ANALYSIS OF PASTORAL LIVELIHOODS DIVERSIFICATION AND FOOD SECURITY IN ASSAITA AND AFAMBO WOREDAS, AFAR REGIONAL STATE, ETHIOPIA

BY

FISSEHA ABENET

FEBRUARY 2025

ADDIS ABABA

COLLEGE OF DEVELOPMENT STUDIES CENTER FOR FOOD SECURITY STUDIES

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ADDIS ABABA

Declaration

This MSc thesis is my original work and has not been presented for a degree in any other university.

Name of Candidate	Date	Signature

This thesis for MSc research has been submitted for examination with my approval as university supervisor.

Name of Advisor	Date	Signature

Thesis Approval Page

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ABBREVIATIONS

ABCD	Asset-based Community Development
ASALS	Arid and Semi-arid Lands
CSA	Central Statistical Authority
CSI	Copping Strategies Index
DFID	The UK Department for International Development
EEPRI	Ethiopian Economic Policy Research Institute
ETB	Ethiopian Birr
FAD	Food Availability Decline (theory)
FAO	Food and Agriculture organization of the United Nations
FCS	Food Consumption Score
FED	Food Entitlement Decline (theory)
FRT	Food Regime Theory
GATT	General Agreement on Tariffs and Trade (GATT),
HFIAS	Household Food Insecurity Access Scale
HFIAS	Household Food Insecurity Access Scale
IBRD	International Bank for Reconstruction and Development
IFAD	International Fund for Agricultural Development
MILL	Ministry of Irrigation and Lowlands
MoA	Ministry of Agriculture
MoWE	Ministry of Water and Energy
NGOs	Non-governmental Organizations
OCHA	United National Office for the Coordination of Humanitarian Affairs
OECD	Organization for Economic Cooperation and Development
OECD	Organization for Economic Cooperation and Development
PENHA	Pastoral and Environmental Network in the Horn of Africa
PSA	Propensity Score Analysis
PSA	Proportional Propensity Score Analysis
PSNP	Productive Safety Net Programme

RBA	Rights-based Approach
SDG	Sustainable Development Goals
SLDI	Simpson's Livelihoods Diversity Index
SLF	Sustainable Livelihoods Framework
SLF	Sustainable Livelihoods Framework
TLU	Tropical Livestock Unit
UK	United Kingdome
UK	United Kingdon
UNDP	United Nations Development Programme
US	United States
WB	World Bank
WFP	United Nations World Food Programme
WTO	World Trade Organization

ABSTRACT

Livelihood diversification is a key strategy for enhancing food security in pastoral and agro-pastoral communities. This study explored the structure of pastoral livelihoods, determinants of diversification, and associated food security outcomes. Mixed methods were employed, including focus groups, key informant interviews, and analytical tools such as Simpson's Livelihood Diversity Index (SLDI), Household Food Insecurity Access Scale (HFIAS), and Food Consumption Score (FCS). Quantitative analysis involved descriptive and inferential statistics: multinomial logistic regression, Firth's penalized logit, Probit regression, and Weighted Propensity Score Analysis. Primary livelihood activities included livestock production (51%), crop production (6%), labor (4%), small businesses (8%), miscellaneous income (56%), and remittances (34%). Based on income, SLDI was low (76%), moderate (22%), and high (2%); based on expense, it was low (58%), moderate (28%), and high (13%), suggesting expense as a more sensitive proxy for identifying diversification. Probit regression indicated that access to irrigation, goat ownership, and larger farm size increased diversification likelihood by 12%, 13%, and 10.9%, respectively ($p < 0.05$). A reduced model highlighted irrigation (17%), miscellaneous income (35.5%), and farm size (9.6%) as significant contributors ($p < 0.05$). Although crop production, small businesses, and miscellaneous income had high marginal effects, they were not statistically significant ($p > 0.05$). Age, gender, and TLU had weak negative effects. The full Probit model explained 96.8% of the variance in diversification, with 90.4% sensitivity and 98.5% specificity. Firth's penalized logistic regression found significant positive effects from crop farming (16.5), livestock production (7.6), small businesses (7.3), miscellaneous activities (11.0), and PSNP participation ($p < 0.05$). HFIAS indicated mild (42%) and moderate (11%) food insecurity with no severe cases. FCS showed poor (55%), borderline (39%), and acceptable (6%) consumption. While diversification showed no significant effect on HFIAS ($p > 0.05$), it significantly improved FCS by 4.8 units ($p < 0.05$; $R^2 = 0.038$). In conclusion, households showed low income and diversification levels with generally poor food security. Diversification did not significantly affect food access (HFIAS) but had a positive impact on dietary quality (FCS). Enhancing off-farm enterprises and optimizing existing livelihood streams, particularly crop and livestock production, can improve diversification, though it alone does not ensure food security across all measures.

Key words: *pastoralism, livelihoods, diversification, income, food security*

Chapter One: Introduction

1.1. Background and justification

The Afar Region of Ethiopia is predominantly inhabited by pastoral and agro-pastoral communities who rely on livestock and small-scale agriculture for their livelihoods (PENHA, 2019; Davies and Bennett, 2007). The region is characterized by an arid and semi-arid climate, receiving low and erratic rainfall, which poses significant challenges to traditional livelihood practices (Davies and Bennett, 2007). In particular, the Afambo and Assaita woredas face heightened vulnerabilities due to recurrent droughts and limited access to essential resources, exacerbating food insecurity. These challenges underscore the critical need to explore livelihood diversification strategies to enhance food security and build resilience against climatic and socio-economic shocks. This necessity has motivated this research into how alternative and diversified income-generating activities could improve food security outcomes in these communities.

Because subsistence crop production is only marginally feasible due to climatic uncertainties and variabilities, pastoral communities heavily depend on livestock for their sustenance, income, and also cultural identity for many centuries (Dong, 2016; Scoones and Nori, 2023). Despite the fact that the pastoral production system in the arid and semi-arid regions has sustained millions of people (Tiwari et al., 2020; Li et al., 2022), it is increasingly evident that the system became highly vulnerable to climate-induced challenges Some of these challenges include recurrent drought, land degradation, feed and water scarcity, disease outbreaks. In addition to these, man-made challenges including: lack of markets and support services, poor infrastructure, conflicts over scarce resources, frequently threaten the customary or traditional pastoral way of life and food security (Schmidt and Pearson, 2016; Tolossa, 2018; Birhanu et al., 2024). These complex blends of these natural and man-made factors have made the viability of conventional pastoral livelihoods more and more challenging, exposing millions of people to food insecurity (Aliyu et al., 2021).

Food security, especially in agrarian systems, is influenced and driven by several factors including development policies and strategies (Munck, 2024), sustainable management of natural resources (mainly, land and water), (Nhamo et al., 2020), climatic related challenges (Lee et al., 2024), peace

and security (John, 2024), markets and infrastructure development (Hamadjoda et al., 2024), and a number of other cultural, social, economic, environmental and political factors (Baker et al., 2021; Wudil et al., 2022).

Due to the above compounding problems, several efforts continue to be made at national, regional and international scope. In fact, ensuring sustainable livelihoods and improvement of food security are at the highest notch of the development discourse at all levels and in all continents of the world (FAO et al., 2023; Varzakas and Smaoui, 2024).

There are several intellectual frameworks and theories underpinning livelihoods and food security which have evolved over the past decades (Mabon et al., 2021; Akbari et al., 2022). The most salient food security theories and concepts can be categorized into one or more of the following typologies, as: resource and production-oriented theories (eg. Malthusian, optimistic, food availability decline and climate theories), human rights-oriented (eg. food sovereignty and food entitlement theories) and political economy and livelihoods-based theories (eg. Sustainable livelihoods framework, political economy approach, food regime and conflict theories).

The contemporary thought on the subject of food security has recently shifted to a food systems approach (Galankis, 2024; Suarez and Ume, 2024). This apparently new approach, unlike the livelihoods approaches (which focus on micro-level analysis) recognizes the interconnections within the entire food system, from production to consumption, including aspects like sustainability, nutrition, and social equity and inclusivity (Kvasha et al., 2024). This study is mainly based on the sustainable livelihoods approach which offers a multidisciplinary view of food security involving the human, social, physical, economic, and natural or ecological aspects at household scale (Zoomers, 2014; Fraval et al., 2018; Mulusew and Mingyong, 2023).

1.2. Statement of the problem

The Afar Regional State faces significant challenges regarding livelihoods and food security. Studies indicate that high rate of food insecurity exist among communities in Afambo where 72.7% household energy consumption was less than 2100 Kcal (Kahsay, et al., 2020). Another research

report including Assaita woreda indicated that about 50% of 2295 households surveyed, were impoverished, with food poverty more prevalent among pastoralist households (36%) compared to agro-pastoralists (30%). The same study also highlighted a high income-inequality (Gini coefficient of 0.592) within these communities PENHA (2019). Both Afambo and Assaita woredas, which used to be one and the same woreda in the past, have many similarities in terms of livelihoods, natural resources and livelihood opportunities, food security and demographic context where it is estimated that 20.2% of the population are urban dwellers, 43.5%, pastoralists and 33.5% agro-pastoralist (CSA, 2016). At the back ground of the above situation, the current study therefore, focusses on exploring the status of livelihoods diversification as this is also a critical indicator of household income and hence food security status at household level.

Livelihood diversification has been a dominant theme in pastoral development discourse across Ethiopia and the Horn of Africa for decades (Headey et al., 2014; Gebeye, 2016; Matsuura et al., 2023; Hertel et al., 2023; Tugjamba et al., 2023). It has been widely promoted as a crucial element of broader economic diversification, aimed at reducing vulnerability to external shocks and serving as a potential catalyst for long-term economic growth and food security (Natarajan et al., 2022). The concept has three broader dimensions: i) expanding economic opportunities for employment and production, ii) engaging in trade (including export markets), and iii) broadening income sources while reducing expenditure or enhancing savings (Dagunga et al., 2020).

While many studies indicated that livelihoods diversification, both in the urban and rural setting, has a positive link and significant impact on household food security (Olutumise et al., 2021; Nyathi and Ndlovu, 2022; Alamneh et al., 2023), others question its actual impact on food security (Upton, 2016; Sulieman and Young, 2023). To this effect, through the government, UN agencies, NGOs, bilateral and multi-lateral donors, many policies, strategics and programs with substantial investments have been implemented in the pastoral areas of Ethiopia (Gebeye, 2016) and the Horn of Africa in general (Catley et al., 2013; Fratkin, 2013; Link et al., 2020; Scoones and Nori, 2023).

However, several empirical evidences on pastoral livelihoods have shown growing inequalities, increasing food insecurity, poverty, increasing environmental degradation and thus, livelihoods vulnerability (Catley et al., 2013; Achiba, 2018; Tolossa, 2018; Byakagaba, 2020; Timpong-Jones

et al., 2023; Dalley, 2024). Research in the Borana pastoral region, indicated that 10% of households control 60% of all livestock, highlighting a trend of increasing wealth concentration over the years (Coppock et al., 2018). The negative impacts of ill-informed and ill-designed pastoral development practice have also been reported by Schmidt and Pearson (2016), Gebeye (2016), Caravani (2019) and Akall (2021; Goshu and Gebre, 2024),

Inconsistent and divergent information in the development literature on the food security outcome of livelihoods diversification in pastoral areas, is the source of our problem statement based on which our research questions were formulated. While the extent and drivers of livelihood diversification are fairly well explored, strong evidences on its food security impact are not widely available. This is why the link between livelihood diversification and household food security remained debatable (Dagunga et al., 2020). In practice, the gradual dissolution of pastoralism in to other forms of livelihoods have rather been criticized as a cause for inter and intra household inequalities, leading to exploitative and extractive economies (Caravani et al., 2019). Many livelihood diversification initiatives have not resulted in universal benefits in terms of food security (Asfaw et al., 2019; Scoones, 2023; Scoones and Nori, 2023). Even when households are forced to diversified integrating crops and livestock, they struggle to achieve their food security (Asfaw et al., 2019; Mulwa and Visser, 2020).

In this study, we therefore challenge the relevance and impact of pastoral livelihoods diversification from a food security point of view. The argument for our hypothesis is that households could be food security without diversification, while others remain food insecure despite achieving diversified livelihoods. Factors such as access to stable, well-paying jobs, weak social safety nets, or insufficient support for productive agricultural practices could explain these outcomes (Dame, 2018; Duguma et al., 2023; Duale, 2024). This suggests that the quality of livelihoods, rather than the number of income-generating activities, which plays a critical role in determining food security. Engaging in multiple activities does not guarantee food security if those activities yield insufficient returns or fail to provide adequate access to food (Matsuura et al., 2023).

Moreover, the study argues that pastoral development efforts should prioritize improving the productivity, profitability, and sustainability of existing livelihoods, rather than striving to diversify

in to crops or other non-agricultural activities. A focus on diversification strategies before exploring ways to strengthen and optimize the quality of existing livelihood opportunities risks dispersing scarce resources across unsustainable initiatives, limiting impact at scale. The study aimed to generate knowledge and bring insights on pastoral livelihoods diversification and its food security impact among households with, and without diversified livelihoods in Assaita and Afamo woredas of the Afar Regional State, Ethiopia.

1.3. Research objectives

1.3.1. General objective

The general objective of the study is to understand the casual linkage of livelihoods diversification status to household food security impact.

1.3.2. Specific objectives

The specific objectives of the research were:

- To study pastoral livelihoods context, challenges, and opportunities.
- To measure pastoral livelihoods diversification and its determinant factors.
- To analyze food security of households with and without livelihoods diversification.

1.4. Research questions

The central hypothesis challenges the notion that livelihoods diversification is a universally necessary or satisfactory condition for ensuring food security. We contend that households can achieve food security even without diversifying their livelihoods. Conversely, households with diversified livelihoods may still experience food insecurity due to inadequate or suboptimal returns from their various income sources. The research therefore, aims to address the following critical questions:

- What are the key features, challenges and opportunities in livelihood strategies?
- Is there significant livelihoods diversification among pastoral households?
- What factors facilitate or impede pastoral livelihoods diversification?

- What kind of livelihoods diversification is taking place? Positive? or negative?
- What is the food security status of the study households?
- Does livelihoods diversification significantly influence food security outcomes?

1.5. Significance of the study

This research holds substantial significance within the domains of pastoral livelihoods, development, and food security in the study areas in the Afar regional state of Ethiopia. It contributes to the body of knowledge on pastoral livelihoods, diversification, determinant factors and the contributions to household food security in the target communities. Policymakers and pastoral development practitioners will benefit from informed decisions regarding alternative pastoral development options, and livelihood programs will gain clarity on which positive diversification pathways could be designed to meaningfully contribute to food security. Additionally, the study will help to draw a distinction between livelihood diversification and coping strategies, the former being a positive strategy to improve livelihoods while the later often result as a result of negative outcomes that deteriorate livelihoods.

1.6. Limitations of the Study

One of the critical limitations of this study is that, the analysis is based on demographic and socioeconomic predictors, through information obtained from individual households which is a cross-sectional observation and does not capture the dynamic drivers and trends of income and food security over time. The study was also carried out in small sample population based on prior assumption by the researcher on these two major variables, livelihoods diversification and food security status and their determinants. A similar condition may not hold true in other communities with a different livelihood opportunities and food security challenges.

Income diversification and food security are dynamic and greatly affected by social, physical, environmental, factors, community rules, government regulations, and even international factors which are not included in the present study. In addition, longitudinal studies need to be conducted to understand the determinants of income diversification and its effect on food security of

households over a considerable period of time to account for agro- climatic patterns. This requires to have a more robust model and a broad-based data to be collected which is beyond the scope of the current study.

1.7. Structure of the Thesis

The thesis is structured in to five chapters: **Chapter 1**: Introduction and Justification, provides the background, defines the research problem, outlines the objectives, and justifies the significance of the study. **Chapter 2**: Literature Review – provides the state of knowledge on the topics of food security and livelihoods based on existing research, identifies gaps in knowledge, and establishes theoretical frameworks to guide our study. **Chapter 3**: Methodology - explains the research design, data collection methods, and analysis techniques and procedures along with ethical considerations. **Chapter 4**: Results and Discussion - presents the analyzed data, interprets the findings in the context of existing literature, and discusses the implications, patterns, and any unexpected results. Finally, **Chapter 5**: Conclusions and Recommendations summarizes the key findings, and offers practical recommendations, and implies the areas for future research.

Chapter Two: Literature Review

2.1. Review of Concepts and Theories

2.1.1. Livelihoods and livelihoods diversification defined

The earliest definition of livelihoods given by Chambers and Conway (1992) defined livelihoods as the capabilities, assets (stores, resources, claims, and access), and activities necessary for sustaining a means of living. A livelihood is considered sustainable when it can withstand and recover from stress and shocks, maintain, and enhance its capabilities and assets, and provide sustainable livelihood opportunities for future generations, while also benefiting other livelihoods at local and global levels over the long and short term.

Natarajan et al. (2022) defines sustainable livelihood diversification as attempts by individuals and households to find new ways to raise incomes and reduce environmental risk, which differ sharply by the degree of freedom of choice (to diversify or not), and whether the outcome will be positive or not (Liao et al., 2015). Livelihood diversification includes both on- and off-farm activities which are undertaken to generate income additional to that from the main household agricultural activities, via the production of other agricultural and non-agricultural goods and services, the sale of waged labour, or self-employment in small firms, and other strategies undertaken to spread risk (Wang et al., 2024).

Taking livelihoods diversification in the context of household and rural economies, it can take two contrasting forms. Evidences from different countries, based on economic growth and structural transformation theories suggest that livelihoods diversification strategies, especially those involving off-farm activities, play greater roles leading to economic growth, creation of new job opportunities and increase incomes (Sun et al., 2023). This represents a progressive approach to diversification, where it is viewed as a positive adaptation strategy resulting in expanded livelihoods and wealth accumulation among rural producers, essentially driven by economic progress (Ho et al., 2024).

Conversely, livelihood diversification can also be a response to distress, serving as a coping

strategy and indicating economic regression (Asfaw et al., 2019; Mulwa and Visser, 2020). Studies showed that exposure to extreme rainfall events is positively associated with livelihood diversification in a number of countries, suggesting that climate-related shocks are key driving factors.

In this case where the diversification is induced by stress and shock, individuals and households will engage in producing low-quality, inferior products for stagnant local markets which is named as 'negative diversification'. The distinction between positive and negative forms of diversification at the household level has been noted by several researchers (Berhanu et al., 2007; Caravani, 2019; Freire, 2019; Tofu et al., 2023; and Scoones and Nori, 2023). These studies further indicate that positive diversification involves more capital-intensive production, higher productivity, and strong demand sources, often driven by economic opportunities. In contrast, negative diversification entails less capital-intensive production, lower productivity, and weaker demand sources, stemming from desperate efforts to address economic scarcities (Freire, 2019).

Existing literature suggests that relatively better-off smallholders with sufficient assets tend to succeed in livelihood diversification by capitalizing on opportunities and synergies between farming and non-farming activities. However, due to asset constraints, the majority of smallholders do not benefit from increased income and wealth resulting from livelihood diversification (Sarah, 2015). The impact of more diverse farming systems on household food security is also influenced by other factors such as the market orientation of a household, livestock ownership, non-agricultural employment opportunities, and available land resources (Liao et al., 2015). The next sections present various conceptual frameworks available to understand and design livelihood policies, strategies and programs.

2.1.2. Livelihood concepts and theories

The sustainable livelihoods framework

Most theories in the subject of livelihoods focus on understanding how people sustain themselves, particularly in contexts of poverty and vulnerability for which some frameworks, approaches or theories are widely recognized. In its simplistic form, sustainable livelihood is a concept of making a living without undermining natural resources (Kumar et al., 2023). The sustainable livelihoods

framework is a systematic framing of five livelihood capitals namely human capital, social capital, financial capital, natural capital, and physical capital (Natarajan et al., 2022; Tambe, 2022b; Ye et al., 2022). The sustainable livelihoods framework is flexible and can be adaptable to diverse local contexts and serve as analytical tool to identify development priorities of communities.

Given the growing vulnerabilities of pastoral livelihoods, particularly to climatic shocks, efforts in pastoral development over recent decades have focused not only on diversifying livelihoods into on-farm and off-farm opportunities, including crop production, small-scale trade, handicrafts, and wage labor but also ensuring durable solution which exploits the sustainable livelihoods framework. This concept has been a prominent topic in academic research, policymaking, and development studies (Davis et al., 2017; Ecker, 2018; Dai et al., 2020; Kassegn and Endris, 2017; Adugna et al., 2022; Nyathi and Ndlovu, 2022).

The earliest precursor of the sustainable livelihood's framework is the publication by Chambers, and Conway (1992) on sustainable rural livelihoods, also known as the sustainable livelihood framework (Natarajan et al., 2022). The approach values local knowledge, engages with local people and uses participatory rural appraisal techniques in the analysis of livelihood context and in the design and implementation of the solutions to livelihood problems (Natarajan et al., 2022; Tambe, 2022b). It consists of five main components namely: livelihood assets, the vulnerability context, transforming structures and processes, livelihood strategies and livelihood outcomes (Figure 1).

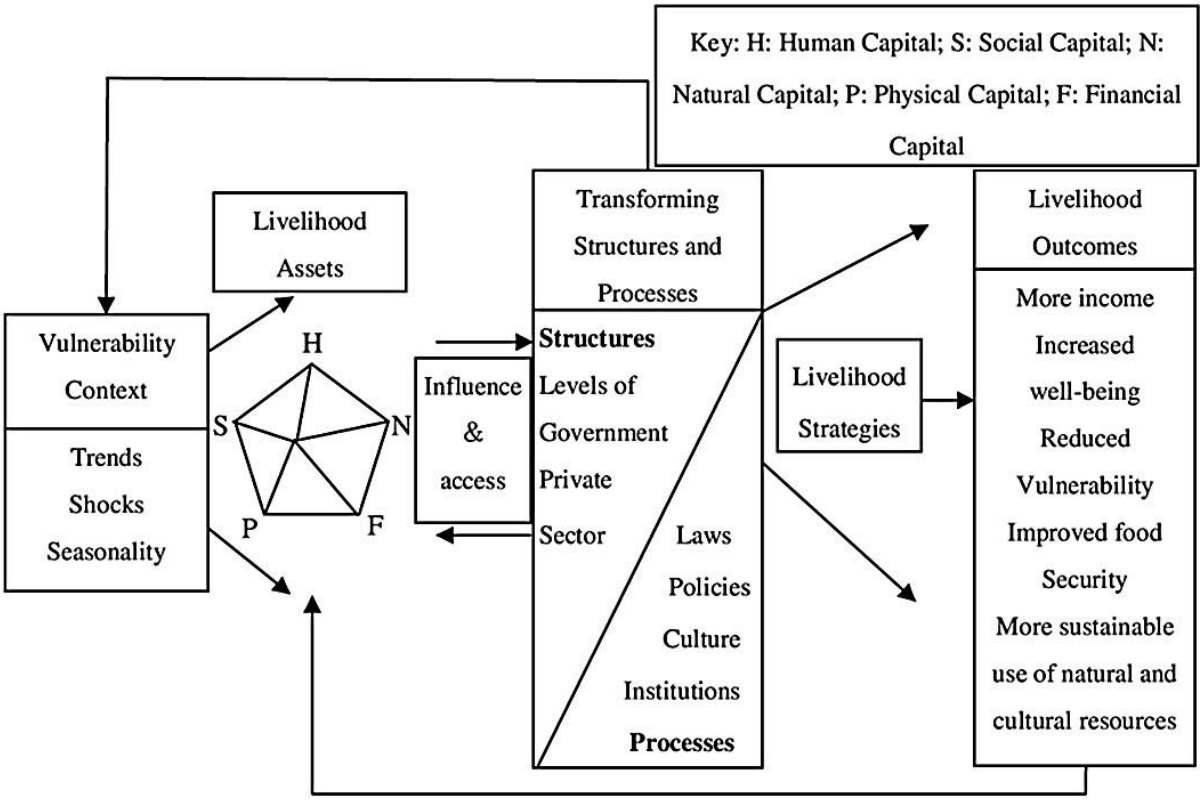

Figure 1 The Sustainable Livelihoods Framework

Source: Karim, 2022

The Livelihood Assets refers to human, natural, financial, social, and physical capitals that are required the sustain one's livelihoods. **The Vulnerability Context** refers to the shocks, stressors, trends, and seasonality factors that affect livelihoods. **Transforming Structures and Processes** are the policies, institutions, and processes that influence access to assets and livelihood strategies. In other words, these are either enabling or disabling factors. **Livelihood** Strategies are the range and combination of activities and choices people make to achieve their livelihood goals. **Livelihood Outcomes** are the results or achievements of livelihood strategies, such as increased income, enhanced well-being, reduced vulnerability, and improved food security.

The capability approach

This livelihood approach of livelihoods emphasizes on the capabilities of communities and households which offers them the freedoms or opportunities to achieve well-being. It is about the various things a person may value to be and to do, i.e., it focusses on the ability of people to pursue

goals that they value (Tiwari, 2014). This theory is also called Amartya Sen's Capability Approach and is influential in the literature of development economics. The approach has contributed to development discourse through strengthening the multidimensional perspective to poverty analysis and stressing the importance of focusing on agency and empowerment (Navarro, 2020; Svitych, 2024).

Asset-based community development (ABCD)

The Asset-Based Community Development (ABCD) is a term coined by John P. Kretzmann and John L. McKnight, who were, by then, directors of the ABCD Institute in Evanston, Illinois, USA (Ibrahima, 2017). They articulated this approach in their seminal work entitled: "*Building Communities from the Inside Out: A Path Toward Finding and Mobilizing a Community's Assets",* published in 1993 (McKnight, and Kretzmann, 1993, as cited by Ibrahima, 2017). This concept of livelihoods development emphasis on community strengths and resources rather than deficiencies. Like the Sustainable Livelihoods Approach, it requires the active participation and engagement of community members in identifying and mobilizing available livelihood assets. The ABCD approach builds on the assets that are already found in the community and mobilizes individuals, associations, and institutions, physical assets, and connections to overcome livelihood problems (Harrison et al., 2019; García, 2020).

