia, however, the

productivity of these crops remains significantly lower than their potential (Emana et al., 2015). Figure 3.3 illustrates a notable productivity gap between Ethiopia, East Africa, and the global average for six key horticultural crops: potatoes, cabbage, tomatoes, green peppers, onions, and carrots. Ethiopia's share of the global horticultural crop yield is notably low for all these crops, ranging from approximately 9.5% for carrots to 69.8% for potatoes. For instance, Ethiopia's potato yield represents about 69.8% of the global average, while cabbage accounts for around 31.3%, tomatoes make up about 13.9%, the green pepper yield share is approximately 31.6%, and the onion yield share is around 46%. Ethiopia still lags behind the world average by a significant margin, likely due to various factors, including differences in agroecological conditions, input use, measurement consistency, production purposes, post-harvest handling, and pests and diseases related to climate change (Rahiel et al., 2018). Thus, these findings underscore the significant gap between Ethiopia's horticultural productivity and the global average, highlighting opportunities for targeted interventions and climate-smart practices to reduce these yield gaps.

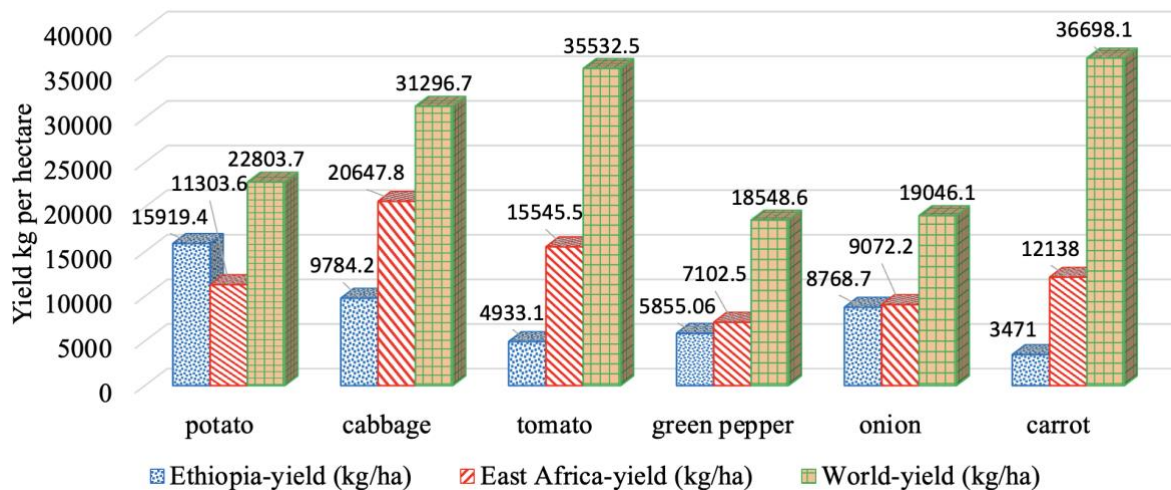


Figure 3-3.: Average Horticultural Crop Yields (kg/ha) in Ethiopia, East Africa, and the world

Source: Author's analysis using FAOSTAT (2023)

3.3. Description of the Study Area

This study was conducted in the Jimma Zone of the Oromia Regional State in southwestern Ethiopia. This area is characterized by diverse agro-ecological zones, ranging from highland to midland. Jimma is rich in natural resources, encompassing abundant water sources, fertile soils, and a diverse ecosystem. Located approximately 350 km southwest of Addis Ababa, Jimma city serves as the administrative center of the Jimma zone. Geographically, it lies between latitudes 7°39' and 7°42' N and longitudes 36°47' and 36°54' E, with

an elevation range of 1,100 meters to 3,341 meters above sea level (Bojer et al., 2025). The area benefits from a tropical climate that brings substantial rainfall and supports dense forests, along with numerous rivers and streams (Mitiku et al., 2024). Jimma experiences a tropical monsoon climate, featuring a prolonged rainy season from June to September and a shorter dry period from November to February. Annual rainfall averages between 1,500 millimeters and 2,000 millimeters, with peak precipitation during the summer months (Gashaw et al., 2023). The region's temperatures fluctuate between 14°C and 34°C throughout the year, supporting agricultural production.

3.4. SHEP Project Intervention

The Smallholder Horticulture Empowerment and Promotion (SHEP) approach was first introduced in Kenya in 2006 (Shimizutani et al. 2021). Since then, the approach has been adapted and implemented in several countries across Africa and Asia, with its components tailored to local contexts based on farmers' institutional access, agroecological conditions, and socioeconomic characteristics. In Ethiopia, the SHEP approach was introduced through bilateral cooperation between the governments of Ethiopia and Japan under the Japan International Cooperation Agency (JICA). As part of this international support program, JICA implemented the Ethio-SHEP project from January 2017 to January 2023, aiming to transform smallholder horticulture from a supply-driven to a market-oriented horticulture production. Different countries implementing the SHEP approach outside of Kenya often incorporate specific prefixes or modifiers to reflect their local adaptation of the program. For example, in Ethiopia, the prefix “*Ethio-*” is added to distinguish the country-specific implementation, hence referred to as “*Ethio-SHEP*”.

The SHEP approach is a market-oriented extension program⁵ that follows the “grow to sell”⁶ philosophy, thereby empowering smallholder farmers to consider “farming as a business” (Shimizutani et al. 2021). It

⁵ **Market-oriented extension program** is the extension officers' total effort to increase farmers' market orientation and participation. Therefore, market-oriented extension encompasses the entire endeavor of 1) counseling and assisting farmers in producing profitable market-oriented commodities and implementing suitable technologies and practices; 2) gathering and disseminating information about market-related information; 3) locating lucrative markets and buyers and connecting farmers with them; 4) enhancing farmers' marketing capabilities; and 5) assisting farmers in organizing to carry out cooperative marketing of their produce (Gebremedhin et al. 2012).

⁶ The “**Grow to Sell**” philosophy represents a novel approach in which farmers first visit relevant markets, assess demand, and produce horticultural products based on these findings, thereby mitigating market risks and price volatility. In contrast, the “**Grow and Sell**” model involves farmers cultivating their crops without considering specific market demand beforehand and seeking a market to sell their produce. This method increases smallholder

focuses on well-rounded and skill-oriented capacity-building training (e.g., sensitization workshops, market demand surveys, technical training on agronomy, developing nurseries, crop establishment, gender mainstreaming (resource control), disease control, post-harvest handling, and profit margin calculation). These program activities are undertaken in place of providing physical agricultural inputs. The Ethio-SHEP program targets all smallholder horticultural farmers who are willing to apply market-oriented horticulture production. While the SHEP program has some preconditions such as farmers should produce horticulture crops, are the member of irrigation association, have better road access for easy monitoring and managing the intervention, express their willingness to attend all trainings.

The sensitization workshop is the initial step to elucidate the SHEP concept, outline detailed activities, share visions, and clearly define the expected roles and responsibilities of farmers and other stakeholders. A market demand survey, part of the SHEP concept, entails farmers visiting nearby markets to observe and assess the sale of crops. Extension officers accompany farmers to gain first-hand market experience and obtain valuable information. This approach enables farmers to identify market dynamics directly and understand crucial aspects, such as marketable crops, required quality, and quantity, thereby helping them establish connections with key market players. Moreover, gender mainstreaming in the SHEP concept involves participatory training for farmers (men and women together), incorporating a combination of lectures and practical sessions that recognize “a couple as a team for farm management,” with gender being integral to the solution for increasing household income.

The SHEP project was implemented in the Oromia and Amhara regions, while this study is conducted in the Oromia region. The SHEP project’s intervention consists of four main steps: 1) Sharing goals: Farmers identify their vision and farming needs; 2) Raising awareness: Motivating farmers and encouraging commitment to improve their practices; 3) Farmers’ decision-making: Allowing farmers to choose which crops are most profitable for them; and 4) Skill acquisition: Providing training from site selection to harvesting to help align farming with their plans. Finally, follow-up and monitoring ensure that farmers apply the knowledge they have gained in their daily farming practices.

farmers' exposure to market risks and may discourage them from selling their horticultural harvests (Shimizutani et al., 2021).

Notably, the SHEP project provides both horticulture skill training and gender-focused education. The project aims to change the mindsets of both men and women, emphasizing shared decision-making within households, which sets it apart from other women's empowerment programs. These programs often concentrate solely on empowering women, neglecting the equally important aspect of men's empowerment (Mwololo et al. 2022), which can be misleading and ineffective. It is crucial for men to understand the workload women carry at home, so SHEP offers different gender training programs to promote mindset change among both genders and encourage thinking beyond traditional roles. Therefore, the main hypothesis of the SHEP intervention addressed in this study is that it helps shift farm households from subsistence farming toward commercialization and fosters joint decision-making between men and women. This, in turn, can lead to better market returns and improved household welfare.

3.5. Study Areas, Data Collection, and Sampling Design⁷

The SHEP project was designed to be implemented in eight *kebeles*⁸ of the Jimma zone of the Oromia region. The intervention kebeles were not randomly selected when the project initially launched, which leads to potential hidden bias (selection bias) when assessing its impact on income. Thus, a quasi-experimental research design (QERD) was employed to control for the potential selection bias associated with the SHEP project intervention. Since the quasi-experimental design lacks randomization, it uses non-random criteria for group assignment (Campbell & Stanley, 1966). The concept of quasi-experiment design was initially pioneered by Campbell et al. (1963), while Shadish et al. (2002) produced a more detailed explanation. The quasi-experimental research design has been widely applied in health sciences (Waddington et al., 2022) and social sciences (Seel, 2012; Tucker, 2022).

The quasi-experimental design selects control *kebeles* (i.e., *kebeles* without project intervention within the intervention *woreda* or district) and pure control *kebeles* (i.e., *kebeles* without project intervention in the non-intervention *woreda*) matched with treated groups (SHEP project beneficiaries) using location-specific GIS data (Figure 3.4). The main research interest for those involving two counterfactual groups (control and pure

⁷ Reprinted from: Fikadu A. A., Nomura H., Gebre G. G., Shah P., Takahashi Y., and Yabe M. (2025). Heterogeneous Effects of Horticulture Commercialization and Gender-based Decision-making on Smallholder Farmers' Income: Evidence from a Quasi-Experimental Study in Jimma Zone, Ethiopia, *Journal of Agriculture and Food Research*, Vol (19). <https://doi.org/10.1016/j.jafr.2024.101565>.

⁸ The *kebele* is the smallest administrative unit in Ethiopia.

control) is whether there will be peer effects or spillover effects within the intervention *woreda*, even though the control *kebeles* differ from the treated *kebeles*. As a result, the assumption was expanded to include an additional counterfactual group, defined as the pure control group, selected from non-intervention *woredas*. These non-intervention *woredas* are located far away from the intervention *woredas* and help to control the project's potential spillover. The key attributes considered for control and pure control *kebeles* include soil properties, slope, elevation, irrigation availability (based on a proxy variable of distance to the nearest river network), distance to major cities, and road density. The summary statistics of these key attributes for treated, unmatched and matched *kebeles* are indicated in Appendix 3.1. These non-random parameters are essential for horticulture production and marketing. Moreover, the Ethiopian administrative boundaries (region, zone, *woreda*, and *kebeles*) were considered to create the counterfactual groups.

The following steps were used to create the counterfactual groups: 1) we divide the entire Oromia region into 1 km by 1 km parcel mesh data⁹ and assign a dummy of 1 to parcels that fall within the *kebeles* with SHEP interventions: these comprise our “treated” parcels. We assign a dummy of 0 to all other parcels as our non-treated parcels. 2) we collected the key attributes listed above at the 1km-by-1km parcel level for all treated and non-treated parcels. 3) we use the nearest neighbor matching method at the 1 km by 1 km mesh level to identify control parcels that are statistically similar to the “treated” parcels based on the key attributes using R programming software¹⁰. 4) We calculate the total number of 1 km by 1km plots identified as “control” and “pure control” for each “no treatment” *kebele* within the intervention *woredas* and without intervention *woredas*, respectively. 5) We assign a *kebele* as a “control” *kebele* if more than 20% of the 1 km by 1 km parcels within a *kebele* (which belongs to an intervention *woreda*) are statistically similar to treated parcels based on the nearest neighbor matching exercise. We assign a *kebele* as a “pure control” *kebele* if more than 20% of the 1 km by 1 km parcels within a *kebele* (which belongs to a non-intervention *woreda*) are statistically similar to treated parcels based on the nearest neighbor matching exercise (Figure 3.4).

⁹ Mesh data is a square polygon that can be represented on a map. It has a unique number and is commonly 1 kilometer by 1 kilometer. This mesh data serves as a spatial grid that divides or breaks down complex information about the study areas into smaller plots to create representative areas based on the given non-random parameters.

¹⁰ We also use propensity score matching as a robustness check and find that the results are qualitatively similar.

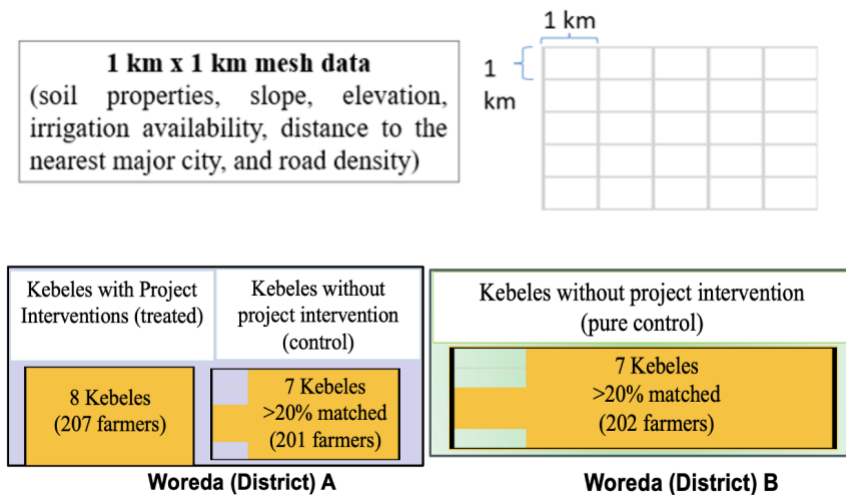


Figure 3-4: Quasi-experimental research design

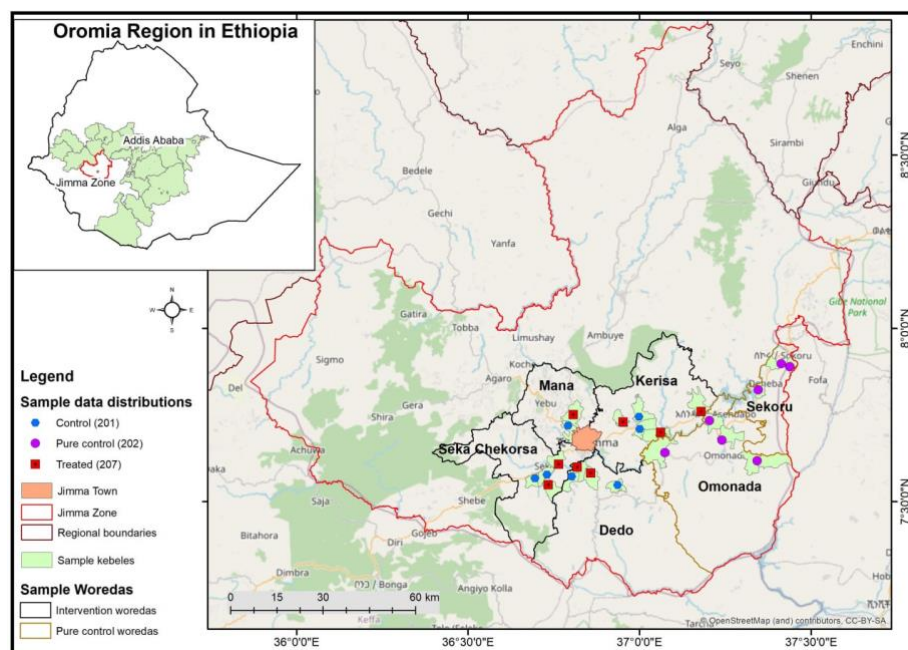


Figure 3-5: Map of the study areas

Based on this quasi-experiment sample identification, we select 22 *kebeles* from six *woredas*: eight treated *kebeles* (Waro Kolobo, Offolie Sadawe, Boba Roge, Buyo Kechema, Kitimbile, Girma, Gibe/Siba, and Somodo), seven control *kebeles* (Gonjo Abaye, Afoli Korti, Meti Ushanie, Ushanie Koche, Tikur Balto, Toli Kerisu, and Gudeta Bula), and seven pure control *kebeles* (Lalo Beyem, Goro Sedem, Chefe Nega, Wagtola, Unkurie, Wengecho, and Daka) (Figure 3.5). Finally, we select 610 horticulture-growing smallholder farmers using a simple random sampling method. The household survey data were collected between December 2022 and January 2023 using a structured questionnaire after the SHEP intervention, making it cross-sectional.

We utilized all 610 sample farmers from 22 *kebeles* for the first research objective (Chapter 4) (Figure 3.4 and Figure 3.5). However, since the control group is located in project *woredas* where farmers share common markets and social networks with the treated groups, this may introduce project spillover effects. Also, due to the cross-sectional nature of the data, we were unable to quantify such spillover effects. Therefore, we excluded the control group from the analysis in the second and third research objectives (Chapters 5 & 6) to clearly assess the impact of the SHEP project intervention while accounting for these spillover effects (Figure 3.7). Thus, for the second and third research objectives, we analyzed data from 15 *kebeles* (eight treated and seven pure control), comprising a total of 409 sample horticulture-growing smallholder farmers (207 from the treated group and 202 from the pure control group) (Figure 3.6 and Figure 3.7).

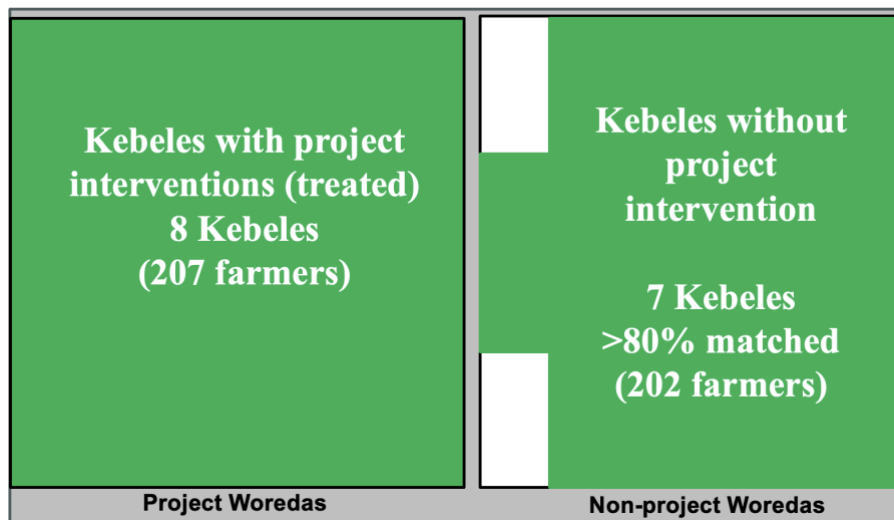


Figure 3-6: Quasi-experimental research design

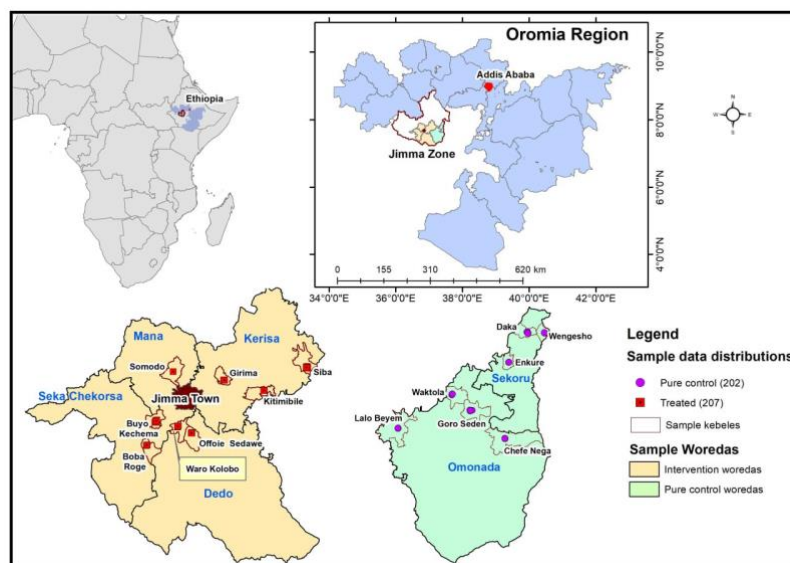


Figure 3-7: Map of the study areas

Source: Sketched by the authors (2024)

CHAPTER FOUR: THE IMPACT OF HORTICULTURE COMMERCIALIZATION AND GENDERED DECISION-MAKING ON INCOME¹¹

4.1. Introduction

In developing countries, agricultural commercialization has become a significant driver of rapid structural transformations in agricultural economies, particularly in those where agriculture plays a crucial role in the national gross domestic product (GDP) and employment and supports other sectors in the form of food, labor, and capital (Etuk & Ayuk, 2021; Pingali et al., 2019; von Braun 1995). Agricultural commercialization has been identified as a pathway to boost productivity (Ochieng et al. 2016), enhance per capita income (Ogotu and Qaim 2019), improve household welfare (Muriithi & Matz, 2015), and promote asset accumulation (Tabe-Ojong et al., 2022). While existing research generally highlights the positive impact of agricultural commercialization on smallholder farmers' income, it often treats these effects as average or uniform outcomes across all farmers (Carletto et al., 2017; von Braun, 1995). Alternately, a handful of studies provide empirical evidence that agricultural commercialization can have varying or heterogeneous effects on income across different quantiles in developing countries due to differences in household- and farm-specific characteristics (Ogotu & Qaim, 2019; Tabe-Ojong et al., 2022).

Additionally, the role of gender in horticulture farming is critical. The empirical evidence on the relationship between gendered decision-making, particularly women-alone decision-making practices and income, shows divergent findings. Some studies argue there is a direct association between women's decision-making and income gained through agricultural commercialization (Muriithi, 2015). Others suggest a negative effect on economic returns or incomes (Maertens & Swinnen, 2010; Mofya-Mukuka & Sambo, 2019; Tavenner et al., 2019), indicating that women have been excluded from high-value horticultural farms. Another group finds

¹¹Reprinted from: Fikadu A. A., Nomura H., Gebre G. G., Shah P., Takahashi Y., and Yabe M. (2025). Heterogeneous Effects of Horticulture Commercialization and Gender-based Decision-making on Smallholder Farmers' Income: Evidence from a Quasi-Experimental Study in Jimma Zone, Ethiopia, *Journal of Agriculture and Food Research*, Vol (19). <https://doi.org/10.1016/j.jafr.2024.101565>.

that decisions on what and where to plant and to sell in agriculture were more frequently perceived as joint compared to solo decision-makers in Uganda (Acosta et al., 2020).

Even though Ethiopia is a diverse country with various cultural and social settings across regions, men and women in the same household often make farm decisions about which crops to produce, how much to consume, and how much to sell, either jointly or separately (Aregu et al., 2011; Doss, 2015). Given this context, there are limited empirical studies examining whether gendered decision-making practices (men-alone, women-alone, joint) might have positive heterogeneous effects on horticulture income. Consequently, the hypothesis posits that gendered decision-making exerts heterogeneous effects on income, highlighting the influence of women-alone, men-alone, or joint decision-makers, depending on income levels.

As a result, Ethiopia prioritizes agricultural commercialization to enhance income (Bekele et al., 2010), household welfare (Muriithi & Matz, 2015), and reduce poverty (Tabe-Ojong et al., 2022), with a particular focus on horticulture crops (Ethiopian Planning and Development Commission [EPDC], 2021). The commercialization and gendered decision-making of smallholder horticulture in Ethiopia has been used as a strategy for agricultural development to improve smallholder farmers' income and livelihoods (EPDC, 2021). Given that horticulture crops are more market-oriented than other cereal crops and livestock farms, our study focuses explicitly on the horticulture sector.

Acknowledging the possibility of horticulture income disparities among smallholder farmers highlights the importance of understanding the distributional effects of commercialization. This understanding is vital for designing targeted interventions and associated assistance that mitigate income disparities and support lower-income farmers. Gendered decision-making, specifically women-alone and joint decision-makers in horticulture sales, offers valuable policy implications for horticulture farming. However, this area has received only limited exploration in the literature. To address these issues, an empirical analysis is conducted using survey data collected by the Smallholder Horticulture Empowerment and Promotion (SHEP) project implemented by the Japan International Cooperation Agency (JICA) from smallholder horticulture farmers in Ethiopia. A quasi-experimental research design is adopted to address the problem of selection bias.

Most studies have not considered the essential agricultural peculiarities or non-random parameters to be controlled. The key attributes considered for control group identification in this study include soil properties, slope, elevation, irrigation availability (based on a proxy variable of distance to the nearest river network), distance to major cities, and road density, all of which are essential for horticulture production and marketing.

To the best of our knowledge, this study comprises an excellent scientific contribution to quasi-experimental research, as it uses the nearest neighbor matching method to identify suitable control groups that account for the key agricultural peculiarities and are comparable with the treated groups at the *kebele* level. Moreover, kernel-based matching is applied at the household level to eliminate hidden bias between farmers in the treated and control groups. Finally, the heterogeneous effects of horticulture commercialization and gendered decision-making on income are examined using quantile regression for policy implications to support more inclusive and sustainable agricultural development.

4.2. The conceptual framework of the study

Empirical studies define agricultural commercialization as the farmer's intention to participate in the input and output markets, which aims to boost income and food security (von Braun 1994). The concept, rooted in profit maximization theory, suggests that shifting from subsistence to commercial farming can enhance farmers' welfare (Barrett, 2008; Carletto et al, 2017; Ogutu & Qaim, 2019; Tabe-Ojong et al., 2022). Findings show a mixed perspective; some argue that agricultural commercialization has an average effect on income (Barrett, 2008; Carletto et al., 2017), while few studies reported it has a heterogeneous impact on income (Ogutu & Qaim 2019; Tabe-Ojong et al., 2022). Heterogeneous impact refers to the idea that the effects of a particular intervention, for example, commercialization, are not uniform across all horticulture-growing farmers, and the effect varies or differs among individuals or subgroups within the sample population. Furthermore, influencing factors vary across subgroups. In line with this, our data allow us to see the heterogeneous effects of commercialization, gendered decision-making, and their interactions with treatment because the outcome variable, horticulture income, has outliers across horticulture-growing farmers. Instead of dropping the outliers from model estimation, including all observations, and estimating the heterogeneous impact of the main interest covariates would be a crucial advantage for policymakers to develop effective strategies to address specific needs in lower or higher income brackets.

This study, therefore, estimates the heterogeneous impact of commercialization and gender-based decision-making regarding horticulture harvest sales and their interaction effects with the SHEP intervention on smallholder farmers' horticulture income to understand the patterns of their effects at lower and higher income levels. Following Ogutu & Qaim (2019) and Tabe-Ojong et al. (2022), It is assumed that horticulture commercialization has heterogeneous effects on the income of the farm households due to differences in farmers' demographic and socioeconomic characteristics, as well as farm-specific and institutional factors,

such as access to extension and infrastructure services (e.g., market information) (Figure 4.1). Moreover, gendered decision-making in horticulture marketing is assumed to have heterogeneous effects on income, implying that its impact magnitude or direction might have been differently observed at the farm households' lowest and highest income holders. Gender-based decision-making specific to horticulture marketing is defined as “who decides on horticulture harvests to sell,” characterized by either solo or joint decision-makers. Besides this, this study evaluates the heterogeneous effects of the SHEP intervention alone and its interactions with horticulture commercialization and gendered decision-making on the income improvement of farm households. The main interest in including the interaction effects is to assess the effectiveness of the SHEP intervention depending on commercialization and gender-based decision-making practices. In our quantile regression estimation, the SHEP intervention is the treatment variable, a categorical variable, appearing as treated, control, and pure control groups.

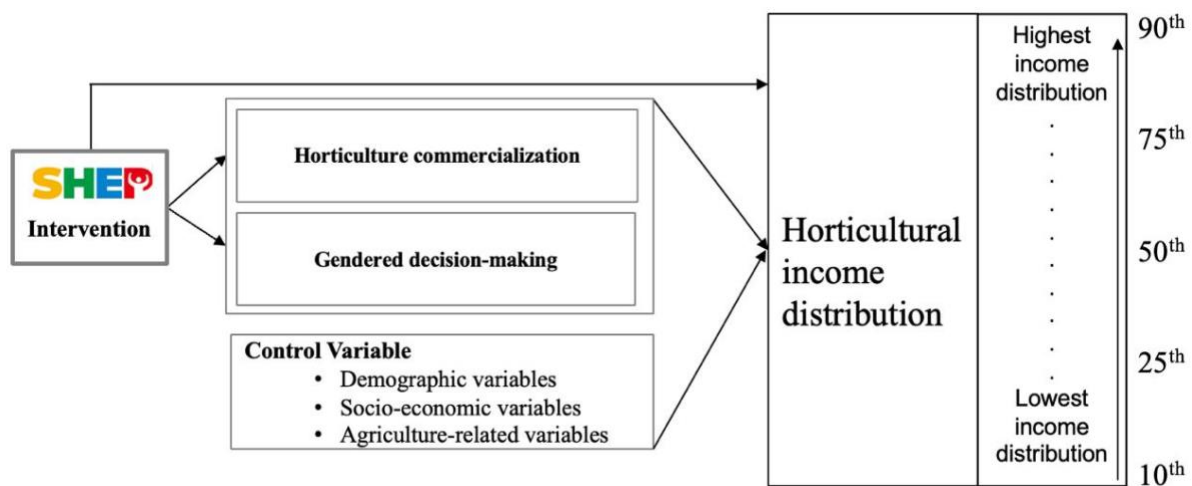


Figure 4-1: The conceptual framework of the heterogeneous effects of horticulture commercialization and gender-based decision-making on income

4.3. Variable Definitions and Descriptions

4.3.1. Measuring horticulture commercialization index (HCI)

Commercialization measures the intensity at which household crop production is oriented toward the market (Strasberg et al. 1999). The horticulture commercialization index is measured by taking the ratio of total horticulture sales to total horticulture production in monetary terms over the 12-month period preceding the survey (equation 4.1). The sales prices of each crop for each sample farmer were collected to drive production and sales in monetary value. This commercialization formula was initially pioneered by Strasberg et al.

(1999), and it is still considered a valid commercialization measurement since it can capture the intention of smallholder farmers to sell their products in the market regardless of the volume of sales. Many empirical studies have also applied the same type of commercialization index (Assaye et al., 2022; Bekele et al., 2010; Carletto et al., 2017; Ogutu & Qaim, 2019). Equation (4.1) is as follows:

$$(HCI)_i = \frac{\sum Sales_{ij} \text{ in terms of monetary value}}{\sum production_{ik} \text{ in terms of monetary value}} \quad (4.1)$$

where: HCI_{Hi} is the horticulture crops commercialization index of the household i ; $\sum Sales_{ij}$ is the summation of the gross monetary value of horticulture crop j (the sample farmers produce, on average, three horticulture crops among the seven horticulture crops, such as cabbage, onion, potato, carrot, tomato, beetroot, green paper) sold outside by a household i ; $\sum production_{ik}$ is the summation of the gross monetary value of total crops k produced by a household i excluding the cereal and other crops. The results revealed that the farmers prioritized these seven horticulture crops during the season of the data collection, but that does not mean that they solely grow those crops continuously every year. Farmers in the treated group prioritize and focus on horticulture crops as per the findings of market survey or market demand results (see Section 3.4 for details).

