

AGRICULTURAL PRODUCTION CONSTRAINTS AND STRATEGIC INTERVENTIONS IN THE AMHARA REGION

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Amhara Agricultural Research Institute

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Bahir Dar, Ethiopia

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Message

It is my great privilege to introduce this timely and insightful publication, *Agricultural Production Constraints and Strategic Interventions in the Amhara Region*. This research report is the result of concerted efforts by dedicated researchers, development practitioners, and subject-matter experts who possess a deep and comprehensive understanding of our region's specific agricultural challenges. Agriculture forms the backbone of the Amhara Region, a cornerstone of



Ethiopia's economy and food security. However, persistent constraints such as environmental degradation, limited access to technology, policy gaps, and market inefficiencies continue to hinder productivity and resilience. Addressing these multifaceted challenges requires rigorous research and practical, evidence-based intervention strategies tailored to the region's context.

This report also delves into the critical constraints hindering agricultural growth, including climate variability and pest problems, poor extension services, soil degradation, moisture stress, soil acidity and salinity, limited access to modern inputs, market inefficiencies, socio-economic barriers, etc. Moreover, rooted in rigorous research and on-the-ground insights, it highlights the region's unique vulnerabilities, such as erosion-prone highlands and fragmented land holdings. The report presents a comprehensive analysis of the key production constraints across various agro ecologies and farming systems in the region, while also proposing context-specific and innovative solutions that can drive sustainable transformation. The recommendations outlined are deeply rooted in local realities, backed by years of rigorous research and meaningful community engagement.

By centering local knowledge and sustainable development, this report is a vital resource for empowering the Amhara Region—and beyond—to achieve food security, economic growth, and environmental stewardship. Join the journey toward a thriving agricultural future. As the Amhara Agricultural Research Institute, we remain committed to supporting research that advances food security, economic development, and environmental sustainability. I also believe this report will serve as a valuable resource for policymakers, development partners, researchers, and farmers alike.

Let me take this opportunity to extend my sincere appreciation to all contributors and reviewers who made this publication possible. Also, I urge all stakeholders to engage with the findings and collaborate on adopting the recommended strategies. Together, let us build a more productive, resilient, and prosperous agricultural sector—both for Ethiopia as a whole and the Amhara Region in particular.

Asmare Dejen Demeke (PhD)

Director General,

Amhara Agricultural Research Institute (ARARI)

Preamble



In response to Ethiopia's pressing challenges of food insecurity, climate vulnerability, and rural poverty, the Ministry of Agriculture (MoA) of the Federal Democratic Republic of Ethiopia has established the Food System Resilience Program (FSRP) for 2023-2029. The Program Development Objective (PDO) is to improve the resilience of food systems and increase preparedness against food insecurity in selected project areas. This World Bank-supported initiative directly supports Ethiopia's 10-year agricultural development strategy and broader national development goals.

The FSRP represents a comprehensive approach to agricultural transformation, structured around three fundamental objectives: (1) generating rural employment opportunities, (2) enhancing the competitiveness of agri-food systems, and (3) fortifying the agricultural sector's resilience. The program is being implemented across all 10 regional states and two city administrations, utilizing innovative, sustainable solutions tailored to address systemic challenges in Ethiopia's agricultural landscape.

Within this framework, the Amhara Agricultural Research Institute (ARARI) plays a pivotal role as the lead implementer of Subcomponent 1.2, focusing on Agricultural Technology Generation and Research System Transformation. FSRP-ARARI is driving the development, adaptation, and scaling of agricultural technologies while enhancing research systems to accelerate technology adoption among smallholder farmers in the region.

Since its inception in 2023, the program has actively supported the entire technology pipeline - from generation and multiplication to dissemination. To ensure these efforts are precisely targeted, FSRP-ARARI conducted an in-depth assessment of current agricultural production systems, identifying critical constraints and opportunities. This research forms the basis for developing context-specific, demand-driven technological solutions that respond to the actual needs of local farming communities. The current document synthesizes these assessment findings, outlining both the significant challenges identified and strategic recommendations for program execution. By grounding interventions in robust evidence, FSRP-ARARI aims to foster inclusive agricultural development that enhances food system resilience and sustainability across the Amhara region.

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This research report on Agricultural Production Constraints and Strategic Interventions in the Amhara Region has been made possible through the collaborative efforts of the Food System Resilience Program and a multidisciplinary research team. The Amhara Agricultural Research Institute (ARARI) was pivotal in leading data collection and report preparation, ensuring alignment with the study scopes and key focus areas.

We extend our heartfelt gratitude to all the farmers, producers, and experts who engaged in the focus group discussions and key informant interviews. Their invaluable contributions, firsthand experiences, and perspectives have played a vital role in shaping the findings and recommendations of this study.

We also acknowledge the dedicated researchers from various research centers within the Amhara Agricultural Research Institute, whose expertise and commitment have been instrumental in shaping this report with scientific rigor and analytical depth. Their contributions have enriched the assessment and provided valuable insights into the production systems examined.

Special thanks go to the editorial team of this research report for their meticulous efforts in refining and structuring the document. Their dedication to clarity, precision, and scientific rigor ensures the report's accessibility and impact.

ARARI is grateful to the Food System Resilience Program for its generous financial support, which made this research possible. Their investment in advancing agricultural sustainability and resilience is truly commendable.

To all contributors, direct and indirect, we express our deepest gratitude. Your collective efforts have made this study a meaningful endeavor toward enhancing agricultural systems in the Amhara region.

1. Executive Summary

This report presents a comprehensive assessment of agricultural production constraints and intervention strategies in the Amhara region, conducted by ARARI with the collaboration of the Food System Resilience Program (FSRP). The study systematically examined key productivity challenges, including crop and livestock management issues, market policy and institutional, gender dynamics, and socio-economic disparities across diverse agro-ecologies.

Key findings showed that agricultural productivity is still limited due to biotic and abiotic factors. The biotic factors that highly reduce crop yields are exotic diseases, insects, and invasive weeds. Meanwhile, the abiotic factors, such as moisture stress, erratic rainfall, soil degradation, salinity, acidity, and inefficient irrigation schemes, exacerbate production inefficiencies. Farmers faced limited access to improved inputs, mechanization technologies, irrigation infrastructure, financial services, and inadequate extension services, which reduced agricultural production. Addressing these issues requires adopting climate-smart crop varieties to enhance resilience, strengthening insect, weed, and disease management strategies, expanding irrigation infrastructure, and promoting mechanization where feasible. Additionally, participatory extension services (bottom-up approach) and farmer-led research initiatives can empower farming communities and ensure interventions align with local needs.

The study also identified prominent crop varieties cultivated across different agro-ecologies, analyzing their strengths, weaknesses, and farmers' preferred traits. Disease susceptibility, low biomass production, and incompatibility with local farming systems all contributed to the low adoption rate of improved varieties. To overcome these challenges, targeted interventions are necessary, including developing and disseminating climate-smart varieties suited to local conditions, improving access to quality inputs, and promoting mechanization.

Additionally, fostering farmer participation in variety selection, strengthening stakeholder collaboration, and enhancing knowledge-sharing through extension services will ensure sustainable agricultural transformation. Critical management practices, such as seed selection, fertilizer application, crop rotation, intercropping, pest controls, and post-harvest handling, are reviewed to highlight opportunities for improving agricultural resilience and long-term productivity.

Livestock production faced equally severe constraints, including feed shortages, genetic limitations, disease prevalence, low extension support, market inefficiencies, and weak veterinary health services, all contributing to low productivity.

Additionally, the study highlighted specific challenges in sectors such as apiculture and fisheries, revealing gaps in infrastructure, disease management, and market access. Given that the Amhara region holds a substantial portion of Ethiopia's livestock, addressing these challenges is crucial for farmers and economic growth. To address these constraints, strategic intervention areas have been outlined, focusing on research-driven solutions, improving livestock genetics through breeding programs, and expanding veterinary services significantly enhance disease control and productivity. Additionally, strengthening feed resources and forage development will provide sustainable solutions to nutritional deficiencies in livestock. Multi-stakeholder engagement—leveraging expertise from research institutes, governmental agencies, and development organizations—will be critical in executing these strategies. By optimizing resource utilization and advancing practical solutions, the livestock sector can be transformed into a more productive and sustainable industry, fostering economic resilience and improved food security for the Amhara Region.

The Amhara region features diverse land uses, including crop cultivation, natural and plantation forests, and grazing areas. However, land degradation—driven by deforestation, soil erosion, unsustainable agricultural practices, and free grazing—has become a pressing concern, threatening both biodiversity and agricultural sustainability. This degradation weakens soil productivity and heightens vulnerability to environmental hazards. To counter these effects, implementing soil conservation initiatives such as reforestation and sustainable land management practices is essential for restoring ecological stability.

Soil fertility is declining due to continuous cultivation, erosion, and nutrient depletion. Limited access to organic and inorganic fertilizers, compounded by soil acidity, further hampers agricultural productivity. Addressing these challenges requires targeted interventions, including lime application, improved fertilizer accessibility, and strategic land use planning to reverse degradation and enhance productivity.

Similarly, water management in the region is impeded by unreliable water sources, inefficient irrigation systems, and inconsistent moisture conservation practices. Strengthening irrigation infrastructure, promoting rainwater harvesting, and providing farmer education are key to optimizing water use, reducing dependence on erratic rainfall, and bolstering agricultural resilience.

Forests, both natural and plantation play a crucial role in maintaining environmental stability, regulating water resources, and supporting local livelihoods. Despite ongoing conservation efforts, threats such as deforestation, free grazing, and the expansion of agricultural land continue to threaten these ecosystems. To ensure responsible resource use, it is essential to implement integrated forest management that actively involves community participation.

Soil and water conservation measures, reforestation, and controlled grazing had yielded positive results, with area closures, physical conservation structures, and multipurpose tree planting (such as Eucalyptus and Acacia species) enhancing ecological resilience and economic benefits. However, concerns persist regarding species selection, soil moisture depletion, and limited tree diversity in restoration initiatives.

This study also explores the socio-economic challenges affecting rural agriculture in the Amhara region, examining key factors such as land use patterns, livelihood strategies, wealth distribution, agricultural inputs, extension services, gender roles, market dynamics, food security, climate-smart practices, and job creation. The study highlights uneven land distribution across districts, underscoring its direct impact on economic stability. This study emphasizes the importance of diversified livelihood strategies to alleviate rural poverty and enhance resilience to economic shocks. The report also highlights market inefficiencies, including price distortions, inadequate infrastructure, and limited value-added processing, which affect farmers' ability to fetch competitive returns for their produce. Gender imbalances in agricultural decision-making and resource distribution limit women's economic participation, affecting overall productivity.

To address all these challenges, the study emphasizes the need for targeted interventions, which include strengthening agricultural extension services with a focus on farmer training and participatory technology selection. In addition, enhancing access to improved crop varieties, mechanization, and financial instruments is crucial to ensure sustainable productivity gains. Also, promoting resilient livestock breeds, alongside improved veterinary and feed systems, will support better animal health and performance. Furthermore, improving market access through better infrastructure, cooperative formations, and integrated value chain systems will foster economic growth. Lastly, empowering women and youth through inclusive agricultural policies and economic programs is vital for encouraging equitable participation in the sector.

Generally, the Amhara region can achieve sustainable agricultural transformation by creating a well-integrated agricultural system that combines resources, technology, markets, and climate adaptation strategies. These coordinated efforts will enhance food security, promote economic stability, and foster long-term resilience in the agricultural sector.

2. Introduction

Economic Role Agriculture is the cornerstone of Ethiopia's economy, underpinning national development and rural livelihoods, particularly in smallholder farming systems (Wondimagegnhu et al., 2019; Zerssa et al., 2021). The sector contributes over 40% of the Gross Domestic Product (GDP) and employs more than 80% of the rural population (Zerssa et al., 2021; USAID, 2020). Beyond its economic significance, agriculture is essential for food security, nutrition, income generation, and employment opportunities.

The Region's Agricultural Potential The Amhara region is one of Ethiopia's most agriculturally endowed areas, characterized by diverse agro-ecological zones, extensive arable land, abundant water resources, and favorable climatic conditions. Its varied topography, ranging from high-altitude plateaus to lowland plains, supports a broad spectrum of crops and livestock, making it a pivotal agricultural hub. Generally, the Amhara region has immense agricultural potential, including fertile lands, abundant water resources, diverse farming systems, and a strategic market position. Despite its potential, the region's agricultural productivity remains below expectations, mainly due to traditional farming practices, limited access to modern technologies, and market inefficiencies.

The region is a leading producer of staple crops, including wheat, barley, teff, maize, sorghum, and pulse crops, which sustain millions of people. Moreover, high-value commodities like sesame, linseed, onions, tomatoes, and potatoes present significant opportunities for market-driven production and agro-processing expansion. The region's wide range of adaptable farming systems has also positioned it as a critical supplier of cereals and legumes for Ethiopia's domestic food supply and commercial export markets.

Amhara also plays a central role in Ethiopia's livestock sector, housing 17.3 million cattle, 10.4 million sheep, and 7 million goats (CSA, 2021), contributing 45% to agricultural production (FAO, 2019). Livestock serves multiple purposes, including providing food, draught power, manure, transport services, and raw materials for industries while also being a source of income, savings, and fuel. Despite advancements in livestock farming, constraints such as inadequate veterinary services and feed shortages persist.

Sectoral Constraints Despite its vast agricultural potential, rural communities in Amhara continue to face food insecurity and economic hardships, relying heavily on food aid. The sector's low productivity, limited technological adoption, soil degradation, and climate variability hinder its contribution to poverty reduction and economic growth. Addressing these challenges requires research-driven innovations, investment in irrigation and infrastructure, and strategic policy interventions.

Development Initiatives Recognizing this need, the regional government, alongside the federal government and development partners, has initiated several agricultural programs, including the Food System Resilience Program (FSRP). This program seeks to enhance the sector competitiveness, create rural job opportunities, and strengthen food system resilience, aligning with Ethiopia's ten-year development plan and revised rural development policies. Within this program, the research institutions at various levels play a crucial role in advancing technology, identifying strategic interventions, and guiding evidence-based policymaking.

Scope of the Study As part of these efforts, the Amhara Agricultural Research Institute has been tasked with assessing the region's agricultural production constraints and marketing challenges. This socio-economic study examines key dimensions such as demographic trends, household structures, farming systems, employment, wealth distribution, agricultural input access, institutional support, gender roles, labor-saving technologies, and food security strategies.

A comprehensive understanding of farming systems and available resources is vital for designing demand-driven and community-focused agricultural research and development interventions. This research report identifies production constraints and proposes strategic frameworks that guide future agricultural development activities in FSRP-implementing districts and the entire region. By recognizing key production barriers, this study lays the foundation for developing problem-oriented agricultural technologies and interventions that effectively address critical sectoral challenges.

Study Approach and Objectives This assessment was conducted by a multidisciplinary research team comprising experts in socioeconomics, crop science, livestock management, soil and water conservation, and forestry. Surveys were carried out across various agricultural research centers, each operating within its respective mandate areas. The findings have, thus, been consolidated into this report to propose area-specific research and development interventions tailored to the region's diverse agro-ecological conditions.

The primary objective of this study was to identify the key constraints hindering agricultural production in the Amhara Region and formulate evidence-based intervention strategies to enhance productivity, sustainability, and livelihoods. To achieve this, the study assessed current agricultural practices and identified the socio-economic factors that hinder progress. Institutional and infrastructural limitations were also examined to understand their impact on agricultural development. A critical review of past interventions was also conducted to understand their effectiveness, particularly in relation to food security and livelihoods. Ultimately, the findings of this study are intended to guide policy formulation and support the design of targeted interventions that enhance agricultural efficiency and long-term sustainability.

Key Focus Areas

This report emphasizes four key focus areas essential to agricultural development in the Amhara Region. The socio-economic dimension addresses critical factors such as credit access, gender equity, and market availability, ensuring inclusive growth opportunities. Environmental considerations center on soil health, efficient water management, and climate adaptation strategies to enhance resilience. Institutional priorities include policy alignment, infrastructure development, and robust extension services to strengthen the agricultural framework. Lastly, technological advancements focus on the adoption of improved seeds, mechanization, and digital tools, fostering innovation and productivity. Together, these focus areas provide a comprehensive foundation for sustainable agricultural transformation.

3. Methodology

3.1. Study Sites and Sampling Methods

The study was conducted across eight administrative zones in the Amhara region of Ethiopia, which included Wag-Himra, North Shewa, North Gondar, Central Gondar, West Gondar, North Wollo, South Wollo, and the Oromo Special Administrative Zone (see Figure 3.1). The districts were purposefully selected to represent three traditional agro-ecological zones: highland (Dega), midland (Woina-Dega), and lowland (Kolla). Detailed information about the selected districts is presented in Table 3.1. The study included six districts from the highlands, six from the midlands, and eight from the lowlands.

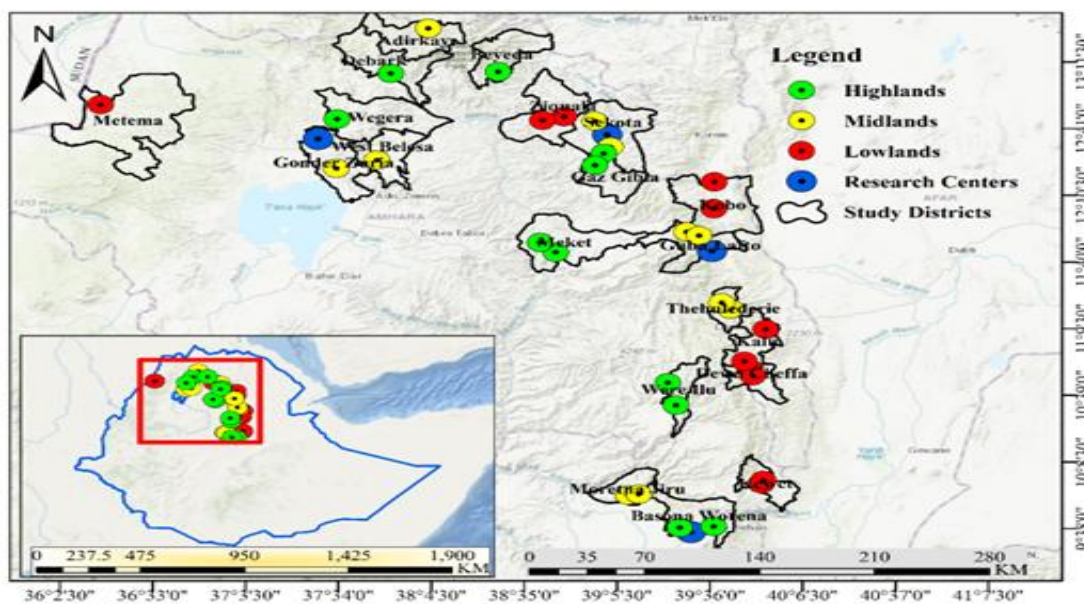


Figure 3.1: Map of the study areas

33 Kebeles from 20 districts across eight zones were selected for this study. In this rapid constraint assessment, 384 agricultural experts and farmers participated in focus group discussions and key informant interviews. Depending on the area coverage, each administrative zone engaged between 12 and 31 people in this study. Among those participants, between 6 and 8 farmers participated in the focus group discussions.

Table 3.1: Lists of the study areas and the number of Farmers who participated in the Focus Group discussion (FGD)

Agroecology	Zones	Districts	Kebeles	FGD participants
Highland	Wag-Himra	Gazgibla	Bella and Debre-Weyla	31
	North Shewa	Bassonawerana	Wushawushign and Angolela	22
	North Gondar	Debark	Mikara	12
	Central Gondar	Wegera	Kosoye	12
	North Wollo	Mekete	Agrit and Sisiye	20
	South Wollo	Woreilu	Tulu-Seritu and Gorebo	20
Midland	Wag-Himra	Sekota Zuria	Woleh and Sirel	30
	North Shewa	Moretnajiru	Kusey and Gerba	21
	North Gondar	Beyeda	Tachhambi	12
	Central Gondar	Gondar Zuria	Tsion	12
	North Wollo	Gubalafto	Woyniye and Gedober	20
	South Wollo	Tewuledere	Paso-mille and Gobeya	20
Lowland	Wag-Himra	Ziquala	Tsinaqolla and Tsitsiqa	31
	North Shewa	Kewot	Charie and Wanza	23
	North Gondar	Adirkay	Adiaregay	13
	Central Gondar	West Belesa	Kalay	12
	West Gondar	Metema	Kokit	13
	North Wollo	Kobo	Jarota and Aradom	20
	South Wollo	Kalu	Arabo and Addis Mender	20
	Oromo Special	Dawachefa	Bedeno and Shekila	20
Total	8	20	33	384

3.2. Description of the Study Areas

The study covered diverse agro-ecologies, ranging from lowland to highlands. Annual rainfall of the surveyed districts ranged from 300-1800 mm. Wag-Himra and few areas from north Wollo receive the lowest annual rainfall, while north Shewa, north and central Gondar receive the highest annual rainfall. Apart from low rainfall in these lowland areas, there is a problem of erratic rainfall distribution. Temperature in the study areas ranges from 2°C (cold) to 35°C (hot). Traditionally, the highland areas of north Shewa are characterized as cold environments, whereas the lowland areas of west Gondar are hot.

The surveyed areas also differed in soil types. Vertisols, Leptosols, regosos, Niisols, Luvisols, Andosols are the major soil types in the surveyed districts. The topography of the study sites ranged from undulating and steeply mountainous in the highlands to flat plain in the lowlands.

3.3. Farming Characteristics within the Three Agro-ecologies

The Amhara region is characterized by a diverse range of altitudes and climates. As mentioned above, the traditional agro-ecological characterizations include lowlands, midlands and highlands. Despite their diversity, these areas are generally characterized by a crop-livestock mixed farming system.

Highlands: The highlands are generally characterized by cool and humid climate, suitable for barley, wheat, highland oilseeds, highland pulses, cool-season vegetable, potatoes, and temperate fruits. Farmers in the highland areas can produce using both rainfed and irrigation. The eastern part of the highland areas of the region is especially characterized by bimodal rainfall distribution, consisting of meher (long rainy season with high precipitation) and belg (short rainy season with low precipitation).

The rain during the long rainy season, the dominant cropping season during which all the arable land is covered with crops, starts in June and ceases in October. On the other hand, the short rainy season mostly starts in January and terminates in April with an intermittent dry spell in between. During the belg season, barley and potatoes are often grown. In the irrigated production system, the most important water sources for irrigation are river water, natural stream, and some parts underground water. Garlic, highland fruits, carrot, potato and cabbage are the major crops produced under irrigation.

Midlands: Based on the traditional agro-ecological classification, midland ranged from 1,500 to 2,300 meters above sea level. The mid-altitude farming system is mainly characterized by mixed crop-livestock production. Wheat, teff, barley, maize, sorghum, chickpea and common bean are the dominant field crops in midland environments. Few areas of the midland in Amhara region receive a bimodal rainfall (Meher and Belg). Similar to the highland areas, Meher season is the dominant growing season in the midland area of the region, during which the majority of arable land is covered with field crops. Late maturing sorghum varieties and early maturing pulse crops like mung bean are grown under belg season. This agro-ecology has recognized by both rainfed and irrigation production seasons. The available water sources for irrigation are mainly river water, natural stream, and underground water.

Lowlands: The lowland areas in the region are often found at elevation of below 1,500 meters above sea level and are characterized by a relatively arid and semiarid climate types, with an annual rainfall below 700 mm and a growing period of up to 180 days (Amsalu and Adem, 2009). Lowland areas of eastern Amhara often have bimodal rainfall pattern. The first rain starts in January and ends in May (Belg), whereas the second rain starts in June and ends in August (Meher).

When the rain comes in April-May, farmers usually plant long maturing sorghum varieties and early maturing pulse crops such as mung bean for double cropping system. If the rain starts late (in June), farmers produce short maturing sorghum varieties. Moreover, farmers produced horticultural crops like papaya, mango, banana, onion, cabbage, tomato and pepper under irrigation. In recent years, production of wheat and maize in irrigation is increasing in lowland areas of Amhara region. The available water sources for irrigation is mainly natural stream, rivers and underground water.

3.4. Data Collection Techniques

Both primary and secondary data were considered from farmers, agricultural experts, agricultural (primary) and livestock office reports, the Central Statistics Authority, and FAOSTAT (secondary). Checklists and semi-structured questionnaires were implemented to collect data using qualitative surveys such as Participatory Rural Appraisal (PRA) tools and other participatory approaches. Focused Group Discussions (FGDs) and Key-Informant Interviews (KII) were employed to triangulate the information obtained from those sources.

3.5. Data Analysis

Data were analyzed using both qualitative and quantitative analytical methods. The quantitative data was analyzed using cross-tabulation, frequency distribution, percentage share, average, etc. On the other hand, the qualitative data are briefly narrated, explained and triangulated. Different ranking methods were also used to prioritize the agricultural constraints and suggested solutions. Graphs, tables, and charts were used to present the results.

4. Major Findings

4.1. Crop Production Constraints and Strategic Interventions

4.1.1. Crop Production Constraints in the Highland Areas

4.1.1.1. Field crops production and management

Major crops and varieties grown

Various cereal, pulse, and oil crops are grown in the highland areas of Amhara region. Of the cereal crops grown in the main rainy season, wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), teff (*Eragrostis tef*), Triticale are major ones in terms of area coverage and total production and barley is produced in both the short and main production season. Wheat and barley are the most important and dominant cereal crops in the highland areas of the Amhara region. Teff is indigenous to Ethiopia used to prepare different traditional dishes and it is widely adapted and produced from highland to lowlands.

Of the pulse crops, faba bean (*Vicia fabae* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.) and Lentil (*Lens culinaris* Medikus) are widely grown in the highland areas of Amhara. Moreover, niger seed (*Guizotia abyssinica* (L.f) cass), linseed (*Linum usitatissimum* L.) are the major oil crops grown in the highland areas. The present finding is in agreement with Central Statistical Agency, agricultural sample survey report (CSA, 2024). These field crops are mainly produced for food and local markets and their straws are the main sources of animal feeds. The improved and landraces underproduction in the study area with their strength and weaknesses are indicated in Table 4.1.

Major varieties by crop types

Bread wheat: Danda'a, Hidassie, Ogolcho, Kekaba, Sekota-1 and Emegua were the major bread wheat varieties grown in the highland areas of ANRS. Because of its high productivity, rust tolerance, earliness and white seed color, Danda'a took the lion-share in area coverage. On the other hand, Kekaba, Hidassie and Ogolcho best adapted under light soil. However, Hidassie and Ogolcho are becoming very susceptible to rust and septoria, respectively and their production coverage are declining through time.

Durum wheat: Ethiopia is the center of origin and diversity of tetraploid wheat. There are tremendous and untapped tetraploid gene-pool resources in Ethiopia. Gojam-Gura, Qurshit and Jiru are commonly grown durum wheat farmers' varieties in some vertisol areas of Amhara region. Water logging is one of the major production constraints in vertisol areas. Farmers preferred to grow durum wheat varieties in highly vertisol areas, because of their relative resistance to water logging.

Teff: Ethiopia is the center of origin for teff genetic resource. Farmers owned diverse teff local landraces. They differ in seed color, use, maturity group, adaptability, resistance to lodging, cold and other abiotic stresses. Thus, farmers benefited from the diverse teff gene pool. Several improved teff varieties were developed and released. Unfortunately, there is no adapted improved teff variety in the studied highland areas of Meket, Bassonawerana, Debark and Wegera. Thus, farmers are growing local landraces. However, Quncho variety was introduced to Woreilu and Gazgibla districts. But farmers are reluctant to adopt Quncho, in some areas because of its fibrous straw. Farmers use teff straw as the major sources of animal feed. However, straw of Quncho teff is stiff and unpalatable for ruminant animals. Thus, adoption of Quncho is very limited in some highland areas of Amhara region. Nech and Bunign teff (local landraces) are widely grown.

Food and malt barley: Both food and malt barley are grown in the highland areas. Farmers used local varieties called Abat Gebes and Maugie with an average growing season of 4-5 months. Agegnehu, Hagere, Debark-1 and HB-1307 are the major improved food barley varieties grown in the highland areas of Amhara. Farmers also grow improved malt barley varieties (Holker, Henrike and Traveler).

Faba bean: Faba bean is one of the most important cool seasoned pulse crops in the highland areas of Amhara. Production and productivity of Faba bean is being challenged by various biotic and abiotic constraints. Faba bean gall, chocolate spot and rust are the major constraints affecting faba bean production and productivity. Currently, Wolki and Ashebeka varieties are widely cultivated under vertisol areas. These varieties are relatively tolerant to water logging and resistant to faba bean gall disease. The introduction of Wolki and Ashebeka varieties to the vertisol areas revived faba bean production. Farmers majorly grow variety Dosha and local landrace under light soil. On the other hand, local landraces of field pea, lentil, linseed and Niger seed are widely grown in the highland. The average life span of improved varieties in the highland areas ranged from five to seven years, depending on the durability of varietal resistance to major diseases and yield performance. Often, varieties will be obsolescent and became out of production when they lose their resistance against major diseases and when they are out-yielded by new variety.

Table 4.1: Widely Grown Crop Varieties and Landraces in the Highland Areas with Their Traits

Crops	Varieties	Varietal category	Strength	Weakness
Bread wheat	Danda'a,	Improved	High yield. Resistant to rusts	
	Emegua		White kernelled	
	Hidassie	Improved	High yield, Adaptable to light soil	Susceptible to rusts
	Ogolcho	Improved	High yield septoria	Susceptible to septoria
	Kekaba	Improved	High yield, Adapted to low midlands	Susceptible to rusts
	Sekota-1	Improved	Adapted to moisture stressed areas	
Durum wheat	Gojam-Gura	Landrace	Resistance to water logging	Low yield
	Qurshit			
	Jiru			
Teff	Quanco	Improved	High yield and biomass	Straw is unpalatable
			White grain	
Barley	Nech teff	Landrace	White grain, Excellent injera quality	
			Straw is palatable	
	Bunign	Landrace	Early maturing. Straw is palatable	Low yielding
	Abat Gebis		High yield	Late maturing
	Enat Gebis	Landraces		Susceptible to scald and net blotch
	Maugie			
	Agegnehu	Improved	High yield	
	Hagere		Resistance to scald and net blotch	Black kernelled
	Debark-1			
	HB 1307			
Faba bean	Holker	Improved	High yield	
	Heniken		Bold kernelled	
	Traveler		good malt quality	
	Wolki	Improved	High yield	
	Ashebeka		Resistant to water logging	
	Dosha	Improved	High yield, Adapted to light soil	
	Local			Low yielding
Chickpea	Teketay	Improved	High yield	
	Dimtu			

Farmers' preferred traits

Farmers are very experienced in selecting varieties of their choice. They have their own selection criterion for different crops. Before developing a new variety, breeders shall consider farmers' preferred traits and include them in the variety selection program. The preferred traits of major highland crops, as reported by farmers, are displayed in Table 4.2. Production and productivity of major highland crops are seriously affected by disease outbreaks. Farmers were unhesitant to reject a variety if the variety was susceptible to disease. Therefore, disease resistance was the first and most important trait that the new crop variety should possess. Moreover, yield components are indirect indicators of crop productivity. Farmers have the experience to easily identify high-yielding varieties by observing specific agronomic markers.

Table 4.2: Farmers' Selection Criteria for Major Crops in the High Land Area of Amara Region

Wheat	Barley	Teff	Pulse crops
Disease resistant	Disease resistant	Productivity (long panicle)	Disease resistant
Productivity (long spike, high spike density, bold kernel size)	Productivity (long spike, high spike density, bold kernel size)	Erect type (non-lodging)	Productivity (pod load, seed size and seeds/pod)
Seed color (Kernel)	Seed color (Kernel)	Seed size (Bold seeded)	Logging tolerant
Earliness	Earliness	High tillering potential	
Lodging tolerant (erect)	Lodging tolerant (erect)	High biomass (for animal feed)	
High biomass (for animal feed)	High biomass (for animal feed)		

Crop management practices

A. Land preparation practices

In the highland areas of Amhara, land preparation is done using oxen and horses. The average landholding size, particularly in Eastern Amhara, is very small (below half a hectare). Thus, farmers didn't use farm machinery for land preparation. Tillage frequency ranged from 2-4 times, depending on the nature of the farm land, precursor crop, soil type, soil moisture content, weed type and weed density, etc. for instance, optimum plowing frequency ranged from 2-3 times (wheat and barley), 3-4 times (Teff) and 2 times (faba bean and fenugreek).

B. Cropping systems

Crop rotation, mixed cropping, and fallowing were the commonly practiced cropping systems in the highland areas of Amhara (Table 4.3). Farmers were aware of the benefits of practicing various cropping systems. These cropping systems were important for yield and income maximization, product diversification, cost minimization, and soil fertility restoration. Farmers usually rotate pulse or oil crops with cereals. For instance, farmers rotate faba bean or field pea with wheat or barley and *vice versa*. Pulse crops can fix atmospheric nitrogen and thus enhance soil nitrogen.

Therefore, crop rotation is a well-established cropping system. Moreover, farmers grow mixed barley and wheat, locally called *Wassera* (in Wollo) or *Duragna* (in Gondar). This practice is believed to improve crop productivity and minimize abiotic and biotic risks. Mixed cropping of faba bean with field pea was also common in the highland areas of Amhara. However, information on the agronomic and economic benefits of mixed cropping was scant. Research attention should be given to examine farmers' indigenous agronomic practices. Moreover, fallowing was practiced to some extent to allow the land to recover and store organic matter and to disturb pests' life cycles by temporarily removing their hosts.

Table 4.3: Major Cropping Systems Used In the Highland Areas of Amhara Region

Cropping systems	Crops	Benefits
Crop rotation	Cereals with pulses	Restore soil fertility
	Cereals with oil crops	Disturb pest life cycles, host searching clue, etc
Mixed cropping		Improve productivity
	Barley with wheat	Produce two types of grains in one plot and
	Teff with <i>Brassica</i> spp	cropping season, create unfavorable
Fallowing	Faba bean with field pea	environmental condition for disease
		development, reduce risk of crop failure and
		improve productivity
		Obtain better nutrition
	Resting/without cultivation period	Improve soil fertility
		Improve soil microbes
		Break pests' life cycles
		Restore soil health

C. Planting time, methods, seed and fertilizer rates and harvesting

Rainfall patterns, soil characteristics, and variety type significantly influenced the optimal planting period in the study areas. Farmers commonly practiced early sowing in soils with low fertility, shallow depth, and high silt and sand content due to their poor water-holding capacity, which increases the risk of terminal moisture stress during the grain-filling stage. To mitigate this risk, early planting helps ensure adequate moisture availability. Conversely, late planting was more suitable for vertisol areas, where soil conditions differ significantly. Early planting was practiced for long-maturing varieties to accommodate their longer growth cycle, while late planting was utilized for short-maturing varieties. Table 4.4 presents farmers' preferred planting timelines.

Optimizing seed rate is essential for achieving the ideal plant population. Excessive seed rates—beyond the optimal level—intensify competition among plants for nutrients, moisture, and sunlight, ultimately reducing productivity. Conversely, insufficient seed rates result in a lower-than-required plant population within a given area, which similarly leads to diminished yields. The optimal seed rates for major crops are presented in Table 4.4.

In several districts, the seed rate varied depending on the planting method, either row planting or broadcasting. In most areas, farmers commonly used the broadcasting method, often exceeding the recommended seed rate, particularly for teff, where they used three to four times the advised amount of seeds than the recommended amount. This practice was primarily driven by concerns over pests, environmental challenges, and inefficient soil moisture at the time of sowing. This practice was primarily driven by concerns over pests, environmental challenges, and inefficient soil moisture at sowing time. Planting and harvesting were predominantly manual. Survey participants noted that preparing highly vertic soils using tractors was particularly difficult. However, when land was flat and tractor services were accessible, some farmers employed tractors for the initial plowing. In contrast, plowing waterlogged soil with oxen during sowing posed significant challenges. The soils in Wag-Himra and North Wollo administrative zones were generally shallow and rocky, rendering them unsuitable for tractor-based tillage.

Consequently, planting, harvesting, and threshing remained largely manual. On the other hand, farmers in North and Central Gondar administrative zones had larger land holdings, which allowed for some adoption of labor-saving machinery, such as tractors and combine harvesters. In these areas, the private sector and cooperatives had begun offering these mechanization services.

Farmers commonly used NPS and Urea fertilizers to cultivate major cereal crops. The widely available NPS fertilizer contains nitrogen (19%), phosphorus (38%), and sulfur (7%), while Urea consists solely of nitrogen (46%). Fertilizer application rates varied depending on crop and soil types, as outlined in Table 4.4. NPS fertilizer was applied entirely at planting, whereas Urea was top-dressed at the full tillering stage (30–35 days after planting). In the highland areas of Amhara, broadcasting was the predominant fertilizer application method. Additionally, farmers incorporated bio-fertilizers for pulse crops at planting to enhance soil fertility and productivity. Harvesting was usually done traditionally or manually, with sickles to mow crops and threshing by trampling a group of animals.

Table 4.4: Planting Date, Seed and Fertilizer Rates of Major Field Crops in the Highland Areas

Crop type	Planting time		Seed rate (kg ha ⁻¹)	Fertilizer rate (kg ha ⁻¹)	
	Light soil	Vertisol		Light soil	Vertisol
Wheat	1 st week of Jun to 1 st week of Jul	2 nd week to end of Jul	150-180	100-150 NPS & 50-200 Urea	120-200 NPS & 100 Urea
Barley	1 st week of Jun to 1 st week of Jul	-	110-150	100-150 NPS & 50-100 Urea	
Teff	2 nd week of Jul to 1 st week of Aug	1 st week to 3 rd week of Aug	15-30	100-150 NPS & 50-150 Urea	100-200 NPS & 50-150 Urea
Faba bean	3 rd week of May to 2 nd week of Jul		160-240	50-100 NPS	50-100 NPS
Field pea	3 rd week of May to 2 nd week of Jul		160-200	50-100 NPS	50-100 NPS
Lentil	3 rd week Jun to 1 st week of Jul	1 st week Aug to 1 st week of Sep	75-120	50 NPS	50 NPS

D. Post harvesting techniques and Transportation

Farmers identified storage insect infestation as the most significant storage challenge for grain crops, and farmers rely on traditional methods to mitigate its impact. Postharvest storage durations vary by crop and agro-ecological conditions. To preserve their harvests, farmers used diverse storage methods and facilities, including mud-built storehouses (Gotera), underground pits, and sacks. Most grain crops were stored for six to twelve months, after which the stored grains were sold, used as seed, or consumed by the household. Additionally, many farmers applied storage insecticides such as sulphonyl to protect grain crops from pest damage.

However, due to the lack of technology to extend storage duration, horticultural crops with short shelf lives, such as potatoes, tomatoes, and onions, were sold immediately after harvesting. In the highland areas, farmers primarily used donkeys and horses to transport grain crops and potatoes. For tomatoes and onions, farmers mostly used baskets and carried them on their heads. However, sometimes, wholesalers bought products directly from the farms, simplifying the distribution process.

Pest management methods

Farmers had various pest management methods to keep pest damage below the economic threshold level. The commonly used pest management methods are presented in Table 4.5. To manage soil-borne diseases and weeds, crop rotation, frequent land plowing, and hand weeding practices were very commonly used methods. Some farmers used herbicides to control weed damage. Wheat production and productivity were severely challenged by rust infestation, and during periods of heavy infestations, foliar application of fungicides such as Tilt or Nativo was a common practice. In most areas, farmers understood the value of rust-resistant wheat varieties in disease management. For instance, the Danda's variety exhibited good tolerance to rust, making it a preferred choice for reducing infestation risks, whereas the Hidassie variety was more susceptible.

Table 4.5: Commonly Used Pest Management Methods for Major Crops in the Highlands

Crop	Target pest	Control methods	Effectiveness
Wheat	Rust	Use of resistant variety Application of fungicide (tilt, native) Minimize human interference while the wheat field is moist	Excellent
	Septoria	Crop rotation Use of healthy seeds	Good
	Weed	Application of herbicide (Palace) to manage weeds Frequent plowing and hand weeding Crop rotation	Excellent
Barley	Shoot fly and aphid	Insecticides	Excellent
Teff	Rust	Use of fungicide	Not effective
	Weed	Plowing and hand weeding use of herbicide (2,4-D)	Excellent
Faba bean	Gall disease	Use of tolerant variety, fungicide	Excellent
	Chocolate spot	Use of fungicide (Redomil and Mancozeb)	Excellent

Exotic invasive pests

Teff rust and faba bean gall diseases were the newly emerged field crop pests in the highland areas. These alien invasive pests were becoming a high challenge to the farming community. Managing the spread of these alien species requires careful attention. Implementing pest quarantine measures is advisable to control invasive pests, as it restricts their movement and prevents them from entering new areas. However, since teff rust is an airborne disease, its spread cannot be controlled using quarantine measures.

Crop production constraints

The production and productivity of field crops in the highland areas of the region remain low due to various biotic and abiotic constraints. Table 4.6 presents the key factors that significantly affect crop performance, highlighting the challenges farmers face in sustaining agricultural yields.

A. Biotic production constraints

Biotic stresses were the primary constraints on crop production and productivity in highland areas. Both pre-harvest and post-harvest pests, such as diseases, insect pests, weeds, weevils, rodents, and birds, significantly affect the quality and quantity of crop yields. The key biotic constraints associated with major field crops are discussed below.

Wheat pests: Pathogens such as rusts, septoria, take-all, and smut were among the most destructive wheat diseases, leading to significant yield losses. In particular, yellow rust (*Puccinia striiformis*) and leaf rust (*Puccinia recondita*) caused a significant yield loss in wheat-growing areas. Moreover, the chafer grub (*Mesek*) and various weeds have also contributed to considerable yield losses.

Teff pests: In the highlands of the Amhara region, teff crops were affected by several insect pests, including the teff shoot fly (*Atherigona hyalinipennis*) and Wollo bush-cricket (*Decticoides brevipennis*). Additionally, teff diseases such as leaf rust (*Uromyces eragrostidis*) significantly reduce productivity. Grasshoppers, ants, and termites sporadically caused significant yield losses. Furthermore, numerous weed species, including broad-leaf and *Poaceae* species, hindered teff productivity. Teff leaf rust, a major fungal disease, was particularly detrimental, often leading to substantial yield reductions.

Barley pests: The most prevalent barley diseases include net blotch, spot blotch, and leaf rust, and common insect pests include the Russian wheat aphid (*Diuraphis noxia*), cutworms (*Agrotis* sp.), and barley shoot fly (*Delia flavibasis* Stein) pose a significant impact on yield and productivity.

Faba bean pests: Faba bean production in the highland areas faced significant challenges due to various pests and diseases. Key diseases included faba bean gall (*Olpidium viciae*), chocolate spot (*Botrytis fabae*), and faba bean rust (*Uromyces viciae-fabae*). Additionally, insect pests such as Bruchid beetles (*Acanthoscelides obtectus*, *Callosobruchus* sp., *Callosobruchus chinensis*, and *Zabrotes subfasciatus*) and African bollworm (*Helicoverpa armigera*) caused severe damage, particularly by damaging pods and reducing yields.

Field pea pests: Field pea aphids (*Pisum sativum*), bollworm (African bollworm (*Helicoverpa armigera*), and Powdery mildew were the most important pests of field peas.

Fenugreek pest: Fenugreek cultivation in the highland areas of the region faced significant challenges due to pests and diseases, including powdery mildew, *Cercospora* leaf spot, and root rot. These issues severely impacted yield and quality, posing a considerable threat to production.

B. Abiotic production constraints

Delayed rainfall onset, early termination, and intermittent dry spells severely impacted field crop production and productivity, particularly in the Eastern Amhara highlands. Soil fertility in some areas of the region was poor, characterized by sandy, shallow soils. The topography of most Eastern Amhara highlands, such as North Wollo and Wag-Himra administrative zones, is highly undulated, with limited vegetation cover, contributing to soil erosion, low fertility, and poor water retention.

Additionally, some highland vertisol areas were affected by waterlogging, leading to serious physiological and root disease issues that significantly reduced crop productivity. In areas receiving high rainfall, soil acidity emerged as a major production constraint. Furthermore, highland areas, particularly above 3,000 meters above sea level, were prone to frost, with crop production and productivity frequently challenged by frost and cold stress.

Table 4.6: Major Abiotic and Biotic Stresses of Major Crops in the Highland Area of Amhara Region

Crops	Biotic stress	Abiotic stress
Wheat	Rust, Take-all, Septoria	Moisture stress, Low soil fertility,
	Smut, Chafer grub, Weed	Water logging, Soil acidity, Cold/frost
Teff	Rust, Grasshopper, Weed	Low soil fertility, Soil acidity,
		Cold/frost
Barley	Scald, Net blotch, Rust, Smut,	Moisture stress, Low soil fertility,
	Aphid, Weed	Water logging, Soil acidity, Cold/frost
Faba bean	Chocolate spot, Rust, Faba	Moisture stress, Low soil fertility, Soil
	bean gall, Bollworm, Weed	acidity, Cold/frost
Field pea	Powdery mildew, Bollworm	Moisture stress, Low soil fertility, Soil
		acidity, Cold/frost

4.1.1.2. Horticultural crops production and management

Major horticultural crops and varieties grown and seed sources

In the highland areas of the region, various horticultural crops are cultivated. Potatoes, cabbage, garlic, carrots, and beetroot were among the most important crops grown during the main rainy season and irrigation periods. Potatoes hold the highest significance, followed by cabbage and carrots. Additionally, leafy vegetables such as lettuce, kale, Swiss chard, and apples were grown in small home gardens using rainwater or irrigation. The most commonly used horticultural crop varieties are listed in Table 4.7. However, farmers face challenges due to the limited availability of high-quality seeds at reasonable prices when needed. Farmers obtain improved horticultural seeds through various sources, including agricultural offices, agro-dealers, Kale-Hiwot Church, Sasakawa Global 2000, ORDA, and Facilitator for Change. These seeds were acquired either through direct purchase or as gifts. However, the cost of improved seeds continues to rise, mirroring the increasing prices of fruits and vegetables.