The alternative livelihoods approach

This is about livelihoods diversification strategies, i.e., engaging people in various income-generating activities, to reduce risk and vulnerability, which is the major focus of this approach (Fratkin, 2013; Roe et al., 2015; Wright et al., 2016). Alternative livelihoods approach is a widely used term for interventions that mainly aim to reduce the prevalence of environmentally damaging livelihood activities and substituting them with less damaging livelihood activities which produce equivalent benefits to the community (Wright et al., 2016; Hanh, 2021). The approach seeks to strike a balance between sustainable natural resource use, conservation, and livelihood outcomes (Kebebe and Shibru, 2017). In the context of the pastoral production system, there is an increasing tendency to promote commercialization of the traditional pasture-based livestock production as a major means to drive alternative livelihoods (Gebeye, 2016; Benti et al., 2022). Increasing commercialization of pastoral livestock system is assumed to reduce rangeland degradation

through increased offtake of livestock (Carbonell et al., 2021). In addition, the income generated from commercialization is likely to improve livelihoods and food security of households (Benti et al., 2022).

Political economy approach

The political economy theory provides a theoretical discourse and analytical framework for understanding current events and long-term developments in the national, regional, and global economy (Cohn and Hera, 2020; Baker et al., 2021). The South-South, North-North and North-South relations are largely influenced by economic and political motives which modify the geopolitics and thus global value chains, food security and livelihoods of people (Cohn and Hera, 2020).

Political economy theory also explores the impact of global institutions such as the IMF, the International Bank for Reconstruction and Development (IBRD or World Bank), and the General Agreement on Tariffs and Trade (GATT), World Trade Organization (WTO) which replaced GATT and Organization for Economic Cooperation and Development (OECD) and the Group of Seven (G7) all of which remained instrumental to manipulate the global development landscape with significant impact on livelihoods and food security of people (Zhu, 2016; Cohn and Hira, 2020).

These organizations, (IMF, WB and WTO) have been criticized as agents of financial imperialism for championing neo-liberal programs such as privatization of the public sector, trade liberalization, and deregulation, all of which have paved the way for the multinational corporations, transnational capitalist class formation (Moyo, 2024).

The political economy approach to livelihoods considers two key aspects in it. The first component is *power relations* which defines how power dynamics and social relations among people influences their access to resources, and thus, their livelihood strategies and choices (Lewkowicz, 2024). The second component is the ecological perspective which determines the interaction between environmental factors and livelihood opportunities (Barnett, 2020; Pereira et al., 2020). Political economy is about the interaction between politics and economy at national, regional, and

global scales which ultimately determines the livelihood opportunities and strategies at country, community, and household levels. (Schmidt and Pearson, 2016; Barrett, 2021). Economic cooperation and international trade are hugely influenced by political drive (Lewkowicz, 2024).

Social capital theory

Social capital refers to the networks, norms, and trust that enable communities to act together more effectively to achieve their common objectives of food security and livelihoods (Mikiewicz, 2021; Woldehanna et al., 2022; Duguma et al., 2023). Like the political economy concept, this theory emphasizes the value of social networks and the potential benefits they bring to individuals and communities (Karanja et al., 2016). There are three social capitals, namely: i) Bonding social capitals – which are strong ties within a homogenous group and are characterized by high levels of trust and mutual support; strong personal connections; ii) Bridging social capital, referring to those connections that link people across diverse social groups which is beneficial to access to new information, resources, and opportunities; fostering innovation and collaboration; and iii) Linking social capital such as relationships between individuals and groups in different social strata, including hierarchical connections (e.g., between citizens and government officials). This offers vertical connections that provide access to power and resources thereby enabling community members to leverage resources and influence institutions and authorities in the best interest of their livelihoods (Jeppesen and Hassan, 2022).

Rights-based approach to livelihoods

The rights-based approach (RBA) to development, and thus, food security and livelihoods, brought a new perspective to traditional development thinking by embracing the role of law and human rights in food security and livelihoods. It challenged the welfare state and market-led models of development thinking, by looking at poverty not as a fault of the individual or the absence of goods and services, but as the result of social injustice (Tambe, 2022a). The right to food has been recognized in the 1948 Universal Declaration of Human Rights (Article 25) as part of the right to an adequate standard of living (UN, 1948). This right-based approach of food security and livelihoods has been further enshrined in the 1966 International Covenant on Economic, Social and Cultural Rights (Article 11) (UN, 1966).

In relation to rights-based approaches to food security concepts even evolved to 'food sovereignty', defined as the "right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems". The food sovereignty discourse emerged to address multiple of concerns and pitfalls related to the global commodity trade-based approach to feeding the world which is, not only inefficient, but also causing significant environmental degradation. The food sovereignty movement finds its roots in the deliberations made by a group of peasant and indigenous leaders met in Central America in the 1990s to discuss the above concerns and to articulate alternative approaches to achieve food security. The movement challenged the further entrenchment of a neoliberal global food economy promulgated by the 1995 World Trade Organization Agreement on Agriculture, which urged developing countries to open their markets to subsidized commodities from the Global North (Mareeh et al., 2021).

In 1996, the Tlaxcala Declaration of La Vía Campesina brought together 69 organizations from 37 countries to *"move forward in the defense of the people of the land and in the building of better alternatives … We are determined to create a rural economy which is based on respect for ourselves and the earth, on food sovereignty, and fair trade."* Through transnational farmer-farmer exchange and advocacy the food sovereignty movement grew to hundreds of organizations in over 200 countries (Shawki, 2014; Rivera et al., 2024).

In general, we can see that the rights-based approach to food security and livelihoods, in practice involve changes in policies, laws, programmes, and budgetary allocations in favor of the disadvantaged groups and will entail mobilizing people, report right violations, and petitioning courts to intervene (Tambe, 2022a). The human right to food is a fundamental pillar for guaranteeing human dignity and the existence of human beings. It is configured in the international legal system as the possibility of supplying a minimum amount of food necessary to avoid death by hunger, as well as healthy and adequate food for all people (Milian, 2024).

These theories and frameworks provide a comprehensive understanding of the multifaceted nature of livelihoods, emphasizing assets, capabilities, diversification, community strengths, power relations, and social networks towards achieving development and food security.

2.1.3. Food security defined

According to the earliest definition of food security, articulated in the World Food Summit (Shaw, 2007), food security exists when all individuals have consistent access to sufficient, safe, and nutritious food that meets their dietary needs and preferences, promoting an active and healthy life. Food security is a multifaceted concept with various dimensions. As defined by the 1996 World Food Summit (Shaw, 2007), food security has four pillars: availability, accessibility, utilization, and stability. Essentially, food security exists when all individuals have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences, allowing for an active and healthy life.

Availability: food availability is 'the amount of food that is present in a country or area through all forms of domestic production, imports, food stocks and food aid'.

Access: this aspect of food security relates to the ability of households to purchase food and transport it. This concept was first presented by Amartya Sen in the early 1980's. It is defined as 'a household's ability to acquire adequate amount of food regularly through a combination of purchases, barter, borrowings, food assistance or gifts. This dimension is a logistical one.

Utilization: food utilization refers to the household's ability to consume foods that provide their required nutritional standards. This aspect of food security further relates to the body's health condition and its ability to metabolize, absorb, and assimilate the nutrients available.

Stability: Stability characterizes the situation where there is adequate food to always satisfy the needs of the people in the country. In other words, it is the special and temporal consistency of the above three pillars. This also refers to the ability of the food system to absorb shocks such as drought, floods and conflicts which may destabilize the system.

These four dimensions operate at different levels: national availability, household accessibility, individual utilization, and a temporal dimension referred to as stability. All four dimensions must be intact to say food security is achieved. Underpinning the above broader concept, there are different theories (Akbari et al., 2022). These theories are briefly highlighted in the next sections.

2.1.4. Food security concepts and theories

Malthusian and Neo-Malthusian theory

This theory finds its roots with a famous British priest called Thomas Robert Malthus (1766 to 1834). Malthusian view to food security contend that food insecurity is caused by the presence of too many people vis-à-vis too little food available to feed them. Malthus wrote his first essay entitled *"An Essay on the Principle of Population"* in 1978 and argued as follows: "*Population when unchecked increases in a geometrical ratio while subsistence food production increases only in an arithmetical ratio*" (Thomas, 1978).

By that law of nature which makes food necessary to life of man, the effects of the two unequal powers (of population and food production) must be kept equal. People who believed in this theory are known as Classic Malthusians. Those who believe this theory until today are termed as Neo-Malthusians; and those who have contrary beliefs are Anti-Malthusians (Rishikesh et al., 2019). Classic Malthusianism remained the dominant thinking about the relationship between population growth and food security until the early 1960s.

Neo-Malthusian ideas dominated thoughts of senior technocrats and government leaders in some developing countries like Idia and China as evidenced by China's one-child policy (1979–2015) and India's forced sterilizations measures during its "Emergency" (1975–77). Neo-Malthusian policies aimed at limiting family size have caused human rights violations such as: 300 million Chinese women fitted with intrauterine devices, irremovable without surgery, over 100 million Chinees sterilizations, over 300 million abortions. Similarly, India's Emergency policy caused 11 million forced sterilizations and increased female infanticide and sex-selective abortion in China and India, skewing the world's sex ratio at birth to 107 boys per 100 girls. (Follette, 2020).

Contrary to Malthus's believes that increased population leads to underdevelopment, other economists like Marx and Engels see it otherwise. In fact, empirical studies proved that population growth is not simplistically related to food insecurity (Ashraf et al., 2011; Joseph et al., 2015; Follett, 2020).

Optimistic or anti-Malthusian theory

In the late 1960s Classic Malthusianism was challenged by Ester Boserup (1911-1999), a Danish Economist, who argued that technological development could boost food production enough to keep up with population growth for many years (Fischer-Kowalski et. al., 2014). Contrary to Malthus, she argued that population growth is a major factor determining agricultural development hence food security. Ester Boserup's theory is known as an optimistic theory, and she based her theorization on the following indications: i) availability of larger workforce to be engaged in agriculture and hence more food is produced; ii) increased innovation on agricultural mechanization leading to more food production; and iii) increased application fertilizers leading to more food production and hence more food security (Boserup, 1965). Boserup's arguments are shared by other anti-Malthusians, for example, Julian Simon argues that the ultimate resource is people; skilled, spirited, and hopeful people who will exert their will and imaginations for their own benefit, and so inevitably, for the benefit of us all (Aligica, 2009; Marian, 2018). Thus, this theory is optimistic on the intellectual capabilities of human beings who can resolve their food security problems using their wisdom on agricultural production.

Opponents to the anti-Malthusian theory (optimistic theory) argues that Boserup has absolutely ignored the unfavorable effects of growing population on agriculture. In agrarian economies where arable lands have already been scarce, the further sub-division and fragmentation of holdings is inevitable. Thus, small farmers in turn will obstruct the use of improved technology and the growing population may adversely affect the process of capital formation (Grigg, 1973). This also explains failure of agricultural intensification led to the suggestion that a new agricultural development paradigm can be formulated by cross fertilizing the intellectual strengths of both Malthusian and Boserup theories (Soby, 2017).

Food entitlement decline (FED) theory

This theory of food security was coined by an economist named Professor Amartya Sen, a noble Prize winner. He developed the entitlement theory to investigate the causes of famine in which he believed that 'famines are caused by entitlement failure' (Sen, 1981; Svitych, 2024). The approach concentrates on the ability of people to command food through the legal means available in the society, including the use of production possibilities, trade opportunities, entitlements vis-àvis the

state, and other methods of acquiring food. A person starves either because he does not have the ability to command enough food, or because he does not use this ability to avoid starvation. The entitlement approach concentrates on the former, ignoring the latter possibility. Furthermore, it concentrates on those means of commanding food that are legitimized by the legal system in operation in a particular society.

Unlike the pessimistic (Malthusian) and optimistic (anti-Malthusian) theories that focus almost exclusively on food supply, the entitlement to food theory focuses more on possession of wealth materials which can be exchanged for food or can be used to get food through other means. The Entitlement approach concentrates on each person's entitlement to commodity bundles, including food, and views starvation as resulting from failure to entitlement to a bundle including enough food. Entitlements are defined as "the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces" (Sen, 1981). Further to this, he argued that "people do not usually starve because of insufficient supply of food at local, national or international level, but because of insufficient resources, including money, 'entitlements' to acquire it". In his book, "Development as Freedom", he further argues that development is people's rights which led to the idea of food security as a human right (Svitych, 2024).

Critiques on Sen's entitlement theory to food security, on the other hand, criticize the weakness of his approach and suggest an alternative analysis that recognizes the importance of non-market institutions in determining entitlements, famine as social process and epidemiological crisis, and violations of entitlement rules in the complex emergencies that typify most contemporary famines (Devereux, 2001). Accordingly, four limitations of the entitlement theory are described as follows:

Choosing to starve - rationing one's own food consumption to protect assets and livelihoods beyond the immediate crisis and choosing to starve others within the household requires an understanding of intrahousehold power relations that cannot be captured within the entitlement framework;
Starvation vis-a-vis epidemics - despite Sen's view of famine mortality as "death by starvation" or heightened susceptibility to hunger-related diseases, increased exposure to disease might not be necessarily hunger-related;

Fuzzy entitlements - the existence of property regimes such as communal land tenure gives rise to uncertainties around entitlement relations. Rights or claims over resources that are held collectively (by groups of people, or institutions) are incompatible with the entitlement approach, which is conceptually grounded in private property regimes, where resources are commoditized and owned by individuals. Rights can also be exercised at varying levels, from ownership (the strongest form, including rights of disposal) to access and usufruct rights (the weakest form, where ownership and use are often separated). The entitlement approach is also inapplicable in contexts where the relationship between individuals and resources is mediated by (non-market) institutions.
Extra-entitlement transfers - The approach cannot explain violations of entitlements such as requisitioning of grain, raiding of cattle and appropriation or withholding of food aid. It cannot also explain "unruly practices" such as deliberate starvation, or the use of famine as a weapon.

The climate theory of food Security

Climate theory focusses on climatic factors and argued that at national or local level, climate linked phenomena such as drought, floods and others are a major factor causing food insecurity. Evidence generated from various studies indicates that the violent conflicts and civil unrest in a series of countries were also induced by food crisis which is ultimately related to the climatic factors (Johnstone and Mazo, 2011; Lee et al., 2024). In a rapidly changing world, agriculture, and thus food production, faces many challenges directly related to climatic extremes such as floods and droughts.

Several authors including Godfrey and Garnett (2014), Baldos and Hertel (2014), Lee et al. (2024) and Zhou et al. (2024) indicated that the coming decades are likely to see increasing pressures on the global food system, both on the demand side from increasing population and per capita consumption, and on the supply side from greater competition for inputs and from climate change.

Food availability decline (FAD) theory

Fundamentally, this theory is related to that of Malthusian theory as its primary focus however is on food supply chain as a major cause of food insecurity (Sen, 1981; Elahi, 2024) . This led to huge investments in green revolution technologies designed to increase food supplies for both national

self-sufficiency and for export. The FAD approach claims that whatever the cause, an acute decline in the supply of food is a necessary condition for famine to emerge (Elahi, 2024). Food availability decline is an attribute of environmental tribulations, population growth, political instabilities, poorly conceived developmental policies, and fluctuation in food prices. It is also caused by natural disasters, and other socioeconomic factors (Martin et al., 2024). This theory differs from climate theory as its focus is on the functioning of the food supply systems. Food availability decline theory is vulnerable to criticism because it is confined on food availability at local levels disregarding food availability at aggregate or macro levels (Demissie and Ayele, 2024; Martin et al., 2024; Subramaniam et al., 2024).

Conflict theory

A growing body of literature indicate both direct and indirect links between food insecurity and conflict - as proxied by environmental scarcity or access to land water resources (Homeida, 2023). In countries like Sudan wheat price fluctuation and thus food insecurity was a root cause of conflict (Chen et al., 2018). According to studies, decreased agricultural and economic productivity due to climate change is a major factor for conflict in the Horn of Africa where food insecurity and conflict are mutually reinforcing and closely linked to each other (Van Weezel, 2020; Bedasa and Deksisa, 2024). A study by Al-Shammari, and Willoughby (2019) on the driving factors of the Arab Springs indicated that political instability in the region was associated to such factors as high food prices and unemployment rate among youth. Rising food prices were also considered to catalyze pre-existing social unrest, and sparking protests in other countries like Egypt, Syria and Morocco, and other MENA countries affected by the 'Arab Springs' (Soffiantini, 2020).

Food regime and food sovereignty

Food Regime Theory (FRT) is grounded on the understanding of food production, distribution, and consumption in the world from an international political economy perspective. It is concerned with explaining, and politicizing, the strategic role of agriculture in the construction and development of the world capitalist economy (Montenegro de Wit, 2021). The food regime theory explains a set of explicit or implicit principles, norms, rules, and decision-making procedures around which actor expectations converge in a given area of interest through international relations. It is largely a Marxist approach to food systems co-originated by Harriet Friedmann and Philip

McMichael (Tilzey, 2019; Jakobsen, 2021).

Food regime analysis will enable to understand the strategic role of agriculture and food in the construction of capitalist economy at a global scale. The theory distinguishes stable periods of capital accumulation followed by particular configurations of geopolitical powers, conditioned by forms of agricultural production and consumption at national and international levels. Contradictory relations within food regimes produce crisis, transformation, and transition to successor regimes (McMichael, 2013). So far, based on this theory, four global food regimes are apparent as described by McMichael (2016), McMichael (2021) and Montenegro de Wit (2021).

The First food regime (1870s-1930s) - centered on European imports of wheat and meat from the 'settler states' of Argentina, Canada, the USA, Australia and New Zealand, 'cheap food' helped underwrite British and other European industrial growth. This was a period of British hegemony in the world economy (Brown, 2020).

The Second food regime (1950s-1970s) – the period where colonialism terminated and international state system extended with emerging independent states from former colonies in Asia and Africa. As a period of US hegemony in the capitalist world economy the US dollar became the medium of international trade and financial transactions (Tilzey, 2019; Brown, 2020).

The Third food regime (1980s-present) – in the world of 'neoliberal globalization' new technologies and markets for food and other agricultural commodities, rising awareness of ecological threat, and emergency of labor classes are the key features of the third food regime (Tilzey, 2019).

2.2. Review of Empirical Literature

2.2.1. Pastoralism as a production system

Pastoralism is a way of life and livelihood system anchored on mobile livestock herding (Catley et al., 2013) and it is one of the most widespread land use systems in the world (Manzano et al., 2021). The historical roots of pastoralism can be traced back as far as 9,000 years ago in Northeast

Africa and around 6,000 years ago in the Andes of South America, likely to have originated from multiple centers which contributed to the presence of pastoralism across all continents (Dong, 2016; Dalley, 2024).

The system is structured along clan lineage which is responsible for the control of optimum rangeland territories and management of the livestock production (Cately et al., 2013; Dong, 2016; Yurco, 2024). The social and economic norms in this production system are under strong patriarchal influence despite most of the burden of pastoral activities is borne by women (Anbacha and Kjosavik, 2019). As a result, empowering women remains one of the key challenges in most of pastoral regions across the world (Fernandez-Gimenez et al., 2021; Flintan and Eba, 2023; Yurco, 2023).

Of the two fundamental forms of pastoralism, namely nomadic and transhumant, the extensive pastoralism covers approximately 25% of the Earth's land area, primarily in the developing world, spanning from the drylands of Africa and the Arabian Peninsula to the highlands of Asia and Latin America (Byakagaba, 2020; Tugjamba et al., 2023). The pastoral livelihood system has three key pillars which are interrelated to each other, namely: the people, the livestock and the environment or rangelands, in some literature these are called as the natural resources, the herd and the family (Gaiballah et al., 2016; Schmidt, and Pearson, 2016). These systems play an essential role in a meaningful exploitation of natural spaces and resources found in marginal lands, often inhospitable for other land use systems. In addition to feeding humans and animals, the pastoral livestock production provides a subsistence income to populations that would otherwise not be able to survive in those harsh arid and semi-arid regions of the world (Nori, 2021; Scoones and Nori, 2023).

Globally, pastoralism plays a crucial role in providing ecological services, supporting ancient civilizations, and making substantial contributions to household and national economies (Schareika et al., 2021; Bacsi et al., 2023; Timpong-Jones et al., 2023). The policy framework for Pastoralism in Africa, and the pastoral development policy and strategy of Ethiopia acknowledges the importance of safeguarding the lives, livelihoods, and rights of pastoral communities.

There are strong scholastic and policy debates on the economic efficiency, environmental sustainability, and rationale of the pastoral livelihood system. On one hand, the system is viewed as a nature-friendly due to its mobile nature of production which avoids livestock concentration at a given place for long period of time. This strategic mobility to maximize rangeland resources gives time for pasture and water bodies to regenerate. (Timpong-Jones, 2023). Researchers further argue that pastoral communities also have strong social and cultural attachment to their livestock and their productive environment which they govern through their traditional institutions (Cately et al., 2013).

On the other hand, many researchers argue that communally managed resources are subject to the concept of the tragedy of the commons where every household strives to maximize its own benefit at the cost of the communal resources (Safarzynska and Sylwestrzak, 2023). According to these scholars the pastoral livelihood system is a self-demolishing system responsible for the increasing degradation and desertification of the arid and semi-arid lowlands (Hernández-Bastida, and Lloret, 2021). This thought is based on Hardin's (1968) concept of the 'tragedy of the commons', an idea indicating that if individuals have unlimited access to communal resources, they tend to over exploit it. Thus, pastoralists striving on communal pasture will over concentrate livestock at the expense of their productive environment leading to rangelands degradation and desertification (Cately et al., 2013; Coppock et al., 2018).

This later thought has been challenged by range ecologies which argue that arid and semi-arid lowlands where pastoralism is widely exercised are ecosystems that have not finished ecological evolution and are always in ecological disequilibrium, meaning that availability of rangeland resources do not follow temporally and spatially predictable patterns, and thus require strategic herd mobility which rationalize the pastoral way of production (Scoones, 2023; Scoones and Nori, 2023; Kour, 2023).

In general, since pastoral and agro-pastoral livelihoods system is dependent on extensive water and pasture management and generally characterized by low-input, low-output mode of production (Dai et al., 2020; Timpong-Jones et al., 2023), it is highly susceptible to climatic shocks (Headey, et al., 2014). Consequently, pastoral, and agro-pastoral households frequently experience

humanitarian crises and food and nutrition insecurity (Mutea et al., 2019; Adugna et al., 2022).

2.2.2. Pastoral livelihoods and food security

Dependence on a climate-sensitive mono-livelihood source, namely, livestock raising, is identified by several scholars as a key factor undermining food security and livelihoods in most of the pastoral areas in Ethiopia and elsewhere. This vulnerability of the livelihoods system is exacerbated by significant climatic variability and uncertainties (Tiwari et al., 2020; Matiwos et al., 2022). Purely pastoral communities worldwide are struggling with declining livelihoods and increasing food insecurity, coupled with reduced resilience to shocks.

Pastoral livelihoods in Ethiopia do share all the characteristic features of pastoralism elsewhere in the Horn of Africa, i.e., high dependence on mobile pasture-based production harnessing the patchy rangeland resources in a heterogenous and quite uncertain environment (Turner and Schlecht, 2019; Maru et al., 2022; Scoones, 2023; Wangui, 2024;). Among pastoral communities, there is a widespread food insecurity driven by a number of factors including climatic uncertainties (Tiwari et al., 2020; Scoones and Nori, 2023), clan-based conflicts (Bekele et al., 2022; Tan and Hassen, 2023), degradation of natural resources (Reda, 2015; Mekuria, 2023). Pastoral livelihoods in the country are located in the arid and semi-arid lowlands peripheries, specifically in the Southern and eastern parts of the country, receiving very low mean annual rainfall (Figure 2).

The livelihood system covers more than 60% of the land area hosting 25% of cattle, 70% of goats and 50% of sheep population of the country. The system also contributes about 90% of export animals (Shapiro et al., 2017). The pastoral areas of Ethiopia are also endowed with huge potentials for irrigated agriculture with vast fertile land and permanent water bodies including rivers and underground water, and mineral resources (FAO and Tufts University, 2019). The production system is dominated by extensive livestock production based on mobile herd management to harness patchy rangeland resources (Azimi et al., 2021; Nori and Scoones, 2023). Generally, pastoralism is a mono-livelihood system which is highly vulnerable to climatic factors (Tiwari et al., 2020), and thus households in this system often suffer different forms of food insecurity (Oluwole and Olagunju-Yusuf, 2022).