4.3.2. Measuring gendered decision-making

Family members may not engage in the same activities simultaneously, and their decision-making may differ accordingly. For example, income decisions among remittance recipients might often be guided by social norms; men typically handle large profits or commercial farming decisions, while women might manage lower-value crops or small livestock. Thus, it is academically relevant to investigate who decides on the production, marketing, and allocation of economic returns. Consequently, the decision-making variable regarding 'who decides on horticulture harvests to sell' within farm households was included in the econometric analysis, as it could directly influence income. This variable is categorized and factorized into joint decision-makers, women-alone decision-makers, and men-alone decision-makers, as shown in Equation 4.2:

$$\text{Gendered decision-making} = \begin{cases} \text{Joint decision-maker (dummy)} \\ \text{Man-alone decision-maker (dummy)} \\ \text{Woman-alone decision-maker (dummy)} \end{cases} \quad (4.2)$$

4.4. Estimation strategy: Model specification

The quasi-experimental design was employed to minimize selection bias at the *kebele* level, matching sample farmers with treated groups based on various observable characteristics (location-specific GIS data). Moreover, propensity score matching (PSM) was employed at the household level to eliminate hidden bias between farmers in the treated and counterfactual groups (control and pure control) prior to quantile regression estimation, thereby creating conditions similar to those of a randomized experiment. PSM follows the unconfoundedness assumption, also known as the “conditional independence assumption,” indicating that when sources of hidden bias (confounding covariates) are controlled for, the SHEP intervention is random, and its actual effects on the outcome variable (horticulture income) can be observed. This is mathematically noted as follows in Equation (4.3).

$$P(Z) = Pr\{T = 1|Z\} = E\{T|Z\} \quad (4.1)$$

where T is Treatment (1 = treated (with SHEP intervention); 0 = control/pure control groups) and Z is the vector of the confounding covariates (sources of hidden bias). The conditional distribution of Z given P(Z) is similar between the treated and control/pure control groups. Moreover, ensuring common support is another critical assumption of PSM. This assumption implies that any combination of farmers' characteristics observed in the treated group must also be observed in the control group. Farmers with significantly different characteristics that do not overlap between the groups will be excluded from the analysis (Bryson et al., 2002). In this analysis, approximately 7% (n = 44) of the total 610 sample farmers were excluded from the final analysis due to a lack of common support (Appendix 4.1 and 4.2).

Quantile regression estimates the effects of commercialization, decision-making, treatment, and other covariates on horticulture income across income levels. This approach accommodates heterogeneity, providing insights into the effects at different quantiles, at both low and higher levels of income (Buchinsky, 1998; Koenker & Hallock, 2001; Ogutu & Qaim, 2019). The quantile regression specification is explained in Equation (4.4):

$$Y_i = X'_i \beta_q + \mu_{qi} \text{ where } (Y_i|X_i = X'_i \beta_q) \quad (4.2)$$

where Y_i is horticulture income in terms of Ethiopian birr (ETB), X_i is the set of covariates, including the horticulture commercialization index, gendered decision-making, and SHEP intervention (treatment

variable), and other control variables such as farmers' socioeconomic, demographic, and institutional characteristics; q is a quantile with $0 < q < 1$ and β_q the parameters to be estimated.

The primary purpose of using different quantiles is to gain insight into how various factors affect the incomes of smallholder farmers at different points along their income distribution. It can be beneficial for identifying factors that affect the incomes of the poorest and richest smallholder horticulture-growing farmers, who may be more vulnerable to changes in market conditions or other exogenous factors. There is no fixed rule to determine the number and level of quantiles; instead, this result depends on the distribution and shape of the outcome variable (horticulture income). If the outcome variable exhibits significant variation, a greater number of quantiles can be chosen to capture the characteristics of the distribution. Thus, different scholars use different quantiles to estimate the effect of commercialization on income. For example, Ogutu & Qaim (2019) and Tabe-Ojong et al. (2022) used five different quantiles (the 10th, 25th, 50th, 75th, and 90th). These five quantiles are common in other empirical studies. Other scholars, for example, Koenker & Hallock (2001) and Konstantopoulos et al. (2019), use seven quantiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th).

On the other hand, while estimating many quantiles can provide a detailed view of the distribution (precision), it may also lead to a more challenging interpretation and require a huge sample size. Thus, balancing both precision and interpretability becomes essential in quantile regression. Following Ogutu & Qaim (2019) and Ojong et al. (2022), the standard quantiles were used, encompassing the median (50th percentile), quartiles (25th and 75th percentiles), and two additional percentiles, one at the lower end and another at the upper-income level (such as the 10th, 25th, 50th, 75th, and 90th quantiles). In our study, the 10th quantile represents smallholder farmers with the lowest annual horticulture income, while the 90th quantile denotes those with the highest annual horticulture income. Analyzing income distribution allows us to observe the frequencies associated with specific income intervals, which entails sorting the data and determining the potential number of quantiles based on their proportion within the dataset.

Unlike ordinary least squares (OLS) regression (which minimizes the sum of the squares of the model prediction errors or residuals (μ_i)), quantile regression minimizes the sum that produces the asymmetric penalties from $q|\mu_i|$ representing under-prediction and $(1 - q)|\mu_i|$ over-prediction (Koenker & Hallock, 2001). Thus, the parameters (β_q) can be estimated at different quantiles (q) of income by minimizing the sum of asymmetrically weighted absolute residuals for all model regressions (Equation 4.5). This means that quantile regression considers the potential asymmetric effects of over-predicting and under-predicting data

points. Quantile regression provides a more nuanced view of how the model performs across different parts of the data distribution by optimizing the sum of absolute deviations at a specific quantile. Applying this change enables the model to focus on specific quantiles of the data distribution, providing more robust estimates, especially in the presence of outliers or asymmetric errors. About 46 (7.54%) of the sample have extremely high-income values. Those farmers are growing green pepper, which has a much higher unit price than other horticultural crops. The value of $1/n$ indicates the scaling or normalization factor, ensuring that the optimization considers the average absolute differences between the observed and predicted values comparable across datasets of different sizes and prevents the optimization of the parameters from being skewed by the number of observations. Equation (4.5) is therefore:

$$Y_i = \min_{\beta_q} \frac{1}{n} \left\{ \sum_{i: Y_i \geq X_i' \beta_q} q |Y_i - X_i' \beta_q| + \sum_{i: Y_i < X_i' \beta_q} (1 - q) |Y_i - X_i' \beta_q| \right\} \quad (4.3)$$

4.5. Results and Discussion

4.5.1. Summary of descriptive statistics

Table 4.1 shows the descriptive statistics of the outcome and independent variables for all of the farm households and disaggregated by treated, control, and pure control groups, along with the variables used for quantile regression estimation. The treated group demonstrated a higher horticulture commercialization index (0.823) compared to the control group (0.664) and the pure control group (0.642), with these differences being statistically significant. Notably, the higher commercialization index is associated with increased income, indicating that the SHEP intervention plays a crucial role in promoting commercialization, leading to higher income levels: 30,754 Ethiopian birr (ETB¹²) (576.8 USD) for the treated group than 17,842 ETB (334.6 USD) for the control group and 19,185 ETB (359.8 USD) for the pure control group. This links SHEP's focus on commercialization to higher income. Regarding joint decision-making, while households with man-alone decision-making in the treated group earn more income (36,674 ETB) (687.8 USD), joint decision-making households (29,209 ETB) (547.8 USD) in the treated group still earn significantly more than their counterparts with values of 18,351 ETB (344.2 USD) and 21,827 ETB (409.4 USD) in the control and pure control group, respectively. This suggests that the SHEP intervention helps households who have practiced

¹² ETB stands for Ethiopian birr. Calculated at 1 United States Dollar (USD) $\approx$ 53.3180 ETB as of February 2023 at the time of data collection. Ethiopian National Bank: <https://combanketh.et/en/exchange-rate/>

joint decision-making by increasing their income compared to non-participants. On the other hand, women-alone decision-makers have lower horticulture income across groups, with values of 15,643 ETB (293.4 USD), 7,377 ETB (138.4 USD), and 14,438 ETB (270.8 U) for the treated, control, and pure control groups, respectively.

The household heads' average age is approximately 41, 40, and 35 years, with schooling averaging 2.8, 3.1, and 3.8 years for treated, control, and pure control groups, respectively. The average number of adult male and female household members is approaching two for each group. In treated, control, and pure control groups, roughly 89.4%, 94.5%, and 95.5% have male heads, respectively. The average share of land devoted to horticulture is about 0.64, 0.56, and 0.49 hectares for treated, control, and pure control groups, respectively. Extension contact frequency occurs approximately 8.9, 5, and 4.9 times per month for treated, control, and pure control groups, respectively. Regarding training, around 78.74%, 38.81%, and 41.09% of treated, control, and pure control groups have received training, respectively. This suggests that government extension officers provide general horticulture training to all farmers, regardless of their group (treated, control, or pure control). However, the SHEP program offers skill-oriented training exclusively to the treated group, covering areas such as market demand surveys, crop agronomy, nursery development, crop establishment, disease control, and post-harvest handling. This training is conducted in group settings to promote peer learning. After completing the training, farmers in the treated group make informed decisions about crop selection, use crop calendars, implement effective pest and disease control, apply proper post-harvest handling, and access better market prices. Descriptively, as a result, the treated group gains higher incomes compared to the control and pure control groups. Regarding horticulture commercialization, treated groups exhibit significant positive mean differences between the control and pure control.

Table 4-1: Summary of descriptive statistics

Variables	Whole sample	Treated	Control	Pure control	Test statistics (Treated vs Control)		Test statistics (Treated vs Pure control)	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Diff (SE)	T-value /X ² -value (P-value)	Diff (SE)	T-value /X ² -value (P-value)
Household income from horticulture (1000 ETB/year)	22.668 (31.288)	30.754 (33.197)	17.842 (34.198)	19.185 (23.876)	12.9112 (3.337)	3.8696 (0.0001)	11.569 (2.865)	4.038 (0.0001)
Horticulture commercialization index (0-1)	0.711 (0.327)	0.823 (0.242)	0.664 (0.357)	0.642 (0.342)	0.1591 (0.030)	5.2814 (0.0000)	0.1805 (0.029)	6.177 (0.0000)
Horticulture income for joint decision-making	23.897 (28.678)	29.209 (26.941)	18.351 (32.551)	21.872 (24.115)	10.859 (3.843)	2.826 (0.0051)	7.337 (3.789)	1.936 (0.0542)
Horticulture income for man-alone decision-making	22.378 (35.278)	36.674 (45.299)	18.438 (37.842)	17.968 (24.229)	18.236 (6.859)	2.659 (0.0087)	18.706 (5.163)	3.623 (0.0004)
Horticulture income f woman-alone decision-making	12.486 (12.454)	15.643 (11.389)	7.377 (6.869)	14.438 (16.691)	8.266 (4.205)	1.9655 (0.0650)	1.205 (6.389)	0.189 (0.853)
Demographic variables								
Gender of the household head (1 = male; 0 = female)	0.931 (0.25)	0.894 (0.31)	0.945 (0.23)	0.955 (0.21)	-	3.6459 (0.056)	-	5.561 (0.018)
Age of the household head (years)	38.9 (11.9)	41.2 (12.7)	40.4 (11.7)	35.2 (10.4)	0.8 (1.21)	0.6635 (0.2537)	5.97 (1.15)	5.209 (0.0000)
Education level of the household head (years of schooling)	3.2 (3.5)	2.8 (3.1)	3.1 (3.1)	3.8 (4.1)	-0.32 (0.31)	-1.0518 (0.1468)	-1.0 (0.36)	-2.801 (0.0027)
Number of adult males in the household	1.7 (0.9)	1.8 (1.0)	1.6 (0.9)	1.7 (0.9)	0.16 (0.09)	1.6008 (0.0551)	0.14 (0.10)	1.381 (0.0840)
Number of adult females in the household	1.5 (0.8)	1.6 (0.9)	1.5 (0.8)	1.4 (0.8)	0.11 (0.09)	1.3110 (0.0953)	0.17 (0.09)	2.032 (0.0214)
Experience in horticulture production (year)	8.2 (6.9)	10.5 (8.7)	8.0 (6.4)	6.0 (4.3)	2.5 (0.76)	3.2721 (0.0006)	4.5 (0.68)	6.625 (0.0000)
Socio-economic variables								
Horticulture farmland size (hectare)	0.56 (0.46)	0.64 (0.61)	0.56 (0.38)	0.49 (0.31)	0.08 (0.05)	1.61 (0.1087)	0.15 (0.05)	3.13 (0.0019)
Number of livestock (¹³ TLU)	4.01 (2.67)	4.3 (2.6)	3.7 (2.3)	4.0 (3.1)	0.618 (0.242)	2.5557 (0.0110)	0.292 (0.280)	1.042 (0.2981)
Agriculture-related variables								
Access to training in horticulture (1 = Yes; 0 = No)	0.523 (0.49)	0.783 (0.41)	0.388 (0.49)	0.411 (0.48)	-	67.2768 (0.000)	-	60.473 (0.000)
Distance to the main market (minutes by foot)	78.8 (57.3)	72.0 (48.2)	80.4 (52.9)	84.2 (68.6)	-8.4 (5.0)	-1.6703 (0.0478)	-12.2 (5.9)	-2.082 (0.0190)
Distance to the cooperative offices (minutes by foot)	38.2 (30.4)	36.2 (19.1)	45.0 (43.6)	33.5 (21.4)	-8.8 (3.3)	-2.6629 (0.0040)	2.7 (2.0)	1.344 (0.0898)
Number of extension contacts per month	6.3 (6.5)	8.9 (7.7)	5 (5.2)	4.9 (5.5)	3.87 (0.65)	5.9624 (0.0000)	3.96 (0.66)	5.979 (0.0000)
Input-related variables								
Cost of chemical fertilizer (ETB/year)	1938.7 (2224.7)	1956.4 (2089.1)	1170.5 (1746.7)	2686.1 (2517.2)	785.89 (190.92)	4.1163 (0.0000)	-728.7 (228.5)	-3.189 (0.0015)
Cost of pesticide (ETB/year)	207.4 (346.6)	274.7 (378.4)	69.1 (157.9)	276.2 (404.9)	205.56 (28.86)	7.1230 (0.0000)	-1.56 (38.74)	-0.040 (0.9680)
Cost of herbicide (ETB/year)	30.2 (145.4)	58.99 (217.1)	12.69 (78.9)	17.97 (90.9)	46.29 (16.26)	2.8468 (0.0046)	41.01 (16.53)	2.482 (0.0135)
Family labor (¹⁴ man-days/year)	54.9 (52.9)	57.5 (62.7)	43.89 (36.6)	63.48 (53.9)	13.6 (5.1)	2.6656 (0.0080)	-5.9 (5.8)	1.034 (0.3017)
Wage for hired labor (ETB/year)	315.1 (2151.5)	427.1 (2688.4)	207.6 (1834.1)	307.4 (1801.7)	219.5 (228.5)	0.9605 (0.3374)	119.7 (226.9)	0.528 (0.5979)

Notes: SD indicates standard deviation, SE is the standard error, and Diff is a difference value between the groups.

¹³ TLU stands for Tropical Livestock Unit. According to Storck et al. (1991) cited by Getachew (2010), the conversion factors for each livestock group are as follows: Calf = 0.34, Heifer = 0.75, Cow and ox = 1.0, Horse = 1.1, Donkey = 0.7, Sheep and Goat = 0.13, and Chicken = 0.013.

¹⁴ Man-Days is a standardized measure of labor hours, representing the ratio of total working hours to the typical number of working hours in a day, commonly set at eight hours. Our study aggregates all family labor hours spent from pre-planting activities (such as plowing and seedbed preparation) to harvesting horticulture crops. We then normalize this total by dividing it by the standard daily working hours (8 hours).

4.5.2. Gendered decision-making regarding horticulture harvest selling

As shown in Figure 4.2, the treated group has a larger share of the sample (65.7%) adopting joint decision-making practices regarding horticulture harvest selling, which is statistically significantly different in proportion compared with the two counterfactuals (control, 51.7%, and pure control, 35.6%) groups. In contrast, men are the dominant decision-makers regarding horticulture marketing in pure control (59.4%) and control groups (43.3%), with a proportional statistical difference between treated groups (29.5%) at 1% and 5% significant levels, respectively. The proportion of women-alone decision-makers is minimal across groups and does not show a statistically significant proportion difference between treated (4.8%) and counterfactual (control, 4.98%, and pure control, 4.95%) groups.

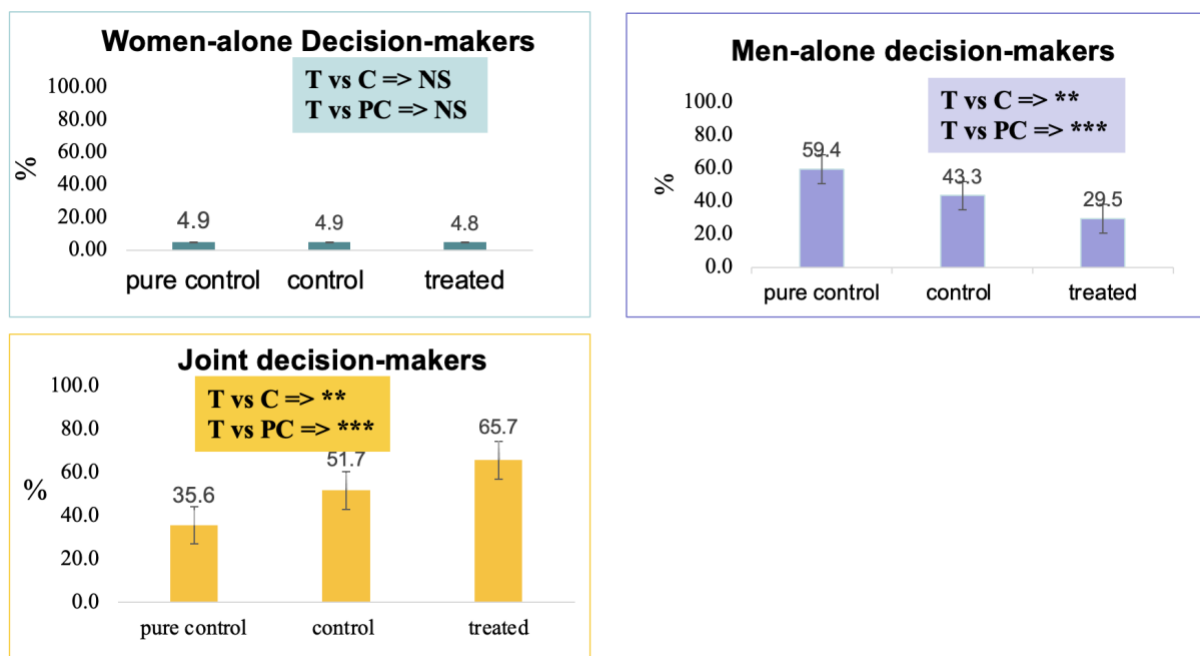


Figure 4-2: Gender-based decision-making regarding horticulture marketing

4.5.3. Power calculation and minimum effect size determinations

Using Cohen's *d* and Hedges's *g* tests, the SHEP intervention's power and effect size between treated and control groups were checked. Both tests measure the effect size using the difference between two means, but Cohen's *d* is straightforward and often used with large sample sizes, potentially overestimating the effect in small samples. Hedges's *g* includes a correction for small sample sizes, providing a more conservative estimate. This study found almost the same results from both tests. The estimated power was 97.1% and

98.1%, with effect sizes of 38.2% and 40%, showing the SHEP intervention's minimal positive effect on farmers' horticulture income compared with control and pure control groups, respectively (Table 4.2).

We check the SHEP intervention's estimation power and effect size between treated and two constructed groups (control and pure control groups) using Cohen's d ¹⁵ and Hedges's g tests, which are detected with the given sample size. Cohen's d and Hedges's g are used to measure effect size, particularly for the difference between two means. They have slight differences. For example, Cohen's d is straightforward and often used with large sample sizes but does not include a correction for small sample sizes. Cohen's d tests assume the sample sizes are large enough for the estimate to be unbiased. Thus, Cohen's d might slightly overestimate the effect size in small samples because it does not account for sample size bias. On the other hand, Hedges's g is used when sample sizes are small to provide a less biased estimate of the effect size. Hedges's g includes a correction factor, which provides a more conservative estimate in small samples, reducing the risk of overestimating the effect size. This study found minimal difference between these two measures because the sample sizes are relatively large, minimizing the impact of the correction factor in Hedges's g . Table 4.2 shows the estimated power of 97.12% and 98.14% between treated versus control and treated versus pure control groups, respectively. Moreover, we found 38.2% and 40% effect sizes of the SHEP intervention on horticulture income compared with control and pure control groups, respectively which show minimum effects.

¹⁵ As explained by Cohen (1988) and Hedges (1981), Cohen's categories of effect size based on the mean comparison are: i) small effect size ($d \approx 0.2$); ii) medium/moderate effect size ($d \approx 0.5$); and iii) large effect size ($d \approx 0.8$).

Table 4-2: Power calculation and effect size using means comparisons

Power calculations						
Parameters	Treated versus control			Treated versus pure control		
Total sample (n)	408			409		
Treated group (n1)	207			207		
Control group (n2)	201			202		
n2/n1	0.9710			0.9758		
d (Mean horticulture income difference)	12.9113			11.5688		
Mean horticulture income for n1 (in thousands)	30.7537			30.7537		
Mean horticulture income for n2 (in thousands)	17.8424			19.1849		
Standard deviation of horticulture income for n1	33.1972			33.1972		
Standard deviation of horticulture income for n2	34.1978			23.8757		
Alpha value	0.05			0.05		
Estimate power	0.9712			0.9814		
Effect size estimation						
Effect size	Treated versus control			Treated versus pure control		
	Estimate	Lower 95% CI	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI
Cohen's d	0.3832	0.1871	0.5783	0.3992	0.2029	0.5949
Hedges's g	0.3825	0.1868	0.5778	0.3984	0.2025	0.5938

4.6. Econometric results

4.6.1. Propensity score matching

Although nearest neighbor matching was applied for control groups identification using location specific GIS data at *kebele* level, farmers in the treated group statistically differ from the two counterfactual groups by various factors such as distance to the nearest main market, years of experience in horticulture farming, level of education of the household head, horticulture land size, and training access (Table 4.3). Therefore, different matching algorithms were used at household level data to check robustness (nearest neighbor matching, caliper matching, kernel matching); among them, kernel matching is more robust, yielding the lowest mean bias and the highest degree of bias reduction for each covariate (Appendix 4.3).

Table 4.3 presents the results of kernel matching, which show the differences in confounding characteristics (sources of hidden bias) between farmers in the treated groups and those in the control and pure control

groups. The percentage of bias reduction using kernel matching ranges from 74% to 100%, which indicates that our PSM estimation successfully removes hidden bias through kernel-based matching. After matching, the main confounding variables (source of selection bias) show an insignificant mean difference between the treated and two counterfactual groups, indicating that these covariates are correctly balanced and hidden biases have been successfully removed; the mean bias after matching is reduced from 38.4 to 2.2. The R^2 value is relatively high before matching (0.174), while becomes very low after matching (0.00), indicating a high level of similarity in post-matching. The p-value of the joint significance of the confounding covariates is statistically lower before matching (0.000) but higher after matching (0.993), further confirming the removal of hidden bias. With the removal of hidden bias, the heterogeneous effects of SHEP intervention, commercialization, gender-based decision-making, and other control variables on horticulture income were estimated using quantile regression.

Table 4-3: Covariates balance indicators using kernel matching (before and after matching)

Confounding covariates (Source of selection bias)	Mean summary for treated group after matching	Mean summary for control groups after matching	% of bias reduction	Mean bias before matching	Mean bias after matching	Value of R² before matching	Value of R² after matching	LR χ^2 (joint significant before matching)	LR χ^2 (joint significant after matching)	Off support sample among the total
Distance to the main market (minutes by foot)	72.5950	71.530	89.6							
Access to horticulture training (1 = yes; 0 = no)	0.7750	0.7746	99.9							
Land size for horticulture production in hectare	0.5991	0.5802	83.7							
Experience for horticulture farming in years	9.2400	9.2251	99.5							
Education of the household head in years of schooling	2.8250	2.9770	74.0							
Matching parameters				38.4	2.2	0.178	0.001	139.24 (0.000)	0.46 (0.993)	44

4.6.2. Quantile regression results

As shown in Table 4.4, the interaction of the commercialization index and treatment significantly influences the horticulture income of smallholder farmers. Given the inclusion of interaction effects in our model, interpreting individual covariates, such as the commercialization index, gendered decision-making, or others in isolation is insufficient because these variables are interdependent with the treatment within the interaction framework. Due to these interactions, examining any single variable on its own would not provide a complete picture of the heterogeneous effects of these factors on income. Thus, it allows us to capture how the effects of one variable change depending on the levels of others, offering a nuanced view of the complex interplay between factors across income distributions.

The interaction effect between commercialization and treatment was statistically significant at the 10th, 25th, and 50th quantiles. This implies that the SHEP intervention with commercialization significantly improved the farmer's income at lower income brackets; The main, interaction, and overall effects of commercialization on horticulture income are presented in Figure 4.3. For example, a 1 percent (0.01 unit) increase in the commercialization index at the 10th, 25th, and 50th quantile has a more significant impact on farmers' horticulture income for those in the treated group compared to those in the pure control group, with values¹⁶ of 128.3 ETB (2.4 USD), 161.8 ETB (3 USD), and 224.4 ETB (4.2 USD), respectively. However, the effects of the SHEP intervention are rendered statistically insignificant within higher income quantiles. Farmers with higher income quantiles are likely already practicing commercialization and have comparatively elevated incomes, so the SHEP intervention will have minimal effects on those quantiles. Joint decision-making positively and significantly influences income at the 10th and 25th quantiles, regardless of its interactions with the SHEP intervention. For example, farmers who practice joint decision-making at the 10th and 25th quantiles have effects on horticulture income compared to those who exercise women-alone decision-making with values of 5,865 ETB (110 USD) and 12,059 ETB (226 USD), respectively.

¹⁶ As the summary statistics mention, horticulture income is measured in thousands of Ethiopian birr. Having this, the calculations of the coefficients are as follows. A 1 percent (0.01-unit) increment of the horticulture commercialization index increases the horticulture income by $\widehat{\beta}_{hct} * 1000 * 0.01$. For example, a 1 percent increase in the horticulture commercialization index at the 10th, 25th, and 50th quantiles increase the horticulture income of the farmers in the treated group by 128 ETB [12.8*1000*0.01], 162 ETB [16.2*1000*0.01], and 224 ETB [22.4*1000*0.01], respectively compared with farmers who are being in the pure control groups.

Moreover, different covariates significantly influence horticulture income along the distribution. The costs of chemical fertilizers, pesticides, and herbicides have a positive and significant impact on the horticulture income of smallholder farmers, with varying income distributions. Despite the added expenses, these inputs are crucial for horticulture production, ultimately increasing farm income. Horticultural crops require good soil fertility and are heavily susceptible to pests and diseases, so farmers are keen to apply agrochemicals. Family labor also positively influences horticulture income at the 10th, 25th, 50th, and 75th, emphasizing the significant role of family members during production and marketing in horticulture income generation.

Livestock holding is positively associated with horticulture income at the higher income brackets (50th, 75th, and 90th quantiles), while the causality remains unknown. Farmers who own livestock have better financial stability, which may allow them to invest in horticulture by purchasing chemical fertilizers and improved seeds through the sale of livestock, thereby increasing their horticulture income. Alternatively, the increased income from commercialization might have resulted in owning more livestock. Additionally, livestock can assist farmers with agricultural tasks, such as plowing fields, further supporting their horticultural activities. The distance to agricultural cooperatives negatively and significantly influences horticulture income at the 10th and 25th quantiles. Smallholder farmers residing distant from agricultural cooperatives tend to observe a decline in horticulture income, particularly in the lower quartiles of the income distribution. Being close to agricultural cooperative benefits farmers mainly with inputs acquisition and sometimes purchasing of their produce. The farmers who are detached from agricultural cooperatives in the lower income brackets have limited resources, including various agricultural inputs and are therefore likely to experience low yields and poor market participation. The number of extension contacts per month negatively influences horticulture income at the lower brackets (10th and 25th quantiles).

The quantile regression also shows no significant effects of the household's age in any quantiles, which could indicate that age may not be a crucial determinant of income in this context. This suggests that younger or older household heads experience similar effects on the acquisition of horticulture income from the intervention and commercialization, possibly because the benefits of the intervention do not vary based with age. The number of adult females in the household is not statistically significant across quantiles, suggesting that an increase in adult females does not have a discernible effect on household horticulture income at different income levels. Similarly, the number of adult males is having no significant impact, except at the 90th quantile. This finding implies that, in wealthier households (for example farmers who is at the 90th

quantile), having more adult males may not contribute positively to household income and, in some cases, may even reduce it. This counterintuitive result could arise from increased consumption without a proportional contribution to income or economic inactivity among additional adult males. It may also reflect structural labor market issues, where additional male family members are not productively employed in high-income households.

4.7. Quantile Plot analysis

The conditional quantile and point estimation from OLS are presented in Figure 4.4.¹⁷ The conditional quantile estimations show more comprehensive results than the OLS estimations. The figures depict the coefficient or slope of the variables of interest (commercialization, treatment, interaction terms, gender-based decision-making). In our context, the quantile plot shows the heterogeneous effects of commercialization and other variables on income. Thus, the y-axis represents the coefficient or slope of commercialization and other covariates from quantile regression estimation. It displays how those coefficients vary across different quantiles of income. First, horticulture commercialization shows an increasing trend across different quantiles (Figure 4.4A). At the same time, it shows that the relationship between commercialization and horticulture income is not constant across the income distribution. These results suggest that the degree of commercialization has a heterogeneous impact on horticulture income at different points of the income distribution. Further, the observed heterogeneous and increasing trends in the interaction effects between commercialization and treatment variables across different quantiles imply that the influence of treatment on income is contingent on the level of commercialization and varies across different segments of the income distribution (Figure 4.4B).

¹⁷ The quantile plots have different scales (minimum and maximum) for the axis because each plot reflects the corresponding quantile's unique coefficient and confidence interval. Therefore, it is not feasible to standardize or unify the scales for all the plots.