Table 4.7: Major Horticultural Crops and Varieties Grown In the Highland Areas

Crop	Variety	Productivity (qt/ha)
Potato	Belete, Jalen and Local	150-240
Garlic	Tsedey and Local	55-85
Cabbage	Copenhagen	85-303
Carrot	Nantens	140
Apple	Anna and Crispi	95

Land preparation and transplanting

Like field crops, land preparation for horticultural crops was carried out using oxen. Since horticultural crops require a finely prepared seedbed, farmers typically plow their fields three to four times. While potatoes, carrots, and garlic are sown directly in the fields, other crops are first grown as seedlings before being transplanted. Seedling cultivation usually begins between late August and early October, with transplanting occurring after 45 to 50 days. Farmers often align planting schedules with major Orthodox fasting periods and holiday seasons to optimize production and market timing.

Cropping system

Crop rotation is a common practice for horticultural crops, which minimizes soil-borne pests and maximizes crop productivity. Farmers recognize its benefits and incorporate it into their cultivation strategies. While intercropping and double-cropping are uncommon in root and vegetable crops, farmers frequently intercrop fruit crops with vegetables, other fruit crops, or spice crops.

Fertilizer and fertilizer application

Fertilizer application rates vary by location and crop type. Typically, farmers apply 100/100 kg ha⁻¹ of NPS/Urea for potatoes and 200/200 kg ha⁻¹ for garlic. In some cases, Urea is used at the nursery stage to stimulate seedling growth. Fertilizers are predominantly applied using the broadcast method. Additionally, some farmers supplement nutrient management with organic fertilizers such as farmyard manure and compost. However, due to the bulkiness and transportation challenges associated with these organic inputs, their usage remains limited.

Product packaging and grading

Traditional packaging techniques are commonly used for transporting horticultural products, with sacks being the primary packaging for potatoes, garlic, and apples. Due to their perishable nature, horticultural crops cannot be stored for extended periods and are highly susceptible to damage during transportation. Consequently, careful handling is essential to minimize both harvest and post-harvest losses. The conventional use of boxes and sacks presents a high risk of damage during loading and unloading.

To reduce harvest and post-harvest losses, research efforts should focus on developing improved packaging technologies. Grading horticultural crops remains uncommon in the Amhara region, although some farmers near urban centers have begun grading their products for hotel supply. They typically classify produce based on marketability, color, size, and variety. Grading is very important to deliver high-quality products to consumers and to fetch a premium price. Moreover, standardized grading fosters trust between producers and consumers. Therefore, researchers should provide guidance and training to farmers on effective grading practices.

Major problems in accessing agrochemicals

The demand for agricultural inputs—fertilizers, fungicides, and insecticides—is exceptionally high. However, fertilizer shortages have become a critical challenge in horticultural crop production. As a result, illegal fertilizer traders operating in the black market have become key suppliers, driving input costs beyond farmers' purchasing capacity.

Horticultural crops faced numerous pest-related threats, yet government support for crop protection remains limited. At the district level, there are full-fledged horticultural crop protection experts, exacerbating the issue. Additionally, the lack of training and absence of personal protective equipment further worsen the situation.

Irrigation method and frequency

Crop water requirements vary based on factors such as crop type, variety, growth stage, soil characteristics, temperature, and humidity. Some horticultural crops, such as cabbage, require frequent irrigation, whereas crops like tomato and pepper thrive with less frequent watering. Table 4.8 presents optimal irrigation methods and schedules for key horticultural crops.

Table 4.8: Irrigation Methods and Frequencies for Major Horticultural Crops in the Highlands

Crop	Irrigation methods	Irrigation frequency
Potato	Furrow/flooding	7-10 days interval
Cabbage	Furrow/flooding	7-10 days interval
Garlic	Furrow	7-10 days interval
Apple	Basin	Supplementary when needed
Lettuce	Furrow	7-10 days interval
Swiss Chard	Furrow	7-10 days interval

Major horticultural crops production constraints

Horticultural crops are primarily grown as cash crops, with market demand driving production. Their high market prices serve as a financial incentive for farmers, generating substantial income while also contributing to food security and job creation. The application of organic and inorganic fertilizers is often inconsistent with recommendations, as vegetable crops are frequently harvested for sale immediately after fertilization. Regarding irrigation water management, the availability of water sources remains a challenge. Although irrigation technologies exist, they are insufficient to meet the growing demand. Both biotic and abiotic factors have a substantial impact on horticulture crop production and productivity. Diseases and insect pests are the most significant challenges to horticulture crop yields. The main pests that affect horticulture crops are listed below.

Potato is one of the primary horticultural crops cultivated in the highland areas of the region. However, production is constrained by major pests and diseases, including late blight (*Phytophthora infestans*), bacterial wilt (*Ralstonia solanacearum*), and potato tuber moth (*Phthorimaea operculella*). To manage late blight infestations, farmers commonly apply fungicides.

Garlic production has been affected by root rot, cutworms, rust, and powdery mildew, while cabbage faces challenges from aphid infestations, which farmers typically control using insecticides like Karate. Powdery mildew remains a significant constraint for both carrots and apples.

Farmers primarily depend on chemical treatments and resistant crop varieties as key strategies for disease control. High humidity increases the incidence and severity of diseases, pressing farmers to refrain from weeding and cultivation during cloudy weather to limit the spread of infections.

Scouting and Pest Monitoring

Regular scouting and monitoring of crop fields are essential for assessing pest incidence and prevalence, enabling farmers to implement timely control measures before economic damage occurs. Farmers understand the importance of scouting and actively observe their fields, making it a routine practice. Typically, they inspect their farms at least every two days.

Major Post-Harvest Pests and Management

Rodents, weevils, and fungi are the primary post-harvest pests affecting field and horticultural crop products. To mitigate these threats, farmers employ various control methods, including chemical treatments, biological control using cats, and rat traps. Farmers use chemicals, cats (biological control), and rat traps to control post-harvest pests. Farmers also used different botanicals to treat weevils. Moreover, cleaning local storage facilities, removing diseased tubers and bulbs, and the use of chemicals are being used.

4.1.2. Crop Production Constraints in the Midland Areas

4.1.2.1. Field crops production and management

Major crops varieties and seed sources

Sorghum, wheat, teff, barley, rice, maize, faba bean, chickpea, common bean, niger seed, linseed, and sunflower are the major field crops cultivated in the midland areas of the Amhara region. These findings align with data from the Central Statistical Agency (CSA, 2022). These crops are primarily grown for food and local markets, while their straws serve as essential sources of animal feed. Sorghum straw, in particular, is widely used for firewood, fencing, and livestock feed. The most commonly cultivated varieties of major crops in the midland areas, along with their preferred traits, are presented in Table 4.9.

Sorghum

Sorghum (*Sorghum bicolor* (L.) Moench) is a drought-tolerant crop well adapted to harsh growing conditions in tropical and subtropical regions. It is primarily cultivated for food, animal feed, and bioenergy (Kimber et al., 2013). In Ethiopia, sorghum ranks as the third most widely grown cereal in terms of area coverage, following teff and maize, and is fourth in total production (CSA, 2022).

The crop is cultivated across nearly all regions, covering approximately 1.35 million hectares, with a national average productivity of 2.631 t/ha (CSA, 2022). In the Amhara region, sorghum occupies a substantial share of farmland, second only to teff, particularly in midland areas where agro-ecological conditions are well suited for its growth.

The major improved sorghum varieties cultivated in the midland areas of eastern Amhara are Melkam and Gobiye. However, no well-adapted improved varieties exist for the midland areas of Gondar and Wag-Lasta, leading farmers to rely on local landraces with an average growth cycle of 8–9 months. The most commonly grown local sorghum varieties include Jamiyo, Degalet, Zengada, Ahiyo, and Jigurti. Adoption rates of improved sorghum varieties remain low (5%) due to their low biomass yield, strong stalks, and poor injera-making qualities.

In addition to grain production, farmer's value sorghum stalks for livestock feed. They prefer varieties with high biomass and palatability, characteristics often lacking in early-maturing sorghum varieties. Moreover, farmers report dissatisfaction with the injera quality from improved sorghum grains, citing issues such as bitterness, fragility, and short shelf life. In contrast, injera made from Jamiyo a grain is widely regarded as the best, further influencing variety preferences among farmers.

Teff

Teff (*Eragrostis tef* (Zucc.) Trotter) is an ancient crop native to Ethiopia, where it is considered the center of origin and genetic diversity for the species (Vavilov, 1951). It is among the country's principal cereal crops, both in terms of area coverage and total production. Teff accounts for 24.05% of the total cereal cultivation area and 17.12% of cereal grain production (CSA, 2022). The Amhara region is one of the major teff-producing regions in the country, where teff covers about 1.2 million hectares annually, from which about 2.2 million tons are produced (CSA, 2022).

Several improved teff varieties—Quncho, Tsedey, Zobel, and Mechare—have been developed and released for cultivation in the midland areas of Amhara. Moreover, commonly grown teff landraces include Magna, Shible, Mure, and Abish-Lemine. Farmers favor Quncho for its earliness, high grain yield, abundant straw biomass, and white seed color, which fetches a premium price in the market. Meanwhile, farmers in Tehuledere prefer Zobel due to its high productivity and superior injera quality.

Wheat

Bread wheat is a key cereal crop cultivated in the midland areas of the Amhara region. Farmers predominantly grow improved varieties, including Denda'a, Ogolcho, and Kekeba. Among these, Denda'a is the most widely adopted due to its superior rust tolerance, early maturity, high productivity, and desirable seed color.

Table 4.9: Widely Grown Varieties of Major Crops in the Midland Areas and Their Preferred Traits

Crops	Varieties	Type	Strength	Weakness
Sorghum	Melkam	Improved	Relatively high yield and early mature	Low biomass
	Gobiye	Improved	Relatively high yield and early mature	Low biomass
	Jamiyo	Landraces	High yield	Late mature
	Degalet		Good quality	
	Zengada, Ahiyo		High biomass	
Wheat	Danda’a	Improved	High yield	Adapted in low land for irrigation
	Ogolcho		Adapted in low land for irrigation	
	Kekeba			
Teff	Quncho	Improved	Relatively high yield and early mature	
	Bosset			
	Zobel			
	Tsedey	Landraces	Adaptability, White grain, Excellent injera quality and Straw is palatable	
	Magna, Shible, Mure			
	Abish-lemine			
	Arereti			
Chickpea	Mariye	Improved	High yield	

Farmers' preferred traits

Farmers' trait preferences play a crucial role in crop variety selection, directly influencing productivity. With extensive experience, farmers skillfully identify and select varieties based on specific criteria tailored to different crops. Therefore, before developing a new variety, breeders must consider farmers' preferred traits and integrate them into selection programs. Table 4.10 presents key trait preferences for major midland crops.

Disease outbreaks frequently threaten the production and productivity of midland crops. Farmers readily discard susceptible varieties, making disease resistance the most critical trait for any new crop variety. Additionally, yield components serve as indirect productivity indicators, and farmers, leveraging their expertise, can efficiently recognize high-yielding varieties based on these agronomic markers.

Table 4.10: Farmers Selection Criteria for Major Crops in the Midland Areas of Amhara

Sorghum	Teff	Wheat
Injera-making quality	Earliness	Disease resistant
Productivity (high head weight, bold seed, compact head)	Productivity	Productivity
Adaptability	Erect type (non-lodging)	Seed color (Kernel)
Drought tolerance	Seed color (white)	Seed size (bold seeded)
Earliness	Seed size (Bold seeded)	Seed size (bold seeded)
Panicle exertion	High tillering potential	High biomass (for animal feed)
Seed color (white kernel is preferred)	High biomass (for animal feed)	High biomass (for animal feed)
Tall plant height (for animal feed)	Stalk palatability	
Palatable sorghum stalk (for animal feed)		

Crop management practices

A. Plowing and plowing practices

Because of the rugged topographic nature of the area and small land holding size, mechanization is less probable, and thus farmers use oxen to plow their farmland. Farmers ploughed 2-3 times (sorghum), 3-4 times (teff), two-three times (wheat), two times (faba bean), once (field pea) and one-two times (common bean), depending on the farmland's nature, predecessor crop, weed kind, and density.

B. Cropping systems

A cropping system refers to the type and sequence of crops grown and practices used for growing them. It encompasses all cropping sequences practiced over space and time based on the available crop production technologies. It is a cropping sequence and management techniques used on a particular plot of land over the years. Cropping system encompasses all cropping sequences practiced over space and time (Blanco-Canqui and Lal, 2010). Crop rotation, intercropping, mono-cropping, mixed-cropping, and double cropping are the most common cropping techniques used in Amhara's midland areas (Table 4.11). Farmers are aware of the benefits of practicing various cropping systems. These cropping systems are important for yield and income maximization, product diversification, cost minimization, and soil fertility restoration.

Crop rotation: Farmers recognize the benefits of crop rotation, which plays a crucial role in minimizing soil-borne pests (insects and diseases), reducing weed infestations, and improving soil fertility and overall crop productivity. Common rotation practices include alternating sorghum with teff, wheat, finger millet, or pulse crops.

Inter-cropping: In the midland areas of the Amhara region, intercropping is sometimes practiced by combining sorghum with haricot beans, sesame, or teff, as well as teff with niger seed, *gomenzer*, sunflower, or sesame. Additionally, border sowing of niger seed alongside teff is a widely adopted practice in these areas. Farmers are aware of the use of crop rotation. Crop rotation is beneficial to minimize soil-borne pests (insect and disease), weed infestation, and to improve soil fertility & crop productivity. Farmers usually rotate sorghum with teff/wheat/finger-millet/pulse crops and vice-versa.

Table 4.11: Major Cropping Systems Practiced In the Midland Areas of Amhara Region

Cropping systems	Crops	Benefits
Crop rotation	Cereals with pulse	Restore soil fertility Disturb pest life cycles Improve productivity
Mixed cropping	Teff with Brassica spp Teff with sunflower Teff with safflower	Produce two types of grains in one plot in one cropping season Create unfavorable environmental condition for disease development Product diversification and crop failure risk reduction Improve productivity
Intercropping	Sorghum with sesame Sorghum with common bean Sorghum with sunflower	Produce two types of grains in one plot in one cropping season Create unfavorable environmental condition for disease development Improve productivity and crop failure risk reduction
Double cropping	Barely with chickpea Wheat with onion	produce two types of grains in one plot in one year with residual moisture Restore soil fertility

C. Planting time, methods, seed and fertilizer rates and harvesting

The optimum planting time depends on the onset of rainfall, soil type, and crop variety. Early sowing is generally used in less fertile, shallow soils with high silt and sand content, which have poor water-holding capacity. This method helps reduce terminal moisture stress, often encountered during the grain-filling stage. In contrast, late planting is more common in areas with vertisols. Furthermore, late-maturing crop varieties are typically planted earlier, while early-maturing varieties are sown later. Farmers' optimum planting schedules are presented in Table 4.12.

The appropriate seed rate is affected by several factors, including the planting method, seed size, and germination rate. Determining the optimal seed rate is essential for maintaining an ideal plant population. Excessive seed rates lead to intense competition among plants for nutrients, moisture, and sunlight, ultimately reducing productivity. Conversely, low seed rates result in insufficient plant populations, negatively affecting yield. Farmers' optimum seed rate for major crops is presented in Table 4.12.

Fertilizer application rates vary based on crop and soil type. Table 4.12 presents fertilizer recommendations for major crops. NPS is applied entirely at planting, while Urea is top-dressed at the full tillering stage (30–35 days after planting). Broadcasting is the predominant fertilizer application method for teff in midland areas of Amhara, whereas row application and side dressing are preferred for row-planted crops. Additionally, farmers incorporate bio-fertilizers when planting pulse crops to enhance soil fertility and crop performance.

Table 4.12: Planting Date, Seed - and Fertilizer Rate of Major Field Crops in the Midland Areas

Crop type		Planting date	Seed rate (kg/ha ⁻¹)	Fertilizer rate (kg/ha ⁻¹)
Sorghum	Late maturing	April 19 – June 7	10-30	100-200 Urea, 100NPS
	Early maturing	June 12 – July 15	10-30	100-200 Urea, 100NPS
Teff		July 12 – August 20	8-12	100-200 NPS & 50-150 Urea
Chick pea		End of August - 1 st week of Sept	40-160	50-100 NPS
Faba bean		June 25 – July 15	100-160	100 NPS
Wheat		June 25 – July 12	133-200	100-200 Urea, 100 NPS
Common bean		July 5 - 10	65	100NPS
Irrigation wheat		End of November	133	100-200 Urea, 100 NPS

Pest management methods

Farmers used different pest management methods to keep pest incidence and prevalence below an economic threshold. Table 4.13 presents the commonly used pest management methods. Farmers employed a combination of practices like fertilizer application (organic and/ inorganic) that would enhance the robustness of sorghum seedlings, the use of striga-resistant varieties, and intercropping sorghum with legumes for managing a parasitic weed striga that severely impacts sorghum production. Sorghum is also severely affected by stalk borers. Infestation of stalk-borer is very high for early planted sorghum if there is rainfall in May. Re-sowing of sorghum is the common practice to minimize sorghum stalk-borer infestation. Thus, if rain comes in May, farmers usually practice re-sowing and replace April-planted sorghum seedlings as a stalk-borer management practice.

The shoot fly was the primary insect pest affecting teff production. Most farmers managed shoot fly infestations using insecticides such as Karate or Farate. Additionally, late planting was believed to help control teff shoot fly populations. Therefore, identifying the optimal planting date is crucial to manage teff shoot fly. Wheat production and productivity faced significant challenges due to rust infestations. To address this problem, farmers often used rust-resistant varieties and applied foliar fungicides, such as Tilt and Nativo, to manage wheat rust.

Newly emerged pests

The fall armyworm (*Spodoptera frugiperda*) is an invasive quarantine pest in Ethiopia, first detected in 2016. Since its introduction, it has caused substantial damage to sorghum and maize, particularly in the midland areas of the Amhara region. Implementing pest quarantine measures is essential for containing invasive species. This approach restricts pest movement and prevents the introduction of alien pests into new areas, thereby mitigating their potential impact on local agriculture.

Table 4.13: Commonly Used Pest Management Methods for Major Cereals Growing in the Midland Areas

Crop	Target pest	Control methods	Effectiveness
Sorghum	Fall army worm	Increase tillage frequency	Excellent
		Remove other host plant	
		Chemical (Agrolambacine supper 315. Proven 44% AC, Tracer, Karate 5% EC)	
	Smut	Hand picking	Good
		Crop rotation	
		Use of healthy seeds	
		Cow urine	
	Weed (Striga)	Seed treatment with Apron star and Proseed plus	Chemicals are very effective Excellent
		Using resistant variety	
		Moisture conservation	
		Increase soil fertility	
		Use clean seed and farm equipment	
Teff	Shoot fly	Hand weeding	Excellent
		Using chemicals like 2.4 D	
		Crop rotation with pulse crops	
		Insecticides (karate 5%, dursuban 48% ec, Metasystox r 250 ec, malathine 50% ec)	
Chickpea	Weed	Crop rotation	Excellent
		Deep tillage	
	Ascochyta blight	Plowing and hand weeding and herbicide spray (2,4-D)	Excellent
		Resistant variety (Eshete variety)	
	Wilt	Crop rotation	Excellent
		Timely planting	
		Mancozeb 80%wp	
	Root rot	Seed treatment	Excellent
Wheat	Rust	Use of resistant variety	Excellent
		Application of fungicide (tilt, nativo)	
		Application of fungicide	
		Minimize human interference while the field is moist	

Crop production constraints

Field crop production and productivity in the midland areas of the Amhara region remained low due to various biotic and abiotic constraints. These challenges significantly impact agricultural output, limiting growth and efficiency. Table 4.14 summarizes the key biotic and abiotic factors that adversely affect crop production and productivity in these areas.

A. Biotic production constraints

Survey results show that crop production and productivity in the midland areas of the Amhara region are mainly affected by biotic stresses. Both pre-harvest and post-harvest pests, such as diseases, insect infestations, weeds, weevils, rodents, and birds, significantly reduce the quantity and quality of crop yields. This finding aligns with Rogers (2004), who reported that biotic stresses caused by viruses, fungi, bacteria, nematodes, insects, and weeds pose serious threats to crop health. These stresses are of historical significance, unlike the abiotic stresses that appeared to be important recently due to climate change. There are some historical events when biotic stresses (diseases) led to the complete failure of the crops, resulting in famine. Notable examples include the potato late blight epidemic in Ireland and the coffee rust outbreak in Brazil, both caused complete damage to crops. The primary biotic constraints affecting major field crops in the midland areas of the Amhara region are outlined below.

Sorghum Production Constraints: Sorghum production in the region faces significant challenges from insect pests, weeds, and diseases. Stalk borer is a major pest, particularly affecting late-maturing sorghum varieties, which are highly susceptible to infestation. The parasitic weed *Striga*, an obligate hemi-parasite, further reduces sorghum productivity in *striga*-prone areas. While covered smut, loose smut, and anthracnose are considered minor sorghum diseases, sorghum midge poses a serious problem in the midland areas of North Shewa, where effective management strategies have yet to be developed. Additionally, the invasive *Parthenium* weed, an alien species, is rapidly colonizing crop fields, posing a growing threat to crop productivity in the midlands of eastern Amhara.

Teff Production Constraints: In the midland areas of the region, grasshoppers and shoot fly pose significant threats to teff cultivation. Shoot fly larvae primarily damage young and juvenile stems, weakening plant development, while grasshoppers target teff seedlings, leading to substantial yield losses if not effectively managed. Additionally, weed infestations, including grass-type and broad-leaved varieties, further hinder teff production and productivity. If left unmanaged, these weeds compete aggressively for nutrients and water, significantly reducing yields.

Wheat Production Constraints: Rust, Septoria, and take-all are among the most devastating diseases affecting wheat production and productivity. Yellow rust (*Puccinia striiformis*), in particular, poses a severe threat to wheat-growing areas in the Amhara region, leading to substantial yield losses if left unmanaged.

Chickpea Production Constraints: Chickpea production in the midland areas of the Amhara region faces multiple biotic stresses. Pod borers (*Helicoverpa armigera* and *Spodoptera exigua*), aphids (*Aphis craccivora*), leaf miners (*Liriomyza cicerina*), and bruchid (*Callosobruchus chinensis*) are prominent insect pests that significantly constrain yield potential. Moreover, several diseases, such as Fusarium wilt, Ascochyta blight, Botrytis gray mold, and various root rots, significantly reduce chickpea productivity in farmers' fields.

B. Abiotic production constraints

Abiotic factors significantly limit crop yield (Zorb et al., 2019). In the study area, key abiotic constraints include moisture stress, delayed onset and early cessation of rainfall, and an irregular rainfall pattern, all of which severely impact the production and productivity of field crops. Low soil fertility is also an essential challenge in the midland areas of Wollo. This issue is compounded by poor water-holding capacity, particularly in Belg production areas, further exacerbating low crop productivity. These findings align with the observations of Waqas et al. (2017), who reported that abiotic stresses, such as extreme temperatures, drought, flooding, salinity, and heavy metals, are primary factors limiting crop productivity and sustainability in mid-altitude ecologies.

Table 4.14: Major Abiotic and Biotic Stresses of Major Crops Grow in Midland Areas

Major Constraints	Sorghum	Teff	Wheat	Chickpea	Faba bean & field pea
Abiotic	Moisture stress Low soil fertility	Moisture stress Low soil fertility Flooding	Moisture stress Low soil fertility	Moisture stress	
Biotic	Stalk borer Striga Parthenium Smut Anthracnose Bollworm Bird	Shoot fly Rust Parthenium Grasshopper	Rusts Take-all Septoria	Cutworm Bollworm	Faba bean Chocolate spot Gall disease Bollworm Field pea Powdery mildew Aphids

4.1.2.2. Horticultural crops production and management

Major horticultural crops, varieties and seed sources

The use of irrigation practices has significantly changed horticultural production, enabling farmers to extend their growing seasons beyond traditional seasons. According to survey findings, the predominant growing seasons for horticultural crops (both vegetables and fruits) are irrigation-based, followed by the Meher season. The midland areas of the Amhara region primarily cultivate onion, tomato, carrot, cabbage, potato, and pepper as major vegetable and tuber crops. Papaya, mango, banana, avocado, guava, citrus, along with coffee, are widely grown fruit crops. A detailed list of the commonly used varieties is provided below (see Table 4.15).

Agro-dealers, along with organizations such as the Sekota Declaration, the Organization for Rehabilitation and Development in Amhara (ORDA), the Institute for Sustainable Development (ISD), and the Netherlands Development Organization (SNV), serve as the primary sources of horticultural seeds in the region. However, a substantial gap remains between the supply and demand for improved horticultural seeds. Farmers access these seeds either through direct purchase or as gifts. While the cost of horticultural seeds continues to rise, the prices of fruits and vegetables are also increasing.

Table 4.15: Major Horticultural Crops and Variety Grown In the Midland Areas

Crop	Variety	Productivity (Qtha ⁻¹)
Potato	Belete	215
Onion	Adama-red, Red king, Jamber, Bombay red	130-300
Tomato	Marglobe, Roman VF	175-300
Pepper	Virgo, Marko-fana	52 (Marko-fana), Virgo (600-700)
Cabbage	Copenhagen	85-303
Carrot	Nantens	140
Banana	Dwarf Cavendish	60
Mango	Apple mango	49.64
Papaya	Solo, local	94.82
Orange		68.82
Lemon		48.05
Avocado	Has	-
Guava		18.91
Coffee	Local	3.95
Chat	Local	7.32

Land preparation and transplanting

Similar to field crops, land preparation for horticultural crops relies on oxen. Given the need for a finely prepared seedbed, farmers typically plow their fields three to four times to ensure optimal soil conditions for horticultural crops. While crops like carrots and cabbage are sown directly in the field, onion, tomato, and pepper seedlings are first raised in nurseries before transplantation. Seedlings are usually prepared between late August and the first week of October, with transplantation occurring 45 to 50 days later. Farmers often align their planting schedules with significant cultural and religious events, such as Orthodox fasting periods and wedding seasons, to optimize market demand and ensure better sales opportunities.

Cropping system

Crop rotation is a widely used practice in the cultivation of horticultural crops. It helps to reduce soil-borne pests and increase crop productivity. Farmers are generally aware of the advantages of crop rotation. However, inter-cropping and double-cropping are less common with root and vegetable crops. On the other hand, inter-cropping of fruit crops with vegetables or spice crops is a practice that many farmers commonly practice.

Fertilizer and fertilizer application

Farmers commonly rely on inorganic fertilizers for horticultural crops, though location-specific recommendations are lacking. During the nursery stage, NPS (Nitrogen-Phosphorus-Sulfur) is typically applied, with some farmers also using urea to enhance seedling vigor. After transplanting, both NPS and urea are applied at rates of 180 kg/ha and 100 kg/ha, respectively, for crops such as onion, pepper, and cabbage. However, in the Tehuledere district, some farmers opt not to use inorganic fertilizers for tomatoes. Fertilizers are generally applied using the broadcast method. Additionally, some farmers incorporate organic fertilizers, such as farmyard manure and compost. However, the bulky nature of these organic fertilizers makes transportation to the fields challenging, which is a significant reason for their limited use.

Planting date

The planting dates for horticultural crops vary by location and season in the study areas. Table 4.16 presents the planting times, methods, and seed rates for the major horticultural crops grown in the midland areas of the Amhara region.

Table 4.16: Planting Date, Planting Method, Seed Rate and Harvesting Dates of the Surveyed Districts

Crop type	Planting	Planting method	Seed rate (kg/ha ⁻¹)	Harvesting date
Onion	July 15-Aug 30 (nursery), Sept 1-20 (transplanting)	Row	2-3	Dec - April
Tomato	Dec 1-15 (nursery) Jan 15-30 (transplanting)	Row	1.5-2	Jan - April
Pepper	Early July	Row	4	December
Carrot	Late July	Broadcast	Unknown	End of November

Product packaging and grading

Survey results indicate a lack of modern post-harvest technology for packaging and processing horticultural products in the region, leading to significant field and post-harvest losses. To mitigate these challenges, farmers employ various traditional methods. For transporting highly perishable crops such as tomatoes, peppers, and bananas, wooden or bamboo boxes are commonly used, while sacks serve as the primary packaging method for potatoes, garlic, apples, and similar produce. Horticultural crops are highly perishable and cannot be stored for long periods. They are also very susceptible to damage during transportation. Consequently, careful handling is essential to minimize losses. However, traditional packaging methods pose high risks, particularly during loading and unloading, contributing to considerable post-harvest waste. To address these issues, research must prioritize the development of improved packaging technologies.

Grading of horticultural crops remains uncommon in the Amhara region, although some farmers near urban centers have begun grading their produce to meet the quality standards required by hotels. These farmers sort their products based on factors such as marketability, color, size, and variety. Grading plays a crucial role in ensuring high-quality produce reaches consumers while enabling farmers to secure premium prices. Additionally, standardized grading enhances trust between producers and buyers. Therefore, researchers and agricultural experts should focus on providing training and guidance to farmers on effective grading practices to improve market competitiveness.

Major problems in agrochemicals

Survey results from the study areas highlight a significant gap between the supply and demand for improved vegetable seeds. The limited availability of improved varieties has compelled farmers to incur substantial costs for seed purchases.

Farmers primarily use improved seed varieties for crops such as onion, tomato, cabbage, mango, and sugar cane. However, due to their short lifespan, these seeds require annual repurchasing. Some vegetable crops—such as pepper and garlic—lack improved varieties, leaving farmers reliant on local varieties.

The demand for agricultural inputs, such as fertilizers, fungicides, and insecticides, remains high. However, fertilizer shortages have become a critical challenge for horticultural crop production. In response, informal and illegal fertilizer markets (black market suppliers) have emerged as a major source of supply.

Consequently, the cost of essential inputs, particularly fertilizers and fungicides, continues to rise steeply, exceeding the financial capacity of many farmers. Horticultural crops also face persistent pest-related challenges. Despite their importance, horticultural crop protection receives minimal attention from the government. Notably, there are no full-fledged crop protection experts at the district level, further exacerbating the problem. Additionally, the lack of proper training and absence of personal protective equipment place farmers at greater risk, worsening the pest management work.

Irrigation frequency

The crop-water requirement varies depending on the type of crop and its variety, growth stage, soil type, soil temperature, and humidity levels. Some horticultural crops, such as onions and cabbage, prefer frequent irrigation, while others, like tomatoes and peppers, do not require as much watering. Table 4.17 shows the optimal irrigation frequency for major horticultural crops.

Table 4.17: Irrigation Frequency for Horticultural Crops in Midland Areas of Amhara Region

Crop	Irrigation frequency
Onion	7-10 days
Tomato	15-20 days
Pepper	15-20 days

Productivity of horticultural crops

The productivity of horticultural crops has generally trended upwards. However, during the 2023/24 cropping season, a decline was observed due to shortages of fertilizer and rising input costs. Since horticultural products are primarily cash crops, they are mainly grown for market purposes (see Table 4.18).

The high market prices of these crops serve as a strong financial incentive for farmers, ensuring substantial income generation. Beyond their economic impact, horticultural crops contribute significantly to food security and employment creation, further reinforcing their role in agricultural sustainability.

Table 4.18: Values of Horticultural Crops in the Midland Areas of Amhara Region

Crop	Market	Food security	Job creation	Nutrition
Onion	1	3	2	
Tomato	1	3	2	4
Carrot	1	3	2	4
Pepper	1	3	2	4
Mango	1	2	1	1
Papaya	1	3	4	2
Banana	1	3	4	2
Orange	1	3	4	2
Avocado	1	3	4	2

Where, value 1 = very high, 2 = high, 3 = low and 4 = very low

Major horticultural crops production constraints

The horticulture industry in the region faces significant challenges in both production and marketing. Key production constraints include improper agronomic practices due to limited skills and knowledge in crop management, restricted access to advanced agricultural technologies, shortages of essential inputs such as fertilizers, improved seeds, and pesticides, as well as the widespread prevalence of diseases and insect pests. Additionally, inadequate harvesting and post-harvest handling practices further hinder productivity. Poor packaging, sorting, and processing techniques reduce product quality, shorten shelf life, and compromise food safety.

Among the market constraints, challenges include the presence of multiple actors leading to unfair competition, lack of reliable market information, seasonal price fluctuations, insufficient market infrastructure, poor handling and transportation practices, and the absence of regulations ensuring fair trade. Furthermore, middlemen and brokers play a considerable role in distorting market dynamics, making it difficult for farmers to maximize returns. The production constraints in the study area are primarily due to biotic and abiotic factors. Numerous studies support these findings; for instance, Melkamu et al. (2015) reported that the production and productivity of horticultural crops are adversely affected by both biotic and abiotic influences. The prevalence of diseases and insect pests presents a significant threat, especially in the mid- and low-altitude areas of the Amhara Region.

Crop pest occurrences and damage levels vary depending on crop type, environmental conditions, farming systems, and varieties. Citrus fruits are particularly vulnerable, with reported losses reaching up to 50% (Gezahegne et al., 2016). Furthermore, Seid et al. (2013) noted that insect pest infestations and plant diseases tend to worsen during the winter season. Post-harvest losses in horticultural crops are mainly the result of pre-harvest infections. Despite efforts to promote and distribute improved production technologies in major tropical fruit-growing areas, progress in managing diseases and pests remains limited, especially for perennial fruit crops (Minyahil, 2015). A detailed list of major horticultural pests is provided in Table 4.19.

Scouting

Crop scouting is the process for accurately assessing pest pressure, particularly from insect infestations, and evaluating overall crop performance. This assessment helps farmers understand the economic risks posed by pests and diseases while determining the potential effectiveness of various control measures. Regular field monitoring plays a vital role in identifying the incidence and prevalence of pests, allowing for timely intervention before significant economic losses occur. Recognizing the importance of scouting, farmers routinely inspect their fields, typically every two days, to ensure proactive management and effective pest control.

Table 4.19: Major Disease and Insect Pests of Horticultural Crops in the Midland Areas

Commodity	Biotic Production Constraints
Onion	Leaf Miner, Purple Blotch, Damping-Off, Rust and Thrips
Tomato	Early Blight, Powdery Mildew and Ball Worm, Late Blight, Root Rot
Cabbage	Aphid Loves Cabbage, Farmers usually spray insecticide (Karate or Farate) to manage aphid
Carrot	Powdery Mildew and Fox
Pepper	Fusarium Wilt
Banana	Cigarette End
Papaya	Anthrachnose, Powdery Mildew, Leaf Curl Virus
Mango	Anthrachnose, White Scale, Powdery Mildew
Citrus	Powdery Mildew, Leaf Miner, Citrus Psyllid, Citrus Woolly Whitefly, Dieback
Coffee	Fruit Fly

Major post-harvest pests

Rodents, weevils, and fungi are the primary post-harvest pests that affect field and horticultural crops. To manage these pests, farmers employ a combination of strategies, including chemicals and biological control methods (such as cats and rat traps). Additionally, they utilize various botanical solutions to treat weevil infestations. Effective pest management also involves cleaning local storage facilities, removing diseased tubers and bulbs, and applying chemicals as necessary.

4.1.3. Crop Production Constraints in the Lowland Areas

4.1.3.1. Field crops production and management

Major crops varieties and seed sources

Sorghum, teff, maize, finger, and pear millets are the major cereal crops grown in the lowland areas of Amhara. Of the pulse crops, soybean, chickpea, mung bean, and common bean are the major ones. Sesame, niger seed and sunflower are the major oil crops produced in the lowland areas of Amhara. Moreover, cotton is the dominant fiber crop produced in this area. The present finding aligns with the Central Statistical Agency agricultural sample survey report (CSA, 2022).

These field crops are mainly produced for food and local markets. Moreover, their straws are the main source of animal feed. Sorghum straw is specifically used for firewood, fence, house building, and animal feed. The most commonly used field crop varieties in the lowlands of the Amhara region are indicated in Table 4.20.

Major varieties

Sorghum: Sorghum is a drought-tolerant crop well-suited for growth in harsh production conditions in tropical and subtropical regions. Sorghum is grown primarily for food, feed, and bioenergy (Kimber et al., 2013). Sorghum is the most important cereal crop in Ethiopia, ranking third in area coverage after teff and maize, and fourth in production (CSA, 2022).

In Ethiopia, sorghum is grown in almost all regions, occupying an estimated total land area of 1.35 million ha and has a national average productivity of 2.631 t/ha (CSA, 2022). In the Amhara region, sorghum covers a significant amount of cultivated land next to teff. It is a major crop in the lowland areas of eastern Amhara, as the agro-ecology of the area best fits the crop.

Girana-1, Melkam, Berhan, Hormat, Argity, Beletew, Chare, Miskir, and Teshale are major sorghum improved varieties grown in the lowland areas of the Amhara region. Because of its relatively high productivity and earliness, Girana-1 and Melkam took the lion's share in area coverage. On the other hand, Jamiyo, Degalet, and Jigurti are the most commonly produced local sorghum varieties. These varieties have high biomass and good injera quality, but their growing period is very long, which leads to low production when a rainfall shortage occurs. Landrace sorghum varieties like Mera, Mubabe, Gorad, and Tengele underscore the rich tapestry of local farming practices in the Oromo special zone.

Teff: Teff is an ancient crop in Ethiopia. The country is considered the center of origin and diversity for teff (Vavilov, 1951). Teff is one of the main cereal crops in Ethiopia, both in terms of area coverage and total production. Nationally, teff accounts for about 24% of the total area covered with cereal crops. Similarly, it accounts for about 17% total annual cereal grain production. The Amhara region is one of the major teff-producing regions in the country, where teff covers about 1.2 million hectares annually, from which about 2.2 million tons are produced (CSA, 2022). Several improved teff varieties were developed and released for the lowland areas of the region, adapted for moisture-deficient environments. In the lowland area of the region, farmers grew an improved variety of Boset, Mena, Zobel, Tsedey, Cr 37, and Quncho (Table 4.20) with an average growing period of 3-4 months.

Maize: Farmers primarily cultivate maize using irrigation methods. The Melkasa-2 variety is the most common improved variety grown in lowland areas. Additionally, farmers in the study area produced high-yielding hybrid varieties.

Millet: Both finger millet and pearl millet are cultivated in the lowland areas of the region. Specifically, finger millet is predominantly grown in the lowlands of Gondar and parts of South and North Wollo. The improved variety known as Mecha and local varieties are the most common in Gondar. In contrast, only the local variety is cultivated in the lowlands of South and North Wollo. In Wag-Lasta, pearl millet is primarily grown in lowland areas, where farmers cultivate the improved variety Kola-1, which is ideal for low-moisture environments. This crop thrives in the moisture-deficient and low soil fertility conditions of Wag-Lasta, making it an ideal choice where other crops struggle to grow.

Oil crops: Ethiopia is one of the top six world producers of sesame and linseed. Oilseeds, such as sesame, Niger seed, and safflower seeds, are high-priority export crops and rank as the second-largest source of export earnings. Thus, production growth and quality improvement of oilseeds can substantially contribute to the economic development at the national, regional, and family levels. Specifically, sesame is the third most important oil crop in Ethiopia and occurs both as cultivated and wild. Ethiopia exhibits a high phenotypic diversity in both phonological and agronomic traits.

Sesame production is increasing in Ethiopia, especially in the southwest and northwestern parts of the country, which is driven by high market value and suitability of environmental conditions (Wijnands et al., 2007). The lowland area of Gondar and Wag-Lasta is the potential area for sesame production, covering large arable land.

Table 4.20: Widely Grown Varieties of Major Crops in the Lowland Areas and Their Preferred Traits

Crops	Varieties	Varietal category	Strength	Weakness
Sorghum	Girana-1, Melkam, Misikir, Beletew	Improved	Relatively high yielding and early maturing	Low biomass to landraces
	Jamiyo, Degalet	Landraces	High yield	Late mature
	Jigurity, Tengele, Mera etc		Good quality High biomass	
Wheat	Kekeba	Improved	High yield	
			Adapted in low land for irrigation	
Teff	Boset	Improved	Relatively high yield and early mature	
	Mena	Improved	High yielding	
			White grain High biomass	
	Magna	Landrace	Adaptability	
			White grain Excellent injera quality Straw is palatable	
	Bunign	Landrace	Early maturing	Low yielding
			Straw is palatable	
Pear millet	Kola-1	Improved	Relatively High yield	
			Early mature	
			Adapted in moisture deficit area where other crops not grow	
Finger Millet	Mecha	Improved	High yield	
Soybean	Afgat, Gisham, Wollo	Improved	High yield	
			Early mature	
Sesame	Gondar-1	Improved	High yield	Shattering
	Abasena		High market price, called white Gold	
	Humera-1			
	Hirhir, Gojam	Landrace	High yielding	Shattering
	Azene, Tejareb		White seeded	
Mung bean	N-26 (Rasa)	Improved	High yield	Shattering
	Arkebe		High market price	
Cotton	-	Local	No improved variety greater than local	
Chickpea	Teketay, Dimtu, Kobo, Habru	Improved	High yield	

Farmers' preferred traits

The trait preference by farmers is crucial, as the selection of crop varieties significantly boosts productivity. Farmers are very skilled at selecting varieties of their choice. They have their own selection criterion for different crops. Before developing a new variety, breeders should consider farmers' preferred traits and include them in the variety selection program. Farmers' preferred traits of major highland crops are presented in Table 4.21.

Often, the production and productivity of major highland crops are seriously affected by disease outbreaks. Farmers are unhesitant to reject a variety if the variety is susceptible to disease. Therefore, disease resistance is the first and most important trait that the new crop variety should possess. Moreover, yield components are indirect indicators of crop productivity. Farmers are experienced in easily identifying high-yielding varieties based on these agronomic markers.

Table 4.21: Farmers' Selection Criteria for Major Crops in the Lowland Areas of Amhara Region

Sorghum	Maize	Teff	Pulse crops
Yield	Cob size/Length	Productivity (long	Disease resistant
Biomass	High biomass (for	panicle)	Productivity (pod load, seed
Earliness	animal feed)	Earliness	size and seeds/pod)
Panicle length	Disease resistant	Erect type (non-	Logging tolerant
Seed color (Kernel)	Productivity	lodging)	Seed color
Seed size	Earliness	Seed color (white)	Earliness
Stalk palatability		Seed size (Bold	Shattering
Disease/insect		seeded)	
tolerance/resistance		High tillering	
Injera Quality		potential	
		High biomass (for	
		animal feed)	

A. Farmers' participation in variety selection

Participatory varietal selection (PVS) is the active participation of farmers during variety selection of finished or pipeline products from plant breeding programs. These include released cultivars, varieties in advanced stages of testing, and well-characterized material such as advanced non-segregating lines in inbreeding crops, or advanced populations in outbreeding crops (Witcombe et al., 1996). Several improved varieties were released from the national and regional research centers via conventional breeding schemes.

Breeders were the sole decision makers in varietal development. Farmers were not allowed to participate in variety development, and their varietal selection criteria were not considered, either. Their long years of varietal breeding and selection skills were overlooked, too. Thus, farmers remained reluctant to adopt improved crop varieties, though breeders claimed improved varieties are superior to the landraces for yield and yield-related traits. Citizen scientists advocate the importance of farmers' participation in varietal development and technology promotion. Participatory Variety Selection (PVS) was coined by the citizen scientist to involve farmers in variety development.

The objective of participating farmers under variety selection is to identify farmers' varietal selection criteria and to incorporate their preferred traits in a conventional breeding scheme. The active participation of farmers in varietal and trait selection helps conventional breeder to exploit their indigenous knowledge and skills to develop demand-driven improved varieties.

Participating farmers in varietal selection will help breeders to develop varieties of farmers' choice. These days, farmers are participating in the participatory variety selection (PVS) scheme to a certain level. Citizen scientists identified four levels of participation: Contractual, Consultative, Collaborative, and Collegiate types in order of degree of farmers' decision making in variety development. As yet, the participation level is no more contractual and consultative types, and hence, decision is often made by the conventional breeder.

Productivity, seed color, seed size, resistance to biotic and abiotic stresses, and straw yield are the key farmers' preferred traits that an improved variety is expected to possess. Moreover, farmers and agricultural experts often participated in technology demonstration and pre-scaling up activities to aware farmers and experts about improved varieties along with their agronomic packages.

B. Seed source and seed exchange methods

Several government and non-governmental organizations were involved in the seed delivery system. Bureau of Agriculture, seed producers, research centers, Universities, NGOs, cooperatives/unions, agricultural transformation institute, market, and local seed exchange system are the major sources of improved seeds in the highland areas of the Amhara region. The seed demand in the study areas is very high. However, the supply of improved seeds is very low. It is not surprising that the price of improved seed is higher than the grain price. Premium seed price may encourage seed producers to invest in the seed business. The survey discussants listed the major problems in the seed supply system.