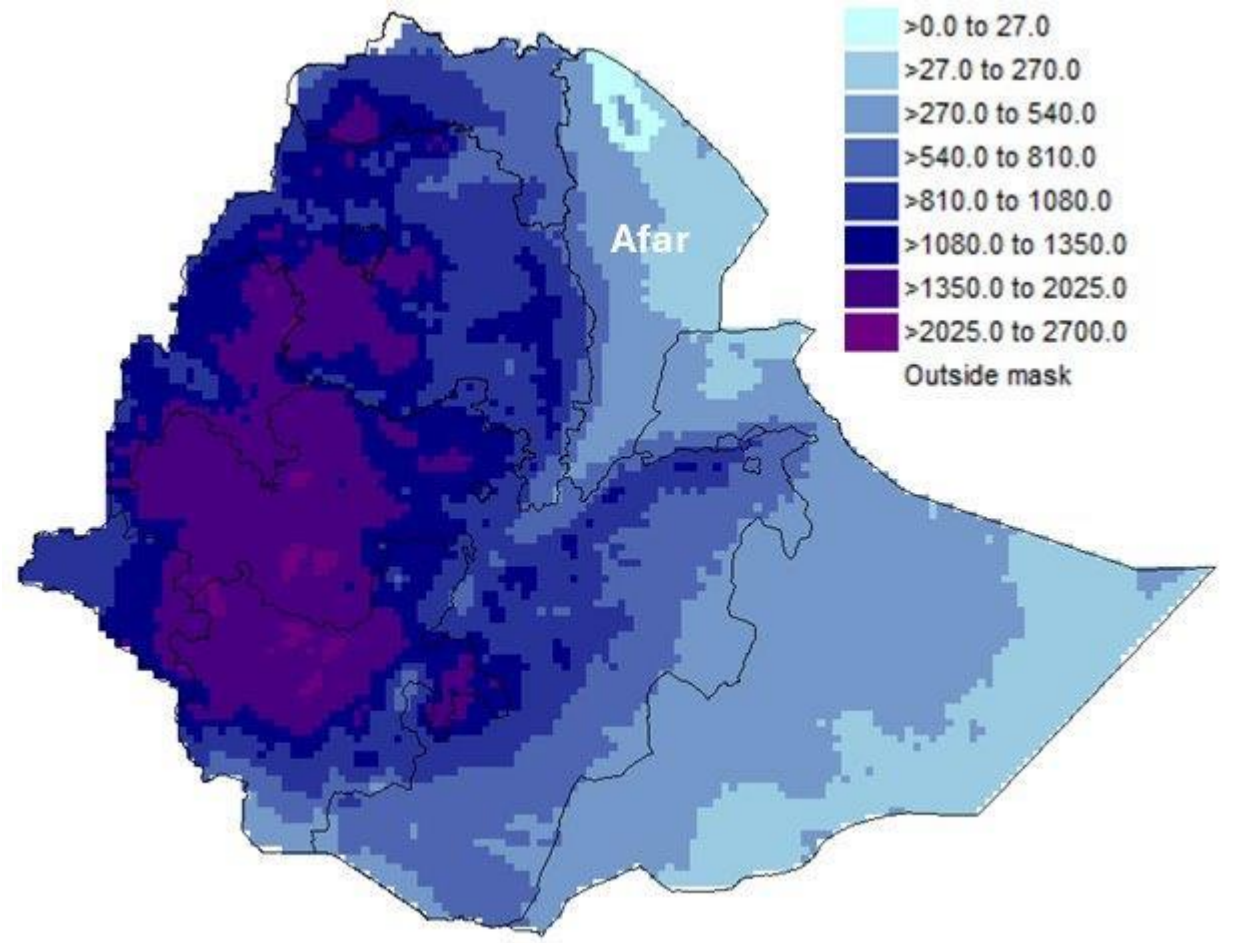

Figure 2 Rainfall distribution pattern in Ethiopia (mean annual rainfall in milimeters)

Source: Livelihoods, Early Assessment and Protection (LEAP) Platform. World Food Programme, n.d., https://www.wfp.org/publications/leap-platform. Accessed [April 15, 2025]

The livelihoods diversification efforts so far aim to engage the pastoral community into a multiple of income-generating activities (off-farm activities) and adopting various agricultural and agro-pastoral practices (on-farm activities) such as engagement in crop production to diversify their income and thus ensure food security. For instance, Abaynew et al. (2024) have found that 34.62% and 50.69% of the pastoral and agro-pastoral households were food secure, respectively, indicating that agro-pastoral households were relatively more food secure than pastoral counterparts. Another study by Dedehouanou and McPeak (2020), indicated that income diversification could lead to

higher food availability, access, and utilization. This implies that livelihoods diversification is crucial for reducing vulnerability to food insecurity challenges. Similarly, Tugjamba et al. (2023) have identified five categories of pastoral community livelihood strategies including movement to areas with better water and pasture, improving seasonal access to water, improving seasonal access to livestock feed, shifts in herd composition, and livelihood diversification (Li et al., 2022).

As argued in the earlier sections, livelihood diversification alone, will not ensure food security without robust interventions addressing the root causes of population growth and the poor productivity in arid and semi-arid lowlands. Apparently, the production system is under a 'Malthusian challenge' also called 'the Malthusian Trap' similar to research observation in the Sahel deserts (Kabir et al., 2023). Due to the scarcity of natural resources and increasing trends in climatic disasters, a business-as-usual approach to food security will not be effective.

Despite substantial investments in pastoral livelihoods and food security over the years, available evidence suggests a growing number of food-insecure individuals (FAO et al., 2023). Ethiopia, for example, witnessed severe suffering during the recent drought caused by consecutive rainfall failures in the Southern and Southeastern regions from 2020 to 2022. Reportedly, more than 3.5 million livestock perished, putting a total of 25 million livestock and 24 million people at risk. Furthermore, 9.9 million people required emergency food assistance, and 2.2 million children faced acute malnutrition. Livelihoods have also become increasingly fragile and less resilient to shocks (FAO et al., 2023; Li et al., 2022; Guye et al., 2023; Scoones and Nori, 2023; Sulieman and Young, 2023; Tofu et al., 2023).

Due to recurrent drought common in the Horn of Africa region, daily lives, livelihoods and food security of million people are under greater pressures (Schmidt and Pearson, 2016; Mauerman et al., 2023). Across the pastoral arid and semi-arid lowlands of Ethiopia living conditions are negatively impacted due to scarcity of food and drinking water, as well as the rapid deterioration of livelihoods. Pastoral livelihoods diversification has been largely driven by the challenges of frequent drought as opposed to a response to economic opportunities (FAO and Tufts University 2019).

2.3. Conceptual framework

The study applied the sustainable livelihoods approach to explore key livelihood assets, enabling and disabling factors as variables affecting livelihoods diversification and food security. Firstly, our approach involved understanding the covariate factors which determined livelihoods diversification. Secondly, status of livelihoods diversification is seen as a predictor variable to explain food security as a final outcome variable. Several factors collectively define livelihood context of households and influence diversification status. However, we have conceptualized that livelihood diversification does not necessarily lead to food security outcomes. Therefore, all diversified households may not be food secure and all non-diversified households could not be food insecure. Furthermore, some of the variables could directly contribute to food security but may not influence livelihoods diversification as it is measured by income. For instance, a strong participation of pastoral and agro-pastoral household in agricultural activities may lead to better produce and feed the household members from own production and yet due low participation in markets, the income from this source may still be low and thus livelihood diversification could not indicate the food security outcome (Figure 3).

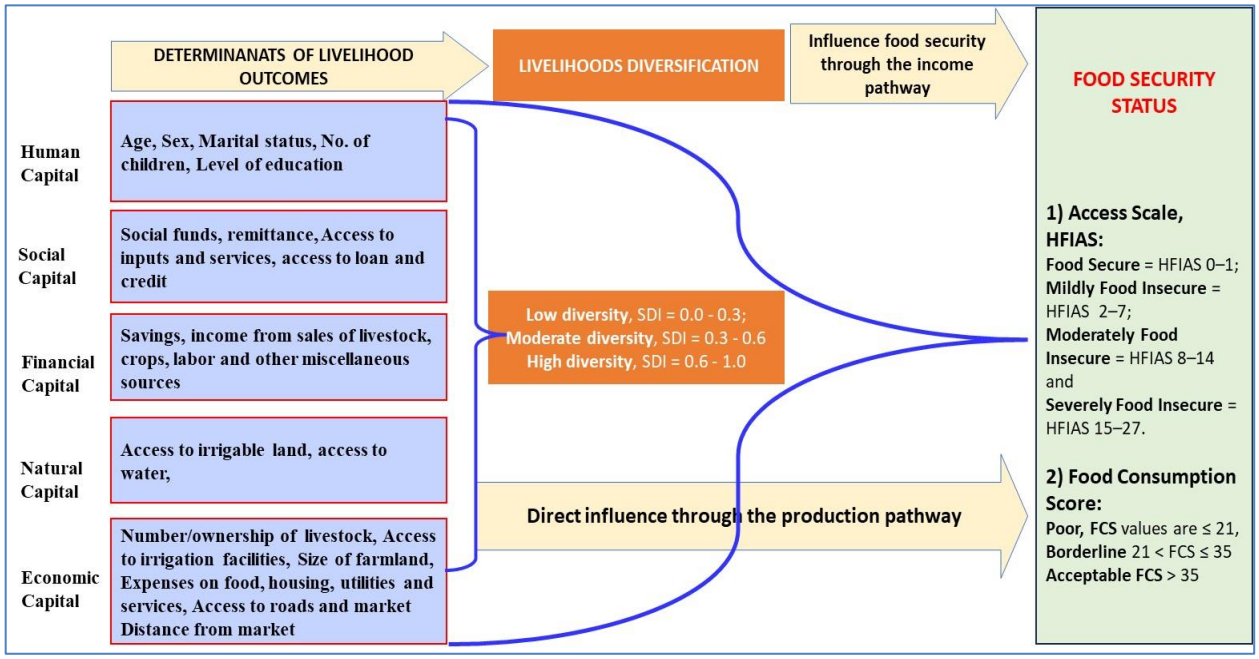

Figure 3 Conceptual framework, on the linkage between livelihoods and food security

Source: Author's suggested graphical abstract

Chapter Three: Research methods

3.1. Description of the study areas

Assaita and Afambo wordas, where the current research has been conducted, are located in the Afar regional state Awsi Resu (Zone 1), Northeastern part of Ethiopia (Figure 3). Assiata is located at a latitude of 11.7500^{o}N and longitude of 41.5000^{o}E with a total area of about 1,678 square kilometers. Afambo is located at a latitude of 11.2500^{o}N and longitude of 41.6670^{o}E and has an area of 1, 259 square kilometers. According to CSA (2007), the population of Afambo is 24,153, (13,312 male and 10,841 female) and that of Assaita is 50,803, (27,284 male and 23,519 female).

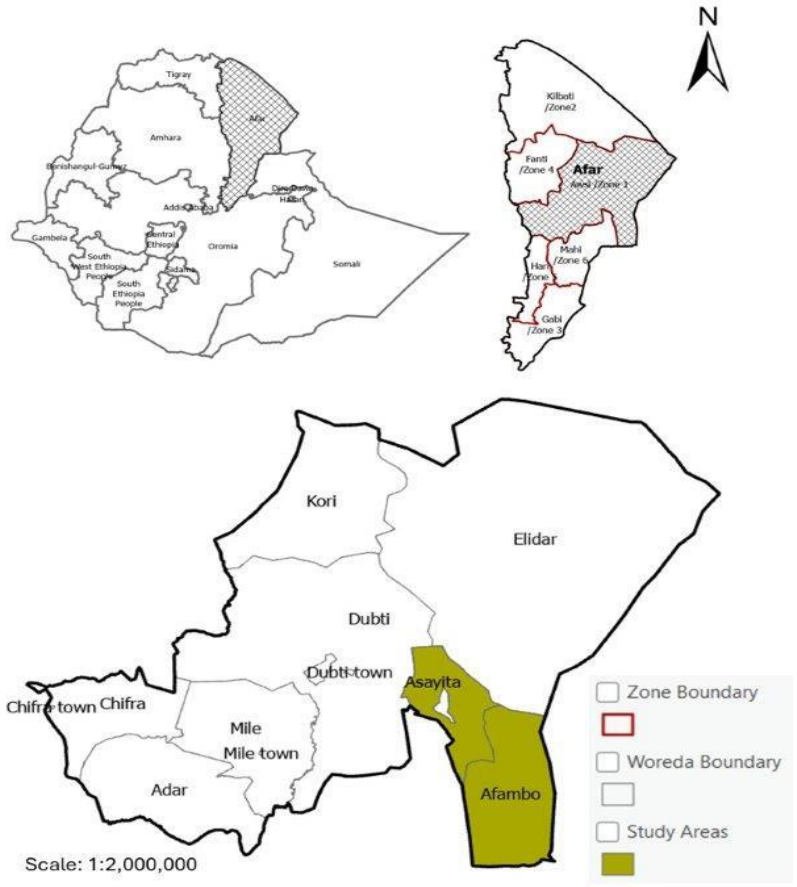

Figure 4 Map of the study locations, Afambo and Assaita woredas, Afar Regional State, Ethiopia

Source: Livelihoods, Early Assessment and Protection (LEAP) Platform. World Food Programme, n.d., https://www.wfp.org/publications/leap-platform. Accessed [April 15, 2025]

The two locations were chosen for this study based on the prevailing livelihood context of the woredas which included the presence of pure pastoralists, agro-pastoralists and other non-agrarian livelihoods groups. This offers the opportunity to explore different typologies and contexts of livelihoods including livestock production, crop production and other off-farm livelihood opportunities. Both woredas also have access to the Awash River which ends up in Afambo lake located at the Ethio - Djibouti border.

3.2. Research design

The study applied a cross-sectional research design with mixed methods for data collection and analysis which is suitable and practical to explore the overall context of livelihoods, measure food security status, livelihoods diversification and the determinant factors. It looked into pastoral livelihoods through a constructivist lens using appreciative inquiry as its main tool. This gave a foundation to broadly understand the system, its potentials and opportunities of livelihood development including the five livelihood assets: human, social, financial, physical and natural capitals (Natarajan et al., 2022). The appreciative inquiry was used following a constructivist approach to explore qualitative aspects of livelihoods followed by a pragmatic approach to understand the qualitative and quantitative aspects of livelihoods diversification and its household food security impact. Finally, we applied analytic realism to draw conclusions for practical recommendations (Kimura, 2024).

3.3. Sample size determination

The sample size for the household survey was determined using standard sample size calculation method described by Cochran (1977) assuming large population (>10,000) using the following formula:

$$n = \frac{Z^2 Pq}{e^2}$$

Where: *n* is the minimum sample size required at analysis stage; *z* is standard normal deviation set at 1.96 with a 95% level of confidence; *p* is expected prevalence (18%) of the population estimated to have diversified livelihoods (Melketo et al., 2026; Adicha and Mengistu, 2022). Taking a 0.05 level of absolute error, the theoretical sample size required at the stage of analysis, n was:

n = $[(1.96)^2 * (0.18)\ (0.82)]/\ (0.05)^2$ = 227 households. However, due to the rural context of the study areas, a non-response rate of 12% was expected. Thus, the total sample size was adjusted to 254.

3.4. Sampling design and sampling technique

The two woredas were purposively selected due to their suitability to conduct the research targeting a household with a variety of livelihood activities including crop, livestock and other off-farm activities. The respective kebeles in each woreda were also purposively selected considering security and accessibility factors. Accordingly, seven kebeles (3 from Afambo and 4 from Assaita) were initially excluded due to their inaccessibility caused by conflict and flooding from the Awash River. A total of 10 kebeles, five from each of Assaita and Afambo were included in the study. Figure 5 shows the sampling design.

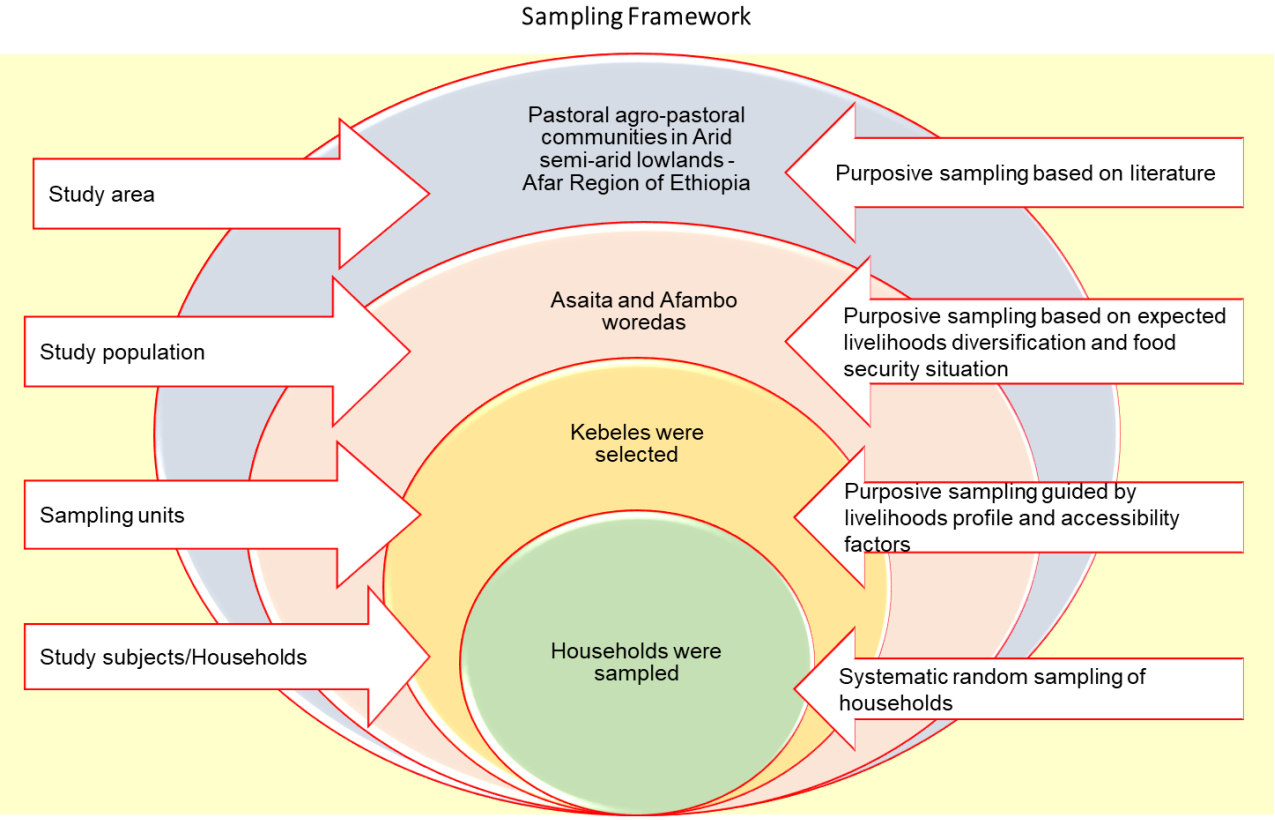

Figure 5 Schematic presentation of the sampling design

The total calculated sample size was proportionally divided between Assaita, 144 (57%) and Afambo, 110 (43%) based on their population size. The sample households were finally drawn from each kebele based on a similar probability proportional to population size per kebele. Systematic random sampling technique was used to select the households. The sampling interval was calculated by dividing the kebele sample size to the population of the same specific kebele (Table 1).

Table 1 Number of samples selected based on kebele's population proportion

Name of Woreda	Name of kebele	Overall population	Population accessible	Percent per kebele	Sample size per kebele	Sampling interval	Accessibility
Afambo	Alasabolo	8,585	8,585	29	32	272	Accessible
	Humedoyita	6,937	6,937	23	25	272	Accessible
	Mego	8,036	8,036	27	30	272	Accessible
	Harisa	4,187			0		Inaccessible
	Deka	3,496	3,496	12	13	272	Accessible
	Horogubi	3,963			0		Inaccessible
	Geneti	2,909	2,909	10	11	272	Accessible
	Obino	3,750			0		Inaccessible
Sub-total Afambo (43%)		41,863	**29,963**		**110**		
Assaita	Berga	5,027	5,027	19	27	187	Accessible
	Kerbuda	4,968			0		Inaccessible
	Galifagie	5,305	5,305	20	28	187	Accessible
	Gahertu	7,060			0		Inaccessible
	Hinele	5,788	5,788	21	31	187	Accessible
	Hanedag	6,224	6,224	23	33	187	Accessible
	Mamule	6,120			0		Inaccessible
	Romayto	5,074			0		Inaccessible
	Korodura	4,588	4,588	17	25	187	Accessible
	Gelealo	4,642			0		Inaccessible
Sub-total Assaita (57%)		54,796	**26,932**		**144**		
Total		**96,659**	**56,895**		254		

Source: Calculated number of samples and sampling interval proportional to population size

3.5. Data collection methods

3.5.1. Qualitative data collection

The qualitative data was collected using the Appreciative Inquiry approach through key informants and focus group discussions. The approach emphasizes on the strengths and opportunities available for communities to address their problems. It consists of constructing qualitative viewpoints along the following '5Ds'. **Defining** and clarifying how community can build on existing assets to improve livelihood opportunities, **discover** both enabling and disabling factors, **dreaming** the ideal future as articulated by respondents based on the needs and aspiration of the community, **designing** actionable strategies for livelihood improvement and set the **destiny** for policy and practice (Bellinger and Elliott, 2011). The 5D approach was employed during Key Informant Interviews (KII) and focus group discussions to systematically guide conversations using open-ended questions. This method facilitated the organization and synthesis of participants' responses within the structured framework of the 5Ds:

- Defining – Identifying existing assets and livelihood opportunities.
- Discovering – Exploring the key challenges highlighted by communities and informants.
- Dreaming – Envisioning ideal livelihood options and potential solutions to these challenges.
- Designing – Developing actionable strategies suggested by respondents to enhance livelihoods and food security.
- Destiny – Establishing a vision for the future of pastoral livelihoods based on insights from the previous four stages.

During our study discussions were systematically structured to generate coherent and actionable findings. The qualitative results presented in the first section of Chapter 3 are derived from this approach and its key insights.

Key informant Interview (KII) – interviews were made with key informants to get preliminary information on the overall context, challenges and opportunities on pastoral livelihoods and food security. Discussions were made using open ended questions guiding the appreciative inquiry.

Focused Group Discussion (FGD) – discussions were made with community members in two

kebeles in each study location with community members (Annex 3). Discussions focus their perception of their livelihood situation and the opportunities available for improvement.
The participants for Key Informant Interviews (KII) and Focus Group Discussions (FGD) were selected through a purposive sampling approach to ensure the inclusion of individuals with relevant knowledge and experience.

FGD participants were identified by local Development Agents (DAs), who played a key role in both participant selection and data collection. As frontline extension workers, DAs have an in-depth understanding of the pastoral and agro-pastoral communities they serve. Their familiarity with local contexts enabled them to identify individuals who are well-informed about the challenges and opportunities related to livelihoods and food security. The selection criteria emphasized participants who have lived experience and knowledge in pastoral or agro-pastoral livelihoods and with due consideration to represent diverse perspectives within the community, including different age groups, genders, and socioeconomic backgrounds.

Key informants were chosen based on their expertise, leadership roles, and direct engagement with pastoral and agro-pastoral livelihoods. Participants included: local community leaders, government officers involved in rural development and food security, representatives from non-governmental organizations (NGOs) working in the area and agricultural and livestock extension workers.

By leveraging the knowledge of Development Agents and ensuring diverse representation, the selection process helped capture a broad and nuanced understanding of livelihood dynamics in the study area.

3.5.2. Quantitative data collection

Household survey - household survey was conducted through face-to-face interview to the household heads using structured and double-blind questionnaires to minimize respondent and interviewer biases. The questionnaires contain a number of key variables expected to determine livelihoods and food security. This included ownership of various livelihood assets, access to resources and services, estimated monthly income and expenditure. Food security was measured

using standard tools including Household Food Insecurity Access Scale (HFIAS) and Food Consumption Score were concurrently administered to the same households (Annex 2). All the questions were uploaded on the Kobo toolbox and link shared to field data collectors using smart phones while the flow and quality of data collected collection was monitored instantly. The data collectors who speak the local language were selected and trained to ensure data quality.

Throughout the study, data quality was closely monitored daily using the KoBoCollect mobile application. The researcher ensured real-time tracking of data collection by regularly syncing responses from field enumerators to the KoBoToolbox Humanitarian Server, hosted on Amazon Web Services (AWS) in the United States under kf.kobotoolbox.org. Enumerators collected data offline using the mobile app, and once get internet access, they uploaded responses to the server. Each day, the researcher accessed the KoBoToolbox dashboard to review submissions, checking for inconsistencies, missing values, or errors. When issues were identified—such as incomplete responses, incorrect data entries, or discrepancies between responses and expected patterns, immediate feedback was provided to enumerators. Corrections were made by revisiting respondents when possible and by clarifying unclear responses through follow-up questions.

To enhance accuracy, the researcher also used in-built validation features of the KoBoToolbox, such as mandatory response settings and constraint functions, to minimize data entry errors during collection. Additionally, GPS tracking ensured data authenticity by confirming that surveys were conducted in the intended locations. By systematically monitoring data uploads, validating responses, and providing frequent corrections, I maintained high data quality throughout the study. The secure cloud storage on AWS-US servers ensured that all collected data remained protected and easily accessible for analysis.

3.5.3. Definition of key variables in the study

The key variables for livelihoods and food security in the current were selected based on their relevance to assessing household income, access to key livelihood assets, and food availability. These variables were identified through a review of existing literature, expert consultations, and insights from preliminary field assessments to ensure they accurately capture the challenges and opportunities within the study areas.

Table 2 presents major predictor variables while Table 3 defines the treatment variables and the outcome variables with their corresponding nature and how they were measured.

