Thesis Ref. No. -------------

IMPACT OF ANIMAL HEALTH INTERVENTIONS ON FOOD AND NUTRITION SECURITY IN EXTENSIVE LIVESTOCK PRODUCTION SYSTEMS IN SELECTED COMMUNITY-BASED BREEDING PROGRAM (CBBP) AND HEARD PROJECT IMPLEMENTATION AREAS OF ETHIOPIA

MSc THESIS

BY

ASMAMAW DURESSA REJE (GSR/7932/15)

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF VETERINARY EPIDEMIOLOGY AND PUBLIC HEALTH

MASTER OF SCIENCE IN VETERINARY EPIDEMIOLOGY

JUNE, 2025

BISHOFTU, ETHIOPIA

IMPACT OF ANIMAL HEALTH INTERVENTIONS ON FOOD AND NUTRITION SECURITY IN EXTENSIVE LIVESTOCK SYSTEMS IN SELECTED COMMUNITY-BASED BREEDING PROGRAM (CBBP) AND HEARD PROJECT IMPLEMENTATION AREAS OF ETHIOPIA

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Sciences in Veterinary Epidemiology

BY

ASMAMAW DURESSA REJE (ID No GSR/7932/15)

JUNE, 2025

BISHOFTU, ETHIOPIA

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF VETERINARY EPIDEMIOLOGY AND PUBLIC HEALTH

As MVSc research advisors, we certify that we have read and evaluated the thesis prepared under our guidance by **Asmamaw Duressa Reje** entitled: "**IMPACT OF ANIMAL HEALTH INTERVENTIONS ON FOOD AND NUTRITION SECURITY IN EXTENSIVE LIVESTOCK SYSTEMS IN SELECTED COMMUNITY-BASED BREEDING PROGRAM (CBBP) AND HEARD PROJECT IMPLEMENTATION AREAS OF ETHIOPIA**". We recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Veterinary Epidemiology.

Submitted by: Asmamaw Duressa Reje ______________ _____________

Name of Student Signature Date

Approved *for submission to a* thesis assessment committee

1. Bekele Megersa (*DVM, MSc, PhD, Professor*) ____________ ____________

   Advisor Signature Date

2. Teshale Sori *(DVM, MSc, PhD, Professor)* ____________ ____________

   Co-advisor Signature Date

3. Shigdaf Mekuriaw *(PhD, Senior Researcher)*  ____________

   Co-advisor Signature Date

Department Head

4. Haileleul Nigussie (PhD, Assoc.Prof) ____________ ____________

Signature Date

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF VETERINARY EPIDEMIOLOGY AND PUBLIC HEALTH

As members of the examining board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by **Asmamaw Duressa Reje,** entitled " **Impact of Animal Health Interventions on Food and Nutrition Security in Extensive Livestock Systems in Selected Community-Based Breeding Program (CBBP) and HEARD project Implementation Areas of Ethiopia** " and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Veterinary Epidemiology.

______________________________ ______________ ______________

Chairperson Signature Date

______________________________ ______________ ______________

External Examiner Signature Date

Dr . Biruhtesfa Asrade ______________ ______________

Internal Examiner Signature Date

I hereby certify that I have read the revised version of this thesis prepared under my direction and recommend that it be accepted as fulfilling the thesis requirement

Advisor:

Prof. Bekele Megersa ______________ ____________

Co-Advisors: Signature Date

Professor Teshale Sori ______________ ____________

Signature Date

Dr. Shigdaf Mekuriaw ______________ ____________

Signature Date

Department Head

Dr. Haileleul Negussie ______________ ______________

Signature Date

AUTHOR DECLARATION

The work presented in this thesis was conducted from December 2023 to May 2025 at Kefa Zone of S/W/Ethiopia, Jarar Zone of Somali and North Shewa Zone of Amhara Region, Ethiopia, under the supervision of Professor Bekele Megersa (AAU), Professor Teshale Sori (AAU) and Dr. Shigdaf Mekuriaw (ILRI). This thesis has been submitted in partial fulfillment of the requirements for the Master of Veterinary Science in Veterinary Epidemiology degree at Addis Ababa University College of Veterinary Medicine and Agriculture. I hereby declare that this thesis entitled '***Impact of Animal Health Interventions on Food and Nutrition Security of Extensive Livestock Systems in Selected Community-Based Breeding Program CBBP) and HEARD project Implemented Areas of Ethiopia***' is an original research work conducted by me and that the thesis or part of it has not been previously submitted for the award of any degree, diploma, fellowship or another similar title, of at any other University or Institution.