Poor seed quality

Seed quality is very important to have a healthy and good stand. However, seeds distributed by some NGOs didn't meet the quality standards. Poor seed germination (<80%), seed impurities, shriveled seeds, and pest-infested seeds are the major problems in the seed delivery system. Farmers are losing trust in seed suppliers to get quality seeds. Regulatory bodies should evaluate and confirm the quality of seeds based on the established criteria before seed distribution. Moreover, administrative measures should be taken against seed suppliers who violate the quality standards set by regulatory bodies.

Inadequate seed supply (demand-supply gap)

The demand for improved seed is increasing. However, the supply of improved seed is very low and doesn't meet the growing seed demand. Therefore, the gap between seed demand and supply is very wide. The Bureau of Agriculture should design strategies to make improved seed more accessible to farmers by establishing community-based informal seed growers.

High seed cost

The cost of agricultural inputs is alarmingly skyrocketing. As of inorganic fertilizers and agro-chemicals, the cost of improved seed is increasing from season to season and has become unaffordable to poor farmers. Costs (transportation, loading & unloading, and administrative), as well as cooperative and micro-finance profit margins, escalate the total seed cost.

Farmers are obliged to use landraces or recycled seeds. However, recycled seeds often have admixtures, which affect crop productivity. Establishing community-based seed producers might be a solution to multiply demand-driven and cost-effective improved seeds. Research centers, universities, cooperatives, the office of agriculture, and plant quarantine should jointly work to establish sustainable community-based seed producers with strong administrative, technical, and financial support.

Untimely seed supply

Optimum planting time is crop and variety-specific. Through long years of experience, farmers identified optimum agronomic timing, called the cropping calendar. Depending on the onset of rainfall, planting time may vary 7-10 days from the cropping calendar. Input delivery schedule should consider the farmers' cropping calendar. However, an untimely supply of agricultural inputs became a common problem in the Amhara region.

Most rural areas lacked all-weather roads. Transporting agricultural inputs during the rainy season is quite challenging. To avoid transportation issues, the distribution of these inputs should be finalized at least a month before the actual planting season. These challenges are significant obstacles in the seed supply system that farmers are currently facing. Farmers utilize a local seed exchange system to ensure the purity and health of seeds based on previous field observations and their own experiences. They employ various methods for exchanging seeds, such as swapping seeds with others who grow similar crops, purchasing seeds from trusted sources, or receiving them as gifts from relatives or friends.

Crop management practices

A. Plowing and plowing practices

In the lowland area of the Amhara region, both ox-drawn and tractor plows are practiced to prepare the land for the cultivation of major crops. In lowland areas, there is some mechanization using a contractual basis for plowing. Moreover, the soil type of Wag-Himra and some parts of the lowland area of Eastern Amhara is characterized by shallow and rocky.

Shallow and rocky soils are not suitable for tractor plowing. Planting, harvesting, and threshing are practiced manually. Agricultural mechanization (tractor) service is practiced at Metema, Raya Kobo, and Dawachefa districts. Given, the average land-holding size of the Metema area is greater than other parts of the region, labor-saving machinery (tractors and combine harvesters) services are commonly used for soybean, sesame, and sorghum.

The frequency of plowing ranged from 1 to 2 times in the lowland area of Gondar. In the other lowland areas, optimum plowing frequency ranged from 2-3 times (sorghum and maize), 3-4 times (teff), depending on the nature of the farm land, precursor crop, soil type, soil moisture content, weed type and weed density, crop type, and agro-ecology.

B. Cropping systems

A cropping system refers to the type and sequence of crops grown and practices used for growing them. It encompasses all cropping sequences practiced over space and time based on the available technologies of crop production. It is a cropping sequence and management techniques used on a particular plot of land over a period of years. Cropping system encompasses all cropping sequences practiced over space and time (Blanco-Canqui and Lal, 2010).

Crop rotations, intercropping, relay cropping, mono cropping, mixed cropping, and double cropping are the commonly practiced cropping systems in the lowland areas of Amhara (Table 4.22). Farmers are aware of the benefits of practicing various cropping systems. These cropping systems are important for yield and income maximization, product diversification, cost minimization, and soil fertility restoration. Farmers usually rotate pulse or oil crops with cereals. Different types of cropping systems are practiced in the lowland areas of the Amhara region (Table 4.22).

Table 4.22: Major Cropping Systems Used In the Lowland Areas of Amhara Region

Cropping systems	Crops	Benefits
Crop rotation	Cereals with pulses	Restore soil fertility
	Cereals with oil crops	Disturb pest life cycles
	Oil with pulse	Improve productivity
	Sorghum with onion	
Mono cropping	Sorghum	Have no advantage
	Teff	
Mixed cropping	Teff with Brassica spp	Produce two types of grains in one plot in one cropping season
	Teff with sunflower	Create unfavorable environmental
	Teff with safflower	Product diversification
	Teff with niger seed	Condition for disease development improve productivity
Intercropping	Sorghum with mung bean	Produce two types of grains in one plot in one cropping season
	Sorghum with sesame	Create unfavorable environmental condition for disease development
	Sorghum with common bean	Improve productivity
	Sorghum with sunflower	
Double cropping	Maize with chickpea	Produce two types of grains in one plot in one year with residual moisture
	Sorghum with mung bean	
	Sorghum with teff	Restore soil fertility

C. Planting time, methods, seed and fertilizer rates and harvesting

The optimum planting time depends on the onset of rainfall, soil, and variety type. Early sowing is normally used in less fertile, shallow depth, and high silt and sand textured soils. The water-holding capacity of shallow depths and soils with high silt content is very poor. Thus, early planting is generally practiced to avoid terminal moisture stress, which normally occurs at the grain-filling stage. On the other hand, late planting is practiced in vertisols areas.

Moreover, late-maturing varieties are planted earlier, while early maturing varieties are sown later. Farmers' optimum planting time is presented in Table 4.23. Seed rate depends on the planting method, Seed size, and germination rate. Determining the seed rate is imperative to use an optimal plant population. Use of excessive seed rate, which is over the optimal seed rate, produces strong competition among plants for nutrients, moisture, and sunlight and results in low productivity. On the other hand, the use of a low seed rate decreases the number of plants population required within a given area, and subsequently results in low productivity. Table 4.23 presents farmers' optimum seed rate for major crops.

The rate of application of fertilizers varied depending on crop and soil types. Fertilizer rate for major crops is presented in Table 4.23. The whole NPS is applied at planting time, while Urea is top-dressed at the full tillering stage (30-35 days after planting). Broadcasting is a common application method of fertilizer for the teff crop lowland areas of Amhara. Row application and side dressing are applicable for crops that are planted in rows. Moreover, farmers also practiced the application of bio-fertilizer for pulse crops at planting time.

Table 4.23: Planting Date, Seed - and Fertilizer Rate of Major Field Crops in the Study Areas

Crop type		Planting date	Seed rate (kg ha^{-1})	Fertilizer rate (kg ha^{-1})
Sorghum	Late maturing	March-half of April	15-20	120-200 NPS & 100 Urea
	Early maturing	End of June-1 st week of July	15-20	100 NPS & 50kg Urea
Teff		End of July	15-30	100-200 NPS & 50-150 Urea
Mung bean		End of June	25-30	50-100 NPS
Chickpea		End of Aug-1 st week of Sept	80-120	50-100 NPS
Soybean		End of June- 1 st week of July	60-80	-
Maize		On set of rain fall	75-120	50 NPS
Finger millet		End of June- 1 st week of July	40	
Cotton		15 June- 1 st week of July	40	
Niger seed		15 June- 1 st week of July	12	
Sesame		15 June- 1 st week of July	4-5	65 Urea
Irrigated wheat		End of November	120-150	

Crop productivity trend

The productivity of field crops remained unstable, oscillating up and down over the last five years. In some seasons, crop productivity showed a declining trend because of sub-optimal use of fertilizers, disease outbreaks, and unexpected climate change (moisture-stress, waterlogging, and frost incidence). Moreover, inaccessibility of inorganic fertilizer was one of the major challenges that severely affect crop productivity in the Amhara region. The survey discussants complained about fertilizer shortage. They bitterly expressed their disappointment about the illegal fertilizer trading.

Frustration is growing among farmers over fertilizer illegal trading since the 2022 cropping season. They believe the shortage of fertilizer is the major bottleneck for the decline in productivity. They desperately ask the government to design a transparent and timely delivery of fertilizer to farmers, and to control illegal fertilizer trading. This is an active discussion topic among farmers these days.

Some farmers used liquid fertilizer as a substitute for Urea fertilizer. However, the effectiveness of liquid fertilizer is very questionable. Based on their assessment, liquid fertilizer is not rewarding. Thus, the discussant didn't show interest in investing in liquid fertilizer. In some seasons, the productivity of field crops showed an increasing trend.

Before the 2022 cropping season, the supply of inorganic fertilizer was not a problem. Optimal use of agricultural inputs & agrochemicals, proper application of agronomic practices thought to boost crop productivity. Farmers who routinely scout and protect their farms from biotic and abiotic stresses, and who apply agronomic practices based on research recommendations (optimum plowing, pest management, drainage application in waterlogged areas, lime application in acidic soils, etc.) have got the reward.

Climate change

Climate change refers to a long-term shift in temperature and weather patterns, and farmers and key informants well recognize its impact on crop production and productivity. One significant indicator of climate change is the increase in temperature, observed both during the day and at night. Highland areas are warming, as evidenced by a decrease in frost incidence compared to the past. Rainfall patterns are also shifting; over the last decades, rainfall amounts have declined, with delayed onset, early cessation, and intermittent dry spells becoming increasingly common in Eastern Amhara. Seasonal rainfall is diminishing, and untimely rainfall during the grain maturity period has emerged as a recent challenge. This unpredictable rainfall during crop maturity causes severe damage to crops, leading to significant yield losses. Excessive rainfall concentrated in a single event, likely due to climate change, leads to flooding that adversely impacts crop production and productivity.

Moreover, rising temperatures combined with reduced rainfall and frequent dry spells create favorable conditions for pest outbreaks. These climate changes are consistently altering environmental conditions and negatively affecting crop productivity, as noted by discussants. Because of climate change, farmers are struggling to control crop pests, leading to greater yield losses. In general, the survey's discussants believed that farmers became victims of climate change. Building climate change resilient farmers and capacitating coping strategies is a prerequisite to minimize their vulnerability and help them survive in the changing environment. Thus, agricultural development actors (GOs and NGOs) should jointly design climate change resilient strategies to minimize the harmful effects of climate change on crop production and livelihoods.

Pest management practices

Farmers are using different pest management methods to keep pest incidence and prevalence below an economic threshold level. The commonly used pest management methods for major cereal crops are pulse and oil crops are presented in Table 4.24 and Table 4.25, respectively.

Newly emerged pests

Fall armyworm in sorghum and maize is a newly emerged and dangerous pest in the lowland areas of the Amhara region. This pest became a headache for the farming community that produces sorghum and maize. Pest quarantine is advisable to contain alien pests. It is a technique to restrict pest movement and to exclude the entry of alien pests into a new area.

Table 4.24: Commonly Used Pest Management Methods for Major Cereals Growing in Lowland Areas

Crop	Target pest	Control methods	Effectiveness
Sorghum	Fall army worm	Increase tillage frequency	Excellent
		Remove another host plant	
		Chemical like Agrolambacine supper 315, Proven 44%	
		AC, Tracer, Karate 5% EC and Best field 360	
	Smut	Hand picking	Good
		Crop rotation	
		Use of healthy seeds	
		Cow urine	
	Weed (Striga)	Seed treatment with Apron star, Proseed plus	Chemicals are effective
		Using resistant variety	
		Moisture conservation	
		Increase soil fertility	
		Use clean seed and farm equipment	
		Hand weeding	
Teff	Shoot fly	Using chemicals like 2.4 D	Excellent
		Crop rotation with pulse crops	
		Insecticides Like, Karate 5%, Dursuban 48% Ec, Metasystox R 250 EC, Malatayon 50%EC	
		Crop rotation	
		Deep tillage	
Irrigation wheat	Weed	Plowing and hand weeding and herbicide spray (2,4-D)	Excellent
	Rust	Use of resistant variety	Excellent
	Weed	Application of fungicide (tilt, nativo)	Excellent
		Hand weeding	

Table 4.25: Pest Management Methods for Major Pulse and Oil Crops in Lowland Areas

Crop	Target pest	Control methods	Effectiveness	
Mung bean/ Common bean	Bean fly	Other Cultural methods	Excellent	
	Powdery mildew	Seed treatment with Crusar 350 AC	Chemicals are very effective	
		Fungicide spray like, Tilt, Mancozeb		
		Timely planting		
		Crop rotation		
	Cercospora leaf spot	Fungicide spray like, Tilt, Mancozeb	Excellent	
		Clean seed		
		Avoid debris		
		Resistant variety		
	Leaf blight	Clean seed	Excellent	
Avoid debris				
Resistant variety				
Tilt, Mancozeb				
Blister beetle	Bun	Excellent		
	Early planting			
Sting bugs	Lamdasychlorine			
	Seed treatment (Cruser 350 AC, Apronstar WS)			
Chickpea	Aphid	Early planting		
		Dimethoate		
	Ascochyta blight	Insecticide spray like, Confidence 60%AC		
		Roger/Dimethoate, Karate		
	Wilt	Resistant variety (Eshete variety)		
		Timely planting		
	Root rot	Mancozeb 80%wp		
		Crop rotation		
	Sesame	Sesame webworm (<i>Antigastra catalaunalis</i>)	Seed treatment	Excellent
			Use of resistant variety	
Sesame gall midge (<i>Asphondylia sesame</i>)		Application of fungicide (tilt, native)	Excellent	
		Avoid debris		
Sesame seed bug (<i>Elasmolomus sordidus</i>)		Crop rotation	Very good	
		Insecticide spray like, Malathaion, Diaznon		
Sesame Phyllody		Insecticide spray like, Malathaion 50%, Diazinon 60%	Excellent	
		Avoid alternate hosts		
Bacterial Blight		Use clean seed	Excellent	
		Insecticide spray like, Carbaril, malathion		
	Avoid infected plant			
	Use clean seed			
	Avoid alternate host			
	Resistant variety			
	Avoid excess water			
	Keep optimum population			
	Timely harvesting			

Crop production constraints

Production and productivity of field crops in the lowland areas are very low, owing to various biotic and abiotic production constraints. The major biotic and abiotic constraints that significantly affect crop production and productivity in the lowland areas of the Amhara region are presented in Table 4.26.

A. Biotic production constraints

Biotic stress is a major constraint on crop production and productivity in the lowland areas of the Amhara region. Pre-harvest and post-harvest pests (diseases, insect pests, weeds, weevils, rodents, birds, etc.) significantly affect the quality and quantity of crop products. In the lowland areas, smut on sorghum, anthracnose on mango, powdery mildew on onion and tomato, wilt on tomato and root rot, and purple blotch on tomato, as well as onion, are very common crop production constraints. This finding is also supported by Rogers (2004), who reported that biotic stresses are the major production constraints limiting crop production and productivity. The major biotic constraints of major field crops are mentioned in Table 4.26.

Sorghum: The stalk borer, fall armyworm, cutworm, shoot fly, and sorghum midge are the most destructive insect pests affecting sorghum production in the lowland areas of the Amhara region. Among these, the sorghum midge poses a significant problem in the lowland areas of North Shewa, where no management options have been developed yet. Additionally, the most common diseases impacting sorghum production include smut and anthracnose.

Teff: The most significant insect pests affecting teff production are the shoot fly and the blister beetle. Grasshoppers also pose a threat, as they feed on teff seedlings, particularly in the lowland areas of the Amhara region. As a result of this pest pressure, farmers in the study area often use a seed rate that exceeds the recommended amount. Additionally, grass and broad-leaved weeds are crucial factors that limit the yield and productivity of teff if not appropriately controlled.

Chickpea: Pod borers, aphids, leaf miners, and bruchids are the main insect pests that affect chickpea production. In the lowland areas of the Amhara region, the primary diseases impacting chickpeas include Fusarium wilt, Ascochyta blight, botrytis gray mold, and root rots.

Sesame: For sesame crops in Ethiopia, common diseases include bacterial blight, phyllody (caused by mycoplasma), Fusarium wilt, powdery mildew, alternaria leaf spot, and cercospora leaf spot. Bacterial blight tends to be a serious issue in humid areas, while phyllody is more problematic in drier regions. However, powdery mildew and wilt are sporadic and economically minor diseases.

Mung bean: The main insect pests affecting mung beans include bruchids, whiteflies, thrips, stem flies, aphids, and pod borers. Additionally, mung beans are susceptible to several diseases, such as yellow mosaic, anthracnose, powdery mildew, cercospora leaf spot, halo blight, bacterial leaf spot, and tan spot (Noble et al., 2019).

B. Abiotic production constraints

The late onset and early cessation of rainfall, along with intermittent dry spells, significantly impact the production and productivity of field crops in the eastern Amhara. Additionally, soil fertility in certain areas of the region is often poor, characterized by sandy and shallow soils. The eastern Amhara lowlands, including the North Wollo and Wag-Himra administrative zones, feature undulating topography with limited vegetation cover. The rugged topography and poor vegetation cover have led to an increase in soil erosion. Consequently, poor soil fertility, affected by steep slopes, poses a major challenge for agriculture in eastern Amhara. The combination of low soil fertility and inadequate water retention contributes to decreased crop productivity. Furthermore, soil salinity is a significant constraint to agricultural production in the lowland areas of the Raya-Kobo and Dawachefa districts.

Table 4.26: Major Abiotic and Biotic Stresses of Major Crops in Lowland Areas of the Region

Crops	Biotic stress	Abiotic stress
Sorghum	Fall armyworm, Stalk borer, Anthracnose, Smuts, Downy mildew, Weed, Sorghum midge, Sorghum shoot fly, Plant hoppers	Moisture stress, Low fertility, Salinity
Teff	Rust, Grasshopper, Shoot fly, Weed	Low fertility, Salinity, Moisture stress
Maize	Smut, Leaf blights, Fall armyworm, Aphid, Weed, Stalk borer	Moisture stress, Low fertility, Salinity
Common bean	Common Bacterial blight, Aphid, Bruchid Bollworm, Weed, Root beetle	Moisture stress, Low fertility, Salinity
Sesame	Sesame webworm, Sesame gall midge, Sesame seed bug, Bacterial blight, Weed	Moisture stress, Low fertility, Salinity,
Irrigated wheat	Rust, Fusarium head blight, Weed	Moisture stress, Low fertility

4.1.3.2. Horticultural crops production and management

Major horticultural crops, varieties grown and Seed source

The adoption of irrigation represents a significant shift in horticulture, allowing growers to move beyond traditional growing seasons. Key crops in this sector include mangoes, lemons, papayas, onions, and tomatoes, highlighting a diversification of agricultural practices. According to survey results, the primary growing seasons for horticultural crops (both vegetables and fruits) are during irrigation and the meher season.

In the lowland areas of the Amhara region, major vegetable crops cultivated under rain-fed and irrigation conditions include onions, tomatoes, carrots, cabbages, and peppers. Additionally, significant fruit crops grown in these areas consist of papayas, mangoes, bananas, avocados, guavas, and citrus fruits. The commonly used variety is indicated below (Table 4.27).

Table 4.27: Major Horticultural Crops and Variety Grown In Lowland Areas of Amhara Region

Crop	Variety	Productivity (Qtha⁻¹)
Onion	Bombey-red and Adama-red	130-300
Tomato	Roma VF, Golden, Gelila, Mersa	175-300
Pepper	Local, Marko fana	52
Cabbage	Copenhagen	85-303
Carrot	Nantens	140
Banana	Dwarf Cavendish, Poyo, Williams	60
Mango	Tomyatkin, Kit, Kent, Apple mango	49.64
Papaya	Solo, Local	94.82
Orange		68.82
Lemon		48.05
Avocado	Has, Eatinger, Fuerte	-
Guava		18.91
Coffee	Local (Buhoro special), B-747,	3.95
Khat	Local	7.32
Sugarcane	Local	264.09

In the study area, improved seeds of major horticultural crops were distributed by various stakeholders and directly purchased by farmers from the market. The main suppliers of seeds to farmers include the agricultural extension system and several non-governmental organizations. Major sources of horticultural seeds are agro-dealers, Kale-Hiwot Church, Sasakawa Global 2000, ORDA, and Facilitator for Change. However, the gap between the supply and demand of improved horticultural seeds is very wide. Farmers can access horticultural seeds *via* purchasing and/or through a gift. The costs of seeds are increasing over time, though the price of fruits and vegetables is increasing.

Land preparation and transplanting

Like field crops, land preparation for horticultural crops is executed using oxen. Horticultural crops require a fine seedbed, so farmers plow their fields 3 to 4 times. Carrots and cabbages are directly sown in the fields, while seedlings for onions, tomatoes, and peppers are raised before being transplanted. Seedlings are typically grown from late August to the first week of October, and then transplanted into the fields after 45 to 50 days. Farmers often synchronize their planting dates with significant Orthodox fasting periods and wedding seasons.

Cropping system

Crop rotation is a widely used practice in horticulture that helps minimize soil-borne pests and maximize crop productivity. Farmers recognize the advantages of crop rotation. While intercropping and double cropping are not commonly used with root and vegetable crops, intercropping with fruit crops alongside vegetables or spice crops is frequently practiced.

Planting date, method, seed and fertilizer rates

There are challenges associated with fertilizer use and irrigation water management in those lowland growing areas. Inappropriate applications of inorganic and organic fertilizers in terms of recommendations and time of application are the main problems. The rate of fertilizer application is location and crop-specific. Typically, farmers apply 200 kg/ha of NPS fertilizer and use urea for crops like onion, tomato, and pepper, usually 30 days after transplanting. In some cases, Urea is also applied during the nursery stage to promote seedling growth. Fertilizer is often applied using the broadcast method. Additionally, some farmers use organic fertilizers, such as farmyard manure and compost, particularly for potatoes.

Farmyard manure and compost are bulky to transport to farmlands, which is a primary reason for the limited use of organic fertilizers. In the study area, the planting date, planting method, and seed rates for major horticultural crops varied by location and across different seasons (see Table 4.28).

Table 4.28: Planting Date, Planting Method, Seed Rate and Harvesting Dates of the Surveyed Districts

Crop type	Planting	Method of planting	Seed rate (kg/ha ⁻¹)	Harvesting date
Onion	July nursery and Sept at the field	Row	2-3	Dec - April
Tomato	Dec 1-15 (nursery) Jan 15 transplanting	Row	1.5-2	Jan - April
Pepper	Early July	Row	4	Starting from Dec
Carrot	Late July	Broadcast/row	Unknown	Starting from end of Nov

Product packaging and grading

The survey results highlight a critical shortage of modern postharvest technologies for packaging and processing horticultural products in the study area. This deficiency has led to substantial field and postharvest losses, particularly for major horticultural crops. To mitigate these challenges, farmers have adopted various traditional strategies.

Currently, horticultural products are transported using conventional packaging methods. Perishable crops such as tomatoes, peppers, and bananas are carried in wooden or bamboo crates, while potatoes, garlic, apples, and similar items are transported in sacks. However, many horticultural crops are often recalcitrant, meaning they cannot be stored for extended periods and are vulnerable to damage during transportation. Minimizing harvest and postharvest losses requires careful handling of these products.

However, the prevailing box and sack packaging techniques are outdated and pose a high risk of losses during loading and unloading. Therefore, research efforts should prioritize the development of advanced packaging technologies to enhance postharvest management and significantly reduce product losses.

Grading horticultural crops is quite rare in the region. However, some farmers near urban areas have begun grading their products to supply local hotels. They assess their crops based on marketability, color, size, and variety. Grading is crucial for delivering high-quality products to consumers and achieving a premium price. It standardizes products and fosters trust between producers and consumers. Therefore, it is essential for researchers to provide advice and training to farmers on how to effectively grade their products.

Irrigation frequency

The water requirements for crops depend on several factors, including the type and variety of the crop, its growth stage, soil type, soil temperature, and humidity levels. Some horticultural crops, such as onions and cabbage, benefit from frequent irrigation, whereas others, like tomatoes and peppers, do not require as much water. Table 4.29 presents the optimal irrigation frequency for major horticulture crops.

Table 4.29: Irrigation Frequency for Horticultural Crops in Lowland Areas of Amhara Region

Crop	Irrigation frequency (days)
Onion	7-10 days
Tomato	15-20 days
Pepper	15-20 days

Major horticultural crops production constraints

Horticultural crop production has grown in recent years; however, the industry faces significant challenges in both production and marketing. Key production constraints include improper agronomic practices stemming from limited skills and knowledge in crop management, restricted access to advanced agricultural technologies, and shortages of essential inputs such as fertilizers, improved seeds, and pesticides. Additionally, the prevalence of diseases and insect pests, inefficient harvesting and post-harvest handling, and inadequate packaging, sorting, and processing hinder value addition and reduce shelf life and product safety.

The horticulture market in the region faces several structural constraints that hinder efficiency and profitability. Key challenges include the multiplicity of actors leading to unfair competition, limited access to market information, seasonal price fluctuations, inadequate market facilities and infrastructure, poor handling and transportation, and the absence of regulatory frameworks to ensure fair trading practices.

Additionally, the significant role of middlemen or brokers further complicates market dynamics. Horticultural products are largely grown commercially as cash crops (Table 4.30). Their high market value provides an economic incentive for farmers, providing significant cash while contributing to food security and job growth in the industry.

Table 4.30: Values of Horticultural Crops in the Lowland Areas of Amhara Region

Crop	Market	Food security	Job creation	Nutrition
Onion	1	3	2	
Tomato	1	3	2	4
Carrot	1	3	2	4
Pepper	1	3	2	4
Mango	1	2	1	1
Papaya	1	3	4	2
Banana	1	3	4	2
Orange	1	3	4	2
Avocado	1	3	4	2

Where, value 1 = very high, 2 = high, 3 = low and 4 = very low

Production and productivity of horticultural crops are constrained by biotic and abiotic factors. Disease and insect pests are the primary production constraints of horticultural crops.

Table 4.31: Major Horticultural Crops Insect Pests and Diseases in Lowland Areas of Amhara Region

Horticultural crops	Insect pests	Diseases
Onion	Leaf miner, Thrips	Purple blotch, Damping-off, Rust
Tomato	Boll worm	Early blight, Powdery mildew, Late blight, Root rot
Cabbage	Aphid	
Carrot		Powdery mildew
Banana		Cigarette end
Papaya		Anthracnose
Mango	White scale	Anthracnose, Powdery mildew
Citrus		Powdery mildew

The use of chemicals and resistant varieties is one of the control methods practiced by farmers. Humidity favors disease incidence and severity. Traditionally, farmers believe that agronomic practices during cloudy weather will aggravate the spread of diseases. Thus, farmers do not practice any agronomic practices (weeding and hoeing) during cloudy weather to minimize the spread of diseases.

Scouting

Scouting, monitoring of crop fields, is very important to assess pest incidence and prevalence and to take immediate control measures before causing economic damage. Farmers are aware of the importance of scouting. They closely watch their crop fields. It is a routine activity of farmers, and they scout their farms at least every two days.

Major post-harvest pests

Rodents, weevils, and fungi are the major post-harvest pests affecting field and horticultural crop products. Farmers use chemicals, cats (biological control), and rat traps to control post-harvest pests. Farmers also used different botanicals to treat weevils. Moreover, cleaning local storage facilities, removing diseased tubers and bulbs, and the use of chemicals are being used.

4.1.4. Strategic Interventions in Crop Production

Agricultural production in the Amhara region faces diverse challenges across its agro-ecological zones, necessitating targeted intervention strategies. These strategies must address both biotic and abiotic constraints while promoting sustainable agricultural practices tailored to highland, midland, and lowland areas. The following detailed interventions aim to enhance resilience, productivity, and overall farm efficiency.

4.1.4.1. Biotic Stress Management Strategies

Biotic stresses, including diseases, pests, and weeds, pose significant threats to crop production. To effectively mitigate these problems, farmers need a comprehensive approach that integrates resistant crop varieties, biological control measures, quarantine restrictions, and optimized pest management techniques.

In the highland areas, diseases such as wheat rust, septoria, and chocolate spot in faba bean significantly reduce productivity. A critical intervention includes developing and disseminating disease-resistant varieties, particularly those adapted to highland conditions. Crop rotation, especially alternating cereals and pulses, helps to break disease cycles and restore soil fertility. Similarly, timely fungicide applications should be promoted alongside improved farmer training programs on disease scouting and early detection.

Pest infestations are a pressing issue, especially in midland and lowland areas, where the fall armyworm, aphids, and shoot fly cause substantial damage. Biological control measures, such as introducing natural predators and parasitoids, offer eco-friendly pest suppression techniques. Additionally, expanding the use of bio-pesticides for sustainable control of insect outbreaks ensures minimal environmental impact. Integrated pest management (IPM) training enhances farmers' ability to identify and respond to threats, reducing reliance on chemical pesticides. Research-driven solutions, such as disease-resistant crop varieties, further stabilize yields while promoting ecological balance.

Weed management is equally crucial. Highland areas require a combination of manual, mechanical, and chemical weed control strategies, including the adoption of herbicide-resistant wheat and barley varieties. In midland and lowland regions, mechanical weeding should be supplemented with cover cropping and intercropping practices, particularly pairing sorghum with legumes to suppress weeds naturally. Research into alternative weed management techniques should also be prioritized to reduce reliance on synthetic herbicides.

4.1.4.2. Abiotic Stress Management Strategies

Abiotic factors such as moisture stress, soil fertility decline, salinity, waterlogging, and temperature fluctuations impede agricultural productivity across agro-ecologies. Addressing these challenges requires innovative soil and water management solutions.

In highland areas, soil acidity and waterlogging are major constraints. To counteract acidity, widespread lime application should be encouraged, coupled with regular soil testing to ensure appropriate amendment strategies. Waterlogging issues, particularly in vertisol areas, require drainage improvements, such as raised-bed planting and efficient irrigation scheduling.

For midland areas, soil fertility must be enhanced through organic amendments like compost and manure. Encouraging leguminous crop rotations (e.g., chickpea after wheat) improves soil nutrient levels and reduces dependency on synthetic fertilizers. Expanding access to precision fertilizer recommendations based on soil analysis will optimize nutrient uptake while preventing overuse or wastage.

In lowland areas, moisture stress and soil salinity present significant hurdles. Drought-resistant maize and sorghum varieties should be introduced to sustain productivity under erratic rainfall conditions. Additionally, micro-irrigation techniques such as drip irrigation can maximize water efficiency. Addressing soil salinity in Raya-Kobo and Dawachefa requires gypsum application and improved drainage infrastructure to prevent salt accumulation.

Climate adaptation measures must be integrated across all agro-ecologies. Promoting climate-resilient crop varieties and improving real-time weather forecasting services ensures farmers receive timely advisories on planting schedules and irrigation management. Encouraging agroforestry initiatives, where trees and shrubs are incorporated into cropping systems, mitigates soil erosion while improving microclimate stability.

4.1.4.3. Market, Post-Harvest, and Seed System Improvements

Beyond production challenges, inefficiencies in seed distribution, post-harvest losses, and market accessibility hinder agricultural profitability. Strengthening these components will enhance farmers' economic returns. Seed system improvements should focus on establishing community-based seed multiplication programs to ensure farmers have access to locally adapted and improved varieties. Enforcing quality assurance measures within governmental and non-governmental seed suppliers will enhance seed purity, viability, and overall performance. Additionally, expanding farmer-participatory varietal selection programs ensures that breeding objectives align with local preferences.

Addressing post-harvest losses, particularly in lowland and midland regions, requires investments in modern storage solutions, such as hermetic bags, metal silos, and improved granaries to prevent moisture damage and pest infestations. Enhanced packaging and grading systems should be developed to increase market value and improve farmers' profitability. Farmers must also receive training on proper post-harvest handling techniques, particularly for perishable horticultural crops.

Market development strategies should prioritize contract farming arrangements between producers and buyers, offering guaranteed price stability. Establishing commodity aggregation centers in lowland and midland regions will streamline market accessibility while minimizing losses. Strengthening agricultural cooperatives ensures transparent trading practices, reducing reliance on exploitative middlemen. Generally, improving resilience, sustainability, and production in the Amhara region requires developing tailored interventions across highland, midland, and lowland agro-ecologies. The region's agriculture can overcome systemic challenges while fostering long-term economic growth by implementing integrated pest and disease management strategies, improving soil fertility and water conservation, enhancing seed and post-harvest handling systems, and strengthening market linkages.

4.2. Livestock Production Constraints and Strategic Interventions

4.2.1. Major Livestock Species and Breeds

The major livestock species that are generally kept to make up the livestock resources of the study areas include cattle, sheep, goats, and equines. Other common businesses that farmers engage in to sustain their livelihoods and as sources of income include poultry production, apiculture, and fisheries (Table 4.32). The proportion of different livestock species varies according to agroecology and is influenced by factors such as vegetation type, land characteristics, and farming practices.

4.2.1.1. Cattle Population and Breeds

The cattle population exhibited a dominant presence across all agro-ecological zones of the study area, with data in Table 4.32 indicating a total of over 2.3 million heads, which accounted for more than 13% of the region's total cattle population. The major indigenous and crossbred breeds observed in the study area included Highland Zebu, Raya Azebo, Fogera, Holstein-Friesian, and Jersey crossbreeds. The proportion of crossbred cattle, which combined traits from different breeds, constituted only 3.4% of the sampled study districts, with minimal representation in the lowlands (0.2%), moderate presence in the midlands (4.25%), and the highest prevalence in the highlands (11.64%). Notably, the highland areas of North Shewa, South Wollo, North Gondar, and parts of North Wollo had a relatively higher number of crossbred dairy cattle than the other sampled areas. The limited number of crossbred dairy cattle within the study districts indicates the continued reliance on indigenous cattle for milk production, despite their relatively low productivity, which remains insufficient to meet the growing regional demand for milk.

4.2.1.2. Small Ruminant Population and Breeds

Small ruminant production is a crucial component of the livestock sector in the Amhara Region, offering significant economic and nutritional benefits to smallholder farmers, particularly within the study areas. Across most of the study sites, the goat population surpassed that of the sheep population. The total sheep population in the study areas exceeded 1,056,650 (Table 4.32), with blood level distribution detailed in Figure 4.1. Although sheep and goats are kept and herded together in comparable proportions, the number of sheep is relatively low in the highland areas. Goats, in addition to cows, serve as essential milk sources for communities in various parts of the study area, particularly in the Wag-Himra zone and lower-altitude regions. Notably, crossbreeding among goats was largely absent across all study districts, except for isolated cases documented in the South Wollo Zone, specifically in the Kalu District. Consequently, indigenous breeds accounted for over 99.9% of the goat population in the study areas. The presence of a small number of crossbred goats in this area is due to the prior introduction of pure Boer bucks by the Sirinka Agricultural Research Center.

Table 4.32: Livestock Population and Structure in the Study Districts of Amhara Region - Disaggregated by Genotype and Agroecology

District	Species														
	Cattle		Sheep		Exotic	Goat			Equine	Camel	Poultry		Beehives		
	Local	Cross	Local	Cross		Local	Cross	Exotic			Local	Exotic	Trad	Trans	Modern
Gazgibla	70497		55475			106256			21288	58	43744	19178	18787	102	3950
Debark	8081	8725	76696			1081			12419		75133	94840	2813	646	911
Wegera	158727		125953			69518			34983		255866	40670	11191	948	1487
Bassona	82,321	29,607	133,901			48,414			31884		167,476	9153	5639	171	335
Meket	82943	2808	28695	1961		46744			10301		38122	71920	12178	4624	6796
Werielu	44784	10914	86551	4842		34468			26029		60150	38883	3345	246	611
Sub total	447353	52054	507271	6803		306481			136904	58	640491	274644	53953	6737	14090
Sekota Zuria	79501		42141			98788			21847		56871	12170	12873	77	1996
Beyeda	30213	562	82936			25907			15702		124856	34182	3386	249	688
Gondar Zuria	188860	3133	69582			67606			35019		263063	49619	14940	250	289
Moretnajiru	51,922	4,950	25,713	278		30,419			21693		59,828	11,149	2,137	130	384
Gubalafto	93672	8928	76655	780		63030			19415	2717	81136	54988	4035	289	1212
Tewlederi	56848	4677	10501	235		27686			11567		44400	23947	2738	165	283
Sub total	501016	22250	307528	1293		313436			125243	2717	630154	186055	40109	1160	4852
Ziquala	57101		37809			117516			11928		20318	3000	18555		151
Adarkay	167631	698	4100			98117			17781		92669	12873	4862	166	783
West Belessa	61490	42	51407			65192			23468		99578	6675	4847	32	545
Metema	582199	17	69439			206826			28687		146881	19537	65993	118	1006
Kobo	152343	487	29195	1015		103418			19634	11755	111254	33882	1427	109	530
Kallu	93664	985	17648	113		55988	14		9716		74346	65400	4141	129	533
Dawachefa	101901	32	22736	0		49977			6044	2701	65631	28491	2158	49	415
Kewet	87,382	60	54,400	290	4	128,564	16	2	10511	1660	36,506	9,375	1179	21	469
Sub total	1303711	2321	232334	1418	4	697034	30	2	127769	16116	610677	169858	103162	624	4432
Total	2252080	76625	1047133	9514	4	1316951	30	2	389916	18891	1881322	630557	197224	8521	23374

The study areas host a diverse range of sheep and goat breeds, each adapted to specific agro-ecological conditions. The predominant sheep breeds include Menz, Wollo, Tikur, Tumelle, Afar, Sekota, Washera, Gumuz, Central Highland, Awassi, and Dorper crossbreds. Similarly, the identified goat breeds encompass Abergelle, Central Highland, Western Lowland, Bati, and Boer crossbreds. The genetic diversity of these breeds plays a crucial role in enhancing resilience, productivity, and adaptation to varying environmental conditions within the region.

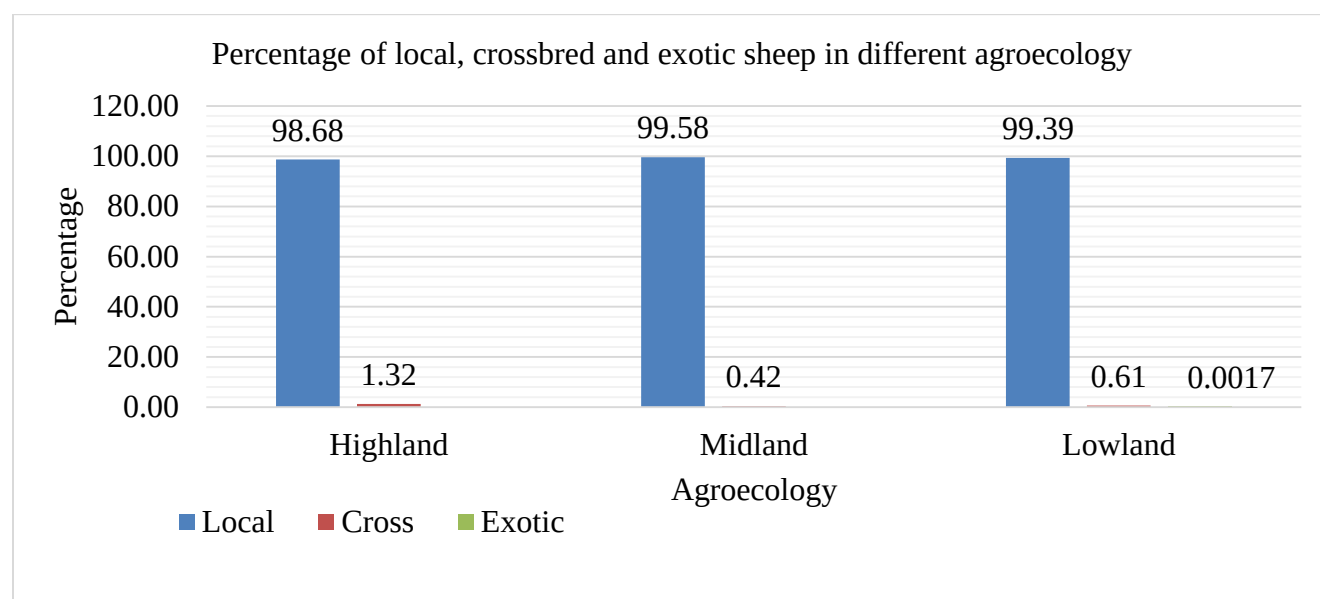


Figure 4.1: The Proportion of Different Blood Level Sheep in Different Agroecology

4.2.1.3. Equines and Camel

Equines play a vital role in transportation and, to some extent, in plowing croplands across rugged and undulating landscapes. Secondary data from the study districts (Table 4.32) revealed distinct distribution patterns of equine populations across various agro-ecological zones. Mules and horses were more prevalent in the highlands and midlands compared to the lowlands, where their numbers were relatively lower. Conversely, donkeys were higher in lowland areas than in the highlands. Camels were predominantly found in lowland areas, with moderate presence in midland zones, while no camel populations were recorded in highland environments.

4.2.1.4. Poultry

Poultry production holds significant potential for job creation, improved household nutrition, and women's empowerment, particularly in rural communities, ultimately contributing to food security (Management Entity, 2021). The distribution and proportion of the local and exotic chicken populations in the study areas are presented in Table 4.33.

A relatively higher number of exotic and crossbred chickens (25.1%) have been reported, reflecting efforts to semi-intensify production systems. A higher number of exotic chickens were reported in highland areas than in other agro-ecologies, mainly because of the support of the sector by different non-governmental organizations through the provision of day-old chicks and concentrate feeds. The primary purpose of keeping poultry across most surveyed districts was income generation and household consumption.

The most widely distributed poultry breeds include non-descript local chickens, Sasso, Koekoek, and Bovans Brown. Although exotic breeds have demonstrated notable productivity improvements, their higher feed requirements have posed challenges for smallholder farmers. The construction of poultry houses, which are built from stone piles and wooden materials, with mud plastering as a finishing layer to enhance durability and protection, is a common practice in most districts.

Table 4.33: Poultry Population by Agroecology and Genotype

Agroecology	Number of chickens		Percentage	
	Local	Exotic	Local	Exotic
Highland	640491	274644	69.99	30.01
Midland	630154	186055	77.20	22.80
Lowland	610677	169858	78.24	21.76
Total	1881322	630557		

4.2.1.5. Bee Keeping

Beekeeping is widely practiced across all surveyed districts, with highland areas exhibiting the largest bee colony populations. Most producers kept beehives in backyard settings, with approximately 86% of colonies managed in traditional hives.

Secondary data from the zonal Office of Livestock and Fisheries sector development (2023/24) indicates that only 3.7% of colonies were maintained in transitional hives, while modern hive-based beekeeping accounted for 10.2% in the study areas (Table 4.32). The deep gorges and series of rugged massifs of the topography, particularly in eastern Amhara, favor diverse vegetation types to grow at the closest distance giving wider choices for bees to forage on. Various honey-producing plant species bloom at different times throughout the year, with the majority flowering during the wet season. Cultivated crops, weeds, shrubs, and trees serve as critical forage sources, particularly during periods of high nectar availability in the rainy season.

4.2.1.6. Fish Farming

Fishery resources remain an underutilized sector in the region, particularly in the Wag-Himra Zone. Fish farming is undertaken only near natural water bodies, such as Logo Lake and Tekeze River. Despite the existence of favorable conditions, such as year-round flowing rivers and man-made dams with potential for aquaculture, fishing practices have not yet fully developed. Smallholder farmers have expressed significant interest in engaging in fish farming, provided that there is investment and support in the sector. However, several critical constraints hinder its expansion, including the lack of updated assessments of water resource diversity and potential, inadequate infrastructure, high post-harvest losses, and the prevalence of illegal fishing activities.

In general, diversified livestock holding is the prime strategy in all areas that farmers traditionally practice to minimize the risk of vulnerability in other agricultural activities. In eastern Amhara, maintaining multiple livestock species provides a critical safeguard against recurring crop failures. In addition, farmers in dryland regions intentionally avoid raising large-frame cattle to minimize energy demand and ensure livestock resilience under challenging environmental conditions.

4.2.2. Production Performances of Major Livestock Species

Efficient productive and reproductive performances are essential for the success of livestock production programs. However, in the surveyed districts, the productivity of all species has been reported as suboptimal, mainly due to prolonged ecological changes that appeared to have negatively impacted livestock productivity. This phenomenon resulted in reduced body weight at market age, decreased milk yield, shorter lactation periods, lower honey harvests, and diminished egg production per hen per year. Milk production performance was notably higher in mid- and high-altitude areas than in the lowlands because of the relative abundance of feed sources. Conversely, honey and egg production performance was higher in the lowland areas, likely influenced by ecological conditions favorable for bee forage and poultry management.

The productive and reproductive performance of cattle in the case-studied areas of North Wollo, South Wollo, Wag-Himra, and the Oromo Special Zones is shown in Table 4.34. The predominant mating system remains uncontrolled; however, in urban and peri-urban areas, farmers use artificial insemination (AI), with or without synchronization. Hormone usage for estrus synchronization is limited, particularly in the midland and highland areas of Wollo, due to shortages and inefficiencies, as injected animals often fail to exhibit heat signs.