Table 4-4: Results of quantile regression

Variables	10 th quantile Coeff. (BSE)	25 th quantile Coeff. (BSE)	50 th quantile Coeff. (BSE)	75 th quantile Coeff. (BSE)	90 th quantile Coeff. (BSE)
Treatment variable – SHEP intervention (pure control group is base)					
Control group	6.721 (3.454)**	11.696 (4.862)**	11.823(13.122)	-4.193 (21.351)	-16.661(15.515)
Treated group	4.488 (4.079)	7.197 (6.965)	10.491(12.674)	-6.322 (22.271)	-17.312(15.763)
Horticulture commercialization index (0-1)	7.356 (1.524)***	11.449(1.492)***	13.786(2.120)***	25.062(4.989)***	23.194(6.034)***
Interaction effects between treatment and horticulture commercialization					
Horticulture commercialization*control group	-1.623 (2.062)	-1.703 (2.182)	1.874 (2.624)	0.353(6.711)	18.374(12951)
Horticulture commercialization*treated group	5.488 (2.566)**	4.735 (2.679)*	8.654(3.848)**	4.066 (5.886)	17.534(12.889)
Gender-based decision-making (women-alone decision-maker is base)					
Man-alone decision makers	5.241 (2.795)*	10.478 (4.419)**	15.662(11.475)	3.138(19.806)	6.829(10.147)
Joint decision makers	5.865 (3.174)*	12.059(4.489)***	16.908(11.776)	1.629(19.636)	9.531(13.318)
Interaction effects between treatment and gender-based decision-making					
Control group*man-alone decision makers	-3.704 (3.146)	-8.158 (4.691)*	-9.797 (12.727)	7.439(21.606)	14.129 (14.192)
Control group*joint decision makers	-5.001 (3.391)	-11.002 (4.774)*	-12.252(13.359)	6.979(21.474)	13.183(14.192)
Treated group*man-alone decision makers	-4.087 (5.529)	-2.310 (6.653)	-5.401 (11.688)	10.296(22.395)	22.866(27.876)
Treated group*joint decision makers	-6.721 (4.548)	-9.145 (5.523)	-11.781 (11.649)	8.397(22.723)	15.349(16.401)
Demographic variables					
Gender of the household head (1 = male; 0 = female)	0.241 (2.398)	-0.188(2.946)	0.979(2.927)	1.175(4.941)	7.899(6.412)
Age of the household head in years.	0.008(0.027)	-0.018(0.034)	-0.073(0.044)	-0.113(0.090)	-0.267(0.209)
Number of adult female family in the household	-0.129(0.632)	0.155(0.579)	0.824(0.889)	0.534(2.205)	2.847(2.682)
Number of adult male family in the household	0.157(0.433)	-0.098(0.317)	-0.728(0.499)	-1.049(0.947)	-3.721(1.145)**

Table 4-4 continues.....

Variables	10 th quantile Coeff. (BSE)	25 th quantile Coeff. (BSE)	50 th quantile Coeff. (BSE)	75 th quantile Coeff. (BSE)	90 th quantile Coeff. (BSE)
Socio-economic variables					
Number of livestock (TLU)	0.242(0.171)	0.260(0.175)	0.858(0.351)**	1.716(0.751)**	2.739(0.772)***
Agriculture-related variables					
Distance to the cooperative offices (minutes by foot)	-0.013(0.008)*	-0.016(0.009)*	-0.022 (0.015)	-0.034(0.038)	0.092(0.091)
Number of extensions contact per month	-0.064(0.033)**	-0.164(0.067)**	-0.144(0.111)	0.265(0.327)	0.685(0.850)
Input-related variables					
Cost of chemical fertilizer (ETB/year)	0.001(0.000)***	0.001(0.000)***	0.002(0.000)***	0.003(0.001)***	0.006(0.002)**
Cost of pesticide (ETB/year)	0.002(0.002)	0.003 (0.001)**	0.005(0.000)*	0.004(0.003)	0.011(0.013)
Cost of herbicide (ETB/year)	0.002(0.004)	0.006 (0.011)	0.022(0.009)**	0.024(0.007)***	0.007(0.014)
Family labor (man-days/year)	0.027(0.001)**	0.027(0.012)**	0.044(0.016)***	0.049(0.029)*	0.084(0.097)
Constant term	-11.179(5.029)**	-14.358 (5.908)**	-19.926(12.219)	-8.420(19.723)	-14.366(13.029)
Number of observations	566	566	566	566	566
Pseudo R ²	0.1754	0.2144	0.2229	0.2477	0.3085

Note: ***, **, and * show the variables' significance at 1%, 5%, and 10% significant levels, respectively. The bootstrap standard error (BSE) is shown in parentheses

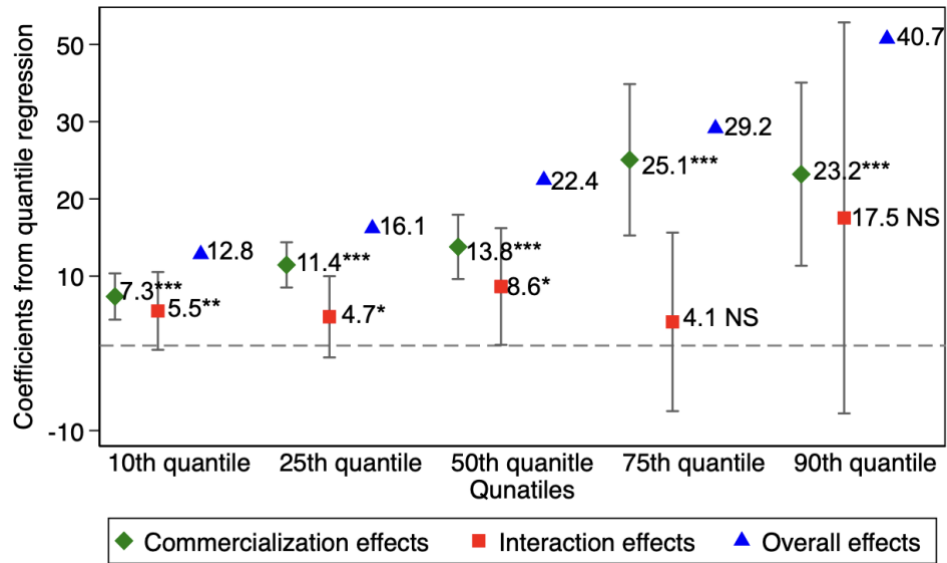


Figure 4-3: The effects of commercialization and SHEP intervention on horticulture income (main effects, interaction effects, and overall effects derived from quantile regression)

Note: ***, **, and * show the variables' significance at 1%, 5%, and 10% significance levels, respectively; "NS" stands for non-significant.

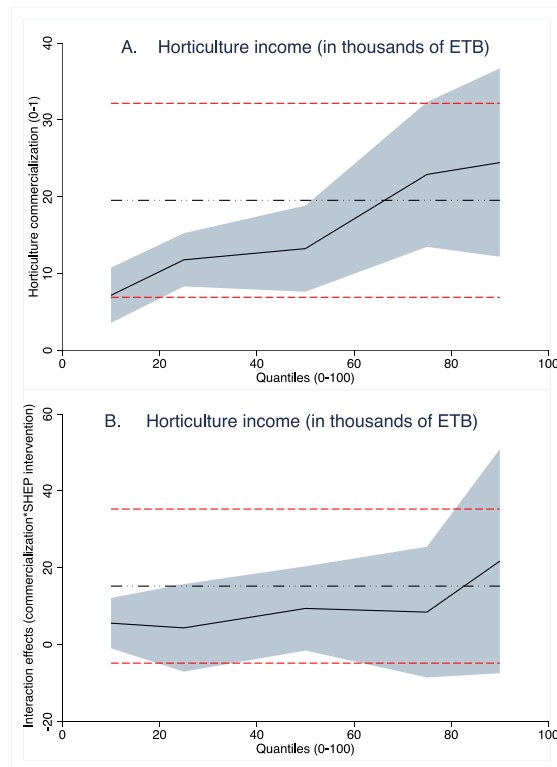


Figure 4.4: quantile regression plot analysis for horticulture income

Notes: The thick solid black lines represent the conditional quantile estimations. The shaded regions indicate 95% confidence intervals from quantile regression. The horizontal dashed-dotted black lines represent the point estimates from the ordinary least square (OLS) model. The dotted horizontal red lines show the 95% confidence intervals of the OLS estimation.

4.8. Discussions

This study addresses two main research hypotheses. First, analyze the effects of commercialization on income generation, considering the SHEP intervention. The results of our analysis show that the interaction effects between horticulture commercialization and SHEP intervention (farmers in the treated group who commercialize their horticulture crops) demonstrate positive effects on horticulture income, notably more pronounced at equal to or lower than the 50th quantile income brackets. Having this, the average value of horticulture commercialization index for the treated group is 82.3%; as a result, let us extend our assumption: the average level of commercialization farmers in the treated group, which is an 82.3 percent increment in the commercialization index at the 10th, 25th, and 50th quantiles, their horticulture income will increase by 10,534.4 ETB (197.6 USD), 13,250.3 ETB (248.5 USD), and 18,435.2 ETB (345.8 USD), respectively, compared to those in the pure control group. Compared to the national-level study by Okoth et al. (2022), who found an average net farm income (sales from crop and livestock) of 24,000 ETB (450 USD) per year in Jimma areas, the farmer's horticulture income in the treated groups represents an improvement of 45.9% to 80.4% of the net farm income across the 10th to 50th quantiles. Moreover, as noted in Appendix 4.4, the share of horticultural income in total agricultural income, excluding income from livestock sales, for farmers in the treated, control, and pure control groups were about 61.5%, 40.2%, and 49%, respectively. This indicates that farmers in the treated group have more significant advantages. Hence, this study underscores the significance of market-driven extension services such as SHEP intervention as a potential instrument to encourage horticulture commercialization and ultimately improve smallholder farmer's income. This aligns with Tabe-Ojong et al. (2022) and Ogutu & Qaim (2019), who found positive heterogeneous effects of agricultural commercialization on income regardless of interaction effects with any interventions.

The second hypothesis of this study examines the effects of joint decision-making on horticulture income. The quantile regression estimation does not provide results similar to the inferential statistics (t-test results without causality) regarding joint decision-making across treated and counterfactual groups. In the t-test, farmers practicing joint decision-making in the treated group showed significantly higher incomes than those in the control and pure control groups (Table 4.1). However, quantile regression does not reveal this effect when accounting for heterogeneous effects with different covariates. This discrepancy may be due to the t-

test measuring averages without accounting for potential confounding factors that could explain income differences. In contrast, quantile regression, which accounts for income distributions and covariates, suggests that once these factors are controlled, the effects of joint decision-making through SHEP on income may become insignificant or even vanish at specific points within the income distribution. As a result, despite hypothesizing that joint decision-making in the treated group would have a heterogeneous effect on income, farmers who practice joint decision-making in the treated group did not demonstrate significantly greater effects on income than joint decision-makers in the pure control group did. Instead, we found that joint and man-alone decision-making is positively associated with income, regardless of the interaction effects. This could be due to several reasons. First, suppose the farmer groups already had strong baseline conditions with existing joint decision-making practices. In that case, the additional effects of joint decision-making by the SHEP intervention may not have produced a noticeable effect. This may be because the effects of the SHEP intervention on joint decision-making could take longer to observe, as gender training primarily focuses on behavior and mindset changes, which may require combined effects with other stakeholders and take time to fully internalize to observe significant effects on income.

Secondly, the prevailing cultural norms in our study indicate the tradition of designating men as the sole decision-makers in production and marketing activities. This situation can hinder efforts to promote joint decision-making through interventions. Consequently, women's involvement in decision-making processes may be constrained, thereby reducing the potential impact of joint decision-making on horticulture income. Our observations also show that men are involved in horticulture marketing even within women's farmer groups.

The result shows that the frequency of monthly extension contacts negatively influences horticulture income. This may be related to the effectiveness of conventional extension service delivery. Gatdet (2022), Leta et al. (2017), and the Ethiopian Ministry of Agriculture and Natural Resources (EMANR) (2017) corroborated that extension agents are often intensively involved in other responsibilities, such as governance, security, and related affairs that may reduce the quality and effectiveness of the extension services, leading to negative consequences for farmers' agricultural investments.

Furthermore, the cost of agrochemicals, such as chemical fertilizers, pesticides, and herbicides, positively correlated with horticulture income at different quantiles. This aligns with Shimizutani et al. (2021), who reported a positive association between the costs of chemical fertilizers and horticulture income in smallholder farms in Kenya. Despite the expenses, investing in chemical fertilizers boosts production and sales. Additionally, our analysis shows that family labor is positively associated with horticulture income, highlighting the importance of considering family contributions. Chang et al. (2012) noted that family labor and hired labor are heterogeneous inputs that affect the income and welfare of farm households.

The main policy implication of this study is the importance of promoting horticulture commercialization within the framework of a market-oriented agricultural extension program, exemplified by initiatives such as SHEP, which are instrumental in facilitating commercialization and improving the income of farm households. Thus, supporting low-income (50th and lower quantiles) smallholder horticulture-growing farmers through market-oriented extension is crucial. Joint participation in decision-making between spouses significantly improves the incomes of smallholder horticulture-growing farmers in the lower quantiles, especially those in the 10th and 25th quantiles, regardless of the interaction effects. However, the interaction between joint decision-making and SHEP intervention did not show significant effects on income; the reason could be that the effects of joint decision-making through SHEP intervention may take longer to observe. Thus, promoting joint decision-making practices among smallholder horticulture-growing farmers is crucial for improving household income. Furthermore, more attention is needed to promote and strengthen agricultural cooperatives in terms of facilities and capacity building, to enhance the effective delivery of essential inputs to smallholder farmers. Moreover, this study's main contribution could be accounting for the non-random agricultural peculiarities for control group identification. This study also indicates that farmers who practice women-alone decision-making tend to have lower income levels; therefore, the SHEP intervention could provide proactive support to help these farmers increase their horticulture income. This methodological innovation could be a valuable reference for future quasi-experimental and impact evaluation studies employing similar approaches in different contexts.

4.9. Summary of Key Findings and Implications

This study examines the heterogeneous impact of horticulture commercialization and gendered decision-making on harvest sales on the income of smallholder farmers, utilizing the Smallholder Horticulture Empowerment and Promotion (SHEP) project dataset in the Jimma zone, Ethiopia. Using a quasi-experimental research design, a nearest-neighbor matching technique using non-random variables or location-specific data to identify suitable control groups that account for the key agricultural peculiarities at the *kebele* level. A total of 610 sample farmers were randomly selected; among them, farmers in the treated group were participants in the SHEP project between December 2022 and February 2023. Moreover, kernel matching was employed to address hidden bias at the household level, which resulted in the exclusion of approximately 44 sample farmers due to a lack of matching. Finally, we estimate quantile regression at the 10th, 25th, 50th, 75th, and 90th quantiles using data from 566 farmers to analyze the distributional effects of factors including commercialization and gendered decision-making. inclu

The results show that the interaction effects between horticulture commercialization and SHEP intervention demonstrate positive heterogeneous effects on horticulture income, notably more pronounced at equal or lower than the 50th quantile. This indicates that SHEP intervention through commercialization effectively uplifts those with low incomes who gain from horticulture sales by delivering valuable training. The study also revealed that farmers who engage in joint decision-making on harvests to sell positively affect income at lower quantiles, irrespective of whether they are in specific groups (treated, control, or pure control). The results further show that proximity to agricultural cooperatives, the cost of agrochemicals, and livestock holding significantly and positively associate with income. Agricultural cooperatives are essential actors, providing necessary inputs to farmers; thus, they should be strengthened through facilities and capacity building to enhance effective access to these inputs for higher production and income. Therefore, an effective market-driven extension approach such, as SHEP, is crucial to improve especially, lowest to the 50th-quantile-income farmers through commercialization.

CHAPTER FIVE: THE IMPACTS OF ADOPTION OF CLIMATE-SMART PRACTICES ON HORTICULTURAL CROP YIELD¹⁸

5.1. Introduction

Smallholder farmers in developing countries continuously face challenges in enhancing agricultural productivity due to climate variability (Asfew & Bedemo, 2022), limited access to agricultural extension services (Leta et al., 2017), and weak implementation of agricultural extension systems (Kitajima, 2024). Climate change poses a significant threat to global agricultural production, particularly affecting developing countries (Kalele et al., 2021). The region's heavy reliance on rain-fed agriculture significantly affects agricultural production, as it is particularly vulnerable to climate variability. Although agriculture accounts for 40% of East Africa's GDP and sustains the livelihoods of 80% of the population in developing countries, shifts in temperature and precipitation patterns significantly reduce agricultural output (Arif et al., 2020; Musyimi, 2020).

Hence, it endangers the livelihoods of over 3.83 billion people worldwide who depend on the agri-food system (FAO, 2023) and also threatens the livelihoods of over 2.5 billion people in developing countries, where agriculture is the primary source of livelihood (Goli et al., 2023). Climate change also encourages the increased presence and outbreaks of existing and new pests and diseases (Patrick et al., 2020). According to the Intergovernmental Panel on Climate Change (IPCC), developing countries are expected to require an estimated \$127 billion annually by 2030 and \$295 billion annually by 2050 to adapt to the adverse effects of climate change (Intergovernmental Panel on Climate Change (IPCC), 2022).

Horticultural farming is one of the essential economic activities in East Africa (Nyasimi et al., 2013). While it is often viewed as a climate-smart practice, particularly when supported by irrigation systems, it may not necessarily include additional climate change adaptation measures. As a result, adaptation efforts have primarily concentrated on cereals and livestock farming (Bello et al., 2024; Berhanu et al., 2024; Ma &

¹⁸ Reprinted from: Fikadu A. A., Nomura H., Gebre G. G., Shah P. (2025). Adoption of Climate-smart Practices and Their Effects on Horticulture Yield: Lessons from SHEP study in Ethiopia. *Journal of the Faculty of Agriculture*, Kyushu University, Vol. 70(2) (Accepted May 16, 2025).

Rahut, 2024; Belay et al., 2023; Demem, 2023; Asfew & Bedemo, 2022; Di Falco & Veronesi, 2013; Ma & Rahut, 2024). However, recent studies suggest that horticultural farming remains vulnerable to the effects of climate change. For instance, horticultural crops are particularly vulnerable to climate change due to their high water demands and specific temperature requirements (Patrick et al., 2020). The effects of climate change on horticultural production in East Africa are complex. Increasing temperatures may exceed crop-specific thresholds, thereby impacting growth and yield. For example, higher temperatures can reduce both the yield and quality of tomatoes (Ayankajo & Morgan, 2020). Changes in rainfall patterns result in greater variability in water availability, which subsequently affects crop growth and irrigation needs (Organisation for Economic Co-operation and Development [OCED], 2014).

As a result, climate-smart agriculture practices (CSA) have been introduced and implemented to adapt to the adverse effects of climate change on agricultural productivity. The CSA serves as a bridge between scientific research and policymaking, contributing to the achievement of sustainable development goals, which were initially outlined by the FAO in 2010 at the Hague Conference on Agriculture, Food Security, and Climate Change (FAO, 2013). CSA practices refer to the sustainable transformation, reorientation, and creation of long-term agricultural development, which improves yields and household welfare (FAO, 2022; Lipper et al., 2014). Developing countries, including Ethiopia, have embraced various climate-smart agriculture (CSA) practices as adaptation strategies to tackle these challenges (Waaswa et al., 2021). CSA practices have been widely implemented due to their effectiveness in mitigating the adverse effects of climate change by enhancing resilience and farm production while reducing greenhouse gas emissions (Di Falco & Veronesi, 2013; FAO, 2022; Mpala & Simatele, 2023; Zheng et al., 2024). Different countries have been adopting CSA practices in various groups, such as innovative agronomic methods (adjusting irrigation scheduling, managing pests and diseases, using improved varieties adapted to climate variability, implementing crop rotation, and changing planting and harvest dates) (Shah & Wu, 2019), soil conservation practices such as using compost, mulching, organic fertilizers, and conservation agriculture, tie ridge (Fikadu et al., 2025; Okoronkwo et al., 2024 Thornton et al., 2018; Wekesa et al., 2018), and farm risk reduction practices (crop insurance, crop diversification, and utilizing water ponds on their farm plots) (Malhi et al., 2021; Naazie et al., 2023). Since horticulture crops are being influenced by climate change and the need for targeted

adaptation strategies to enhance their resilience and long-term sustainability, recently, the concept of climate-smart horticulture (CSH) practices has been customized from the CSA concept, which shares the definition of CSA, which follows the same principles of adaptability and building resilience to climate variability. However, the CSH concept involves adopting and building the resilience of horticulture to climate variability (Chachar et al., 2023; Mwikamba et al., 2024).

Moreover, the Ethiopian and Japanese governments have collaborated to implement market-oriented extension programs called Smallholder Horticulture Empowerment and Promotion (SHEP) to improve farmers' welfare. The primary focus of the SHEP program is to facilitate and teach farmers to adopt a “*grow to sell*” approach, which involves farmers continuously analyzing market demand before growing horticultural crops, rather than simply planting crops as usual. The SHEP program has provided various comprehensive soft skills training, including sensitization workshops (which clearly communicate the vision), market demand analysis, improved agronomic training (covering crop selection, crop calendar, soil management, planting protocols, weed management, pest and disease control, and harvesting techniques), post-harvest handling, profitability analysis, gender mainstreaming, and climate-smart agricultural practices. The SHEP interventions have also been implemented to improve horticultural crop yield, equipping farmers with essential skills and knowledge to make informed production decisions align with the market demand within climate-variability scenarios. A detailed explanation of the SHEP intervention's training packages is documented in Section 3.4. Thus, the SHEP intervention significantly promotes commercialization and joint decision-making, thereby improving the income of smallholder farmers (Fikadu et al., 2025). On the other hand, even though CSH practices are not a frontline objective of the SHEP program, they have broadly been promoted in every single training session of the SHEP program. For example, disease-resistant varieties, diversifying market-demand horticulture crops, adjusting planting and harvesting times, adjusting irrigation schedules, and other climate-smart practices have been provided to farmers as integral components of the SHEP training packages (Nomura et al., 2024). In line with this, the SHEP intervention promotes CSH practices to increase productivity, adapt to agricultural risks, which are called adapting climate-related risks (Nomura et al., 2024).

Despite the increasing literature on adopting CSA practices and their effects on crop yield, few studies have concentrated on identifying the factors influencing smallholder farmers' decisions to adopt CSH practices. For example, the research conducted by Mwikamba et al. (2024) highlighted the factors affecting the adoption of CSH practices in Kenya. They treated the data as count data and employed a negative binomial regression model, but did not address how these practices influence horticultural crop yield. Nevertheless, the effects of adopting CSH practices on horticultural yield, especially within irrigation-based horticultural farming using methodologically rigorous approaches, have been less documented. Addressing these gaps by analyzing the effects of CSH adoption on horticultural yield will offer a more comprehensive understanding of sustainable horticultural farming. A study by Nomura et al. (2024) confirmed that participation in the SHEP program increases the likelihood of adopting agricultural practices that manage climate-related risks in accordance with climate-smart principles. However, the effects of market-oriented extension programs, such as the SHEP approach, on smallholder farmers' decisions regarding the adoption of CSH practices have not yet been examined. The heterogeneity in yield among adopters and non-adopters within the SHEP intervention framework remains underexplored. Therefore, this study aims to identify the factors affecting farmers' adoption of climate-smart horticulture practices and their effects on horticultural crop yield.

5.2. Conceptual Framework and Methodological Framework

This study conceptualizes the relationship between the SHEP intervention, the adoption of CSH practices, and their effect on horticultural crop yield (Figure 5.1). The framework suggests that embracing various CSH practices, such as adjusting irrigation schedules, using disease-resistant crop varieties, adjusting planting and harvesting times, and promoting market-based crop diversification, is a crucial pathway through which the SHEP intervention impacts horticultural output. Farmers who adopt these practices are expected to achieve higher adjusted yields, ultimately enhancing their food security.

The study employs a multivariate probit model to analyze the determinants of CSH adoption decisions. This model enables the estimation of multiple interrelated adoption choices, acknowledging that farmers may simultaneously adopt more than one CSH practice, influenced by common underlying factors such as access to extension services, participation in farm demonstrations, and household socio-demographic characteristics. Following the adoption analysis, the study estimates the average treatment effects of CSH adoption on

horticultural crop yield using inverse probability-weighted regression adjustment (IPWRA). This method controls for potential selection bias by reweighting observations based on their probability of treatment assignment, ensuring robust causal inference regarding the effectiveness of CSH adoption without dropping sample observations in both adopters and non-adopters. Finally, the study employs quantile regression as a regression adjustment to assess the distributional effects of CSH adoption, the SHEP intervention, and other control variables on horticultural crop yield. This method provides a nuanced understanding of how these factors impact productivity across various yield distributions, ranging from the lowest to the highest-performing farmers. Unlike mean-based estimations, quantile regression captures heterogeneous effects, revealing whether the benefits of CSH adoption and the SHEP intervention are more pronounced among farmers at the lower, median, or upper yield quantiles. By integrating quantile regression, this study offers comprehensive insights into the drivers of CSH adoption, the effects of the SHEP intervention, and their heterogeneous effects on horticultural productivity. The findings contribute to the broader discourse on climate-resilient agricultural extension models, providing policy insights into how market-oriented interventions can promote sustainable horticultural development in Ethiopia and similar contexts.

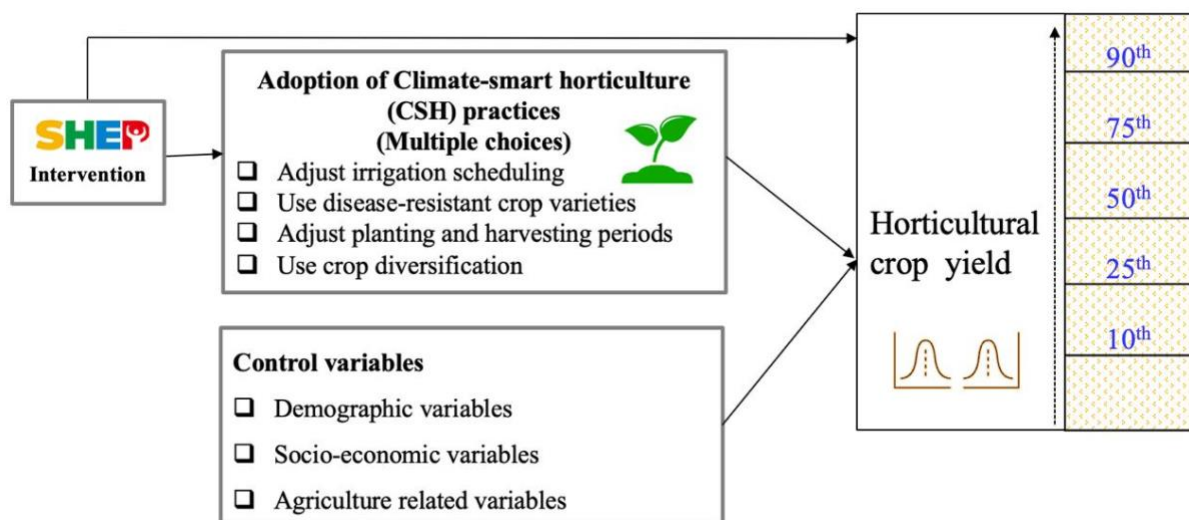


Figure 5-1: Conceptual framework of adoption of multiple CSH practices and their effects on aggregate yield

5.2.1. Descriptions of the variables

Aggregate weighted horticulture yield

Weighting in aggregate yield estimation is crucial in contexts where farmers cultivate multiple horticultural crops within the same season; for example, farmers in the study area have grown different horticultural crops, such as cabbage, onion, potato, tomato, carrot, sweet potato, and green pepper, on separate plots in a single production season. It ensures that crops occupying a larger share of land contribute more to the overall measure. This approach enhances comparability across households by standardizing yield metrics and preventing distortions caused by crops from small plots. Additionally, it balances representation by mitigating the risk of overinflating yield for high-yield crops grown on small plots while ensuring that low-yield crops cultivated in larger areas are not underrepresented. Furthermore, the sample size for each horticultural crop in this study is small, which is insufficient for econometric model estimation for the individual crop. Therefore, we use the aggregate weighted yield to represent overall household-level horticultural crop yield. The ratio of land allocated for each crop to the total horticultural land of the household serves as a weighting factor, acting as a proxy for the relative importance of each crop in the farmer's production strategy. We follow the following three steps to calculate the household production system's aggregate weighted yield of the horticultural crops.

First, we calculate the yield of each crop produced by the farmers, which is the ratio of the quantity of harvests multiplied by the land allocation of each crop.

$$(Productivity)_{ij} = \frac{(Quantity\ of\ harvest\ measured\ in\ kg)_{ij}}{(Land\ area\ measured\ in\ hectare)_{ij}} \quad (5.1)$$

Where j denotes the horticultural crop types produced by farmer i .

Second, we calculate the weighting factor for each crop to estimate the aggregate yield of farmers' horticulture crops.

$$(Weight)_{ij} = \frac{(Land\ allocation)_{ij}}{(Total\ land\ size\ for\ horticulture\ production)_{ij}} \quad (5.2)$$

Third, we aggregate the yield of each crop using the weight factor for the individual farmers who produced them in the same season. This approach accounts for the relative importance of each crop based on land

allocation decisions. It provides a balanced representation of all crops, preventing overemphasis on high-yielding crops that might occupy smaller areas.

$$(Aggregate\ weighted\ horticultural\ yield)_i = \sum_{j=1}^7 [(Weight)_{ij} * (Yield)_{ij}] \quad (5.3)$$

Where i represents the sample farmers and j denotes the number of horticultural crops produced by the sample farmers.

Adoption of climate-smart horticulture (CSH) practices

Farmers adopt various strategies to adapt to climate change, aiming to enhance production and household income. Participation in the SHEP intervention empowers farmers to take a proactive approach toward climate change adaptation, particularly by integrating CSH practices into their agricultural activities. While the SHEP initiative does not explicitly target CSH practices, its comprehensive training program fosters their adaptation. These practices include utilizing disease-resistant crop varieties, optimizing irrigation schedules, adjusting planting and harvesting periods, and diversifying crops within the same season based on demand analysis. Although the formal curriculum of the SHEP project does not explicitly emphasize these CSH strategies, its practical components inherently support adaptation measures that address horticultural challenges caused by climate change. For instance, in areas with limited irrigation water, the project advocates for efficient water management techniques and facilitates the dissemination of climate-related information, thereby creating an environment that enables farmers to implement CSH practices effectively. In this study, the adoption of CSH practices is measured in terms of dummies (adopters and non-adopters) for each practice implemented by the farmers.

5.3. Econometric model specification

We used an inverse probability weighting regression adjustment to estimate the average effects of CSH adoption and assess the impact of farmers' adoption of CSH practices on overall weighted horticultural crop yield.

5.3.1. Inverse Probability Weighting Regression Adjustment (IPWRA)

We used the Inverse Probability Weighted Regression Adjustment (IPWRA) model to estimate the effects of adopting CSH practices in a quasi-experimental design setting, which makes a causal inference by creating

the best possible counterfactual groups. The IPWRA estimates the average treatment effects on the treated, which is the difference in outcome variables between adopters and non-adopters, and it serves as a “therapy” for biases that arise from the misspecification of Propensity Score Matching (PSM) (Ogunniyi et al., 2023). Misspecification of the propensity score model occurs when important covariates are excluded, irrelevant ones are included, or nonlinear relationships are assumed linear, leading to poor covariate balance and biased treatment effect estimates. Similarly, the outcome model may suffer from missing key covariates, including irrelevant ones, or failing to capture nonlinear or heterogeneous effects, resulting in biased estimates of the average treatment effect on the treated (ATET). These issues compromise the accuracy of both models, as the propensity score fails to balance treated and untreated groups, and the outcome model misestimates the relationship between covariates and outcomes. The IPWRA estimator is a “doubly robust” model, indicating that consistent treatment effects can be estimated even if one of the two models (the treatment or outcome model) is incorrectly specified (Sibhatu et al., 2022; Wooldridge, 2010). Thus, this estimator allows us to estimate the effects of smallholder farmers’ adopting CSH practices on horticulture production.