Table 2 Definition of key predictor variables and corresponding nature

Assets	Indicator/predictor Variables	Type of variables and measurement
1. Human assets	1.1. Age	1.1. Continuous (Numbers 1, 2, 3)
	1.2. Gender/sex	1.2. Binary (Male = 1; Female = 0)
	1.3. Marital status	1.3. Nominal (Single = 0; Married = 1; Widowed = 2)
	1.4. Number of children	1.4. Continuous (1, 2, 3)
	1.5. Education level	1.5. Continuous (0, 1, 2, 3)
	1.6. Vocational educ	1.6. Binary (Yes = 1; No = 0)
2. Social assets	2.1. Have social funds	2.1. Binary variable (Yes = 1; No = 0)
	2.2. Access credit and loans	2.1. Binary variable (Yes = 1; No = 0)
	2.3. Savings	2.2. Binary variable (Yes = 1; No = 0)
3. Physical assets	3.1. Access to irrigation facilities	3.1. Binary (Yes = 1; No = 0)
	3.2. Size of farmland	3.2. Continuous (1, 2, 3,..heactars)
	3.3. Livestock ownership	3.3. Binary (Yes = 1; No = 0)
	3.4. Tropical Livestock Unit, TLU	3.4. Continuous (1,2,3,)
	3.5. Number of livestock	3.4. Continuous (1, 2, 3,..livestock numbers by type)
	3.6. Access to inputs, and services	3.6. Binary (Yes = 1; No = 0)
	3.7. Access to roads and market	3.7. Binary (Yes = 1; No = 0)
	3.8. Distance from market	3.8. Continuous (in kilometers)
4. Financial assets	4.1. From sales of livestock	4.1. Continuous (1, 2, 3,..Birr/annum)
	4.2. From sales of crops	4.2. Continuous (1, 2, 3,..Birr/annum)
	4.3. From remittance	4.3. Continuous (1, 2, 3,..Birr/annum)
	4.4. Saving	4.4. Continuous (1, 2, 3,..Birr/month)
	4.5. Access to loan	4.5. Binary (Yes = 1; No = 0)
	4.6. Employment/wage labor	4.6. Continuous (1, 2, 3,..Birr/month)
	4.7. Other miscellaneous sources	4.7. Continuous (1, 2, 3,..Birr/month)
	4.8. Expenses on food, housing, utilities and services	4.8. Continuous (1, 2, 3,.. by type of expense)
	4.9. Remittance	4.9 Binary (Yea = 1; No = 0)

	5.1. Access to farmland	5.1. Binary (Yes = 1; No = 0)
5. Natural assets	5.2. Size of farm land	5.2. Continuous (hectare)
	5.3. Access to water/irrigation	5.3. Binary (Yes = 1; No = 0)

Table 3 Definition of key outcome variables and corresponding measurements methods

Key measurements	**Method of measurement**	
Simpson's livelihoods diversity index, SLDI	Standard categorical measurement 1) Low diversity, SDI = 0.0 - 0.3; 2) Moderate diversity, SDI = 0.3 - 0.6 and 3) High diversity, SDI = 0.6 - 1.0.	Treatment variable: Livelihoods diversity (also treated a binary; diversified =1 undiversified =0
Household Food Insecurity Access Scale, HFIAS	Standard categorical measurement 1) Food Secure = HFIAS score of 0–1; 2) Mildly Food Insecure = HFIAS score of 2–7; 3) Moderately Food Insecure = HFIAS score of 8–14 and 4) Severely Food Insecure = HFIAS score of 15–27.	Outcome variable: Food availability and access
Food Consumption Score, FCS	Standard categorical measurement 1) Poor, FCS values are ≤ 21, 2) Borderline 21 < FCS ≤ 35 3) Acceptable FCS > 35	Outcome variable: Food availability, access, utilization and dietary quality

3.5.4. Ethical considerations

The proposal for this study was evaluated by the Addis Ababa University (AAU) College of Development Studies (CoDS) Institutional Review Board (IRB) which issued an ethical clearance for the research. The researcher and data collectors placed strong emphasis on ethical considerations throughout all phases, including data collection, analysis, and presentation. All individuals involved, including the researcher and data collectors, were obligated to prioritize ethical matters. This included ensuring that research participants are not subjected to any form of harm and maintaining utmost respect for their dignity during interactions, avoid the use of offensive or discriminatory language, during formal and informal communication with study participants. Prior to collecting the data, full verbal consent of the participates was obtained.

3.6. Analytical model and data analysis

3.6.1. Thematic analysis

Thematic synthesis was used to analyze qualitative findings from KII and FGDs. This maps out aspiration, strengths and opportunities with regard to livelihoods. Key insights were then extracted to formulate a constructive discourse on how pastoral and agropastoral livelihoods could be improved for sustainable outcomes and impact on food security.

3.6.2. Measurement of livelihoods diversification

Livelihood diversification was measured using Simpsons Livelihood Diversity Index, SLID which is a method most preferred to understand the diversity of income from different sources including, farm and off- farm activities (Shan and Ahmed, 2020; Rubiyanto and Hirota, 2021; Alemu, 2023). We calculated SLDI in terms of income and in terms of expenditure, as a proxy indicator to get additional insight (Chai et al., 2014). Simpsons Livelihood Diversity Index can be denoted by the following formula:

(1) $SLDI_i = 1 - [(I_1 / TH_i)^2 + (I_2 / TH_i)^2 + (I_3 / TH_i)^2 + ... + (I_n / TH_i)^2]$

(2) $SLDI_e = 1 - [(E_1 / TH_e)^2 + (E_2 / TH_e)^2 + (E_3 / TH_e)^2 + ... + (E_n / TH_e)^2]$

Where:

$SLDI_i$ is livelihood diversity index as measured from income, $SLDI_e$ is the same index measured by expense, THi and THe are total household income and total household expense respectively.

The value of SLDI ranges from 0 to 1. A zero value indicate that a household derive its income from a single source (absolute specialization), a value closer to one indicates completely diversified livelihood. A similar index was generated using the expenditure data from the same households as magnitude of expenditure and pattern of household expense on food and non-food needs can be used as a proxy measure of income (Chai et al., 2014). As a rule of thumb, the scores were interpreted as follows: SLDI = 0.0 - 0.3 indicates low diversity; SLDI = 0.3 - 0.6 indicates moderate diversity and SLDI = 0.6 - 1.0 shows high diversity.

Since we measured SLDI based on income and expenses of households, the odds of income over expenditure were also calculated for the poor, moderate and high livelihood diversity groups to get additional insights on which group of livelihood diversity has higher odds of income relative to expense.

3.6.3. Probit regression analysis

A probit regression was used to identify the critical determinant factors livelihood divarication using a set of estimators to predict the probabilities of livelihoods diversification. The livelihood diversification indices were used to categorize households in to binary categories as an outcome (diversified =1 and non-diversified = 0). Based on the SLDI values, only few households were observed in highly diversified category. This required to combine them with moderately diversified households to end up with only two strata of livelihoods, namely diversified (SDLI>0.03) and non-diversified (SLDI≤0.03).

Then the probit regression which applies a maximum likelihood estimation (MLE) method was conducted to estimate the likelihood of households to diversify or not, given the independent predictors (Breen et al., 2019; Flat and Jacobs, 2019). The mathematical denomination of the probit model has the following general form:

$Pr(Y_i = 1/X_i) = \Phi(X_i'\beta_i)$ which can also be written as $Pr(Y=1|X) = \Phi(\beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k)$

Where:

- Y_i = 1 if the household engages in livelihood diversification, and Y_i =0 otherwise.
- Φ = Cumulative Distribution Function (CDF) of the standard normal distribution.
- X_i' = Vector of independent variables (predictors).
- β = Vector of coefficients associated with the independent variables.

The coefficients and their marginal effects for each predictor were estimated followed by a classification statistic to test the model efficiency in terms of sensitivity and specificity, positive and negative predictive values.

3.6.4. Household Food Insecurity Access Scale (HFIAS)

This tool developed by Food and Nutrition Technical Assistance (FANTA) project was used (Coates et al., 2007). It consists of nine question measuring occurrence and frequency of occurrence of problems in food advisability and access over a 30 days period. The calculation of the HFIAS score was done according to the following formula:

$$HFIAS = \sum_{i=1}^{9}(Fi)$$

The Nine food insecurity questions (F_i) were assigned scores based on the frequency of their occurrence in a particular household. Accordingly, 0 = No (never), 1 = Rarely (1–2 times), 2 = Sometimes (3–10 times), 3 = Often (more than 10 times). The HFIAS scores of each household is calculated by adding the scores for all the nine questions. The total score ranges from 0 to 27, with higher scores indicating higher levels of food insecurity and lower scores indicating a better food security. The method classifies households in to four categories as follows: (i) Food Secure: HFIAS score of 0–1; (ii) Mildly Food Insecure Access: HFIAS score of 2–7; (iii) Moderately Food Insecure Access: HFIAS score of 8–14 and (iv) Severely Food Insecure Access: HFIAS score of 15–27.

3.6.5. Food Consumption Score (FCS)

The study also applied the Food Consumption Score described by the World Food Program. (Marivoet et al., 2019; Sileshi et al., 2023). It is based on the frequency and diversity of food groups consumed in the households over a seven days recall period. The method provides an indication of dietary quality and access to food and thus it is more robust method to measure food security of households (Marivoet et al., 2019).

In brief, data on types of foods served in the household in the past seven days was collected. The food items consumed were grouped into: main staples (e.g., cereals, tubers); pulses (e.g., beans, lentils); vegetables; fruits; meat, fish, and eggs; milk and dairy products; sugar and sweets; and oils and fats. To accommodate the dietary habits of the local community sugar and other condiments were considered together. The standard weights based on relative nutritional value of each food item, were used, which means: Main staples = 2; Pulses = 3; Vegetables = 1; Fruits = 1; Meat, fish,

and eggs = 4; Milk and dairy products = 4; Sugar = 0.5; Oils = 0.5). The weighted scores were then calculated by multiply the frequency of consumption of each group of food by the corresponding factor. The formula for calculating FCS has the following form:

$$FCS = \sum_{i=1}^{8} Xi \,.\, Pi$$

Where X_i is frequency of consumption of each food groups and P_i is the weight assigned to each food group. The food consumption score of a given household was then calculated based on the sum of the weighted scores for all food groups. The food consumption of each household was then classified as poor (FCS ≤ 21, borderline (21 < FCS ≤ 35) or acceptable (FCS > 35) (Marivoet et al., 2019). This measurement was chosen as it gives a holistic, simple and practical result standardized to enable comparison of results across different regions and countries and different time periods. Despite there can be slight difference in the nutritive values of food types across regions, soils types, plant and animal genetic differences, the tool provides a strong measure of food security pillars including availability, access, utilization and dietary quality of food which makes it a powerful tool to measure food security (Marivoet et al., 2019; Sileshi et al., 2023).

3.6.6. Propensity score analysis

A Propensity Score Analysis (PSA) method was chosen to answer one of the main research questions of the present study, whether livelihoods diversification has a causal relationship to household food security or not. Propensity score, is a conditional probability of assignment to a particular treatment group given a vector of observed covariates. It is a powerful tool to make causal inference based on a data generated from cross-sectional observations by closely mimicking a randomized control trial (Garrido et al., 2014). The approach also enables to control confounding factors which may influence both food security and livelihoods of households (Austin, 2011; Gariido et al., 2014; Lee and Lee, 2022; Lee et al., 2024). It has been used in similar food security analysis previously (Gidey and van der Veen, 2015). The method involves the following key steps:

Estimating the Propensity Scores - ordinal logistic regression was used to estimate the propensity score for each household based on a set of covariates. The propensity scores indicate the probability of each household receiving the treatment variable (whether having access to livelihood diversifying factors or not) based on observed covariates. This was used to classify households in

to treatment (diversified) and control (non-diversified) groups.

Choosing matching techniques – among various methods useful to classify households in to matched groups of treatment and control, we applied the Nearest Neighbor Matching, a primary method which yields each treated individual matched to untreated individual with the closest propensity score comparing households of similar propensity on a one-to-one basis. We have also applied the Caliper Matching method up to a caliper size of 0.4 standard deviations.

Checking balance - after matching, this procedure was used to check if there is acceptable balance between treated and control groups in terms of the covariates.

However, in the present study, it was not possible to get matched groups of treatment and controls from the data. Therefore, the next procedure in PSM procedure, *ie*. Estimation of treatment effects on food security was done using weighted Propensity Score Analysis.

3.6.7. Multinomial logistic regression

Multinomial logistic regression using the maximum likelihood estimation (MLE) method was applied to identify significant determinant factors of livelihoods diversification at three categories of ordinal outcomes (poor, moderate and high diversification). Multinomial logit is a method of choice to model the relationship between an outcome variable having more than two ordinal categories with one or more predictor variables defining the outcome. In the current study the predictor variable is livelihoods diversity which has more than two ordinal categories (namely: poot, medium and optimal diversity). Furthermore, the outcome variable, which is food security, has four ordinal levels as measured by HFIAS and has three ordinal levels as measured FCS.

Fitting the regression model - the mathematical notation of a cumulative logit model can be written as follows:

$$Log\{\frac{P\leq j}{1-P(Y\leq j)}\} = aj + (\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta n Xn),\ j = 1 \ldots, J-1$$

Where:

αj is the threshold parameter (intercept) for category j, (in our case livelihoods diversification level defined as poor, moderate and high diversity).

β is the vector of regression coefficient for the independent predictor variables

$X_1, X_2, X_3, \ldots X_n$ are the independent/predictor variables included in our model and

J is the number of levels or orders of the categorical outcome/response variable, which is livelihoods diversification. The equation gives the log-odds of the cumulative probability of households to be in category *j* or less, given the predictor variables $X_1, X_2, X_3, \ldots X_n$.

Assumptions of the model - the following key assumptions were considered for the model to be valid.

i) An ordinal response/outcome – the outcome should be is a categorical variable for which there is a clear ordering of the category levels no matter what the explanatory/predictor variables may be, either continuous or categorical (Myung, 2003). Since the two key variables in the current study (livelihoods diversification and food security), have ordinal categories, they fulfil the requirement;

ii) Proportional Odds assumption – it was assumed that the relationship between each pair of outcome groups is the same. That is, the coefficients do not have significant variation between the different thresholds. It means that the coefficients $\beta 1, \beta 2, \ldots, \beta n$ do not significantly differ when comparing the cumulative logits for different thresholds. In other words, the effect of the predictor variables on the odds of being in a higher or lower category is consistent, regardless of which threshold group is receiving the treatment.

iii) Similar probability density functions – the study also considered that both the outcome and predictor variables are influenced by a number of covariant factors; thus, both will have similar probability density functions which is one of the key assumptions for using Maximum Likelihood Estimation method (Myung, 2003). This was checked visually using box plots, histograms and kernel densities of HFIAS, FCS and SLDI values which shows overlapping patters, suggesting similar probability density functions.

Interpretation of the model - using a multinomial regression, it was possible to understand how much closer each combination of predictor variables contributed to the outcome variable.

Coefficients ($\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$) represents the impact of each predictor variable $X_1, X_2, \ldots, X_n$

on the probability of livelihood diversification and food security (the response variables) taking on a particular ordinal level. Each β_i represents the log-odds of being in the next category of the ordinal outcome variable, i.e. log-odds of having a diversified, moderately diversified and poorly diversified livelihoods for a one-unit increase in the corresponding predictor variable X_i assuming all other variables are held constant. A positive coefficient β_i indicates that as the predictor X_i increases, the probability of being in a higher category also increases. A negative coefficient β_i indicates that as the predictor X_i increases, the probability of being in a lower category also increases.

3.6.8. Firth's penalized logistic regression

The first attempt of the standard multinomial logistic regression modeling procedure to failed to converge despite a stepwise inclusion of the independent variables, and thousands of iterations. The model was not able to identify the most significant predictors of livelihood diversification. High multicollinearity between predictors was consequently evident, at later stage. This may have been aggravated by the sample size (n =254), which was not large enough relative to the number of predictor variables essentially included and due to the fact, that finding pastoral households with better livelihoods diversification was also observed to be a rare event.

As a result, another modified technique, the Firth's Penalized logistic regression was applied to enable the convergence of the model. Firth's penalized maximum likelihood estimation (Firth's logit) was chosen due to its suitability to deal with situations where the outcome (livelihood diversity) is binomial, rare condition, where sample sizes are relatively small and potential bias in the sample limit convergence (Guan and Fu, 2022). In addition, the outcome variable (status of household livelihood diversity), was also restructured as a binary outcome where households with SLDI values ≤ 0.06 were all considered in one category (as less diversified) and those households with SLDI > 0.06 were considered as diversified. This is a requirement to apply the Penalized logit regression. The estimation procedure and the interpretation of Firth's penalized maximum likelihood estimation is similar to MLE but it applies a penalization procedure to the likelihood function, which helps to mitigate the influence of extreme values or outliers and thus improves the estimation of coefficients by modifying the log-likelihood (Almeida et al., 2021; Guan and Fu, 2022).

This penalization term counteracts the bias that arises from small sample sizes and separations, shrinks the parameter estimates slightly toward zero, reducing the overestimation of coefficients in small or imbalanced datasets. Like standard logistic regression, Firth's method follows similar iterative optimization of the model, estimation of the propensity scores through multinomial logit and matching the propensity scores. In this regard, the study step by step applied a one-to-three nearest neighbor matching, followed by one-to-five NNM and one-to-ten NNM combined with caliper method of matching at 0.4 standard deviations which all did not result in optimal matching of the treatment and control groups. As a result, a weighted propensity score regression procedure was applied.

3.6.9. Weighted propensity score analysis

Weighted probability scores were generated using Firth's logit which was used to regress livelihood diversity score with FCS and HFIAS to understand the impact of livelihoods diversification on food security of households. Regarding normality test, since the model estimations were done using propensity score regression with robust procedure normality was not a critical concern. However, the Shapiro-Wilk test statistic was considered to check normality Breusch-Pagan test was used to assess heteroskedasticity while Variance Inflation Factor was applied to test for multicollinearity. Statistical tests and the corresponding statistical commands used in the current study are annexed (Annex 1).

Chapter Four: Results and discussion

4.1. Qualitative findings on existing livelihood opportunities

Discussion on livelihood opportunities in the study areas as summarized into key thematic areas reflect both existing resources and potential areas for livelihood diversification, which, if effectively harnessed, could improve livelihoods and food security of the study communities. The themes are still within the 'pastoral' domain and others related to 'non-pastoral' activities, some of which are already adopted and others remained potential areas to be exploited.

Crop farming and agro-pastoralism: with appropriate support for irrigation infrastructure and sustainable inputs supply, crop farming was identified as a viable alternative, particularly in areas with more predictable water resources, especially along the Awash River.

Handicrafts and artisanal work: various income generating activities such as handicrafts and small-scale processing and marketing of livestock products, were stated as potential areas for economic activities, though these sectors are still underdeveloped in the study areas.

Engagement in small-scale businesses and trade: engaging in local and regional markets by selling goods, livestock products, and agricultural produce was seen as an important source of supplementary income. Some households have successfully ventured into trade, particularly around market centers and towns where households engage in small-scale businesses.

Milk processing and preservation: dairy production was frequently mentioned as a growth area, given the huge livestock production the community widely practice. Stakeholders expressed the need in expanding small-scale milk processing capabilities, if supported with interventions which can create access to cooling facilities to extend the shelf life of dairy products and increase income.

Meat processing: there is growing interest to exploit meat processing and live animals for both domestic and export markets. Stakeholders highlighted the need for better infrastructure such as standardized slaughtering facilities, cold chain, transportation and training to add value to their livestock products.

Hides and skins processing and leather products manufacturing: another potential livelihood opportunity mentioned was the potential for developing small-scale leather processing industries, which could tap into local resources and create jobs for men, women and youth. According to key

informants, hides and skins are not properly collected and preserved presently. They are thrown away due to lack of infrastructure, functional market and absence of livestock skin traders.

4.2. Findings on major livelihood challenges

Stakeholders also provided insights into the key challenges that hinder livelihood improvement and diversification in pastoral areas. These themes focus on systemic and structural issues affecting both traditional pastoralism and non-pastoral livelihood activities.

Climate variability and environmental degradation: one of the most frequently cited challenges was the increasing impact of climate change on people's livelihoods. Erratic rainfall, prolonged droughts, and the continued degradation of natural resources were implicated as major threats to pastoral livelihoods.

Decreasing availability of livestock feed and water: lack of feed and water scarcity, caused by both drought and the degradation of traditional water sources, was cited as a critical constraint for livelihoods.

Land degradation: overgrazing of rangelands and deforestation, caused by the need for firewood and charcoal production have led to the depletion of rangelands, reducing the carrying capacity of land for livestock.

Invasive species (prosopis juliflora): the extensive invasion of both pasturelands and irrigation sites which limited both livestock and agriculture production was mentioned as one of the challenges. Many stakeholders stressed their concern over the long-term sustainability of pastoralism in the face of all these environmental pressures.

Limited access to markets and infrastructure: the lack of access to markets and infrastructure such as poor road networks leaving many rural kebeles isolated, limiting their access to markets, agricultural inputs, and essential services were also noted as key livelihood challenges.

Limited access to finance and credit services: participants highlighted the lack of access to finance and credit as a major barrier to pursuing new livelihood opportunities. Women and youth, in particular, were mentioned as economically disempowered groups as jobs are not available.

Weak and inconsistent extension services: stakeholders expressed the lack of institutional support tailored to the needs, culture and context of the pastoral livelihood system. Extensions services were further labeled as inconsistent, irrelevant, irregular and insufficient.

Lack of tailored interventions: participants emphasized that many development interventions do not consider the specific needs of pastoral communities and the peculiarities of the arid and semi-arid agroecology.

Conflict and insecurity: conflict with neighboring communities over natural resources, particularly water and grazing land, was raised as a significant challenge. These conflicts, displace people and limit access to scarce resources.

4.3. Qualitative analysis of alternative livelihood strategies

The study shows that while there are potentials for diversification into non-pastoral activities, value addition within the livestock sector, and engagement in irrigated agriculture, several barriers remain unaddressed. Climate variability, market access, lack of finance, and weak institutional support continue to impede livelihood development. Therefore, the findings suggest that pastoral livelihoods diversification is still low despite the evidence that there exist a number of opportunities to achieve it.

The following thematic discourse on the available options and strategies for pastoral livelihoods diversification, emerge from the qualitative findings. The study argues that a stepwise and systematic approach should be devised and supported by key policy measures and strategies. These can be framed around four dominant conceptual pillars; namely: livelihoods optimization, livelihoods expansion, livelihoods diversification and livelihoods provision. Each of these pastoral livelihood enhancement strategies are discussed below.

4.3.1. Livelihoods optimization

The first step of all development measures aiming livelihood improvement in pastoral livelihoods should be start by optimizing the existing pastoral production system to make it effective and efficient in the face of all climatic and man-made challenges. Optimization does not require the

introduction of new forms of livelihoods, mostly unknown to the community, it rather consists of improving the current production and productivity levels to make them efficient, profitable and sustainable. (Liao, 2018 ; Wu et al., 2020; Cao et al., 2023; Sun et al., 2023). One of the findings in the current study is the need for local value addition on the products of the pastoral system, namely milk, meat and hides and skins processing. This can be followed by a gradual scaling up from small and medium subsistence herds to large-scale commercial farms with increasing market-oriented objectives. This preposition is similar to how the grazing-based pastoral livelihoods transformation which took place in countries like Australia (Dalley, 2024), Newzealand (Mackay-Smith et al., 2024) and Brazil (Pereira et al., 2024). Beginning from a traditional pastural mode of production, these countries have now transformed their pastoral livestock production in to a more competent commercial industry at international level (Basso et al., 2024; Moreira et al., 2024; Nehring, 2024).

There are several avenues to achieve livelihood optimization for the pastoral and agro-pastoral communities through transforming the traditional resource management practices. Some of these transformative pathways include: modernizing herd management, optimize land use strategies, efficient management and utilization of feed resources, sustainable management of water and rangelands and application of relevant breeding technologies (Liao, 2018; Cao et al., 2023; Basso et al., 2024; Birhanu et al., 2024; Yu et al., 2024).

Supporting the existing livelihood system with vital services such as access to high quality animal health services (Ahmed et al, 2024; Kirk et al., 2024), creating access to alternative livestock feed, water and market infrastructure (Benti et al., 2022) will lead to better incomes and food security to households. Ultimately, understanding the peculiar context and providing tailored support to make the existing livelihood system more climate-adaptive will enable households to absorb shocks and sustainably strive in the face of inevitable climatic challenges (Tamene et al., 2023; Aytenfisu et al., 2024).

4.3.2. Livelihoods expansion

The second option towards pastoral livelihoods should be livelihood expansion, mainly referring to actions which will scale up the existing livelihood activities to bring them to economies of scale

(Robinson et al., 2021). Such livelihood expansion efforts will capacitate households to engage in more of the same livelihood activities in a focused, entrepreneurial, output-driven and market-oriented manner (Vall et al., 2021) as opposed to prestige on the number of livestock and subsistence-oriented scale.

This pathway of pastoral development will require deliberate efforts of fodder production, breed improvement, strong sanitary phytosanitary (SPS) investments and market innovations to make the sector internationally competent (Hertel et al., 2023; Santos and Batalha, 2023). These critical measures will boost the overall output of the pastoral livelihood system without any need to convert them in to farming communities. Strategic investments will leverage pastoral communities to harness huge opportunities from the growing demand for livestock and livestock products in Ethiopia (Shapiro et al., 2017) and globally (Galanakis, 2024; Juri et al., 2024; Santos and Batalha, 2023). Such transformative measures necessitate to introduce and deliberately adapt the elements of intensive farming such as adapting technologies and innovations, leading to a gradual transformation of the production system (Bilotto et al., 2024), ending up in a modernized, efficient and sustainable pastoral livelihoods and dryland food system.

4.3.3. Livelihoods diversification

Respondents indicated that there is a critical shortage of water and animal feed, a reality in most of the arid and semi-arid lowlands in Ethiopia, (Tofu et al., 2023) which is posing fundamental challenges to livelihoods and food security to pastoralists (Schmidt and Pearson, 2016). There is compelling evidence where the extensive traditional mobile herd management on natural pasture is on the verge of total collapse due to a constant pressure from population growth, urbanization, land degradation and increased frequency and intensity of climatic challenges (Tilahune et al., 2017; Ndemo, 2024). In fact, this is the main imperative justifying this third option why some households need to diversify their livelihood to remain viable and ensure their food security (Schmidt and Pearson, 2016).

Since livelihoods diversification is about choosing and engaging in new and additional livelihood activities, it is worth to raise a couple of relevant questions; what viable opportunities of livelihoods

diversification exist? and who should diversify and how? Despite huge potential opportunities to engage in irrigated agriculture in Ethiopia's lowland areas as a means of diversifying livelihoods, there is lack of proper training and access to irrigation facilities, inputs and equipment's (Shiferaw, 2020).

4.3.4. Livelihood specialization

While the first three livelihood support pathways could be beneficial to poor and resource constrained families, other households with increased levels of market orientation and better level of development, there is a need to pursue strategies for specialization which is appropriate for continued growth (Peng et al., 2022).

4.3.5. Livelihoods provision

Some highly vulnerable groups of the community, (eg. pastoral dropouts), there is a need for direct provision to give them a means of decent livelihoods, beyond sustaining their lives through short-term relief support. Enhanced social safety nets, and productive safety net programs are required to confer sustainable and adaptive livelihoods (Duguma, 2019; Kebede et al., 2024). Summarizing the livelihoods discourse above, the simple graphical abstract below shows a context- driven and step by step introduction of livelihood support packages which decision makers could use to redefine the pastoral livelihoods development policies and strategies in Ethiopia's lowland areas (Figure 6).