Name: Asmamaw Duressa Signature _______________

College of Veterinary Medicine and Agriculture, Bishoftu, Ethiopia

Date of Submission 09/ 06/2025

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

First and foremost, I am grateful to God for providing me with the health and strength I need for all aspects of my life and my work. Second, this work would not have been possible without the unwavering support of my advisors, instructors, colleagues and family. I extend my heartfelt gratitude to Professor Bekele Megersa, Professor Teshale Sori, and Dr. Shigdaf Mekuriaw for their invaluable guidance and supervision throughout this study. I am particularly grateful to Professor Bekele Megersa and Professor Teshale Sori of Addis Ababa University for their encouragement in joining the ACIAR project. I would also like to acknowledge the contributions of those who worked tirelessly in the North Shewa zones of the Amhara region, the Debre Birhan Agricultural Research Center (especially Dr. Chekol and Asfaw), the Somali region (Dr. Mohammed, Dr. Ahmed, Dr. Yahiya, and Dr. Abdulfata), and the Kefa zone of S/W/Ethiopia, Bonga Agricultural Research Center. Their facilitation and provision of essential data were instrumental to this study. Special thanks go to the enumerators who took big responsibility to collect quality data. I am deeply grateful to driver Ato Daniel Tekalign, who ensured the success of our fieldwork.

This research was made possible through the support of the ACIAR project and ILRI. I am especially thankful to Dr. Shigdaf (ACIAR project coordinator) and Suzanne (Unique Land Use GmbH, Germany) for their guidance and assistance. Big respects should go to Joseph Opiyo (Egerton University, Kenya) and the FANRPAN team (South Africa) for providing us virtual training on STATA and food and nutritional security, respectively. I also extend my appreciation to the entire ACIAR project team, including fellow students and advisors, for their constructive feedback, shared resources, and support during data collection, and document preparation. Special thanks go to the steering and technical committee members, particularly Dr. Dawit and Dr. Ayinalem, for their precious guidance. I would like to acknowledge Mr. Mesay for his technical expertise in training us on Kobo Tools and managing the data collection process. I am profoundly grateful to the Ministry of Agriculture for facilitating my MSc program through financial support. This opportunity was made possible through the efforts of H.E. Dr. Fikru Regassa, Mr. Tesema Gebremedhin, and Mr. Kefeyalew Zeleke.

Finally, I owe immense gratitude to my friends, colleagues, and family for their constant encouragement and support. A special thank you goes to my wife, Meskerem Sileshi, for shouldering the responsibilities of our family and providing exceptional care to our beloved children, Melala and Hila, during this journey.

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

ABBREVIATIONS

AAU	Addis Ababa University
ACIAR	Australian Centre for International Agricultural Research
AHI	Animal Health Interventions
ASF	Animal Source Foods
CAHWs	Community Animal Health Workers
CBBP	Community-Based Breeding Program
CBPP	Contagious Bovine Pleuropneumonia
CCPP	Contagious Caprine Pleuropneumonia
CEP	Control and Eradication program
CSA	Central Statistical Agency
DOVAR	Disease Outbreak and Vaccination Activity Reporting
EPHI	Ethiopian Public Health Institute
ESS	Ethiopian Statistics Service
EU-SHARE	European Union-Supporting Horn of Africa Resilience
FAOSTAT	Food and Agriculture Organization's (FAO) global statistical database
FBDG	Food-Based Dietary Guidelines
FCS	Food consumption score
FGD	Focus Group Discussions
FHI	Family Health International
FNS	Food and nutrition security
GHI	Global Hunger Index
GIT	Gastrointestinal Tract
HEARD	Health of Ethiopian Animals for Rural Development
HFIAS	Household Food Insecurity Access Scale
HHs	Households
ICARDA	International Center for Agricultural Research in the Dry Areas
IGAD	Intergovernmental Authority on Development's