Following Ogunniyi et al. (2023), we assume the linear regression function of the model estimation is $Y_{ij} = \beta_i + \gamma_i X_i + \varepsilon_i$. Then, we follow three steps to estimate ATET using the IWPR: First, we generate the propensity score using the observable factors $p(x; \hat{y})$. Second, we calculate the weights for the adopters and non-adopters, using the inverse of the propensity score values to create balanced pseudo-populations, such as weights for the treated group $1/p(x; \hat{y})$ as well as the weights for the control group. Third, we estimate the average treatment effects on the treated (ATET) using inverse probability-weighted least squares from the adopters and non-adopters.

$$\min_{\beta_1, \gamma_1} \sum_{i=1}^n (Z_i - \beta_1 - \gamma_1 X_i) / p(x; \hat{y}) \text{ if } T_i = 1 \quad (5.8)$$

$$\min_{\beta_0, \gamma_0} \sum_{i=1}^n (Z_i - \beta_0 - \gamma_0 X_i) / p(x; \hat{y}) \text{ if } T_i = 0 \quad (5.9)$$

where (β_1, γ_1) is the estimation for the adopters or $T_i = 1$ and (β_0, γ_0) is the estimation of non-adopters or $T_i = 0$.

Then, estimate the ATET, which is the difference between equations 5.8 and 5.9.

$$ATT = \frac{1}{n_t} \sum_{i=1}^{n_t} [(\hat{\beta}_1 - \hat{\beta}_0)](\hat{y}_1 - \hat{y}_0)X_i \quad (5.10)$$

where n_t is the total number of smallholder farmers who adopted the CSH practices, $(\hat{\beta}_1\hat{y}_1)$ denotes the estimated inverse probability weighted parameters for the adopters, and $(\hat{\beta}_0\hat{y}_0)$ represents the estimated inverse probability weighted parameters for the non-adopters.

Fourth, quantile regression is estimated by including the treatment and other control covariates to assess the robustness of the ATET.

$$Y_i = \beta_i + \theta_i T_i + \omega_i D_i + \gamma_i X_i + \varepsilon_i \quad (5.11)$$

where T_t denotes the treatment variable (adaptation of CSH practices), and D_i shows the SHEP intervention (1 = treated and 0 = pure control), and X_i represents the other control variables.

The outcome variables (Y_i), in this model (IWRA), are aggregated weighted horticultural yield. All sample farmers are included in estimating the average treatment effect on the treated (ATET) of adoption to Climate-Smart Horticulture (CSH) practices on aggregated horticultural production.

After estimating the average treatment effect on the treated (ATET) using the inverse probability weighted regression adjustment (IPWRA), we further investigate the factors influencing aggregated weighted horticultural yield through quantile regression because the study setting is a quasi-experiment, there is still some confounding bias (hidden bias) that has been inherited after IPW matching. The rationale for using quantile regression arises from our findings on the average treatment effect (ATE), which reveal that the benefits of adopting CSH practices are not uniform across all smallholder farmers. The mean-based estimators may obscure these heterogeneous effects. In contrast, quantile regression allows us to examine how the effects of various factors differ across the aggregate yield distribution, ranging from the lowest to the highest quantiles. In quantile regression estimation, we decompose the adoption of CSH practices into four practices: adjusting irrigation schedule, using disease-resistant crops/varieties, changing sowing and harvesting time, and using crop diversification. Quantile regression reveals the heterogeneity effects of covariates, providing insights into the effects at different aggregate weighted yield distributions, ranging from the lowest to the highest levels of aggregated weighted yield (Buchinsky, 1998; Fikadu et al., 2025; Koenker

& Hallock, 2001; Ogutu & Qaim, 2019). Following Fikadu et al. (2025) and Tabe-Ojong et al. (2022), the standard quantiles were used, encompassing the median (50th percentile), quartiles (25th and 75th percentiles), and two additional percentiles, one at the lower end and another at the upper-income level (the 10th, 25th, 50th, 75th, and 90th quantiles).

The quantile regression specification is explained in Equation (5.12):

$$Y_i = X_i' \beta_q + \mu_{qi} \quad \text{where; } (Y_i | X_i = X_i' \beta_q) \quad (5.12)$$

where Y_i the aggregate weighted yield; X_i is the set of covariates, including adoption of different CSH practices, SHEP intervention, Interaction effects, and other control covariates such as farmers' socioeconomic, demographic, and institutional characteristics; q it is a quantile with $0 < q < 1$ β_q the parameters to be estimated.

5.4. Summary of the descriptive statistics

Table 5.1 summarizes various covariates across adopters and non-adopters, highlighting the statistically significant differences between the two groups. The average education level of the household head was over three years, whereas non-adopters had an education level below three years, suggesting that better education may influence adoption decisions. The average land area allocated for horticulture production is 0.58 hectares, which is almost similar for both adopters and non-adopters. The average years of experience in horticulture farming for adopters were over eight years, whereas non-adapters had seven years, which is a statistically significant mean difference between them. Farmers with more years of experience may have contributed to the likelihood of adopting new CSH practices. Approximately 60.7% of the adopters were in the treated group, while about 43.2% were non-adopters, which differs significantly from the control group, indicating that participation in the SHEP intervention is strongly associated with adopting CSH practices. Another essential factor is participation in farm field demonstrations, which is statistically significant; a higher percentage of adopters (65.5%) participated in farm demonstrations compared to non-adopters (53.6%). This emphasizes the role of hands-on learning in adaptation. Similarly, the frequency of extension contact is significant, showing that adopters had more frequent monthly extension visits than non-adopters,

suggesting that greater access to agricultural advice facilitates the adoption of CSH practices. The distance to the agriculture office is marginally significant, where adopters are closer to the agriculture office than non-adopters, implying that proximity to the agriculture office may enhance access to resources and support for adopting CSH practices. Livestock ownership, measured in Tropical Livestock Units (TLU), is statistically significant, indicating that adopters own more livestock than non-adopters. This suggests that wealthier households, in terms of livestock assets, are more likely to adopt CSH practices. We used IPW to remove the potential background differences between adopters and non-adopters (Appendix 5.1). As presented in Table 5.1, the baseline difference between adopters and non-adopters was removed after applying matching (ipw), which indicates the household characteristics between adopters and non-adopters are well balanced. After matching, the standardized mean differences are consistently below 0.1 and not statistically significant, as recommended by Austin (2009) (Table 5.1).

Table 5-1: Summary statistics before and after matching

	(1) Full sample	(2) Adopters	(3) Non- adopters	(4) diff (2) – (3)	(5) standardized diff (2)–(3)
Sex of the household head (1 = male; 0 = female)	0.92	0.94	0.93	-0.01	0.00
Age of the household head (years)	42.46	42.59	42.46	0.04	0.01
Education level of the household head (years of schooling)	3.22	3.47	2.99	0.43	0.04
Participation in farm field demonstration in village (1 = yes; 0 = no)	0.64	0.66	0.54	0.19 ***	0.03
Frequency of extension contact (frequency per month)	6.94	7.18	5.69	1.56 **	0.01
Land allocation for horticultural crop production (ha.)	0.56	0.59	0.55	0.03	0.04
Experience of horticulture farming (years)	7.87	8.50	7.36	0.61	0.00
Total family size in the household	6.14	5.99	6.11	-0.06	0.06
Road access (number of months passable for vehicles)	10.81	10.83	10.67	0.24	0.00
Distance to agricultural cooperatives (minutes by foot)	34.84	35.65	40.00	-0.86	0.02
Distance to farmers training center (minutes by foot)	30.00	30.81	29.91	-0.27	0.05
Distance to main market (minutes by foot)	78.07	77.98	79.45	4.41	-0.01
Distance to agriculture office (minutes by foot)	29.87	28.08	31.18	-3.10 **	0.01
Livestock (in TLU)	4.16	4.37	3.75	0.49 *	0.01

5.4.1. Association between adopting CSH practices and SHEP intervention

Farmers who adopted CSH practices constituted 41.3%, while the remaining 58.7% did not adopt, regardless of disaggregating into the SHEP group (Figure 5.2A). In alignment with this, the decision to adopt CSH practices is notably higher among treated farmers at 50.7% compared to 33.7% in the pure control group (Figure 5.2B). This suggests that participation in the SHEP intervention positively affected farmers' willingness to embrace climate-smart practices. Furthermore, when we break down the different CSH practices, we observe a consistent trend in farmers' decisions to adopt these practices. The adoption of irrigation schedule adjustments varies significantly between the pure control and treated groups, with approximately 13% of farmers in the treated group making this adjustment, compared to 2.9% in the pure control group (Figure 5.4A). This indicates that participation in the treatment (SHEP intervention) slightly increases the likelihood of adopting irrigation schedule adjustments, though overall adoption remains relatively low. Adopting disease-resistant crop varieties is more prevalent than adjusting irrigation schedules, with adoption rates of 38.7% in the treated groups and 28.7% in the pure control groups (Figure 5.4B). This implies that farmers in the SHEP intervention are more inclined to adopt disease-resistant crop varieties to mitigate disease risks than those in the pure control group. Adjusting sowing and harvesting times represents another adaptation strategy that entails modest decision-making. Farmers in the treated group adopted their sowing and harvesting times at a rate of 21.7%, while those in the pure control group reached 14.4% (Figure 5.4C). This disparity indicates that SHEP participants made more informed adoption decisions regarding planting schedules in response to climate variability. This shift suggests that the intervention has a positive, albeit limited, impact on promoting adaptive agronomic practices. Crop diversification, a vital risk management strategy, exhibits the lowest adoption rates among all practices. In the treated group, only 15.9% of farmers utilized crop diversification as a CSH practice, whereas 5.4% of farmers in the pure control group adopted it (Figure 5.4D).

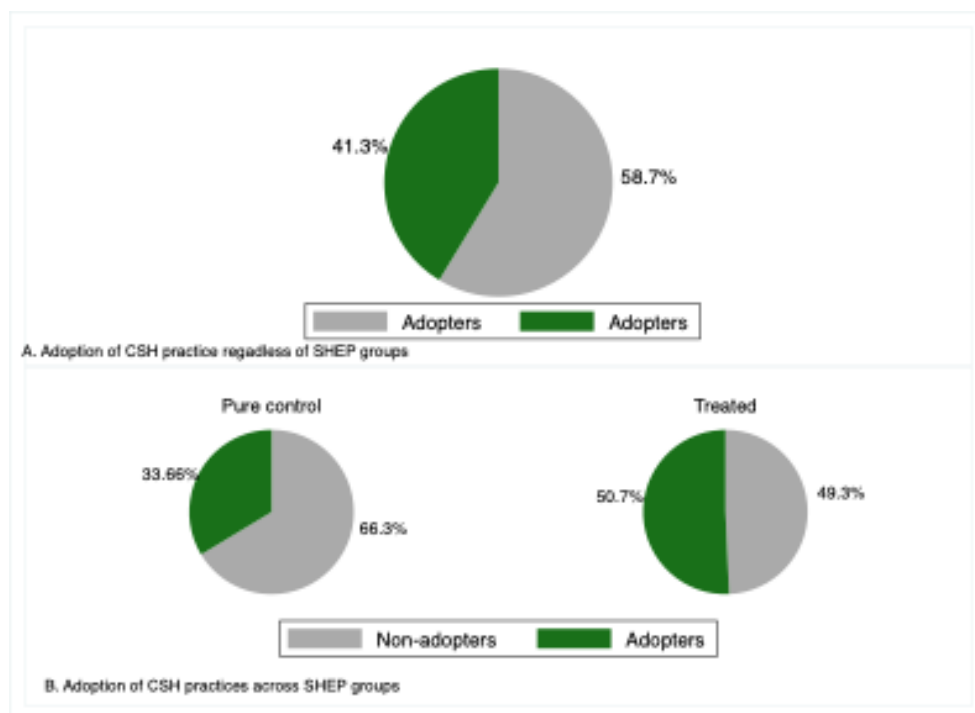


Figure 5-2: Adoption of CSH practices across the treated and pure control groups

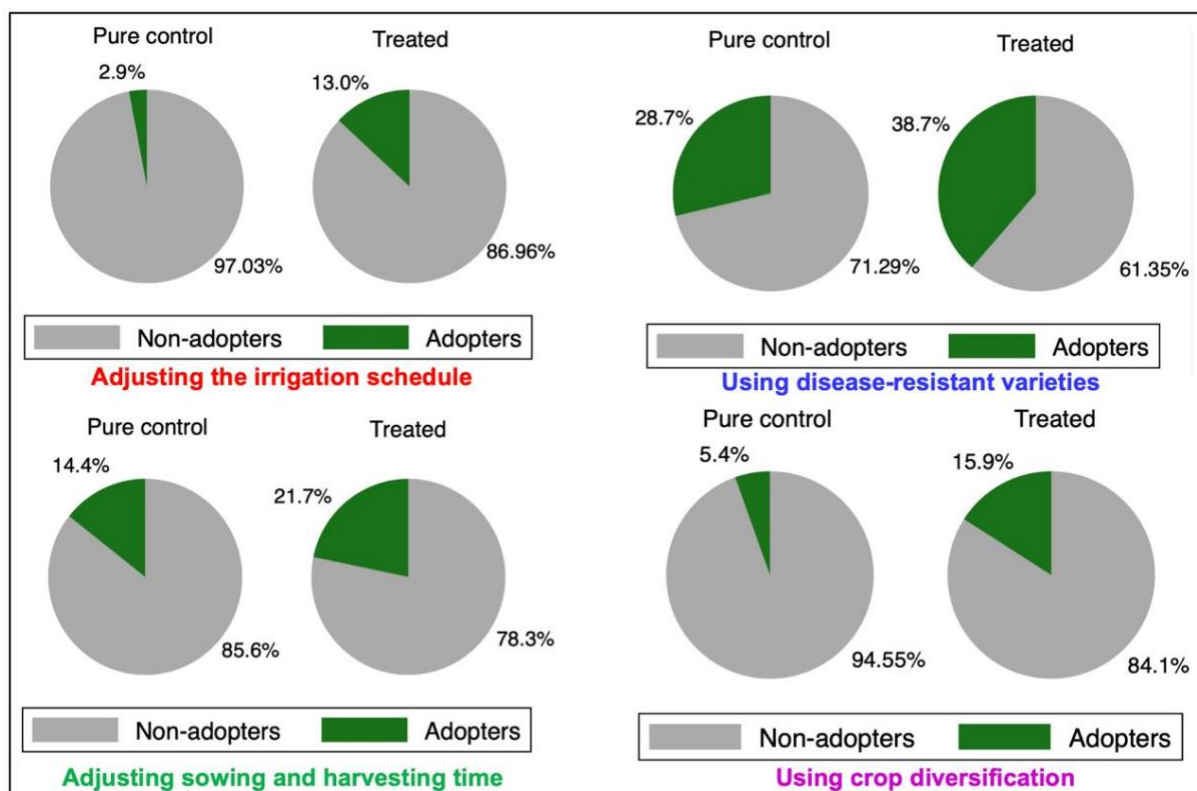


Figure 5-3: Adoption of different CSH practices across the treated and pure control groups

5.4.2. Aggregate weighted horticulture yield across CSH adoption and SHEP groups

Figure 5.4 shows the red line (non-adopters: pure control), which shows the highest peak, indicating a larger proportion of individuals with very low horticultural yields (up to 2,000 kg). The green line (Non-adopters: Treated) shifts slightly to the right compared to the red line, suggesting that treatment has a positive influence on the aggregate weighted horticultural yield of non-adopters. The blue line (adopters: pure control) is skewed to the left but has a longer tail, implying that adopters without treatment achieve higher production levels than non-adopters. The purple line (adopters: treated) shifts further to the right and has the flattest distribution, signifying a significant improvement in the horticultural yield of adopters due to treatment. Thus, adopters (from treated and pure control) consistently demonstrate higher production levels than non-adopters, underscoring the benefits of adopting climate-smart horticultural (CSH) practices. Moreover, the shift from blue (adopters: pure control) to purple (adopters: treated) is more pronounced than the shift from red (non-adopters: pure control) to green (non-adopters: treated), suggesting that treatment is more effective for adopters compared to non-adopters.

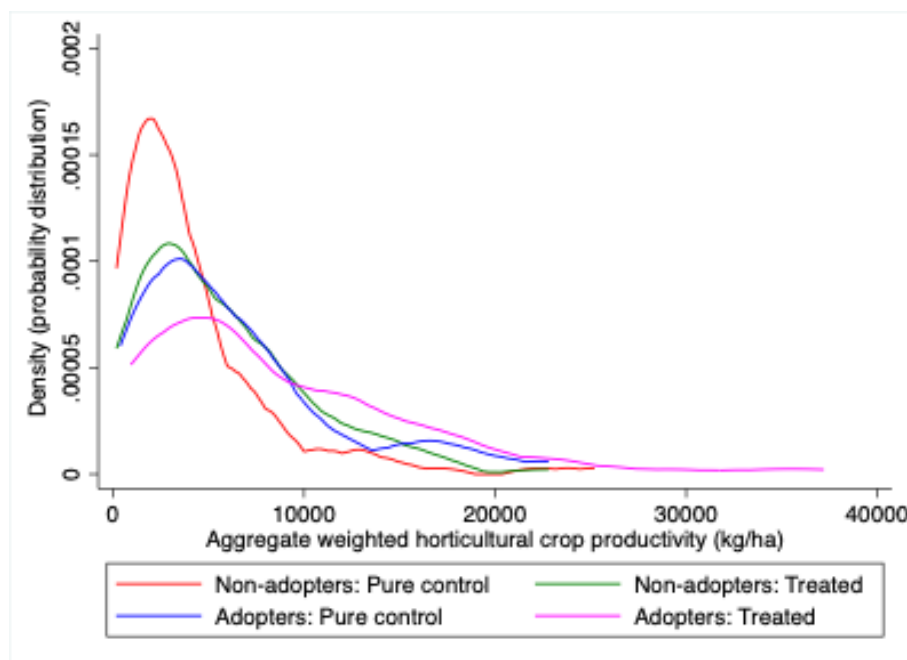


Figure 5-4: The results of Kernel density estimation - Distribution of horticultural production between adopters and non-adopters across treatment groups

The t-test results reveal that treated farmers who adopted climate-smart horticulture (CSH) practices achieved significantly higher aggregate weighted horticultural yields (8,598.69 kg/ha) compared to their pure control counterparts (6,334.51 kg/ha), with the difference being statistically significant at the 5% level. Similarly, even among non-adopters of CSH, treated farmers still outperformed pure control farmers in yield (5,717.57 kg/ha vs. 4,060.95 kg/ha), with a highly significant difference at the 1% level. Descriptively, these findings suggest that the SHEP intervention contributes to yield improvement, whereas its combination with CSH adoption gives greater aggregate yield gains.

Table 5-2: The descriptive statistics of aggregate weighted horticultural crop yield

T-test statistics	Adopters of CSH practices			Non-adopters of CSH practices		
	Treated	Pure control	Test T vs PC	Treated	Pure control	Test T vs PC
Aggregate weighted Horticultural yield (kg/ha)	8,598.69 (7,064.17)	6,334.51 (5,259.91)	**	5,717.57 (4,389.10)	4,060.95 (4,058.42)	***

Note: The standard deviations are in parentheses

5.4.3. Average treatment effects of adopting CSH practices on aggregated weighted horticultural crop yield

Table 5.3 presents the estimated impact of adopting Climate-Smart Horticulture (CSH) practices on aggregated weighted horticultural yield, using inverse probability weighted regression adjustment (IPWRA). The average treatment effect on the treated (ATET) is 0.430, meaning that CSH adopters experience a 43.0% increase in yield compared to what they would have experienced had they not adopted these practices. This confirms that adopting CSH practices significantly enhances yield among those who adopt them. The average treatment effect (ATE) is 0.059, indicating that when considering the entire population, the overall effect of adopting CSH practices is only a 5.9% increase and is statistically insignificant, which suggests that while adopting CSH practices is highly beneficial for adopters, expanding it to all farmers may not yield the same level of yield gains. Compared to the value of ATET, the small and insignificant ATE highlights heterogeneous treatment effects, meaning that certain farmers could benefit more from adopting CSH

practices than others. Thus, this finding underscores that CSH adaptation is highly effective for those who voluntarily adopt it. However, its benefits might not be uniform across all farmers; instead, it will likely be heterogeneous. Consequently, rather than promoting broad or blanket climate change adaptation policies (one-size-fits-all), policymakers should focus on context-specific, location-sensitive CSH interventions. This approach ensures that CSH adaptation strategies align with different farming communities' socioeconomic and agroecological conditions, maximizing their effectiveness and long-term sustainability. Moreover, the potential outcome means (POMean) for adopters and non-adopters provide additional insights into the post-treatment yield levels. The expected yield level for adopters is 8.177, while for non-adopters, 8.177 and 8.248, respectively. This suggests that the estimated yield levels between the two groups remain relatively comparable in absolute terms after accounting for selection bias. However, the positive and significant ATET effect indicates that adopters achieve a notable relative advantage due to adopting CSH practices.

Table 5-3: Average treatment effect of adopting CSH practices on aggregated weighted horticulture yield

	ATET	POMean	ATE	POMean
Adoption of CSH practices	0.430 (0.086) ***	8.177 (0.072) ***	0.059 (0.051)	8.248 0.053 ***

Note: The standard errors are in parentheses

5.4.4. Heterogeneous effects of adopting CSH practices and SHEP intervention on aggregated horticulture yield

We decompose the CSH practices into four components: (i) adjusting irrigation schedules, (ii) using disease-resistant crop varieties, (iii) adjusting planting and harvesting periods, and (iv) implementing crop diversification. This disaggregation enables a nuanced assessment of their effects on aggregated weighted horticultural yield (Table 5.4). By disaggregating CSH practices, we provide a more realistic representation of farmers' decision-making processes, as adoption is often selective rather than uniform. Farmers tailor their choices based on specific agroecological conditions, resource availability, and market incentives, resulting in varying impacts on horticultural yield. This nuanced approach enhances the understanding of diverse adaptation pathways, offering more targeted insights for policy and extension services.

Our findings indicate varied results regarding the effects of adopting various CSH practices through the SHEP intervention on aggregated weighted yield. For example, the SHEP intervention has a positive influence on aggregated weighted horticultural yield across all quantiles except the 10th quantile, regardless of whether farmers adopt CSH practices (Table 5.4: Model 1). Moreover, the interaction effects of the SHEP intervention and the use of disease-resistant crop varieties are notably significant at the 75th quantile of aggregated weighted horticultural yield, suggesting that farmers in the higher yield range benefit the most from the synergy between market-oriented extensions like the SHEP intervention and climate-resilient crop choices, such as adopting disease-resistant crops (Table 5.4: model-2). On the other hand, the interaction effects of SHEP and crop diversification show reverse effects on aggregate yield, indicating that adopters in the pure control group exhibit higher aggregate weighted yield per hectare than those in the treated group.

Road access has a significant heterogeneous effect on aggregated weighted yield across all quantiles except for the lowest (10th quantile), indicating that better road infrastructure benefits most farmers by enhancing their aggregated horticulture yield (Table 5.4). The distances to agricultural cooperatives and farmers' training schools are crucial factors affecting horticulture yield, particularly in the higher quantiles, such as the 75th and 90th percentiles (Table 5.4: model-2).

Table 5-4: Factors affecting aggregated weighted horticulture yield using quantile regression estimation

Covariates	10 th		25 th		50 th		75 th		90 th	
	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2
	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)
SHEP intervention (1 = treated group; 0 = pure control group)	0.740 (0.137)	1.016 (0.241) ***	0.520 (0.149) ***	0.627 (0.188) ***	0.419 (0.117) ***	0.497 (0.135) ***	0.347 (0.072) ***	0.388 (0.114) ***	0.406 (0.101) ***	0.375 (0.144) **
Adjusting irrigation schedule (1 = yes; 0 = no)	-0.451 (0.316)	0.052 (0.287)	-0.365 (0.138) ***	-0.432 (0.962)	-0.436 (0.241) *	-0.519 (0.252) **	0.014 (0.358)	-0.449 (0.203) **	0.066 (0.123)	-0.453 (0.841)
SHEP intervention * Optimizing the irrigation schedule		-0.628 (0.391)		0.086 (0.982)		0.188 (0.386)		0.588 (0.448)		0.493 (0.858)
Use of disease-resistant varieties (1 = yes; 0 = no)	0.541 (0.147) ***	0.869 (0.346) **	0.320 (0.136) **	0.650 (0.303) **	0.270 (0.131) **	0.254 (0.145) *	0.199 (0.098) **	0.047 (0.134)	0.087 (0.114)	-0.031 (0.159)
SHEP intervention * Use of disease-resistant varieties		-0.349 (0.372)		-0.419 (0.339)		-0.023 (0.226)		0.309 (0.181) *		0.193 (0.185)
Adjusting the sowing and harvesting time (use effective crop calender) (1 = yes; 0 = no)	0.392 (0.142) ***	0.291 (0.347)	0.169 (0.139)	0.006 (0.382)	0.127 (0.199)	0.266 (0.278)	0.280 (0.104) ***	0.540 (0.152) ***	0.143 (0.115)	0.282 (0.147) *
SHEP intervention * Adjusting the sowing and harvesting time		0.156 (0.358)		0.171 (0.409)		-0.228 (0.335)		-0.312 (0.331)		-0.116 (0.181)
Use of crop diversification (1 = yes; 0 = no)	-0.135 (0.159)	-0.286 (0.643)	0.024 (0.335)	0.009 (0.320)	0.370 (0.238)	1.052 (0.828)	0.370 (0.069) ***	1.132 (0.096) ***	0.146 (0.225)	1.017 (0.243) ***
SHEP intervention * Use of crop diversification		0.109 (0.665)		0.058 (0.493)		-0.699 (0.845)		-1.000 (0.187) ***		-1.024 (0.258) ***
Sex of the housheold head (1 = male; 0 = female)	0.169 (0.242)	0.177 (0.179)	0.001 (0.202)	0.024 (0.230)	0.077 (0.282)	0.069 (0.291)	0.023 (0.110)	-0.149 (0.112)	0.149 (0.182)	0.138 (0.175)
Age of the housheold head measured in years	0.001 (0.07)	-0.000 (0.005)	-0.011 (0.006) *	-0.012 (0.005) **	-0.001 (0.006)	-0.000 (0.005)	-0.001 (0.003)	-0.002 (0.004)	-0.008 (0.005)	-0.007 (0.004) *
Education level of the household head measured in years of schooling	0.061 (0.022) ***	0.049 (0.016) ***	0.021 (0.029)	0.032 (0.018) *	0.023 (0.019)	0.016 (0.019)	0.017 (0.011)	0.030 (0.012) **	0.000 (0.017)	-0.004 (0.015)
Total family size in the household	0.006 (0.032)	0.015 (0.023)	0.021 (0.029)	0.009 (0.028)	0.003 (0.028)	-0.013 (0.025)	0.017 (0.018)	0.020 (0.018)	-0.018 (0.020)	-0.015 (0.023)

Table 5-4: Factors affecting aggregated weighted horticulture yield using quantile regression estimation Continuous

Covariates	10th		25th		50th		75th		90th	
	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2	Model-1	Model-2
	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)	$\hat{\beta}$ (SE)
Road access measured in number of months passable for veheciles	-0.010 (0.034)	-0.022 (0.033)	0.094 (0.041) **	0.095 (0.039) **	0.126 (0.035) ***	0.147 (0.031) ***	0.106 (0.021) ***	0.103 (0.023) ***	0.103 (0.035) ***	0.086 (0.0279) ***
Distance to agricultural cooperatives	-0.003 (0.002)	-0.003 (0.005)	-0.004 (0.004)	-0.005 (0.005)	-0.001 (0.003)	-0.001 (0.003)	-0.002 (0.002) **	-0.004 (0.002) **	-0.004 (0.003)	-0.004 (0.001) ***
Distance to farmers training school	0.002 (0.002)	0.002 (0.005)	0.001 (0.005)	0.001 (0.005)	-0.004 (0.004)	-0.003 (0.003)	-0.006 (0.002) **	-0.003 (0.003)	-0.007 (0.003) *	-0.007 (0.003) ***
Constant	6.262 (0.560) ***	6.190 (0.602) ***	6.685 (0.504) ***	6.608 (0.528) ***	6.730 (0.560) ***	6.501 (0.528) ***	7.595 (0.289) ***	7.670 (0.321) ***	8.609 (0.476) ***	8.748 (0.422) ***
Pseudo R ²	0.1414	0.1495	0.0810	0.0854	0.0957	0.1048	0.1126	0.1305	0.1199	0.1514

Note: Model-1 is the model estimation “without interaction effects”; Model-2 represents model estimation “with interaction effect”; and SE indicates the standard error and $\hat{\beta}$ the coefficients of the covariates. : ***, **, and * show the variables’ significance at 1%, 5%, and 10% significant levels, respectively.

5.5. Discussions

This study examines two research hypotheses. First, we identify the factors that affect smallholder farmers' decisions to adopt climate-smart horticulture practices, such as adjusting irrigation schedules, adopting disease-resistant varieties, changing sowing and harvesting times, and diversifying crops. The SHEP intervention is crucial for promoting the adoption of disease-resistant varieties and crop diversification. In its training packages, SHEP encourages farmers to adjust irrigation schedules to respond to climate change-related challenges. Moreover, SHEP advocates crop diversification based on market-demand analysis. This indicates that SHEP primarily focuses on farmers cultivating market-responsive crops, thereby promoting market-based crop diversification rather than growing multiple crops without regard for market demand. This finding aligns with the study by Nomura et al (2024), which showed that SHEP's training curriculum promotes agricultural risk adaptation strategies that align with climate-smart agriculture (CSA) principles. Another critical factor is participation in farm field demonstrations, which statistically improves farmers' decisions to adopt disease-resistant crop varieties, modify sowing and harvesting times, and implement crop diversification. This finding corroborates various studies; for instance, farm demonstrations play a crucial role in promoting the adoption of climate-smart practices by disseminating knowledge. This is exemplified by the '*demonstration plot approach*' design, which involves forming up to four plots per group (Smith et al., 2021). Furthermore, demonstration activities emphasize testing adaptation strategies and implementing advanced agricultural and water-saving technologies (FAO, 2013). Conversely, participation in farm field demonstrations is inversely associated with the decision to adjust irrigation schedules, possibly because such adjustments may be managed by group leaders rather than individual farmers. The finding aligns with the study by Habtu (2024) and Yohannes et al.(2019), who showed that farmer-led field irrigation management is widely practiced, and farmers make irrigation schedules with their irrigation groups and select watering techniques based on intuition rather than informed assessments of soil conditions, crop needs, or weather patterns.