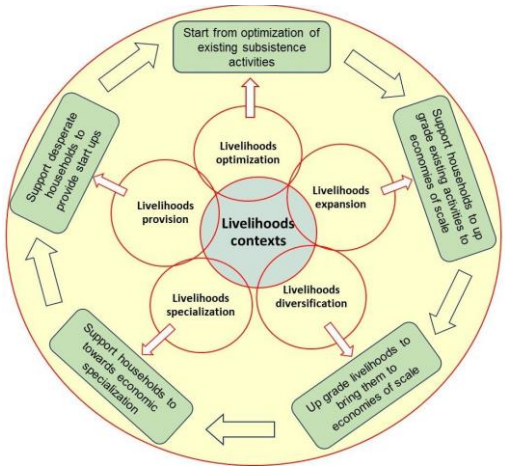

Figure 6 Suggested framework of action for comprehensive livelihood programming

Source: a graphical abstract proposed based on qualitative findings of the current study

4.4. Demographic characteristics

Table 4 presents the distribution of household heads across different age groups. The majority of household heads fall within the 38-47 age group (29%), followed by 48-57 years (22%) and 28-37 years (20%), indicating that most household heads are in their middle-aged years. Younger household heads aged 18-27 years represent only 6%, while older age groups, 58-67 years and 68-77 years, account for 10% and 12%, respectively, which may have implications for livelihood strategies and household decision-making (Table 4).

Table 4 Proportion of household heads under different age groups

Age groups	Frequency	Percentage
18-27	15	6
28-37	47	20
38-47	71	29
48-57	52	22
58-67	25	10
68-77	29	12
>78	2	1
Total	241	

Table 5 shows the distribution of households based on household size. The majority of households fall within the 6-10 members category (31%), followed by 16-20 members (21%) and 11-15 members (20%), indicating that medium to large households are common. Smaller households with 1-5 members account for 15%, while 12% of households have more than 21 members, suggesting the presence of extended family structures. With a total of 235 households, after excluding some 19 households with extreme values, the data highlights that most households are relatively large, which could have implications for resource allocation, food security, and livelihood strategies.

Table 5 proportion of households with a range of household sizes

Household Size	Frequency	Percentage
1-5	35	15
6-10	74	31
11-15	47	20
16-20	50	21
Above 21	29	12
Total	235	

This is a high household size which could be attributed to a number of factors including the tradition of polygamy and extended family members where male household heads will have more children from multiple spouses (Kahsay et al., 2018). In addition, some respondents tend to include other people with clan relations whom they consider as members of their household (Yazew and Kassa, 2024). Complementing to this factor is high number of internally displaced people (IDPs), due to clan conflict, flood from the Awash River and the Northen Conflict (Tefera et al., 2024). The implication of this finding is that clan-based social structure could be used as a unit of analysis instead of a household concept, in which requires a different data collection and analytic method. (Alene et al., 2023). Clan-based clustering techniques could effectively represent population parameters in non-stationary environments and enable to reduce difficulties of defining households in communal societies (Babu, 1995). Marital status of the study population showed a significant difference between the two woredas with Aysaita having higher number of individuals in all categories of marital status. The (p-value
<0.05) (Table 6).

Table 6 Marital Status by study location

Marital Status	Engaged	Married	Single	Widowed	Total
Afambo	8 (7%)	74 (66%)	4 (3%)	26 (23%)	112
Aysaita	7 (4%)	69 (48%)	18 (12%)	48 (33%)	142
Total	**15 (5%)**	**143 (56%)**	**22 (8%)**	**74 (29%)**	**254**

Chi-square statistic: Pearson chi2 =12.32; P-value: =0.006

It can be observed that marital status was also influenced by gender, with male being significantly higher in engagement, to be married, to be single or widowed ($p<0.05$). Males were more likely to be married (129 out of 143; (90%) and females are more likely to be widowed (32 out of 74; 43%) (Table 7).

Table 7 Association of gender and marital status in the study population

Marital Status	Engaged	Married	Single	Widowed	Total
Female	6 (10%)	14 (23%)	8 (13%)	32 (53%)	60
Male	9 (4%)	129 (66%)	14 (7%)	42 (22%)	194
Total	**15 (5%)**	**143 (56%)**	**22 (9%)**	**74 (29%)**	**254**

Chi-square statistic: Pearson chi2 = 35.16; P-value: = 0.000

4.5. Major sources of livelihoods

Results show that communities are engaged in crop production (6%), livestock production (51%), labor work (4%), small business (8%) miscellaneous activities (56%), and receive remittance (34%) as their means of livelihoods (Table 8).

Table 8 Key livelihood (income) sources mentioned by respondents

Key livelihoods	Response	Frequency	Percentage
Crop production	Yes	14	6
	No	239	94
Livestock production	Yes	128	51
	No	125	49
Labor work	Yes	9	4
	No	244	96
Small business	Yes	19	8
	No	234	92
Charcoal production	Yes	0	0
	No	253	100
Miscellaneous	Yes	142	56
	No	111	44
Remittance	Yes	58	34

	No	168	66

4.6. Major livelihood assets

Table 9 presents the responses of households to questions related to key livelihood assets available and accessible to them. Accordingly:

Humam capital - households had very low levels of elementary formal education (3%), vocational skills (16%).

Natural capital – 52% of the households indicted that they have access to farmland irrigable using the Awash River which traverses through two woredas.

Physical capital – about 29% of the households reported to have access to markets within 1 km radius while 25% travel above 10 Km to access markets. Irrigation is also accessible to 49% of the respondents.

Financial capital – about 12% expressed that they have access to credit services from a variety of sources including borrowing from neighbors, bank, micro-credit services and informal saving and credit groups.

Social capital – the households (42%) mentioned that they have received at least one or the other types of extension services regarding crop and livestock production.

Table 9 Access to livelihood assets, infrastructure and relevant services

Variables	Response	Frequency	Percent
Education status	Yes	7	3
	No	246	97
Vocational skills	Yes	40	16
	No	213	84
Extension services	Yes	106	42
	No	147	58
Credit access	Yes	31	12
	No	222	88
Savings	Yes	66	26
	No	187	74
Irrigation access	Yes	123	49
	No	130	51

Market access	<1Km	74	29.3
	1-10 Km	115	45.3
	>10Km	64	25.3
Farmland access	Yes	131	52
	No	122	48
Size of farmland	0Ha	122	48
	1Ha	13	5
	2Ha	52	21
	3Ha	66	26

Substantiating the qualitative findings, it was observed that livestock production and related activities were the predominant livelihood strategies, with 51% of respondents engaged in this sector. In contrast, non-agricultural livelihood opportunities remained limited—only 4% engaged in casual labor and 8% in small businesses—indicating low levels of entrepreneurship and job availability. This situation is likely linked to limited access to capital, financial resources, training, and underdeveloped infrastructure (Abdu and Adem, 2021; Abdulkadir, 2021).

Ethiopia holds significant potential for irrigation, especially in arid and semi-arid lowlands (Awulachew, 2019; Effa et al., 2023). Transitioning from pure pastoralism to agro-pastoralism and off-farm livelihoods is not only an opportunity but a necessity, driven by complex social, economic, and climatic factors affecting livelihood sustainability (FAO and Tufts University, 2019; Schmidt and Pearson, 2016; Adicha and Mengistu, 2022; Adugna et al., 2022). However, according to the Ethiopian Economic Policy Research Institute (EEPRI, 2021), only 3.3% of the Afar population live in areas suitable for irrigated agriculture. This, combined with high pre- and post-harvest crop losses (88.4%) due to rain failure, diseases, weeds, and pests, may explain the high non-engagement (94%) in crop farming observed in this study.

Despite these constraints, the participation of over 50% of the community in livestock production confirms its centrality as a livelihood source. Hence, pro-pastoral investment strategies should focus on enhancing productivity, value addition, and market integration (Vall et al., 2021). Livestock systems offer an efficient way to utilize marginal pastoral lands by converting rangeland resources into meat and milk. Any expansion of crop production, whether rainfed or irrigated, must

be cautiously approached to avoid undermining mainstream pastoralism, which supports 86% of the population (Caravan, 2019).

The low participation in casual labor (4%) further emphasizes the need for rural job creation to provide decent employment and reduce over-reliance on climate-sensitive agricultural livelihoods. Integrated livelihood approaches—including livestock, crop, fishery, and trade—have proven effective in diversification (Addisu, 2017). Similarly, Alemu (2023) found that crop and livestock production contribute 97.74% to livelihood diversification strategies. A poverty index study in Afar by Abaynew et al. (2024) revealed that agro-pastoral households were more food secure than purely pastoral ones. Benti et al. (2022) also found that engagement in commercial livestock activities reduced food insecurity. However, contrasting evidence from China suggests that diversification may not always lead to improved welfare for pastoralists (Liao et al., 2025).

This study underscores the need for a blended approach that prioritizes livelihood optimization and expansion before diversification—especially into crop production, which is more vulnerable to climate variability than livestock. Supporting this, Ghahramani and Moore (2016) reported that climate change poses lower risks to pasture-based livestock systems. Likewise, Ghahramani and Bowran (2018) found that focusing on livestock enterprises with higher stocking rates and pasture development is a profitable, low-risk strategy during periods of extreme drought.

4.7. Level of household income

The average monthly and yearly gross income of households was predicted from the responses households gave to each income source (Table 10). Accordingly, despite large variances in income levels generated from different livelihoods activities, our results show that households get a little more than 100 USD per household per month. Livestock activities generate 41% and miscellaneous activities contribute 43% followed by crop production contributing 8% to household income. The average annual income per household is therefore estimated to be 1,224 USD.

Table 10 Estimation of average income from different sources per household

Source of income	Average monthly income/HH		Percentage	Average yearly income/HH		Percentage
	Birr	USD		Birr	USD	
Crop production	448.8	7.8	8	5,385.8	94.0	8
Livestock production	2,409.6	42.0	41	28,914.6	504.4	41
Labor work	112.2	2.0	2	1,346.5	23.5	2
Small business	291.7	5.1	5	3,500.8	61.1	5
Charcoal production	33.5	0.6	1	401.6	7.0	1
Miscellaneous	2,519.1	44.0	43	30,229.1	527.3	43
Remittance	33.5	0.6	1	401.5	7.0	1
Total	5,848.3	102.0	100	70,179.9	1,224.2	100

Given the low level of livelihood diversification, both the monthly and yearly estimated average income of the households are very low. Similar findings have been reported bey Benti et al. (2022) who reported that livestock activities significantly contributed to household income in the same study area. Another study elsewhere showed that household income of pastoralists significantly improved largely when they participate in non-pastoral non-agricultural livelihood diversification (Sun et al., 2023).

The lower per capita income observed in the current study also closely conforms with recent reports by Ali et al. (2024) who estimated regional per capita income at 1126 dollars in the year 2022. However, this level of monthly income is not enough even to cover the basic food and non-food needs of a household which is currently 8,000 ETB/month/hh (139 USD/month/hh at exchange rate of the time (57.3265 ETB for a dollar). The low level of household income is compounded by low level of market development and price inflation of food and non-food items and devaluation will have clear bifurcations on undermining food security and livelihood status of the studies households.

4.8. Major food sources

Data on food sources of households provided an insight into the primary means through which households secure their food. Table 11 shows that a significant majority (94%) of respondents

reported not relying on their own crop production for food, suggesting that crop farming is not a primary source of food for most households. Similarly, 85% of respondents indicated that they do not depend on their own livestock for food, also indicating that it has a limited contribution to household food supply in this community. Productive Safety Net Program (PSNP), was reported by only 2% of respondents as a means of securing food. In contrast, (35%) of respondents reported that they do receive food from relief sources and another 33% primarily depend on traditional or localized and informal means for accessing food.

Table 11 Major sources of food mentioned by study respondents

Major Source of food	**Response**	**Frequency**	**Percentage**
Own crop production	Yes	15	6
	No	238	94
Own livestock production	Yes	38	15
	No	215	85
PSNP	Yes	5	2
	No	248	98
Relief food aid	Yes	89	35
	No	164	65
Other food sources	Yes	83	33
	No	170	67

From the above results, it is evident that both crops and livestock production of the households have limited contribution to meet food needs of the studied households. This finding is in line with other socioeconomic studies which reported high level of food insecurity and economic vulnerability of the region (Ali et al., 2024; Skoufias et al., 2024). Reports by OCHA (2024) estimated that close to 800 thousand people including IDPs and drought affected communities, (40%) out of the total population 2,033,176 (CSA, 2013, projection for 2022) are in need of humanitarian assistance in the Afar region alone.

In the present study, the fact that even livestock, which is the mainstay of the community, did not contribute enough to household food basket. This can be attributed to the low level of production and productivity of the production system in general. The compounded impacts of the northern

conflict (Abate, 2022), severe drought and displacements (OCHA, 2024) and desert locust infestation which recently impacted in the region could also have undermined its contribution to food security (Peng et al., 2021; Alemu and Neigh, 2022; Hassan and Aslam, 2024; ACAPS, 2024).

The situation where close to two-third of the population being food insecure, being dependent on food aid, warrant to pose rational questions on the relevance, efficiency and impact of several past and on-going investments to support pastoral livelihoods, food security and resilience in the region. For instance, the widespread invasion of one's productive rangelands, by prosopis *juliflora*, a leguminous plant, introduced by development organizations and promoted by government in the 1970's to combat desertification, has now become, a national threat to food security and one of the critical challenges to sustain livestock and crop production in the arid and semi-arid lowlands (Shiferaw et al., 2022; Shiferaw et al., 2023).

Less arguably, ill-designed development interventions could also negatively impact pastoral livelihoods as it can be observed from expansion of large-scale state and private farms along the Awash River, which has been largely contested since the imperial regime (Gebeye, 2016). A number of scholars have critically argued on the negative consequences of such irrigation schemes as pastoralists will inevitably be evicted out of their dry-season grazing lands (Gebeye, 2016; Lind et al., 2020). Some economists consider the past irrigation schemes for cotton and sugarcane plantation in Ethiopia as economic irrationality comparing their performance with the opportunities forgone by weakening the pastoral livelihood system (Melketo et al., 2021; Gebretsadik, 2023).

The above two cases, namely invasion by prosopis juliflora and agricultural expansion are illustrations how deleterious ill-informed decisions would be. In fact, there are also reports indicating an improvement in pastoral food security (Bekele et al., 2021) and most recently wheat self-sufficiency (Effa et al., 2023) through introduction of largescale irrigation facilities in the country. As a result, there is a renewed interest in large-scale irrigation spearheaded by the Ministry of Irrigation and Lowlands (MILL). One of its objectives says: "In collaboration with the Ministry of Agriculture (MoA) and the Ministry of Water and Energy (MoWE), the ministry expands irrigation development in pastoral and semi-pastoral areas". However, such great decisions require

deliberate efforts, in-built in the design of the programs, to empirically substantiate the tradeoffs on pastoral livelihood and food security from a whole of society perspective and using a food systems lense (Hertel et al., 2023). Studies elsewhere also imply that a focus on greater livestock enterprises as compared to crops could be equality profitable and sustainable (Ghahramani and Moore, 2016; Ghahramani and Bowran, 2018).

4.9. Major livelihood treats

Over 90% of all respondents reported that they have not experienced any shock from disasters in the past couple of years. However, they expressed that flood, drought, livestock diseases and desert locust infestation were the most common types of shocks. (Table 12).

Table 12 Frequency of various livelihood challenges in the study population

Type of disaster	Response	Proportion	Std. Err.	[95% Conf.	Interval]
Flood	Yes	9	2	6	13
	No	91	2	87	94
Drought	Yes	7	2	4	11
	No	93	2	89	96
Livestock diseases	Yes	0	0	0	0
	No	100	0	.	.
locust	Yes	0	0	0	0
	No	100	0	.	.
Other	Yes	1	0	0	3
	No	99	0	97	99.8

Although only 9% and 7% of respondents, reported that they experienced floods and droughts respectively, these shocks are still significant risks to livelihoods in the study population since the study initially excluded 8 kebeles which were inaccessible due to flood and clan conflict. Climate variabilities, uncertainties and extremes are confirmed problems in the arid and semi-arid lowlands of the Afar regional state by previous studies (Peng et al., 2021; Aytenfisu et al., 2024; Wakeyo, 2024). Therefore, proactive and anticipatory measures such as effective early warning systems with institutional capacity and preparedness to respond need to be in place. Several studies also indicated

that such preparedness measures will protect households' livelihoods and also minimize the cost of reactive humanitarian responses to disasters (Busker 2024; Isaev et al., 2024; Morinere et al., 2024; Parodi et al., 2024).

4.10. Livelihoods diversification

4.10.1. Livelihoods diversification as measured by income and expense

Using reported income amounts from different sources, the calculated Simpson's Livelihoods Diversification Index (SLDI) showed that 76%, 22% and 2% of households had low, moderate and high livelihood diversity respectively (Figure 6). The SLDI estimated using expense as a proxy indicator to income showed that 58% 28%, 13% of households had low, moderate and high livelihoods diversity respectively (Figure 7). Bahta and Nyaki (2024) have also reported similar findings among smallholder livestock producers. The study provided an intuition that future livelihood diversification assessments need to consider both income levels and expenditure patterns of households in order to measure their livelihood diversity. In both cases, majority of the study population had lower levels of livelihoods diversification, especially when it was measured by direct income levels.

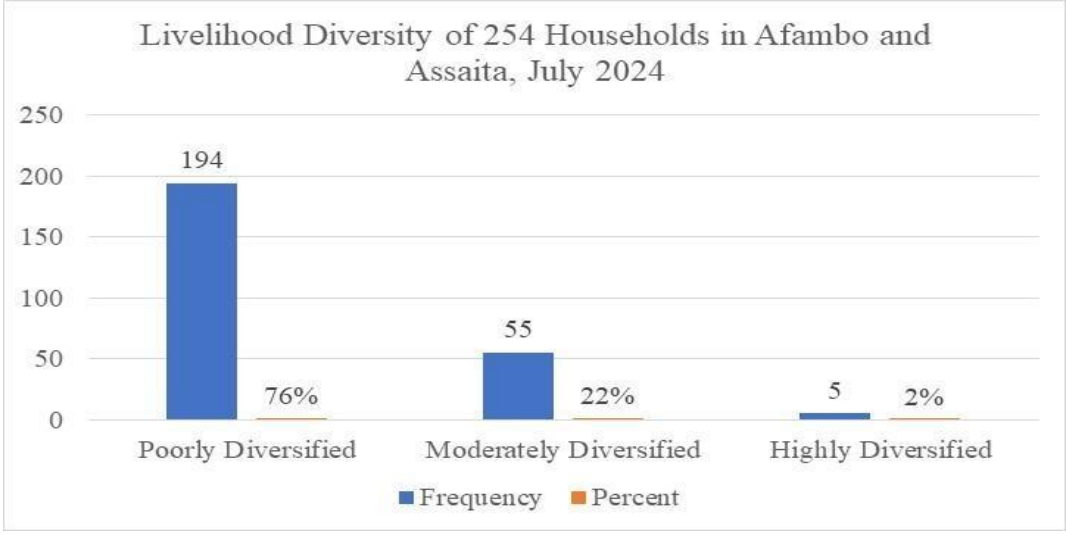

Figure 7 Simpson's Livelihood Diversity Index based on direct measurement of income

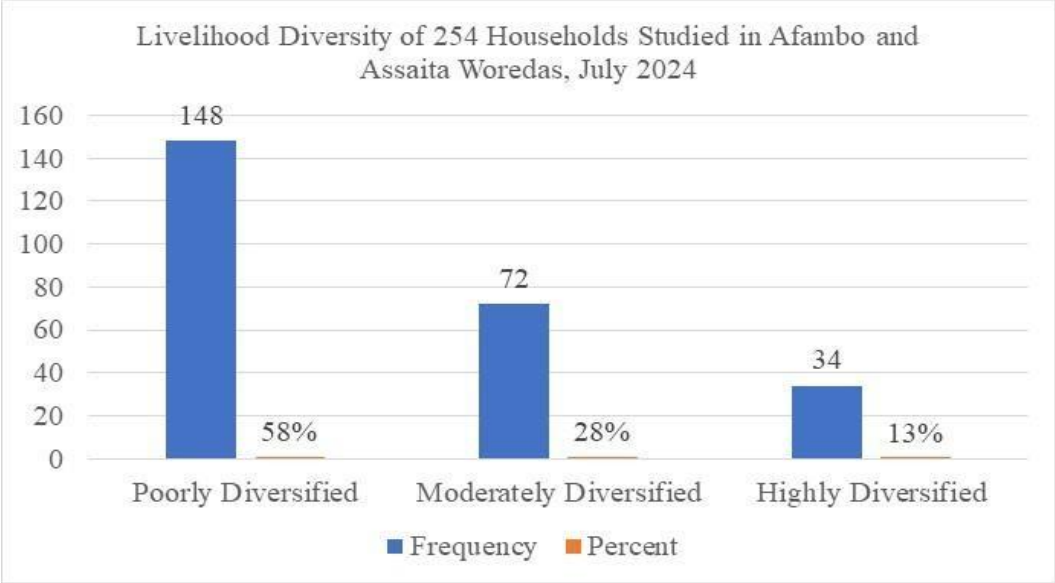

Figure 8 Simpson's Livelihood Diversity Index based on expenditure as a proxy indicator

4.10.2. The odds of income over expenditure

Analysis of the odds of income over expenses between the different livelihood groups revealed differences among them. In both income-based and expense-based estimation of SLDI the study showed that majority of the study population not only had lower levels of livelihoods diversity but also, apparently, higher odds of income over expenditure for poorly than moderately and highly diversified households (Table 13 and Table 14). This finding could be explained using the Engel's Law of household income and expenditure patterns. Accordingly, households which are at the lower levels of income spend more of their proportion of income on basic necessities, mainly food as compared to richer households (Chai et al., 2014). On the contrary, as household income increases, the spending pattern also increases where households will spend less proportion of their income on food and more on other diversified food and non-food items (Chai et al., 2014; Ritchie, 2023). Our study conforms to previous studies where poorly diversified households appear to have higher odds of income compared to their expenses due to low levels of expense in diversified needs. In short, the lesser the household income, the lesser expense on food and non-food items and vice versa (Were et al., 2023; Chain et al., 2024). A recent study on food expenditure patterns in Central and Western Europe has reported that there could be some deviation from the well-established Engel's Law in which case Olipra (2024) showed that households in richer countries tend to spend

less on food due to price differences in processed foods where food prices are cheaper in rich countries compared to poor countries.

Table 13 Odds of income over expenses within-groups of livelihood diversification

Livelihood Categories	Income-based (IB)	Expense-based (EB)	Within Groups Odds Ratio (IB/EB)
No of poorly diversified (PD)	194 (76%)	148 (58%)	1.31
No of moderately (MD) diversified	55 (22%)	72 (28%)	0.76
No of highly diversified (HD)	5 (2%)	34 (13%)	0.15
Total	254	254	

Table 14 Odds of income compared to expenses between livelihood groups

Livelihood categories	Odds of Income over expenses	Between group odds ratios
Poorly Diversified versus Moderately Diversified	1.31/0.76	1.72
Poorly Diversified versus Highly Diversified	1.31/0.15	8.73
Moderately Diversified versus Highly Diversified	0.76/0.15	5.07

Another point worth discussing based on our finding is the nature of livelihoods diversification in reference to quality and intensity of income which matters a lot in providing households with economic wellbeing or not (Patidar et al., 2024). A study from Nepal have shown that well-being is largely associated with the households' involvement in 'high return sectors' such as trade or well salaried jobs and not only a mere diversification alone (Gautam and Andersen, 2016). Similarly, many observations elsewhere also corroborate with this observation (Asfaw et al., 2019).

In order to improve the livelihood diversification of the study communities, multi-directional effort is required to engage them in economically productive and rewarding activities with a focus on both the number and magnitude of income from each source. In this regard, ones optimizing the viable livelihood opportunities at hand including livestock production, crop production and non-agrarian business ventures, intervention to step up and expand these could be fruitful (Ho et al., 2024; Ojo et al., 2024; Taye et al., 2024). Similar studies by Kolog et al. (2024) and Duale (2024)

have also emphasized the significance of access to road networks, credit and market information to enable households to sustainably diversify their livelihoods. Kihoro et al. (2024) also reported that livelihood diversification is a complementary action to livelihood intensification by studying semi-intensive dairy farmers which strongly corroborates to our earliest arguments presented in this study to consider a more comprehensive and stepwise strategy for livelihood optimization, expansion, diversification and intensification strategies.

4.11. Probit regression analysis of livelihoods diversification

4.11.1. Estimation of coefficients and marginal effects

In a first attempt of the probit regression model 23 variables were included which led to a complete prediction of the model with LLR = -15.1, Chi-square (23) 226.8, Pseudo R-square 0.88 and $p<0.000$. However, all the predictor variables were statistically insignificant. In our second attempt 18 variables were included by reducing some of the variables with suspected collinearity and those having relatively few numbers of observations. Accordingly, ownership of different species of livestock was removed and substituted by a single variable, TLU. Access to credit, education level and vocation skills were also removed due to their low number of observations with 12, 3 and 16 percent of the sampled households respectively. In addition, ownership of farmland is removed since it could be colinear with size of farm land. We also reclassified size of farm land in to a categorical variable as (no farm land, 1-2 hectares and > 3 hectares). Similarly, distance of households from markets was reclassified as (<1 km, 5-10 km and >10 km). The model then changes as follows: log-likelihood = - 21.6, Chi-square (18) 213.8, Pseudo R-square = 0.83 and $p<0.000$.

Since the above results also indicated a complete prediction rather than indicating the most significant ones, we continued to remove a number of variables with possible multicollinearity step by step and aggregated all income generating activities in to one variable - total household income. This procedure resulted a statistically significant model with strong explanatory power (Pseudo R2 83% and $p<0.05$). Household size, access to irrigation, ownership of goats and size of farm land showed strong positive statistical significance ($p<0.05$). All other variables were not statistically significant including gender, TLU and agricultural extension services which tend to negatively

affect livelihoods diversification (p>0.05) (Table 15).