The low effectiveness of estrus synchronization and AI is due to technological incompatibility, feed and input shortages, sustainability concerns, and inadequate technical expertise in some districts. According to the focus group discussion (FGD), key reproductive and productive metrics for indigenous cattle were identified as follows: mean age at first calving (47.61 months), calving interval (20.93 months), daily milk yield (2.89 liters), lactation length (9.44 months), calf weaning age (9.93 months), and total number of calves produced in a lifetime (8.13). Additionally, lactation duration and average daily milk yield of indigenous cows were estimated at 7 months and 1.48 liters, respectively (CSA, 2021).

In contrast, crossbred cattle exhibited improved performance, with mean age at first calving (31.30 months), calving interval (16.00 months), daily milk yield (6.9 liters), lactation duration (11.1 months), calf weaning age (5.9 months), and total number of calves produced in a lifetime (7.3). The survey identified significant variations in reproductive and productive parameters between Indigenous and crossbred cattle, with the Wag-Himra zone recording the lowest productivity and prolonged reproductive cycles due to harsh environmental conditions and insufficient feed availability.

Table 4.34: Mean Age at First Calving, Calving Interval, Milk Yield, Lactation Length, Weaning Age, and Number of Calves

Traits	AFC (Month)	CI (Month)	DMY (liter's)	Lactation length (month)	CWA (month)	Number of calves produced/life span
Overall	47.61	20.93	2.89	9.44	9.93	8.13
Agroecology						
Highland	43	18.32	3.5	9.32	9.63	9.29
Midland	48.65	21.93	2.82	10.12	8.72	7.56
Lowland	51.17	22.56	2.36	8.89	11.45	7.56
Breed						
Indigenous	43.93	16.21	2.82	7.71	8.71	9.79
Crossbred	31.3	16.00	6.9	11.1	5.9	7.30
Minimum	38	15.11	1	8.13	7.25	6
Maximum	62	30	5.75	10.71	15	10.2
Stdev	3.42	1.87	0.47	0.51	1.14	0.82

The sheep mating system in the study areas was predominantly uncontrolled, though a few farmers implemented controlled mating by selecting specific rams for mating. Findings from the focus group discussion (FGD) revealed key reproductive performance indicators: the average age at first lambing (14.00 ± 1.08 months), lambing interval (8.92 ± 0.52 months), marketing age of male sheep (6.55 ± 1.21 months), and marketing age of female sheep (7.29 ± 0.83 months) (Table 4.35).

In lowland areas, the age at first lambing was notably shorter than in the midland and highland areas of Wollo and Oromia Special Zones, whereas the reverse was true for the Wag-Himra Zone. According to Teranmj A. (2020), the estimated age at first lambing for highland and midland local sheep breeds was 13.08 ± 0.21 months and 12.86 ± 0.09 months, respectively.

The current FGD survey findings closely align with the lambing interval reported by Taramaj A. (2020), which was 8.5 ± 0.16 months for highland breeds and 8.43 ± 0.09 months for midland breeds. FGD responses also revealed that single births predominated throughout all agro-ecological areas, with 87% of ewes gave birth to single lambs in Wollo regions, and singletons were even more common (96%) in the Wag-Himra Zone.

Table 4.35: Age at First Lambing, Lambing Interval, and Market Age for Male and Female Sheep

Traits	AFL (months)	LI (months)	MAM (months)	MAF (months)
Overall	14	8.92	6.55	7.29
Highland	13	8.5	6.75	7.5
Midland	13.5	8.75	5.25	6.38
Lowland	15.5	9.5	7.65	8
Minimum	10	8	4.3	5
Maximum	21	12	11	11
Stdev	1.08	0.52	1.21	0.83

In all surveyed areas, goats predominantly follow an uncontrolled mating system, except for very few attempts at controlled mating, where community-based breeding programs are in practice. Farmers across most survey areas expressed minimal concern regarding the mating of their female animals in grazing and browsing areas alongside bucks. The average age at first kidding and kidding intervals were recorded as 13.8 ± 3.33 months and 8.7 ± 0.72 months, respectively (Table 4.36). Additionally, the mean market age for male and female goats was estimated at 7.63 ± 1.02 months and 8.08 ± 0.96 months, respectively.

Significant variation in the age at first kidding was observed across the study areas, with longer intervals reported in the lowlands of the Wag-Himra Zone. In contrast, shorter values were reported in the lowlands of Wollo. The findings align with the study by Mezgebu, G., et al. (2022), which reported an average age at first kidding of 13.02 ± 2.18 months for eastern Gojam goats. However, the kidding interval identified in this study exceeded the values reported for eastern Gojam goats by Mezgebu, G., et al. (2022).

Table 4.36: The Age at First Kidding, Kidding Interval, Market Age for Male Female Goats

Traits	AFK (months)	KI (months)	MAM (months)	MAF (months)
Overall	13.83	8.7	7.63	8.08
Highland	11	8.3	6.5	7
Midland	13	8.3	8.5	8.5
Lowland	17.5	9.5	7.9	8.8
Minimum	10.5	7	4.8	5.5
Maximum	24	12	11	12
Stdev	3.33	0.72	1.02	0.96

AFK = age at first kidding; KI = kidding interval; MAM = male average market age; MAF = Female average market age

The average number of eggs laid per year by exotic chickens was 211.33 ± 12.77 , ranging from the lower values of 155.33 ± 9.866 in Wag-Himra areas to 268.29 ± 26.03 in Wollo areas (Table 4.37). The average age of the first lay was 5.75 ± 0.59 months. The number of eggs laid per year was almost similar in all agro-ecological zones of the study areas. In contrast, the average age at first lay was highly variable at different agro-ecologies for exotic chickens. The average number of eggs produced per clutch was 13.79 ± 0.89 , and the average number of clutches per year was 3.01 ± 0.23 times for local chickens. The average number of eggs hatched per year was 24.63 ± 4.66 eggs. The FGD results revealed that the average age at first laying for indigenous chicken was 5.44 ± 0.22 months.

Table 4.37: Reproductive and Egg Production Performances of Chickens by Genotype and Agroecology

Traits	Exotic		Local			
	NEY	AAFL	NEPPC	NCPY	AAFL	EHPY
Overall	211.33	5.75	13.79	3.01	5.44	24.63
Highland	224.5	5.88	14.57	2.75	5.5	23.2
Midland	199	5.63	12.82	3.13	5.2	29.84
Lowland	210.5	5.75	14	3.17	5.63	20.85
Minimum	150	4.75	12.13	2	5	15.53
Maximum	289	6.51	16	3.5	6	34
Stdev	12.77	0.59	0.89	0.23	0.22	4.66

NEY = Number of eggs laid per year, AAFL = Average age at first laying, NEPPC = Number of eggs produced per clutch, AAFL = Average age at first laying for local, and EHPY = Egg hatched per year

Honey and wax production in the study areas primarily relies on traditional hives. In the Wag-Himra zone, wax production has ceased across all surveyed districts due to the prevailing practice of selling honey with its foundation sheet and the overall decline in honey yield. The average honey harvest per hive was recorded at 8.28 ± 4.82 kg for traditional hives, 13.77 ± 7.8 kg for transitional hives, and 21.28 ± 7.15 kg for modern hives, as shown in Table 4.38 from the eastern Amhara region (Wollo areas and Wag-Himra zone). Honey productivity was significantly higher in the lowlands compared to the midlands and highlands, though honey production using transitional hives remains uncommon in lowland areas.

Most honey harvesting occurs once a year, with occasional double harvesting in certain highland and midland areas of Wollo. Overall, honey and wax production has been declining due to multiple factors, including drought, reduced availability of bee forage, chemical use, pest infestations, bird interference, inadequate inputs, limited sector engagement, and widespread colony collapse, commonly referred to as "Mich."

However, some experts have presented contrasting perspectives, arguing that honey production has increased in response to interventions by non-governmental organizations. These efforts have introduced input provisions such as bee forage and training programs targeting both organized youth groups and individual beekeepers. Given these contradicting results, further research is needed to determine the exact trend of honey production in the region.

Table 4.38: Honey Productivity by Agroecology and Hive Type (Case Study from Wag-Himra Zone)

Agroecology	Honey production(kg/harvest)		
	Traditional	Transitional	Modern
Overall	8.28	13.77	21.28
Highland	5.73	12.75	18.4
Midland	5.28	9.5	16.01
Lowland	13.84	24.33	29.42
Minimum	4.5	8	14.5
Maximum	15.75	24.33	36.33
Stdev	4.82	7.8	7.15

4.2.3. Livestock Production System

The livestock production system in the study areas is predominantly extensive, relying on indigenous breeds and low-input, low-output husbandry techniques. The extensive production system is the primary factor limiting reproductive performance and productivity across all livestock species.

According to focus group discussions (FGD), semi-intensive cattle production is the predominant method used in highland, midland, urban, and peri-urban areas. In contrast, lowland areas primarily practice extensive cattle production systems except for some fattening farms in the lowland areas of Western Gondar and peri-urban dairy farms, where semi-intensive and intensive systems are employed.

Sheep and goat production remains predominantly extensive, except for a few farmers in urban and peri-urban areas who use semi-intensive fattening systems. FGD findings also indicate that exotic chicken production primarily follows a semi-intensive method, with some instances of intensive production systems near cities. Native chickens, however, are predominantly raised in backyard or scavenging systems. The primary production system for each livestock species across different agro-ecologies is presented in Table 4.39.

Table 4.39: Major Production System of Different Species of Livestock in Different Agroecology

Agroecology	Cattle	Sheep	Goat	Chicken
Highland	EX+I +SI	EX	EX	SC+ SI + I
Midland	SI	EX	EX	SC+BY+SI
Lowland	SI	EX + SI	EX	SC+BY+SI+I

EX = Extensive, SI = Semi-intensive, I = Intensive, SC = Scavenging, and BY = Backyard

4.2.3.1. Livestock Feed and Water Resources and Management

The primary feed resources available across all surveyed districts include natural pasture, shrubs, crop residues, hay, crop aftermath, weeds, browse trees, improved forage, industrial by-products, and local brewery by-products. However, their importance varies depending on agroecology and seasonality. Additionally, some farmers in the midland areas of Wollo utilize sugarcane shoots and improved forage grown near homesteads and along irrigated farmland borders. Natural pasture/shrubs, followed by crop residues, were identified as the most widely used livestock feed sources year-round in all districts. Grazing lands have been shrinking, and their productivity is steadily declining due to cropland expansion, urbanization, and overgrazing. However, in the lowland areas of West Gondar, grazing land conditions are good. Even if the feed quality is poor, animals can obtain feed from natural pastures during the dry season.

In the Wollo areas, focus group discussions (FGD) revealed that cattle in highland and midland regions predominantly graze on open pastures from January to June, following the crop harvest. From July to November, farmers adopt a controlled feeding system, keeping their animals near their homesteads or on their farms and providing feed through a cut-and-carry method using weeds and green grass.

A few farmers also utilize private grazing pastures with tethered animals. Free grazing remains the dominant feeding practice in the region. Farmers who engaged in lamb and cattle fattening supplement their animals' diet with "Atela," a traditional beer by-product, and concentrate feed. In contrast, lowland areas rely primarily on free grazing, with controlled feeding and cut-and-carry practices implemented from July to October to prevent livestock from consuming standing crops. During the cropping season, the primary feed sources include green sorghum, maize stalks, and weeds.

In Gondar, farmers provide crop residues as feed for all livestock species, with particular emphasis on oxen. Hay, industrial by-products, and grains, such as sorghum, maize, and beans, are used as supplementary feed during the dry season, primarily for milking cows and weaker animals. Crossbred cows and fattened cattle are also supplemented with hay, commercial feeds, and grains to enhance their productivity. Hay-making is a common practice in highland and midland areas, while its adoption remains minimal in lowland areas. The utilization of improved forage is generally low across all surveyed areas, with only a few farmers in highland and mid-altitude areas incorporating it as a supplementary feed. Additionally, the leaves of various trees and shrubs serve as valuable green feed during the dry season.

In the North Shewa areas, the major feed resources remain largely consistent across dry and wet seasons, with some variations observed in specific woredas, such as Siyadebirna Wayo and Moretina Jiru, where crop weeds serve as a feed source during the wet season. The feeding system primarily involves grazing on natural pasture, supplemented with minor amounts of roughage and brewery residues. In some cases, livestock receive a more structured diet with adequate roughage supplemented by wheat bran, noug cake, cotton seeds, brewery residues, and improved grasses and legumes. Additionally, hay production is a well-established practice in the low and mid-altitude areas of Antsokiagemza wereda, contributing to feed availability during periods of scarcity.

The use of private grazing land as a forage source is nearly absent across all districts, except for cropping land borders. Improved forage species, such as napier grass, cowpea, oat, vetch, sesbania, pigeon pea, and latus (a bee forage in highlands), have been widely introduced, although their adoption varies due to agro-ecological adaptation.

Despite their availability, the adoption and utilization of improved forages remain limited, as farmers rarely purchase or cultivate forage seeds unless supported by the government or non-governmental organizations. Teff and barley straw, bean and lentil haulms, sorghum and pearl millet stover are the predominant crop residues used for animal feeding in the study districts.

Across all districts, livestock feeding systems are predominantly based on free grazing, with minimal practices of home-based feeding. During the wet season, nearly all animals depend on natural pasture and shrubs, while in the dry season, all livestock species, except equines, rely on crop residues, hay, and dried weeds collected and stored from croplands.

In the study area, the feeding management of indigenous chickens primarily relies on scavenging, supplemented with household leftovers. In contrast, exotic chickens receive better care, with their diets supplemented by grains and concentrates. The use of improved forage and industrial byproducts as feed sources remains limited across all districts. To mitigate prolonged feed shortages during critical dry periods, farmers employ coping strategies such as purchasing additional crop residues, selling lower-quality animals, and conserving feed for later use.

Communal grazing lands and shrub-lands are freely accessible, allowing unrestricted grazing for all livestock species. However, this practice contributes to natural resource degradation and declining grazing land productivity. As a result of poor resource management and environmental degradation, the Wag-Himra zone experiences an approximately six-month feed gap, with the highest severity observed in lowland areas, according to the zone's livestock and fisheries sector development office.

The primary water sources for livestock across all surveyed districts include rivers, ponds, boreholes, streams, and water wells, with tap water also utilized in some areas. Water scarcity was not reported as a severe issue in Wollo, North Shewa, and some highland parts of Gondar, except for distance issues. However, in the Wag-Himra zone, particularly in mid- and lowland districts, water shortages were identified as a primary problem during the dry season. During the wet season, all livestock species receive water at least once daily. In contrast, during the dry season, animals, especially in the lowland parts of the Ziquala district, are often limited to watering once every two days. During the dry season, animals are forced to travel for more than five hours to access water.

4.2.3.2. Livestock Diseases and its Management

Livestock diseases pose a significant challenge to production and productivity across all studied areas. Outbreaks of infectious diseases, such as anthrax, blackleg, pasteurellosis, foot-and-mouth disease, sheep and goat pox, and mastitis, are prevalent threats in surveyed districts, as detailed in Table 4.40. Both ecto- and endo-parasites are recognized as major concerns affecting all livestock species, while skin diseases caused by mange mites and lice remain widespread health issues.

Mortality and morbidity have been reported across nearly all agro-ecological zones over the past five years, according to focus group discussions (FGD) and key informant reports. Small ruminants, young calves, and equines are identified as the most vulnerable species. Despite the implementation of scheduled vaccination campaigns, conducted once or twice annually by animal health experts, respondents across all districts expressed strong dissatisfaction with veterinary services, citing a critical shortage of essential drugs for treatment. Animal health challenges in the study areas are exacerbated by several predisposing factors, including drought, severe feed shortages, and the long distances livestock must travel across rugged, hilly, and stony terrain in search of feed. These conditions weaken the animals' immune systems, making them more susceptible to disease. Additionally, seasonal movement, whether for feed, water, or trade, further contributes to health risks, increasing exposure to environmental stressors and potential disease transmission.

The animal health sector faces several significant challenges, including drug shortages, difficulties in maintaining the cold chain, limited availability of combined vaccines, disease resistance to treatments, and gaps in the identification of livestock diseases. Despite these challenges, farmers continue to rely on traditional methods to treat sick animals, employing ethno veterinary practices and performing minor local surgeries, such as making incisions on the hip, shoulder, thigh, or neck, to address blackleg (locally known as "Kofa" or "Dirra"). In the Gondar area, farmers frequently use traditional medicine to treat diseased animals. Lemon juice and *Endod* are commonly mentioned as remedies for poultry diseases, while the juice of *Endod* and *Zegita* leaves is traditionally used to combat parasites in cattle and small ruminants. Similarly, in Wollo, farmers utilize both conventional treatments, such as soaking wounds in warm water with dissolved salt, and local veterinary services to manage livestock health.

Annual vaccinations are administered to protect livestock against diseases such as African horse sickness (AHS), foot-and-mouth disease (FMD), blackleg, and anthrax. Pasteurellosis vaccines are given twice a year, once before and once after the rainy season. Additionally, vaccines for lumpy skin disease (LSD) and sheep and goat pox are administered every two years, while Peste des Petits Ruminants (PPR) vaccination occurs in June, July, and August once every three years. Newcastle disease vaccination follows a structured schedule: the Lasota vaccine is administered at 21 and 42 days of age with a three-month gap, the Gumboro vaccine is provided at 14 and 28 days of age, and the Newcastle HB1 vaccine is given between 3 and 7 days of age. Each agro-ecological zone has a deworming and spraying schedule, typically planned before and after the rainy season. Despite established vaccination campaigns, many animals do not receive timely immunizations, and some remain entirely unvaccinated. For example, in the Wollo areas, outbreaks of LSD and foot-and-mouth disease occurred in 2022/2023 GC in specific highland locations (Mekete District), attributed to immunization gaps in 2021 GC caused by conflict. According to focus group discussions (FGD), certain kebele in the study areas continue to lack sufficient animal health experts at their veterinary centers, further exacerbating disease risks.

Table 4.40: Major Diseases and Parasites of Surveyed Districts

Agroecology	Cattle		Sheep and goats		Poultry	
	Disease	Parasites	Disease	Parasites	Disease	Parasites
Highland	Anthrax, Blackleg, FMD, LSD, Trypanosomiasis, Pasteurellosis, Mastitis, Fasciolosis, Cardioids	Leech, Ticks, Liver fluke, Nematodes	Anthrax, pox, Pasteurellosis, Foot rot, PPR	Mange mites, ticks, Lungworms, Liver fluke, GIP	Newcastle, Fowl pox, Salmonellosis, Fowl typhoid, Gumboro, Coccidiosis, Colibacillosis	Lice
Midland	Blackleg, Anthrax, FMD, LSD, Pasteurellosis, Mastitis, Brucellosis, CBPP	Tick, Mange, Leech, internal parasites, Demodex	Anthrax, pox, Pasteurellosis, PPR, CCPP	Mange, Tick, internal parasite	Newcastle, Coccidiosis, Gumboro, Marks	Lice
Lowland	Anthrax, Blackleg, Pasteurellosis, FMD, Brucellosis	Tick, Nematode	Anthrax, pox, Pasteurellosis, PPR, Diarrhea, Cenorosis	Mange, Nematode	Newcastle, Pox, Salmonellosis	Lice, mange

4.2.4. Animal Products Processing

This survey study confirmed that farmers across all districts rely entirely on traditional methods for processing and preserving milk and meat. They produce yogurt and cheese primarily for home consumption, while butter is made for both household use and sale using conventional techniques. Butter production begins with washing the milking and storage materials using *mentesie*, *damakesie*, dried grass, and *chifrig*, followed by smoking with wood from trees such as olive *abalo* and *misrcho*. The milk is then added to the container. Depending on the number of cows, this process takes approximately two days for morning and evening milk and can be left for two to seven days, depending on agro-ecological conditions, to produce yogurt.

The fermentation period tends to be shorter in lowland areas. Subsequently, the milk was converted into yogurt. Once formed, the yogurt was transferred to a churning container, which was washed and smoked before use. In highland and midland areas, farmers operated a traditional method of agitation using three joined sticks to churn the yogurt. The churning period varies from 30 minutes to 3 hours, influenced by the quantity of yogurt, the churner's strength, and the agroecology of the surrounding area. Differences in yogurt production time were observed across highland, midland, and lowland areas. Findings from the focus group discussions (FGD) indicated that factors such as milk volume, ambient temperature, and the type of container significantly affected the yogurt production process. Additionally, the selection of plant materials for smoking and cleaning differs based on agro-ecological conditions.

Meat preservation follows a widely practiced traditional technique across various agro-ecological zones. It is typically thinly sliced, coated with salt powder, and hung on a rope to dry. Once fully dehydrated, the meat is collected and stored in a clean, covered container for future use. In most agro-ecological zones, traditional honey processing methods remain prevalent. After harvesting, the honeycomb is typically cut from the hive and processed by combining honey with the comb without separation. This approach preserves natural flavors but limits refinement compared to modern extraction techniques.

The closure of the central market for hides and skins has forced producers to dispose of them around their homesteads, contributing to environmental pollution. While hides are, to some extent, repurposed for local carpentry and harnessing materials in farming activities, their broader utilization remains limited. Findings from the focus group discussions (FGD) in the Wollo area indicated that lowland farmers currently do not sell cattle, sheep, or goat hides or skin, although the reason for this remains unclear.

In contrast, highland farmers sell hides and skin at varying prices, ranging from 100 to 1,000 birr per cattle hide, 30 to 50 birr per sheep skin, and 20 to 30 birr per goat skin. According to FGD insights, the local market mainly demands cattle hides for saddles and mule decorations.

Overall, there is a lack of modern agro-processing technologies, with significant gaps in market linkage, transportation, and information accessibility. Additionally, there is a considerable knowledge gap regarding technological advancements in the sector. Livestock byproducts, such as manure and poultry litter, are widely utilized as fertilizer and fuel sources across all the surveyed zones. However, farmers generally lack awareness of potential pathogens linked to the use of animal manure in cropping systems, except when disease concerns arise during compost transportation due to *Michi*.

4.2.5. Livestock Technologies Used To Improve Productivity

Various agricultural technologies, such as artificial insemination (AI), bull service, estrus synchronization, modern and transitional bee hives, fattening, improved forage production, improved genetics (day-old chickens and HF heifers), queen-rearing techniques, bee pest management, vaccination, and other technologies, have been introduced to farmers. However, their adoption remains limited due to restricted access and scale. None of these technologies were observed in the study districts, primarily due to inadequate infrastructure, which continues to hinder their implementation and utilization.

4.2.5.1. Livestock technologies and services required to support livestock production

The livestock sector requires broader adoption of existing technologies to enhance productivity and sustainability. Key areas that need future modification and transformation include modern hive dimension approaches, feed quality improvement, optimized fattening shed designs, genetic advancements for ruminants, fish farming expansion, honey bee disease identification, and improved forage seed production and distribution systems. Further advancements in feeding and watering infrastructure, expansion of bee forage cultivation, and modernization of honey extraction and processing equipment are essential for strengthening the sector. In addition, adopting more efficient food processing and preservation methods will enhance productivity and sustainability.

Key priorities for future development include cost-effective milk processing, improved vaccine cold chain management, solar refrigeration solutions, and the establishment of advanced animal nutrition and health laboratories. Innovative livestock housing designs and enhanced water supply technologies should also be integrated to support long-term sectoral growth.

4.2.6. Climate Change Impacts on Livestock Production and Its Measures

Climate change has significantly impacted the livestock sector, including crop production. Rainfall distribution and high temperatures directly and indirectly affect livestock health and production. Direct effects include reductions in animal populations and production levels, driven by increased temperatures, the frequency of extreme heat waves, and intensified climatic stress.

Indirect effects are associated with shifts in the availability and quality of feed resources and drinking water and changes in the survival and redistribution patterns of pathogens and their vectors. Additionally, climate change is closely linked to the rising global frequency of natural hazards and disasters, which directly affect agriculture, including the livestock sector, posing threats to food security and nutrition (FAO, 2021). The effects of climate change on the livestock sector are now evident, significantly impacting livestock productivity and grazing lands across all districts. Farmers in the surveyed areas unanimously identified key climate change indicators, including rising temperatures, drought, feed shortages, recurrent disease outbreaks, and declining productivity due to natural resource degradation. Similarly, farmers are knowledgeable about climate change adaptation and mitigation measures. These measures include controlling deforestation, protecting natural resources through soil and water conservation, planting multipurpose trees and animal forage, preventing the further expansion of croplands, grazing land/shrub land improvement through over-sowing of perineal forage varieties, identification and utilization of short-term and multipurpose crop and forage varieties, optimized management of livestock, and destocking and supporting these measures through continuous and inclusive training.

4.2.7. Major Livestock Sector Constraints

The major livestock production constraints identified through focus group discussions are listed in Table 4.41, ranked by importance. The most pressing challenge across all studied areas was feed shortage, both in quantity and quality, primarily due to grazing land shrinkage and the degradation of pasture quality. Additionally, feed scarcity is exacerbated by rising costs, limited accessibility, and the absence of improved forage varieties and seeds. Livestock diseases represent the second most significant constraint, characterized by shortages in drug supply (both in quantity and variety), poor drug efficacy, inadequate veterinary clinics, and inefficient service delivery. Other key challenges of the sector include the lack of improved breeds, restricted access to essential inputs, high feed costs, increased chemical spraying (herbicides and pesticides), poor management practices, insufficient access to honeybee inputs and wax, weak market linkages, limited credit availability, and inadequate extension support.

Table 4.41: Major Livestock Constraints in Different Agro-ecologies

Highland	Midland	Lowland
Feed shortage (grazing land shrinkage, limited access and high price of concentrate feed, shortage of improved forage varieties)	Feed shortage	Feed shortage
Livestock disease (drug shortage, poor efficacy, shortage of veterinary clinics, illegal drugs, veterinarian shortage, poor service delivery)	Disease	Disease
Lack of improved breeds (sheep and goat, poultry)	Market problem	Drought
Lower productivity	Lack of credit access	Lack of improved breeds
Lack of credit access	Lack of improved breeds	Poor market linkage
Poor market linkage	Drought	Lack of credit access
Poor extension support	Lack of inputs	Lack of productivity
Lack of inputs	Chemical spray	Poor extension support
Chemical spray (honey bee)	Skill gap	Skill gap

4.2.7.1. Feed shortage and related constraints

Livestock serves as a cornerstone of farmers' livelihoods in certain lowland areas, sometimes surpassing crop production in significance. Even in the fertile highlands and midlands, livestock remains equally essential as crop cultivation. However, this sector faces growing challenges due to persistent feed shortages, primarily caused by the depletion of previously abundant vegetation. A focus group discussion identified several contributing factors to this scarcity, including population growth, urbanization, cropland expansion, recurring droughts, and the shrinking availability of grazing and hay-producing land.

The scarcity and high cost of animal feed, mainly concentrate feed, are exacerbated by the absence of adequate suppliers and processing facilities in the region. Additionally, the limited availability of improved forage varieties and insufficient forage seed supply restrict farmers' access to quality feed resources. The small number of forage seed multiplication groups further compounds this challenge, making it difficult to secure adequate forage seeds. Moreover, the primary feed sources, such as crop residues, natural pastures, and industrial by-products, offer insufficient crude protein levels, failing to meet the nutritional needs of livestock. Meanwhile, grazing lands continue to shrink due to urban expansion and cropland encroachment, further reducing pasture availability. Again, repeated droughts, as highlighted in the focus group discussion, continue to diminish feed availability.

Even in favorable seasons, farmers face difficulties in securing enough forage. The high price of concentrate feed makes it unaffordable for many farmers, and the adoption rate for improved forage production remains low. Additionally, insufficient infrastructure, such as feeding shades and troughs, and limited expertise in formulating locally available feed ingredients, combined with a lack of technology for crop residue enhancement, further hinder livestock nutrition. Farmers also face challenges in forage conservation and processing techniques. Overall, poor-quality commercial feed and the absence of a structured forage seed system further compound these challenges, making sustainable livestock nutrition increasingly challenging.

4.2.7.2. Animal disease-related constraints

Despite advancements in government animal health services supported by technology, livestock production systems face significant constraints owing to persistent health challenges. Although the risk of some contagious diseases has been reduced, infectious diseases and internal and external parasites still contribute to high mortality and morbidity rates among animals. This survey identified several major health concerns, including an inadequate supply of animal drugs, with vaccines being more accessible than treatments. Scheduled vaccination programs remain insufficient, and experts' knowledge gaps in identifying and understanding important diseases, such as those affecting bees, complicate the service delivery. Furthermore, the lack of a reliable cold chain system and limited infrastructure for vaccine storage, including solar refrigeration, significantly hampers effective disease prevention.

Moreover, drug resistance has emerged as a challenge in reducing the treatment efficacy. Service delivery is inadequate, and many areas lack veterinary clinics, leaving farmers without essential healthcare support for their livestock. A key issue is the farmers' limited awareness of cost-effective disease prevention; many hesitate to vaccinate their animals for less than one birr per head, only to incur treatment costs exceeding 500 birrs per head when diseases spread. Addressing these challenges is essential to improving livestock health and ensuring sustainable production systems.

4.2.7.3. Lower productivity-related constraints

Over 90 percent of the livestock in the study areas are indigenous breeds. While the productivity of local animals is significantly lower than that of improved animals, they possess valuable traits, such as adaptability to harsh and unpredictable environments and strong disease resistance. However, livestock productivity remains constrained by the limited availability of superior animals. Lower productivity of local breeds is further compounded by drought and feed-related constraints.

Essential resources for cattle genetic improvement programs, including AI semen, synchronization hormones, trained personnel, and the percentage and breed of semen provided to the animals remain in short supply. Poultry production also faces challenges, as 45-day-old chickens are scarce and expensive, with Bovan Brown egg-laying chickens similarly in limited supply. In the highlands, farmers express interest in acquiring Awassi and Washera rams, as well as quality goat and sheep breeds, yet availability remains low. Farmers in the highland areas are also keen to keep "Sinar" donkeys, but there is a lack of support to facilitate their access.

Attempts to improve dairy cattle productivity through crossbreeding have been reported, particularly in the highland and midland areas. However, these initiatives face several challenges. Limited access to artificial insemination (AI) and oestrus synchronization restrict breeding success, and the efficiency of available technology remains suboptimal. Furthermore, in certain areas, crossbred progenies display high feed consumption, making them ill-suited to prevailing feed shortages. Adding to these challenges is a skill gap among technicians, particularly in AI management and pregnancy diagnosis, which affects the successful implementation of genetic improvement strategies. Farmers also lack sufficient information regarding the most suitable breeds and genetic compositions for their specific environments, making informed breeding decisions difficult. Addressing these constraints is vital for advancing livestock productivity and ensuring a more sustainable livestock production system in the region.

4.2.7.4.Drought-related constraints

The study areas, particularly the districts of Wag-Himra, have experienced repeated droughts, significantly impacting agricultural activities, especially in the lowland areas where moisture stress conditions prevail. Drought disrupts farming operations and worsens other sector challenges. Its effects extend to livestock production by altering rainfall distribution, reducing the growth of natural vegetation, and limiting the availability of essential feed resources.

4.2.7.5.Apiculture sector constraints

Apiculture is a vital part of the livestock sector in the Wag-Himra zone, yet it faces several challenges that hinder its development. The adoption rate of modern hives remains low, limiting productivity improvements. Additionally, beekeepers struggle with inadequate access to essential equipment, such as protective clothing, specialized tools, and honey processing facilities. The shortage of forage plants and seeds further restricts honeybee nutrition and hive sustainability. Compounding these issues, bee pests and diseases continue to threaten colony health, posing a significant risk to beekeeping operations.

4.2.7.6. Fishery sector constraints

The primary constraint in the fishery sector is inadequate infrastructure, which significantly hampers production, distribution, and utilization. Poor road networks, limited storage facilities, and the scarcity of cold trucks make it difficult to transport and preserve fish, leading to post-harvest losses. Additionally, fish consumption as a homemade food remains relatively low, restricting market demand and utilization. Compounding these challenges, illegal fishing activities threaten sustainability, further straining the sector's growth and efficiency. Addressing these issues through improved infrastructure, better regulation, and enhanced consumer awareness would be essential for fostering a more resilient and productive fishery industry.

4.2.8. Strategic Interventions and Major Actors

4.2.8.1. Feed-related research interventions

Feed-related research interventions should focus on enhancing livestock nutrition and optimizing feed resources through various strategic approaches. These efforts include the introduction and evaluation of different short-term forage species and varieties, which allows farmers to identify the most suitable options for their local conditions. Determining appropriate agronomic and management practices for adapted forage species is essential for maximizing productivity and sustainability. Additionally, identifying forage species that are compatible with the cut-and-carry system and integrating them into crop production enhances the efficiency of feed utilization.

The development of a technological package for managing grazing land is essential for the sustainable use of natural pastures. Demonstrating adapted forage species and improved feeding trough designs will help farmers adopt better feeding practices. Similarly, showcasing fattening house construction designs supports more effective livestock growth and management. Evaluating, demonstrating, and promoting feed formulation methods, as well as crop residue improvement techniques, contribute to enhancing the nutritional value of locally available feed materials. Conservation and processing methods should also be assessed to improve feed availability during lean seasons. Finally, forage seed multiplication initiatives ensure a steady supply of quality forage seeds, facilitating the widespread adoption of improved feeding strategies.

4.2.8.2.Feed-related development interventions

Feed-related development interventions focus on enhancing agricultural extension services and ensuring reliable livestock feed supply across all districts. Strengthening the capacity of extension systems in feed development is crucial for equipping farmers with the knowledge and skills necessary to improve feed production, utilization, and management. Additionally, establishing an efficient livestock feed supply system in every district will help mitigate shortages, stabilize feed accessibility, and support sustainable livestock production. These interventions collectively contribute to improving animal nutrition, increasing productivity, and fostering a more resilient agricultural sector.

4.2.8.3.Animal health-related research interventions

Animal health-related research interventions focus on improving disease management, treatment efficacy, and reproductive health in livestock, including bees and fish. Epidemiological studies are needed to assess the prevalence and impact of various livestock diseases, enabling targeted prevention and control strategies. Evaluating the efficacy of different drugs and vaccines ensures that treatments remain effective against emerging disease threats. Additionally, research explores combined vaccination protocols to optimize immunization efficiency and reduce disease outbreaks. Further investigations focus on refining artificial insemination (AI) and synchronization tools, particularly for sheep and goats, to enhance breeding success and genetic improvement efforts. These interventions collectively strengthen livestock health, productivity, and sustainability in the sector.

4.2.8.4.Animal product processing research interventions

Animal product processing research interventions focus on enhancing milk post-harvest handling through the development and demonstration of advanced processing technologies, including those specifically suited for goat milk. Introducing and evaluating post-harvest materials plays a crucial role in improving milk quality, extending shelf life, and ensuring better utilization of dairy products. These efforts contribute to strengthening the dairy sector, promoting efficiency, and supporting sustainable production practices.

4.2.8.5.Animal health development interventions

Animal health development interventions aim to enhance veterinary services by addressing critical gaps in expertise, resources, and infrastructure. Strengthening the skills of veterinary technicians in disease identification and application of artificial insemination (AI) protocols is essential for improving livestock health and reproductive success.

Besides, equipping veterinary clinics with adequate materials and personnel ensures efficient service delivery and better disease management. Establishing a veterinary laboratory will further support the diagnostic capabilities, enabling timely and accurate disease detection. Infrastructure improvements, including cold chains, cold rooms, and solar refrigerators, are also necessary to maintain vaccine efficacy and ensure proper storage of medical supplies. Together, these interventions contribute to a more resilient and well-equipped animal health care system.

4.2.8.6. Apiculture sector research interventions

Research interventions in the apiculture sector should focus on improving productivity, disease management, and resource standardization to enhance beekeeping efficiency. The introduction and evaluation of productive bee forages plays a crucial role in supporting colony health and increasing honey yield. Additionally, demonstrating and promoting effective methods for controlling bee diseases and pests will help safeguard hive populations and maintain sustainability. Standardizing honey resources within the region ensures consistency in quality and market competitiveness, benefiting both beekeepers and consumers. Furthermore, evaluating the dimensions of modern hives supports optimization efforts, ensuring that hive structures are well-suited to local environmental conditions and bee behavior. These research initiatives collectively aim to strengthen apiculture practices and improve overall sector performance.

4.2.8.7. Apiculture sector development interventions

Development interventions in the apiculture sector should focus on strengthening beekeeping practices by enhancing access to honey processing and preservation methods, while also promoting the adoption of modern hives. Enhancing the capacity of beekeepers for honey processing and preservation ensures better product quality, longevity, and marketability, contributing to a more sustainable and profitable sector. Further, efforts to increase the uptake of modern hives will help improve colony management, boost honey yield, and optimize beekeeping efficiency. These interventions will play a crucial role in advancing apiculture productivity and supporting the beekeeper's livelihoods.

4.2.8.8. Productivity improvement interventions

Livestock productivity improvement interventions prioritize research aimed at enhancing small ruminant production, focusing on key areas such as growth rate, disease tolerance, reproductive efficiency, and feed conversion optimization.

Developing livestock species that are well-adapted to specific ecological niches is essential for sustainable productivity, particularly in regions where environmental conditions demand resilient breeds. Special attention is given to dairy goats, which offer promising potential for increased milk production while thriving in diverse agricultural settings. Advancing genetic selection, nutritional strategies, and breeding programs will be crucial in fostering a more efficient and productive livestock sector.

4.2.8.9. Animal product processing development interventions

Animal product processing development interventions focus on ensuring access to diverse processing technologies to enhance efficiency and quality in animal product handling. By facilitating the supply of advanced processing tools and equipment, these interventions aim to improve post-harvest management, extend product shelf life, and boost market competitiveness. Strengthening processing infrastructure supports the sustainable development of the sector while enabling producers to maximize value addition and meet consumer demand more effectively.

4.2.8.10. Fishery sector research interventions

Fishery sector research interventions focus on assessing and monitoring aquatic resources to enhance sustainable management and productivity. Identifying existing fish resources in water bodies is essential for understanding species diversity, population dynamics, and potential for fisheries development. Additionally, routine follow-up and evaluation of the physicochemical properties of water bodies help ensure optimal environmental conditions for aquatic life. Monitoring factors such as water quality, temperature, and nutrient levels supports conservation efforts and informs strategies for maintaining a healthy and productive fishery sector.

4.2.8.11. Fishery sector development interventions

Fishery sector development interventions focus on strengthening infrastructure and environmental monitoring to support sustainable fisheries. Ensuring the necessary infrastructure for landing sites, including roads, power supply, and vehicles, is essential for efficient fish transportation, processing, and market access. Additionally, establishing a water quality evaluation laboratory will enable routine monitoring of aquatic ecosystems, ensuring optimal conditions for fish health and productivity. These initiatives contribute to a more resilient and well-managed fishery sector, enhancing both economic viability and environmental sustainability.

Table 4.42: Strategic Intervention Areas and Major Actors

Constraints	Interventions	Actor(s)
Feed shortage	Variety development Agronomic management Capacity building	ARARI, HLIs, NGOs, EIAR, CGIAR centers
Livestock Disease	Optimization of protocols Improving service delivery efficiency Capacity building	ARARI, Livestock Agency, NGOs, EIAR, CGIAR centers
Drought	Variety development Capacity building	ARARI, Livestock Agency, NGOs, EIAR, CGIAR centers
Shortage of improved genetics/Lower productivity	Genetic evaluations Breed development	ARARI, Livestock Agency, HLIs, NGOs, EIAR, CGIAR centers
Grazing land Shrinkage	Policy Restrictions Maximizing improved forage production Capacity building	ARARI, NGOs, EIAR, CGIAR centers
Skill gap	Capacity building	ARARI, Livestock Agency, NGOs, EIAR, CGIAR centers
Marketing issue	Policy	ARARI, Livestock Agency, NGOs, EIAR, CGIAR centers
Lack of inputs	Capacity building	ARARI, Livestock Agency, NGOs, EIAR, CGIAR centers

4.3. Natural Resource Management Constraints and Strategic Interventions

4.3.1. Major Constraints in the Highland Agro-ecology

4.3.1.1. Land Use and Land Cover in the Highlands of Amhara Region

The findings of this survey showed that the land is mainly used for crop production, plantation & natural forest and grazing while there are still bare degraded landscapes (Table 4.43). Crop production and livestock management are key agricultural practices to the livelihoods of the local communities. However, poor management of agricultural practices with less emphasis of sustainable land management in the highlands of the Amhara Regional State has been the causes of land degradation. Change of land use from natural forest to cultivated land had been exercised for many years that resulted in devoid of natural forests and worsen land degradations including soil erosion. Most of the existing vegetation cover of the highlands is characterized by plantation forest.

The challenges of land degradation related to deforestation, soil erosion, overgrazing, and are particularly pronounced in the rugged terrain of the highlands, which is highly susceptible to erosion and degradation (Table 4.43). Land degradation, driven by factors like over cultivation, and deforestation, has been a major concern of the Amhara Regional State in general and the highlands in particular. Land degradation has led to severe ecological consequences, including the formation of gullies, loss of vegetation, loss of biodiversity, reduced soil productivity, reduced water storage and sustainable flow and increased vulnerability to natural disasters like landslides and flooding. The region's undulating topography makes vulnerable to environmental stress, further exacerbating the risks to both ecosystem stability and land productivity (Hurni 1993; Gete, 2000; Mesfin et al., 2018).

In the highlands of the Amhara Regional State, a range of soil and water conservation practices have been under taken to reverse the situation of land degradation (Table 4.43). The findings of this survey showed that area closures, physical conservation structures, and replanting have been widely adopted in an effort to reverse the degraded land.

Accordingly, soil and water conservation efforts have been successful in improving the recovery of degraded soils, increasing vegetation cover, and boosting soil health and improving soil productivity. Promoting multi-purpose tree and shrub species to rehabilitate degraded lands played key roles in strengthening the region's ecological resilience. The survey highlighted that combining rehabilitated degraded landscapes with controlled grazing has yielded positive results in many areas (Table 4.43).

Tree species such as *Eucalyptus* and *Acacia* have been used widely in the highly degraded areas of the region and showed a very good performance for most of the cases. They have significantly improved the ecological, economic and social situations of the degraded landscapes. These species have contributed to greater biodiversity and the provision of valuable services for fuel and construction purposes. However, the choice of tree species is still limited and not sufficient. There are speculations that eucalyptus depletes soil moisture, disrupt local water cycles, and inhibit the growth of other plants. These concerns echo findings from previous research in the Ethiopian highlands, where the ecological effects of *Eucalyptus* and other non-native species have been carefully examined (Mekonnen et al., 2019).

Additionally, Fekadu et al. (2021) emphasize the importance of using indigenous species for restoration efforts, as they are better suited to local environments and help maintain ecological balance and sustainability in the long run. On the contribution of eucalyptus to save Ethiopia natural forest from further depletion and its economic value to the country is tremendous that pushes its expansion in the fertile lands of the region. It is also known that it co-exist with other species as clearly seen at Etoto mountain of Ethiopia over the generations.

A. Natural and plantation forests

Natural forests in the Amhara highlands are home to a remarkable diversity of tree species, including *Juniperus procera*, *Hagenia abyssinica*, *Olea europaea*, and *Ficus sur* (Table 4.43). These forests are vital for maintaining ecological balance, regulating water cycles, and supporting the livelihoods of local communities. However, they have been facing threats from deforestation, overgrazing, and agricultural land expansion.

The survey results revealed that practices such as free grazing and illegal logging have led to a sharp decline in forest cover, intensifying soil erosion, water loss, and biodiversity loss (Table 4.43). These findings are consistent with research by Tesfaye et al. (2021), which highlights the rate of forest degradation in Ethiopia is driven by unsustainable land use practices. Similarly, Tadesse et al. (2020) reported that agricultural expansion and uncontrolled livestock grazing are the main causes of deforestation in the highlands of Ethiopia that limits the ecosystem services of forest. In response to these challenges, a range of conservation interventions have been introduced (Table 4.43). These include the establishment of firebreaks, and preparation of land use policies for forest resource management. Additionally, tree planting initiatives like *Cordia africana* and *Grevillea robusta*, have been launched to restore forest ecosystems and offer additional environmental benefits.

Despite these efforts, however, forest degradation remains a persistent issue, particularly in areas facing high population pressures and lacking effective forest management. This survey results suggested that a more integrated forest management with active participation of the local communities could help to promotes sustainable use and management of Ethiopian forests.

Plantation forests increased in the highlands of the region. The dominant tree species that characterize plantation forest are: *Eucalyptus globulus*, *Acacia*, and *Grevillea robusta*. Their high adoptability in degraded landscapes and their economic values justify for their fast expansion, more importantly the case with eucalyptus (Table 4.43). However, the survey results revealed that poor management practices, such as improper planting time and the use of low-quality seedlings undermines the overall effectiveness of plantation forest. The expansion of plantation forests has also led to tensions with local communities, as these plantations often replace natural ecosystems and restrict access to traditional land resources use. To address these issues, the study recommends improving the selection of plantation sites, enhancing forest management practices, and integrating agroforestry techniques that can balance conservation goals with the needs of local populations.