Second, adopting CSH practices and SHEP interventions significantly enhances the aggregate yield of horticultural crops. Our findings indicate that adopting different CSH practices through the SHEP intervention has varying effects on the aggregated weighted horticultural yield, suggesting that these effects

are conditional on the specific CSH practices employed. On the one hand, the SHEP intervention enhances yield across all quantiles except the 10th quantile, regardless of farmers' adoption of CSH practices. Furthermore, the interaction between the SHEP intervention and the adoption of disease-resistant crop varieties is significantly positive at the 75th quantile, indicating that farmers with higher yields benefit the most from the combined effects of market-oriented extensions, such as the SHEP intervention, and climate-resilient practices, including cultivating disease-resistant crops. Disease-resistant varieties help mitigate yield losses from pests and diseases, particularly in intensively managed horticultural systems, which positively correlate with crop yield (Autio et al., 2021). Alternatively, the interaction between the SHEP intervention and crop diversification adoption exhibits an inverse effect on aggregate yield, suggesting that adopters in the pure control group achieve higher aggregate weighted yield per hectare than those in the treated group. The reason could be that SHEP is a market-oriented extension approach designed to help farmers cultivate crops that align with market demand rather than merely maximizing yields. This market alignment strategy has improved income and food security (Fikadu et al., 2025). In contrast, farmers in the pure control group, who are not members of SHEP's market-driven approach, may focus on crops that do not necessarily align with market demand. While such crops may contribute to higher aggregate yield per hectare, they may not translate into higher income gains. This pattern aligns with prior findings from Shimizutani et al. (2021), which reported that Kenyan farmers who participated in SHEP shifted to market-responsive crops, leading to a 70% increase in horticultural income despite potential yield reductions. Furthermore, as Kitajima (2024) highlights, the SHEP approach is not a one-size-fits-all solution. This could explain why adopters in the treated group do not necessarily achieve higher aggregate yield per hectare.

Road access shows a significant heterogeneous effect on aggregated weighted yield across all quantiles, except for the lowest (10th quantile), indicating that improved road infrastructure generally enhances horticultural yield for most farmers. For those in higher yield quantiles, better road access increases the likelihood of generating a marketable surplus by facilitating access to higher-quality inputs. Moreover, a well-developed road network encourages input providers to deliver high-quality agricultural supplies more efficiently, boosting horticultural yield. This result aligns with the findings of Wudad et al. (2021); they found

that improved road networks allow them to access agricultural inputs, extension services, and higher-value urban markets, further enhancing yield and income gain in Dedo woreda of Jimma zone, Ethiopia.

The proximity to agricultural cooperatives and farmers' training schools is critical in influencing horticultural yield, especially at higher quantiles, such as the 75th and 90th percentiles. It indicates that farmers close to the agricultural cooperatives are more likely to get various agricultural inputs, including improved seed, fertilizer, technical training, and market linkages, which could contribute to higher aggregated yield. Moreover, farmers in the upper yield quantiles tend to possess the resources and knowledge necessary to leverage cooperative membership and training programs fully. This enables them to optimize input usage, adopt improved agronomic practices, and enhance post-harvest handling. This finding aligns with the study of Akinola et al. (2023), who highlighted that farmers who are members of agricultural cooperatives have significantly improved their tomato yield compared to non-member farmers in Nigeria. In another study by Abate et al. (2014), agricultural cooperatives play a crucial role in improving farm efficiency in Ethiopia by providing easy access to improved inputs and embedded supports, including information and training on applying these inputs to their farms. In line with this, the farmer's training center significantly positively affects crop productivity in Ethiopia (Wonde et al., 2022).

5.6. Summary of key findings and implications

This study investigates the relationship between the adoption of CSH practices and participation in the Smallholder Horticulture Empowerment and Promotion intervention. The findings show that 41.3% of farmers adopted CSH practices, with a notably higher adoption rate among the SHEP-treated group (50.7%) compared to the pure control group (33.7%). Disaggregated analysis indicates that farmers in the SHEP group more frequently adopt specific CSH practices, such as adjustments to irrigation schedules, disease-resistant crop varieties, and changes in sowing and harvesting times. However, crop diversification demonstrates the lowest adoption rates among all practices. The SHEP intervention significantly increases the likelihood of adopting irrigation schedule adjustments and crop diversification, emphasizing its market-oriented approach to crop selection. Participation in farm field demonstrations emerges as a crucial determinant, significantly influencing the adoption of disease-resistant crop varieties, adjustments to sowing and harvesting times, and crop diversification, while inversely affecting irrigation schedule adjustments, possibly due to irrigation being

managed collectively rather than individually. The average treatment effect on the treated (ATET) reveals a 43.0% increase in yield among adopters compared to non-adopters. The SHEP intervention significantly improved aggregated horticulture yield across all quantiles, regardless of its interaction with CSH adoption. Furthermore, considering the interaction effects of SHEP with the adoption of CSH practices reveals greater aggregated yield gains for farmers in the SHEP group who adopt disease-resistant crop varieties. In contrast, the interaction between SHEP and crop diversification is negatively associated with yield after addressing hidden biases, likely due to SHEP's focus on market-responsive crop selection instead of maximizing aggregate yields. Road access, proximity to agricultural cooperatives, and farmers' training schools influence aggregated horticulture yield. These findings underscore the necessity for targeted, market-oriented extension strategies that balance yield optimization with context-specific and market-oriented climate-smart practices rather than applying blanket adaptation policies. Such a strategy would ensure the scalability of CSH practices among smallholder farmers, thereby enhancing horticulture yields.

CHAPTER SIX: SYNERGY OR TRADE-OFF? THE EFFECTS OF COMMERCIALIZATION, GENDERED DECISION-MAKING, AND CLIMATE-SMART PRACTICES ON FOOD SECURITY

6.1. Introduction

Food security remains a critical global challenge that affects millions, manifested by hunger and malnutrition. In response, on 25 September 2025, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, which includes goals such as SDG-1, "no poverty," and SDG-2, "zero hunger," aimed at ensuring everyone has access to safe, adequate, and nutritious food throughout the year (FAO, 2017). Despite these efforts, food security remains a pressing issue, with approximately 29% of the global population and 62.8% of the population in Sub-Saharan Africa experiencing moderate or severe food insecurity in 2023 (FAO et al., 2024). Various empirical studies (e.g., Agidew & Singh, 2018; Drammeh et al., 2019; Abafe et al., 2022) have demonstrated that food insecurity is more severe in Africa than in other continents.

The agricultural sector, particularly in Sub-Saharan Africa (SSA), shows conflicting evidence regarding commercialization's impact on household food security. From a synergy perspective, agricultural commercialization enhances agricultural productivity, income, and food security (Carletto et al., 2017; (Fikadu et al., 2025). Moreover, smallholder farmers engaged in commercial production often experience higher income and better access to food, which contribute positively to their household welfare (Bolarinwa et al., 2021). However, commercialization also introduces trade-offs. Commercial-oriented farming, especially cash crops, can negatively affect food security by diminishing food availability and dietary diversity within households, as farmers often prioritize high-value cash crops over nutritious ones for household consumption (Linderhof et al., 2019; Mausch et al., 2020). Also, commercialization might come at the expense of using land and resources for cash crops rather than food crops, potentially affecting food availability for household consumption (Fleuret & Fleuret, 1980). Commercializing horticultural crops, whether cash or food crops, may lead to different outcomes on household food security depending on the type of crops they commercialize.

Similarly, gendered decision-making research presents mixed findings. Some studies support joint decision-making (Mohammed et al. 2023), while others emphasize the benefits of women's participation in decision-making in ensuring household food security (Sariyev et al., 2020). This study highlighted that when women have the authority to make decisions and control household assets, they are more likely to prioritize investment in food crop production that can directly contribute to and ensure their household food security. Gendered decision-making, whether by men alone, women alone, or jointly, involves active participation and consensus on crop selection, input use, sales, and profit allocation. This can induce differential effects on household food security, resulting in either trade-offs or synergies.

Additionally, while climate-smart agriculture (CSA) practices have been widely practiced in all crops and livestock farming, the CSA practices on food security have received limited attention. They sustainably transform, reorient, and create long-term agricultural development, improving productivity and food security (FAO, 2022; Lipper et al. 2014). Recently, the concept of climate-smart horticulture (CSH) practices has been customized from the CSA concept, which shares the definition of CSA. The CSH concept involves adapting and building the resilience of horticulture to climate variability, which helps to increase productivity and improve household food security (Mwikamba et al., 2024). Thus, adopting CSH practices is more likely to have a synergistic effect on household food security than presenting a trade-off despite receiving limited attention in broader empirical evidence.

Despite the growing literature on the commercialization of horticulture and gendered decision-making in agriculture (Carletto et al., 2017; Tadesse et al., 2022), the effects of these factors on the food security of smallholder farmers remain debated, with either synergistic or trade-off effects. Moreover, despite numerous studies focusing on adopting CSA practices in cereal and livestock farming, empirical studies on the effects of adopting CSH practices on food security have received less attention. It remains unclear whether the adoption of CSH practices creates synergies with, or trade-offs against, household food security. Thus, this study provides empirical evidence on the ongoing debates on how horticulture commercialization, gendered decision-making, and adoption of multiple CSH practices contribute to household food security in Ethiopia. Specifically, this study addresses the following questions: How does horticulture commercialization relate to food security, and is this relationship more synergistic or a trade-off? Which decision-maker (man-alone,

woman-alone, or joint) among the given gender-based decision-making arrangements positively improves household food security? Does adopting CSH practices play a synergistic role in improving household food security?

6.2. Conceptual framework of the Study

Given that horticulture crops make a vital contribution to the welfare of smallholder farmers, our study focuses explicitly on the horticulture sector. Smallholder farmers in Ethiopia mainly practice subsistence-oriented farming and encounter various factors, including a lack of quality extension provisions (Leta et al., 2017), unreliable market information (Ethiopian Ministry of Agriculture and Natural Resources [EMANR], 2017), and unclear understanding of decision-making arrangements, which highlights the unequal level of participation in decision-making among the couples (Dandena et al., 2017). The Japanese and Ethiopian governments have collaborated on a bilateral economic agreement in agricultural development through the Japan International Cooperation Agency (JICA), which introduced the SHEP project. This market-oriented extension program aims to empower smallholder farmers and enhance their welfare. The project tailored a “*grow to sell*” principle, showing that farmers should consider a specific market before growing horticultural crops. Adopting the “*growth-to-sell*” approach enables farmers to secure better market prices and reduces market problems as they cultivate crops guided by an analysis of market demand. Moreover, the interventions focus on promoting joint decision-making practices instead of a unitary (either man- or woman-alone) decision-making arrangement through directing mindset change for both the man and woman in the household. Thus, this study analyzes the synergetic or trade-off relationship of the three concepts pertaining to food security using the case study of SHEP.

It also focuses on the interplay between horticulture commercialization, gender-based decision-making, and adopting CSH practices. The SHEP intervention introduced market-oriented extension services by providing well-rounded training packages to improve the welfare of smallholder farmers. This study conceptualizes three main pathways through which the SHEP intervention influences household food security (see Figure 6.1).

First, it investigates whether commercialization and its interaction with SHEP intervention in a synergistic relationship, enhancing household food security (Bolarinwa et al., 2021 ; Tabe-Ojong et al., 2022) or a trade-off, where gaining higher income through commercialization may lead to food insecurity (Linderhof et al., 2019; Mausch et al., 2020; Waha et al. 2022). Second, SHEP intervention primarily encourages joint decision-making by providing gender-related training to improve farmers' income and food security; instead, it focuses less on solo decision-making practices. Thus, we identify the interaction effects of joint decision-making with SHEP intervention on household food security. Third, the SHEP's training curriculum advocates CSH practices such as using disease-resistant crop varieties, adjusting irrigation scheduling, optimizing sowing and harvesting timelines, and promoting market-responsive crop diversification within the same season. Thus, SHEP intervention through the adoption of CSH practices improves household food security by increasing the resilience of food production, thereby improving food security. In our empirical model, we include four distinct levels of adoption for CSH practices: non-adopters, adopters of a single practice, adopters of two practices, and adopters of three or more practices. This classification assumes that farmers who adopt more CSH practices are more likely to be food secure than those who adopt fewer practices. Moreover, our estimation includes household characteristics, including demographic, institutional, and socioeconomic factors as control variables, to check the robustness of the treatment effects on household food security. It is noted that the SHEP project emphasizes road access, as efficient road networks are crucial for facilitating the project's implementation and monitoring. Consequently, farmers who do not have good road access might be excluded, leading to the endogeneity of the SHEP intervention. As a result, we apply an extended ordered probit model to account for the endogeneity issues and estimate the average treatment (SHEP) effects on household food security. Our study is also complemented by inverse probability weighting to remove the potential selection bias at the household level.

survey limitations, which can result in systematic errors in capturing food security prevalence (Tadesse et al., 2020; Gebre & Rahut, 2021). Despite these limitations, objective measures remain vital for evaluating household food security. On the other hand, subjective measures rely on respondents' experiences, using self-reported perceptions of food availability and accessibility within their households. An example is the Household Food Insecurity Access Scale (HFIAS), developed by the USAID Food and Nutrition Technical Assistance (FANTA) project, which serves as a widely used experimental or subjective indicator of food security (Appendix 6.1).

In this study, food security is measured in terms of HFIAS, which is a standardized measure of a household's perceptions of their food security status with four-level ordered responses derived from nine questions (Coates et al., 2007). The HFIAS assesses the prevalence (occurrence and frequency of occurrence) of household food in/security situations via a set of questions that explore the uncertainty of food availability within the household, feelings of indignity from resorting to shocking ways of obtaining food, perceptions of food deficiency in terms of quantity and/or quality, and reductions in food intake (Coates et al., 2007). The HFIAS measures include whether any household was worried that their food supply would run out, whether any household member slept hungry due to inadequate food, whether any household member ate fewer times due to inadequate food, and whether any household member could not eat their preferred food due to a lack of resources. The HFIAS uses nine indicators specific to a household's experience of food in/security in the past four weeks. The HFIAS-approved standard scoring was used, where 0 = nonoccurrence (food insecurity situation never occurred in the household) and 1 = occurrence (it has three levels, such as 'rarely occurring' [1–2 times], 2 described it as 'sometimes occurring' [3–10 times], and 3 described it as 'often occurring' [>10 times]). The frequency of occurrence for each household's food insecurity measure was aggregated to generate a total HFIAS score. The aggregate HFIAS is bounded from 0 to 27, which indicates that the households that answered the nine questions 'no' were scored '0', which is the minimum value of the score, and answered 'yes' with the frequency of occurrence being 'often,' which is 27 (3×9), which is the maximum value of the HFIAS. The household scores were categorized into four-level ordered food security outcomes consistent with the HFIAS guidelines (Coates et al., 2007). The four levels included food secure (HFIAS = 0–1), mildly food insecure (HFIAS = 2–7), moderately food insecure (HFIAS = 8–11), and severely food

insecure (HFIAS >11). The definitions of the food security groups are as follows: A food-secure household experiences no food access challenges or only rare concerns about food availability; mildly food insecure households may worry about food availability sometimes or often or consume less preferred and monotonous diets, but they do not reduce meal size or frequency. Moderately food-insecure households frequently sacrifice diet quality by eating undesirable foods or cutting back on meal sizes or frequency. However, they do not face the most extreme forms of food deprivation (running out of food, going to bed hungry, or going a whole day without eating). Severely food-insecure households often reduce the size or number of meals. They may experience severe conditions such as running out of food, going to bed hungry, or going a whole day without eating. Even one instance of these severe conditions in the past 30 days categorizes a household as severely food insecure.

6.3.2. Horticulture commercialization index (HCI)

Commercialization reflects the extent to which household crop production is oriented toward market exchange (Strasberg et al., 1999). In this study, the horticulture commercialization index is calculated as the ratio of total horticultural sales to total horticultural production, expressed in gross monetary terms. A detailed explanation of the computation is provided in Chapter 4, Section 4.3.1.

6.3.3. Gendered decision-making in horticulture farming

Decision-making is a critical aspect of household dynamics, as noted by Sariyev, Loos, and Zeller (2020), who examined who determines production, input use, harvests to sell, and the distribution of economic returns. Family members may not participate in the same activities simultaneously; instead, decisions can vary by activity. For example, income decisions are often linked to remittance recipients and influenced by social norms; men typically manage profits, while women oversee smaller-scale home garden activities (Sariyev, Loos, and Zeller 2020). In this study, we focus on gendered decision-making regarding decisions on harvests to sell, with respondents indicating whether these decisions were made solely by a man, solely by a woman, or jointly. Following Acosta et al. (2020), we define joint decision-making as decisions made collaboratively by both male and female household members, excluding those made solely by individuals of the same gender within the household.

Gendered decision-making is constructed through a series of questions, including 1) determining responsibility for selecting vegetables to cultivate, 2) deciding on agricultural inputs to use, 3) selecting vegetable harvests to sell, and 4) deciding on horticulture sales to allocate. The respondents could indicate whether these decisions were made solely by a man, solely by a woman, or jointly by both. Family members may not engage in the same activities simultaneously, and decisions may differ based on the activities. For example, farmer's income decisions are related to remittance recipients, guided by social norms; men often handle profits, whereas women manage smaller-scale home garden activities. This is academically relevant for investigating who determines production, marketing, and allocation of economic returns. We descriptively discuss those four decision-making variables linked with household food security; however, we only use "decisions on vegetable harvests to sell" in our extended ordered probit model estimation because of multicollinearity.

6.3.4. Adoption of climate-smart horticulture practices

Farmers employ various adaptation measures to enhance productivity and improve household food security in the era of climate change. Having this, participation in the SHEP intervention fosters a proactive approach among farmers toward climate change adaptation measures, mainly through adopting CSH practices. Although the SHEP initiative does not explicitly focus on CSH practices, its comprehensive training package encourages their adoption. These practices include adjusting irrigation scheduling, using disease-resistant crop varieties, optimizing planting and harvesting periods, and promoting crop diversification within the same season through demand analysis. While the project's formal curriculum may not explicitly highlight these CSH strategies, its operational tasks inherently align with adaptation measures that address horticultural risks due to climate change. For example, in contexts where irrigation water is limited, the project promotes the efficient use of available water resources. Additionally, the project facilitates the dissemination of critical information regarding the selection and acquisition of inputs, such as improved and disease-resistant crop varieties, thereby creating a supportive environment for implementing CSH practices. Measuring the adoption of CSH practices as a binary variable, adopter versus non-adopter, can be overly simplistic and may obscure essential variations. For instance, farmers adopting only one practice may exhibit different levels of food security compared to those adopting two or more practices. To capture these scalabilities, we classify

adoption into four categories: non-adopters, adopters of a single practice, adopters of two practices, and adopters of three or more practices.

6.4. Econometric model specification

We use an extended ordered probit model with endogenous treatment assignment to assess the effects of the endogenous treatment (SHEP intervention) and other factors, including commercialization, gendered decision-making, and adoption of CSH practices on food security of the smallholder farmers. The outcome variable, food security, is logically ordered, such as food secure, mildly food insecure, moderately food insecure, and severely food insecure, which reflects the prevalence of food insecurity among households. As expressed in Wooldridge (2010), the notation of the ordered probit model is given as follows:

$$Y_i^* = \beta X_i + \delta T_i + \varepsilon_i \quad (6.1)$$

where Y_i^* is a latent variable; i represents the category of the food security situation, such as severely food insecure, moderately food insecure, mildly food insecure, or food secure; X_i is a vector of covariates explaining the household food security situation, including horticulture commercialization, gender-based decision-making, adoption level of CSH; T is the endogenous treatment variable, which is defined as a dummy (1 = treated and 0 = pure control); β and δ is the coefficient to be estimated; and ε_i is the random error for food security conditional on covariates. Thus, to define the probability of a household's self-reported food security situation, we should assume certain unknown thresholds or cutoff points such that $\tau_1 < \tau_2 < \tau_3$.

$$Y_i = \begin{cases} 0 & \text{if } Y_i^* \leq \tau_1 \Rightarrow \text{Severely food insecure} \\ 1 & \text{if } \tau_1 < Y_i^* \leq \tau_2 \Rightarrow \text{Moderately food insecure} \\ 2 & \text{if } \tau_2 < Y_i^* \leq \tau_3 \Rightarrow \text{Mildly food insecure} \\ 3 & \text{if } Y_i^* \geq \tau_3 \Rightarrow \text{Food secure} \end{cases} \quad (6.2)$$

The treatment (T_i) assignment equation is explained in equation 6.3.

$$T_i^* = \gamma Z_i + \mu_i \quad 1 \text{ if } T_i^* > 0 \text{ and } 0 \text{ if } T_i^* \leq 0 \quad (6.3)$$

where Z is a vector of exogenous variables, including the instrumental variables; μ_i is the random error related to treatment conditional on covariates (Z_i).

The instrumental variable is the availability of road access, measured by the number of months the road is passable for vehicles. It is a potential and essential factor in being a SHEP project participant. The SHEP project considers the availability of road access because good road access in sample kebeles helps facilitate project implementation and monitoring. However, this criterion may systematically exclude more remote farmers. This could lead to selection bias by favoring areas with better infrastructure, which already have market access and economic advantages. The SHEP intervention's estimated effects might differ from its potential effects in more remote areas. This variable can directly influence the treatment (being a SHEP beneficiary) but may not directly influence the household's food security unless through treatment. As a result, the first condition of instrument validity is satisfied (Appendix 6.3).

To test the exogeneity assumption of the instrument, we need to show that the number of months the road is passable for vehicles does not affect food security through mechanisms other than treatment. Most kebeles in Ethiopia, including those in our study areas, need paved roads, limiting vehicle passage throughout the year. During the Ethiopian winter season (from mid-June, July, August, September, and until mid-October), vehicle passage is further hindered by heavy rainfall and severe mud conditions. Consequently, kebeles with better road access and roads passable for vehicles are more likely to participate in the SHEP program. Farmers with good road access can sell their harvests and generate income, improving food security. Although good road access provides smallholder farmers with better opportunities to obtain market information and agricultural technologies, this does not necessarily imply that farmers without such access will inevitably face food insecurity because they might prioritize producing and securing their household food consumption over selling their harvests. This indicates that merely having road access does not guarantee food security if other critical elements, such as stable markets and adequate agricultural input access, are lacking. Instead, food security is more likely influenced by market conditions, prices, and other factors, which are more robustly addressed by structured programs such as SHEP than by road access alone. Therefore, road access is exogenous to food security unless it occurs through SHEP participation. The test shows that the instrument is not significantly associated with food security, but it is significantly associated with the treatment variable. As a result, the test results suggest that the second condition of instrument validity is also satisfied (Appendix 6.3). Equations (1) and (3) were simultaneously estimated via maximum likelihood via the Stata syntax

“extended ordered probit (eoprobit) with endogenous treatment assignment,” which accounts for both the ordinal and binary natures of the outcome and treatment variables (StataCorp, 2021). We tested the instrument for its relevance and exogeneity using the falsification test, as explained in Di Falco et al. (2011) and Melaku et al. (2024). The instrument is significantly correlated with SHEP participation; however, it is not significantly associated with food security for the subsample of farmers who did not participate in SHEP intervention, which suggests there is no effect through any mechanisms other than SHEP participation (Appendix 6.3).

Regarding the error structure, the error terms ε and μ are assumed to have a bivariate normal distribution with correlation ρ : $(\varepsilon, \mu) \sim \text{BVN}(0, \Sigma)$. where Σ is the variance-covariance matrix:

$$\Sigma = \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \quad (6.4)$$

The assumption of bivariate normality for the error terms ε and μ means that the unobserved factors affecting the outcome (food security) and the treatment decision are jointly normally distributed. This assumption allows us to capture and correct for endogeneity in the model, leading to more reliable and unbiased estimates of the treatment effect. By modeling the errors as jointly normally distributed, we can use techniques such as maximum likelihood estimation to estimate the model's parameters, considering the endogeneity consistently. The extended ordered probit model with endogenous treatment accounts for the correlation between the treatment and outcome through the bivariate normal distribution, allowing for more accurate treatment effect estimation. The main properties of this bivariate normality of the error terms are as follows:

- 1) Marginal Distributions: Both ε and μ individually follow a normal distribution.

$$\begin{aligned} \varepsilon &\sim N(0, \sigma_\varepsilon^2) \\ \mu &\sim N(0, \sigma_\mu^2) \end{aligned} \quad (6.5)$$

- 2) Joint distribution: The pair (ε, μ) follows a bivariate normal distribution:

$$(\varepsilon, \mu) \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\varepsilon^2 & \rho\sigma_\varepsilon\sigma_\mu \\ \rho\sigma_\varepsilon\sigma_\mu & \sigma_\mu^2 \end{pmatrix} \right) \quad (6.6)$$

where ρ is the correlation coefficient between ε and μ , which helps correct the model's endogeneity problem. The correlation ρ captures the degree to which unobserved factors that affect the treatment decision (T) are related to the unobserved factors affecting the outcome (Y). For example, if $\rho \neq 0$, it indicates the presence of endogeneity due to unobserved confounders that affect both the treatment and the outcome. Additionally, if ρ is significant, ignoring this correlation could lead to biased estimates of the treatment effect because the error term in the outcome equation would be correlated with the treatment variable. However, if $\rho = 0$, the treatment is exogenous, indicating that we cannot specify the structure of the correlations between the potential outcome errors. This means we do not need information about these correlations to estimate treatment effects because all covariates and the outcome are observed in observations from each group.

Based on the assumption of normality for the error term, the probability of observing each ordered response to the food security situation can be explained as follows:

$$\begin{aligned}
3a) \quad & P(Y_i = 0|X_i) = P(Y_i^* \leq \tau_1|X_i) = P(\beta X_i + \varepsilon_i \leq \tau_1|X_i) = \Phi(\tau_1 - \beta X_i) \\
3b) \quad & P(Y_i = 1|X_i) = P(\tau_1 < Y_i^* \leq \tau_2|X_i) = \Phi(\tau_2 - \beta X_i) - \Phi(\tau_1 - \beta X_i) \\
3c) \quad & P(Y_i = 2|X_i) = P(\tau_2 < Y_i^* \leq \tau_3|X_i) = \Phi(\tau_3 - \beta X_i) - \Phi(\tau_2 - \beta X_i) \\
3d) \quad & P(Y_i = 3|X_i) = P(Y_i^* \geq \tau_3|X_i) = 1 - \Phi(\tau_3 - \beta X_i)
\end{aligned} \tag{6.7}$$

Notably, the sum of those probabilities is unity. As a result, the log-likelihood function for the parameters τ and β along $1(Y_i = 0)$, $1(Y_i = 1)$, $1(Y_i = 2)$, and $1(Y_i = 3)$ is explained as follows:

$$\begin{aligned}
\Gamma_i(\tau, \beta) = & 1(Y_i = 0) \log[\Phi(\tau_1 - \beta X_i)] + 1(Y_i = 1) \log[\Phi(\tau_2 - \beta X_i) - \Phi(\tau_1 - \beta X_i)] + 1(Y_i = \\
& 2) \log[\Phi(\tau_3 - \beta X_i) - \Phi(\tau_2 - \beta X_i)] + 1(Y_i = 3) \log[1 - \Phi(\tau_3 - \beta X_i)]
\end{aligned} \tag{6.8}$$

where $\Phi(\cdot)$ indicates the standard normal cumulative distribution function.

The estimated coefficients from the extended ordered probit model are not directly interpreted; instead, they show the direction of the covariate's effect on the dependent variable (food security) (Wooldridge, 2010). As a result, the marginal effects of changes in the covariates should be estimated through partial differentiation for each covariate (equation (5)).

$$\frac{\Delta P(Y_i = 0|X_i)}{\Delta X_i} = -\phi(\tau_1 - \beta X_i)\beta$$

$$\begin{aligned}
\frac{\Delta P(Y_i = 1|X_i)}{\Delta X_i} &= \beta[\phi(\tau_1 - \beta X_i) - \phi(\tau_2 - \beta X_i)] \\
\frac{\Delta P(Y_i = 2|X_i)}{\Delta X_i} &= \beta[\phi(\tau_3 - \beta X_i) - \phi(\tau_2 - \beta X_i)] \\
\frac{\Delta P(Y_i = 3|X_i)}{\Delta X_i} &= \phi(\tau_3 - \beta X_i)\beta
\end{aligned} \tag{6.9}$$

where $\phi(\cdot)$ denotes the standard normal density function.

We also used inverse probability weighting (IPW) to address the selection bias at the household level. This study uses six covariates, such as the household head's sex, age, education, frequency of extension contact, land allocation for horticulture production, and farm experience in horticulture production, which are used for IPW (Appendix 6.2). Thus, IPW successfully matches the treated and control groups and is well-balanced.

6.5. Results and Discussions

6.5.1. Descriptive summary statistics

Table 6.1 presents the descriptive summary statistics of the independent variables, which help estimate the influence of horticulture commercialization, gendered decision-making, and adoption of CSH practices on the household food security of smallholder farmers. For the food-secure group, treated households have a significantly higher average horticulture commercialization index (0.84) than pure control households (0.71). The index in the treated group remains significantly higher for mild, moderate, and severe food-insecure groups than the pure control group counterparts. Statistically significant differences between the treated and pure control groups across food security categories suggest that SHEP project participants are more commercially oriented in horticulture production than the pure control groups, without indicating causal relationships. The share of adopters of CSH practices for treated households is higher in food-secure (54%), mild food-insecure (49%), moderate food-insecure (36%), and severe food-insecure (22%) categories than in pure control households with values of 47%, 29%, 18%, and 21%, respectively, while statistical significance is only noted for the mild food insecure group.

Regarding the gender of the household head, male-headed households are more observed in the pure control group than in the treated group across food security categories, showing a significant association only in food-secure and mild food-insecure groups. The age of the household head in the treated group shows higher

average values than the pure control groups across food security categories, showing a significant association only in food-secure and moderate food-insecure groups. The education level of the household head in the treated group is lower than that of the pure control group across different food security categories, except the moderate food-insecure category. However, the experience in horticulture production in the treated group has statistically higher average values than the pure control group across different food security categories, showing that the treated households have more experience in horticulture production. On average, road access, measured by the number of months roads are passable by vehicles, exceeds 10 months per year. There is no statistically significant difference in mean road access between the treated and pure control groups across food security categories. This suggests that both groups had comparable baseline conditions in terms of road accessibility, reinforcing the importance of the SHEP intervention as a distinguishing factor influencing treatment outcomes rather than pre-existing infrastructural advantages.