Table 15 Probit regression analysis of livelihoods diversification – full model

Independent predictors	Coefficient	Std. Err.	z	P>z	95% CI
Age	0.03	0.02	1.240	0.216	-0.015 - 0.065
Gender	-0.31	0.60	-0.520	0.604	-1.496 - 0.870
Household size	0.08	0.04	1.870	0.062	-0.004 - 0.162
Crop production	11.7	331.42	0.040	0.972	-637.9 - 661.3
Irrigation access	2.60	0.78	3.330	0.001	1.069 - 4.134
TLU	-0.01	0.00	-1.650	0.098	-0.014 - 0.001
Camel ownership	1.04	0.75	1.390	0.165	-0.429 - 2.508
Goat ownership	2.86	0.99	2.900	0.004	0.927 - 4.794
Engagement in small business	17.58	331.43	0.050	0.958	-632.02 - 667.17
Miscellaneous incomes	11.42	331.42	0.030	0.973	-638.15 – 661.0
Size of crop land (Ha)	2.43	0.67	3.640	0.000	1.12 - 3.74
Access to extension	-1.33	0.90	-1.480	0.138	-3.096 - 0.430
Access to market (km)	0.79	0.50	1.570	0.116	-0.195 - 1.777
Overall income	0.00	0.00	0.140	0.886	-0.000 - 0.001
_cons	-23.64	331.45	-0.070	0.943	-673.27 - 625.99

LR chi2(14) = 215.25; Prob > chi2 = 0.0000; Log likelihood = -20.891; Pseudo R2 = 0.8374

The marginal effects estimation showed that household size, access to irrigation, goat ownership and farm land size contributed to the model at 0.4%, 12%, 13% and10.9% respectively. It can be observed that key predictors such as participation or non-participation in crop production, small business and other miscellaneous non-agricultural activities, despite their high coefficients and marginal effects, they appear to be highly insignificant, with p-values close to 1 (Table 16).

Table 16 Marginal effects estimation using the full model

Predictor variables	dy/dx	Std. Err.	z	P > z	95% CI
Age	0.001	0.001	1.26	0.206	-0.0006 - 0.003
Gender	-0.014	0.027	-0.52	0.603	-0.067 - 0.039
Household size	0.004	0.002	1.97	0.048	0.00002 - 0.0071
Crop production	0.53	14.95	0.04	0.972	-28.77 - 29.83
Irrigation access	0.12	0.03	3.57	0.000	0.05 - 0.18

TLU	-0.0001	0.0002	-1.66	0.10	-0.001 - 0.0001
Camel ownership	0.05	0.03	1.38	0.17	-0.02 - 0.11
Goat ownership	0.13	0.04	3.18	0.001	0.05 - 0.21
Engagement in small business	0.79	14.95	0.05	0.96	-28.51 - 30.09
Miscellaneous incomes	0.515	14.95	0.03	0.97	-28.78 - 29.82
Size of crop land (Ha)	0.109	0.025	4.32	0.001	0.06 - 0.16
Access to extension	-0.06	0.04	-1.49	0.14	-0.14 - 0.02
Access to market (km)	0.036	0.02	1.57	0.12	-0.01 - 0.08
Overall income	0.00	0.00	0.14	0.886	-7.23e-06 8.38e-06

Some of the key predictors such as participation or non-participation in crop production, small business and level of total household income had very high p<values despite their exceptionally higher coefficients and marginal effects, especially for crop production (marginal effects = 53%) and engagement or non-engagement in small business (marginal effects = 79%). This led us to suspect some anomalies in the data, sample size effect or any other problems in the model specification. Therefore, we run another reduced model without these variables to see how they could affect the overall model performance. Table 17 presents the outcome of the reduce probit regression model.

Table 17 Probit regression analysis of livelihoods diversification – reduced model

Independent predictors	**Coefficient**	**Std. Err.**	**z**	**P > z**	**95% CI**
Age	-0.0	0.0	-1.2	0.25	-0.026 - 0.007
Gender	-0.2	0.3	-0.8	0.43	-0.761 - 0.327
Household size	0.0	0.0	0.2	0.82	-0.026 - 0.033
Irrigation access	1.0	0.3	2.8	0.01	0.300 - 1.645
TLU	-0.0	0.0	-1.8	0.07	-0.01 - 0.0003
Camel ownership	-0.2	0.2	-0.6	0.52	-0.646 - 0.327
Goat ownership	-0.3	0.4	-0.8	0.41	-0.982 - 0.404
Miscellaneous incomes	1.9	0.3	6.9	0.00	1.331 - 2.536
Size of crop land (Ha)	0.5	0.2	2.7	0.01	0.138 - 0.911
Access to extension	0.3	0.3	0.9	0.35	-0.295 - 0.843
Access to market (km)	-0.1	0.2	-0.6	0.54	-0.423 - 0.221

_cons	-2.3	0.7	-3.5	0.00	-4.65

LR Chi2(11) = 100.53; Prob > Chi2 = 0.000; Log Likelihood = -78.251; Pseudo R2 = 0.3911

Accordingly, the reduced probit model resulted in log likelihood = -78.3; LR Chi2(11) = 100.53 and Pseudo R2 = 0.39 indicating that the explanatory strength of the overall model reduced to 39.1%, despite the fact that the model is still statistically highly significant ($p<0.001$). It is also evident that access to irrigation, miscellaneous off-farm income sources and size of farm land significant determinants with high coefficients for increasing livelihoods diversification ($p<0.05$). On the other hand, the reduce model also showed that age of household heads, ownership of camels and goats and increased distance of households from markets have negative influence on the probabilities of household livelihoods diversification. In the full model we also observed that gender (being male), having higher TLU and increased access to extension services were negatively associated to livelihood diversification, despite all of these negatively associated variables did not show statistical significance ($p>0.05$).

Marginal effects estimation of our full model revealed that access to irrigation, goat ownership and size of crop land contribute to 12%, 13% and 10.9% to the chances of households to have a diversified livelihoods respectively ($p<0.05$), other variables held constant. Excluding crop production from the modeling, the reduced model, access to irrigation, miscellaneous income and size of farm land contributed to 17%, 35.5% and 9.6% to the chance of higher livelihoods diversification ($p<0.05$) (Table 17). Crop production, engagement in small business and miscellaneous income showed very high marginal effects though not statistically significant ($p>0.05$). similarly, age, gender (being male) and TLU had weak negative marginal effects on likelihood of livelihoods diversification (Table 18).

Table 18 Marginal effects estimation using the reduced model

Predictor variables	dy/dx	Std. Err.	z	P > z	95% CI
Age	-0.0	0.0	-1.2	0.24	-0.005 - 0.001
Gender	-0.0	0.1	-0.8	0.43	-0.14 - 0.060
Household size	0.0	0.0	0.2	0.82	-0.005 - 0.006
Irrigation access	0.2	0.1	2.9	0.00	0.056 - 0.299

TLU	-0.0	0.0	-1.8	0.07	-0.002 - 0.002
Camel ownership	-0.0	0.0	-0.7	0.52	-0.118 - 0.060
Goat ownership	-0.1	0.1	-0.8	0.41	-0.180 - 0.074
Miscellaneous incomes	0.4	0.0	7.6	0.00	0.264 - 0.447
Size of crop land (Ha)	0.1	0.0	2.8	0.01	0.028 - 0.165
Access to extension	0.1	0.1	1.0	0.34	-0.054 - 0.155
Access to market (km)	-0.0	0.0	-0.6	0.54	-0.078 - 0.040

Our findings are in agreement with conventional thought and conforms several other study findings that off-farm activities significantly improve the income of rural households (Shan and Ahmed, 2020; Melketo et al., 2021; Getaneh et al., 2022; Kolong et al., 2024). Similar to previous reports by Benti et al. (2022) and Kolong et al. (2024), who reported that access to good roads and nearby market, and market information positively influenced the income of households although coefficients are not statistically significant in the current study. In addition, without regard to the low statistical significance, the finding that age of household heads, ownership of camels and goats and gender (being male), having higher TLU and increased distance of households from markets have negative influence on their probabilities of better diversification. This is similar to various reports in the past (Adjimoti and Kwadzo, 2018; Abaynew et al., 2024). This can be attributed to the low level of pastoral and agro-pastoral extension service provision both for crops and livestock, and weak rural infrastructure and market access (Benti et al., 2022; Duale, 2024). The low level of livestock production and poor productivity characterized by low-input, low-output, subsistence orientation (Shapiro et al., 2017) could also indicate that the sector, despite the fact it is a means of subsistence for majority of the population, it is not a significant contributor to livelihoods diversification. It is rather negatively associated to diversification outcomes, as increasing TLU exhibited a negative coefficient though smaller in magnitude.

Many factors inherent in the pastoral production system could be mentioned to justify this. There is little value addition along the pastoral livestock value chain (Abdulkadir, 2021), the system suffers from high shortage of livestock feed (FAO, 2018) and rangeland degradation and invasion by invasive species such as prosopis juliflora, which have undermined the coefficient of contribution of livestock to livelihoods in our estimation (Lind et al., 2020; Shiferaw et al., 2022;

Shiferaw et al., 2023). Livestock's role in negatively influencing livelihoods diversification could have been even higher and significant than observed in the current study if not for the above limiting factors. This can be correctly explained by the fact that most pastoral families, having considerable size of livestock, do not diversify and tend to maintain their traditional pastoral lifestyle based on mobile production system to better cope with climatic variabilities and uncertainties and stay in the system (Scoones, 2023; Schoones and Nori, 20023). However, some researchers describe the pastoral livelihood system as a self-demolishing system responsible for increasing degradation and desertification of the arid and semi-arid lowlands through continual herd accumulation, instead of diversifying the livelihood based (Hernández-Bastida, and Lloret, 2021; Safarzynska and Sylwestrzak, 2023).

On the other hand, our findings on access to irrigation, ownership and size of farmlands had significant impact on household income and thus, increasing the chances of livelihood diversification. However, despite the existing potential, our data showed that less percentage of households (6%) indicated their involvement in crop farming which was also reported by previous studies (FAO and Tufts University, 2019; EEPRI, 2021). Studies indicate that main factors which limit pastoral households from exploiting the potentials of irrigated agriculture, include lack of agricultural inputs, extension services (Shiferaw, 2020), high frequency of crop loss due to pests and post-harvest problems (EEPRI, 2021). On account of these bottlenecks, despite the potential, for livelihoods diversification observed in agropastoral households elsewhere (Akrasi et al., 2020; Sisay, 2024), it is less surprising to find irrigated crop production opportunities are not significantly exploited for livelihood diversification by the study households. Rather, it warrants a strong justification that much is yet to be done to optimize both crop and livestock production to sustainably diversify income bases integrating both agrarian and non-agrarian livelihood strategies.

4.11.2. Sensitivity, specificity, positive and negative predictive values of the model

Classification statistics of the full and the reduced models enabled to evaluate the predictive accuracy of the models in determining the probabilities of households to have a diversified (D) or non-diversified (~D) livelihoods given the independent predictors considered. The models classified households as + or diversified if predicted probability, Pr (D) >= 0.5. Accordingly, Tables 19 and 20 respectively show the classification table and the statistics for the

full model and Tables 21 and 22 for the reduced model.

Table 19 Classification table for the full probit model

True Classification	Classified as D	Classified as ~D	Total
Diversified, D (True Positive)	47	5	52
Undiversified, ~D (True Negative)	3	198	201
Total	50	203	253

Table 20 Classification statistics for the full probit model

Statistics	Probability	Value
Sensitivity	Pr(+/D)	90.4%
Specificity	Pr(-/~D)	98.5%
Positive Predictive Value	Pr(D/ +)	94.0%
Negative Predictive Value	Pr(~D/ -)	97.5%
False Positive Rate (True ~D)	Pr(+/~D)	1.5%
False Negative Rate (True D)	Pr(-/D)	9.6%
False Positive Rate (Classified +)	Pr(~D/ +)	6.0%
False Negative Rate (Classified -)	Pr(D/ -)	2.5%
Overall Correct Classification		96.8%

Table 21 Classification table for the reduced probit model

True classification	Classified D	Classified ~D	Total
Diversified, D (True Positive)	35	3	38
Undiversified, ~D (True Negative)	17	198	215
Total	52	201	253

Table 22 Classification statistics for the reduced probit model

Statistics	Probability	Value
Sensitivity	Pr(+/D)	67.3%
Specificity	Pr(-/~D)	98.5%
Positive Predictive Value	Pr(D/ +)	92.1%
Negative Predictive Value	Pr(~D/ -)	92.1%
False Positive Rate (True ~D)	Pr(+/~D)	1.5%
False Negative Rate (True D)	Pr(-/D)	32.7%

False Positive Rate (Classified +)	Pr(~D/ +)	7.9%
False Negative Rate (Classified -)	Pr(D/ -)	7.9%
Overall Correct Classification		92.1%

Based on the classification statistics, it is possible to see that both models have high specificity and sensitivity, despite the full model is superior in all the parameters. The reduce model have a reduced sensitivity of only 67.3% while the full model 90.4%. Here we prefer to discuss in detail the merits of the full model.

Sensitivity - as can be seen from Table 19 above, the model's sensitivity, which is its ability to identify true positives, i.e. households identified as likely to diversify because they actually do is 90.4%, which means, the model correctly identifies more than 90% of households that are likely to achieve livelihoods diversification given they are engaged/exposed to the predictor variables.

Specificity – the model is also able to correctly identify 98.5% of true negatives, i.e. households which are less likely to achieve livelihoods diversification despite their similar exposure the determinant factors.

Positive Predictive Value (PPV) - the positive predictive value of the model is 94%, which means from the households predicted by the model to have the chance to diversify their livelihoods, 94% of them actually achieve livelihood diversification, given the predictor variables.

Negative Predictive Value (NPV) - the negative predictive value of the model is 97.5%, indicates that from the households predicted by the model as less likely to engage in livelihood diversification, given the predictor variables, 97.5% of them do not actually diversify.

False Positive Rate (Type I Error) - the full model mistakes only 1.5% of households as if they diversify, while they do not actually do so which is similar for the reduced model as well.

False Negative Rate (Type II Error) – the full model mistakes about 9.6% of the households as if they do not diversify while they actually do so. But the reduced model mistakes 32.7% of the households as diversified while they do not.

Overall Model Accuracy – the overall model correctly indicated the chance of livelihoods diversification status of 96.8% of the households while the reduced model has an accuracy of 92%.

In summary the classification statistics shows that the full model is more reliable and efficient

compared to the reduced model, warranting that the variables reduced from the full model (i.e. engagement in crop production, small businesses and overall household income) and had high practical relevance for boosting the probability of livelihood diversification, in combination with the other factors (i.e. holding the other factors constant).

4.11.3. Akaike and Bayesian information criterion (AIC and BIC)

As additional tests supporting our decision on which model to choose, Table 23 presents the AIC and BIC of the two models.

Table 23 Akaike's and Bayesian Information Criterion for the full and reduced models

Model	**Observations**	**LL (null)**	**LL (model)**	Degrees of freedom	**AIC**	**BIC**
Model -1 Full model	253	-128.5	-20.9	15	71.8	124.8
Model – 2 Reduced model	253	-128.5	-78.3	12	180.5	222.9

Since the log likelihood of the null model (disregarding the predictor variables) both the full model and the nested model are the same (-128.5). However, the LL of the full model is closer to zero, indicating that the actual predictive probability of the full model is closer to the reality since log of 0 is 1. On the other hand, with its high negative LL (-78.3), the reduced model is far from the theoretical expectation of probability values, between 0 and 1, and largely underestimating the chances of household's livelihoods diversification due to the omission of the three seemingly insignificant predictors. Substantial amount of evidence exists in empirical research confirming the importance of crop production and small business activities to enhance livelihoods diversification in rural areas (Addisu, 2017; Ghahramani and Bowran, 2018; Abdu and Adem, 2021; Melketo et al., 2021; Adicha and Mengistu, 2022; Alemu, 2023; Tamene et al., 2023; Abaynew et al., 2024; Kolog etal., 2024).

4.11.4. Log-likelihood ratio test between the nested models

A log-likelihood ratio test resulted in LR chi2(3) = 114.72 (p<0.000) indicating a statistically very significant difference between the two models due to the three variables reduced especially crop production and engagement in small business which had very large coefficients and corresponding marginal effects of 53% and 79%, regardless of their p-values in the full model. Therefore, this test again confirms that the full model has a higher goodness of fit than the reduced model.

4.12. Measurement of Food Insecurity Access scale (HFIAS)

The study showed that the 42%, 11% households had mild and moderate food insecurity respectively while no one had severe food insecurity (Figure 9).

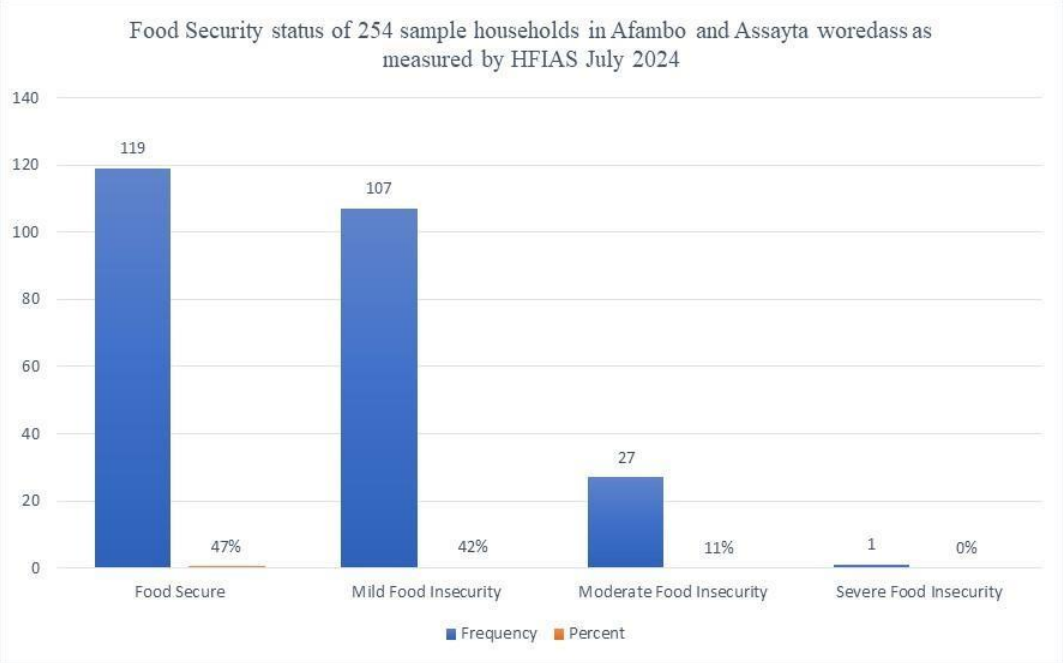

Figure 9 Food Security as Measured by Household Food Insecurity Access Scale (HFIAS)

Evidently, the above result is not surprising as income level of households was low and most of them reported that they get access to food through means other than their own dignified sources including food aid (35%) and other means of social safety net (33%) which could have contributed to the HFIAS scores. This is because HFIAS measures the frequency of food availability and access, regardless of the source. In this regard, it can be argued that the method obscures the actual

food insecurity conditions of the households (Coates et al., 2007).

A similar study by Getaneh et al (2022) had previously reported 64% prevalence of food insecurity which is slightly higher than our current finding (53%). This may be related to relatively improving situation over the past couple of years where the 2020-2022 drought, desert locust and the Northen war have now subsided (Abate, 2022; Alemu and Neigh, 2022). Given that households studied are predominantly agrarian with livestock dominating and crop being a huge potential, they could be supported to produce their own food, to support them achieve food security through the production pathway (Godara et al., 2024). Similarly, by improving their income diversity, they could be made to afford food expenses through the market pathway (Mekuyie et al., 2018; Etea et al., 2019).

4.13. Measurement of food consumption

4.13.1. Food consumption frequency

Data on frequency of food consumption shows that less than 1% of respondents confirmed to have consumed staple foods every day while only 32% consume staples only for one day per week. Pulses were consumed for 2 days in a week by 44.5% of households and vegetables were mostly consumed for 1 day by 52.8% of households and 2 days by 37.01% of households per week while fruits were rarely consumed, with 83.46% of households reporting no consumption at all. The result further indicates that 41.7%, 83% and 30.1% of households did not consume animal-sourced foods, fruits and dairy products at all within a week's time respectively. About 42% of households did not consume meat, fish and poultry products and fruits in a week's time (Table 24).

Table 24 Consumption frequency of different food groups in the study households

Food Groups	Days Consumed	Proportion (%)	Std. Err. (%)	95% Confidence Interval (%)
Staples	0 days	0.79	0.56	0.20 - 3.12
	1 day	32.68	2.95	27.15 - 38.73
	2 days	42.52	3.11	36.54 - 48.72
	3 days	15.35	2.27	11.40 - 20.37
	4 days	0.79	0.56	0.20 - 3.12
	5 days	6.30	1.53	3.88 - 10.06
	6 days	0.79	0.56	0.20 - 3.12
	7 days	0.79	0.56	0.20 - 3.12
Pulses	0 days	1.57	0.78	0.59 - 4.15
	1 day	30.31	2.89	24.94 - 36.29
	2 days	44.49	3.12	38.45 - 50.69
	3 days	16.14	2.31	12.09 - 21.23
	4 days	4.72	1.33	2.69 - 8.16
	5 days	1.57	0.78	0.59 - 4.15
	6 days	0.39	0.39	0.05 - 2.78
	7 days	0.79	0.56	0.20 - 3.12
Vegetables	0 days	4.72	1.33	2.69 - 8.16
	1 day	52.76	3.14	46.56 - 58.86
	2 days	37.01	3.04	31.25 - 43.16
	3 days	5.51	1.43	3.28 - 9.12
Fruits	0 days	83.46	2.34	78.34 - 87.57
	1 day	12.60	2.09	9.03 - 17.31
	2 days	3.54	1.16	1.85 - 6.70
	3 days	0.39	0.39	0.05 - 2.78
ASF (meat, fish, egg)	0 days	41.73	3.10	35.78 - 47.93
	1 day	38.19	3.05	32.38 - 44.36
	2 days	20.08	2.52	15.57 - 25.50

Dairy	0 days	30.31	2.89	24.94 - 36.29
	1 day	44.88	3.13	38.83 - 51.09
	2 days	20.08	2.52	15.57 - 25.50
	3 days	1.18	0.68	0.38 - 3.62
	4 days	0.39	0.39	0.05 - 2.78
	5 days	1.57	0.78	0.59 - 4.15
	7 days	1.57	0.78	0.59 - 4.15
Sugar	0 days	3.54	1.16	1.85 - 6.70
	1 day	75.98	2.69	70.31 - 80.87
	2 days	13.39	2.14	9.70 - 18.19
	3 days	2.76	1.03	1.31 - 5.69
	4 days	2.36	0.95	1.06 - 5.18
	5 days	1.97	0.87	0.82 - 4.67
Fats/Oils	0 days	2.76	1.03	1.31 - 5.69
	1 day	79.53	2.54	74.08 - 84.08
	2 days	10.24	1.91	7.05 - 14.64
	3 days	2.76	1.03	1.31 - 5.69
	4 days	1.57	0.78	0.59 - 4.15
	5 days	1.97	0.87	0.82 - 4.67
	6 days	0.39	0.39	0.05 - 2.78
	7 days	0.79	0.56	0.20 - 3.12

Our results warrant that the community could have serious inadequacy of essential proteins, fatty acids, minerals and vitamins which requires further investigation. Supporting this finding a high prevalence of anemia among children aged 6 to 59 months (46.41% overall prevalence; 43.7% mild, 42.3% moderate, and 14.1% severe) was reported (Hailu et al., 2024), which was mainly attributed to low level of monthly income, larger family sizes and rural residence. About 70% households consume dairy products at least ones a week which is a characteristic consumption pattern of most pastoral communities including Afar region (Hirata et al., 2017).

4.13.2. Food consumption score (FCS)

The Food Consumption score (FCS) shown on Figure 10 indicates that the households had poor (55%), Borderline (39%) and Acceptable (6%) food consumption scores.

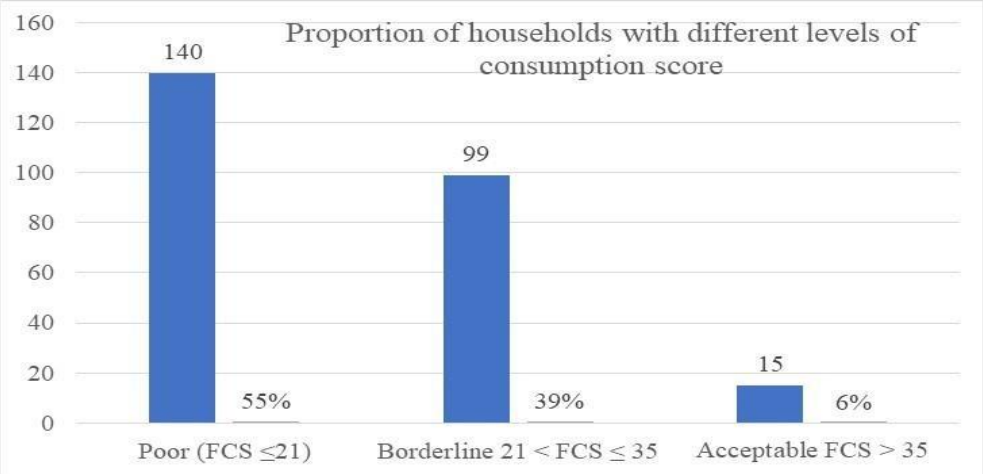

Figure 10 Food Status as measured by Food Consumption Score (FCS)

The previous finding on less frequent consumption of most of the nutritious food groups agrees with this finding. It is critical to note that our result based on HFIAS indicated that there is no household with severe food insecurity, while the result from the FCS showed revealed that only 6% of the households had acceptable consumption scores. This contradiction warrants that future food security analysis should be done using multiple of indicators (Maxwell et al., 2014). A very similar result has been reported by previous studies (Tadesse et al., 2024) who reported 51.3% poor consumption score.

4.14. Multinomial logistic regression

4.14.1. Outcome estimation

The multinomial logistic regression conducted using livelihoods diversity as a three-level ordinal outcome (poor, moderate and high diversity) is presented in Annex 2. The overall model was statistically significant with Log likelihood 0; Likelihood Ratio Chi-Squared LR Chi2 (28) 303.94 and Pseudo $R^2 = 1$ and $P<0.001$ which is a sign of complete prediction or over fitting of the model. While a different analysis has been conducted to overcome this situation, the implications of the model in reference to each livelihood category is highlighted below.