B. Agroforestry systems

In the highlands of the Amhara Regional State, the survey revealed that agroforestry practices, such as home gardens and boundary plantations, are commonly used. These systems include species like *Rhamnus prioides*, *Acacia decurrens*, and *Myrtus communis*, contribute significantly to food security and environmental sustainability (Table 4.43). Agroforestry, which blends tree species with agricultural production, is crucial in the region, offering benefits like increased biodiversity, improved soil fertility, and better water retention (Endale et al., 2019; Yirga et al., 2024). Although these advantages, several challenges prevent agroforestry from reaching its full potential in the highlands. Issues such as water scarcity, limited knowledge of agroforestry techniques, land tenure complications, and free grazing are major obstacles. The survey also highlighted concerns like frost damage, pest infestations, and species selection. (Table 4.43)

C. Best practices for sustainable land management

The survey findings highlight the complex challenges faced by the highland agroecology of Amhara Regional State, related to land degradation and rehabilitation as well as managements in natural and plantation forests. Addressing these challenges requires improved management practices and their promotion.

A combination of good practices has proven effective in enhancing the rehabilitation, productivity and maintenance of the land resources sustainability. Successful practices include restoring degraded lands through biophysical conservation, promoting and managing adaptable multipurpose tree species for plantation forests. Integrating agroforestry with crop production has also proven to be a valuable practice that improves both the productivity and rehabilitation of the land. For example, the introduction of *Rhamnus prioides* has been beneficial for reducing soil and improving the livelihoods of the community. The best practices identified in the study emphasize the importance of community involvement and selecting the right species that fits the system. Awareness campaigns and experience-sharing platforms are crucial for ensuring the long-term success of good practices. Building on successful practices, the Amhara Regional State can achieve a resilient and sustainable land for its highland agroecology.

4.3.1.2. Sustainable Soil Fertility Management in the Highlands of the Amhara Region

The highlands the Amhara Regional State are home to a diverse range of soil types, each with its own unique potential and management challenges (Table 4.44). The major soils in this parts of the region includes Vertisols, Cambisols, Regosols, Leptosols, Luvisols, and Andosols Vertisols, one of the soil types in many highland areas of the Amhara Regional State with unique potentials and challenges (Table 4.44). Vertisols are known for their richness in chemical fertility with excellent water holding capacity.

These soils are prone to forming hardpans during the dry season that makes difficult land preparations by traditional plough with oxen in the dry season while in the rainy season Vertisols become waterlogged, leading to poor drainage and stunted plant growth as well as prone to erosion (Berhanu, 1985, Tadesse and Haile, 2016). Drainage practices such as Broad Bed and Furrow (BBF) have been effective to improve crop productivity as well as soil and water conservation by minimizing the negative effects of water lodging (Muluken et al., 2021). In general, because of physical limitations and challenges the Vertisols of the region is not optimized to its attainable yield potentials. This makes them difficult to till and prone to erosion (Berhanu, 1985, Tadesse and Haile, 2016). Therefore, good practices to drain excess water and reduce soil erosion are critically important (Getachew et al., 1993, Teklu, 2005).

Cambisols, *Regosols*, *Leptosols*, and *Andosols* are mostly located in the landscapes vurnable to soil erosion except *Luvisols*. Anodosols are characterized with high soil organic carbon that characterizes excellent drainage that lead to a very productive soil under good rainy season. Cambisols are the youngest soil and very productive soil under very good rainy season as it has very good drainage.

Regosols are characterized are soils that characterized with high level of degradation and low level of fertility. It needs immediate and sustainable interventions of soil and water conservation practices to recover the soil based ecosystems of the highland areas characterized with this soil. Luvisols are located in the bottom parts of a given watershed or landscape and characterized with better soil fertilities that are transported from the above parts of the landscapes. Despite the variations of the soil types, all soils are deficient in nitrogen and phosphorus nutrients and are responsive to the applied nitrogen and phosphorus nutrients. Moreover, soil and water erosion is critically important for all the soils.

A. Soil fertility

Soil fertility is the most limiting factor of agriculture production, productivity and the livelihoods of the community in the highlands of the Amhara Regional State next to rainfall. The state of soil fertility in the highlands of the Amhara Regional State is very poor resulted from continuous cultivation for generations with no sufficient inputs to improve or maintain it and soil erosion. Cultivated lands of the highlands are generally characterized with low levels of primary nutrients (nitrogen and phosphorus), low level of pH and low levels of soil organic carbon that finally give very low agricultural productivity (Table 4.44).

Without any laboratory assistance someone can simply understand the state of soil fertility by looking the poor performance of vegetation visually in the highlands of the region. This degradation is worsened by the loss of essential nutrients, especially nitrogen, phosphorus, and potassium. Soil acidity, a major concern in many highland areas, exacerbates the problem by reducing nutrient availability and hindering crop growth (Getachew et al., 2019). Furthermore, the region's steep terrain accelerates erosion, further damaging the soil and complicating efforts to maintain agricultural productivity (Amanuel and Worku, 2024). Introduced soil and water conservation practices are still not sufficient to restore and maintain soil fertility. Several challenges hinder the management of soil fertility in the highlands (Table 4.44). For smallholder farmers, a major issue is the limited availability of both inorganic and organic fertilizers, often made worse by high costs, distribution problems, and inefficient delivery system.

The quantity of organic fertilizers needed is very high compared to the synthetic inorganic fertilizers that challenges the farmers to depend on imported in organic fertilizers. But still organic fertilizers are critically important to improve the productivity of applied inorganic fertilizers. Infrastructure and transportation challenges also make it difficult to deliver bulk organic inputs and lime to remote areas, worsening the soil fertility situation (Table 4.44).

Addressing these issues will require a coordinated effort to improve fertilizer access, strengthen infrastructure, and adopt more localized soil management practices based on soil testing. Research indicates that having detailed information about the specific properties of soil can greatly assist farmers in making more informed decisions about fertilizing their crops. This helps efficient use of fertilizer resources that ultimately, results in higher crop yields and greater profits for farmers with sustainable soil fertility (Ozaki et al., 2024). In a nutshell, inorganic fertilizer remains the top priority and fortunately all soils of the highlands of the region are responsive first to nitrogen and then phosphorus.

Soil acidity is an issue in the highlands of the Amhara Regional State that strongly limit the productivity of crops and feeds (Table 4.44). Low soil pH levels hinder nutrient availability, and increase the solubility and availability of Aluminum affecting plant growth and reducing yields. Specifically, acidic soils limit the availability of calcium, magnesium, and phosphorus, (Barrow et al., 2023). The area coverage and extent of soil acidity has been increasing in high rainfall regions of the highlands of the region. As a result, the diversity and productivity of crops have been declined, leading to food and nutritional challenges of the highlanders. Survey results indicated that farmers apply lime at rates of 4 to 4.8 tons per hectare, typically two months before sowing (Table 4.44).

Lime application is widely recognized as an effective method for neutralizing acidic soils and improving nutrient uptake (Enesi et al., 2023). However, access to lime is often hindered by transportation difficulties, delayed supplies, and high costs, which prevent smallholder farmers from using it at the ideal time (Table 4.44).

In addition to lime, farmers in the highlands of Amhara Region use organic fertilizers and adoptable crop species. Further, area closures, which allow land to rest and recover, have also shown reducing soil acidity. Despite these efforts, the study highlights that soil acidity has been increasing over time for both area coverage as well as its extent and will be continued as one of the challenges agricultural productivity in the highlands of Amhara unless immediate and sustainable measures are in place.

B. Soil management practices for fertility restoration

Farmers in the Amhara highlands employ a wide range of soil management strategies to restore and maintain soil fertility (Table 4.44). These strategies include physical, biological and chemical interventions. Physical measures, such as building terraces and erosion control structures, are commonly used to reduce soil loss and better manage water resources (Table 4.44).

Research report showed that terraces can help farmers adapt to modern climate challenges, improving the effectiveness of soil and water management practices in Ethiopia (Frédéric, 2018). Fertilization, including both organic and inorganic options, is another key component of soil fertility management (Table 4.44). Fertilizer application practices in the highlands can vary widely depending on the type of crop, the condition of the soil, and local customs (Table 4.44). Unfortunately, inconsistent use of fertilizers, poor timing, and incorrect application methods and rates often limit crop yields. Farmers face several challenges, such as high fertilizer costs, limited access, and unreliable delivery schedules. Many also struggle with understanding how to adjust fertilizer application based on the specific needs of their soil, which reduces the overall effectiveness of their efforts. These challenges align with the findings of Tesfaye et al. (2020), who emphasize the need for fertilizer recommendations based on soil testing and improved distribution systems.

Organic fertilizers play a vital role in improving the state of fertility in the highlands of Amhara Region; especially in areas where chemical fertilizers are either inaccessible or too expensive (Table 4.44). Organic fertilizer such as compost, farmyard manure, and, green manure, bio-fertilizers, help to enhance soil structure, improve water and nutrient retention, supplies nutrients and stimulate microbial activity. However, the survey results revealed several challenges related to their use, including low quality and bulkiness, which hinder their effectiveness (Table 4.44). For example, bio-fertilizers, which are particularly beneficial for pulse crops like faba beans, face obstacles such as limited availability, lack of farmer awareness, and difficulty applying them at the correct growth stages. Additionally, poor storage and handling practices reduce the effectiveness of these organic inputs.

Previous studies have highlighted that, while progress has been made in managing organic inputs to address biophysical challenges, the socio-economic factors have not received as much attention. To make real progress, it's important to consider both the technical aspects and the socio economic factors, as both plays a key role in the success of effective use of organic fertilizers in East Africa, including Ethiopia (Peter, 2011).

4.3.1.3. Soil erosion and conservation measures in the highlands of Amhara

A. Soil erosion and its causes

The survey results on soil erosion and conservation measures across the highland, midland, and lowland agro-ecologies of the Amhara Region are presented in Table 4.45. Soil erosion is a major environmental challenge in the highland areas of Amhara, driven by factors such as overgrazing, deforestation, and the region's steep slopes (Table 4.45).

These issues have led to significant land degradation, loss of soil fertility, and decreased agricultural productivity, which directly impact food security and the economic well-being of farming households, especially in the highland areas. Research report has shown that soil erosion not only depletes soil fertility but also increased the region's vulnerability to natural disasters like floods and droughts. These events are experienced frequently and intensively due to climate change and poor sustainable land management practices. As a result, farming communities are increasingly suffered and under extreme cases communities are displaced, lose self-sufficient, and depend on external support (Addis et al., 2016; Alemayehu et al., 2020; Kebede and Hurni, 2020). To restore and maintain agricultural productivity sustainably in the highlands of the Amhara Region, it is essential to implement effective soil and water conservation practices.

B. Soil and water conservation practices

In the highland agroecology of the Amhara Region, soil erosion poses a significant challenge, largely driven by overgrazing, deforestation, and the region's steep slopes (Table 4.45). To combat this, various soil and water conservation techniques have been introduced, including terraces, contour bunds, and mulching. These measures help maintain and improve soil fertility, conserve moisture, reduce erosion, and lower the risk of landslides, ultimately boosting agricultural productivity (Table 4.45). Studies have shown that methods like terracing and bunding are effective in reducing soil erosion and enhancing water retention. In particular, these techniques have led to noticeable improvements in agricultural output in the Ethiopian highlands (Amsalu and de Graaff, 2007).

Despite these benefits, significant barriers remain in implementing soil conservation practices in the highlands of the Amhara Region. Low adoption rates and insufficient financial support are major challenges (Table 4.45). Success in applying these practices depends on support, access to information, and incentives for participation (Addis et al., 2016). Additionally, Mulugeta and Zerihun (2020) highlighted that the high labor and input costs associated with these conservation efforts often discourage farmers from engaging in such practices. The rate of restoration takes longer times in some cases with the loss of cultivable lands that are taken by bunds and difficulties of cultivation by oxen as the size of the terraces reduced are also additional challenges for fast promotion of the soil conservation practices.

C. Climate change, soil erosion, and long term sustainability

Climate change has worsened the problem of soil erosion in the highlands of Amhara (Table 4.45). Local farmers have shared that changes in rainfall patterns and rising temperatures are making soil erosion worse. Research by Alemayehu et al. (2020) and Amsalu et al. (2010) points out that human activities like over cultivation, deforestation, and overgrazing are only making the problem worse by accelerating soil degradation. These actions contribute to greater erosion, loss of biodiversity, and a decline in agricultural productivity further threatening farmers livelihoods. The combination of climate change and soil erosion creates a vicious cycle that's tough to break, making it even harder for farmers to adapt and recover.

To tackle both soil erosion and climate change, it is crucial to implement integrated strategies for mitigation and adaptation. These include afforestation, area closure, soil conservation, land rehabilitation, drought-resistant crops, and rainwater harvesting (Table 4.45). Amsalu and de Graaff (2007) found that these methods are effective in restoring degraded land and reducing erosion. Additionally, land-use planning that considers climate variability and land capability is a key to minimizing erosion and ensuring sustainable farming (Kebede and Hurni, 2020). Investing in climate adaptation and sustainable land management is vital to secure the long-term resilience of the Amhara highlands.

4.3.1.4. Water management in the highland of Amhara Region

A. Irrigation practices

The survey findings on water management, moisture conservation, irrigation practices, and the challenges faced by the highland, midland, and lowland agro-ecologies of the Amhara region are summarized in Table 4.46. In the highland areas, irrigation is less common than in other parts of the region but remains vital for crop production, primarily relying on water sources like rivers, springs, and groundwater (Table 4.45). A mix of traditional irrigation techniques, such as flooding, border, furrow, and basin irrigation, is used alongside modern methods that tap into rivers, springs, and groundwater (Table 4.46). In these regions, however, irrigation schedules are often fixed, with farmers watering crops at regular intervals rather than adjusting to the specific needs of the crops. This can lead to inefficiencies, particularly when water resources are limited, as crops may not receive the right amount of water during critical growth stages. Awulachew et al. (2007) noted that many smallholder farmers lack the knowledge to synchronize irrigation with crop water requirements, which leads to water waste and reduced crop yields.

Water management in the highlands faces several significant challenges (Table 4.46). A key issue is the heavy reliance on unreliable water sources, such as rivers and ponds, which fluctuate with the seasons. This often leads to water shortages during critical periods of crop growth, particularly during dry spells. In the highlands of Amhara, for example, despite the presence of several rivers and springs, water shortages still occur during the late stages of crop growth and development due to inadequate infrastructure for storage and poor management (Table 4.46).

Additionally, water management practices are often insufficient, with little attention given to proper scheduling or conservation techniques. In many areas, water distribution is handled informally through community agreements, which can lead to conflicts when water becomes scarce. Another challenge is the underutilization of groundwater in many highland districts. Although groundwater could be a valuable resource, farmers face difficulties accessing and using it due to limited technical knowledge and insufficient extension services. This issue is compounded by poor infrastructure, including malfunctioning or poorly maintained irrigation pumps and canals.

B. Fertilizer use in irrigated agriculture

In the highland areas of the Amhara region, irrigated crops include pepper, garlic, onion, wheat, maize, cabbage, tomato, and potato (Table 4.46). Fertilizer use in these areas tends to follow broad, generalized recommendations rather than being tailored to the specific needs of crops or irrigation systems. Common fertilizers, such as Urea and NPS, are applied in fixed amounts (100 kg/ha Urea and 60 kg/ha NPS), especially for crops like garlic, onion, and pepper. However, this one-size-fits-all approach doesn't always match the crops' nutrients requirements, leading to inefficient water use. The over-reliance on flood irrigation further reduces fertilizer effectiveness, as waterlogging can prevent crops from properly absorbing nutrients (Table 4.46).

Research report has shown that crop yields could improve significantly with the adoption of site-specific fertilizer management, which takes into account soil nutrient levels and water availability (Kassa et al., 2017). The absence of customized fertilizer recommendations for irrigated crops in the highlands highlights the need for integrated soil fertility management practices that consider the complex interactions between water, nutrients, and soil types.

C. Water harvesting and moisture conservation practices

Water harvesting and moisture conservation practices in the highlands of Amhara show a mixed picture. In some areas, techniques such as terracing, half-moon structures, and fanaya juu are commonly used to enhance groundwater recharge and conserve moisture (Table 4.46).

These methods have proven effective in boosting productivity, particularly in regions with seasonal rainfall. However, the adoption of these practices is more limited in other parts of the Amhara highlands, where farmers lack the knowledge and resources needed to implement water harvesting techniques. In some areas, water harvesting is even less common, with existing water resources mainly being used for livestock and domestic purposes rather than agriculture. Moreover, moisture conservation practices such as mulching and in-situ moisture retention are not widely adopted in certain regions, leaving the soil more vulnerable to erosion and water loss. As a result, these areas face greater challenges in maintaining soil fertility and securing moisture for crop production.

D. Challenges and solutions in irrigation and water management

In the highlands of the Amhara region, managing irrigation water is a complex challenge, driven by several key issues, including neglected infrastructure, a lack of technical expertise, and limited water resources (Table 4.46). These problems are compounded by water conflicts, drainage issues, the underuse and illegal extraction of groundwater, and a shortage of qualified professionals. Water conflicts, in particular, are common during peak irrigation seasons in some areas, where informal agreements are often the only means of resolving disputes.

The absence of well-structured irrigation schemes and monitoring systems leads to inefficiencies and increased tensions. In certain parts of the Amhara highlands, outdated irrigation infrastructure and the lack of a formal water distribution system make the situation worse. Consequently, water is frequently wasted, and many farmers struggle to secure enough water for their crops. The shortage of skilled professionals to maintain irrigation pumps and other essential infrastructure intensifies challenges.

Several solutions could help address the challenges related to agricultural water. Developing improved irrigation systems, such as drip and sprinkler systems, could reduce water wastage and increase efficiency. Expanding the use of water-saving technologies and improving irrigation scheduling based on crop needs and water availability, would help make better use of available water.

Building more geo-membrane ponds and improving groundwater management are also crucial steps to address water scarcity. Additionally, promoting rainwater harvesting techniques, like constructing small ponds and terraces, would improve water availability during dry periods. Strengthening extension services and providing farmers with training on these practices could greatly enhance the adoption of water-saving technologies and moisture conservation methods.

4.3.2. Major Constraints in the Midland Agro-ecology

4.3.2.1. Land use and land covers

A. Land use, degradation, and ecological restoration

The land use and land cover patterns in the midland agroecology of the Amhara region are shown in Table 4.43. This area features a diverse landscape with a combination of cultivated land, communal areas, grazing land, natural forests, plantation forests, and agroforestry (Table 4.43). Agricultural land is the most dominant, with extensive areas dedicated to crop cultivation and grazing, as well as notable forestry activities. Farming plays a central role in the local economy. In addition to cultivation, grazing land, communal areas, natural forests, plantation forests, and agroforestry play important roles in sustaining the region's environment and livelihoods (Table 4.43).

Overgrazing, especially on communal lands, and the conversion of grazing areas into farmland are contributing to soil degradation. This issue is further compounded by rapid population growth and a rising demand for food and fuel, which heighten the pressure on both natural forest and protected landscapes. Research report showed that overgrazing and land fragmentation are significant drivers of land degradation in Ethiopian highland regions, including Amhara (Mesfin et al., 2018).

Land degradation is a major challenge in the midland agroecology (Table 4.43), with ongoing issues such as soil erosion, loss of fertility, and declining agricultural productivity. Overgrazing, deforestation, and poor farming practices are gradually depleting soil quality, making it harder for communities to sustain their livelihoods.

To tackle these problems, various land restoration initiatives have been put in place (Supplementary Table 4.43). One such measure is area closure, a practice where land is temporarily excluded from grazing and cultivation. This approach has proven successful in preventing further degradation and allowing natural vegetation restoration. Research by Fenta et al. (2020) and Kindeya (1997) highlights that area closures have improved soil structure, reduced erosion, and restored vegetation cover in Ethiopia.

In addition to area closures, afforestation and reforestation efforts, including planting multipurpose trees, have gained momentum. These measures are not only enhancing soil quality but also providing economic benefits to local communities through the sale of timber and non-timber forest products. Despite these positive outcomes, there is still a critical need for better monitoring and stronger community engagement to ensure the long-term effectiveness and sustainability of restoration efforts.

B. Natural and plantation forests

The natural forests in the midland agroecology are home to a rich variety of tree species, including *Acacia abyssinica*, *Cordia africana*, and *Ziziphus mucronata* (Table 4.43). These forests are crucial for maintaining the ecological balance, providing wildlife habitat, enhancing water retention, and enriching soil fertility. However, they are increasingly under threat from deforestation, free grazing, and the expansion of agriculture (Table 4.43).

As local populations grow and farmland expands over time, the pressure on these forests intensifies. To address these challenges and promote sustainable forest management, several strategies have been put in place. These include forming forest protection committees, establishing watershed management groups, and enforcing local bylaws to regulate forest use. While these efforts have seen some success, especially when local communities are actively involved, deforestation remains a pressing issue, driven by economic pressures and the rising demand for fuelwood (Girma et al., 2021).

Plantation forests in the midland agroecology, often made up of species like *Eucalyptus camaldulensis*, *Grevillea robusta*, and *Moringa stenopetala*, play an important role in providing fuelwood, conserving soil, and generating income (Table 4.43). Despite their value, these plantations face a range of challenges, including free grazing, water shortages, and low seedling survival due to inconsistent rainfall.

Free grazing, in particular, hampers the growth and establishment of these plantations. To tackle this, the cut and carry system has been proposed, where grasses are harvested and fed to livestock away from the plantations. This reduces grazing pressure on the trees, allowing them to grow more successfully. Additionally, selecting the right tree species and improving seedling handling practices are key to increasing the survival rates of trees.

C. Agroforestry systems

Agroforestry practices are widely embraced in the midland agroecology, with systems like home gardens, boundary plantations, and scattered trees in agricultural fields being common (Table 4.43). These systems integrate trees into farming landscapes, offering a variety of ecological and economic benefits, such as enhancing soil fertility, reducing erosion, and providing additional income through tree products like fruits and timber. Species such as *Cordia africana*, *Ziziphus mucronata*, and *Acacia decurrens* are frequently used in these systems. However, agroforestry practices in the region face a number of challenges, including pest infestations, water shortages, and conflicts with free grazing (Table 4.43). A lack of experience in managing agroforestry systems and insufficient attention to tree care further reduce their effectiveness. The success of these systems could be greatly improved with better species selection, improved tree management practices, and the use of supplementary irrigation (Endale, 2019; Yirga et al., 2024).

D. Best practices for sustainable land and forest management

In the midland region, several best practices have been adopted to tackle land management challenges. One of the most effective strategies for land restoration has been area closure, which has shown significant improvements in vegetation cover and soil quality in multiple districts (Table 4.43). Similarly, the cut and carry system has proven successful in reducing grazing pressure on plantation forests. When properly managed, agroforestry systems have the potential to make agricultural practices more sustainable and boost biodiversity. Furthermore, the creation of watershed committees, forest task forces, and participatory management approaches has been instrumental in promoting sustainable resource management. These practices not only help restore degraded lands but also improve the livelihoods of local communities by enhancing resource management and increasing access to forest products.

4.3.2.2. Soil fertility management

A. Soil types and soil specific challenges

The midland agroecology of the Amhara region consists of various soil types, such as Cambisols, Vertisols, Luvisols, Regosols, and Nitisols, each affecting agricultural productivity uniquely (Table 4.44). Cambisols, found in several districts, are prone to cracking and a decline in organic matter, which over time reduces their fertility.

Survey results showed that Cambisols are especially vulnerable to nutrient depletion, requiring careful management practices such as organic amendments and crop rotations to preserve their fertility. Vertisols, another prevalent soil type, face challenges of waterlogging during the rainy season and cracking during the dry season (Table 4.44).

These conditions make tillage and crop growth difficult. On the other hand, Luvisols and Nitisols tend to have moderate fertility and are easier to manage, providing a more stable base for crop production. Vertisols in the midland agroecology of Amhara present particular challenges that require specialized management, especially in addressing waterlogging during the rainy season and cracking during the dry season (Table 4.44). To manage these issues, techniques such as broad bed furrows (BBF) and traditional drainage methods are essential for improving water retention and preventing waterlogging, which can otherwise cause significant crop losses. The formation of a hard pan during the dry season further complicates tillage and negatively affects crop growth, necessitating careful management interventions.

Common crops such as teff, sorghum, chickpea, and grass pea are typically grown in Vertisols, with crop rotations like chickpea-teff-sorghum being common. However, vertisol can grow all crops with excellent drainage. The most yield limiting nutrients under Vertisols are nitrogen followed by phosphorus. Effective management of drainage is critical for maintaining long-term productivity and diversity of crops in the Vertisol (Table 4.44)

B. Soil fertility

Soil fertility in the midland agroecology is generally low to medium, with organic matter depletion being a major constraint, alongside issues like cracking, waterlogging, erosion, and poor fertility (Table 4.44). Challenges in improving soil fertility include access to fertilizers, labor limitations, and the low nutrient content of organic fertilizers. In addition, the lack of extension services and knowledge gaps among farmers about proper fertilizer use and soil management make the situation more difficult.

Soil erosion, moisture stress, and the degradation of organic matter remain significant obstacles, especially in areas with low water retention capacity. In general, the fertility of soils in the midland agroecology is considered low to medium, with organic matter depletion being a key constraint (Table 4.44). Fertility assessments consistently show deficiencies in nitrogen and phosphorus and these nutrients are the only yield limiting nutrients, (Haileslassie et al., 2017). Therefore, inorganic fertilizer that contains nitrogen and phosphorus remains the key component of crop production.

C. Soil management practices for fertility restoration

Farmers in the midlands of the Amhara region use a variety of soil management practices to restore and maintain soil fertility. Among the most common methods are biophysical techniques, such physical and biological soil conservation measures and afforestation efforts (Table 4.44). These practices play a crucial role in controlling soil erosion, preventing waterlogging, and improving moisture retention, especially in areas with Vertisols, where waterlogging and soil cracking are frequent challenges.

Together with these physical methods, fertilization both organic and inorganic is a critical component of soil fertility management. Organic fertilizers such as compost, farmyard manure, green manure, vermicompost, and bio-fertilizers are widely used and have a positive impact on soil structure, water retention, and microbial activity (Table 4.44).

However, there are several challenges to the wider use of organic fertilizers. Producing and applying these materials is labor-intensive, and the high costs, limited availability, and bulky nature of organic fertilizers make them difficult to use on a large scale. Additionally, the lack of standardized preparation methods for compost and farmyard manure results in inconsistent quality, which can undermine their effectiveness. This challenge is not unique to the Amhara region but is also seen across Ethiopia, where farming with organic fertilizers struggles with low nutrient content and high labor demands (Abate et al., 2018). Transportation difficulties in remote areas also limit access to organic fertilizers, making their wider adoption even more challenging. Bio-fertilizers offer an alternative to nitrogen chemical fertilizers, for legumes, and could play a key role in improving legumes productivity and soil fertility.

Chemical fertilizers, such as urea and NPS (Nitrogen, Phosphorus, and Sulfur), are commonly used by farmers in the midland for crops like teff, sorghum, maize, and wheat (Table 4.44) and NPS is expected to be replaced by DAP starting from the next cropping seasons. While these fertilizers help address immediate nutrient deficiencies, their use comes with several challenges. The high costs and delayed supply of chemical fertilizers often prevent farmers from applying them at the critical time, which can result in missed opportunities to attain maximum efficiency of fertilizers. The rate and time of fertilizer application is a challenge that results in overuse or sub-optimal application. In areas like Jiru and Enewari, for instance, farmers tend to apply too much urea and NPS fertilizers for bread wheat. The typical amount of urea used is 300 to 500 kg per hectare, while the recommended rate is only 275 kg. Similarly, NPS is applied at rates of 300 to 500 kg per hectare while the recommended rate is 270 kg.

This reflects a common issue of applying more fertilizer than needed indicating that farmers prefer to take the risk of fertilizer costs than reducing the grain yield. This situation underscores the pressing need for improved extension services and better farmer education on how to improve fertilizers application. In Ethiopia, limited support from extension services remains a major hurdle in achieving effective fertilizer management (Beshir et al., 2016). Additionally, there is untapped potential in expanding the use of bio-fertilizers, which are still underused in the region.

4.3.2.3. Soil and water erosion and conservation measures

A. Soil erosion

Soil erosion remains one of the most significant environmental challenges in the midland agroecology of the Amhara Region. The region is, known for its rugged terrain and intense rainfall, experiences severe erosion caused by both natural factors and human activities (Table 4.46). The main types of erosion in the Amhara region include sheet erosion, rill erosion gully erosion, and riverbank erosion (Mulugeta et al., 2010). These erosion processes are worsened by deforestation, poor farming practices such as hillside plowing, overgrazing, and a lack of effective soil conservation measures (Hurni, 1993). As a result, soil fertility is significantly diminished, leading to reduced agricultural productivity.

B. Soil and water conservation practices

In the midlands of Amhara Region, a variety of soil and water conservation (SWC) practices have been introduced to reduce soil and water losses, restore degraded land, improve soil fertility, and increase water retention. These practices include area closures, grass strips, soil bunds, stone bunds and improved tillage techniques (Table 4.45). The benefits of these conservation efforts practices are well known. As highlighted by Hurni (1993) and Mulugeta et al. (2010), restoring degraded land through SWC practices leads to better soil fertility, higher agricultural productivity, and improved groundwater recharge. Additionally, moisture retention in the soil helps make crops more resilient during dry spells. The regrowth of vegetation also boosts biodiversity and provides essential ecosystem services, including forage for livestock and habitats for wildlife.

Despite these positive outcomes, implementing soil and water conservation measures has faced several challenges. Issues such as high labor demands, low awareness among farmers, and poor implementation have hindered progress. Furthermore, there are significant challenges to managing soil erosion effectively, including the lack of efficient conservation practices and limited resources (Table 4.45).

Research has identified key challenges such as limited farmer awareness, financial constraints, and difficulties in selecting suitable technologies due to unfavorable topography or environmental factors (Kassa et al., 2015). Soil and water conservation is a labor intensive activity especially for activities like terracing and grass planting, remain a major barrier. Additionally, technical support and inputs such as seeds for grass strips and trees are critically important for the success of conservation practices (FAO, 2011).

C. Climate change, soil erosion, and long-term sustainability

Climate change has been intensified strongly affect soil erosion in the midland agroecology of the Amhara region. Shifts in rainfall patterns, frequent floods, and rising temperatures have worsened the already existing problem of soil degradation (Table 4.45).

Soil erosion in these areas is severe because of the combined effects of changing climate and human activities like deforestation and overgrazing (Alemayehu et al., 2019). Additionally, Tessema et al. (2020) highlighted that erratic rainfall characterized by high intensity followed by flash floods, worsens soil erosion further. Changing weather patterns also disrupt crop productivity, as unpredictable rainfall and fluctuating temperatures interfere with growing seasons. In these parts of the region, several strategies have been proposed to combat the impacts of climate change on soil erosion. Mitigation efforts include afforestation, raising awareness, and promoting improved land use planning (Table 4.45). Previous research suggested that agroforestry and afforestation can help reduce climate change effects by stabilizing soil and increasing vegetation cover (Kassa et al., 2015).

Climate adaptation practices such as improved water management, introduction of drought-resistant crop varieties, and in general implementing climate smart agricultural practices are essential for reducing soil erosion and boosting food security (Alemayehu et al., 2019). Community based initiatives, like area closures and controlled grazing also play a crucial role in restoring ecosystems and mitigating the impacts of climate change on agricultural land. Tadesse et al. (2017) emphasized that empowering local communities through training and capacity building enhances their ability to adapt to climate change and ensures long term sustainability.

4.3.2.4. Water management

A. Irrigation practices and water management

In the midland agroecology, rivers, springs, lakes, groundwater, and dams and ponds are the sources of water (Table 4.46). To access these water sources, farmers commonly use diversion structures, fuel pumps, and traditional wells. Flooding, furrow, and basin irrigation techniques are commonly used. Irrigation frequency and depth depends the type of crop, soil and water availability. Crops like garlic, wheat, and maize are irrigated, with intervals ranging from 5 to 12 days, depending on the available water and the soil types. However, water use remains largely inefficient due to the reliance on traditional methods that often lack proper scheduling.

This leads to either overuse or underuse of water, ultimately impacting crop yields and water productivity (Gebremedhin et al., 2015; Asfaw et al., 2017). The practice of mono-cropping with irrigation further strains water resources and intensifies competition for limited water. Water management is a significant challenge under both traditional and modern practices (Table 4.46). For instance, in some areas, a combination of traditional flood irrigation and modern systems like furrow and basin irrigation is common.

However, inconsistent irrigation intervals persist due to limited water availability and poorly maintained infrastructure. Farmers often rely on water user committee to resolve conflicts over water allocation, but the committee sometimes lacks the authority or capacity to manage water effectively. Research report has highlighted that poor maintenance of irrigation infrastructure, such as leaking ponds, sediment buildup in dams, and ponds, exacerbates water management problems (Tadele et al., 2017).

B. Fertilizer use

Fertilizer plays a crucial role in crop productivity in the irrigated midland regions of Amhara, where garlic, wheat, onion, tomato, cabbage, and chickpeas are grown commonly (Table 4.46). Very high rate of fertilizer is used: Urea (200 kg/ha) and NPS (300 kg/ha). However, there is high rate variability among and between farmers for the same crop for the same soil in the same location across this agro-ecological zone. To improve crop yields and enhance water use efficiency, it is essential to standardize and optimize fertilizer practices in the midlands of Amhara.

C. Water harvesting and moisture conservation

In the midlands of the Amhara region, water harvesting and conserving is commonly achieved through the use of concrete ponds, micro trenches, and terracing (Table 4.46). Widespread adoption of these water harvesting structures is often limited by labor shortages, a lack of skilled workers, and limited access to the materials needed to build effective water harvesting (Negessa, 2021). Additionally, there is often a lack of awareness about the importance of moisture conservation, especially in areas where these practices have not traditionally been used.

D. Challenges and solutions

In the midland agroecology of Amhara, irrigation water management faces several challenges, including irregular water distribution intervals, weak management practices, and high levels of seepage (Table 4.46). Irregular irrigation intervals are common problems, with some farmers struggling to follow schedules that meet crop water requirements (Demeke et al., 2018). This inconsistency is often linked to water scarcity, inadequate irrigation infrastructure, and poor management practices. Many farmers lack the training and tools needed to effectively manage irrigation systems, leading to water inefficient water use (Gebremedhin et al., 2015; Negessa, 2021). Moreover, the state of irrigation infrastructure presents a significant challenge for optimally use of the water resources.

Addressing these challenges requires a comprehensive and integrated approach. Improving irrigation scheduling based on crop water needs and available water supply and soil type is critically important. Research suggests that better scheduling can reduce water use by 20-30% while maintaining or even improving crop yields (Hailu et al., 2022). Promoting moisture conservation practices, such as mulching, early planting, and proper soil conservation, is also crucial. Furthermore, greater investment in irrigation infrastructure is needed, particularly in the maintenance and construction of new ponds, weirs, and irrigation channels. Proper maintenance can boost water storage, improve water availability during dry spells, and help prevent conflicts over water allocation (FAO, 2019).

4.3.3. Major Constraints in the Lowland Agroecology

4.3.3.1. Land use and land cover

A. Land use, degradation, and restoration

Land use and land cover patterns in the lowland agroecology of the Amhara region are shown in Table 4.43. These areas exhibit significant variation in land use, with large portions of land dedicated to crop production, along with natural forests and grazing lands. However, the growing pressure from an increasing population is intensifying land use challenges, deforestation, overgrazing, and land use conversion, has led to severe natural resources degradation. A major challenge across the lowlands is the absence of adequate bylaws and effective enforcement mechanisms to regulate land uses and protect natural resources.

Land degradation remains a pressing challenge in lowland agroecosystems, where vast areas are plagued by overgrazing, deforestation, and poor land management practices (Table 4.43). Some interventions including area closures, afforestation, and soil and water conservation (SWC) have been implemented (Table 4.43). Area closures avoids temporarily grazing, have proven positive effects in restoring degraded landscapes and enhancing biodiversity. Studies on the use of area enclosures for managing dryland biodiversity indicate that they can significantly boost vegetation cover and improve soil quality (Kindeya, 1997). Furthermore, the planting of multipurpose trees in degraded areas has emerged as a key strategy for both restoring land and supporting sustainable agricultural practices.

B. Natural and plantation forests

Natural forests in the lowland agro-ecological regions of Amhara are home to a variety of indigenous tree species, including *Balanites aegyptica*, *Acacia polycantha*, *Boswellia papyrifera*, *Croton macrostachyus*, and *Podocarpus falcatus* (Table 4.43). Despite their ecological importance, these forests face significant threats, including illegal logging, deforestation for agricultural purpose, and overgrazing. Intensive use of charcoal, construction and fuelwood further degrade the natural forest in the lowlands (Table 4.43). To address these challenges, enforcing local bylaws and deploying forest guards have been identified as important measures to be considered. Additionally, promoting forest regeneration through replanting and establishing protected zones is essential for preserving the overall ecosystem services of low land forests.

Plantation forest in the lowlands is very limited and most of them are concentrated around homesteads and boundaries. As a result there is a high demand gap of plantation forest products mainly for construction. The current source of construction wood materials to the lowlands region is from the highlands and midlands. *Moringa stenoptera* and *Azadirachta indica* are commonly grown tree species in this agroecology used as plantation forest (Table 4.43). These plantations play a crucial role in the local economy by providing timber, fuelwood, and other resources. However, their long-term sustainability is at risk due to factors such as low tree survival rates, erratic rainfall patterns, and the encroachment by grazing (Table 4.43).

Free grazing, during dry seasons when forage is scarce, is a major threat to the survival of plantation trees. Free grazing and poor land management practices are significant contributors to the degradation of plantation forests in the Amhara Region (Wubalem et al., 2019). Therefore, it is essential to implement measures like protecting plantation areas with enclosures, improving seedling survival rates through different managements, and optimizing plantation forest through efficient managements including by water applications. Additionally, adopting a more integrated land-use approach that balances the needs of plantation forestry and local communities is crucial, as highlighted in other studies across Ethiopia (Zelege et al., 2019).

C. Agroforestry systems

Agroforestry systems, which incorporate trees into agricultural landscapes, are commonly practiced in the lowland agro-ecologies of the regions (Table 4.43). Popular tree species in these systems include *Cordia africana*, various *Acacia* species, *Moringa*, and *Ziziphus mauritiana*. These trees offer a range of benefits, such as fuelwood, fodder, timber, and replenishing soil fertility. However, agroforestry systems face several challenges, particularly their shading effect on crops, hiding crop pests including bird damage, and sometimes competition for water under moisture stresses. Farmers often struggle to integrate trees into their farming systems without negatively affecting crop yields.

Studies from Ethiopia, including those conducted in the Amhara region (Endale, 2019; Yirga et al., 2024), suggest that despite these difficulties, agroforestry holds significant potential for sustainable land use, especially in areas where soil fertility is deteriorating. Solutions to these challenges include pruning trees, optimizing tree spacing, and selecting tree species that complement agricultural activities. Additionally, raising awareness and promoting better management practices are crucial for maximizing the benefits of agroforestry.

D. Best practices for sustainable forest management

There are effective land use and natural resource management practices in lowland agroecology (Table 4.43). These include area closures and restoration efforts, which help prevent overgrazing and encourage natural regeneration or afforestation in degraded areas. Biophysical soil and water conservation (SWC) techniques, such as terraces, are essential for controlling erosion and improving land productivity (Table 4.43). Additionally, planting multipurpose trees, particularly indigenous species like *Acacia* and *Balanites*, helps restore soil health, reduce erosion, and enhance biodiversity. Improved agroforestry management, including practices like pruning, selecting appropriate tree species, and managing tree-crop interactions, can minimize crop losses while maximizing benefits. Successfully implementing these practices can significantly support land restoration and sustainable natural resource management in lowland agro-ecologies.

However, to ensure a sustainable long-term success, it is crucial to scale up good practices by integrating them into local development plans. There also need a strong support both from local communities and government institutions. A strongly decline trends of vegetation cover in the lowland of the region is should get a higher priority of the region to build a resilient community in these areas as climate change adverse effect is expected worse this parts than the highlands and midlands of the region.

4.3.3.2. Soil fertility management

A. Soil types and soil specific challenges

The lowland agroecology of Amhara is characterized by a diverse range of soil types, including Vertisols, Regosols, Cambisols, Luvisols, and Lithosols (Table 4.44). Vertisols are notable for their high water-holding capacity, which can be helpful during dry periods but problematic during the rainy season. These soils tend to become waterlogged, limiting root growth and nutrient uptake. Managing Vertisols in the lowland agroecology of Amhara presents unique challenges and opportunities, (Table 4.44).

Farmers typically rely on drainage systems, such as cut-off drains, to address waterlogging, but these systems are often inadequate due to poor infrastructure (Ayele et al., 2023). Furthermore, during the dry season, soil cracking and the formation of a hard pan makes tillage difficult and impossible to prepare before the rainy season. It gives only a short range of time for the soils at its field capacity of moisture content for the land preparation, rather it is getting into waterlogged conditions.

Regosols are less fertile, pose additional challenges for crop production due to their low moisture retention and nutrient deficiencies. Cambisols, while moderately fertile, are still reliant on fertilization to maximize yields, supporting crops like sorghum, teff, and cotton. In contrast, Luvisols, found in certain parts of the lowland agroecology, are fertile and yet require significant fertilizer for the production of crops. These variations in soil types highlight the importance of site specific fertility management approaches to sustainably and optimally crop productions in the lowlands.

B. Soil fertility and constraints

Soil fertility in the lowland agroecology of Amhara varies across different soil types (Table 4.44). Vertisols are generally considered moderately fertile and are commonly used for growing high-value crops like cotton, sesame, and sorghum. However, nitrogen and phosphorus deficiencies are widespread in the region, often leading to low crop yields. To address these deficiencies, farmers apply fertilizers like urea and NPS (Nitrogen, Phosphorus, and Sulfur). A major challenge with Vertisols is waterlogging, which can severely hinder crop growth and the efficiency of applied fertilizer. Integrated use of fertilizer and drainage could increase the productivity of crops in the Vertisols. Additionally, soil salinity is becoming an increasing concern in some lowland areas particularly in the lowlands of East Amhara, contributing to reduced crop yields.

Farmers also face challenges with limited access to fertilizers, and high prices further complicating the situation (Table 4.44). These issues make it difficult for farmers to properly optimize the resources and bridge the attainable yield gaps. Despite these obstacles, Vertisols continue to support crops like sesame, cotton, and sorghum, but crop responses to fertilizers are often limited by the soils physical constraints and nutrient dynamics. As highlighted by Tadesse et al. (2021), blanket fertilizer recommendations often fail to take into account the unique needs of crops grown in Vertisols. To improve soil fertility and boost crop productivity, it is essential to adopt soil-specific management practices such as enhanced drainage, a better understanding of nutrient dynamics, and tailored fertilizer application strategies.

C. Soil management practices for fertility restoration

Farmers in the lowland agroecology of Amhara have implemented various soil management practices to restore fertility, but these efforts often fall short of meeting the region's needs (Table 4.44). Inorganic fertilizers, mainly urea and NPS, are commonly used for crops such as sorghum, sesame, and teff.

However, the absence of standardized recommendations particularly concerning the right timing and application rates often leads to inefficient use of these fertilizers. Fertilizer application in this region faces multiple challenges that hinder crop productivity.

Despite the widespread use of urea and NPS to supplement soil fertility, the lack of clear guidelines on how much and when to apply fertilizers results in suboptimal. The high cost and limited availability of fertilizers make things worse. Delays in fertilizer distribution, especially during the critical growing season, prevent many farmers from applying fertilizers at the most effective times. Often, farmers apply fertilizers without expert advice, leading to very low productivity. Research by Alemayehu et al. (2022) shows that fertilizer application rates are often determined by local practices or trial and error, rather than being guided by scientifically supported recommendations. This approach only adds to the challenge, leading to inefficient fertilizer productivity.

Organic fertilizers, such as farmyard manure (FYM) and compost, play an important role in enhancing soil fertility in the lowland agroecology of Amhara (Table 4.44). FYM is particularly valuable for crops like teff, sorghum, and pearl millet, helping to improve soil health. However, the widespread adoption of organic fertilizers faces several challenges.

One of the main obstacles is low nutrient content that needs high amounts of FYM, which makes it difficult to transport, especially in areas with poor road infrastructure. This transportation challenge, along with labor constraints, limits its use. Additionally, many farmers are hesitant to use compost due to concerns about the labor-intensive process involved in its production (Table 4.44). The time and effort required to produce compost also discourage many farmers from using it as a soil amendment (Shiferaw et al., 2021).

Despite these hurdles, organic fertilizers remain important parts for improving soil fertility in the region. In general, an integrated soil fertility management (ISFM) practices shall be give a priority in the lowlands. Moreover, the high biomass in some parts of the low lands of the region (low lands of Gondar) should be considered an entry point for making organic fertilizers.

4.3.3.3. Soil erosion and conservation measures

A. Soil erosion and its causes

Soil erosion, including gully erosion and riverbank expansion, has become a significant environmental issue in the lowland agroecology of Amhara (Table 4.45). The region is especially vulnerable to severe gully erosion, which is driven by deforestation, overgrazing, poor land management, and unsustainable farming practices and poor designs of drainage systems including in road constructions. This erosion is widespread, leading to a decrease in agricultural productivity and the loss of the fertile soil that farmers rely on. On site effects of erosion depletes soil fertility while it's off site effect is sedimentation in lower-lying areas, which in turn impacts water quality and as well as water quantity (Mengistu et al., 2021).