Table 6-1: Summary of the descriptive statistics of the explanatory variables across treatment and food security categories

	Food secure			Mild food insecure			Moderate food insecure			Severe food insecure		
	Treated	Pure control	Weighted t / χ^2 test	Treated	Pure control	Weighted t / χ^2 test	Treated	Pure control	Weighted t / χ^2 test	Treated	Pure control	Weighted t / χ^2 test
Horticulture commercialization index (0-1)	0.86(0.02)	0.75(0.03)	3.25 ***	0.85(0.26)	0.68(0.04)	3.46 ***	0.75(0.10)	0.52(0.07)	1.82 *	0.73(0.10)	0.50(0.07)	1.80 *
Gender of the household head (1 = male; 0 = female)	0.94(0.02)	0.97(0.02)	1.41	0.90(0.04)	0.96(0.03)	-1.75	1.00 (0.00)	1.00(0.00)	-	0.72(0.15)	0.72(0.39)	0.00
Age of the household head (years)	42.19(1.06)	40.83(1.11)	0.89	43.05(1.89)	44.57(1.71)	-0.60	48.29(5.24)	42.52(2.29)	0.01	46.79(4.27)	41.55(2.05)	1.11
Education level of the household head (years of schooling)	3.31(0.33)	3.63(0.52)	-0.53	3.01(0.55)	3.39(0.48)	-0.53	3.01(0.97)	1.34(0.48)	1.54	1.86(0.95)	2.62(0.85)	-0.60
Number of family size	5.92(0.18)	6.52(0.22)	-2.10 **	5.79(0.36)	6.56(0.26)	-1.74 *	5.49(0.46)	7.03(0.56)	-2.13 **	5.88(0.79)	6.02(0.32)	-0.15
Experience in horticulture production (year)	8.13(0.47)	8.91(1.69)	-0.44	7.46(0.72)	6.76(0.59)	0.75	6.80(1.57)	7.69(2.04)	-0.35	9.25(2.04)	6.06(0.68)	1.48
Total farmland size (hectare)	1.80(0.11)	1.52(0.09)	1.99 **	1.43(0.14)	1.63(0.13)	-1.06	1.02(0.73)	1.28(0.13)	-1.78 *	1.49(0.41)	1.39(0.12)	0.24
Land allocation for horticulture production (hectare)	0.58(0.04)	0.48(0.04)	1.86 *	0.54(0.06)	0.59(0.07)	-0.58 *	0.49(0.07)	0.47(0.06)	0.18	0.36(0.13)	0.49(0.03)	-0.98
Number of livestock (TLU)	4.66(0.27)	4.65(0.59)	0.02	3.66(0.24)	4.47(0.46)	-1.56	3.39(0.37)	3.52(0.53)	-0.18	2.53(0.64)	2.95(0.35)	-0.58
Road access (number of months passable for cars)	11.07(0.13)	10.94(0.21)	0.52	11.18(0.19)	10.89(0.21)	0.97	11.15(0.38)	10.33(0.39)	1.51	10.79(0.50)	10.09(0.37)	1.14
Number of extension contacts per month	6.96(0.54)	8.48(2.11)	-0.70	7.09(0.80)	7.72(1.96)	0.30	8.58(2.32)	5.42(1.33)	1.18	10.38(2.46)	6.98(1.05)	1.27
Distance to main market (minutes by foot)	65.31(3.69)	93.79(15.83)	-1.75 *	74.55(7.28)	90.58(10.28)	-1.27	62.16(20.36)	92.03(11.83)	-0.42	69.49(9.89)	79.18(11.35)	-0.64
Distance to agricultural cooperatives (minutes by foot)	34.43(1.99)	28.09(2.65)	1.91 *	40.69(3.40)	37.03(4.15)	0.68	33.03(6.78)	37.59(8.06)	-0.43	35.71(4.88)	34.75(3.52)	0.16

where the standard deviation is in the parenthesis; the sign represents the significance level from t-the test and χ^2 test

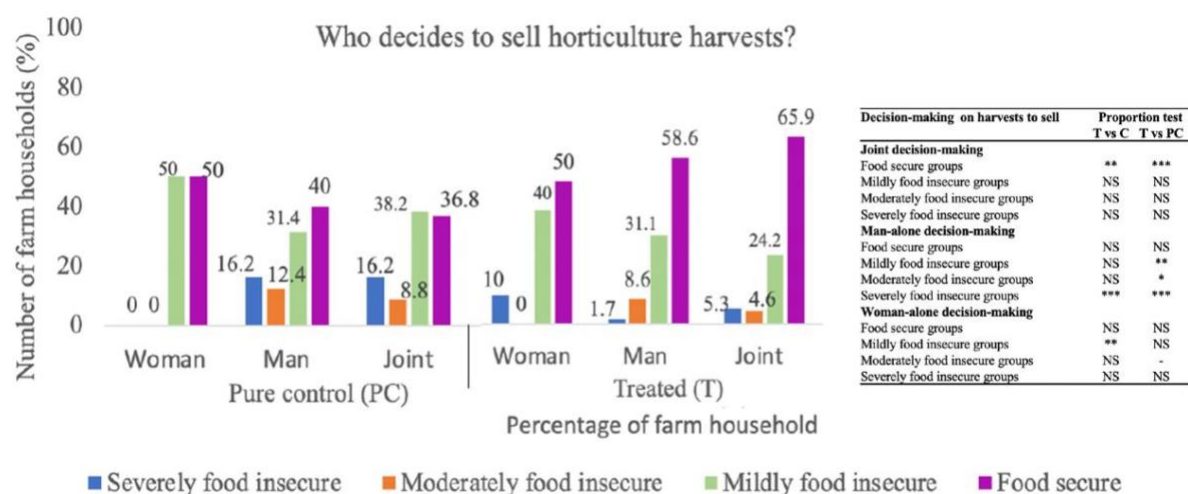
Note: TLU stands for Tropical Livestock Unit. The conversion coefficients for each category of livestock are provided as follows: horse = 1.1, cow and ox = 1.0, heifer = 0.75, donkey = 0.7, calf = 0.34, sheep and goat = 0.13, and chicken = 0.013 (Stock et al.,1991)

6.5.2. Summary of gendered decision-making in horticulture farming and food security

As shown in Figure 6.2, among smallholder farmers in the treated group, those practicing ¹⁹joint decision-making on harvest to sell had a significantly higher proportion of food secure group prevalence, at about 65.9%, compared to the 36.8% observed in the pure control group, after controlling for selection bias. This descriptively suggests a higher prevalence of joint decision-making among the SHEP project beneficiary households, likely attributable to the project's gender-inclusive training approach. It could also be due to different factors; for example, when couples in agricultural households engage in collaborative decision-making, it fosters a greater sense of shared responsibility and commitment toward improving food security outcomes. This shared ownership often translates into more meaningful efforts to achieve these goals. Furthermore, joint decision-making facilitates a valuable household exchange of knowledge and resources. Men and women bring diverse perspectives, expertise, and assets to decision-making. For instance, women, who typically manage household food resources, can provide crucial insights into the family's nutritional needs, while men might contribute more knowledge about market access and financial considerations. Thus, integrating these complementary viewpoints enables households to make more comprehensive and informed decisions that address their overall needs, thereby enhancing household food security. This synergy of perspectives and shared commitment in joint decision-making aligns with findings from previous research,

¹⁹ In our study, approximately 7.58% of households are female-headed in both pure control and treated groups, which may initially appear to limit opportunities for joint decision-making within the household. However, we found that these households often include elder sons with an average age of over 15 who actively participate in decision-making. This dynamic enables female-headed households to engage in joint decision-making across various aspects of horticulture farming, with elder sons serving as key decision-making partners. Interestingly, female-headed households in the study areas are more likely to consult with family members, close relatives, and neighbors when making decisions about crop selection, cultivation and irrigation practices, land preparation, and price information, alongside involving their elder sons. Additionally, about 22.58% of female-headed households (7 out of 31 female-headed observations) are married women whose husbands reside separately in a different household. These cases are common within Muslim communities where polygamy is practiced, allowing men to have multiple wives. In such situations, the women stood up to the role of household heads, managing the household and children even though they acknowledged they had husbands.

such as the study by Malapit et al. (2019), highlighting the positive effects of empowering gender (both men and women) decision-making on household welfare outcomes.



Note: * = $p < 0.10$; ** = $p < 0.05$; *** = $p < 0.01$; NS = non-significant

Figure 6-2: Gendered decision-making on household food security across treatment groups

As presented in Figure 6.3, approximately 4% (9) and 14% (28) of the treated and pure control group households experienced severe food insecurity, respectively. About 5% (11) and 11% (22) of the treated and pure control group households experienced moderate food insecurity, respectively. Approximately 27% (11) and 36% (73) of the treated and pure control group households experienced mild food insecurity, respectively. Moreover, approximately 64% (132) and 39% (79) of the households in the treated and pure control groups have food security situations, respectively.

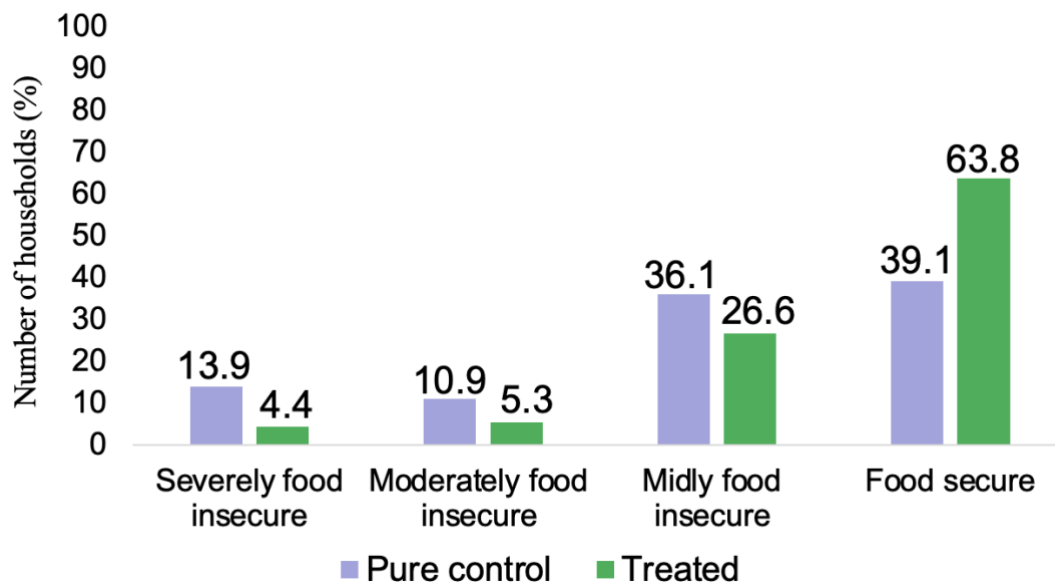


Figure 6-3: Food security across the treated and pure control groups

6.5.3. Adoption of climate-smart horticulture (CSH) practices and food security

The association between CSH practices and household food security is illustrated in Figure 6.4, indicating significant improvements in food security as adoption levels increase. Among non-adopters, 44.5% of households are food secure, while 30.9% are mildly, 10.1% are moderately, and 14.5% are severely food insecure. Adopters of a single CSH practice show substantial improvements, with 65.2% achieving food security, 23.5% being mildly food insecure, 7.6% moderately food insecure, and only 3.8% severely food insecure. Households adopting two CSH practices experience further progress, with 66.3% classified as food secure, 26.3% as mildly food insecure, 2.5% as moderately food insecure, and 5% as severely food insecure. Among households adopting three or more CSH practices, 62.5% are food secure, 31.3% are mildly food insecure, and 6.3% are severely food insecure, with no households classified as moderately food insecure. These findings emphasize the positive associations of adopting multiple CSH practices in reducing food insecurity and improving household food security prevalences.

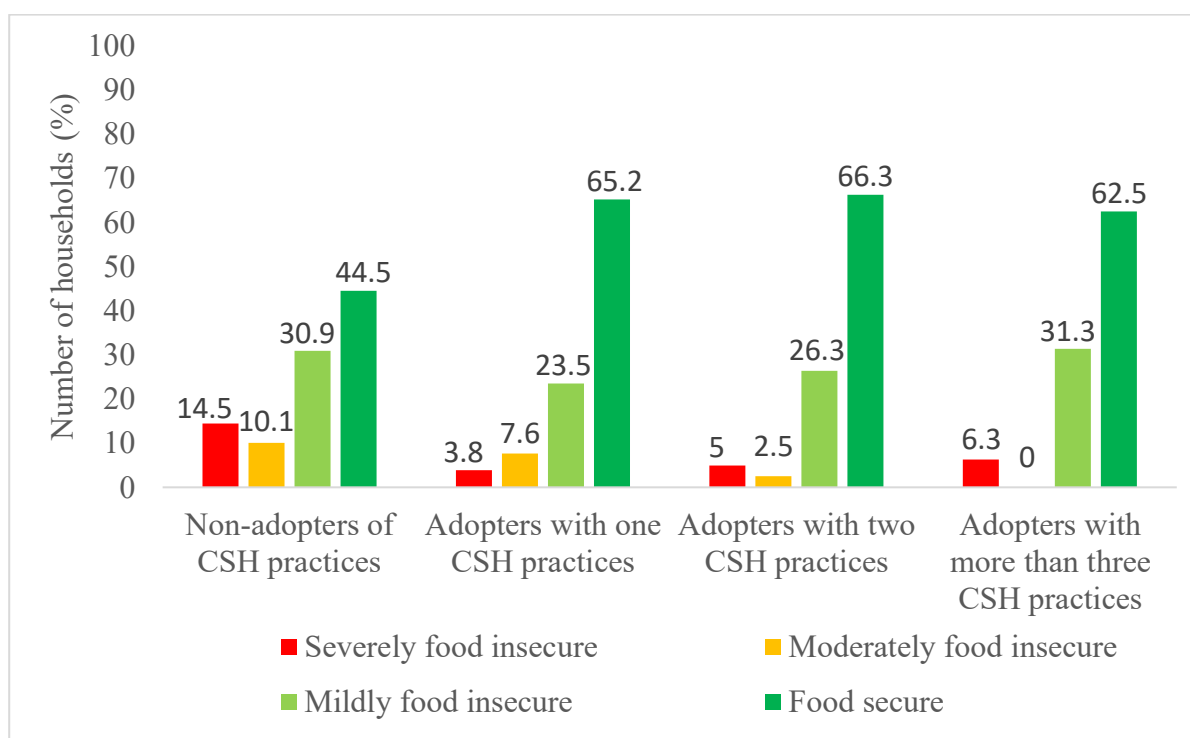


Figure 6-4: Association between climate-smart horticulture practices (level of adoption) and food security

6.6. Econometric results on factors influencing household food security

Table 6.2 presents the results of the extended ordered probit model, examining the factors influencing household food security. The significant coefficients of endogeneity for both the treated and pure control groups are -0.895 and -0.953, respectively, indicating that unobserved factors, which the model accounts for, reduce the likelihood of food insecurity by 89.5% and 95.3% for the treated and pure control groups, respectively. This underscores the necessity of using an extended ordered probit model with endogenous treatment to robustly account for these unobserved influences. When properly addressed, the model reveals a clear food in/security prevalence pattern in both the treated and pure control groups.

The study demonstrates that the SHEP intervention significantly enhances households' food security. Specifically, households in the treated group have about 81.4% probability of being food secure, compared to 20.3% for those in the pure control group, making the treated households 61% more likely to be food secure. Furthermore, the intervention reduces the prevalence of mild, moderate, and severe food insecurity by 11.8%, 9%, and 40.2%, respectively, compared to the pure control group. Households with average levels of horticultural commercialization have a 52.7% probability of being food secure, with a corresponding

marginal effect of 21.1%. Commercialization also plays a protective role, significantly reducing the prevalence of mild, moderate, and severe food insecurity by 4.9%, 5.3%, and 10.9%, respectively.

Moreover, the interaction between horticultural commercialization and the SHEP intervention further improves food security, with 81.1% of households in the treated group classified as food secure, compared to 21.2% in the pure control group. This suggests that households engaged in commercialization within the treated group are 59.9% more likely to be food secure than their pure control counterparts. In addition, the SHEP intervention, combined with commercialization, significantly reduces the likelihood of mild, moderate, and severe food insecurity by 11.1%, 8.4%, and 40.4%, respectively, compared to the pure control group. These findings highlight the robust synergistic effect of the SHEP intervention and commercialization on improving food security rather than a trade-off.

Gendered decision-making plays a critical role in household food security. Households where women are the sole decision-makers on harvests to sell have a higher predicted probability of being food secure (66.5%) compared to households where men alone (47.8%) or both men and women jointly (52.2%) make decisions. The marginal effects reveal that man-alone and joint decision-making negatively influence household food security regardless of its interaction effects with SHEP intervention, reducing the likelihood of being food secure by 18.6% and 14.3%, respectively, compared to woman-alone decision-making households. However, the interaction between gendered decision-making and the SHEP intervention improves household food security outcomes. In the treated group, the predicted margin of being food secure for households with joint decision-making, man-alone, and woman-alone decision-making are 83.4%, 76.7%, and 83.5%, respectively. In contrast, in the pure control group, the predicted margins are 18.8% for joint, 20.2% for man-alone, and 35.7% for woman-alone decision-making. This indicates that households in the treated group practicing joint, man-alone, and woman-alone decision-making are 64.6%, 56.6%, and 47.7% more likely to be food secure than their counterparts in the pure control group, respectively. The SHEP intervention also significantly reduces the prevalence of mild, moderate, and severe food insecurity, with reductions ranging from 7.9% to 42.3% for treated households with joint, man-alone, and woman-alone decision-making, compared to their counterparts in the pure control group.

Adopting multiple CSH practices significantly enhances household food security, and this effect is more pronounced with SHEP intervention. Households in the treated group who adopted over three CSH practices had the most significant improvements in food security, with 72.3% more likely to be food secure and 50.6% less likely to be severely food insecure. Similarly, adopting two or one CSH practices under the treated group also showed substantial positive effects, with households being 50.5% and 57.7% more likely to be food secure, respectively, and experiencing reductions in severe food insecurity by 26.9% and 33.5% compared to the counterparts in the pure control group. Households in the treated group who did not adopt any CSH practices also demonstrated improved food security outcomes. They were 62.5% more likely to be food secure and 45.6% less likely to be severely food insecure than their counterparts in the pure control group. This could be attributed to their focus on applying SHEP techniques in their horticultural farming. By prioritizing these techniques over the CSA practices promoted through the SHEP intervention, they generate higher yield, enabling them to improve their household food security.

Livestock holdings are positively associated with household food security. A one-unit increase in livestock holdings increases the likelihood of being food secure by 3.1%. Similarly, it reduces the probability of mild, moderate, and severe food insecurity by 1.4%, 0.6%, and 1.1%, respectively. Increasing livestock ownership may encourage farmers to invest more in horticultural production by selling livestock and purchasing improved seeds, herbicides, fertilizers, and other horticultural inputs, thereby improving household food security. Additionally, households with larger livestock holdings are more likely to meet their food needs, probably due to the multiple benefits livestock provide, such as access to nutritious food (e.g., milk, meat) and the ability to use livestock as a financial buffer during periods of need. This financial security may have a significant protective effect against food insecurity.

The distance to agricultural cooperatives statistically influences household food security; despite its minimal effects or coefficients, it reduces the probability of being food secure and increases the probability of being food insecure (moderate and severe). Smallholder farmers distant from agricultural cooperatives might lack various resources, including agricultural inputs and information, which may lead to low horticulture production and contribute to the household's food insecurity.

Table 6-2: Results of the extended ordered probit model

Variables	Food secure		Mild food insecure		Moderate food insecure		Severe food insecure	
	PM (SE)	AME(SE)	PM (SE)	AME(SE)	PM (SE)	AME(SE)	PM (SE)	AME(SE)
Treatment (Pure control is base)								
Treated	0.814(0.029) ***	0.610(0.039) ***	0.134(0.026) ***	-0.118(0.031) ***	0.023(0.006) ***	-0.090(0.023) ***	0.029(0.007) ***	-0.402(0.071) ***
Control	0.203(0.025) ***		0.252(0.044) ***		0.114(0.027) ***		0.431(0.076) ***	
Horticulture commercialization (HCI)	0.527(0.028) ***	0.211(0.091) **	0.323(0.026) ***	-0.049(0.049)	0.076(0.014) ***	-0.053(0.019) ***	0.074(0.013) ***	-0.109(0.032) ***
Interactions (HCI and treatment)								
Treated*HCI	0.811(0.029) ***	0.599(0.039) ***	0.135(0.025) ***	-0.111(0.027) ***	0.024(0.006) ***	-0.084(0.023) ***	0.029(0.008) ***	-0.404(0.068) ***
Pure control *HCI	0.212(0.025) ***		0.247(0.040) ***		0.108(0.027) ***		0.434(0.073) ***	
Gender decision-making (GDM): Who decides on horticulture harvests to sell)								
Joint	0.522(0.035) ***	-0.143(0.089) *	0.307(0.027) ***	0.049(0.050)	0.079(0.015) ***	0.038(0.019) *	0.092(0.019) ***	0.056(0.025)**
Man-alone	0.478(0.042) ***	-0.186(0.089) *	0.336(0.032) ***	0.079(0.050)	0.083(0.016) ***	0.043(0.020) *	0.099(0.017) ***	0.063(0.024) **
Woman-alone	0.665(0.081) ***		0.257(0.052) ***		0.042(0.017) **		0.037(0.018) **	
Interactions (GDM and treatment)								
Treated*joint	0.834(0.035) ***	0.646(0.048) ***	0.120(0.028) ***	-0.129(0.033) ***	0.021(0.006) ***	-0.094(0.024) ***	0.025(0.008) ***	-0.423(0.078) ***
Treated*man-alone	0.767(0.035) ***	0.566(0.044) ***	0.159(0.027) ***	-0.097(0.034) ***	0.031(0.008) ***	-0.084(0.023) ***	0.041(0.014) ***	-0.385(0.067) ***
Treated*woman-alone	0.835(0.067) ***	0.477(0.119) **	0.119(0.046) **	-0.172(0.042) **	0.021(0.010) **	-0.079(0.019) **	0.025(0.014) *	-0.226(0.100) **
Pure control*joint	0.188(0.032) ***		0.249(0.044) ***		0.115(0.027) ***		0.448(0.082) ***	
Pure control*man-alone	0.202(0.027) ***		0.256(0.043) ***		0.115(0.026) ***		0.426(0.075) ***	
Pure control*woman-alone	0.358(0.088) ***		0.292(0.036) ***		0.099(0.019) ***		0.250(0.101) **	
Climate-smart horticulture practices (CSH)								
Adopters with over three practices	0.522(0.088) ***	0.049(0.095)	0.289(0.038) ***	-0.043(0.033)	0.085(0.027) ***	-0.005(0.025)	0.104(0.075)	-0.001(0.076)
Adopters with two practices	0.629(0.067) ***	0.157(0.076) **	0.282(0.045) ***	-0.050(0.045)	0.047(0.014) ***	-0.043(0.018) **	0.041(0.016) **	-0.063(0.020) ***
Adopters with one practice	0.596(0.050) ***	0.123(0.059) **	0.297(0.034) ***	-0.035(0.031)	0.057(0.015) ***	-0.033(0.016) **	0.049(0.017) ***	-0.055(0.020) ***
Non-adopters	0.473(0.035) ***		0.333(0.029) ***		0.089(0.017) ***		0.104(0.015) ***	

Note: PM is the predicted margin or probability; AME is the average marginal effect; SE is the standard error in parentheses; whereas * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$

Table 6-2: Results of the extended ordered probit model (cont.)

Variables	Food secure		Mild food insecure		Moderate food insecure		Severe food insecure	
	PM (SE)	AME(SE)	PM (SE)	AME(SE)	PM (SE)	AME(SE)	PM (SE)	AME(SE)
Interactions (CSH and treatment)								
Treated*adopters with over three practices	0.873(0.043) ***	0.723(0.089) ***	0.096(0.031) ***	-0.123(0.068) *	0.015(0.006) **	-0.094(0.037) **	0.016(0.009) *	-0.506(0.164) ***
Treated*adopters with two practices	0.819(0.045) ***	0.505(0.096) ***	0.131(0.033) ***	-0.151(0.043) ***	0.023(0.007) ***	-0.085(0.017) ***	0.028(0.011) **	-0.269(0.118) **
Treated*adopters with one practice	0.837(0.047) ***	0.577(0.064) ***	0.119(0.035) ***	-0.149(0.043) ***	0.020(0.007) ***	-0.093(0.023) ***	0.024(0.010) **	-0.335(0.082) ***
Treated*non-adopters	0.794(0.039) ***	0.625(0.042) ***	0.146(0.031) ***	-0.085(0.029) ***	0.026(0.008) ***	-0.085(0.023) ***	0.033(0.010) ***	-0.456(0.060) ***
Pure control*adopters with over three practices	0.149(0.079) **		0.219(0.067) ***		0.109(0.037) ***		0.522(0.167) ***	
Pure control*adopters with two practices	0.314(0.79) ***		0.282(0.052) ***		0.107(0.019) ***		0.296(0.123) **	
Pure control*adopters with one practice	0.259(0.040) ***		0.269(0.048) ***		0.113(0.025) ***		0.359(0.086) ***	
Pure control *non-adopters	0.169(0.022) ***		0.230(0.037) ***		0.111(0.031) ***		0.489(0.064) ***	
Livestock holding (TLU)	0.527(0.027) ***	0.031(0.008) ***	0.316(0.027) ***	-0.014(0.004) ***	0.076(0.014) ***	-0.006(0.002) ***	0.081(0.012) ***	-0.011(0.004) **
Total family size (number)	0.521(0.026) ***	-0.002(0.008)	0.313(0.025) ***	0.001(0.004)	0.078(0.014) ***	0.000(0.002)	0.088(0.012) ***	0.000(0.004)
Distance to main market (minutes)	0.516(0.027) ***	-0.001(0.000)	0.317(0.026) ***	0.000(0.000)	0.078(0.014) ***	0.000(0.000)	0.088(0.012) ***	0.000(0.000)
Distance to agricultural cooperatives (minutes)	0.521(0.026) ***	-0.001(0.001)	0.315(0.026) ***	0.000(0.000)	0.078(0.014) ***	0.000(0.000) *	0.086(0.012) ***	0.001(0.000) **
Observations	409							
Log pseudolikelihood	-1361.833							
Wald chi2(21)	509.68							
Prob > chi2	0.0000							
Cut1	-0.093(0.288)							
Cut2	0.189(0.282)							
Cut3	0.920(0.292)							
Endogeneity coefficients								
Treated	-0.895(0.063) ***							
Control	-0.953(0.151) ***							

Note: PM is the predicted margin or probability; AME is the average marginal effect; SE is the standard error in parentheses; whereas * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$

6.7. Discussions

This study addresses four key hypotheses. First, the SHEP intervention significantly improves household food security, with a 60.4% greater likelihood of treated households being food secure than pure control households. This corroborates Ecker's (2018) and Malapit et al. (2019) findings on the positive effects of agricultural interventions on food security. A recent report from (FAO et al., 2024) reveals that 59% of Ethiopia's population faced moderate to severe food insecurity between 2021 and 2023, highlighting the ongoing challenge at the national level. This study demonstrates that SHEP intervention significantly improves food security and reduces food insecurity prevalences in the study areas, even within broader national challenges. The SHEP interventions significantly reduced the probability of severe food insecurity to 40.4% through horticulture commercialization, 42.3% through joint decision-making practices, and 50.6% through promoting multiple climate-smart horticulture practices than pure control group counterparts. These findings suggest that while food insecurity remains a critical national issue, targeted interventions like SHEP intervention can effectively address the problem at local levels and underscore the potential effects of scaling up such interventions to mitigate food insecurity across Ethiopia and similar settings.

Second, horticulture commercialization significantly enhances food security, leading to a 21.1% increase in the probability of being food-secure, regardless of the interaction effects. When combined with the SHEP intervention, this effect is significantly amplified and elevated the probability of being food-secure to 59.9%, with an additional 38.8% improvement for food-secure households in the treated group. Furthermore, horticulture commercialization significantly reduces the likelihood of mild, moderate, and severe food insecurity without accounting for the interaction effects by 4.9%, 5.3%, and 10.9%, respectively. However, when interacting with the SHEP intervention, the reductions in food insecurity are even more pronounced, decreasing by 11.1%, 8.4%, and 40.4% for mild, moderate, and severe food insecurity, respectively (Figure 6.5). This reflects an additional reduction in food insecurity prevalence ranging from 6.2% to 29.5%, underscoring the synergistic effect of horticulture commercialization and the SHEP intervention in improving household food security rather than creating a trade-off. The finding is consistent with studies highlighting that agricultural commercialization improves food security by increasing household income and access to food markets (Ogutu et al., 2020). Moreover, as highlighted by (Linderhof et al., 2019), horticulture commercialization generates income for households, which enhances their purchasing power and ability to

access diverse and nutritious diets. The additional income serves as a synergy, which can be used to buy food items the household does not produce, thereby improving household food security. Thus, commercialization improves household food security and reduces the prevalence of insecurity rather than serving as a trade-off for food security. Moreover, agricultural commercialization can potentially increase the productivity and yields of horticultural crops, thereby significantly increasing food availability and income (Justus et al., 2015). Our findings contrast with those by (Linderhof et al. (2019) and (Mausch et al. (2020), suggesting that commercialization is negatively associated with food security. These studies argue that commercialization can reduce household food availability as farmers often prioritize growing higher-value crops for sale rather than focusing on more nutritious crops for household consumption.

Third, joint decision-making on harvests to sell positively influences food security. Households that practice joint decision-making on harvests to sell have a 14.3% lower probability of being food-secure than those with woman-alone decision-making, regardless of interaction effects. However, after considering the interaction effects, the effects of joint and woman-alone decision-making in the treated group turned positive, leading to a 64.6% and 47.7% higher probability of being food-secure than their counterparts in the control group. This indicates that, although the SHEP intervention primarily focuses on joint decision-making, it also effectively empowers women to participate in household decision-making on harvests to sell. Additionally, these practices significantly reduce the prevalence of food insecurity (moderate, mild, and severe), ranging from 7.9% to 42.3% (Figure 6.5), highlighting the synergistic effect of both joint and women-alone decision-making through the SHEP intervention in improving household food security rather than a trade-off. This finding is consistent with the study by (Mohammed et al., 2023), who found that joint decision-making improves food security. The reason could be that when women independently decide to sell their horticultural harvests, they may prioritize their household's consumption and carefully determine the quantity to sell. This is likely because, in many societies, including Ethiopia, women are culturally and socially viewed as the primary caregivers, often placing the household's nutritional needs first (Kurz & Johnson-Welch, 2001), who reported that women play important roles in promoting and protecting their family members' food intake and nutritional status through the food they produce and process. The role of women in maintaining household food security, as their primary focus, despite their generally lower income levels, is on buffering against household food consumption shortfalls. Even when decisions may be

undertaken jointly within households, women typically bear greater responsibility for supporting food security. Another study also highlighted that when the proportion of women involved in decision-making increases, the share of the household's resources spent on food for their family also increases (Sraboni et al., 2014). In contrast, men usually focus on the market and prioritize sales quantity without considering household consumption (Gebre et al., 2021). As noted by Antriyandarti et al. (2024), women contribute significantly to agricultural-production, often performing labor-intensive tasks such as sowing, weeding, and harvesting. Thus, giving women more control over agricultural decision-making might allow them to optimize horticulture production for household food needs.

Fourth, adopting multiple CSH practices improves household food security, leading to a 15.7% increase in the probability of being food-secure, regardless of the interaction effects. Further, the effect is more pronounced when it interacts with SHEP intervention, to 72.3% with an additional 60.6% improvement for food-secure households in the treated groups compared with their counterparts in the pure control group (Figure 6.5), which shows the synergistic effect of adopting multiple CSH practices through the SHEP intervention in improving household food security rather than a trade-off. These findings align with those of Lipper et al. (2014), who reported that adopting climate-smart agricultural practices likely mitigates the adverse effects of climate variability, stabilizing food production and improving food security outcomes. The SHEP training curriculum advocates farmers to proactively manage agricultural risks (climate change-related risks), particularly by adopting CSH practices. The SHEP's comprehensive training package advocates for the adoption of CSH principles, such as adjustments to irrigation scheduling, utilization of disease-resistant crop varieties, promotion of market-responsive horticultural crop diversification, and optimization of sowing and harvesting timelines; thereby gives synergistic effects on food security. During the operational tasks, the intervention inherently aligns with the climate change adaptation measures pertinent to horticultural risks; for example, in scenarios where irrigation water availability is constrained, the SHEP intervention actively promotes the prudent utilization of existing water resources and encourages farmers to adjust their irrigation schedule. Also, the project enables the diffusion of relevant information regarding the acquisition and selection of inputs, including disease-resistant and improved crop varieties, fostering a conducive environment for implementing CSH practices. Thus, these findings highlight the

synergistic effect of combining market-oriented interventions such as SHEP with climate-smart practices to improve household food security.