For Category 1 (poorly diversified households with SLDI <0.03) – the relative risk ratio for age,

RRR = 0.71 showed lower odds of being in Category 1 with increasing age; for gender, the extremely small value of RRR suggests that being male or female does not statistically significantly affect livelihoods diversification. However, marital status has a very large (RRR = 18670.1), indicating a strong effect, on livelihood status. The RRR for household size (RRR = 1.95), indicating that larger households had higher odds of being in Category 1, i.e more likely to have poor livelihood diversity. Likewise, engagement in livestock, and crop, access to education, irrigation facilities showed extremely high RRR values, suggesting strong effects on livelihoods diversification.

For Category 2 (moderately diversified households with SLDI between 0.03 – 0.06) – achieving moderate livelihood diversity had smaller odds with increasing age (RRR = 0.31) while increased household size have a significant effect (RRR = 4.64). The RRR values for livestock and crop production are also very high indicating higher odds for increased livelihood diversity for households which participate in these livelihood activities.

For Category 3 (highly diversified households with SLDI between 0.03 – 0.06) – the odds of being in Category 3 (to have high livelihood diversity decreases with increasing age (RRR = 0.44). Household size (RRR = 1.84) indicates that larger household sizes have a higher probability of being in this category. Likewise, education and engagement in crop production and livestock production has extremely high RRR values suggestive of a strong correlation of livelihood diversity with these variables.

4.14.2. Post-estimation

Since our first estimation attempt resulted in extremely high RRR values for most of the predictors, for which standard errors and z-values and were not available, the result was not suitable for statistical interpretation of their relative significance to the model. This is an indication of over fitting of the model for which conducting post-estimation procedures became meaningless leading us to the next estimation procedure taking livelihoods diversification as a nominal binary outcome.

4.15. Firth's penalized maximum likelihood estimation

4.15.1. Outcome estimation

Firth's penalized maximum likelihood estimation procedure automatically excluded nine variables out of 46 considered for the modeling due to multicollinearity and eventually converged with a penalized log likelihood 54.03, Wald chi2(37) 54.99, and $P< 0.05$. This result showed that the overall model is statistically significant at a 5% level, where variables collectively have a significant effect on our outcome (livelihoods diversification) (Table 25).

Looking into the individual variables, with the exception of engagement in small businesses (Coef. = 4.36; $p<0.05$) and miscellaneous activities (coef = 6.10; $p<0.05$), most were not statistically significant when taken individually. This indicate that participation in small business and miscellaneous off farm activities have significant positive contribution to the chance of households to achieve livelihoods diversification. In addition, although they did not come statistically significant, participation in crop, livestock and charcoal production had higher positive contributions to livelihood diversification with coefficients 9.92, 5.10 and 3.18 ($P >0.05$) respectively.

Our findings on the positive impacts of engagement in small business and other off-farm miscellaneous income sources is also substantiated by many previous studies (Addisu, 2017; Achiba, 2018; Asfaw et al., 2019; Akrasi et al., 2020; Adicha and Mengistu, 2022; Alemu, 2023). Despite their high coefficients, variables such as crop and livestock production which are logically and practically known to contribute to better livelihoods were statistically insignificant in this model. High level of multicollinearity is the most likely reason for this condition (Almeida et al., 2021; Guan and Fu, 2022). Therefore, we run another model with a reduced set of variables by reducing those showing multicollinearity and those with very small coefficients along with very large p-values.

Table 25 Result of Firth's penalized maximum likelihood estimation (full model)

Wald chi2(37) =						**54.99**
Penalized log likelihood =				**54.0273**	**Prob > chi2 = 0.0288**	
Predictors	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% CI**	
Age	0.03	0.06	0.47	0.637	-0.08616	0.140898
Gender	-0.06	1.33	-0.05	0.964	-2.67437	2.553755
Marital status	-0.59	0.90	-0.65	0.514	-2.35736	1.178642
Household size	-0.01	0.04	-0.25	0.803	-0.07872	0.060928
Crop production	9.82	6.16	1.6	0.111	-2.24634	21.88485
Livestock production	5.10	3.22	1.58	0.113	-1.20991	11.41578
Labor	-0.31	3.43	-0.09	0.927	-7.04145	6.413346
Small business	4.36	2.28	1.92	0.055	-0.09877	8.824373
Fishing	0.00	(omitted)				
Remittance	0.00	(omitted)				
Cross-border trade	0.00	(omitted)				
Charcoal production	3.18	3.00	1.06	0.289	-2.70435	9.066792
Gums and incense	0.00	(omitted)				
Miscellaneous	6.10	2.02	3.03	0.002	2.150409	10.05187
Level of income from crop	-0.00	0.00	-0.73	0.467	-0.00108	0.000498
Level of income from livestock	-0.00	0.00	-0.26	0.792	-0.00092	0.000705
Level of income from labor	0.00	0.00	1.12	0.263	-0.0007	0.002564
Level of income from small business	0.00	0.00	0.89	0.373	-0.00043	0.00114
Level of income from fishing	0.00	(omitted)				
Level of income from remittance	0.00	(omitted)				
Level of income from cross-border trade	0.00	(omitted)				
Level of income from charcoal	0.00	0.00	0.72	0.473	-0.00239	0.00516
Level of income from gums & incense	0.00	(omitted)				

Table 26 Result of Firth's penalized maximum likelihood estimation (reduced model)

Farmland	-0.18	2.11	-0.09	0.932	-4.32456	3.962201
Size of farm land (ha)	-0.00	0.00	-0.81	0.416	-0.00222	0.000916
Ownership of cattle	-0.12	1.72	-0.07	0.944	-3.49756	3.254263
Number of cattle	0.01	0.09	0.15	0.877	-0.15475	0.181256
Ownership of camels	0.70	1.58	0.44	0.658	-2.40076	3.802613
Number of camels	-0.01	0.12	-0.06	0.952	-0.24827	0.233339
Ownership of sheep	0.27	1.31	0.21	0.835	-2.2884	2.834204
Ownership of goats	0.81	1.67	0.49	0.626	-2.4615	4.08946
Ownership of chicken	-0.83	3.10	-0.27	0.789	-6.89603	5.2376
Access to education	1.38	1.11	1.26	0.208	-0.77051	3.531456
Access to vocational skills	0.940403	1.794576	0.52	0.6	-2.5769	4.457708
Access to extension services	1.105451	1.562922	0.71	0.479	-1.95782	4.168722
Access to credit	-2.72348	1.68004	-1.62	0.105	-6.01629	0.569343
Access to irrigation	0.289785	1.56403	0.19	0.853	-2.77566	3.355227
Exposure to flood	2.712555	2.511959	1.08	0.28	-2.21079	7.635904
Exposure to drought	-1.04591	2.007925	-0.52	0.602	-4.98137	2.889549
Exposure to desert locust	0	(omitted)				
Access to market (km)	-0.16445	0.644245	-0.26	0.799	-1.42715	1.098249
Access to food from own crop	0.322992	3.244264	0.1	0.921	-6.03565	6.681632
Access to food from own livestock	0.518162	2.403493	0.22	0.829	-4.1926	5.228923
Access to food from PSNP	3.002656	2.383039	1.26	0.208	-1.66802	7.673327
Access to food from relief aid	-0.04726	1.587803	-0.03	0.976	-3.1593	3.064775
Amount of savings	-2.87E-06	0.001085	0	0.998	-0.00213	0.002124
_cons	-10.5716	3.435263	-3.08	0.002	-17.3046	-3.83864

Accordingly, our reduced model with 16 selected predictors resulted in Wald chi2(16) = 21.39 and a penalized log likelihood of 27.62 and P>0.05 making the overall model statistically insignificant. This is an indication that these new set of variables, as a group, do not significantly improve the fit of the reduced model compared to the full model and rather it lost its overall validity (Table 27).

However, this penalized model showed that some of the variables have very significant contribution to livelihoods diversification. According to this procedure, other variables held, constant, a one-unit increase in crop farming increases the chance of households to achieve

livelihoods diversification (Coef. = 16.53; p <0.01). Similarly, engagement in livestock production, small business, miscellaneous livelihood activities and participation in PSNP all contributes to the chance of households to achieve livelihood diversification with considerable magnitude (as evident from their coefficients) and high statistical significance (P<0.05).

This result is in line with previous studies which reported that households' engagement in diversified farm and off-farm income generating activities had positive impact on livelihoods diversification (Adicha and Mengistu, 2022; Getaneh et al., 2022; Godara et al., 2024; Kolog et al., 2024).

Table 27 Result of Firth's penalized maximum likelihood estimation (reduced model)

Wald chi2(16)						**21.39**
Penalized log likelihood				**27.62195**	**Prob > chi2**	**0.1641**
Predictors	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% CI]**	
Crop production	16.53	4.81	3.43	0.001	7.096547	25.95993
Livestock production	7.58	2.21	3.43	0.001	3.254254	11.90793
Small business	7.27	2.86	2.54	0.011	1.664821	12.88048
Charcoal production	5.05	2.61	1.93	0.053	-0.07288	10.16423
Miscellaneous	11.03	3.53	3.13	0.002	4.115614	17.94373
Level of income from crop	-0.00	0.00	-1.95	0.051	-0.00113	2.08E-06
Level of income from labor	0.00	0.00	2.45	0.014	0.000282	0.002521
Level of income from small business	0.00	0.00	0.98	0.329	-0.00045	0.001348
Level of income from charcoal	0.00	0.00	1.54	0.124	-0.00055	0.004602
Size of farm land (ha)	0.00	0.00	2.27	0.023	0.000184	0.002524
Access to extension	2.23	1.40	1.59	0.111	-0.51307	4.981575
Access to credit	-4.25	1.78	-2.38	0.017	-7.74909	-0.75715
Exposure to flood	5.48	2.51	2.18	0.029	0.560778	10.40903
Exposure to drought	-1.07	2.12	-0.5	0.614	-5.21944	3.080918
Access to market (km)	-0.05	0.57	-0.09	0.932	-1.15565	1.059177
Access to PSNP	6.45	2.91	2.21	0.027	0.735464	12.16135
_cons	-16.76	4.58	-3.66	0	-25.7249	-7.78923

4.15.2. Post-estimation

Variance Inflation Factor (VIF)

Since the second procedure involved Firth's penalized maximum likelihood estimation, there is no need to perform Variance Inflation Factor (VIF) test for collinearity because the estimation procedure itself is typically designed to handle issues that arise from small sample sizes, separation, and multicollinearity making it more robust to the types of problems that VIF is designed to diagnose in such regression models (Almeida et al., 2021; Guan and Fu, 2022).

Likelihood Ratio Test (LRT)

Although Firth's method uses a penalized log likelihood, the nested models (a full model versus reduced model) were compared. The likelihood Ratio **(**LR) chi2 (37) was 52.03 for the full model, a value representing the likelihood ratio chi-squared statistic, which is used to test the null hypothesis that the reduced model with 16 predictors fits the data better than the full model. The p-value indicated that the significance level of the LRT test with $P< 0.01$ is very small which is strong evidence against the null hypothesis, suggesting variables reduced from the full model contributed significantly to model fit as compared to the reduced model (Table 28). Therefore, the reduced model is subject to rejection and consider the full model for practical purposes as it explains more variance in livelihood diversity than the reduced model. In reality, a diverse set of strategies are involved to improve livelihoods, which in combination determine level of income diversification (Dedehouanou and McPeack, 2020; Wang et al., 2024). Not only economic but also wider social factors are also important in determining livelihoods diversification strategies (Duguma et al., 2020), including access to social protection schemes to cope with livelihood shocks (Guguma, 2019).

Table 28 Result of Likelihood Ratio Test (the full model vs the reduced model)

Likelihood-ratio test	LR chi2(21) =	52.81
(Assumption: reduced model nested in full model)	Prob > chi2 =	0.0001

Pseudo R^2 for the nested models

McFadden's Pseudo R^2 approach of model comparison which is a means to test the quality of a single model by comparing it with its null model (i.e. assuming none of the predictor variables) was used here to compare two nested models (full and reduced) to confirm which one fits more to the reality of livelihoods diversification using their log odds.

Accordingly:

Pseudo $R^2 = 1 - \frac{\text{Log likelihood reduced model}}{\text{Log likelihood full model}}$, substituting the log-likelihoods of the reduced and full models in the formula, we get 0.489 indicating that the full model has a predictive capacity of about 49% of the variation in livelihood diversification among households. This further confirms that the full model should be adapted.

4.16. Propensity scores matching analysis

This section presents the ultimate objective of the present study which is to compare the food security outcome of livelihood diversification as measured by key parameters, HFIAS and FCS against the treatment variable, i.e. livelihood diversification and a list of covariates (age, gender, household size, assets, income, access to services and various opportunities considered in the modeling procedure. The following sections presents the results of the PSM analysis step by step.

4.16.1. Matching based on demographic factors

The variance ratios for all demographic variables except gender and marital status were found outside the normally acceptable range (0.57 - 1.74). Household size contributed most of the bias (70%) (Table 29) (Table 30).

Table 29 Propensity score matching treated and control groups for demographic covariates

Demography	Variable	Treated Mean	Control Mean	% Bias	t-test	p-value	Variance Ratio (V(T)/V(C))
	Age	47.17	48	-6.1	-0.49	0.623	10.32*
	Gender	0.77	1	-54.3	-3.91	0.000	.
	Marital Status	2.04	2	5.1	0.47	0.641	.*
	Household Size	16.14	8.33	70.0	4.02	0.000	215.27*

The Likelihood Ratio Chi-square (LR $\chi^2 = 53.32$) signifies the joint significance of all covariates used to predict the probability of being treated. However, after the matching procedure, a lower value of LR χ^2 was expected, as it indicates better balance between treated and control groups, which is not the case in this analysis. The Pseudo R^2 value of 0.432 indicates that the goodness-of-fit of that the propensity score model explains 43% of the variation in treatment assignment (Table 28). Therefore, it was not possible to match households based on demographic factors despite a 100% of variance matched, i.e matching attempt included all households under treatment and control groups. Overall Standardized Bias (151) exceeds the acceptable threshold of 25%, indicating a substantial imbalance of demographic covariates.

Table 30 The overall summary of the PSM balance test on demographic covariates

Pseudo R^2	LR χ^2	p-value (χ^2)	Mean Bias	Median Bias	B (Standardized)	R (Variance Ratio)	% Variance Matched
0.423	53.32	0.000	33.9	30.2	151.0*	66.75*	100%

4.16.2. Matching based on livelihood opportunities

The matching attempt on major livelihood sources also indicated that both diversified (treatment group) and non-diversified (control group) do not have significant difference in their engagement in small businesses (Table 31).

Table 31 Propensity score matching treated and control groups for key livelihood covariates

Livelihood sources	Treated Mean	Control Mean	% Bias	t-test	p-value	Variance Ratio (V(T)/V(C))
Crop production	0.12	0.33	-81.7	-2.73	0.007	.
Livestock production	0.85	0.67	41.3	2.16	0.033	.
Labor work	0.04	0.33	-156.0	-4.14	0.000	.
Small business	0.21	0.33	-37.7	-1.39	0.166	.
Charcoal production	0.10	0.00	44.5	2.33	0.022	.
Miscellaneous	0.79	0.33	99.2	5.21	0.000	.

However, the overall Variance Ratio is missing and Standardized Bias is 118.2 (exceeding the 25% thresh hold). Variance ratio was also way outside the acceptable range (0.5; 2) and did not appear in the outputs, suggesting significant ($p < 0.05$) imbalances of in different livelihood sources among treated and control households (Table 32).

The overall summary of the PSM balance test on livelihood covariates

Pseudo R^2	LR χ^2	p-value (χ^2)	Mean Bias	Median Bias	B (Standardized)	R (Variance Ratio)	% Variance Matched
0.320	43.88	0.000	76.7	63.1	118.2*	4.08*	.

4.16.3. Matching based on level of income

The matching of households in terms of their income levels from different livelihood activities suggest that there is a great difference among treated and control groups ($p<0.05$). However, the model showed that less diversified households generate more income from paid labor work ($P<0.05$) and from small businesses through statistically insignificant $P >0.05$). The result also indicated that more diversified households (treatment groups) generate significantly higher income from all the livelihood sources considered ($P<0.05$) except labor work and small businesses. These households also generate a highly significant income from miscellaneous income generating activities. This single variable contributed the highest variance ratio (1230.74) (Table 31).

Table 31 Propensity score matching treated and control groups for main income covariates

Main income sources	Treated Mean	Control Mean	% Bias	t-test	p-value	Variance Ratio (V(T)/V(C))
Income from crop	846.15	2666.7	-76.1	-2.75	0.007	0.57*
Income from livestock	3220.8	2166.7	38.1	2.39	0.019	1.26
Income from labor	96.15	666.67	-81.9	-3.49	0.001	0.53*
Income from small business	582.69	1000	-33.3	-1.56	0.122	0.82
Income from charcoal	125	0	37.3	1.90	0.060	.*
Income from gums and incense	0	0	.	.	.	.*
Miscellaneous income	1862.5	33.333	63.7	7.90	0.000	1230.74*

As depicted from high Pseudo R^2 value of 0.816, the model explained much of the variance in income among treated (more diversified households) and control (less diversified) households. However, all other measurements including Likelihood Ratio Chi-square (LR $\chi^2 = 113$), P -value < 0.05, Standardized Bias 176.2, Variance Ratio (621.56) all indicates that the matching did not result comparable groups despite the fact that variance matched is 67% (Table 32).

Table 32 The overall summary of the PSM balance test on main income sources (covariates)

Pseudo R^2	LR χ^2	p-value (χ^2)	Mean Bias	Median Bias	B (Standardized)	R (Variance Ratio)	% Variance Matched
0.816	113.00	0.000	55.1	50.9	179.2*	621.56*	67

4.16.4. Matching based asset ownership and access to services

The analysis showed that treated groups (more diversified households) have significantly higher ownership of key livelihood assets and access to services. However, in terms of cattle ownership, access to education, distance from markets and benefit from relief assistance, both treated and control groups showed no statistically significant differences. Ownership of camel sheep and goats and access to farmland and extension services were the covariates which induced greater percentage bias among the treated and control groups (Table 33) indicating that treated groups (more diversified households) own more of these assets and access services more than less diversified households.

Table 33 Propensity score matching treated and control groups for assets and access to services covariates

Assets and access to services	Treated Mean	Control Mean	% Bias	t-test	p-value	Variance Ratio (V(T)/V(C))
Access to farmland	0.88	0.67	52.1	2.73	0.007	.
Size of farmland (ha)	2.17	1.33	0.3	3.73	0.000	0.66
Own cattle	0.77	0.67	23.6	1.16	0.249	.
Own camels	0.48	0.00	95.6	6.87	0.000	.
Own sheep	0.60	0.33	53.4	2.76	0.007	.
Own goats	0.92	0.67	77.3	3.38	0.001	.
Education	0.11	0.00	21.0	1.53	0.130	.*
Vocational training	0.12	0.00	32.9	2.58	0.011	.
Extension services	0.73	0.33	86.2	4.38	0.000	.
Access to credit	0.08	0.33	-83.4	-3.38	0.001	.
Remittance	0.35	0.67	-67.3	-3.42	0.001	.
Access to irrigation	0.79	0.67	26.8	1.39	0.166	.
Market distance (km)	1.77	1.67	8.6	0.41	0.685	1.08
Food from own crop	0.11	0.33333	-90.9	-3.05	0.003	.
Food from own livestock	0.13	0.00	38.1	2.82	0.006	.
Benefit from PSNP	0.00	0.00	0.0	.	.	.
Benefit from relief food	0.23	0.33	-22.4	-1.16	0.249	.
Practice savings (Amount)	525	833.33	-54.4	-2.03	0.044	0.62

Despite the model is highly explanatory of the differences between the treatment and control groups based on the covariates included in the model (Pseudo $R^2 = 1$; LR $\chi^2 = 90.07$), the result showed that treatment and control groups were not effectively matched as the overall mode resulted in a high standardized bias (318.1), high variance ratio (1646.76) and low percentage variance matched (25%) (Table 34).

Table 34 The overall summary of the PSM balance test on assets and access to services

Pseudo R^2	LR χ^2	p-value (χ^2)	Mean Bias	Median Bias	B (Standardized)	R (Variance Ratio)	% Variance Matched
1.000	90.07	.	46.3	45.1	318.1*	1646.76*	25

All in all, the PSM procedure enabled to identify key predictors in general, similar to the previous

modeling procedures but not able to result in matched treatment and control groups. This necessitated to consider another regression approach to establish the impact of livelihood diversity (SLDI scores) on HFIAS and FCS scores.

4.17. Weighted P-Score regression analysis

4.17.1. Regression of Livelihoods with HIFIAs Scores

The results of the weighted p-score regression analysis using robust procedure using the p-score for livelihood diversification against the HFIAS scores are presented in Table 35.

Table 35 Model output for regression of livelihood diversification and HFIAS

Source	SS	df	MS	
Model	2.98	1	2.98	Number of obs = 253
Residual	2590.43	251	10.32	F (1, 251) = 0.29
Total	2593.41	252	10.29	Prob > F = 0.5915
				R-squared = 0.0011
				Adj R-squared = -0.0028
				Root MSE = 3.2125

Model fitness

The result suggests that variance explained by the model is extremely low with only 0.11% of the variance in HFIAS scores has been explained by livelihoods diversification scores (R-squared = 0.0011). The total sum of squares, is 2593.4 which is the total variation of the dependent variable (variation in food insecurity as measured by HFIAS) out of which the model explained only 2.98 while residual variance in HFIAS (2590.4) remained unexplained by the model. This suggests that, HFIAS is not a function of livelihood diversification in the present study. The F-statistic (0.29) and (P>0.05) also suggest the same.

Regression coefficients

The coefficient for livelihood diversification suggests that a one-unit increase in livelihoods diversification is associated with 0.26 units of average increase in HFIAS score, even though this

effect is not statistically significant (p = 0.591). The constant term (2.78) is significant, representing the expected value of HFIAS even when livelihoods diversification efforts were not made (Table 36).

Table 36 Estimates of coefficients for livelihood diversification index

Variable	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]
Livelihoods diversification	0.26	0.49	0.54	0.59	[-0.7027, 1.2301]
_cons	2.78	0.23	12.18	0.000	[2.3288, 3.2273]

Normality test – the Shapiro-Wilk test statistic is close to 1 indicating that the residuals, i.e the variance in the HFIAS, is not normally distributed since the p-value is less than 0.05, and hence, the null hypothesis (H_O that the residuals are normally distributed is rejected and the alternative hypothesis (H_A that the residuals are not normally distributed) is accepted (Table 37). However, since normality is not a critical requirement in propensity score regression analysis with a robust procedure, the model can be considered still valid.

Table 37 Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
Residuals	253	0.94	11.00	5.58	0.000

Heteroskedasticity test – the post-estimation test (Breusch-Pagan test) showed a chi-squared value of 0.16 with a p-value of 0.69, indicating no significant evidence of heteroskedasticity in the model. This suggests that the residuals have constant variance, supporting the validity of the standard errors used (Table 38).

Table 38 Results from the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Test	Breusch-Pagan / Cook-Weisberg Test
Null Hypothesis (H0)	Constant variance
Variables Tested	Fitted values of HFIAS scores
Chi-squared (chi2)	0.16
Degrees of Freedom	1
Prob > chi2	0.69

From the post estimation result (Table 36) the Null Hypothesis (H_0) tests whether the residuals have constant variance or homoskedasticity, indicates a p-value of 0.6930 suggesting that there is no significant evidence to reject the null hypothesis, since the residuals have constant variance.

Multicollinearity – the model is not affected by multicollinearity, with a Variance Inflation Factor (VIF = 1.00) which suggests that livelihoods diversification scores were completely independent of HFIAS scores.

Though variance explained by the model is extremely low with only (R-squared = 0.0011 or 0.11%), livelihoods diversification did not show a significant effect on HFIAS score of households (F-statistic 0.29 and a p-value 0.5915). Other studies on the food security impact of livelihood diversification on household food security are also equivocal. Some indicated that livelihood diversification will have positive impact on food security status (Alemu, 2023; Salifu, 2024). Study by Raholiarimanana et al (2023) also showed that households involved in livestock production were better food secured. Yet, some other studies have indicated that the course of the outcome on food security all depends on the quality and intensity of livelihood diversification. Beyene et al. (2023) and Sisay (2024) argue that livelihood diversification with off-farm income sources are the ones which improve food security and welfare of households. Benti et al. (2022) also indicated that market participation by pastoralists is required to significantly decrease the severity of food insecurity as measured by HFIAS, and reduced coping strategy index (rCSI).

In the current study the regression coefficient for livelihood diversification suggests that a one-unit increase in livelihoods diversification is associated with a 0.26 unit increase in HFIAS score, which is not statistically significant ($P>0.05$). On the hand the constant term (2.78, $P<0.01$) is highly significant, indicating the expected value of HFIAS even when livelihoods diversification efforts were not made, which is further indication that livelihood diversification has insignificant impact in determining food security outcome as measured by HFIAS). This could be attributed to a lower level of access to market and limited participation in off-farm opportunities as observed in our study.

4.17.2. Regression analysis of Livelihood diversification and FCS

Model fitness

The R-squared value (0.0377) suggests that only 3.77% of the variance in FCS scores was explained by livelihoods diversification. However, the F-statistic (9.84) P<0.01 indicates that the model has high statistical significance, meaning livelihoods diversification is a significant predictor of household FCS scores (Table 39).

Table 39 Regression analysis of Livelihood diversification and FCS

Source	SS	df	MS	
Model	975.960738	1	975.960738	Number of obs = 253
Residual	24899.0463	251	99.1993877	F (1, 251) = 9.84
Total	25875.0071	252	102.678599	Prob > F = 0.0019
				R-squared = 0.0377
				Adj R-squared = 0.0339
				Root MSE = 9.9599

Regression coefficients

The regression coefficient (4.77) suggests that an average one-unit increase in livelihoods diversification is associated with a 4.77 unit of average increase in FCS scores which is statistically significant (P<0.05). The Constant term (19.95) represents the expected value of FCS scores when livelihoods diversification is zero, and it is also statistically significant (Table 40).

Table 40 Estimates of coefficients for livelihood diversification index

Variable	Coef.	Std. Err.	t	P > t	[95% Conf. Interval]
Livelihoods diversification	4.7720	1.5214	3.14	0.002	[1.7757, 7.7682]
_cons	19.9499	0.7072	28.21	0.000	[18.5571, 21.3428]

Normality – similar to the case of the regression modeling of livelihoods diversity with HFIAS, normality is not a critical concern for propensity score regression since the model estimations are done using robust procedure which also factor in the nature of the data (the weighted p-scores).