B. Soil and water conservation practices

Efforts to combat soil erosion in the lowland agroecology of Amhara have involved various physical and biological conservation techniques, such as stone check dams, brushwood dams, soil bunds, and grass strips (Table 4.45). These practices have proven effective in several key areas: they prevent soil and water loss; they restore the degraded land, replenished soil fertility, and finally increase crop yields. Field observations in the region have shown that these techniques successfully trap sediment, enhance vegetation cover, and improve crop performance. Additionally, they protect against further soil loss and strengthen the structural integrity of the landscape. Ultimately, these conservation practices contribute to higher land productivity sustainably (Berhanu et al., 2017).

However, soil conservation efforts in the lowland agroecology still face significant challenges because of its high cost, labor intensive, and lack of awareness about good practices, poor management, insufficient maintenance, and free grazing (Table 4.45). High costs are related to construction of soil conservation structures, like check dams and bunds and to maintain these structures such as clearing sediment from check dams and replanting grass strips (Fenta et al., 2020). One of the primary challenges in Ethiopia is the limited involvement of farmers in soil conservation practices planning, and inadequate training.

C. Climate change, soil erosion, and long term sustainability

In the lowland areas of Amhara, temperature is increasing with frequent flooding, worsening soil erosion (Table 4.45). The effect of climate change reflects on increasing temperatures, erratic rainfall patterns, frequent droughts, increased crop pest and disease and land degradation (Assefa et al., 2020). Mulugeta et al. (2019) reported that climate change negatively affects soil fertility, posing a direct threat to food security. In response to these climate challenges, several mitigation and adaptation strategies have been implemented in the lowlands of Amhara. These include gully management, tree planting, and broader soil conservation efforts, all aimed at reducing the impact of climate change and strengthening the resilience of the local environment (Table 4.45). Gully management, tree planting, and soil conservation can help mitigate climate change by restoring vegetation cover, improving soil fertility, and boosting water retention in the soil (Sileshi et al., 2020). But, challenges remain, including ongoing deforestation and the failure of some conservation structures due to poor maintenance, which continue to undermine these efforts. Moreover, research by Degefu et al. (2018) highlights the importance of integrating soil and water conservation with broader climate change adaptation strategies that includes enhancing local capacity to manage natural resources and promoting sustainable land-use practices.

4.3.3.4. Water management in the Lowland Agroecology of Amhara

A. Irrigation practices and water management

In the lowland agroecology of the Amhara region, irrigation is practiced (Table 4.46), though it remains limited and underdeveloped in many areas. The primary sources of irrigation water are rivers, springs, and some groundwater, but the extent of water use is often restricted by inadequate infrastructure and inefficient irrigation practices (Table 4.46). Furrow irrigation is used for vegetables like onions and tomatoes, basin irrigation for fruits such as mangoes and papayas, and flooding in some areas for cereals. However, flooding in certain areas can lead to inefficiencies, as excess water from this method is not always fully utilized. In the lowland Amhara region, irrigation scheduling is often inconsistent, with intervals ranging from 3 to 7 days. Many farmers also fail to adjust irrigation based on the specific water needs of their crops, leading to wasted water and suboptimal crop yields (Table 4.46). This observation aligns with the findings of Awulachew et al. (2007), who noted that farmers often lack the necessary knowledge to match irrigation schedules with crop water requirements, resulting in water wastage and poor crop performance.

Water management in the Amhara lowlands remains highly inefficient (Table 4.46). In these areas, water measurement is often absent, and distribution can be irregular. In some locations, water allocation is arbitrary, with no structured system in place to ensure that available resources are used equitably and efficiently. This problem is further worsened by inadequate infrastructure maintenance and the absence of water-saving technologies, which contribute to significant water wastage.

Research has shown that inconsistent water management and poor infrastructure are major barriers to efficient irrigation in Ethiopia (Asfaw et al., 2017). Furthermore, water user associations, which could help ensure more organized and fair distribution, often lack the authority and capacity to resolve conflicts effectively. Strengthening water user associations in Ethiopia could greatly enhance water management by promoting fair distribution and reducing conflicts (Gebremedhin et al., 2015).

To make this happen, water user committee need to be strengthened, with well-defined roles in managing water allocation and resolving conflicts. This committee should also be provided with greater authority and resources to effectively carry out its duties.

B. Fertilizer use in irrigated agriculture

Fertilizer use in the Amhara lowlands is common, but its application is often inconsistent and lacks technical guidance (Table 4.46). Fertilizers are often broadcast without a clear understanding of the specific needs of each crop. Research report has shown that this issue is widespread across many regions of Ethiopia, with a particular focus on the absence of clear guidelines for fertilizer application (Getachew et al., 2018). As a result, crop yields are often suboptimal, and resources are not used efficiently. The lack of extension services and insufficient technical support further compound these challenges, leaving farmers with limited capacity to optimize fertilizer use for improved crop production.

C. Water harvesting and moisture conservation

Water harvesting and moisture conservation practices in the Amhara lowlands are limited and underdeveloped (Table 4.46). While some areas have implemented concrete, earthen, and geomembrane water harvesting structures. In other parts of the lowlands, practices like Shilshallo a physical soil and water conservation method used for sorghum are employed to control erosion and conserve moisture.

However, despite these localized initiatives, moisture conservation remains far from widespread, and many farmers still lack access to efficient water-saving technologies. This situation aligns with the findings of Yirga et al., (2014), who observed that moisture conservation practices are underused in many parts of Ethiopia due to high costs and limited local knowledge of water harvesting techniques.

D. Challenges and solutions in water management

The challenges to effective water management in the lowlands are complex and stem from a combination of factors, including water scarcity, outdated infrastructure, inefficient irrigation systems, and frequent water conflicts (Table 4.46). These problems are made worse by a lack of accurate water measurement, poor maintenance of irrigation systems, and limited awareness among farmers about the specific water needs of different crops. The widespread use of flood irrigation often results in excess water, which is wasted rather than stored for future use. Additionally, the low adoption of water saving technologies and the failure of water harvesting structures, such as geo-membranes increase the problem.

To tackle these challenges, several practical solutions can be implemented. One key step is to promote irrigation scheduling based on the water requirements of each crop, which would help reduce water wastage and improve crop yields. Introducing more efficient irrigation methods, such as drip irrigation and sprinkler systems, could also boost water use efficiency. At the same time, better maintenance of existing infrastructure and the development of more reliable irrigation systems are critical for making the most of available water resources. Providing farmers with training and extension services is essential to bridge the knowledge gap about effective irrigation practices and water conservation. Lastly, strengthening local water user associations is crucial to ensuring fair and sustainable management of water resources at the community level.

4.3.4. Strategic Interventions across Agro-ecologies

To address the natural resource management constraints in the highland, midland, and lowland agro-ecologies of the Amhara Region, a multi-faceted approach integrating ecological restoration, soil fertility management, water conservation, and sustainable agricultural practices is essential. For land degradation and deforestation, expanding area closures, afforestation, and agroforestry initiatives with locally adapted multipurpose tree species can enhance ecological resilience while ensuring economic benefits for local communities. Strengthening forest protection through community-based management and enforcement of regulations will mitigate illegal logging and overgrazing.

To combat soil erosion, implementing biophysical soil and water conservation measures such as terraces, bunds, and check dams will help retain soil and improve moisture availability, while controlled grazing and crop rotation will promote sustainable land use. Soil fertility restoration requires targeted interventions, including balanced applications of inorganic fertilizers tailored to site-specific needs, integrated soil fertility management (ISFM) that combines organic amendments such as farmyard manure and compost, and lime application to manage soil acidity.

For Vertisols, improving drainage infrastructure and optimizing broad bed and furrow (BBF) techniques will enhance crop production potential. Addressing irrigation inefficiencies in the highlands and lowlands necessitates improved scheduling, enhanced water harvesting infrastructure, and the adoption of efficient irrigation methods such as drip irrigation to maximize water use efficiency. Additionally, strengthening farmer training programs and extension services to promote best practices in agroforestry, soil conservation, and integrated water management will enhance adoption rates. Policy-level interventions should focus on ensuring land tenure security, providing financial support for sustainable farming inputs, and fostering collaboration among stakeholders to implement locally adapted strategies effectively. By integrating these intervention strategies, the Amhara Region can achieve resilient agricultural systems that support food security, economic growth, and environmental sustainability.

4.3.4.1. Sustainable Land Management and Restoration Strategies

To mitigate land degradation in the highlands, midlands, and lowlands of the Amhara Region, adopting sustainable land management practices is essential. Expanding area closures and implementing afforestation programs with native tree species will restore degraded landscapes while improving biodiversity. Agroforestry systems integrating multipurpose trees with crops will enhance soil health and productivity. Encouraging community-based forest protection and conservation efforts, including enforcing bylaws against illegal logging and free grazing, will safeguard forest resources. Additionally, promoting soil and water conservation measures such as terraces, bunds, and check dams will reduce erosion risks and strengthen resilience against natural disasters.

4.3.4.2. Integrated Soil Fertility Management Strategies

To address soil fertility issues, a balanced nutrient management approach is required, including proper applications of inorganic fertilizers alongside organic amendments such as farmyard manure, compost, and bio-fertilizers.

Implementing integrated soil fertility management (ISFM) practices tailored to site-specific needs will improve nutrient availability, enhance soil structure, and boost agricultural productivity. Addressing soil acidity through lime application will optimize pH levels and improve plant nutrient uptake. Moreover, crop rotation and cover cropping techniques can further replenish soil nutrients and reduce erosion.

4.3.4.3. Efficient Water Management and Irrigation Improvement

Strengthening irrigation efficiency through optimized water scheduling and improved irrigation infrastructure will enhance water use in agriculture. Expanding water harvesting systems such as ponds, trenches, and reservoirs will increase water availability during dry seasons. Additionally, promoting drip irrigation and other efficient water-saving techniques will maximize water utilization while minimizing losses. Integrating moisture conservation measures such as mulching, terracing, and controlled irrigation timing will further improve soil moisture retention and reduce drought vulnerabilities.

4.3.4.4. Climate Resilience and Sustainable Agricultural Practices

Climate change adaptation strategies require a holistic approach, integrating drought-resistant crop varieties, soil conservation measures, and agroforestry techniques. Strengthening rainwater harvesting and promoting climate-smart agriculture, including conservation tillage and crop diversification, will mitigate the adverse effects of erratic rainfall and temperature fluctuations. Encouraging community-led climate adaptation programs will support local capacity-building, ensuring long-term resilience.

4.3.4.5. Strengthening Stakeholder Engagement and Policy Interventions

A collaborative approach is essential for implementing sustainable agricultural and natural resource management strategies. Enhancing stakeholder engagement through agricultural forums and participatory decision-making processes will improve policy adoption and local buy-in. Strengthening institutional frameworks for land tenure security and financial incentives for sustainable practices will further support agricultural transformation. Encouraging multi-sector collaboration, including research institutions, government agencies, and local communities, will ensure integrated solutions tailored to regional contexts.

By implementing these intervention strategies, the Amhara Region can build resilient agricultural systems that support food security, economic growth, and environmental sustainability.

Table 4.43: Summary of Land Use and Land Cover and Constraints in the Highland, Midland, and Lowland Agro-ecologies

Criteria	Highland	Midland	Lowland
Land use and land cover	Cultivated land, grazing land and bare land, some natural forests	Cultivated land, communal land, grazing land, natural forests, plantation forests, agroforestry	Cultivated land , Grazing land , Natural forests
Challenges	Soil erosion, low forage production, deforestation, overgrazing, population growth, misuse of land	Overgrazing, deforestation, soil erosion, population pressure	Deforestation, overgrazing, land conversion, local security issues
Management options	Area closure, afforestation, conservation, law enforcement	Forest protection, awareness, law enforcement, soil conservation, managed grazing	Area closure, soil conservation, reforestation, physical SWC measures Forest protection, awareness, law enforcement,
Dominant tree species in natural forests	Juniperus procera, Hagenia abyssinica, Olea europaea, Ficus sur, Acacia species	Entada abyssinica, Cordia africana, Croton macrostachyus Acacia polycantha, Ziziphus mauritiana	Acacia asak, Acacia polycantha Adansonia digitata, Balanites aegyptica, Croton macrostachyus
Dominant tree species in plantation forests	Eucalyptus species, Acacia decurrens, Juniperus procera	Grevillea robusta, Azadirachta indica, Moringa stenopetala, Eucalyptus species	Oxytenanthera abyssinica, Azadirachta indica, , Acacia nilotica
Agroforestry practices	Home gardens, woodlots, hedges, boundary plantations	Home gardens, hedge plantations, boundary plantations scattered tree systems,	Home gardens, , scattered tree systems, boundary plantations
Dominant tree species in agroforestry	Rhamnus prioides, Catha edulis, apple, Myrtus communis	Rhamnus prioides, Coffee arabica, Catha edulis, Ziziphus mucronate, Mango, Papaya	Croton macrostachyus, Podocarpus falcatus, Acacia saligna, Ziziphus mauritiana
Agroforestry challenges	Water scarcity, land scarcity, free grazing, frost, , competition for nutrients	Free grazing, bird and pest incidence, options for adaptable and compatible, spp, Shedding effect Tree management	Free grazing, bird damage, options for adaptable and compatible, spp shade for on crops, low survival rates, competition for water

Table 4.44: Summary of Soil Fertility Management Issues and Constraints in the Highlands, Midlands, and Lowland Agro-ecologies

Criteria	Highland	Midland	Lowland
Dominant soil types	Vertisols, Cambisols, Regosols, Leptosols, Luvisols, Andosols	Cambisols, Vertisols, Luvisols, Regosols, Nitisols	Vertisols, Regosols, Cambisols, Luvisols,
Soil fertility status	Low soil fertility status	low soil fertility status	low to medium fertility status, (low in N and medium in P)
Key soil constraints	Soil acidity, erosion, low soil fertility with, high NP deficiency, moisture stress	Drainage, soil acidity, erosion, low fertility with high NP deficiency	Drainage, salinity (east Amhara), nutrient deficiencies (mainly N), moisture stress
Soil management practices	Soil and water conservation, crop rotation, lime application, organic fertilizer, inorganic fertilizer, rotations,	Biophysical soil and water conservation, organic fertilizers, crop rotation, inorganic fertilizers, lime applications	Inorganic fertilizers (Urea, NPS), organic fertilizers, rotation, drainage and water management such as shilshalo to improve the efficiency of nutrients applied
Fertility restoration with organic fertilizers	Compost, farmyard manure, green manure, bio-fertilizers, integrated soil fertility management	Compost, farmyard manure, vermicompost, green manure, bio-fertilizers, ISFM	Compost, farmyard manure, limited use of bio-fertilizers
Fertility restoration with inorganic fertilizers (current)	Urea, NPS	Urea, NPS	Urea, NPS,
Challenges with organic fertilizers	Low nutrient content, bulkiness, scarcity, competition to other purposes, high labor demand	Low nutrient content, bulkiness, scarcity, competition to other purposes, high labor demand	Low nutrient content, bulkiness, competition to other purposes, high labor demand
Challenges with inorganic fertilizers	High cost, distribution issues, lack of rate and time of application recommendations	High cost, poor access, distribution issues	High cost, limited availability, inconsistent use
Soil Acidity and Management	Lime application, crop selection for acidity management	Lime application, crop selection for acidity management	No significant acidity issues
Vertisol management for efficient nutrient management	Drainage management	Drainage management	Drainage management crops
Salinity issues	No salinity	No salinity	Salinity issues in some areas (East Amhara)
Crop types	Barley, potato, Teff, Faba bean, field pea	Sorghum, Maize, Teff, Wheat, Barley, Sorghum, finger millet,	Sorghum, teff, sesame, Pearl Millet, cotton, soybean, common

Table 4.45: Soil & Water Erosion and Conservation Practices and Constraints in the Highland, Midland, and Lowland Agro-ecologies

Criteria	Highland	Midland	Lowland
Soil erosion	Severe erosion due to overgrazing, deforestation, steep slopes, and poor management practices	High erosion in the form of sheet, rill and gully erosion, worsened by deforestation poor agricultural practices, and animal grazing rainfall	In the form of gully erosion, riverbank expansion
Biophysical soil and water conservation measures	Terraces, soil and stone bunds, area closures, a	Terraces, soil and stone bunds, area closures, grass strips, improved tillage	Stone check dams, brushwood dams, soil bunds, grass strips
Benefits of soil conservation measures	Soil retention, water retention, soil fertility maintenance and improvement, and crop yields	Retention, water retention, soil fertility maintenance and improvement, and crop yields	Retention, water retention, soil fertility maintenance and improvement, and crop yields
Challenges of soil conservation measures	Low adoption, lack of financial support	High labor demand, poor awareness, and inadequate implementation	High input costs, labor intensive, lack of awareness
Obstacles to effective soil erosion management	Low government commitment for financial support, unclear land ownership, free grazing	Lack of effective soil conservation practices, limited resources, free grazing	Poor management, insufficient maintenance, Free grazing
Climate change impacts and effects	Erratic rainfall, increased temperature , reduced vegetation cover, increased land degradation, droughts, reduced crop diversity and reduced productivity,	Erratic rainfall, increased temperature , reduced vegetation cover, increased land degradation, droughts, reduced crop diversity and reduced productivity,	Erratic rainfall, increased temperature , reduced vegetation cover, increased land degradation, droughts, reduced crop diversity and reduced productivity,
Mitigation strategies for climate change	Afforestation, area closure, soil conservation, land rehabilitation Drought-resistant crops, rainwater harvesting	Afforestation, area closure, soil conservation, land rehabilitation Drought-resistant crops, rainwater harvesting	Afforestation, area closure, soil conservation, land rehabilitation Drought-resistant crops, rainwater harvesting

Table 4.46: Summary of Water Management Practices and Constraints in Highland, Midland, and Lowland Agro-ecologies

Criteria	Highland	Midland	Lowland
Irrigated crops	Pepper, garlic, onion, wheat, maize, cabbage, tomato, potato	Garlic, wheat, maize, onion, tomato, cabbage, chickpea	Onion, tomato, kudra, ginger, mango, banana, papaya, pepper
Irrigation water sources	River, spring, ponds and groundwater	Rivers, springs, groundwater, ponds, dams water harvesting	Rivers, springs, groundwater, dams and ponds
Irrigation practices	Flooding, border, furrow,, flood, alternate methods based on crop types	Flood, furrow, alternate furrow irrigation method, , flood	Ring, basin, furrow (depending on crop), flood
Irrigation water scheduling	Weekly intervals,	10-12 days for shortage, 5-10 days interval	Weekly or 5-7 day intervals
Fertilizer use	Urea (100 kg/ha) and NPS (60 kg/ha),	Urea (200 kg/ha), NPS (300 kg/ha)	Urea (125 kg/ha) and NPS (125 kg/ha) for pepper
Water harvesting and moisture conservation	Terracing, half-moon, fanaya juu for	Concrete ponds, micro trenches, terracing	Concrete, earthen, geomembrane ponds, limited moisture conservation
Challenges in irrigation water management	Water conflicts, drainage issues, underutilization of groundwater, illegal use of groundwater, lack of professionals, limited water resources, poorly maintained infrastructure, and a lack of technical expertise	Water conflicts, drainage issues, underutilization of groundwater, illegal use of groundwater, lack of professionals, limited water resources, poorly maintained infrastructure, and a lack of technical expertise	Water shortage, conflicts, sediment deposition
Water use conflicts resolution	Water committee, bylaws	Water committee, bylaws	Water committee, bylaws

4.4. Socio-economic Constraints of Rural Agriculture in Amhara Region

4.4.1. Land Use and Farming System

Sustainable land use largely associated with the dominant economic sector or the nature of economic activities carried out in the region. Although the proportion of agricultural gross domestic products is remaining high in the region, there is only a small shift in the economic activities from the agriculture sector into services and industrial sectors. Agriculture still continues as the backbone of the economy of the region. Therefore, targeted land use is necessary to enhance agricultural productivity sustainably. Unless land is expanded for agriculture activity via deforestation, which has negative consequences for the environment, land is an inelastic resource.

Land resources are predominantly crucial to the livelihood of the rural people. This is because of (i) agriculture is a purely land-based farm activities: the contribution of land to agricultural sector is greater than that of the other sectors; therefore, lack of access to land is directly correlated with the incidence of poverty in rural areas, (ii) quality of land has a direct bearing on the productivity of agriculture, which does not work for other sectors, and (iii) land ownership has also a social value serve as a security for credit, natural hazards, or life contingencies.

Table 4.47 presents diverse characteristics in population distribution and agricultural land availability in Gondar areas of the Amhara region. The average land owned is approximately 0.43 hectare of cultivated land in Adarkay woreda, indicating a relatively modest land distribution pattern. Farmers in Beyeda woreda have a slightly higher land own; actually it is about 0.84 hectares per household, suggesting a more favorable land distribution for agriculture. In contrast, the land holding of farmers in Debark district drops significantly to 0.09 hectares per household, indicating limited land availability for cultivation per household. Farmers in Wogera and Gondar zuria districts owned 0.91 and 1.05 hectares per household, respectively, indicating a moderate availability of land for cultivation. Mirab belesa presents a higher ratio of 1.29 hectares per household, indicating relatively more land per household.

In contrast, Metema stands out with a significantly higher ratio of 6.99 hectares per household, suggesting considerable land abundance per household compared to other districts. This disparity highlights varying agricultural potential and livelihood opportunities across the study area's districts, emphasizing the importance of tailored agricultural and development strategies.

Table 4.47: Land Use Distribution

Woreda	Cultivated (Ha)	Household	Cultivated land: Household
Adiarkay	10722	24,857	0.43
Beyeda	17415	20,671	0.84
Debark town	4315	45,539	0.09
Wogera	30,037	32,885	0.91
Gondar Zuria	38873	36,873	1.05
Mirab Belesa	38036	29,560	1.29
Metema	184,836.96	26,430	6.99

Source: Office of agriculture, 2024.

A mixed (crop-livestock) farming system is the dominant farming system north and west Gondar zones. Despite this, livestock rearing is the dominant economic activity in the lowland areas, while crop production is dominant in the midland and highland areas of the zones. In the study areas, most of the farmers engage on subsistence farming and their agricultural practices mainly rely on rain-fed. Farmers practice irrigation as complementary farming, with a focus on horticultural crops. Woleh, Bela, and Debrewoyla kebeles have higher irrigation potential compared to Sireal, Tsitsika, and Tsinakola kebeles. Farmers mainly use irrigation to grow vegetable and fruits, pulse and oil crops (chickpea and lentil), and cereal crops (maize and wheat) are produced in midland and highland areas.

4.4.2. Livelihood Strategies

Sustainable livelihood strategies attract the attention of both local and federal governments, as well as donors in the region. These strategies focus on the definition of sustainable livelihood, which encompasses adequate stocks and flows of food and cash, along with the maintenance or enhancement of resource productivity in the long-term. Recently, sustainable livelihood security also has attention by the policymakers. A rural household may achieve sustainable livelihood security through ownership of resources (such as land, livestock and forest), access to use communal resources (such as grazing, fishing, hunting or gathering), and stable employment with adequate remuneration or varied repertoires of activities.

It is well argued by several scholars (e.g., Chamber and Conway, 1992) that livelihood strategies comprise the capabilities and assets, including material and social resources, as well as activities required for a means of living. A livelihood is sustainable only if it can cope with and recover from stress and shocks while maintaining or enhancing its capabilities and assets both now and in the future, without undermining the natural resource base. Moreover, according to Stage et al. (2002), household livelihood security is often influenced by the household's ability to diversify its livelihood sources and assets.

This indicates that household with a greater variety of livelihood strategies and assets have a better chance of achieving secure livelihood compared to those with fewer assets. Livelihood diversification is therefore important to reducing household's vulnerability to various risks and shocks. In a household with diversified livelihood strategies, if one productive activity does not provide enough or fails, the household can rely on the other sources of livelihood.

Table 4.48 presents the major livelihood activities in the study areas, ranked according to their significance to the community. Farming is the predominant livelihood activity in these study areas, which is not surprising given the region's agrarian economy. Intitutively, farming is followed by off-farm activities. Non-farming activities are also important as they help reduce risks and uncertainties associated with agricultural failure. More importantly, they can play a significant role in enhancing productivity through the use of improved agricultural inputs. Generally, the findings reveal the multifaceted nature of livelihood strategies in the rural areas of the region.

In summary, both government and non-governmental organization should pay attention to off-farm and non-farm livelihood activities in addition to farming. Importantly, off-farm and non-farm activities not only help meet households' cash needs but also have a multiplier effect by enabling investments in agricultural activities.

Table 4.48: Major Livelihood Activities Rank

Sources of livelihoods	Ranking
Farming	1
Off-farm	2
Non-farm	3
Government employment	4

Source: Survey data, 2024

The lowland and highland areas of north Shewa have unique features compared to the two administrative zones described above in the region. Their unique features are primarily associated with sociocultural factors and resource endowments. Some of the features include clothing styles, social dignity, food habits, resources-sharing practices, and saving habits. Sand, stone, and opal are some of the resources available in the administrative zone. Given its heritage values and developed mountains, the zone has potential for tourism. The zone is exemplary regarding social inclusion, such as providing youth with access to resources, particularly communal lands, by establishing common youth group. In contrast, the concern in the zone is the less efficient use of the scarce resources.

Similar to the other administrative zones in the region, the major income source is the agricultural sector. Income generated from agricultural activities, such as farming, animal rearing and afforestation), constitute 98% of household income, while the remaining 2% comes from non-farming activities such as petty trade, wages and small industries.

Livelihood diversification here also plays a crucial role given climate change and imperfect markets. As well argued by Ellis (2000), farmers induce income diversifications due to seasonal labor use, differentiated labor markets, risk coping, imperfect credit and insurance markets, and household savings and investment strategies. For example, income generated from non-farm and off-farm activities can help overcome credit and insurance market problems. It could also provide income-earning opportunities outside the growing season, employ the household's extra labor, help in managing weather and other risks, such as eviction from their agricultural land, and ensure smooth consumption pattern throughout the year.

Most farmers are engaged in mixed crop-livestock production (see Table 4.49 below). The yield harvested from irrigation and the vegetable garden supplements the yield of cereal crops produced during the main (rainy) season. Based on the key informant interviewers and secondary data obtained from district office of agriculture, farmers are practicing irrigation due to suitability of water charge in lowland and midland agro-ecologies. However, the participation of farmers in irrigation farming is low in the highland agro-ecologies.

Table 4.49: Major Sources of Livelihoods of the Community of Wollo Areas

Sources of livelihoods	Agro-ecologies		
	Lowland	Midland	Highland
Farming (both crop and animal production)	Ranked 1 st	Ranked 1 st	Ranked 1 st
Off-farm (daily laborer)	Ranked 3 rd	Ranked 3 rd	Ranked 3 rd
Petty trade and remittance from relatives)	Ranked 2 nd	Ranked 2 nd	-
Crop and livestock selling) only	-	-	Ranked 2 nd

Source: Own FGD

Based on the findings of the FGD, there are disparities across agro-ecologies regarding keeping improved breeds. Households, in all study districts except Kalu, are more likely to keep improved breeds (dairy, sheep and poultry) in midland and highlands compared the lowland agroecology. Selling of animals and their by-products are an important means of meeting immediate cash needs of farmers. Livestock is an exchangeable asset or has better liquidity feature than other rural resources. This is because rural households can sale and meet their cash need when the cash needs arises specifically for food purchases during food shortages, farm input purchases, and medical expenses.

In addition, households are engaged on both non-farm and off-farm activities in addition to farming. In this study zone, unlike other administrative zones, non-farm activities comes a head of off-farm activities, which is associated with high youth labor mobility to abroad. In this study zone, we define non-farm activities include petty trade of crops and small ruminants in mid and highland agro-ecologies and remittances in lowland agro ecology, while off-farm activities include engaging on other farmers farming activities.

The findings reveal that farmers participate on both off-farm and non-farm economic activities. Agricultural development policies should take into accounts not only farm activities but also off-farm and non-farm activities. However, it is important to note that farming alone is not a sufficient livelihood strategy for many farming households.

Interestingly, farmers invest the cash generated from off-farm and non-farm activities in farm inputs that increase agricultural productivity, indicating their multiplier effect. Therefore, these policies should focus on the entire spectrum of farming, off-farm and non-farm activities. Designing and implement policies in a way that will impact the performance of these activities positively is far-reaching rural development approach for improving the wellbeing of rural people. For example, ensuring access to credit and avoiding sever problems of credit constraints can help to flourish rural business, ultimately making agriculture resilient to climate changes.

Similar to Gondar areas, farm communities in Sekota areas diversify their livelihood sources. Their livelihood diversification could be enterprise diversification or participation in off- and non- farm activities. The results in Table 4.50 show that majority of farm households depend on mixed farming, followed by off- and non- farm activities.

Even though there is high diversity in important enterprises, the major livelihood sources in the farming activities were crop production and livestock (cattle, small ruminants, beekeeping, and poultry) and off-farm activities. The crop production activities are dominant in midland and highland agro-ecologies, while livestock production especially small ruminant (sheep and goat) production is dominant in lowland agro-ecologies.

Table 4.50: Rank of Livelihood Sources in Sekota Areas

Source of livelihood	Percentage	Rank
Farming activities	100%	1 st
Off or non-farm activities	55%	2 nd

Source: Survey data, 2024

4.4.3. Wealthy Status

Wealth reflects control over resources. Household wealth plays a crucial role in determining the resilience of both individuals and nations to any type of shock (Global Wealthy Report, 2022). It has the capacity to reduce vulnerability to shocks such as unemployment, ill health, natural disasters, or a pandemic. The holistic indicator of economic progress - Inclusive Wealth Index (IWI), combines natural capital, produced (manufactured) capital and human capital stocks, to provide an overall picture of the productive base of countries.¹ Putting a price on these assets with multiple benefits allows us to measure a country's real wealth – its true well-being (UN, 2023).

The contextualized indicators for different wealth categories highlight significant disparities in access to resources. Households are identified as rich by society when they have more than 20 cattle, a retail shop, a motor vehicle, and a permanent house with cement walls. In addition, their children attend school, and they provide balanced nutrition to them. Households categorized as moderately rich have sufficient resources, but these are smaller than those of the rich. They own 2-3 hectares of land, a motorcycle, and 3-5 cattle, with children attending private schools and enjoying three meals a day.

In contrast to the moderately rich and rich households, poor households have limited assets. Some own only a small plot of land, living in mud houses, and struggling to provide one or two meals a day for their children. Very poor households face severe deprivation, being landless, homeless, and lacking necessities like proper clothing and bedding. Their children often do not attend school due to financial constraints. The households rely on casual labor with no steady income, leading to challenges in accessing healthcare and medications.

Similarly, as per the perception of the community in Wollo, households are categorized into different wealth categories, depending on livestock ownership, land ownership, and bank deposits. In addition to livestock and land ownership in the lowland agronomy, remittances from abroad (Saudi Arabia) were identified to be the key indicator to categorize farmers in different wealth strata. In the context of lowland agro-ecology districts, households categorized as relatively well-to-do (rich) are those that own more than 7 cattle with a pair or more of oxen for farm operations, about 20 goats and liquid assets at the bank exceeding birr 300,000 (Table 4.52).

¹ Produced (also called manufactured) capital refers to investment in roads, buildings, machines, equipment, and other physical infrastructure. Human capital comprises knowledge, education, skills, health, and aptitude. Natural capital includes forests, fossil fuels, fisheries, agricultural land, sub-soil resources, rivers and estuaries, oceans, the atmosphere, and ecosystems more generally.

Table 4.51: Rank of Livelihood Sources in Sekota Areas

Indicators	Assets	Education	Nutrition	Other
Rich Household	- >20 cows (with good management) - Owns retail Shop - Permanent house (Cement walls) - 10 hectare of land - Have deposit account	- All children in school	- All members Have balanced diet	- Employs others - Job with pension - Has good Business
Moderately rich Household	- Owns 2-3ha of land - Semi-Permanent house (with iron sheet roof) - 3-5 cows - Multiple sets of clothes	- Children can attend private school	- Eat 3 meals per day	-Owns a business
Poor Household	- Small plot of land - Mud house - One bed - Food security problem	- Can only afford Government schools - Not all children attend - Children drop Out after primary School	- Can only afford one meal or two Meals per day - high nutritional security problem	-Household head cultivates for someone else
Very poor Household	- Household is landless - Does not own their home - Grass thatched roof - No mattress - No bedding - High food security problem	- Children not in School - Cannot afford School fees	- Can only afford one meal per day - High nutritional security problem	- Casual labor -No steady income - Cannot afford Medications -Cannot afford Medical care

Source: Survey data, 2024

These wealth indicators exhibit differences in the case of midland farmers, who have pairs of oxen, two milking cows, 5 to 20 sheep and/or goats, and bank deposit exceeding birr 100,000, classifying them as a well-to-do (rich) (Table 4.52). Households in highland areas who own one to two pair of oxen for farm operations, two milking cows (at least one of them must be cross breed cows), one riding mule or horse, about 20 sheep, and one grind mill or house in an urban center are considered rich household (Table 4.52).

The farmers perceive that owning large livestock ensures high production of grain and livestock products such as milk and butter. This implies that they can afford to purchase agricultural inputs and often interested to trying new technologies. They are food secured and often frequently diversify their income sources. To achieve this level of wealth, they adopt various practices, such as the use of small-scale irrigation, sending their daughters abroad for remittance in the lowland and midland areas, and producing hybrid onion and green pepper varieties for the market in lowland agroecology.

Demonstrations of new agricultural technologies enable farmers to experiment risky and uncertain innovations. Model farmers are volunteers willing to host new technology experiments. Moreover, they interested to apply full packages of new technologies.

Even though there could be variability from district to district, the proportion of rich households is on average 10%, 5%, and 15 % in lowland, midland, and highland agro-ecologies, respectively. The proportion of rich households in highland agroecology is slightly higher than the other two agro-ecologies. This is primarily associated with the land fertility, weather condition and agricultural inputs supply. For example, Werilu district has a better land fertility, given relatively suitable weather conditions for agricultural activities and sufficient agricultural inputs supply.

Table 4.52: Wealth Status of the Study Districts on Lowland Agroecology of Wollo Areas

Wealth category	Livestock ownership	Land ownership	Other livelihood factors	Proportional pilling tool
Rich	- 7 or more cattle out of which 2 paired oxen and 3 milking cows - 20 and above shoats.	- Large size of own land (3-4 ha) out of which 0.375-0.5 ha irrigated own land	- Bank saving (300,000 ETB & above) - Own house in urban centers - Produced cash crops.	About 10%
Medium	- One pair of oxen and one –two cows - Less than 10 shoats (5 goats and 5 sheep)	- Medium size of own land (0.75-2ha)	- Participated in off farm IGA (animal and retail crop trading)	About 40%
Poor	- One and below ox - Three and below shoats	- 0.25-1ha of own land but it is either rented out or shared out	- Engage in daily laborer - Participated on working for food	About 50%

In the context of lowland agro-ecology, farmers who are under medium wealth category often own pair of oxen and one milking cow. Apart from agricultural produce, they also strive to generate supplementary incomes through non-farm activities, such as petty trading of small ruminants and crop (Table 4.52). During a normal agriculture year, they produce food for their home consumption, and the surplus they produced is supplied to the market to generate income for purchasing agricultural inputs. However, they are vulnerable for adverse agro-climatic conditions and cannot absorb shocks.

Based on contextualized wealth indicators presented in Tables 4.52, 4.53, and 4.54, households in the medium wealth group account for approximately 40%, 48%, and 49% of the population in lowland, midland and highland agro-ecologies, respectively.

Table 4.53: Wealth Status of Study Districts on Midland Agro-ecologies

Wealth category	Livestock ownership	Land ownership	Other livelihood factors	Proportional pilling tool
Rich	- Paired oxen and 2 milking cows - 5 or 20 shoats.	- 1.5-2 ha of own land	- Bank saving 100,00 and above - Owned house in urban centers - Produced cash crops	About 5%
Medium	- One ox and one cow - Less than 5 shoats	- 0.75-1ha Own land	- Participated in petty trading	About 48%
Poor	- One or zero ox - Two or below shoats	- ≤ 0.75 ha of land but it is either rented or shared	- Engage in daily laborer - Participated on working for food	About 47%

On the other hand, the resource-poor households account for approximately 50%, 47% and 36% of the population in lowland, midland and highland agro-ecologies, respectively (see Tables 4.52, 4.53, and 4.54). Unlike to the medium and rich households in terms of assets, poor households do not own an ox or other necessary resources for farming activities. Because of this, they contract out their farm land either through crop sharing or rental agreements. They mostly rent out their farmland for a year. The important point that attracts the attention of policymakers and doors is that poor households struggle to meet their annual food demand and often run out of food for five months each year. Hence, they seek government-supported programs and borrow both cash and in-kind support from their relatives.

Table 4.54: Wealth Status of Study Districts on Highland Agro-ecologies

Wealth category	Livestock ownership	Land ownership	Other livelihood factors	Proportional pilling tool
Rich	- 1 to 2 paired of oxen and 2 milking cows (cross breed) - 20 and above sheep - Riding mule or horse	- 1-1.5 ha of own land	- Grinder mill - House in urban centers - Diversified income sources	About 15%
Medium	- One to two oxen, one milking cow - Less ≤ 5 sheep	- 0.75-2ha own land	- Participated in petty trading	About 49%
Poor	- ≤ 1 ox - ≤ 3 sheep	- ≤ 0.5 ha of land but it is either rented or shared	- Engage in daily laborer - Participated on working for food - Seasonal migration for working	About 36%

In the case of Wag-Himra zone, even though the administrative zone has plenty of economic resources, the community is still in poverty and is known for internal migration and malnutrition in the region. To offset the effects of regular food shortage, people rely on a combination of waged labor, petty trades, food aid, and seasonal migration to make up their household food basket deficit. The other coping strategies of farmers have been stretched to the limit by the need to meet household food and non-food requirements.

Based on the data from the FGD, the criteria used to categorize the wealth status of the community are livestock ownership of the household, land ownership, amount of yield produced covered his family consumption throughout the year, amount of money saved, having the house in the towns and property/asset ownership are the major criteria to level the community wealth status. When we see livestock ownership, the farmer who has more pairs of oxen, cows, sheep and goats, mules or horses is the major indicator of leveling.

Table 4.55: Indicators of Wealth Category in the Sekota Areas

Wealth category	Livestock ownership	Land ownership	Other livelihood factors
Rich	- Higher flock size of animals - More than a pair of farm oxen - Having mules/horses	- Higher land holding > 2.5 ha	- Surplus crop production - Higher income from off/non-farm
Medium	- Medium flock size of animals - Having at least one farm oxen	- Medium size of land holding 1.5-2.5 ha	- Produced grain yield covers at least yearly family consumption
Poor	- Have no animals	- Lower size of land holding - Even they cannot plow their farmland due to a lack of farm oxen	- Lower yield production and depend on aid - No other sources of income

4.4.4. Agricultural Inputs Application

Over the past two decades in Ethiopia, policymakers have pursued a range of policies and investments to boost agricultural productivity, focusing on staple crops, which are crucial for poverty reduction. The central aim of this policy strategy is to boost agricultural productivity by increasing availability of improved seed, chemical fertilizers, and advisory services for small-scale and resource-poor farmers. State-led policies to promote improved seed, chemical fertilizer and advisory services initially has positive impacts on agricultural productivity in the country. However, this public led approach has adverse impact on the quality of input services and public budget (David et al., 2011).

Currently, several challenges affect the availability and affordability of agricultural inputs and services. These challenges are high inputs and labor costs, lack of supply of quality inputs, lack of timely supply of inputs, and shortage of inputs. Seeds obtained from both markets and research institutions face issues related to quantity, timely delivery, and high prices, which hinder farmers' ability to acquire the necessary inputs for planting. Similarly, fertilizers sourced from markets and agricultural offices encounter challenges regarding volume, timely delivery, and high prices, impacting soil fertility management. Additionally, agro-chemicals from markets face quantity issues, potentially affecting pest and disease management.

Animal feeds encounter challenges in quantity, timely delivery, and high prices, affecting animal nutrition and health. Inputs for bee production sourced from agricultural offices are susceptible to problems related to diseases and forage availability. Fishery production inputs suffer from a lack of availability, limiting the expansion of this sector. Access to agricultural lime, which is crucial for soil reclamation, faces challenges. Lack of availability of machinery limits mechanization and efficiency of farmers. These challenges highlight the complexity of input supply chains and the need for targeted interventions to ensure farmers can access affordable and timely inputs to enhance agricultural productivity.

In lowland, midland and highland areas of north Shewa zone: the government through cooperatives, private sector, the community and non-government organization (NGO's) participate in the agricultural input production, distribution and marketing activities.

Table 4.56: Major Sources of Agricultural Inputs in Gondar Areas

Type of inputs	Sources	Related problems (price, quality, quantity, time of delivery)
Labor	Market	High payment price
Seeds	Market and research	Quantity, time of delivery, high price
Fertilizers	Market and agricultural office	Quantity, time of delivery, high price
Agro-chemicals	Market	Quantity
Machinery	No availability	-
Feeds	Market	Quantity, time of delivery, high price
Bee production inputs	Agricultural office	Disease, forage problem
Fish production inputs	No availability	
Agricultural lime		

Source: Survey data, 2024

In the lowland of the north Shewa zone: The government facilitates the distribution of chemical fertilizers, improved seeds, agro-chemicals and provides training to smallholders, as well as mobilize communities specifically for natural resource management. The private sectors supply the required agro-chemicals, improved seeds, and farm implements. The community institutions supply credit, chemical fertilizers, agro-chemicals, and improved seeds. NGOs help the farmers by providing training, technology, seedlings, farm implements, livestock breeds, and improved seeds.

Banks and microfinance are the main financial institutions, which provide both credit and saving services. Banks provide only saving services for farmers, while microfinances provide both credit and saving services for farmers. The regular rural cooperatives provide credit services for farmers in both cash and in-kind (agricultural inputs) form, while NGOs provide revolving funds for specific activities.

In the midland and highland of the north Shewa zone: The government is both provider and facilitator of chemical fertilizers, agro-chemicals, farm implements, improved seeds, seedlings, improved animals (poultry), and training. The private sector providers are providing chemicals, vegetable seeds, and seedlings. The community institutions provide fertilizer, chemicals, improved seeds, and farm implements. NGOs also have a role in the provision of improved animal breeds, forages, vegetable seeds, and training services.

As described above, farmers obtain credit and saving services from financial institutions, particularly from banks and microfinance. The important point that needs future policy interventions is that farmers have opportunity to get credit only from microfinance. The problem regarding microfinance is that they do not provide sufficient credit for farmers, causing credit constraint problem. This is because banks provide only saving services to rural people, or do not provide credit services to smallholder farmers.

Like other areas of the region, understanding the existing institutional services, such as extension services, input supply services, and credit and saving services in Wollo areas of the region has significant importance in designing effective interventions. Many NGOs are found in the study district, primarily focus on relief. Few NGOs such as IFAD, SNV, ISD and ORDA undertake development of infrastructures), advisory services and input supply. Sirinka Agricultural Research Center (SARC) is the major supplier of starter seed in the eastern Amhara region. In addition to SARC, Woreda office of Agriculture (WOA) through cooperatives, Woldia University, Wollo University, SNV, ISD, and IFAD are the major input suppliers through the extension program. Credit is mainly supplied by Tseday Bank Services - the former Amhara Credit and Saving Institute (ACSI). The viability of credit services for rural poor farmers is still not convincing. Regarding agricultural extension services, crop, livestock, and natural resource management packages are demonstrated to smallholder farmers. However, their technology adoption and they are not as successful as the rest part of the highlands due to recurrent rainfall failure. In general, the lowland farmers are relatively in a worse position about input use.

Major sources of agricultural inputs

Agricultural inputs are any materials, resources or services used in agricultural production processes to facilitate crop cultivation, livestock management, and overall farm operations. By leveraging a combination of these inputs, farmers can enhance their agricultural productivity and improve livelihoods, ultimately contributing to food security and economic development (Spielman et al., 2013). Specifically, agricultural inputs essential for agriculture production include improved seeds, chemical fertilizers, agro-chemicals (pesticides and herbicides), irrigation facilitates, skilled and unskilled labor, animal feeds, beekeeping equipment, fishery production inputs, and advisory services.

In the study districts, public enterprises, cooperatives and private traders hold the major proportion of pesticide distribution. Among these pesticide suppliers, as the focus group discussant mentioned, many farmers purchase agro-chemicals from private traders and hence they perceived private trader as the major actors of the agro-chemicals suppliers, including herbicides.

Table 4.57 shows cooperatives are the dominant distributor of improved seeds and chemical fertilizers. In this in-depth constraint assessment, we measure the major sources and distribution of seeds using proportional pilling (percentage) in the study districts. Own saved seeds took the lion's share of seed sources. About 97% farmers used their own saved seeds and they recycle for many years (or substitute after many years). On the other hand, private sector actively participates in supplying animal feeds and farm machinery.