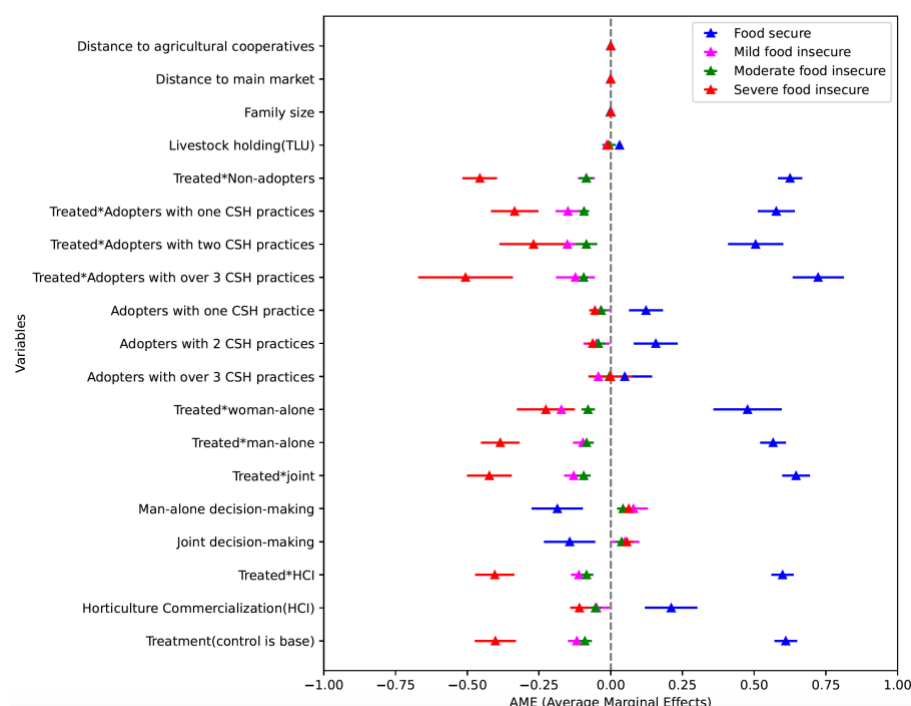


Figure 6-5: Forest plot²⁰ of the covariates that influence household food security

6.8. Summary of Key Findings and Implications

Food security remains a critical challenge in developing countries, particularly for smallholder farmers. This study examined the impacts of horticulture commercialization, gendered decision-making, and climate-smart horticulture practices on household food security in Jimma, Ethiopia. The motivation for this research stemmed from the ongoing debate about the effects of agricultural commercialization, gendered decision-making, and the adoption of CSH practices on food security. For example, while some argue that commercialization improves income and food security, others contend it may reduce crop diversity for home consumption. Additionally, the role of gendered decision-making and the adoption of climate-smart practices in shaping food security outcomes remains unclear, and there is less attention given to whether they have synergistic or trade-off effects. This study sought to address these knowledge gaps and provide evidence-

²⁰ The X-axis delineates the magnitude and direction of each factor's impact on household food security, while the Y-axis lists the covariates used in extended ordered probit estimation. Dots in the figure represent the average marginal effects of each covariate for different food security categories, and the horizontal lines represent the 95% confidence intervals for the average marginal effects. If the confidence interval does not cross the zero line, it suggests that the effect is statistically significant.

based insights for policy formulation. We use data from 409 randomly selected farmers, including participants from the SHEP project. We used an extended ordered probit model with endogenous treatment complemented by inverse probability weighting to address potential endogeneity and selection bias. This robust methodological approach allowed us to isolate the effects of the intervention and associated factors on household food security.

The findings reveal synergistic effects of horticulture commercialization, women-alone and joint decision-making, and climate-smart practices on household food security. Participation in the SHEP project significantly improved food security, with treated households showing a 61% greater probability of being food secure than the control group, representing an effective strategy for reducing food insecurity. Horticulture commercialization in the treated group is associated with a 59.9% increase in the likelihood of being food secure. It also decreases the probability of being severely food insecure by 40.4% compared to the control group. Additionally, joint decision-making in treated households increases the probability of being food secure by 64.6% and reduces the likelihood of being severely food insecure by 42.3% compared to their counterparts in the pure control group. The study further demonstrates that SHEP intervention significantly improves food security through women-alone decision-making, emphasizing that SHEP empowers women in horticulture farming decisions. Adopting climate-smart horticulture practices further enhances food security, especially when paired with the SHEP intervention; farmers utilizing multiple CSH practices are 72.3% more likely to be food secure and 50.6% less likely to experience severe food insecurity than those using fewer practices.

The main policy implication of this study is that scaling up market-oriented extension programs is essential for improving household food security. Specifically, the findings underscore the importance of woman-alone and joint decision-making in enhancing food security so that policies can encourage and facilitate joint participation between couples in agricultural decision-making processes. Moreover, integrating climate-smart horticulture practices such as using an appropriate crop calendar for production and harvesting, using improved disease-resistant varieties, and adjusting the irrigation schedule in horticulture farming is essential, which suggests that these practices should be mainstreamed into agricultural policies and extension services. This could involve developing tailored training programs and investing in research to create and disseminate context-specific climate-smart technologies to improve household food security.

CHAPTER SEVEN: CONCLUSIONS AND POLICY IMPLICATIONS

7.1. Introduction

The welfare of smallholder farmers remains a critical development concern in developing countries, including Ethiopia, where subsistence farming, limited market integration, and climate change continue to pose persistent challenges. In response, Ethiopia has implemented a comprehensive agricultural strategy focused on commercialization, gender-inclusive decision-making, and climate-smart practices. This study conceptualizes farmers' welfare as a multidimensional construct encompassing income, food security, and yield, emphasizing the need to move beyond income alone to include productivity and resilience to shocks. Despite global efforts, such as those outlined in SDG-1 and SDG-2, to eradicate poverty and hunger, food insecurity remains a pressing issue, affecting 29% of the global population and 62.8% in Sub-Saharan Africa as of 2023. Studies consistently show that Africa's food insecurity is more severe than in other regions. To address these challenges, several household-level strategies have been promoted, including market-oriented farming, empowering gender in decision-making, and adopting climate-smart agricultural practices. However, the collective impacts of these strategies, whether synergistic, heterogeneous, or involving trade-offs, remain underexplored, especially within structured interventions. Thus, this study provides comprehensive empirical insights into the collective heterogeneous and synergistic effects of horticultural commercialization, gendered decision-making, and the adoption of climate-smart horticulture (CSH) practices on the welfare of smallholder farmers in the Jimma zone of Ethiopia. Using the Smallholder Horticulture Empowerment and Promotion (SHEP) intervention as a case study. This chapter synthesizes the study's findings and underscores that integrating commercialization, gendered decision-making, and climate-smart horticultural practices, when adapted to local contexts and implemented through structured interventions like SHEP, can generate heterogeneous and synergistic effects that significantly enhance the multidimensional welfare of smallholder farmers.

7.2. The Impact of Commercialization and Gendered Decision-making on Horticulture Income

This study examined the heterogeneous effects of horticultural commercialization and gendered decision-making on the income of smallholder farmers with a specific focus on the role of the SHEP intervention. Using quantile regression, the findings reveal that the interaction between commercialization and the SHEP

intervention yields positive and statistically significant income effects at the lower and middle quantiles (10th, 25th, and 50th). Based on the average horticultural commercialization index (82.3%) in the treated group, an 82.3% increase in commercialization at the 10th, 25th, and 50th income quantiles is associated with an income gain of 10,534.4 ETB (197.6 USD), 13,332.6 ETB (250.1 USD), and 18,435.2 ETB (345.8 USD), respectively, compared to the pure control group. Relative to the national estimate by Okoth et al. (2022), which reported an average annual farm income of 450 USD in Jimma, these horticultural income gains represent 43.9% to 76.8% of total net farm income across the lower quantiles, signaling substantial income improvements among commercially engaged households. This suggests that commercialization through market-oriented extension programs is effective in uplifting relatively poorer farmers, who otherwise face structural barriers to market participation. These farmers likely benefit more from training on market analysis, crop selection, and profitability assessment, as these interventions help them overcome market entry constraints and adopt more strategic production practices. Furthermore, the results indicate that joint household decision-making significantly contributes to increased income at the lower quantiles, reflecting the potential welfare gains from collaborative decision-making processes, especially for economically low-income households. However, the interaction between joint decision-making and SHEP intervention did not produce significant observed income effects, which may be attributed to the behavioral and cultural nature of gender-focused training. Since mindset shifts and household negotiation patterns evolve gradually, the income effects of gender empowerment interventions, particularly those aimed at changing intra-household norms, may require a longer time horizon to fully materialize. The study also finds that proximity to agricultural cooperatives is positively associated with higher income among lower-quantile farmers, highlighting the critical role of collective action institutions in enhancing access to inputs, markets, and information for marginalized producers. Overall, the findings emphasize that income heterogeneity among smallholder horticulture farmers cannot be fully understood through the analysis of average treatment effects alone. Rather, a nuanced understanding of differential impacts across the income distribution is vital. As a result, commercialization and joint decision-making significantly enhance horticulture income among lower-income smallholder farmers, particularly under structured interventions like SHEP. These heterogeneous effects underscore the need for targeted and context-sensitive strategies to uplift economically marginalized households.

7.3. The Impact of the Adoption of CSH Practices on Horticulture Yield

This study rigorously assessed the impact of adopting CSH practices on yield outcomes using the inverse probability weighting regression adjustment (IPWRA) method. The findings reveal a substantial 43% increase in aggregate weighted horticultural yield among adopters compared to non-adopters, underscoring the effectiveness of CSH practices in enhancing productivity. This yield improvement highlights the potential of climate-resilient practices to address production constraints in smallholder farming systems, particularly in the context of horticulture production. Further insights were gained through quantile regression analysis, which revealed that the SHEP intervention is positively associated with horticultural yield across all quantiles, regardless of whether CSH practices were adopted. This consistent positive effect suggests that the SHEP approach contributes to productivity gains beyond specific practices by reinforcing broader agronomic and market-oriented behaviors. Moreover, the interaction effects between the SHEP intervention and specific types of CSH practices yielded nuanced outcomes. The combination of SHEP with the adoption of disease-resistant crop varieties was particularly beneficial, with a pronounced positive effect observed in the upper quantiles (75th), indicating that such integration helps farmers in the higher yield spectrum stabilize and sustain their horticultural production. These results imply that targeted interventions promoting the adoption of improved varieties within structured extension frameworks can significantly benefit relatively better-off farmers in terms of yield. In contrast, the interaction between crop diversification and SHEP exhibited a negative association with yield at the higher quantiles (75th and 90th), deviating from conventional expectations. This finding suggests that not all forms of diversification are equally beneficial. Specifically, the SHEP approach appears to encourage a shift toward market-responsive crop diversification rather than simple expansion of crop varieties. As a result, farmers may cultivate fewer but more commercially viable crops, leading to improved income prospects but potentially lower aggregate yields. Conversely, farmers in the counterfactual group might focus on a wider variety of non-market-responsive crops, resulting in higher physical yields but potentially lower market value. Furthermore, the study found that practices such as using disease-resistant varieties, adjusting crop calendars, and modifying irrigation schedules are crucial for driving yield improvements. These findings emphasize the importance of not only promoting CSH adoption but also tailoring specific practices to the local context and individual farmer profiles. The findings emphasize that adopting CSH practices through market-oriented extension

interventions significantly improves yield, with heterogeneous effects across the yield spectrum. Beyond promoting CSH adoption, the results highlight the importance of tailoring specific practices to local contexts and farmer profiles to support market-responsive and climate-resilient horticultural production.

7.4. Synergy Effects of Household-level Strategies on Food Security

This study further examines the effects of commercialization, joint decision-making, and the adoption of CSH practices on household food security using an extended ordered probit model. The findings reveal that the SHEP intervention plays a crucial role in enhancing food security outcomes by promoting market participation, joint decision-making, and the adoption of CSH practices. The analysis demonstrates that 80.8% of farmers in the treated group who engage in commercialization are food secure, compared to only 21.5% in the pure control group. This significant gap suggests that commercialization through market-oriented extension programs creates a synergistic effect with food security rather than inducing trade-offs that might arise from market risks or reduced subsistence production. In terms of intra-household decision-making, the results further show that 82.9% of households in the treated group, which practices joint decision-making, are food secure, compared to just 18.8% in the pure control group. This finding underscores the significance of joint decision-making in enhancing household welfare, as couples who make joint decisions are more likely to plan, allocate resources, and manage consumption in ways that improve food access and stability. Moreover, the adoption of multiple CSH practices within the treated group is strongly associated with higher food security outcomes than among both pure control group members and farmers who adopted fewer or no practices. This finding reinforces the notion that integrating multiple climate-smart strategies, rather than relying on isolated interventions, amplifies resilience and sustainability in food systems. The study finds that, rather than evaluating each household-level strategy in isolation, integrating commercialization, joint decision-making, and the adoption of multiple CSH practices within a single analytical framework, through structured interventions like SHEP, reveals synergistic effects that significantly enhance household food security.

7.5. Policy Implications

This study highlights the importance of developing integrated, context-specific policy approaches to enhance the welfare of smallholder farmers in Ethiopia. First, emphasis should be placed on promoting commercialization and joint decision-making through market-oriented extension programs to improve

farmers' income. The market-oriented extension interventions (SHEP intervention) have a significant positive impact via promoting commercialization on farmers' income, in which lower-income farmers are more benefited to improve their income than those who have higher incomes. As a result, agricultural interventions should consider the heterogeneity among smallholder farmers and tailor their strategies to meet the specific needs of individual farmers, rather than providing blanket interventions. Second, integrating climate-smart horticultural practices that are tailored to local conditions will boost horticultural crop yields and food security. Policymakers should promote the adoption of practices such as disease-resistant varieties and irrigation adjustments while strengthening institutional linkages to agricultural cooperatives. Additionally, agricultural interventions should intentionally include elements of CSH practices in their training packages and strategies, alongside the standard implementation framework. Lastly, integrating these approaches can create synergies that enhance household food security while minimizing potential trade-offs. These integrated strategies are crucial for achieving sustainable agricultural transformation amid climate uncertainty.

7.6. Research Contributions and Future Research Suggestions

This study contributes to the literature by offering a holistic analysis of the collective and heterogeneous effects of commercialization, gendered decision-making, and climate-smart horticulture practices on farmers' welfare. It moves beyond average treatment effects to explore quantile-based heterogeneity, providing nuanced insights for policy design. The use of a quasi-experimental design, integrating GIS-based spatial matching, represents a methodological innovation for agricultural impact evaluation in the absence of randomized control trial settings. Furthermore, the study offers empirical evidence from horticulture, a relatively under-researched sector in Ethiopia, thereby filling an important gap in agricultural development research. Future studies should consider longitudinal or panel data to capture the dynamic and long-term effects of integrated agricultural interventions. More in-depth research is needed to assess the gendered impacts of joint decision-making over time, particularly in the context of intra-household bargaining and resource allocation. Lastly, assessing the scalability of integrated interventions like SHEP in diverse agroecological and institutional settings would help guide broader national and regional agricultural policy.

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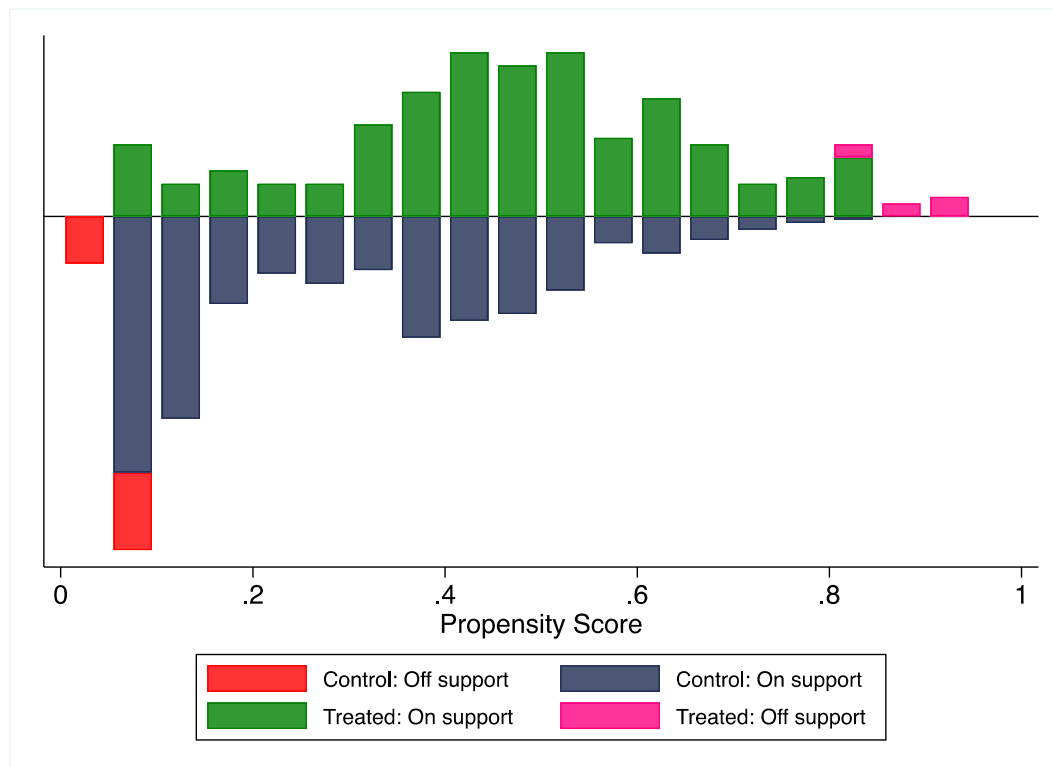
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Appendices

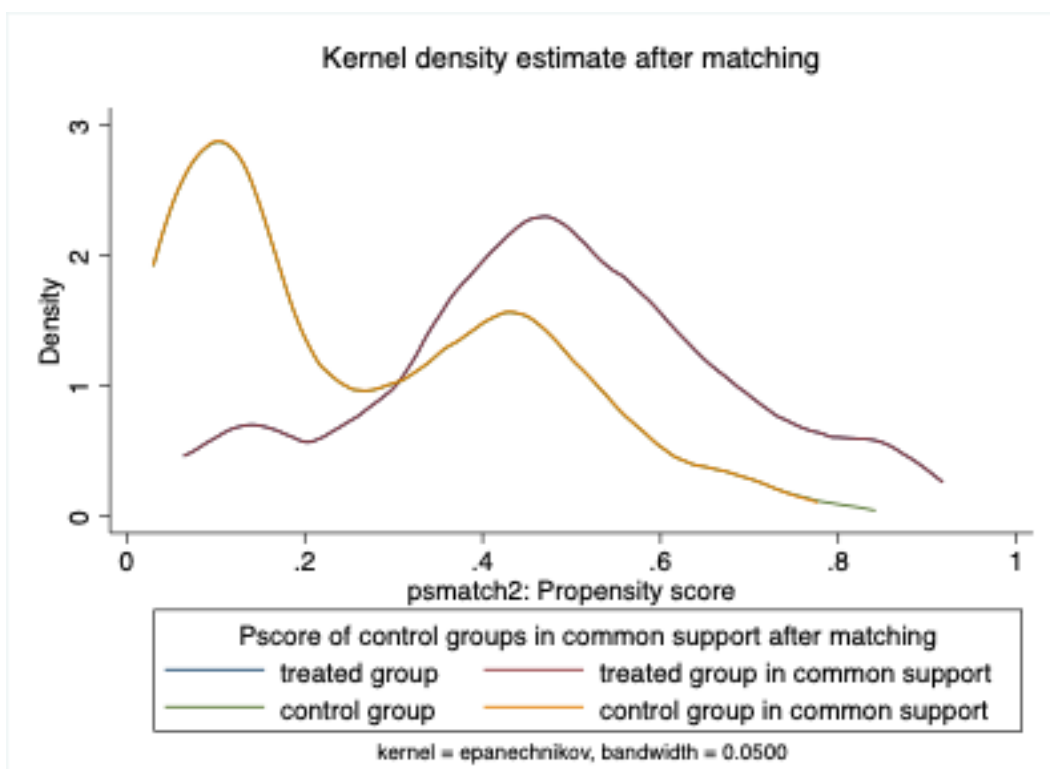
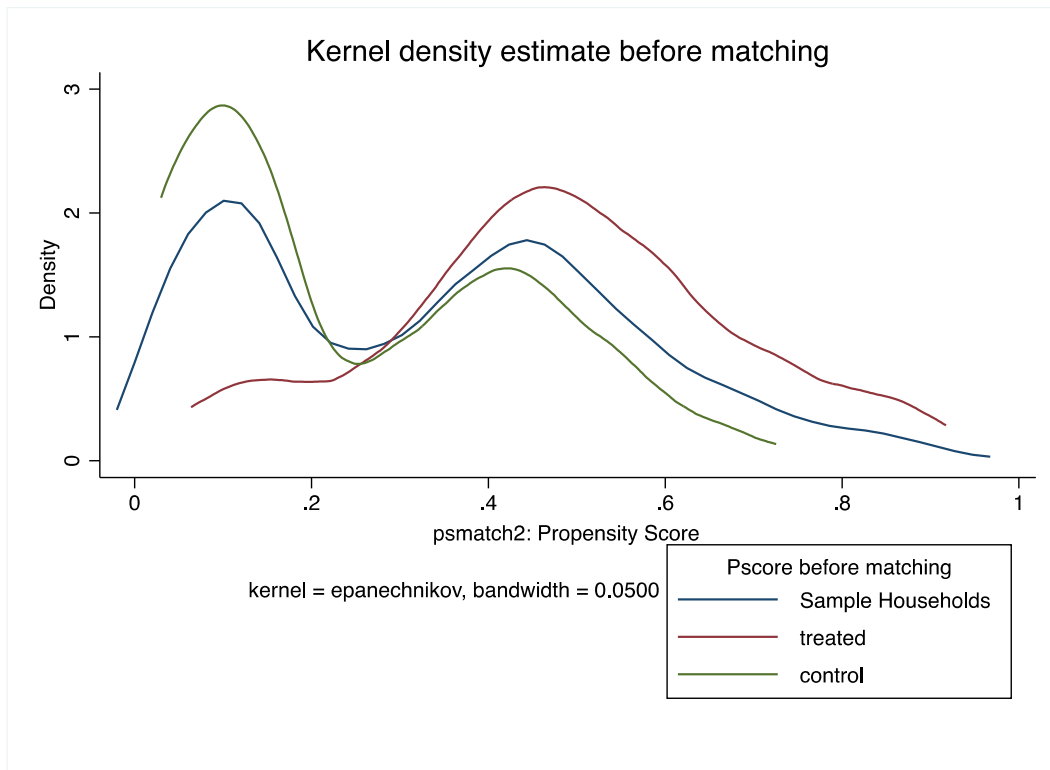
Appendix 3.1: Summary statistics of key attributes (agricultural peculiarities) used in the matching process at *kebele* level for control group identification

Variables	Unmatched Kebeles	Treated Kebeles	Matched Control Kebeles	Matched Pure Control Kebeles
Soil Clay Depth (%)	36.30	46.37	45.15	43.20
Soil Nitrogen Depth (%)	1.61	2.36	2.71	1.70
Soil Carbon Depth (%)	24.91	34.10	39.51	30.54
Soil pH*10	65.17	56.56	56.22	58.69
Distance to nearest major city (km)	317.05	251.43	262.72	214.38
Slope (degree)	6.64	5.71	5.54	5.64
Elevation (m)	1609.33	1803.35	1980.84	1721.97
Distance to River (m)	139442.24	65830.29	65232.33	69727.16
Length road network	1786.18	6425.73	3349.66	4278.63

Appendix 4.1: Propensity score matching estimates (common support assumption) using kernel matching



Appendix 4.2: Common support using kernel density plot before and after matching



Appendix 4.3: Robust check for the hidden bias correction using different matching algorithms

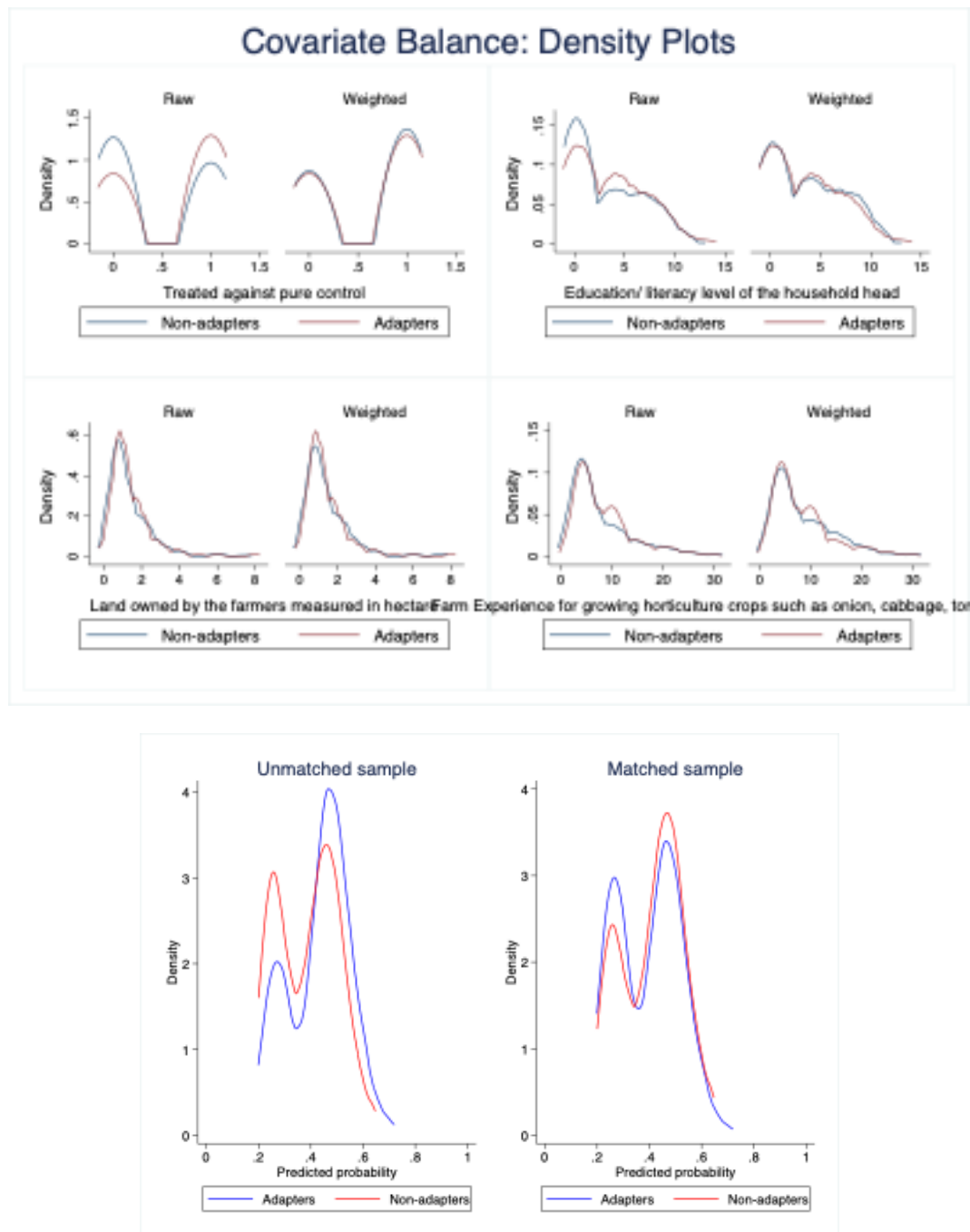
Matching algorithms	Mean bias before matching	Mean bias after matching	% of Bias reduction (in range)	Value of R ² before matching	Value of R ² after matching	LR χ^2 (p-value) before matching	LR χ^2 (p-value) after matching	Off support sample
Nearest neighbor matching	38.4	5.1	48.3% - 100%	0.178	0.006	139.24 (0.000)	3.18 (0.672)	44
Kernel matching	38.4	2.2	74% - 100%	0.178	0.001	139.24 (0.000)	0.46 (0.993)	44
Radius caliper matching	38.4	5.1	48.3% - 100%	0.178	0.006	139.24 (0.000)	3.18 (0.672)	44

Appendix 4.4: Household horticulture income

Lists of income	Treated (T)		Control (C)		Pure control (PC)		T vs C	T vs PC
	Mean	SD	Mean	SD	Mean	SD		
Total agricultural income (ETB/year)	48,526	40,908	39,719	43,521	34,821	32,982	**	***
HH's income from Horticulture (ETB/year)	30,754	33,197	17,842	34,198	19,185	23,876	***	***
IHH's income from fruits (ETB/year)	11,886	15,237	14,781	19,085	6,323	8,179	**	***
HH's income from non-horticulture (ETB/year)	5,885	9925	7,095	13,172	9,313	16,224	-	**
HH's Income from non-farm (ETB/year)	3,583	7,250	4,246	7,478	4,665	7,131	-	-
HH's total income (ETB/year)	52,108	42,531	43,966	44,079	39,487	34,257	**	***
Share of horticultural income in total agricultural income (%)	61.48	28.31	40.17	32.04	49.12	34.25	***	***

Note: HH is household; SD is standard deviation

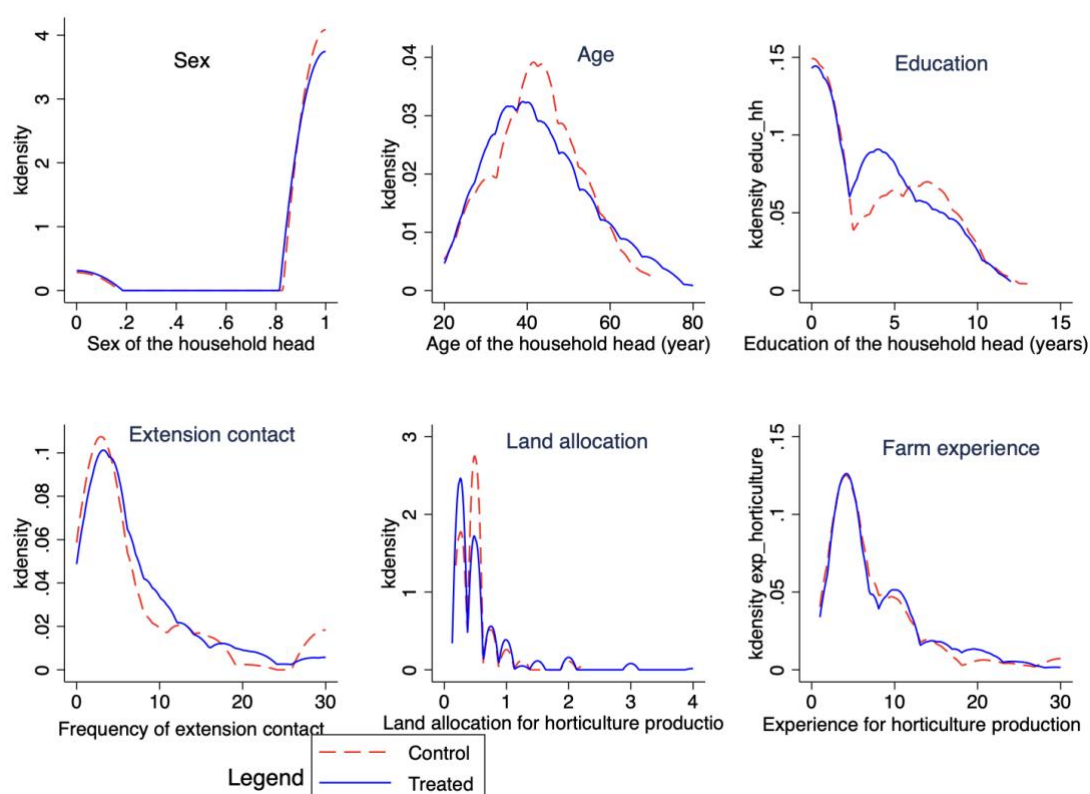
Appendix 5.1: Balancing or distribution of covariates by treatment after inverse probability weighting (IPW)



Appendix 6.1: Definition of food security

Food security conditions	Definition
Food secure household	Who experiences no food insecurity (access) conditions or just experiences worry, but rarely.
Mildly food insecure household	Who worries about not having enough food sometimes or often, and/or is unable to eat preferred foods, and/or eats a more monotonous diet than desired and/or some foods considered undesirable, but only rarely. But it does not cut back on quantity nor experience any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating).
Moderately food insecure household	Who sacrifices quality more frequently by eating a monotonous diet or undesirable foods sometimes or often and/or has started to cut back on quantity by reducing the size or number of meals, rarely or sometimes. But it does not experience any of the three most severe conditions.
Severely food insecure household	Who has graduated to cutting back on meal size or number of meals often and/or experiences any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating), even as infrequently as rarely. In other words, any household that experiences one of these three conditions even once in the last four weeks (30 days) is considered severely food insecure.