Heteroskedasticity - the post-estimation test (Breusch-Pagan test) showed a high chi-squared value of 7.67 with a $P<0.05$ suggesting strong evidence against the null hypothesis, that there is heteroskedasticity (non-constant variance) in the residuals of the model. However, since the model estimation was made using robust procedure which controls such factors, assumption of constant variance in the residuals is not violated and the model is still considered valid (Table 41).

Table 41 Results from the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Test	**Breusch-Pagan / Cook-Weisberg Test**
Null Hypothesis (H0)	Constant variance
Variables Tested	Fitted values of FCS score
Chi-squared (chi2)	7.67
Degrees of Freedom	1
Prob > chi2	0.0056

Multicollinearity – the model is not affected by multicollinearity, with a Variance Inflation Factor (VIF = 1.00) which suggests that the independent variable livelihoods diversification scores were completely independent of FCS scores.

Similar studies on impact of livelihood diversification on food security, especially engaging in the production of multiple food crops and off-farm livelihoods have shown positive results on food consumption (Akrasi et al., 2020; Rehan et al., 2021; Sisay, 2024). Recent study report by Abaynew et al. (2024) indicated, 34.62% and 50.69% of the pastoral and agro-pastoral households were food secure, respectively, indicating that agro-pastoral households were relatively more food secure than purely pastoral households. Supporting this argument, Sileshi et al. (2023) have indicated that the use of a single food security indicator could under-estimate the level of food insecurity by using calorie intake and FCS measurements together. Therefore, this suggests that studies in the future should adopt a more robust designs which can demonstrate the food security outcome of livelihood diversification. The present study demonstrated that, while SLDI did not show significant association with HFIAS, it did show significant association with FCS.

Since both regression analysis of SLDI with HFIAS and SLDI with FCS had weak predictive values of the variation in food security of the studies households, we generalized that, the initial hypothesis of our research that livelihood diversification could be an indicator to food security holds true. Therefore, ensuring food security is a subject above and beyond livelihood diversity status of households, which does not necessarily guarantee food security. Thus, on-going efforts of development actors to enhance and diversify livelihoods in the pastoral areas need to consider the actual impact of their investments in terms of food security measures.

Chapter 5: Conclusions and recommendations

The findings of this study reveal that livelihoods in the pastoral and agro-pastoral production systems of Assaita and Afambo woredas remain largely undiversified and highly vulnerable to food insecurity. The majority of households continue to rely on climate-sensitive livelihoods, primarily traditional livestock production and limited crop farming, while off-farm income-generating opportunities remain underutilized. Despite the existing potential for diversification, the integration of crop production and livestock-based livelihoods at scale has not guaranteed improved food security outcomes. Households classified under a higher livelihood diversity index achieved marginally better food consumption scores (FCS), yet livelihood diversification alone did not consistently translate into improved food security, particularly when measured using the Household Food Insecurity Access Scale (HFIAS). This underscores the need for a more comprehensive approach that goes beyond diversification to address systemic livelihood and food security challenges.

The study further highlights the limited contribution of employment in decent jobs to household income, with many families remaining dependent on food aid. Sustainable livelihood diversification, when complemented with targeted support mechanisms, could enhance food availability, access, and dietary diversity, mitigating the severity of food insecurity. Additionally, while Sustainable Livelihood Diversification Index (SLDI) assessments based on income and expenditure confirmed low diversification levels, income-based SLDI classifications indicated a higher proportion of households as poorly diversified. These findings suggest that future interventions should consider both income and expenditure dimensions to accurately assess livelihood diversity and inform policy decisions.

Recommendations

- Enhancing livelihood diversification strategies - efforts should focus on optimizing and expanding the prevailing pastoral production system while integrating viable alternative and complementary livelihood strategies. This includes investments in irrigated crop farming, value chain development, and the commercialization of livestock products to enhance productivity, resilience, and income diversification.

- Reevaluating pastoral transformation policies - policies aimed at transitioning pastoralists into crop farming should be reassessed, recognizing the socio-economic and ecological realities of pastoral households. Instead of promoting crop production as a primary alternative, a balanced approach that strengthens livestock-based livelihoods should be prioritized, considering the sector's dominant role in household income and resilience.
- Promoting sustainable agrarian and non-agrarian opportunities - expanding irrigated crop farming should be pursued cautiously, with due consideration for the long-term sustainability of agriculture in arid and semi-arid regions. Simultaneously, non-agricultural income opportunities, such as small-scale enterprises and vocational employment programs, should be developed to reduce dependency on climate-sensitive livelihoods and enhance economic diversification.
- Strengthening off-farm income-generating activities - given the significant contribution of off-farm activities to household livelihoods, targeted programs that facilitate market linkages, entrepreneurship training, and access to credit should be promoted. Encouraging microfinance initiatives and cooperatives can improve financial inclusion and support business development in rural pastoral areas.
- Addressing seasonal variations in food security - to establish a clearer causal link between livelihood diversification and food security outcomes, future research should adopt longitudinal designs that capture seasonal patterns of food security and income fluctuations. This would provide more robust evidence to guide policy decisions and intervention designs.
- Investing in climate-resilient livelihood strategies - given the vulnerability of pastoral and agro-pastoral livelihoods to climate variability, resilience-building interventions should prioritize sustainable rangeland management, water conservation, and climate-smart agricultural practices. These measures will help safeguard household incomes and enhance food security in the face of environmental uncertainties.
- Targeted policy and programmatic interventions - government and development partners should implement well-targeted interventions that take into account the diverse livelihood conditions of pastoral and agro-pastoral communities. Programs should be designed with a clear understanding of the local socio-economic context and should integrate both short-term relief mechanisms and long-term resilience-building strategies.

All in all, by aligning various policies and programs on pastoral livelihoods development and food security with the core findings of this study, stakeholders can enhance the effectiveness of livelihood diversification efforts, ultimately improving food security and economic resilience for pastoral and agro-pastoral communities in the two study woredas.

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Annexes

Annex 1: Stata commands used in the analysis of the data

Key stata commands used	**Purpose**
Statistics>>summary tables and tests>> frequency tables>>multiple one-way tables	Percent and frequency through statistics tab
[tabulate vaviable1 variable2 varible3, chi2]	Chi-square analysis
[probit dependent variable independent variables]	Probit regression analysis
[margins, dydx(*)]	Marginal effects estimation
[estat classification]	Classification Statistics from Probit Model
[estat ic]	Goodness-of-fit to evaluate each model against itself comparing it with the null (without the predictors)
Fit the restricted and the unrestricted models and save after each step as follows: [estimates store restricted_model] [estimates store unrestricted_model] [lrtest restricted_model unrestricted_model]	Compare two nested models with each other (restricted or reduced model vs unrestricted or full model)
[firthlogit treatment variable covariate1 variable covariate2 variable covariate3]	Step 1: Estimate the firth logit
[predict log_odds]	Step 2 predict the log odds
[gen pscore = exp(log_odds) / (1 + exp(log_odds))]	Step 3: generate the p-score
[psmatch2 treatment variable, pscore(pscore) out(outcome variable) neighbor(1)] [psmatch2 treatment variable, pscore(pscore) out(outcome variable) neighbor(3)] [psmatch2 treatment variable, pscore(pscore) out(outcome variable) neighbor(3) caliper(0.4)] [psmatch2 treatment variable, pscore(pscore) kernel out(matched_data.dta) bandwidth(0.2)]	Step 4: do the matching based on either and any combination of Nearest neighbor matching, caliper methods and matching
[pstest covariate1 variable covariate2 variable covariate3, graph treat(treatment variable)]	Weighted P-score Analysis: Step 1: P-test
[gen weight = treatment/pscore + (1 - treatment)/(1 - pscore)]	Step 2: Weighted P-score
regress outcome variable treatment variable [aw=weight]	Step 3: Regressing HFIAS with the weighted pscores of SLDI

regress outcome variable treatment variable [aw=weight]	Step 3: Regressing FCS with the weighted pscore of SLDI

Annex 2: Result of multinomial logistic regression of livelihood categories

Number of obs = 254							
LR chi2(28) = 303.94							
Prob >chi2 = 0.000							
Log likelihood = 0							Pseudo R2 = 1
Livelihood diversification status	RRR	Std. Err.		z	P>z	[95%	Conf.
0 (base outcome)							
1 = Poor diversity (SLDI < 0.03)							
Age	0.7137851	1.09E+08	0	1	0	.	
Gender	8.75E-13	.	.	.	.	.	
Marital status	18670.1	.	.	.	.	.	
Household size	1.946223	.	.	.	.	.	
Engagement in crop production	1.40E+54	.	.	.	.	.	
Engagement in livestock production	1.44E+43	.	.	.	.	.	
Engagement in labor	2812446	.	.	.	.	.	
Engagement in small business	1.33E+54	.	.	.	.	.	
Engagement in fishing	1	(omitted)					
Receiving remittance	1	(omitted)					
Engagement in cross-border trade	1	(omitted)					
Engagement in charcoal production	6.32E-09	.	.	.	.	.	
Engagement in gums & incense	1	(omitted)					
Engagement in miscellaneous IGA	1.07E+75	.	.	.	.	.	
Level of income from crop	1.007976	942276.7	0	1	0	.	
Level of income from livestock	1.001648	1027555	0	1	0	.	
Level of income from labor	1.026906	5552158	0	1	0	.	
Level of income from small business	1.017105	336972.7	0	1	0	.	
Level of income from fishing	1	(omitted)					
Level of income from remittance	1	(omitted)					
Level of income from cross-border trade	1	(omitted)					
Level of income from charcoal	1.154917	.	.	.	.	.	
Level of income from gums & incense	1	(omitted)					
Farmland	7.15E+23	.	.	.	.	.	
Size of farm lands (ha)	0.9835553	3.30E+07	0	1	0	.	
Ownership of cattle	3.04E-12	.	.	.	.	.	

Number of cattle	1.216214	6.57E+08	0	1	0	.	
Ownership of camels	4.27E+08	.	.	.	.	.	
Number of camels	0.6082651	4.49E+08	0	1	0	.	
Ownership of sheep	2.72E+10	.	.	.	.	.	
Ownership of goats	5755881	.	.	.	.	.	
Ownership of chicken	0.0003672	.	.	.	.	.	
Access to education	3.86E+12	7.16E+21	0	1	0	.	
Access to vocational skills	3.96E+09	.	.	.	.	.	
Access to extension	1.47E+09	.	.	.	.	.	
Access to credit	1.70E-33	.	.	.	.	.	
Access to irrigation	246.0368	.	.	.	.	.	
Exposure to flood	1.16E+20	.	.	.	.	.	
Exposure to drought	9.76E-19	.	.	.	.	.	
Exposure to livestock diseases	1	(omitted)					
Exposure to desert locust	1	(omitted)					
Access to market (km)	0.6503822	.	.	.	.	.	
Access to food from own crop	6.47E-30	.	.	.	.	.	
Access to food from own livestock	0.0000527	.	.	.	.	.	
Access to food from PSNP	32162.3	.	.	.	.	.	
Access to food from relief aid	0.0000749	.	.	.	.	.	
Amount of savings	0.9828181	3523115	0	1	0	.	
_cons	2.10E-122	.	.	.	.	.	
2 = Medium diversity (SLDI: 0.03-0.06							
Age	0.3058812	2.71E+08	0	1	0	.	
Gender	2.48E+12	.	.	.	.	.	
Marital status	1.21E+16	.	.	.	.	.	
Household size	4.635937	6.10E+09	0	1	0	.	
Engagement in crop production	4.10E+103	.	.	.	.	.	
Engagement in livestock production	2.95E+50	.	.	.	.	.	
Engagement in labor	6.04E+40	.	.	.	.	.	
Engagement in small business	1.80E+128	.	.	.	.	.	
Engagement in fishing	1	(omitted)					
Receiving remittance	1	(omitted)					
Engagement in cross-border trade	1	(omitted)					
Engagement in charcoal production	1.79E-08	.	.	.	.	.	

Engagement in gums & incense	1	(omitted)					
Engagement in miscellaneous IGA	2.27E+50	.	.	.	.	.	
Level of income from crop	0.9858153	8465602	0	1	0	.	
Level of income from livestock	0.9980707	7712690	0	1	0	.	
Level of income from labor	0.9913615	2.69E+07	0	1	0	.	
Level of income from small business	0.9684865	1.99E+07	0	1	0	.	
Level of income from fishing	1	(omitted)					
Level of income from remittance	1	(omitted)					
Level of income from cross-border trade	1	(omitted)					
Level of income from charcoal	1.158744	4.65E+07	0	1	0	.	
Level of income from gums & incense	1	(omitted)					
farmland	812160.6	.	.	.	.	.	
Size of farm lands (ha)	0.9798701	1.15E+08	0	1	0	.	
Ownership of cattle	5.08E-13	.	.	.	.	.	
Number of cattle	0.7118757	1.47E+09	0	1	0	.	
Ownership of camels	1.31E+22	.	.	.	.	.	
Number of camels	1.799942	4.69E+09	0	1	0	.	
Ownership of sheep	1.50E+36	.	.	.	.	.	
Ownership of goats	6.34E-11	.	.	.	.	.	
Ownership of chicken	33321.95	.	.	.	.	.	
Access to education	1.71E+16	.	.	.	.	.	
Access to vocational skills	5.816335	.	.	.	.	.	
Access to extension	1.54E+07	.	.	.	.	.	
Access to credit	6.77E+07	.	.	.	.	.	
Access to irrigation	4.29E-19	.	.	.	.	.	
Exposure to flood	69.30803	.	.	.	.	.	
Exposure to drought	0.0000203	.	.	.	.	.	
Exposure to livestock diseases	1	(omitted)					
Exposure to desert locust	1	(omitted)					
Access to market (km)	419057.2	.	.	.	.	.	
Access to food from own crop	0.0070971	.	.	.	.	.	
Access to food from own livestock	6.92E+10	.	.	.	.	.	
Access to food from PSNP	2.27E+09	.	.	.	.	.	
Access to food from relief aid	7388.071	.	.	.	.	.	
Amount of savings	0.99085	2.94E+07	0	1	0	.	
_cons	1.80E-162	.	.	.	.	.	

3 = high livelihood diversity (SLDI>0.06)							
Age	0.4376382	2.09E+08	0	1	0	.	
Gender	2.68E-08	.	.	.	.	.	
Marital status	4.51E+16	.	.	.	.	.	
Household size	1.841729	1.55E+09	0	1	0	.	
Engagement in crop production	8.91E+37	.	.	.	.	.	
Engagement in livestock production	6.72E+36	.	.	.	.	.	
Engagement in labor	2.67E+26	.	.	.	.	.	
Engagement in small business	1.69E+69	.	.	.	.	.	
Engagement in fishing	1	(omitted)					
Receiving remittance	1	(omitted)					
Engagement in cross-border trade	1	(omitted)					
Engagement in charcoal production	6.90E-33	.	.	.	.	.	
Engagement in gums & incense	1	(omitted)					
Engagement in miscellaneous IGA	3.61E+48	.	.	.	.	.	
Level of income from crop	0.9892267	6807028	0	1	0	.	
Level of income from livestock	0.9958498	4152792	0	1	0	.	
Level of income from labor	1.002235	1.71E+07	0	1	0	.	
Level of income from small business	0.9968173	9984951	0	1	0	.	
Level of income from fishing	1	(omitted)					
Level of income from remittance	1	(omitted)					
Level of income from cross-border trade	1	(omitted)					
Level of income from charcoal	1.153841	3.72E+07	0	1	0	.	
Level of income from gums & incense	1	(omitted)					
farmland	6.63E+43	.	.	.	.	.	
Size of farm lands (ha)	0.9867632	2.65E+08	0	1	0	.	
Ownership of cattle	3.91E-08	.	.	.	.	.	
Number of cattle	1.728153	1.93E+09	0	1	0	.	
Ownership of camels	11252.46	.	.	.	.	.	
Number of camels camels	0.5239749	.	.	.	.	.	
Ownership of sheep	6.26E+32	.	.	.	.	.	
Ownership of goats	5.81E-13	.	.	.	.	.	
Ownership of chicken	3.63E-15	.	.	.	.	.	
Access to education	2.17E+11	.	.	.	.	.	
Access to vocational skills	9.97E-10	.	.	.	.	.	
Access to extension services	1.56E-21	.	.	.	.	.	

Access to credit	220192.6	.	.	.	.	.	
Access to irrigation	7.60E-07	.	.	.	.	.	
Exposure to flood	2.26E-18	.	.	.	.	.	
Exposure to drought	0.0000918	.	.	.	.	.	
Exposure to livestock diseases	1	(omitted)					
Exposure to desert locust	1	(omitted)					
Access to market (km)	0.6302878	.	.	.	.	.	
Access to food from own crop	904.4132	.	.	.	.	.	
Access to food from own livestock	2.31296	.	.	.	.	.	
Access to food from PSNP	1.06E+49	.	.	.	.	.	
Access to food from relief aid	2.52E+07	.	.	.	.	.	
Amount of savings	1.004279	1.56E+07	0	1	0	.	
_cons	4.40E-125	.	.	.	.	.	
Note: 254 observations completely determined. Standard errors questionable.							

Annex 3: Questionnaire for household livelihood assessment

Questionnaire Designed to collect data from the field for an MSc in the partial fulfilment of the degree Master of Science in Development Studies and Food Security, Addis Ababa University, College of Development Studies

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Introduction

Purpose: The purpose of this study is to assess livelihoods diversification, its determining factors and its impact on household food security in Asaita and Afambo woredas of the Afar regional State

Confidentiality: all information collected from respondents will be held confidentially and results be reported at aggregate level and keeping strict anonymity

Consent: Are you willing to participate in this assessment? _____if yes, then proceed to the questionnaires.

Part 1: Livelihoods

1. Household location (woreda_____kebele_____, village_____
2. Respondent Name _____
3. Respondent Age (in years) _____
4. Gender
   - Male
   - Female
5. Marital status
   - Single
   - Engaged
   - Married
   - Widowed
6. Number of adult male household members
7. Number of adult female household members
8. Number of boys < 18 years
9. Number of girls <18 years
10. What is/are the livelihood strategies (means) of the household (tick multiple options)?

- Crop production
- Livestock production
- Wage Labor
- Small Business
- Fishing
- Remittance
- Cross border Trade
- Charcoal/firewood sales
- Gums, incense and other forest products
- Others (Please specify): _____

11. How much is the household's annual income from:
    - Crop production
    - Livestock production
    - Wage Labor
    - Small Business
    - Fishing
    - Remittance
    - Cross border Trade
    - Charcoal/firewood sales
    - Gums, incense and other forest products
    - Others (Please specify): _____
12. Do you own agricultural land?
    - Yes
    - No
13. If yes, what is the size of the land? (in hectares) _____
14. Do you own cattle?
    - Yes
    - No
15. If yes, how many cows_____
16. How many oxen_____

17. How many heifers_____

18. How many bulls_____

19. Do you own camels?

- Yes
- No

20. If yes, how many mature female camels? _____

21. How many mature male camels? _____

22. How many young female camels? _____

23. How many young males/camel bulls_____

24. Do you own sheep?

- Yes
- No

25. If yes, how many eves (mature female sheep) _____

26. How many mature male sheep_____

27. How many young lamps_____

28. Do you own goats?

- Yes
- No

29. If yes, how many eves (mature female goats) _____

30. How many mature male goats_____

31. How many young goats_____

32. Do you own chicken?

- Yes
- No

33. If yes, how many layers _____

34. How many cocks_____

35. How many young chickens (pullets and cockerels) _____

36. What is the highest level of education attained by the head of the household?

- No formal education
- Primary education; grade_____
- Secondary education, grade_____

- Higher secondary education, grade_____
- Graduate and above, grade_____

37. Do any members of the household have vocational training or special skills?
    - Yes (Please specify): _____
    - No
38. Do you have access to farm advisory (extension services)?
    - Yes
    - No
39. If yes, the type of extension services received?
    - Advise on planting seasons
    - Advise on breeding of livestock
    - Advise on meteorology (weather conditions)
    - Advisor on market information
    - Advise on fertilizers
    - Advise on improved seeds
    - Advise on livestock diseases (vaccination and/or treatment)
    - Advise on product handling storage, and transportation (PHM)
    - Other, please specify _____
40. Do you have access to credit facilities?
    - Yes
    - No
41. If yes, what is the primary source of credit?
    - Banks
    - Microfinance Institutions
    - Informal lenders
    - Cooperatives
    - Others (Please specify): _____

42. How often do you receive remittances from family members working outside the

household?

- Never
- Rarely
- Sometimes
- Often
- Very often

43. Do you have access to irrigation facilities for your agricultural land?
    - Yes
    - No
44. Has your household been affected by any natural disasters in the past year?
    - Yes
    - No
45. If yes, what type of natural disaster?
    - Flood
    - Drought
    - Livestock diseases
    - Desert locust
    - Other (Please specify): _____
46. How far is the nearest market from your residence? _____kilometers
    - Less than 1 km
    - 1 - 5 km
    - 5 - 10 km
    - More than 10 km

Part 2: Income expenditure pattern

1. Do you have housing expenses?
    - Yes
    - No
2. If yes, how much is your annual expenses for housing - construction

3. How much is your annual expenses for housing – maintenance
4. How much is your monthly expenses for housing - house rent
5. Do you have food expenses?

 Yes

 No

6. If yes, how much is your average monthly expenditure on food items
7. If no, how do you cover household's food needs?

 Own production of crops

 Own production of livestock

 PSNP

 Relief food aid

 Other (specify)

8. Do you have utilities expenses?

 Yes

 No

9. If yes, how much is your average monthly expenditure on electricity?
10. how much is your average monthly expenditure on water?
11. how much is your average monthly expenditure on fuel?
12. how much is your average monthly expenditure on telephone airtime/ internet?
13. how much is your average monthly expenditure on any other utilities (specify)
14. Do you have expenses on service fees?

 Yes

 No

15. If yes, how much is your average monthly expenditure on transport fees?
16. how much is your average monthly expenditure on medical services including medicines?
17. How much is your average monthly expenses on animal health services?
18. How much is your average monthly expenses on animal drugs and vaccines?
19. Do you have education expenses?

 Yes

 No

20. If yes, how much is your average monthly expenses on school fees?
21. how much is your average monthly expenses on books and uniforms, etc?
22. how much is your average monthly expenses on other education related purposes?
23. How much is your average annual expenses on clothing?
24. How much is your average monthly expenses on social contributions?
25. How much is your average monthly savings?

Annex 4: Questionnaire for Household Food Insecurity Access Scale (HFIAS)

- Date and place _____
- Names, addresses and responsibilities of interviewees _____
- The interviewer should confirm that respondents verbally give their consent for voluntary participation
- Briefly introduce the objective of the interview and the discussion and highlight the question below.

Anxiety and Uncertainty about Food Supply

Q1: In the past 30 days, did you worry that your household would not have enough food?

 Yes, No,

Q1a: If yes, how often did this happen?

 rarely, sometimes, often Insufficient Quality

Q2: In the past 30 days, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?

 Yes, No,

Q2a: If yes, how often did this happen?

 rarely, sometimes, often

Q3: In the past 30 days, did you or any household member have to eat a limited variety of foods due to a lack of resources?

 Yes, No,

Q3a: If yes, how often did this happen?

 rarely, sometimes, often

Q4: In the past 30 days, 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?

 Yes, No,

Q4a: If yes, how often did this happen?

 rarely, sometimes, often Insufficient Food Intake

Q5: In the past 30 days, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?

 Yes, No,

Q5a: If yes, how often did this happen?

 rarely, sometimes, often

Q6: In the past 30 days, did you or any household member have to eat fewer meals in a day because there was not enough food?

 Yes, No,

Q6a: If yes, how often did this happen?

 rarely, sometimes, often

Q7: In the past 30 days, was there ever no food to eat of any kind in your household because of lack of resources to get food?

 Yes, No,

Q7a: If yes, how often did this happen?

 rarely, sometimes, often

Q8: In the past 30 days, did you or any household member go to sleep at night hungry because there was not enough food

 Yes, No,

Q8a: If yes, how often did this happen?

 rarely, sometimes, often

Q9: In the past 30 days, did you or any household member go a whole day and night without eating anything because there was not enough food?

 Yes, No,

Q9a: If yes, how often did this happen?

 rarely, sometimes, often

- Finally give opportunity to the respondents if they want to ask any question?
- Thank you for participating in the survey!

Annex 5 Questionnaire for Food Consumption Score (FCS)

- Date and place _____
- Names, addresses and responsibilities of interviews _____
- The interviewer should confirm that respondents verbally give their consent for voluntary participation
- Briefly introduce the objective of the interview and the discussion and highlight the questions below.

How often do you consume the following specific food groups over the past seven days.

Food groups	Weights	How many days	Frequency* weights
• Main staples (e.g., cereals, tubers)	2		
• Pulses (e.g., beans, lentils)	3		
• Vegetables	1		
• Fruits	1		
• Meat, fish, and eggs	4		
• Milk and dairy products	4		
• Sugar and sweets	0.5		
• Oils and fats	0.5		
Total Consumption Score			

- Finally give opportunity to the respondents if they want to ask any question?
- Thank you for participating in the survey!

Annex 6 Questionnaire/discussion guide for FGD and KII

The following questions are prepared to guide the discussion with key informants and during focused group discussions on livelihoods and food security issues.

- Date and place _____
- Names, addresses and responsibilities of interviews _____
- The interviewer should confirm that respondents verbally give their concept for voluntary participation
- Briefly introduce the objective of the interview and the discussion and highlight the question below.

1. What is your opinion on the broader food security and livelihood situation in the region, in Afambo and Assaita?
2. Kindly mention and elaborate the livelihood strategies and viable opportunities for people in the region.
3. What factors affect people's ability and the outcome of their participation in different livelihood activities?
4. What are the critical challenges for diversifying livelihoods?
5. What do you recommend in order to improve the livelihood status of the community in general?
6. Do what to say any other thing in relation to pastoral and agro-pastoral livelihoods and food security?

- Finally give opportunity to the respondents if they want to ask any question?
- Thank you for participating in the survey!