Table 4.57: Sources of Agricultural Inputs and Related Problems in Wollo Areas

Type of inputs	Sources	Related problems
Labor	- Own (Family) - Private(market)	- High price (400birr/man/day)
Seeds	- Own - WOA - Cooperative - SARC - NGO	- Not delivered at the right time - Limited amount of supply - Mismatch with demand
Fertilizers	- Cooperative	- Not delivered at the right time - Price is not affordable due to illegal trading (NPS=7000 birr/qt, UREA=6000birr/qt)
Agro-chemicals	- Private (market)	- High price - Traders have not experienced about the usage (level)
Machinery (tractor)	- Private (market)	- High price (1 birr/m ²)
Feeds	- Private (market)	- High price (2400 birr/qt) - Low quality
Bee production inputs	- Office of Agriculture	- Not delivered at a right time - Limited amount of supply

In the Sekota areas, government agricultural offices, cooperatives, research centers, NGOs, and private sectors (traders) primarily provide agricultural inputs. Agriculture offices serve as crucial providers of extension services to farmers, facilitating access to seeds, fertilizers, animal health drugs, and other inputs and in addition often providing technical support and advisory services to farmers. They collaborate with cooperatives to distribute fertilizer inputs. Private sectors also play a pivotal role by distributing agricultural inputs such as seeds, animal feeds, and pesticides. Agricultural cooperatives significantly contribute to negotiating prices and collectively purchasing inputs at reduced costs.

Additionally, NGOs and development agencies implement programs aimed at enhancing agricultural productivity by supplying inputs, delivering training, and technical support, and offering support to smallholder farmers. Furthermore, agricultural research centers develop improved crop varieties, agricultural technologies, improved forage, agronomic practices, technical advisory services, training for farmers and experts, and technical manuals that contribute to the advancement of agricultural inputs, thereby bolstering overall agricultural development in the region.

Table 4.58: Type, Sources, and Major Constraints Related To Agricultural Inputs in Sekota Areas

Type of inputs	Input Sources	Related problems (price, quality, quantity, time of delivery)
Labor	- Own family and hired	- Wage increment of hired labor
Seeds	- Agriculture office	- Poor improved seed supply
	- NGOs	- Lack of not demand driven improved seeds (especially distributed by NGOs)
	- Research centers	- Late delivery of improved seed
	- Own seed/themselves	- Poor quality seeds
	- Private/mostly exchange from their neighboring farmers and purchasing from markets	- Poor access and availability of improved seeds
Fertilizers	- Agriculture office	- Higher price of fertilizer
	- Research centers	- Poor supply of fertilizer
	- NGOs	- Late delivery of fertilizer
Agro-chemicals	- Private sectors /traders	- Poor access and availability of agro chemicals
		- Higher price of chemicals
		- Quality is not guaranteed/expired chemicals
Feeds	- Agriculture office (forage seeds)	- Poor access and availability of improved forage seeds and concentrate feeds
	- Research centers (forage seeds)	- Higher price of concentrate feed
	- Own crop residues and hay	- Poor awareness and skill of farmers
	- Private traders (concentrate feeds)	- Lack of access and availability of beekeeping equipment and materials
Beekeeping inputs	- Agriculture office	- Input supply focused only on targeted groups rather than the whole beekeepers
	- NGOs for targeted groups like youth groups and women	- Higher price of inputs like wax, hive
	- Private sectors (traders)	- Poor technical support about input use

Source: Survey data, 2024

4.4.5. Agricultural Extension Services Provision

Agricultural extension program promotes the advisory services, improved seed and chemical fertilizers to boost agricultural productivity. To facilitate on-hands experiences, Farmer Training Centers (FTCs) has been established, with three Development Agents (DAs) specialized in different disciplines. They provide a broad range of demand-responsive extension and short-term training services. In the region, the delivery of agricultural extension services to smallholder farmers is public dominant. Although DAs recruitment and training has largely successful, FTCs are still not fully functioning.

In Gondar areas, as shown in Table 4.59, agricultural experts deliver extension services for different commodities such as crop production extension services, livestock production extension services (including health care), and natural resource management and conservation extension services. However, access to marketing information and access to credit for agricultural production are not successfully delivered to farmers in the study area.

Farmers have unequal access to extension services for various commodities, which varies across different types of services. Extension services focusing on crop production are accessible and facilitated by agricultural offices. These services include advisory services on crop type and variety, cultivation techniques, and pest management. Additionally, extension services on livestock production and animal health care are accessible through agricultural offices, indicating the government's focus on livestock production in addition to crop production.

On the other hand, marketing services, such as access to market information, and other related extension services, which are essential for connecting farmers to markets and improving their income, are not accessible to them. This lack of access may hinder farmers from obtaining essential market information and selling their produce at competitive prices.

Moreover, the lack of access to credit for rural households is a significant constraint on agricultural production. This lack of access to financial services may inhibit farmers from investing in their farms, particularly in acquiring improved seeds and chemical fertilizer, and withstanding shocks due to adverse climate changes.

In summary, although agricultural extension services focusing on crop and livestock production are accessible to smallholder farmers through agricultural offices, there are gaps in agricultural-related services, such as access to financial and market information services. These are crucial for enhancing the productivity and welfare of smallholder farmers.

Table 4.59: Agricultural Extension Service in Gondar Areas

Type services	Access (yes/no)	Service providers
Crop production extension services	Yes	Agricultural offices
Marketing and other related extension services	No	-
Livestock production and animal health extension services	Yes	Agricultural offices
Natural resource management and conservation extension services	Yes	Agricultural offices
Access to credit for agricultural production	No	-

Source: Survey data, 2024

In north Shewa, farmers can have access to training technology packages for fertilizer application, row planting of teff and sorghum, weed management, tillage frequency, and irrigation water use in a group-based arrangement through the office of agriculture. The training modules are distributed through Farmers Training Centers (FTCs) and community-development groups. Development agents distribute leaf lets to individual farmers during farmers' field day and training. The main extension system is designed for agricultural activities, while various farmers groups, such as one-to-five groups and development groups, focus on other development interventions.

Access to marketplaces varies across different agro-ecologies. In the lowland areas, household have access to many markets, with around 10 markets, two of which are semi-structured. The number of marketplaces in highland areas is estimated to be around 5, which is lower than the lowland areas but higher than in the midland areas, which have approximately 3. Despite this, the marketplaces in these areas are small and not well-developed.

In the region including Sekota areas, the establishment of Farmers' Training Centers (FTCs) serves as a cornerstone for agricultural development and capacity building among rural communities (Woldu et al., 2016). FTCs offer a range of training programs covering diverse aspects of agriculture, including crop cultivation, livestock management, natural resource management, irrigation, and pest and disease management. By delivering on-hands extension services, they enable to enhance agricultural productivity and promote sustainable rural livelihoods (Muzadzi, 2013).

Agricultural extension is an institutional factor that affects agricultural production in the study areas. The agricultural extension employs FTCs as an approach to provide evidence based extension services to smallholder farmers. Development Agents from the Office of Agriculture, along with universities, research institutions and non-governmental organizations, conduct experiments on FTCs to generate site-specific evidence for policymakers and practitioners. Farmers involved in the experiments through process-based demonstrations and field days benefit by learning from the practices demonstrated. Based on the FGD in all study areas, almost all households' have access to extension services on crop production and natural resource management, however only 33.33% and 50% of them have access to extension service on marketing and livestock production, respectively.

From the FGD, we find that most of the farmers obtain advisory services from development agents from the Office of Agriculture (95%), researchers from the national research system (3.25%), and scientists from the international research organizations (1.75%) in the study areas.

Table 4.60: Access to Extension Service and Credit Service in Sekota Areas

Questions	Response	Frequency	Percentage
Have you extension service access to crop production	Yes	6	100.0
	No	-	-
Have you extension service access to marketing	Yes	2	33.3
	No	4	66.7
Have you extension service access to livestock production	Yes	3	50.0
	No	3	50.0
Have you extension service access to NARM	Yes	6	100.0
	No	-	-
Have you extension service access to credit service	Yes	1	16.7
	No	5	83.3

Source: Survey data, 2024

Wag-Himra zone has about 109 FTCs and 620 development agents specialized on plant science, natural resource management and livestock production serving as platforms for knowledge exchange, networking, and community engagement that fostering collaboration among farmers, extension workers, and agricultural experts. Sampled districts take 45.87% (50) and 55.32% (343) of FTCs and DAs from zonal resources, respectively. Gazgibla and Sekota districts cover 12.84% and 21.1% of FTCs, and 21.61% and 19.35% of development agents, respectively, while the remaining is covered by Ziquala district. Based on the zone office of agriculture report 2023, at zonal level, DA to farmer ratio is 1DA for 196 household heads and 1 to 1180 people for the total population.

Table 4.61: Number of Development Agents (Das) In Wag-Himra Zone and Sampled Districts

Disciplines	Professions	Wag-Himra zone	Study districts				
			Sekota	Gazgibla	Ziquala	Total	%
Crop production	DAs	128	27	31	16	74	57.81
Livestock production	DAs	124	16	22	15	53	42.74
Natural resource management	DAs	162	28	42	28	98	60.49
Cooperative	DAs	58	16	3	9	28	48.28
Irrigation	DAs	38	5	9	7	21	55.26
Animal health	DAs	137	28	27	14	69	50.37
Total		620	120	134	89	343	55.32

Source: Wag-himra zone, Sekota, Gazgibla and Ziquala districts reports, 2024

In Sekota areas, demand-driven agricultural technology refers to the development and adoption of agricultural technologies based on the specific needs and requirements of farmers and the market. Instead of creating technologies and then trying to find a use for them, demand-driven approaches involve identifying the challenges faced by farmers, understanding market demands, and then developing technologies that address these specific needs.

This approach aims to ensure that agricultural innovations are relevant, practical, and effectively meet the needs of farmers and the market, ultimately leading to increased productivity and sustainability in agriculture.

According to the FGD and key informant interview participants, the status of accessibility and availability of demand-driven agricultural technologies in livestock rearing, crop production, and natural resource management (Table 4.62) shows that responses regarding the availability and accessibility of demand-driven agricultural technologies 37.5% of the total respondents rated the availability and accessibility as "Medium" and 62.5% of respondents rated as "Poor" availability and accessibility. This indicates that the majority of respondents perceive the availability and accessibility of demand-driven agricultural technologies as poor.

Table 4.62: Accessibility and Availability of Demand-Driven Agriculture Technologies in Sekota Areas

Question	Answers	Frequency	Percentage
Availability and accessibility of demand-driven agricultural technologies	Good	-	-
	Medium	3	37.5
	Poor	5	62.5
	Total	8	100.0

Source: Survey data, 2024

Extension services and uptake of improved technologies of the community: The investment in extension systems in Ethiopia is low, which can negatively affect adoption and intensity levels. On the other hand, different scholars suggest that the adoption of new technologies among Ethiopian farmers, such as improved seed varieties and agricultural practices, is on the rise.

The Table 4.633 presents the results of a survey conducted on the use of community extension activities and technology in a particular community. As shown in the table, approximately 50% of the respondents reported a low uptake level of community extension activities.

In the case of technology, the majority of respondents (76.9%) perceived an increasing rate of technology adoption, while only a small proportion (23.1%) believed there was no change. Finally, in terms of the intensity of adoption, around 69.2% stated that the adoption was increasing. Although propensity and intensity of adoption of agricultural technologies shows increasing trend, there is also higher rate of dis-adopting of technologies in the study areas.

Table 4.63: Summary of Extension Uptake of Farmers and Their Adoption Status in Sekota Areas

Question		Frequency	Percentage
Status of the community extension uptake	High	1	16.7
	Medium	2	33.3
	Low	3	50.0
	Total	6	100.0
Rate of technology adoption	Increasing	10	76.9
	No change	3	23.1
	Decreasing	-	-
Intensity of Adoption	Increasing	9	69.2
	No change	2	15.4
	Decreasing	2	15.4

Source: Survey data, 2024

In summary, the major constraints in the adoption of new technologies by farmers are:

- ✗ Poor attitude and perception among farmers regarding new technologies
- ✗ High level of dependency syndrome in which farmers link these technologies with aid and inefficiency of their farming activity
- ✗ High dis-adoption rate among farmers
- ✗ Current situation forced extension agents and experts to allocate their time out of their professions instead of working their planed jobs
- ✗ Despite the presence of the research center (SDARC) in the study areas and the released numerous technologies, some stockholders choose to deliver other technologies developed and released by other research centers for other agro-ecologies instead of the intended recipients. This leads to failure and ultimately minimizes farmers' confidence in the technologies that have been developed and released
- ✗ Weak linkage of stockholders working in the sector: as the data from key informants indicated, especially the linkage between NGOs and agriculture offices is very weak, except for some NGOs like Healvetas and ORDA Ethiopia
- ✗ Poor access and availability of agricultural technologies
- ✗ Lack of improved crop varieties, E.g., pulse crops (faba bean, field pea, and lentil) and cereal crops (barley and sorghum)
- ✗ Higher price of agricultural inputs
- ✗ Similar recommendations of technologies for low land to highland agro-ecologies eg, similar fertilizer rate
- ✗ Technologies delivered by NGOs not consider the agro-ecology differences and farmers' interest (not demand driven).

4.4.6. Social Institution

The study area is characterized by a variety of social institutions that play important roles in the community. Cooperatives are a prominent feature of society. One public cooperative has been identified, serving as an important economic entity that facilitates collective action and resource pooling among members in the rural areas of the region. Another important social institution is Edir, which often plays role in social and cultural affairs. It provides support during unforeseen situations and organizes community events, serving as a coping mechanism for shocks.

Ensuring access to health services to smallholder farmers and their animals has implication for labor, farm and livestock productivity. Similarly, access to schools has long-term effects on labor productivity. In the study areas, there are six public schools, one public human health center, and one public animal health center. In contrast, private institutions, such as agro-processing companies, and input suppliers are not represented in the study area. Their absence could potentially hinder the growth of the agricultural sector. Therefore, these sectors present potential areas for private investment to complement the existing public institutions.

Table 4.64: Availability of Institutions (Social, Public, and Private) in Gondar Areas

Social institutions	#	Public institutions	#	Private institutions
Cooperatives	1	FTCs	1	Agro-processing companies
Ekub	-	Animal health centers	1	Private animal health clinics
Edir	3	Schools	6	Input suppliers
		Human health centers	1	Others
Others		Financial institutions		
		AI service		

Source: Survey data, 2024

Table 4.65 presents the infrastructure status of the study districts in Gondar administrative zone of Amhara region. The districts vary in their levels of infrastructure. For example, access to marketing centers is relatively high in Adiarkay, Debark, Wogera, West Belesa and Metema districts. It ranges from 9 (West Belesa) to 21 (Metema) centers.

In terms of irrigation facilities, Debark and Gondar Zuria districts have the lowest levels compared to Wogera and West Belesa districts (see Table 4.65). Surprisingly, although Metema district has ample potential for irrigation, it lacks any irrigation facilities, which could negatively affect water and land productivity. In the case of road infrastructure, Debark districts leads with five all-weather roads, while Wogera and Adiarkay districts are more prevalent in seasonal roads. Except Metema, which has more than 18 telecommunication facilities, all other study districts have only one telecommunication facilities.

Electricity access is notable in Metema and Gondar Zuria districts, with 15 and 8 facilities respectively. Adiarkay and Metema districts have high clean water access. In contrast, Debark, Wogera, Gondar Zuria and West Belesa districts lack access to clean water, which negatively affects the health of farmers and ultimately impacts farm productivity. In summary, the infrastructure inventory highlights the presence of significant disparities in infrastructure levels across the study districts. For example, while Metema district show high levels of specific infrastructures such as marketing centers, telecommunication facilities, and electricity, it lacks irrigation facilities and access to clean water.

Table 4.65: Infrastructure in Gondar Areas

Infrastructure	Adiarkay	Debark	Wogera	Gondar Zuria	West Belesa	Metema
Marketing centers	2	2	9	5	9	21
Irrigation facilities	3	1	5	9	16	0
All-weather roads	2	5	6	3	2	6
Seasonal roads		5	0	7	4	2
Telecommunication facilities	1	1	1	1	1	18
Electricity facilities	1	1		8	1	15
Clean water	18	0	0	0	0	16

Source: Survey data, 2024

Inflation of the prices of inputs: Both the key informant and FGD results showed that high and continuously rising prices of agricultural inputs are the major constraints that hinder increased farm productivity. In the worse-case scenario, for example, the prices of chemical fertilizer, agrochemicals, commercial animal feeds, and improved crop seeds exceed the purchasing power or affordability level of many farmers. Specifically, the discussants mentioned that the prices of these inputs increased by more than double in the last five years.

Poor input distribution channel of inputs: In addition to shortage of inputs such as improved crop seeds, chemical fertilizer and agrochemicals, poor input distribution channel of inputs for these inputs, especially chemical fertilizers for smallholder farmers, result in high prices. Apart from poor input distribution, illegal fertilizer marketing and the selection problems faced by chemical fertilizer users make input marketing complex. Regarding the identification of actual fertilizer demand by farmers, those who have not cultivated land and even those who have not participated in crop production, but are residents of the kebele take the fertilizer and sell it at the local market. However, the actual fertilizer demanders cannot access fertilizer at a reasonable price through kebele-level cooperatives. Due to this market failure, farmers, especially the poor, cannot access and afford chemical fertilizers. Another problem is that the amount of inputs - such as chemical fertilizer, agrochemicals and improved seeds - supplied to farmers is below the required levels. This leads farmers to purchase inputs that are of low quality, particularly horticultural crop seeds.

Lack of input supply preferred by farmers: The third constraint mentioned by FGD's discussant is the lack of input supply preferred by farmers. In detail, there is a difference between what the farmers' prefer and the inputs supplied by the research institutions and input suppliers. For example, most farmers demand improved sorghum varieties that produce high-quality injera and high biomass yields. However, the sorghum varieties delivered to farmers are short-maturing, with low injera quality and low biomass yields for animal feed.

Table 4.66: Available Institutions in Wollo Areas

Type of institution	Units	Raya kobo	Kalu	Dawa chefa
Cooperatives	Number	10	11	7
Cooperative to kebele ratio	Proportion	1:5	1:3	1:4
FTC	Number	40	31	12
Animal health centers	Number	27	23	22
FTC own kebeles	Percent	88.9	88.57	46
Ikub/rotating saving	Number	150	140	-
Idir/kire	Number	225	200	160

Multipurpose cooperatives

The primary aim of the multipurpose rural cooperatives is to improve agricultural input and output marketing. They purchase agricultural products from their member when the price of grain are low and then sell them when the prices are high, ultimately providing dividends to their members. In addition, cooperatives supply improved crop seeds and chemical fertilizers to smallholder farmers, contributing to increased farm productivity.

Given this purpose, individual farmers should have access to rural cooperatives at least in their kebele. However, in the study districts, there are kebeles without multipurpose cooperatives. As a result, farmers forced to go to other kebele to access cooperative services. A specific multipurpose cooperative provides services to farmers from 3 to 5 kebeles. For example, one multipurpose cooperative in Kalu, Dawa chefa and Raya Kobo districts provides serves to farmers from 3, 4 and 5 kebeles, respectively. Of course, this potentially reduces the operational costs, allowing farmers to access services at a relatively low cost.

During the FGD, farmers revealed that the multipurpose cooperatives are sidetracked by other activities instead of focusing on the primary objectives. This results in inefficiency in supplying sufficient agricultural inputs - such as chemical fertilizer, improved seeds and agro-chemicals, and consumer goods. Another concern is that cooperatives have limited human and financial capacity to collect grain from their members.

Farmers Training Centers (FTCs)

FTCs were established to facilitate the provision of demonstration-based extension services and learning among farmers. Although FTCs are not operating to meet their intended objectives, it was reported that 89%, 88% and 46% of FTCs in Raya kobo, Kalu and Dawacheffa districts, respectively, are functional for demonstration of agricultural technologies to smallholder farmers.

In each kekbele, there are three to four specialist Development Agents (DAs), specialized on plant science, natural resource management, animal science and irrigation management. For example, there are 172, 111 and 94 DAs in Raya kobo, Kalu and Dawacheffa districts, respectively. These districts DA to farmers' ratio are 1:506, 1:523 and 1:432, respectively. Despite this, it was reported that DAs have little experiences to demonstrate best practice innovations in the FTCs.

Besides to lack of technical skills to operate FTCs, lack of budget is the bottleneck to function the existing FTCs. It was also observed that the majority of FTCs have no operating equipment or inputs to pursue typical extension activities on demonstration farms. Additionally, due to urbanization, FTCs (example Dawacheffa district) face land ownership problem. Finally, the overall field-level system is often limited and constrained in its ability to meet farmer needs and demands. It was also perceived that the extension service was mostly skewed to crops with very limited attention for livestock.

In summary, the findings indicate that FTCs are not fully functional mainly due to a lack of adequate resources such as extension facilities. The budget allocated to FTCs is also meager to meet their intended objectives. The possible solutions rose during the focus group discussions include cost-sharing and revenue-generation to strengthen FTCs. Another suggested solution is to enhance DAs' technical skills through experience sharing with model sites.

Informal sector: *Iquib* and *Idir*

Iquib is an association that can be established by a small group of people, aimed at collecting money from the members and then providing it to individual members in a rotating basis. Such associations focus on enhancing the economic well-being of the individuals and the communities, particularly to improve the livelihood and living conditions of those in poverty. *Iquib* can address the financial market failures in terms of collateral, as well as high mentoring and enforcement costs. Organized in voluntary-basis, anyone can become a member as long as they can pay the weekly or monthly contributions, leading to the formation of several *Iquib* in each district.

They provide the money collected from individual members through a lottery system to each member on weekly or monthly basis based on their agreement. Interestingly, to reach the market clearing point, individual members have the right to sell their lottery tickets to other members who are interested in purchasing them, with an interest rate set by the members themselves.

In the study areas, *Iquib* enables a family, particularly those in poverty, to obtain the necessary funding for agricultural activities, such as purchasing inputs, and to access seed money to start small business. There are 140 and 150 *Iquib* organized in Kalu and Raya Kobo districts, respectively. Individual member in Kalu districts contributes from Ethiopian Birr 1000 to 2000, while their contribution at Raya Kobo districts ranges from Ethiopian Birr 2000 to 4000.

Idir is an association that can be established among neighbors or staff workers to raise funds for emergencies such as family death and reburial treatments for the members and their family members. Analogous to *Iquib*, *Idir* can address the health insurance market failures in the region. Additionally, *Idir* provides credit to low-income members who are unwell, allowing them to repay the money without interest rate after they recover and back to farming. An interesting aspect of *Idir* is that, in addition to covering accident and damage on the members and their family, it also provides insurance for property, such as death of hybrid dairy cows and ploughing oxen. Therefore, *Idir* serves as livestock insurance. There are approximately 160, 200 and 225 *Idir* organized in Raya kobo, Kalu and Dawachefa, Kalu and Raya Kobo districts, respectively. In these districts, *Idir* covers 70-85% of the cost of the animal that dies accidentally.

In summary, the informal sector, in our case *Iquib* and *Idir*, helps fill the financial and insurance market failures that are prevalent phenomena of the markets of sub-Sahara African countries. These remarkable associations have direct and indirect impacts on farm productivity.

There are also other institutions that exert impact on farm productivity and welfare of smallholder farmers. For example, in Sekota areas, the result also indicated that institutions that have contributed in societal development were recorded in number like public institutions (schools, FTCs, animal health clinics, health post clinic), private institutions (veterinary clinics, drug shops, input dealers) and social institutions (cooperatives). Cooperatives and *Debo* or *Wobera* are the two fundamental social institutions that have played a vital role in enhancing agricultural productivity and promoting community cooperation in the study areas. *Debo* is a traditional method of working together that involves pooling the community labor to address financial and labor shortages, while cooperatives consist of organized individuals who can pool capital resources, share costs, and access inputs such as improved seeds, chemical fertilizers and agro-chemicals.

Based on the collected primary and secondary data, public institutions in rural areas of Wag-Himra zone are typically include human health centers, schools, farmers training centers, financial institutions, and animal health centers. Health centers provide healthcare services, medical treatment, and health education to the local population.

In the rural areas of Wag-Himra zone, schools offer educational opportunities, promote literacy, and provide formal education to children and youths. Farmers' training centers also offer agricultural training, guidance, and support to farmers to improve farming practices and productivity. Water supply facilities are providing access to clean water for drinking, irrigation, and sanitation purposes.

On the other hand, private institutions include private schools, medical clinics, agricultural businesses, small enterprises, and other private entities that provide services to the community. The available private institutions in the study areas include agro-processing companies, and private animal health clinics, which often contribute to the local economy, provide employment opportunities, and offer services that complement those provided by public institutions.

In Sekota areas in all study districts, the respondents mentioned that there are no labor-saving technologies. They only mentioned the presence of generators, irrigation canals, and pedal pumps for irrigation purposes. These facilities and technologies were reported to help reducing labor consumption within the community.

Table 4.67: Available Institutions in Wag-Himra Zone and Across Districts in Sekota Areas

Types of institutions	Wag-Himra	Sekota	Ziguala	Gazgibla
Social institutions				
Cooperatives	178	17	55	21
Public institutions				
Farmers Training centers	109	23	13	14
Animal health clinics	59	28	15	21
Schools	300	25	31	-
Human health centers	138	6	20	5
Financial institutions	-	3	3	2
Private institutions				
Agro-processing	3	-	-	-
Private animal health clinics	3	1	-	-
Input suppliers	-	-	-	-

Source: Survey data, 2024

In Sekota areas, credit service is an important factor that increases agricultural production. The majority (67.42%) of the sample respondents said that the community in the study areas had no credit services in the two years. The reasons why households did not get credit services are high interest rates, lack of collateral and religious influences.

However, a few respondents (33%) said that there is access to credit services in the area and they used the credit for purchasing agricultural inputs (chemical fertilizers, improved seeds, and agro-chemicals), animals for fattening (or breeding) and food for home consumption. The major credit providers were credit and saving associations (40.40%), microfinance institutions (30%), government organizations and non-governmental organizations (17.17%).

In lowland areas of north Shewa: social institutions, which are influential and have significant contributions to agricultural production, include different types of cooperatives like multipurpose, credit and saving, and irrigation water use cooperatives. These institutions have a crucial role in input supply, market access saving and credit services efficient use of water resources, and conflict resolution. The other social institutions established and managed by the community are funeral associations. They exist in all areas and are influential and important for development, mobilization and conflict resolution.

Churches are available in all areas of the district influential for crop production improvement extension system, opening speech conflict resolution. Mosques are available in towns and some rural areas are influential for crop production improvement extension systems, opening speech, and conflict resolution. The public institutions available in the area help the society with the provision of different services and have contributions to social, cultural, and economic well-being are different levels of schools (2 high schools and 47 elementary), health service providers (18 posts and 3 centers), agricultural service provider institutions (18 Farmers training centers, 18 kebele level offices of agriculture, 9 Animal health post and 1 animal clinic and 1 AI services).

Financial and other market institutions are influential in smoothening the market transaction and financial flow. There are marketplaces, microfinance branch offices, and banks. The number of institutions includes; 1 main market with semi-structured facilities and 8 small markets in the village without facilities. The marketplaces without facilities include *Werase*, *wokfwlw*, *ayaber*, *tere*, *yelen*, *birbira*, *abayatir* and *kureberet*. The financial institutions found in the area are 3 microfinance offices and 8 commercial banks.

The private institutions with access to the input and output market improves production and productivity including agro-processing service providers of many grain millers animal health clinics and three agricultural input suppliers. The major income sources in the study area include agricultural (crop, livestock, and multipurpose tree species) and non-agricultural sectors (trade, wage, and small industry).

Regarding socio-cultural setting and resource endowments, the people have the social values and customs of effective work habits, verti soil management, input utilization, and fattening practices. The social norms and cultural values are also social interaction, food habits of meat, helping social groups during health and other problems, and working together.

Available resources for the specific areas are productive soils, livestock products, large and suitable areas for different production purposes, and excess human labor. Resource utilization trends showed that the people have good habits of proper use of land resources for optimum production with good soil drainage practices, and improved fattening practices and the one that needs intervention is inefficient use of surface water and limited water harvesting structures.

In north Shewa midland areas: the social institutions that are influential and have significant contributions to agricultural production include different types of cooperatives like multipurpose, saving and credit, seed producer and marketing, milk producer and marketing, natural resource management, and irrigation water use cooperatives in the area. There are 56 socially established cooperatives (8 multipurpose and 7 seed producers and marketing). These institutions have a crucial role in input supply, market access to credit and saving services, and capital accumulation.

The other social institutions established and managed by the community are funeral associations. More than 200 associations exist in all areas and are influential and important for social affairs, mobilization, and soil and water conservation. Churches available in all areas of the district 99.9% of the population are Orthodox Christian followers; churches are influential for cultural practice, conflict resolution, and social mobilization for soil and water conservation. The public institutions available in the area help society with the provision of different services and contribute to social, cultural, and economic well-being. These are different levels of schools (1 preparatory, 2 high school, and 37 elementary), health service providers (18 posts and 4 centers), agricultural service provider institutions (12 Farmers training centers, 13 kebele level offices of agriculture, 10 animal health clinics and 1 AI services).

Financial and other markets institutions are influential in smoothening the market transaction and financial flow. There are marketplaces, microfinance branch offices, and banks. The number of institutions includes; 1 main market with semi-structured facilities and 5 small or village markets with no market facilities. The financial institutions found in the area are 3 microfinance offices and 1 commercial bank. The private institutions having access to the input and output market improves production and productivity including agro-processing service providers, 3 veterinary drug shops, 3 animal health clinics, and 2 agricultural input suppliers.

The major income source in the study area is the agricultural sector (crop 74%, livestock 18%, and multipurpose tree species 0.75%) and the non-agricultural sectors have (trade, 3%, wage 4% and querying 0.25%) economic contributions.

In the highland areas of north Shewa, when we look at socio-cultural setting and resource endowments of highland areas of north Shewa, the people in the district have the social values and customs of respecting each other and old age e, loyalty, commitment, and confidence, resistance to accept new ideas, approaches, and active work participation. The social norms and cultural values are also religious stands, working together, share of resources, participation in social ceremonies, and helping each other.

Available resources for the specific areas are construction materials stone, sand, different vegetation having different purposes, tourism areas, vegetation of forest trees, large number of livestock, different topography/land scape, and water potentials, large areas suitable, for different production purposes, diverse and suitable agro ecology, and excess human labor. Resource utilization trends showed that the use of stone and sand, unidentified plant species, and its propagation strategies, inefficient use of surface water, water-harvesting structures are limited, inefficient use of labor forces, low utilization of tourism resources, improvement of livestock potential resources.

Social institutions that are influential and have significant contributions to agricultural production include different types of cooperatives like multipurpose, saving and credit, seed producer and marketing, milk producer and marketing, natural resource management, and irrigation water use cooperatives in the area. There are a total of 56 socially established cooperatives (20 multipurpose, 5 irrigation water use, 18 saving and credit, 2 seed producer and marketing, 7 milk producer and marketing, 4 natural resource management and use, and 1 beekeeping cooperative). These institutions have a crucial role in input supply, market access saving and credit services efficient use of water resources, capital accumulation, and conflict resolution.

The other social institutions established and managed by the community are funeral associations. They exist in all areas and are influential and important for supporting each other respecting the bylaws, mobilize the society to different actions. Churches are available in all areas of the district majority are Orthodox Christian followers, and each society is under the umbrella of the church, bringing acceptance for good will improvement in urban and per-urban areas. The public institutions available in the area help the society with the provision of different services and contributes if social, cultural, and economic wellbeing.

These are different levels of schools (both preparatory, high school and elementary), health service providers (31 posts and 4 centers and 2 hospitals), agricultural service provider institutions (18 Farmers training centers with full facilities, 31 kebele level offices of agriculture, 20 animal health post and 1 animal clinic and 1 AI services).

These institutions are influential in smoothening the market transaction and financial flow. There are marketplaces, microfinance branch offices, and banks. The numbers of institutions include; three main markets with semi-structured facilities and eight small or village markets with no market facilities. The financial institutions found in the area are 5 microfinance offices and 15 commercial banks. The private sector having access to the input and output market improves production and productivity including agro-processing service providers, 5 veterinary drug shops, more than 10 human drug shops, health clinics, and 2 agricultural input suppliers.

4.4.7. Gender Roles and Responsibility

Women represent approximately 50 percent of the total population and contribute 48 percent of agricultural labor force (Ministry of Agriculture Environmental Protect and Development, 1992). Specifically, women and children often allocate their labor to livestock rearing. The contribution of rural women is quite significant, although it is often underestimated by society. In addition to farming activities, rural women participate on other off-farm and non-farm activities to generate additional income for their households. Despite this, gender inequality remains a significant issue in agricultural activities. This can be manifested in the case of distribution of resources, power sharing and privileges between women and man. Additionally, women are exposed to deeply root traditional malpractices and abuses, highlighting the flaws in the socialization process in our society.

A basic understanding of gender mainstreaming requires clarity on the concept of gender and gender equality as well as an appreciation for the reason it is given due attention. The reason is that various actions that have been taken so far have not brought meaningful results whereby women could be engaged in more productive activities, which are beyond the traditional way of capitalizing in subsistence economy.

In Gondar areas, according to Table 4.68, gender mainstreaming is significant issue for agricultural development and growth. In addition to the non-productive activities, females can participate in most of agricultural activities. That means, female-headed household engaged on both productive (homestead and farm activities) and non-productive (caring household) activities. Specifically, females implement crop production, livestock husbandry and natural resource management activities.

The noteworthy point is that the workload of females and their benefit levels are not comparable; they earn less money than males in the study areas, even though females spend more time for working by sacrificing their leisure time. The division of labor among the household members in implementing agricultural activities is based on gender and age groups. For example, in agronomic practices, the responsibility of lime application falls on children and the household head (male).

Sowing by row planting, animal feeding, crop residual harvesting, green feed harvesting, housing, milking, milk churning, animal health care, and selling of cattle and small ruminants are conducted by both males and females jointly. Most agricultural activities are undertaken by males and females together. These include land preparation, fertilizer application, bed preparation, cultivation, pest protection, harvesting, threshing, transportation, selling of crops, and various natural resource management practices such as terracing, drainage of excess water, moisture conservation, preparation of compost, and application of compost.

Gendered division of labor in agricultural activities reveals that males often engaged in tasks that requiring physical strength, while females are more involved in activities related to livestock rearing and partially on crop production activities. Detailed information about gendered roles and responsibilities of various agricultural activities is presented in Table 4.68. The evaluation indicates a clear division of labor in the rural societies. Some agricultural activities are dominated by males, while others are led by females, and some are equally shared between both genders. This has important implications for policymakers, particularly concerning the provision of advisory services, access to credit and women's empowerment. Generally, it helps designing interventions that promote gender equality and enhance agricultural productivity.

Our interventions should aim to:

- Provide equal access to resources and opportunities for both men and women.
- Recognize and support the valuable contributions of women in agriculture, particularly in activities like livestock management and selling of agricultural products.
- Encourage the sharing of knowledge and skills between men and women to improve overall agricultural practices.
- Address social and cultural norms that may restrict women's participation in certain agricultural activities.
- Enhance collaboration between men and women in decision-making processes related to agriculture.

Table 4.68: Gender Roles and Responsibility in Gondar Areas

Activities	Males & children	Females & children	Male & female	Mostly by male	Mostly by female
Crop					
Land preparation			✓		
Sowing (broadcasting)				✓	
Sowing (Row planting)			✓		
Fertilizer application			✓		
Lime application					
Bed preparation			✓		
Weeding			✓		
Cultivation			✓		
Pest protection			✓		
Harvesting			✓		
Threshing			✓		
Transportation			✓		
Selling of crops			✓		
Livestock					
Feeding			✓		
Crop residual harvesting			✓		
Green feed harvesting			✓		
Housing			✓		
Milking			✓		
Milk churning					✓
Animal health care			✓		
Cattle and small ruminant selling				✓	
Animal product and chicken selling		✓			✓
Natural resource management					
Terracing			✓		
Drainage of excess water			✓		
Moisture conservation			✓		
Preparation of compost			✓		
Application of compost			✓		

Source: Survey data, 2024

Table 4.69 presents resource access and control disaggregated by gender in Gondar areas. We discuss in details whether males and females have access to and control over various resources.

- Both males and females have access to and control over cattle.
- Both males and females have access to and control over crops in bulk.
- Females have access to and control over crops in the retail system.
- Females have access to and control over fruits and vegetables in bulk.
- Both males and females have access to and control over poultry and eggs.
- Both males and females have access to and control over milk and milk by-products (butter/cheese).
- Both males and females have access to and control over woodlots.
- Both males and females have access to and control over charcoal.

Based on this, we can conclude that access to and control over most resources between males and females are relatively balanced. However, some resources are predominantly accessed and controlled by male, while others are led by females.

Table 4.69: Resource Access and Control by Gender in Gondar Areas

Income sources	Male		Female	
	Access	Control	Access	Control
Cattle	√	√		√
Crop (in bulk)	√	√		√
Crop (in retail system)		√	√	√
Fruit and vegetable (in bulk)			√	√
Fruit and vegetable (in retail at primary market)				
Poultry and egg		√	√	√
Milk and milk by-products (butter and cheese)			√	√
Wood lot	√	√		√
Timber				
Charcoal	√	√		√
Honey				
Others				

Source: survey data 2023

In north Shewa lowland areas: the most common male based farming activities on different agriculture production are ploughing, cultivation, harvesting, trashing and transportation on crop production, herding, health management, marketing and feeding of cattle and small ruminant and beehives and seedling preparation and transplanting, marketing of forest products on natural resource production and management.

The most common female-based farming activities in different agriculture production are seed cleaning, weeding, marketing of home garden cultivation on crop production, milking, processing of milk, poultry production and marketing, and barn cleaning and management of cattle on livestock production and no specific activities on natural resource production and management. The common agricultural activities operating jointly are soil and water conservation and storage and marketing of crop products. The resources in male-headed households owned by males or husbands are cash, fixed assets like houses, trees, and vegetables of irrigation produce. While the resources owned by females or wives in the same household are poultry, milk and milk products, home garden vegetables, and a small amount of cash.

The main farm decisions led by the male himself with and without consulting the wife or his daughter are a market exchange, resource transfer of both cash and assets, deciding the type of crop to be grown in each specific field, renting of lands, schooling decision while the farm/household decisions leading by female with or without consulting her husband or son include household chore, food items, diet preparation, home management, kitchen management and purchasing of consumable items.

In North Shewa Midland Areas: the most common male-based farming activities in different agriculture production are land preparation, plantation, weeding, harvesting, thrashing, transportation, marketing, storage on crop production, feed provision and collection, preparation of shelter management of trough power animals, marketing of fattened animals on livestock production and mass mobilization, preparation of stone bunds and soil bunds seedlings preparation, plantation of and management of field vegetation.

The most common female-based farming activities in different agriculture production are plantation, weeding, harvesting of crops other than wheat, storage, and marketing on crop production, feeding of dairy cows and poultry milking and processing, marketing of dairy products on livestock production and home garden plantations activities on natural resource production and management. The resources in male-headed households dominantly owned by males include cash, livestock, small ruminants, and farm tools and the resources dominantly owned by females are milk products, poultry, a small amount of cash gained from small grain marketing, and household tools.

The main farm decisions led by the male himself with and without consulting the wife or his daughter are buying animals, type of crops grown, and renting in the land, while the farm/household decisions led by a female with or without consulting her husband or son include is social participation and marketing of consumable goods

In North Shewa Highland Areas: the most common male-based farming activities in different agriculture production are land preparation, harvesting, trashing, transportation, storage and marketing on crop production, home feeding, milking, marketing of poultry businesses, and milk and milk products on livestock production and plantation, marketing of agroforestry trees, physical and biological conservation, seedling preparation on natural resource management.

The most common female-based farming activities in different agriculture production are weeding, trashing, transportation of small markets on crop production, feeding of dairy cows and poultry milking and processing, marketing of dairy products on livestock production, and minor participation in soil and water conservation practices on natural resource production and management.

The resources in male-headed households dominantly owned by males include grain, livestock, and livestock products, cash resources dominantly owned by females are household furniture, food items, and inputs. The main farm decisions led by the male himself with and without consulting the wife or his daughter are marketing of grain and livestock, transfer of money and other assets, land renting, plantation of crops and agroforestry trees on farmlands, while the farm/household decisions leading by a female with or without consulting her husband or son include schooling of child, food item, social participation.

In Wollo Areas, farming activities involve the active participation of all the household members, despite variability in the extent of participation within the household. As noted stated in other administrative zones, the role of females in crop production is significant. For example, women contribute labor required for seed maintenance, sowing in rows, weeding, harvesting, transporting, and selling crops (see Table 4.70). In the case of women-headed households, other activities, such as threshing, are also included.

Table 4.70: The Role of Gender in Crop Production in Wollo Areas

Crop Activities	Males and children	Females and children	Males and females	Mostly by male	Mostly by female
Land preparation	✓				
Broadcasting	✓				
Row planting			✓		
Fertilizer application			✓		
Lime application					
Bed preparation			✓		
Weeding			✓		
Cultivation			✓		
Pest protection	✓				
Harvesting			✓		
Threshing	✓				
Transportation			✓		
Selling of crops					✓

As shown in Table 4.71, the extent of participation of women, men, and youth in livestock production activities indicates that all family members are involved in livestock management-related activities with varying levels of participation. For instance, during the FGD discussion, estimations indicate that women and daughters alone carry out different livestock management operations.

For example, only women and female children are responsible for husbandry practices (such as housing, milking, and milk churning) and animal product and chicken selling activities. Both men and women share animal feeding and health care activities (Table 4.71). In summary, females engaged on labor-intensive activities such as feeding, house cleaning, milking and churning, while men are responsible to gather crop residual harvesting for feeding, selling cattle, sheep and goats.

Table 4.71: The Role of Gender in Livestock Management in Wollo Areas

Livestock Activities	Males and children	Females and children	Male and female	Mostly by male	Mostly by female
Feeding			✓		
Crop residual harvesting				✓	
Green feed harvesting	✓				
Housing		✓			
Milking		✓			
Milk churning		✓			
Animal health care			✓		
Cattle and small ruminant selling				✓	
Animal product and chicken selling		✓			

During the focus group discussions, various awareness building programs - such as training and experience sharing visits - primary prioritize men. Ignoring nearly half of the labor force, women, could potentially negatively impact farm productivity. Therefore, there should be reasonable consideration of the different household members (men, women, and youth) in capacity-building training, technology demonstration, and promotion based on their level of involvement in the various crop and livestock management activities. Inadequate attention has also been given to the inclusion of a sizable number of female-headed women in the training of the participatory demonstration and pre-scaling up of technologies. Most extension services are geared to the head of household men.

In the lowland study districts, except for Kalu district, both men and women respondents associated ownership with decision-making power. All household members participated in decision-making, resulting in jointly owned resources. Men had more decision-making power over income from selling cattle, crop selling in bulk, fruit and vegetable selling in bulk, while women were able to make decisions about how to use and when to sell milk, butter, chickens, eggs, and crops sold in retail at the primary market.

In Sekota areas, gender roles and responsibilities in agriculture are often influenced by cultural norms and traditions. Based on the data provided, it is evident that there is a distinct gender division in agricultural activities. In crop production, tasks like land preparation, sowing (both broadcasting and row planting), and weeding are predominantly carried out by females and children.

Conversely, activities such as fertilizer application, cultivation, pest protection, harvesting, and transportation involve both males and females. In livestock production, feeding, crop residual harvesting, green feed harvesting, housing, milking, and animal health care are shared among males, females, and children. Notably, females mainly do milk churning. In natural resource management (NRM) activities, tasks like terracing, and moisture conservation, and males mostly handle compost preparation and application. When it comes to agricultural marketing, the selling of cattle and small ruminants is primarily done by males, while the selling of animal products and chickens is mainly carried out by females.

Table 4.72: Gender Roles and Responsibilities in the Study Area in Sekota Areas

Activities	Male & children	Female & children	Male & female	Mostly by male	Mostly by female
Crop production		-	-	-	-
Land preparation	16.67	-	-	83.33	-
Sowing (broad casting)	16.67	-	-	83.33	-
Sowing (Row planting)	-	-	100	-	-
Fertilizer application	-	-	-	100	-
Weeding	-	-	83.33	16.67	-
Cultivation	-	-	66.67	33.33	-
Pest protection	-	-	-	100	-
Harvesting	-	-	100	-	-
Threshing	16.67	-	-	83.33	-
Transportation	-	-	-	100	-
Livestock Production	-	-	-	-	-
Feeding	16.67	-	50	-	33.33
Crop residual harvesting	16.67	-	33.33	50	-
Green feed harvesting	16.67	-	33.33	50	-
Housing	16.67	-	-	66.67	16.67
Milking	-	-	16.67	33.33	50
Milk churning	-	-	-	-	100
Animal health care	-	-	33.33	66.67	-
NRM	-	-	-	-	-
Terracing	-	-	100	-	-
Moisture conservation	-	-	-	100	-
Preparation and application of compost	-	-	-	100	-
Agricultural marketing	-	-	-	-	-
Cattle and small ruminants selling	-	-	-	100	-
Animal products and chicken selling	-	-	-	-	100
Selling of crops	-	-	50	-	50

Source: Survey data, 2024

In the study zone, based on the provided data on income from selling various agricultural products, there is a clear indication of gender differences in access and control over income sources in the study areas. Men have predominant access and control over income from cattle, crops in bulk, fruits, and vegetables (bulk), poultry and eggs, milk and milk by-products, wood lot, timber, charcoal, and honey.

On the other hand, women have significant access and control over income from crop retail systems, fruits and vegetables at primary markets, and to a lesser extent on some other products like charcoal. This disparity underscores the need for addressing gender inequalities in income generation opportunities and empowering women to have more control and access to various income sources in rural agricultural settings.