Appendix 6.2: Balancing or distribution of covariates by treatment after inverse probability weighting (IPW)



Appendix 6.3: Falsification test for instrumental variables

Variables	Stage-1 Selection into SHEP intervention (probit)	Stage-2 Farmers did not participate in SHEP intervention (ordered probit) Food security prevalence
The road access measured in the number of months passable for vehicles	0.105(0.048) **	0.043(0.048)
Sex of the household head (1 is male)	-0.467(0.323)	1.400(0.444) ***
Education level of the household head in terms of years of schooling	-0.045(0.023) **	0.049(0.025) **
Frequency of extension contact per month	0.055(0.011) ***	-0.012(0.015)
Land size for horticulture production in terms of hectare	0.397(0.199) **	0.051(0.279)
Experience on horticulture production in terms of years	0.096(0.015) ***	-0.007(0.021)
Horticulture commercialization index	1.282(0.296) ***	0.836(0.249) ***
Household decision-making		
Joint decision-making	0.681(0.381) *	-1.289(0.453) ***
Man-alone decision-making	-0.139(0.389)	-1.166(0.446) **
Adaptation of climate-smart horticulture (CSH) practices		
Adopters with one CSH practice	0.133(0.201)	0.437(0.227) **
Adopters with two CSH practices	0.167(0.218)	0.867(0.276) ***
Adopters with over three CSH practices	0.546(0.313) *	0.594(0.510)
Livestock holding in terms of TLU	0.005(0.027)	0.032(0.029)
Family size in the household	-0.089(0.037) **	0.025(0.039)
Distance to main market in minutes by foot	-0.003(0.001) **	-0.000(0.001)
Distance to agricultural cooperatives in minutes by foot	0.004(0.004)	-0.006(0.004) **
Constant	-2.605(0.742) ***	
Cut1		0.232(0.808)
Cut2		0.738(0.812)
Cut3		1.841(0.815)
Wald test	4.72(0.0297) **	1.873(0.818)
LR test	182.24 ***	54.46 ***
Sample size	409	202

Robust standard errors are in parentheses. The selection model is estimated with a probit specification, and the food security model is estimated with ordered probit, whereas * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$.

Appendix 6.4: Questionnaire

General Information

Date of the interview: Date: month: year:

Name of the enumerator/Interviewer:

Address of the enumerator: mobile: email:

Checked by (supervisor name)

Signature for the enumerator _____ signature for the supervisor _____

Location: Region _____ Zone _____ Woreda _____ Kebele/Village _____

GPS location: latitude _____ Longitude _____ Altitude _____

Agroecology of household farm location 1. Lowland 2. Mid-altitude 3. Highland

Do you have any questions for me? Enumerator: pause and respond to any question, then continue with the following statement. May I continue to ask you some questions? Yes No By continuing this interview, you indicate your willingness to participate in the study voluntarily

Part 0: Respondent/Household Identification

1. Identification number of the respondent
2. Sex of the respondents: 1 = Male, 0 = Female
3. Age of respondent in years
4. Education level in years
5. Religion of the respondents 1 = Muslim, 2 = Orthodox Tewahido, 3 = Protestant, 4 = Catholic, 5 Traditional

Part 1: Household and Village identification

1. Sex of the household head _____ (1 = male, 0 = Female)
2. Distance to the nearest village market from residence (km) _____ walking time in minutes
3. Distance to the nearest main market from residence (km) _____ walking time in minutes
4. Distance to the nearest financial institution or credit providers (km) _____ walking time in minutes
5. Number of month's road from resident to the main market is passable for cars in a year _____
6. Average single transport cost (per person) to the main market using a car in ETB _____
7. Distance to the nearest source of seed seller from residence (km) _____ walking time
8. Distance to the nearest source of fertilizer seller from residence (km) _____ walking time
9. Distance to the nearest farmer cooperative from residence (km) _____ walking time
10. Distance to the nearest farmers' training center from residence (km) _____ walking time
11. Distance to the nearest agricultural extension office from residence (km) _____ walking time
12. The total farming experience in years? _____
13. Experience (years) in growing horticulture crops such as onion, cabbage, tomatoes, and potatoes) _____

Part 2: Current Household Composition and Characteristics

Total household members _____ Children _____ Adult Female _____ Adult male _____

Family code	List of Household members	Gender 1 = M 0 = F	Marital status Codes A	Age in years	Education in years	Currently, attending school? 1= yes 2 = no	Relation to household Codes B	What is the Main occupation? Codes C	Labour contribution (women) for vegetable production 2014 E.C (How much time do you work in the field per working day ?) Codes D	How satisfied are you with leisure time for visiting neighbors and relatives? Code E
01										
02										
03										
04										
05										
06										
07										
08										
09										
10										

Codes A 1. Married living with a spouse 2. Married but spouse away 3. Divorced/separated 4. Widowed 5. Never married/single 6. Other, specify.....	Codes B 1. Household head 2. Spouse 3. Son/daughter 4. Son/daughter-in-law 5. Cousin 6. Grandson/daughter 7. mother/Father 8. brother/sister 9. Hired worker 10 Other specify ____	Codes C 1. Agriculture 2. Salaried employment 3. Self-employed off-farm activities 4. Casual laborer on-farm 5. Casual laborer off-farm 6. Student 7. Non-school child 8. Domestic work 9. Other, specify		Codes D 1. from 6:00AM to 6:00PM (early morning to late evening) 2. from 6:00AM to 5:00PM (early morning to early evening) 3. from 8:00AM to 5:00PM (late morning to early evening) 5. from 8:00AM to 6:00PM (late morning to late evening) 6. None 7. others ____ Code E 1= very dissatisfied; 2 = dissatisfied; 3 = neutral, 4 = satisfied; 5 = very satisfied
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Part 3. Number of livestock and ownership in 2021/2022

Livestock type owned by household in 2021/2022	The number available in 2021/22	Who owned this livestock			
		Husband	Wife	Joint	Others family members
Oxen					
Cow					
Calf					
Sheep					
Goat					
Donkey					
Mule					
Horse					
Heifer					
Bees (number of beehives)					
Poultry					
Total number of livestock					

Part 4. Farm Plot Characteristics in 2021/2022

1. Land ownership

- 1) Owned _____ hectare
- 2) Rented-in _____ hectare
- 3) Shared-in _____ hectare
- 4) Total farm size by household _____ hectare

2. Total irrigated farmland owned by household _____ hectare

3. Did you cultivate horticulture crops in 2the 021/2022 production season? 1 = yes; 0 = no

4. Land allocation for horticulture crop production _____ hectare

5. Which crops, vegetables, tubers, fruits, and trees did you grow in 2021/2022

	Name of crop	plant ed area in ha	who mostly managed this crop in the HH?						Who utilizes or uses the profit/return gained from each crop?					
			Backyard vegetable production			Other than backyard (other fields) production			Backyard vegetable production			Other than backyard (other fields) production		
			Men	Women	Joint	Men	Women	Joint	Men	Women	joint	Men	Women	joint
1	Cabbage													
2	Onion													
3	Potato													
4	Sweet potato													
5	Carrots													
6	Tomatoes													

7	Beetroot													
8	Yam/ Taro													
9	Banana													
10	False banana													
11	Chat													
12	Coffee													
13	Mango													
14	Common been													
15	Faba bean													
16	Tef													
17	Wheat													
18	Barley													
19	Maize													
20	Bamboo													

Enumerator read: Now we have some questions about the plots on which your HH planted **Vegetables and tubers** in 2021/2022.

Part 5: Input use for horticulture (vegetables and tubers) crops

A) The input used in horticulture (vegetable, tuber, and root) crop production

1) The input used for men

No	name of vegetable	The land area covered in hectares	Inputs source (seed, fertilizer, herbicide, pesticide) ¹	Seed type ²	quantity of seed use in kg		Price of seed per kg in ETB		Use chemical fertilizer 1= Yes 0 = No	Which chemical fertilizer you used? ³	Quantity of chemical fertilizer you applied per hectare in kg			Frequency of fertilizer use	Use herbicide 1 = yes; 0 = no	Quantity of herbicide used per liter per ha	Price of herbicide per liter	Use pesticide 1 = yes; 0 = no	Quantity of pesticide used per ha per liter	Price of pesticide per liter
					Improved seed	Local seed	Improved seed	Local seed			Urea	DAP	NPS							
1	Cabbage																			
2	Onion																			
3	Potato																			
4	Sweet potato																			
5	Carrots																			
6	Tomatoes																			
7	Beetroot																			
8	Yam/ Taro																			
9	Others																			

1) Seed source: 1 = JICA-SHEP 2 = Own source; 3 = Government; 4 = Trader/private seller; 5 = Other farmers; 6 = Cooperatives; 7 = others _____

2) Type seed: 1 = improved variety seed; 2 = local variety seed; 3 = improved and local varieties seed

3) Types of chemical fertilizer: 1 = Urea; 2 = DAP; 3 = NPS; 4 = Urea and DAP; 5 = DAP and NPS; 6 = all (Urea + DAP+ NPS) fertilizer

⇒ If you were not applying inputs (seed, fertilizer, pesticide, herbicide), what are your main reasons? 1 = Lack of cash; 2 = inputs are not available; 3. = lack of enoughland; 4 = No information about the inputs; 5 = Others ____

⇒ How much you paid for transport cost to transport your chemical fertilizer from the place you purchased to your home in ETB _____

2) The input used for women

No	name of vegetable	The land area covered in hectares	Inputs source (seed, fertilizer, herbicide, pesticide) ¹	Seed type ²	quantity of seed use in kg		Price of seed per kg in ETB		Use chemical fertilizer 1= Yes 0 = No	Which chemical fertilizer you used? ³	Quantity of chemical fertilizer you applied per hectare in kg			Frequency of fertilizer use	Use herbicide 1 = yes; 0 = no	Quantity of herbicide used per ha per liter	Price of herbicide per liter	Use pesticide 1 = yes; 0 = no	Quantity of pesticide used per ha per liter	Price of pesticide per liter
					Improved seed	Local seed	Improved seed	Local seed			Urea	DAP	NPS							
1	Cabbage																			
2	Onion																			
3	Potato																			
4	Sweet potato																			
5	Carrots																			
6	Tomatoes																			
7	Beetroot																			
8	Yam/ Taro																			
9	Others																			

1. Seed source: 1 = JICA-SHEP 2 =Own source; 3 = Government; 4 = Trader/private seller; 5 = Other farmers; 6 = Cooperatives; 7 = others _____

2. Type seed: 1 = improved variety seed; 2 = local variety seed; 3 = improved and local varieties seed

3. Types of chemical fertilizer: 1 = Urea; 2 = DAP; 3 = NPS; 4 = Urea and DAP; 5 = DAP and NPS; 6 = all (Urea + DAP+ NPS) fertilizer

⇒ If you were not applying inputs (seed, fertilizer, pesticide, herbicide), what are your main reasons? 1 = Lack of cash; 2 = inputs are not **available**;

3. = lack of enough land; 4 = No information about the inputs; 5 = Others _____

⇒ How much you paid for transport cost to transport your chemical fertilizer from the place you purchased to your home in ETB _____

3) Input use for joint (men and women)

No	name of vegetable	The land area covered in hectares	Inputs source (seed, fertilizer, herbicide, pesticide) 1	Seed type ²	quantity of seed use in kg		Price of seed per kg in ETB		Use chemical fertilizer 1= Yes 0 = No	Which chemical fertilizer you used? ³	Quantity of chemical fertilizer you applied per hectare in kg			Frequency of fertilizer use	Use herbicide 1 = yes; 0 = no	Quantity of herbicide used per ha per liter	Price of herbicide per liter	Use pesticide 1 = yes; 0 = no	Quantity of pesticide used per ha per liter	Price of pesticide per liter
					Improved seed	Local seed	Improved seed	Local seed			Urea	DAP	NPS							
1	Cabbage																			
2	Onion																			
3	Potato																			
4	Sweet potato																			
5	Carrots																			
6	Tomatoes																			
7	Beetroot																			
8	Yam/ Taro																			
9	Others																			

1) Seed source: 1 = JICA-SHEP 2 = Own source; 3 = Government; 4 = Trader/private seller; 5 = Other farmers; 6 = Cooperatives; 7 = others _____

2) Type seed: 1 = improved variety seed; 2 = local variety seed; 3 = improved and local varieties seed

3) Types of chemical fertilizer: 1 = Urea; 2 = DAP; 3 = NPS; 4 = Urea and DAP; 5 = DAP and NPS; 6 = all (Urea + DAP+ NPS) fertilizer

⇒ If you were not applying inputs (seed, fertilizer, pesticide, herbicide), what are your main reasons? 1 = Lack of cash; 2 = inputs are not available; 3. = lack of enough land; 4 = No information about the inputs; 5 = Others ____

⇒ How much you paid for transport cost to transport your chemical fertilizer from the place you purchased to your home in ETB _

Labor for horticulture production

No	name of vegetable	Male family labor in terms of man day per activity			Female family labor in terms of man day per activity			Male hired labor in terms of man day per activity				Female hired labor in terms of man day per activity			
		Pre- plant	plant	Harvest	Pre-plant	plant	Harvest	Pre-plant	plant	Harvest	Amount of daily wage paid in ETB	Pre-plant	plant	Harvest	Amount of daily wage paid in ETB
1	Cabbage														
2	Onion														
3	Potato														
4	Sweet potato														
5	Carrots														
6	Tomatoes														
7	Beetroot														
8	Yam/ Taro														
9	Others														

NOTE: Male and female family labor work hours per hectare suppose to the adult family member of the households ☐ child labor is not considered as input for horticulture production.

Part 6: Household Decision making and labor division for vegetable production and marketing

Remark: Please tick the numbers in the five-point response to indicate the extent to which you involve in decision-making for each activity in vegetable production and marketing.

1= no involvement; 2 = very few involvements; 3 = some involvements; 4 = most involvements; 5 = full involvement

	Production and marketing activities of vegetables in 2021/2022	Men					Women					Joint (husband, wife, and adult family members)				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	Who owned vegetable farmland in the household?															
	The extent of involvement in activity #1?															
2	Who managed vegetable farmland in the household 2021/22?															
	The extent of involvement in activity #2?															
3	Who decided on vegetables to produce in 2021/22?															
	The extent of involvement in activity #3?															
4	Who prepared the land for vegetable production?															
	The extent of involvement in activity #4?															
5	Who plants vegetables in the household?															
	The extent of involvement in activity #5?															
6	Who decides on agricultural inputs (fertilizer, seed, credit) to use?															
	The extent of involvement in activity #6?															
7	Who harvested vegetables in the household?															
	The extent of involvement in activity #7?															
8	Who collected the harvested vegetable?															
	The extent of involvement in activity #8?															
9	Who decides on vegetables to sell?															
	The extent of involvement in activity #9?															
10	Who sold vegetables in the market?															
	The extent of involvement in activity #10?															
11	Who retains/ received money from vegetable sales?															
	The extent of involvement in activity #11?															
12	Who decides the utilization/ allocation of money received from vegetable sales?															
	The extent of involvement in activity #12?															

Part 7: Production and marketing of horticulture crops

- Did you have access to vegetable market price information? 1 = Yes; 0 = No
 - If yes, in your household, who heard market information first? 1. Wife
2. Husband 3. Adult family members 4. Others -----
 - What was your source of vegetable market information?
- For which market you sold your vegetable? 1 farm gate 2. Village market 3. Main market 4. Others ____
- Amount sold in quintal at 1. Farm gate ____ 2. Village market ____ 3 main market 4. Others ____
- In which month you sold _____
- Means of transportation to the market _____
- Total transportation cost to market per Qt/kg/ _____

7. Who is the main buyer of your products? 1.= Consumer/other farmer; 2 = Rural assembler; 3 = Retailers;4 = Wholesaler; 5 = Cooperative
8. What is your relationship with buyer? 1 = Relative; 2 = Friend; 3 = Money lender; 4 = Long term buyer; 5 = Others _____
9. Please fill the following tables about the production and marketing value of horticulture crop

					Man			Woman			Joint		
No	name of vegetable	The land area covered in hectares	The amount harvested in Quintal	Amount consumed at home per week	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ¹	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ⁴	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ¹
1	Cabbage												
2	Onion												
3	Potato												
4	Sweet potato												
5	Carrots												
6	Tomatoes												
7	Beetroot												
8	Yam/ Taro												
9	Others												

1. Market name/ type: 1 = Central market; 2 = main market; 3 = local or village market

10. Did you sell other crops other than horticulture crops in 2021/22? 1 = Yes; 0 = No
11. If your answer for question (10) is yes, please answer the following table about the crop types and amount of you sold in 2021/22?

					Man			Woman			Joint		
No	Types of non-horticulture crops	The land area covered in hectares	The amount harvested in Quintal	Amount consumed at home per week	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ¹	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ⁴	Amount sold in the market in Quintal	Price per quintal in ETB (use farm get price)	Name of market ¹
1	Banana												
2	False banana (Inset)												
3	Chat												
4	Coffee												
5	Mango												
6	Common bean												

7	Faba bean												
8	Wheat												
9	Barely												
10	Tef												
11	Maize												
12	Bamboo												
13	Eucalyptus												
14	Avocado												
15	Cassava												
16	Ginger												
17	Groundnuts												
18	Other1												
19	Other2												
20	Other3												

	Type of crop	Man		Woman		Joint	
		Amount sold in Qt	Price per Qt	Amount sold in Qt	Price per Qt	Amount sold in Qt	Price per Qt
1	Banana						
2	False banana (Inset)						
3	Chat						
4	Coffee						
5	Mango						
6	Common been						
7	Faba bean						
8	Wheat						
9	Barely						
10	Tef						
11	Maize						
12	Bamboo						
13	Eucalyptus						
14	Avocado						

15	Cassava						
16	Ginger						
17	Groundnuts						
18							
19							
20							
21							

If you are not cultivating vegetables and tubers at all, what are your main reasons? (Give rank if your answer will be more than one reason). 1 = Lack of cash to buy seed; 2 = Seed not available; 3 = Susceptible to disease/pests; 4 = no irrigation water; 5 = Lack of enough land; 6 = No information about vegetable; 7 = No market; 8 = Drought/rainfall shortage; 9 = Others

12. Do you have source of income other than you're farming in 2021/22? 1. Yes 2. No

13. If yes, what is source of your non-farm (other) income? 1 = petty trade; 2 = fuel wood/ charcoal selling; 3 = seasonal labor migration; 4 = fishing, 5 = remittances; 6 = NGO project; 7 = others

14. Amount received from non-farm (other sources) in ETB _____

Part 8: Contract farming

- Did you make an agreement with your buyer regarding the quantity that should be delivered? 1 = yes; 0 = no
- If yes, are these agreements written down? 1= yes; 0 = no
- Did you make an agreement regarding the price? 1= yes; 0 = no
- If yes, are this agreement written down? 1= yes; 0 = no
- Did you negotiate with your buyer? 1= yes; 0 = no
- Did you make agreement regarding the delivery date? 1= yes; 0 = no
- If yes, are these agreements written down? 1= yes; 0 = no
- Did you make agreements regarding the quality? 1= yes; 0 = no
- If yes, are these agreements written down? 1= yes; 0 = no
- When do you receive your money? 1 = at the delivery date; 2 = later; 3 = before delivery date;

11. If later, when exactly? 1 = after a day; 2 = after one week; 3 = after two weeks; 4 = after three weeks; 5 = after a month; 6 = after a season; 7 = other, specify _____
12. Do you always receive your money the day the buyer promised you? 1 = yes; 0 = no
13. Does your buyer always buy the total amount of vegetables you have or just a part?
1 = yes; 0 = no

Part 9: Finance Access

1. Did anyone in your home have credit access for horticulture farming? 1. Yes 0 = No
2. Who made the decision to receive credit? 1 = Wife; 2 = Husband; 3 = Others HH member _____
3. If yes, who received credit from your household members? 1. Wife 2. Husband 3. Jointly (wife and husband) 5 = adult household members
4. What is the source of that credit? 1 = farmer lending group; 2 = Microfinance; 3 = NGO; 4 = vegetable traders; 5 = Bank; 6 = Others _____
5. Do you have an existing loan for vegetable production purposes? 1 = yes; 0 = no
6. If your answer to question #6 is yes, please fill the following table accordingly

# Sources of credit		# Loan amount you borrowed			The interest rate in %	Loan period in # months
	In-cash	In-kind		Year of credit took and signed the agreement		
		Name of equipment	Estimated price in			
Farmer lending group						
Microfinance						
NGO						
Vegetable traders						
Bank						
Others						

7. If your answer to question 6 is no, why you did not use credit? 1 = no need to borrow loan; 2 = high interest rate; 3 = Unavailability of credit on time; 4 = shortage of money for down payment; 5 = the repayment time is short; 6 = lack of collateral; 7 = the credit providers are far from my residence; 8 = others _____

Part 10: Extension Services and training Access

1. Did you /farmer/household head/ contact with development agent in 2021/22? 1. Yes, 2. No
 - a. If yes, how many times you contacted with government extension (DAs) in 2021/22? On horticulture production? _____
 - b. If no for question 1, what was your reasons? _____
2. Have you attended any farm demonstration field in your village before (in) 2021/22? 1. Yes 2. No
3. Have you attended any farm demonstration field outside your village before (in) 2021/22? 1. Yes 2. No
 - a. If yes, who attended the demonstration farm in your household? 1. Wife 2. Husband 3. Adult household members 4. Others specify _____
 - b. If no, what was your reasons? _____
4. Did anyone among your household members participate in farmer training center (FTC)

before (in)2021/22? 1. Yes; 2. No

5. If your answer for question #4 is yes, who participated from your household members?
1. Wife 2. Husband 3. Adult household members 4. Others specify _____
6. If your answer for question #4 is no, what was your reason?
7. Are you a SHEP project member? 1 = yes; 0 = no
8. If your answer for question #7 is yes, when you were getting a membership in SHEP? ____ years
9. If your answer for question #7 is yes, among your household members, who frequently participate during SHEP training? 1 = wife; 0 = husband; 3 = joint; 4 = other household members
10. If your answer for question #7 is yes, which training they participated? Please fill the following table accordingly

		Degree of involvement/ participation 1 = Rarely; 2 = Sometimes; 3 = Often			Did this training helpful for your horticulture farming? (1 = yes; 0 = no)			Who mostly managed each activity in your HH? (1 = yes; 0 = no)		
		M	F	Joint	M	F	Joint	M	F	Joint
No	Training content									
1	Sensitization workshop (need assessment training)									
2	Meeting the stakeholders (financier, input suppliers, traders, etc.)									
3	Market survey training									
4	Technical training (crop agronomy packages including post-harvest handling)									
5	Gender mainstreaming training									
Farming practice (In-field training)										
7	Nursery establishment									
8	Crop establishment									
9	weeding/pest/disease management									
10	Crop management/ fertilizer application									
11	Harvest training: post-harvest handling									
12	Sale									
13	Calculation of profit margin									
14	Others									

Part 11. Membership in other horticultural projects and wheat policy

1. Are you (your household) is a member of any horticultural projects (other than SHEP)?
1) yes 2) no
2. if yes, what is name of the horticultural project? _____

3. Number of years (months) participated in horticultural project/s?
4. Have you received inputs from the projects other than SHEP? 1 = yes, 0 = no
5. If you received inputs, what types of inputs you received from the project? _____
6. Did you convert vegetable-growing land into wheat production? 1) yes 2) no
7. if yes, the amount of land areas converted from vegetable production into wheat production in hectare _____
8. if no, do you have a plan to convert horticultural land into wheat production? 1) yes 2) no
9. if yes, the amount of vegetable production area planned to convert for what production in hectare _____

Part 12: Social Capital and Networking

Participation in informal/informal institutions

	Institution type	Are you (HH) currently a member of any of the following groups? 1. yes 2. No	If yes, who is the member? 1. Husband 2. Wife 3. Jointly	Role in the group 1 = leader/chair 2 = Committee 3 = member	Years joined
1	Saving and credit association				
2	Input supply/farmer cooperative				
3	Seed producer group/cooperative				
4	Women's Association				
5	Youth association				
6	SHEP-JICA group				
7	Government team				
8	Water user associations				
9	Transporters				
10	Buyers (middlemen or traders)				
11	Other NGO, team (give name)				

Part 13: Farmer's perception

- 1) Will you continue growing (adopting) these vegetables in the future? 1 = Yes; 0 = No
- 2) If not continue growing vegetable (dis-adopt) crops for future, what is your reason _____
- 3) What kind of indigenous knowledge/ techniques do you apply in your horticulture farming? 1 = use local seed or variety; 2 = pests and diseases management (use trapping,

scaring, use ash); 3 = use local storage methods or facilities; 4 = use bucket irrigation; 5 = land preparation like burn crop residue in the plot; 6 = use manure as a fertilizer; 7 = others

- 4) How do you see the productivity of (Qt/ha) of vegetables you produced in the last five years? 1. Increasing 2. No change or constant 3. Decreasing
- 5) How do you see the income you got from the sale of vegetables in the last five years? 1. Increasing 2. No change or constant 3. Decreasing
- 6) Do you believe Cultural beliefs influence you to access and control resources? 1 = yes; 2 = no
- 7) Do you perceive there is an equal share of roles and responsibilities in terms of decision-making in the household after joining the SHEP project? 1 = yes; 2 = no
- 8) If your answer to question 7 is no, who is the most influential decision-maker in the household? 1 = husband; 2 = wife; 3 = adult family members
- 9) Do you believe there is gender transmission due to getting frequent gender mainstreaming training through SHEP? 1 = yes; 2 = no
- 10) If your answer to question 9 is yes, how do you express this mindset change or transmission? ____

Part 14: Asset and investment accumulation

1. Do you have any investments for the last five years? 1 = yes; 0 = no
2. If your question is 'yes', what type of investment do you have? 1 = poultry farm; 2 = dairy farm; 3 = small-scale irrigation equipment; 4 = cash money saved in the bank 5 = new house; 6 = teaching my children; 7 =
3. What type of small-scale irrigation equipment do you have? 1 = generator; 2 = irrigation pipes, 3 = drip tubing; 4 = pesticide or herbicide sprayer
4. Who controls those investments among the household members? 1 = husband/ man 2 = wife/ woman; 3 = joint by husband and wife; 4 = men members of the household; 5 = women members of the household
5. Based on question 4, how much input/involvement did you have in making decisions to control your asset/ investment? 1 = no involvement in decisions; 2 = very few involvements in decisions; 3 = some involvement in decisions; 4 = most involvement in decisions; 5 = full involvement in decisions
6. Do you think the JICA project/ intervention helped you to run this investment (your existing investment)? 1 = yes; 0 = no
7. If your response to question #6 is yes, how do you perceive your mindset change due to the SHEP approach? 1. Totally unacceptable 2. Unacceptable 3. Slightly unacceptable 4. No change 5. Slightly acceptable 6. Acceptable 7. Perfectly acceptable
8. Do you feel happy since you're a horticulture-growing farmer and a beneficiary of the SHEP project? 1 = yes; 0 = no
9. If your response to question #8 is yes, how do you rate your level of happiness? 1 = very unhappy, 2 = unhappy, 3 = indifference, 4 = happy, and 5 = very happy
10. Do you feel satisfied in your life because of growing horticulture and being a beneficiary of the SHEP project? 1 = yes; 0 = no
11. If your response to question #10 is yes, how do you rate your level of life satisfaction? 1 = not satisfied at all, 2 = not satisfied, 3 = indifference, 4 = satisfied, and 5 = very satisfied
12. Do you have any adaptation strategies for adapting to agricultural risk 1 = yes; 0 = no

13. If your answer to question (11) is yes, what type of adaptation mechanism have you applied? 1 = use insurance, 2 = use disease-resistant variety; 3 = change irrigation schedule; 4 = change sowing and harvesting date; 5 = switch from horticulture farm to cereal crop production or animal rearing or non-farm activities; 6 = reduce the number of horticulture crop planting; 7 = diversify horticulture crops in the same season; 8 = others
14. Do you have insurance? 1 = yes; 0 = no
15. If you used insurance, what type of insurance you have used? 1 =crop-index insurance; 2 =weather-index insurance; 3 = others
16. How many years do have insurance that you told us above? Years
17. Have you received weather index insurance-related training? 1 = yes, 0 = no
18. For which crop you purchased weather index insurance? 1 = cereal crops, 2 = vegetable crops, 3 = perennial trees, 4 = livestock, 5 = other
19. How much is the annual payment for the insurance? Birr/years

Part 15: Food Security

Enumerator read: The interview is almost over. Thank you so much for your patience. Now, I have some questions about the food security situation of your household. This is some questions about the food security situation of your household in the last four weeks, that is, between [DATE four weeks earlier] and [the DATE yesterday].

No.	Question (Instructions)	Response	Code
1	In the past four weeks, did you worry that your household would not have enough food?	No (Skip to #3)	0
		Yes (Continue to #2)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
2	In the past four weeks, were you or any household member not able to eat the kinds of food you preferred because of a lack of resources?	No (Skip to #5)	0
		Yes (Continue to #4)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
3	In the past four weeks, did you or any household member have to eat a limited variety of food due to a lack of resources?	No (Skip to #7)	0
		Yes (Continue to #6)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
4	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	No (Skip to #9)	0
		Yes (Continue to #8)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
5	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	No (Skip to #11)	0
		Yes (Continue to #10)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3

No.	Question (Instructions)	Response	Code
6	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	No (Skip to #13)	0
		Yes (Continue to #12)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
7	In the past four weeks, was there ever no food to eat of any kind in your household because of a lack of resources to get food?	No (Skip to #15)	0
		Yes (Continue to #14)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
8	In the past four weeks, did you or any household member sleep hungry at night because there was not enough food?	No (Skip to #17)	0
		Yes (Continue to #16)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	No (end the interview)	0
		Yes (Continue to #18)	1
	How often did this happen?	Rarely (once or twice in the past 4 weeks)	1
		Sometimes (3 to 10 times in the past 4 weeks)	2
		Often (more than 10 times in the past 4 weeks)	3