The data from FGD respondents indicated that in livestock production, males have full access at 100% but slightly less control at 83.33%, while females have slightly lower access at 83.33% and a lower control percentage of 16.67%. In crop production, males have full access at 100% and control at 66.67% of the crop (in bulk) and 83.33% of the crop (in retail system), whereas females have slightly lower access at 83.33% and control percentage of 50% concerning males. For horticultural crop production, males enjoy full access at 100% and full control at 100%, while females have a slightly lower access rate of 83.33% and the same control rate of 8%. In natural resource management, males have a high access rate of 83.33% but slightly less control at 66.67%, whereas females have a lower access rate of 66.67% and the same control rate of 66.67%.

Table 4.73: Gender Resource Access and Control in Sekota Areas

Income sources	Male		Female	
	Access	Control	Access	Control
Cattle	√√√√√	√√√√	√√√√	√
Crop (in bulk)	√√√√√	√√	√√√√	√√
Crop (in retail system)	√√√√	√√√√	√√√	√√√
Fruit and vegetable (in bulk)	√√√√√	√√√√√	√√√	-
Fruit and vegetable (in retail at primary market)	√√√√√	√√√	√√√	√
Poultry and egg	√√√√√	-	√√√√√	√√√√√
Milk and milk by-products (butter, cheese)	√√√√√	-	√√√√√	√√√√√
Wood lot	√√√√√	√√√√√	√√	-
Timber	√√√√√	√√√√√	√√	-
Charcoal	√√√	√√	√√√√√	√√
Honey	√√√√√	√√√	√√√√	√

Where: √√√√√=100%, √√√√= 83.33%, √√√=66.67%, √√=50%, √=33.33%, √=16.67%

Source: Survey data, 2024

Affirmative actions for women in relation to agricultural production are specific measures designed to address gender inequalities in the agricultural sector. Affirmative action empowers women in agriculture, providing them with equitable access to resources, training, technology, financing and markets. In addition, affirmative actions can include policies that promote the active participation of women in decision-making, land ownership and farm management, with the objective of improving their position and contribution within the food and agricultural chain.

In the table provided, it is observed that of a total 66.7% of respondents indicated that there are affirmative action is available for women headed households, while 33.3% mentioned that there is none. This suggests that the majority of those surveyed perceive that affirmative action's exist for households headed by women in the analyzed context (Table 4.74).

Table 4.74: Availability of Affirmative Actions for Female-Headed Households in Sekota Areas

Questions		Frequency	Percentage
Is there availability of affirmative actions for female headed households?	No	2	33.3
	Yes	4	66.7

Source: Survey data, 2024

4.4.8. Market and Marketing Strategy

Agricultural marketing encompasses all activities, agencies, and policies related to procuring farm inputs and moving agricultural products from farms to consumers. It serves as a vital link between the farm and non-farm sectors, involving the organization of raw material supply to processing industries, demand assessment for inputs and raw materials, and the formulation of policies regarding the marketing of farm products and inputs (Kotler, Philip, 1998). In developing countries, including the study area, the agricultural marketing system consists of two main sub-systems: input and product marketing. Input marketing includes manufacturers, distributors, associations, importers, exporters, and others who provide production inputs to farmers, while product marketing involves various actors such as farmers, traders, wholesalers, processors, cooperatives, market committees, and retailers.

In the study area, based on findings from focus group discussions, key informant interviews, and secondary information, there are no major market price problems for most crops and livestock products. However, seasonal market price fluctuations affect irrigated horticultural crops like onions, tomatoes, and garlic. Despite the absence of significant price problems for most products, challenges remain in the marketing of both crop and livestock products. These challenges include availability of market information, marketplaces, value addition, and competitiveness. Agricultural marketing services can play a crucial role in addressing these challenges by providing valuable services that give buyers and sellers of agricultural products a competitive advantage in the global marketplace.

The main challenges in input-output markets in the Gondar districts include:

- Limited availability of inputs: farmers face challenges in accessing quality seeds, chemical fertilizers, and other inputs essential for crop and livestock production.

- Limited access to markets: inadequate infrastructure and far distance of marketplaces limit farmers' access to markets, affecting their ability to buy inputs and sell their products.
- Low adoption of both crop and livestock technologies: farmers are not fully adopting or benefiting from modern agricultural technologies.
- Yield loss: several factors, such as pests, diseases, and adverse weather conditions, lead to lower yields.
- High prices of agricultural inputs: the costs of improved seeds and chemical fertilizers are high, leading farmers to invest less in their farms.
- Less emphasis on agricultural sustainability: farmers place less emphasis on agricultural sustainability, particularly regarding soil and water conservation. As a result, their practices exacerbate environmental degradation.
- Lack of market information: lack of access to market information, or untimely and inaccurate information, challenges farmers to make informed decisions on what to produce and when to sell.
- Credit constraints: lack of sufficient credit to invest in new technologies and inputs hinders improvements in farm productivity.
- Presence of a long value chain for inputs: long value chains for inputs result high prices for those inputs. Specifically, the presence of intermediaries or brokers in the market can lead to unfair pricing, ultimately reducing profits for farmers.

Table 4.75 shows the agricultural market infrastructures of the north Shewa areas. Agricultural market infrastructures, such as marketplaces and roads, are available at different levels in the study districts. The types of markets are categorized as main markets and village markets. The main markets are located in the town of specific district, while village markets are found in the rural kebeles. The facilities of main markets include fencing, shades, and entrance roads. Both weather roads and seasonal roads are found in the study districts. Except for a few kebeles with all-weather roads, the others only have seasonal roads.

Table 4.75: Agricultural Marketing and Market Infrastructure in North Shewa Areas

Agro-ecologies	Main market	Village market	All-weather roads	Seasonal roads	Remark
Lowland	8	5	6	1	Only 1 kebele has seasonal road
Midland	3	3	4	2	Two kebeles have seasonal road
Highland	3	8	9	2	Two kebeles have seasonal road

In Wollo areas, two highway roads cross the three study districts, which pass from Addis to Mekelle via Kemsie town, Kombolcha and Raya kobo, which is asphalt road. In addition, there is a railway from Addis to Mekelle, which is under construction. All-weathered roads are found in almost all districts in Wollo areas. Djibouti port is one of the largest ports, which Ethiopia is using through a rental agreement, and this port is very near to the region. This leads to the region to have potential for importing and exporting agricultural inputs and outputs. Kombolcha town, located in South Wollo zone, is designated as an industrial zone due to its proximity to the Djibouti port. However, this industry zone is operating below capacity due to shortage of raw materials and inefficiency. In the Wollo areas, a few horticultural crops are being supplied to the big tertiary markets, specifically Addis Ababa and Mekelle.

In Sekota areas, the majority of the farmers in the study area use local markets to sell their produce as well as to buy merchandise goods. Markets, which are found in the study areas, can be categorized as main markets. Main markets are relatively big and composed of grain, livestock, and outputs of natural resources, while village markets are small and accommodate either grain or livestock markets. The main or village markets may or may not have full facilities like roads, electricity, ware houses, etc. Human labor (family labor) and animal force (e.g., equines) are the dominant means of transportation of agricultural inputs and products. All sampled districts have access to all-weather roads. To connect districts to the zonal capital, Sekota town and other neighboring districts, i.e., Gazgibla and Sekota districts, have asphalt roads, while Ziquala district uses gravel roads. Interestingly, the administrative centers of the study districts have access to electricity and mobile telephone services. The following tables show the road access, the number, and the type of markets across the study districts.

In Sekota areas, there are grain markets and animal markets located in local and district markets. The common grains supplied to the markets include teff, wheat, maize, barley, sorghum, faba bean, field pea, and lentil in the midland and highland agro-ecologies, while sorghum, pearl millet, mung bean, and sesame are the major marketable crops in the lowland parts of the zone. Since the zone does not produce surplus, these essential staple grains are marketed mainly to the local market.

As mentioned previously, livestock plays a significant role in the region, particularly in Sekota areas, providing food, income, and prestige values, and serving as a form of savings and assets. The animals transacted in the study areas include cattle, sheep, goats, equines, and poultry. Local and district-level markets are essential for rural communities across all agro-ecologies to meet their cash needs at any time. As indicated in Table 4.76, there are 13 local markets and 3 district markets, totaling 16 markets across the 3 sampled districts.

Table 4.76: Infrastructures and Related Constraints in the Study Districts in Sekota Areas

Types of Infrastructures	Sekota	Ziquala	Gazgibla	Related constraints
District marketing centers	1	1	1	- Lack of market infrastructure
Local marketing centers	6	4	3	- Poor market facilities
				- No separate places for marketed commodities. (eg. No separate places for crop and livestock market)
Irrigation facilities	22	8	30	- Shortage of canals
				- Lack of timely maintenance
				- Poor quality of canal construction
All weather roads	11	1	4	- Poor timely maintenance
				- Poor quality of maintenance
Seasonal roads	14	3	-	- Poor timely maintenance
				- Poor quality of maintenance
Telecommunication facilities	21	1	4	- Lower area coverage of the district in Ziquala and Gazgibla districts
Electricity facilities	9	1	4	- Lack of proper power supply
				- Lower coverage especially in Gazgibla and Ziquala districts
Clean water supply	25	84	3	- Lack of timely maintenance
				- Poor quality of construction
				- Poor community management of resources

Source: District Office of Agriculture, 2024

Various actors are involved in both grain and animal markets in the study areas. Common participants in these markets include farmers (producers and consumers), collectors, traders (retailers and wholesalers) and consumers. Farmers usually participate in the market to sell their produce. It is also important to note that they rarely participate in the markets to buy grain for consumption or to purchase animals to restock or replenish their herd. Collectors serve as intermediaries between producers and traders, gathering agricultural products from producers and supplying them to traders with minimum premiums.

Therefore, traders purchase grains directly from farmers or through collectors. They then sell the grains to consumers within the same district, or to other districts in the region or to regions beyond, often through intermediaries. For instance, mung bean, sesame, and honey are primarily purchased by traders in Ziquala market, while lentils, faba bean and other oil crops are mainly bought in the Sekota and Gazgibla markets and sold to other regions for better prices.

Table 4.77: Major Actors of Livestock and Grain Markets in Sekota Areas

Types of market actors	Frequency	Percentage
Farmers	6	100
Consumers	6	100
Retailors	5	83.33
Collectors	4	66.67
Wholesalers	3	50

Source: Survey data, 2024

Participants in the focus group discussion highlighted the lack of access to formal market information for smallholder farmers across all study districts. To address these gaps, farmers in the community exchange weekly marketing information regarding at least the local and district markets with one another. However, the lack of formal market information is a present challenge for farmers and traders in terms of knowing when and where to buy or sell their products. Without access to reliable market information, they may face information asymmetry, which leads to lost opportunities or poor decision-making.

4.4.9. Food and Nutrition Security

Ensuring food accessibility, affordability and utilization remain a priority agenda for Amhara region. This is because food and nutrition security is essential for the region's development, and as such contributing to a productive workforce and sustainable economic and social growth. Achieving food and nutrition security involves providing healthy diets, promoting knowledge of nutritious foods, improving food utilization, ensuring food safety and quality, reducing food and nutrient losses, preparing for food and nutrition emergencies, and building resilience (FDRE, 2018).

The findings of focus group discussions, key informant interviews and secondary information revealed that farmers in low and midland areas are generally food secure but face challenges related to food nutrition security. They typically consume *injera* (light bread) that made up of sorghum and teff with traditional wot that prepared from chickpeas, field peas, or grass peas. In addition, they occasionally consume livestock products such as meat, milk, and eggs and rarely consume fruits and vegetables. Unlike the lowland and midland areas, farmers in the highland areas face the challenges of food security.

Similar to the other two areas, these farmers in highland area have limited variety of food in their diet. Those farmers suffer from critical food shortages during August and September, causing them to borrow from neighbors, seeks credit from financial institutions, and sells their livestock. To address these challenges, it is important to increase farm productivity, diversify food sources, and raise awareness about the importance of food and nutrition based on Ethiopia's food system guidelines. These strategies can help alleviate food and nutrition security issues in the study area and improve the overall well-being of the people.

In the lowland areas of north Shewa, the main food items utilized are composed of crops of cereals, pulses, vegetables, fruits, and livestock products (e.g., egg, meat, and milk) combinations. The main diet combinations comprised mainly cereal-based of sorghum, teff, maize, wheat, and barley with combinations of faba bean, field pea, lentils, and occasionally small portions of vegetables like onion, tomato, carrot, kale, and cabbage.

Those cereals are also rarely combined with livestock products of egg, milk, and meat occasionally. When people are eating mainly cereal and vegetable combinations, the cereal of teff, sorghum, and wheat are mainly combined with vegetables of onion. When people are eating cereal with livestock product combinations, cereals of sorghum, teff, and wheat are mainly combined with milk. When people are eating vegetables with livestock product combinations, vegetables of onion will combined with milk products of butter cheese, and meat.

In the midland areas of north Shewa, the main food items utilized are composed of crops of cereals, pulses, and livestock products of combinations. The main diet combinations comprised main cereal based on wheat, teff, faba bean, chickpea, and lentils with occasionally small portions of vegetables like potato and kale. Those cereals are also sometimes combined with livestock products of egg, milk, and meat occasionally. When people are eating cereal with vegetable combinations, the cereal of teff, barley, and wheat are mainly combined with vegetables of potato, garlic, and kale. When people are eating cereal with livestock product combinations, cereals of teff, wheat, and barley are mainly combined with egg and milk products. People are not experienced in combining vegetables with livestock product combinations.

In the highland areas of north Shewa, the main food crops utilized are composed of crops of cereals, pulses, and livestock products combinations. The main diet combinations comprised mainly cereal-based barley and wheat, pulses of faba bean and lentil with unusually small portions of vegetables like potato and kale. Those cereals are also sometimes combined with livestock products of egg, milk, and rarely meat. When people are eating cereal with vegetable combinations, the cereal of teff, barley, wheat, and sorghum are mainly combined with vegetables of potato and kale. When people are eating cereal with livestock product combinations, cereals of wheat and barley are mainly combined with milk products. When people are eating vegetables with livestock product combinations, vegetables of potato and garlic will combined with milk products of butter and meat.

In Wollo areas, the major staple food in lowland agro ecology districts is “*Injera*” with “*Wot*”. *Injera* is baked bread prepared from the fermented dough of sorghum and teff flour with a 1:3 teff to sorghum ratio. However, in Dawachefa district, it is prepared from sorghum, maize, and teff flour at a proportion of 75%, 15%, and 10% of sorghum, maize, and teff flour, respectively. At times of food shortage in Dawachefa district, it is prepared from 90% sorghum and 10% of maize flour. ‘*Wot*’ is a sauce to soften this baked bread in rural areas. *Wot* is mainly prepared from pulse crops (like haricot bean, faba bean, and lentil), onion, tomato, edible oil, and salt. Farmers also have some meal types, which remain to be supplementary.

In the case of midland agro-ecology districts, “*Injera*” with “*Shiro Wot*” is the major staple food in midland agro-ecology. *Injera* is prepared from the fermented dough of sorghum and teff flour with 2:3 teff to sorghum ratio and *Shiro Wot* is prepared mainly from pulses (like grass pea, faba bean and chickpea), onion, tomato, salt and edible oil. These days’ farmers are not able to produce enough faba beans, grass pea and field pea to prepare *nifro* and *Shiro Wot* flour due to pest infestation.

In the case of midland and highland areas “*Injera*” with “*Shiro Wot*” is also the major staple food in highland agro ecology. *Injera* is prepared from the fermented dough of wheat and teff flour with a 1:3 teff to wheat ratio and *Wot* is prepared mainly from pulses (like grass peas, faba bean and chickpea, lentils), onion, tomato, salt, and edible oil. Within the same scenario, these days, farmers cannot produce enough faba beans, field peas, and lentils to prepare *nifro* and *Wot* flour due to gal disease and insect (mainly aphid) infestation. It does not mean that the currently used meals are available until the next harvest season. Most of the farmers among the groups have said their annual crop production is not sufficient for their family members in lowland agroecology.

In the mid and highland agro-ecologies, the annual production is significant but not sufficient to feed their family year round. Many farmers in most of the lowland areas face food shortages for six months from June to November. Farmers in midland and highland areas face food insecurity from July to October and from April to November, respectively.

In Sekota areas, the survey participants said that, in the study areas, food insecurity and critical food shortages are most prevalent during what is known as the “*lean season*”. The lean season is a period of time between harvest seasons, typically lasting from June to September, during which food stocks are depleted and new crops are not yet ready for harvesting (Brunelin and Lain, 2023).

The exact timing and severity of the lean season can vary depending on factors such as climate, rainfall patterns, and agricultural productivity in any given year. In general, the majority of the households living in the study areas are experiencing food shortages during this period. During the lean season in the study areas, households forced to ration food, reduce the number of meals they eat each day, resort to eating less nutritious (less desirable foods).

As the respondent said that, children, pregnant women, and the elderly are particularly vulnerable to malnutrition during this period. In the study areas, many peoples face severe food shortages in various months of the year. In all sampled districts, the critical food shortage months are from June to September. To escape these food shortage periods, the community employs different coping strategies.

These include taking loans from credit providers, selling animals for purchasing grain, working for daily wages, reducing family food consumption, switching to a lean diet, consuming seasonal green leaves, engaging in petty trading, migrating seasonally to productive areas, and receiving aids from government organizations or NGOs (Table 4.78). These measures contribute to helping the communities in the various districts to manage and overcome the food shortage situation they face during the critical months.

Table 4.78: Critical Food Shortage and Strategies to Overcome Critical Food Shortage in Sekota Areas

Districts	Target Groups	Responses about critical food shortage months	Responses of TGs about strategies to overcome the critical food shortage periods
Sekota	TG-I	July to September	- Taking loan from credit suppliers - Selling animals and buying of grain - Working daily wages - Minimizing family food consumption - Shift to less desirable foods - Distribution of food aids from government or NGOs
	TG-II	June to October	- Taking loan from credit suppliers - Consuming seasonal green leaves - Selling animals and buying of grain - Distribution of food aids from government or NGOs
Gazgibla	TG-III	June to September	- Working daily wages - Taking credit from any credit supplier in kind or cash - Selling animals and buying of grain - Petty trading - Distribution of food aids from government or NGOs
	TG-IV	July to September	- Taking credit from any credit supplier in kind or cash - Decreasing quantity of family consumption - Change food type (Shift to less desirable foods) - Selling animals and buying of grain - Distribution of food aids from government or NGOs
Ziquala	TG-V	June to September	- Selling animals and buying of grain - Taking credit from neighboring in kind or in cash - Decreasing amount of family consumption - Consuming seasonal green leaves - Receiving aids from government or NGOs
	TG-VI	June to September	- Selling animals and buying of grain - Seasonally migrate to productive areas of the country - Taking credit from neighboring in kind or in cash - Receiving aids from government or NGOs

Source: Survey data, 2024

4.4.10. Climate-Smart Agriculture

Consistent with Sustainable Development Goals (SDGs), incorporating climate-smart agriculture practices into the agricultural activities are essential to meet the sustainable agricultural intensification and enhance resilience of smallholder farmers to climate change in the region. Here are some of climate smart agriculture practices that can be practiced in Gondar areas.

- Early planting (*Belg season*): by planting early, farmers can take advantage of the shorter Belg rainy season, ensuring that crops have enough moisture to grow before the dry season begins.
- Intercropping (*Wasera*): planting different crops together can help maximize land use efficiency and reduce the risk of crop failure due to pests or diseases.
- Shifting cultivation: this practice involves moving agricultural activities to different plots of land over time, allowing the soil to regenerate and maintain its fertility.
- Rotation cropping: rotating crops helps prevent soil depletion by alternating between crops that use different nutrients, reducing the need for synthetic fertilizers.
- Soil fertility protection: implementing practices like cover cropping, mulching, and composting can help protect soil fertility and structure.
- Double cropping: growing two or more crops in the same field in a single year can increase overall productivity and income for farmers.
- Protecting natural resources: conservation practices such as terracing, agroforestry, and watershed management can help protect soil, water, and biodiversity.

In summary, by adopting these climate-smart agriculture practices, farmers in the Gondar areas can improve their resilience to climate change, enhance food security, and sustainably manage natural resources for future generations. By implementing practices such as early planting, intercropping, and soil fertility protection, farmers can mitigate the impacts of climate change, increase their productivity, and protect natural resources. Double cropping and rotation cropping further enhance resilience and food security, ensuring a more stable income for farmers. Overall, these practices contribute to a more sustainable agricultural system that can withstand the challenges posed by a changing climate while maintaining the region's rich agricultural traditions.

In the lowland areas of north Shewa zone, people have different survival strategies for different uncertain phenomena of food shortage and disease outbreaks. The main survival strategies practiced for food shortage phenomena are food aid by external intervention, and the purchase of food by selling animals and cash gained from remittance. The major survival strategies for livestock diseases and outbreaks used medicaments and mass vaccination, respectively. In addition, in the survival strategies for disease and pest outbreaks on crops, people use different chemicals and integrated pest management for the expected outbreaks. People have no survival strategy mechanisms for disease and outbreaks of multipurpose tree species; this is due to the lack of introduced technologies in the area.

Climate-smart agriculture (CSA) and identifying climate change parameters: The identified sensible climate change parameters in the area are shifting agriculture from rain-fed to irrigation-based production on the use of groundwater, incorporating organic manure to improve soil fertility for cereal production, and implementing of crop rotation practices on cereal with cereal and pulse and oil crops interchangeable.

Climate change adaption practices: Farmers tried to continue production of the same crops of sorghum and teff with the special merits of having short matured, low moisture requirement, and moisture deficit tolerant. The demand for short-matured and drought-tolerant improved varieties of all crops is increasing from time to time. The area covered by mung bean crops, which have a very short field stay, is increased year after year.

Mitigation: The main mitigation practices implemented to maintain the climate to be good and suitable for agricultural practices and for day-to-day human activities include an improvement of soil and water conservation campaigns, afforestation and area closure practices.

Survival strategies for drought and water shortage: When drought happened in the area the people tried increase production crops and livestock feeds using irrigation and reducing the number animals through transferring to other areas to survive for the current drought phenomena. The survival strategies for the shortage of water are transportation and seasonal movement.

In the midland areas of north Shewa zone, people have different survival strategies for different uncertain phenomena of food shortage and disease outbreaks. The main survival strategies practiced for food shortage phenomena are local credit access, daily laboring, livestock fattening, and petty trade migration of male laborers purchase of food by selling animals land renting. The major survival strategies for livestock diseases and outbreaks use medicaments for the sick and mass vaccination for the herd. And, the survival strategies for disease and pest outbreaks on crops, people use different cultural practices, chemicals, and integrated pest management for the expected outbreaks. People have no survival strategy mechanisms for disease and outbreaks of multipurpose tree species; this is due to the lack of introduced technologies in the area.

Climate-smart agriculture (CSA) (identifying climate change parameters, climate change adaption practices, mitigation): The identified sensible climate change parameters in the area are shifting of agriculture from cereal to pulse crops, early planting, organic manure in low land areas, and crop rotation pulse with cereals.

Climate change adaption practices: Farmers tried to continue production of crops with early plantings of crops, plantation of early-matured crops. The demand for short matured and drought tolerant improved varieties of all crops are increasing from time to time.

Mitigation: The main mitigation practices implemented to maintain the climate to be good and suitable for agricultural practices and for day-to-day human activities include an improvement of practices in environmental protection, afforestation, and soil and water conservation.

Survival strategies for drought and water shortage: When drought happens in the area the people have no proven exposure to the event and difficult to judge the survival strategies. The survival strategies for water shortage are digging wells, moving long distances to save the use of water, transportation of animals, and transportation of animals.

In the highland areas of north Shewa: People have different survival strategies for different uncertain phenomena of food shortage and disease outbreaks. The main survival strategies practiced for food shortage phenomena are food aid by external intervention, purchase of food by selling animals and forest products, borrowing from family and neighbors, and saving grain and money from the previous produces. The major survival strategies for livestock diseases and outbreaks they isolating the diseased animals using medicaments for the sick and mobilizing mass vaccination for the herd. In addition, for the survival strategies for disease and pest outbreaks on crops, people use early warning information; and apply different cultural practices, chemicals, and integrated pest management for the expected outbreaks. People have no survival strategy mechanisms for disease and outbreaks of multipurpose tree species; this is due to the lack of introduced technologies in the area.

Climate smart agriculture (CSA) and identifying climate change parameters: The identified sensible climate change parameters in the area are shifting of agriculture like late plantation of barley, mixed cropping for diversification, use of early-matured varieties, use of inputs, reduce fallowing, diversification, shift of production from short season to main season, and remove excess water from their farm. Another possible solution is shifting farmland from crop production to perennial tree plantations.

Climate change adaption practices: Climate adaptability practices shift of cultivation, moisture conservation, early planting, following rain of rainfall distribution patterns to grow different types of crops depending on weather changes, use of irrigation resources, and use of early matured improved varieties. Farmers tried to continue production of the same crops in the existing situations using short-matured, low moisture requirement, and moisture deficit tolerant varieties. They practice early planting. Applications of organic manure incorporation, and crop rotation of cereals with pulse crops.

Mitigation: The main mitigation practices implemented to maintain the climate to be suitable for agricultural practices and day-to-day human activities include natural resource conservation, reduced runoff and improved infiltration rate of soil afforestation, plantation of trees from farmlands.

Survival strategies for drought and water shortage: When drought happened in the area the people tried to reduce livestock numbers, sell forest products, hire daily laborers, exchange products, and participate in trading activities. The survival strategies for the shortage of water are to move long distances and transfer animals, from place to place.

Similar to other parts of the country, the study areas in Wag-Himra zone are heavily impacted by climate change, experiencing frequent droughts, flash floods, erratic rainfalls, higher temperatures, and other extreme weather events. Farmers in the study areas have various experiences with climate-smart agricultural practices that aim to mitigate the effects of climate change on their crops and soil. These practices include soil and water conservation structures, using drought-tolerant crop varieties, intercropping techniques, crop diversification, organic fertilizers (manure and compost) application, and integration of beekeeping into protected water shades to increase their resilience to climate change. The participants of the focus group discussions said that there is no designed practical efforts are being implemented to promote and scale up climate-smart agriculture practices. With the adoption of climate-smart agriculture practices, farmers can build resilience and adapt to the changing climate while still producing enough food to feed themselves, their families, and their communities.

4.4.11. Agricultural Job Opportunities

In Sekota areas, the survey data analysis indicated that crop production, cattle fattening, poultry production, beekeeping, fishery, and off and non-farm activities are the main opportunities for creating agricultural jobs in the study areas (Table 4.79). All these agricultural activities are available in all sampled districts (from lowland to highland agro-ecologies), except for fishery production. The Wag-Himra zone shows higher potential for fishery production in the three districts, namely Ziquala, Sehala, and Abergele, where the Tekeze hydroelectric dam is located and it is used as the major job opportunity for youths. The data presented in (Table 4.79) suggests that the amount of employment opportunities generated for youths and women is quite restricted, which could be attributed to budget constraints resulting from the two-year Northern Ethiopia conflict and perhaps the government's focus on resolving the conflict instead of prioritizing developmental activities.

Table 4.79: Available Agriculture Job Opportunities for Youth and Women in Sekota Areas

Lists of job opportunities	Number of engaged					
	Sekota District		Gazgibla District		Ziguala District	
	Youth	Women	Youth	Women	Youth	Women
Crop production	181	92	72	16	39	7
Cattle fattening	21	11	70	65	14	-
Poultry production	46	-	389	789		66
Beekeeping	-	-	65	257	18	102
Fishing	-	-	-	-	796	5
Off/non-farm activities	20	-	-	-	-	-
Total	268	103	596	1127	867	180

Source: Woreda Agricultural Offices, 2023

Based on the data from FGD, KII, and secondary data, the major constraints about job creation are poor awareness of the youth and women for new technologies, poor availability and accessibility of agricultural inputs, poor monitoring and evaluation from the respective actors after creating the job, poor market linkage and information, limitation of initial capital to create more jobs, lack of credit access, and diseases and pest occurrence. Wag-Himra zone is one of the Northern Ethiopia conflict-affected areas. Hence, many youths and women need rehabilitation or job creation, but on the other way, there is a higher limitation of resource and credit access to create more jobs for those who are affected by the conflict.

4.4.12. Major Constraints and Opportunities

In the Gondar areas, a multitude of constraints hinders agricultural development across various sectors. Lack of availability of improved agricultural inputs such as high-yielder varieties, chemical fertilizers, and pesticides result in low agricultural productivity. Additionally, unpredictable weather patterns cause agricultural yield variability. Lack of irrigation facilities and mechanization hubs limit the growth of agriculture sector in the region.

High rates of soil erosion, deforestation, and water scarcity have adverse effects on agricultural productivity and sustainability. These challenges associated with inadequate soil and water conservation practices that mitigate environmental impacts of depletion of the natural resources. In addition, the region cannot exploit the potential of livestock production. This is mainly associated with poor breed types, lack of forage and feed, disease outbreaks, underdeveloped livestock marketing, and lack of post-harvest technologies, ultimately constraining profitability and market penetration.

Although agricultural extension services can play a crucial role in addressing these challenges, they are not well functioning in providing practical-based advisory services to smallholder farmers. Specifically, farmers training centers have not been providing the intended demonstration-based training to smallholder farmers. There are notable knowledge and skills gaps on development agents managing farmers training centers.

Another challenge of the agriculture sector is under development of the agricultural and livestock marketing. Lack of marketing facilities such as storage and transportation and market information affects both the supply and demand side of agricultural commodities. Unlike investment in agricultural system, investment in the development of agricultural marketing has given less emphasis by the government. For example, cost recovery public investment scheme could play significant role in the development of livestock marketing (Yitayew et al., 2024). Insufficient credit access and capital limits investment opportunities in the agricultural sector. Poor road networks and limited access to clean water and electricity have adverse impact on economic and social development in the rural communities.

In summary, addressing these multifaceted challenges requires holistic approaches, integrating technical solutions with socio-economic and cultural considerations to promote sustainable agricultural development in the Gondar areas.

Table 4.80: Major Constraints in Gondar Areas

Crop Production	Livestock	Natural Resources	Agricultural Extension	Marketing	Infrastructure	Socio-Cultural
Low crop productivity Limited access to improved inputs	Breed limitations AI service constraints	High soil erosion Climatic change	Limited awareness creation Insufficient training	Transportation challenges Price fluctuation and market distortion	Road accessibility Clean water availability	Security concerns Poverty issues
Challenges in agronomic practices Plant diseases	Low productivity Forage and feed shortages	Deforestation Soil fertility depletion	Limited field exposure Lack of experience-sharing programs	High cost of agricultural inputs Seasonal market demand variation (vegetables)	Electricity access Telecommunications access	Nutrition security Food security concerns
Weather variability	Disease outbreaks	Water scarcity	Weak practical support	Storage limitations	Energy supply	Gender-related challenges
Land shortages	Land shortages	Soil management issues	Knowledge and skill gaps	Limited access to marketplaces	Credit availability	Capital shortages
Mechanization limitations	Drug shortages	Weak soil and water conservation	Gaps in new technologies and practices	Weak market linkages		Population growth
Irrigation water and canal shortages	Limited market space	Soil acidity problems	Low adoption of improved technology packages	Market development challenges		Land shortages

Table 4.81 summarizes the major agricultural production constraints in seven districts of Gondar areas. The major agricultural production constraints in the study area are ranked based on their severity, with a total score calculated for each challenge. Accordingly, climate change is ranked as the first challenge of agricultural production, followed by lack of access to agricultural services and poor infrastructure. Next to these challenges, lack of agricultural inputs and institutions are ranked as important agricultural challenges. Lastly, underdevelopment of agricultural and livestock marketing is presented as a challenge that hinders farmer to benefit from the sector.

Climate change can lead to unpredictable weather patterns, which can negatively influence crop yields, livestock health, and overall agricultural productivity in the study areas. Implementing adaptation and mitigation strategies is crucial to develop resilient agriculture for climate change and achieving sustainable agriculture in the region.

- Improving infrastructure can enhance market access, reduce post-harvest losses, and improve overall efficiency in the agricultural value chain.
- Improving access to agricultural services can enhance farmers' knowledge and skills, leading to improved agricultural practices and productivity.
- Ensuring the availability and affordability of inputs can improve crop yields and overall farm productivity.
- Strengthening institutions can improve governance, policy implementation, and overall support for farmers.
- Improving market access, information, and infrastructure can help farmers fetch better prices for their produce and improve their overall livelihoods.

Table 4.81: Aggregate Major Agricultural Production Constraints' Point and Rank in Gondar Areas

Problems	Adiarkay	Beyeda	Debark	Wogera	Gondar Zuria	West Belesa	Metema	Total	Rank
Markets	1	1	0	0	0	1	2	5	5
Infrastructure	4	3	2	2	3	3	2	19	2
Inputs	1	4	1	4	1	4	1	16	3
Institutions	2	1	3	2	2	0	1	11	4
Access to services	2	1	4	2	4	2	4	19	2
Climate change	5	5	5	5	5	5	5	35	1

Source: Survey data, 2024

Major Opportunities

Despite the challenges of agricultural activities, there are several opportunities for agricultural development in the study areas. These advantages include the following: (1) suitable agro-climatic conditions for crop and livestock production; (2) good market prices; (3) a willingness among people to engage in agriculture; (4) increased demand for agricultural technologies; (5) investment in infrastructure; (6) high market demand for agricultural commodities; and (7) enhanced local and international relations. Overall, these opportunities can be leveraged to promote sustainable agricultural development, improve food security, and enhance the livelihoods of farmers in the study area.

In the lowland areas of north Shewa, there are several challenges. These challenges include: (1) quality loss due to post-harvest problems; (2) identification of effective fattening methods; (3) lack of resource access and low decision role in farming for women; and (4) limited diet combination of cereals based pulse combination food habits. The possible interventions to address these challenges include (1) introduction of shelf life improvement technologies; (2) Introduction of post-harvest handling tools; and (3) provision of training and awareness creation.

In the midland areas of north Shewa, there are several challenges. These challenges include: (1) low grain market of wheat and sorghum; (2) lack of suitable harvester and thresher tolls; (3) limited access to improved technologies for low land areas; (4) lack of developed value chain guide lines for CIG. The possible interventions to address these challenges include: (1) conducting market and value chain studies; (2) market linkage establishment and experience sharing on utilization of improved mechanized farms with similar agro-ecologies; and (3) introduction and evaluation of available technologies in the lowlands.

In the highland areas of north Shewa, there are several challenges. These challenges include (1) limited diet combination habits, (2) lack of seasonal market linkage for potato and carrot, (3) lack of mechanization tools for wheat and barley production, (4) lack of established learning watershed, and (5) lack of training in different agricultural production. The possible interventions to address these challenges include (1) provision of training and introduction of new technologies, (2) integration of smallholder farmers with market actors depending on the production season, and (3) introduction of different storage facilities to lengthen storage periods. In Sekota areas, there are several major socioeconomic challenges in agricultural production, including livestock, crop production, and natural resource management (NRM).

Table4.82: Socioeconomic Problems of Agricultural Production in Sekota Areas

Major Problems	Sekota (Midland)	Gazgibla (Highland)	Ziquala (Lowland)
Market-related problems	- High input prices - Market information asymmetry - Few buyers and price-setting traders (especially for mung bean and sesame) - Poor market infrastructure - Lack of storage and poor post-harvest handling - No value addition on major crops - Very low price of hide and skin - High inflation of consumer goods	- Market information asymmetry - Poor market infrastructure - Lack of storage and poor post-harvest handling - Very low price of hide and skin - High inflation of consumer goods	- Few buyers and price-setting traders (especially for mung bean and sesame) - Market information asymmetry - Poor market infrastructure - Lack of storage and poor post-harvest handling - High inflation of consumer goods - High transportation costs due to poor road facilities
Climate change-related problems	- Soil erosion and land degradation - Erratic weather patterns (rainfall, temperature) - Deforestation - Increase in disease, insect, and pest outbreaks - Declining groundwater levels for drinking and irrigation - Rising temperatures	- Soil erosion and land degradation - Erratic weather patterns - Deforestation - Increase in disease, insect, and pest outbreaks - Declining groundwater levels - Rising temperatures	- Soil erosion and land degradation - Erratic weather patterns - Deforestation - Increase in disease, insect, and pest outbreaks - Declining groundwater levels - Rising temperatures
Gender-related problems	- Limited access to education - Limited economic opportunities - Limited decision-making power - Limited control over resources	- Limited access to education - Limited economic opportunities - Limited decision-making power - Limited control over resources	- Limited access to education - Limited economic opportunities - Limited decision-making power - Limited control over resources
Population growth-related constraints	- Limited farmland - High unemployment - Youth landlessness - Increased demand for goods and services	- Limited farmland - High unemployment - Youth landlessness - Increased demand for goods and services	- Limited farmland - High unemployment - Youth landlessness - Increased demand for goods and services

Source: Survey data, 2024

Table 4.83 presents the ranking of the major problems faced by Sekota, Ziquala, and Gazgibla districts. Across all three locations, market-related issues are the most significant problem, ranking in the top two for each location. Input-related challenges are also prominent, ranking second in Sekota and first in Gazgibla. Climate change is a significant challenge in all locations, ranking third in Sekota and Ziquala and fourth in Gazgibla. In terms of infrastructure, Sekota ranks lowest at four while it is the most prominent challenge for Gazgibla. For institutions, there are uniform struggles across the board, ranking fifth or lower for each location. Lastly, accessing services is the lowest-ranked problem, ranging from fifth to sixth in all locations.

Table 4.83: Major Agricultural Production Constraints in the Study Areas in Sekota Areas

Major Problems	Sekota Rank	Ziquala Rank	Gazgibla Rank
Market related	1	2	2
Inputs	2	4	1
Climate change	3	3	4
Infrastructures	4	1	3
Institutions	5	6	6
Access to service	6	5	5

Source: Survey data, 2024

Table 4.84: Socioeconomics Prioritization of Problems, Screening Options, and Interventions in North Shewa Areas

Prioritized Problems	Screening Options	Interventions	Intervention Areas
Lack of suitable improved farm tools	Technology	Demonstration of available technologies	All areas
High post-harvest losses on onion, tomato, potato, and sorghum	Awareness	Training & mobilization	Antsokiagemiza, Efaratanagdim, Kewet, Bassonawerana
Low market access for horticultural crops during peak harvest	Market linkage	Integrate producers with high-market areas	Antsokiagemiza, Efaratanagdim, Kewet, Bassonawerana
High price variability for consumable commodities across regions	Information	Conduct market study	Efaratanagdim
High broker intervention in grain marketing	Policy	Conduct survey & identify causes	Efaratanagdim, Kewet
Limited training access for skill development	Training	Organized training	Siyadebirnawayu, Moretinajiru, Tarimaber
Limited access to technology choices	Intervention	Introduce diverse technologies	Antsokiagemiza, Tarimaber, Kewet
Limited access and control over household resources for women	Information	Conduct gender-related survey study	All areas
Insufficient nutrition availability	Awareness	Organized training & technology demonstration	All areas
Low level of value chain guidelines for CIG	Information	Conduct value chain study on CIG areas	Moretinajiru, Bassonawerana, Tarimaber, Minjar Shenkora
Lack of market study information on wheat and sorghum	Information	Conduct market study on wheat & sorghum	Moretinajiru, Siyadebirnawayu, Minjar Shenkora
Lack of watershed learning and area closure management	Awareness	Organize training and experience sharing	Tarimaber, Kewet, Bassonawerana
Lack of effective fattening practices for cattle	Technology	Demonstration and evaluation	Kewet, Antsokiagemiza

5. Conclusion and Recommendations

Agriculture plays a significant role in Ethiopia's economy, contributing approximately one-third of its Gross Domestic Product (GDP) and engaging more than 63% of its population. The Amhara National Regional State (ANRS), an autonomous region bordered by Tigray (to the north), Oromia (to the south), Benishangul (to the southwest), Sudan (to the west), and Afar (to the east), accounts for about one-third of the country's annual crop production. Although the region has significant agricultural potential, crop production, and productivity are still low and cannot meet the demands of a growing population. These challenges are primarily due to a combination of biotic and abiotic constraints.

The Amhara region has various agro-ecological zones, traditionally classified as Bereha (extremely hot lowlands, below 500 meters above sea level), Kolla (lowlands, 500–1500 masl), Woina-Dega (midland, 1500–2300 masl), Dega (highland, 2300–3200 masl), and Wurch (extreme highlands, above 3200 masl). However, the agricultural significance of Bereha and Wurch is relatively minimal compared to Kolla, Woina-Dega, and Dega. Therefore, this survey focuses on the region's lowland, midland, and highland agro-ecologies.

This assessment identifies several key constraints that hinder agricultural production, which are essential for future interventions to promote sustainable agricultural practices. The primary challenges include (1) the adverse effects of climate change, (2) limited access to agricultural services, (3) inadequate infrastructure, (4) insufficient agricultural inputs, (5) weak institutional support, and (6) underdeveloped agricultural and livestock markets. Other critical constraints requiring attention include the low adoption of new technologies and practices, abiotic stress, and various biotic threats such as diseases, insect pests, weeds, and post-harvest losses. Abiotic stresses encompass moisture deficiency, low soil fertility, soil acidity, salinity, frost, and waterlogging, causing a reduction or failure in crop yields. Addressing these challenges requires strong collaboration among research institutions, universities, and agricultural departments to facilitate the dissemination and adoption of innovative farming technologies among farmers.

Farmers play a limited role in identifying agricultural challenges and contributing to technological development, resulting in a gap between the technology developed and the realities they face. Actively involving farmers in the innovation process is essential, as their extensive agricultural experience and indigenous knowledge provide valuable insights that can enhance the relevance and effectiveness of new technologies.

A significant challenge facing the agricultural sector in the region is the limited access to essential inputs, such as improved seeds, inorganic fertilizers, and agrochemicals. Despite the increasing demand, the supply remains inadequate, compounded by high costs, poor quality, and delays in delivery. Addressing these issues is crucial for ensuring sustainable agricultural productivity.

Agricultural mechanization is known for improving farm productivity and reducing post-harvest losses. While the Ethiopian government has recently approved policies to promote its expansion, mechanization is still in its early stages and needs further development, especially in the Amhara region. Strengthening implementation efforts will be crucial for advancing mechanization and fully realizing its benefits.

Although the Amhara region is known as the water tower of Africa, its extensive surface and groundwater resources remain underutilized. Unlocking its irrigation potential is vital for enhancing crop production and productivity, necessitating government prioritization of modern irrigation infrastructure. Additionally, the region's favorable conditions for horticultural crop cultivation, especially in the Tana Growth Corridor and the Kobo-Girana Valley, remain largely untapped. These areas could significantly enhance horticultural production in the region; however, the lack of sufficient storage facilities and effective post-harvest loss mitigation strategies hinders their growth. To address these challenges, investments in storage infrastructure, packaging technologies, grading systems, value addition, and market linkages are essential for transforming horticultural production in the region.

Farmers in the region are increasingly aware of the adverse impacts of climate change on agriculture. Over the past few decades, rising temperatures and declining rainfall patterns have disrupted crop productivity, with delayed rainfall onset, early cessation, and prolonged dry spells becoming more frequent. Additionally, climate change has contributed to the proliferation of pests, further threatening agricultural yields. Given the inevitability of these changes, it is imperative to develop climate-resilient farming systems and equip farmers with effective adaptation strategies. Collaborative efforts between government agencies and NGOs are essential to designing and implementing interventions that enhance farmers' resilience and reduce their vulnerability.

Land use and land cover issues in the region's highland, midland, and lowland agro-ecologies are largely influenced by agricultural expansion, deforestation, overgrazing, and land degradation. Intensive cultivation and grazing have accelerated soil erosion, deforestation, and biodiversity loss in the highland agroecology. Despite ongoing conservation efforts, including biophysical structures, controlled grazing, and ecological restoration, land tenure insecurity and illegal encroachment remain significant obstacles to the recovery of these areas.

Similarly, in midland agroecology, overgrazing and the shift of grazing land to cropland continues to disrupt the ecological balance. However, interventions such as area closures, afforestation, and agroforestry provide promising opportunities to mitigate these challenges and restore ecological stability.

Agriculture remains the backbone of Ethiopia's economy, with the Amhara region playing a crucial role in national crop production. Despite its vast potential, several challenges hinder agricultural productivity, including biotic and abiotic constraints, limited access to essential inputs, and low adoption of modern technologies. Although significant advancements have been made in developing pest-resistant and high-yielding crop varieties, the gap between research innovations and their practical implementation on farms remains substantial. Besides, traditional agronomic practices, limited mechanization, and the underutilization of irrigation resources further restrict agricultural development.

The region's agro-ecological diversity presents both challenges and opportunities. The lowland, midland, and highland areas face unique environmental and production-related issues, yet they also hold untapped potential, particularly in horticulture and water resource utilization. Climate change, exacerbating existing stressors, adds another layer of complexity, making it imperative to focus on building climate-resilient farming systems. Farmers' active engagement in identifying real challenges and co-developing appropriate technologies is crucial for ensuring practical and effective solutions.

Addressing these complex issues requires a collaborative approach. Government agencies, research institutions, and NGOs must work together to develop tailored interventions that improve input delivery systems, promote sustainable farming practices, and optimize the region's water and land resources. Strengthening climate resilience among farmers, improving infrastructure, and advancing modern agricultural practices will be fundamental to unlocking the full potential of the Amhara region's agricultural sector—ultimately ensuring food security and sustainable livelihoods for its growing population.

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