ILRI	International Livestock Research Institute
KII	Key Informant Interviews
LFSDP	Livestock and Fisheries Sector Development Project
LLRP	Lowland Livelihood Resilience Project
LSD	Lumpy Skin Disease
MDD-W	Minimum Dietary Diversity for Women
MoA	Ministry of Agriculture
MoLF	Ministry of Livestock and Fisheries
NADSS	National Animal Disease Surveillance System
NVI	National Veterinary Institute's
PARC	Pan-African Rinderpest Campaign
PAs	Peasant Associations
PDS	Participatory Disease Surveillance
PPR	Peste des Petits Ruminants
PSI	Policy Studies Institute
PVS	Performance of Veterinary Services
RC	Research Center
RPLRP	Regional Pastoral Livelihoods Resilience Project
SGP	Sheep and Goat Pox
TADs	Trans boundary Animal Diseases
WHO	World Health Organization

ABSTRACT

Ethiopia is home to a large population of small ruminants, although their contribution to the livelihoods is sub-optimal. This study examines the impact of animal health interventions on food and nutrition security within Ethiopia's extensive livestock systems, with a focus on Community-Based Breeding Programs and the HEARD project. Literature review, key informant interviews, focus group discussions, secondary data analysis, and a targeted survey were employed to compare households in intervention and non-intervention areas regarding access to veterinary services and food security. Household Food Insecurity Access Scale (HFIAS), Food Consumption Score (FCS), and Minimum Dietary Diversity for Women (MDD-W) were used to measure food and nutrition security of the study households. A total of 497 households were surveyed, comprising 321 from intervention areas and 176 from control areas. The study results showed significantly better access to veterinary services among intervention households (e.g., vaccination: 67.9% vs. 54.0%; training: 62.1% vs. 24.8%, $P < 0.05$). Food security was higher in animal health intervention areas: 72.4% vs. 54.7% (HFIAS), 64.6% vs. 56.3% (FCS), and nutrition security 65.4% vs. 62.9% (MDD-W). Logistic regressions revealed deworming increased odds of food security (OR = 3.6, P = 0.000) and treatment (OR = 2.27, P = 0.006) using the HFIAS indicator. Deworming and treatment also improved FCS (OR = 1.66, P = 0.05 and 1.88, P = 0.023), and awareness of zoonoses had a strong effect (OR = 3.20, P = 0.000). Vaccination was linked to better MDD-W (OR = 2.02, P = 0.043), and primary education improved MDD-W (OR = 2.97, P = 0.000). However, anthrax vaccination was negatively associated with all three indicators. This study showed that targeted animal health interventions significantly enhance food and nutrition security. The findings support national efforts to strengthen livestock strategies and food security. Further experimental research is needed to strengthen evidence on the relationship between animal health interventions and human nutrition.

***Keywords**: Households, animal health intervention, livestock disease, food and nutritional security, Ethiopia*

1. INTRODUCTION

Small ruminant productivity is hampered by several technical and non-technical factors including diseases in Ethiopia. Diseases have impacted food security and livelihoods of smallholder farmers and pastoralists and the national economy at large by limiting export earnings due to stringent animal health requirements (Gizaw *et al*., 2019). Based on data from the 2021/2022 livestock sample survey (ESS, 2021/2022), the off take rates due to sale (17.5%) and mortality (11.7%) were similar in sheep where only 11.9% were vaccinated. The burden of diseases on small ruminants is estimated at 1.342 Billion ETB, which accounts for 1.8% of losses to the national GDP (Global Burden of Animal Diseases, 2021-2022).

In response to the rapid population growth, increased urbanization and the growing demand for high-value animal-source foods livestock production is expected to change by 2050 (Otte *et al*., 2019). Since rangelands, in East and Southern Africa (ESA), including Ethiopia are not suited to other types of agricultural production, the demographic and economic changes are expected to provide opportunities for extensive livestock keepers to meet the future demand for livestock products. However, the relative distance of most rangeland communities from urban centers, poor linkages to markets and access to other services, compounded by climate variability and change, could be a challenge for livestock producing communities (Godde *et al*., 2020). Therefore, extensive livestock keeping households and communities need to respond to the challenges and find ways to improve food and nutrition security (FNS) and livelihoods (Thornton *et al*., 2009; Béné *et al*., 2014).

The Government of Ethiopia developed a ten-year strategic plan with ten focus areas ("Ten in Ten") four of which focus on livestock development. In addition, a National Livestock Development Initiative called '*Ye Lemat Tirufat* (Bounty of the Basket) was launched in 2022 and is a four-year development program that aims to boost productivity and production of dairy, eggs, chicken meat, and honey and related hive products. Animal health intervention is one the pillars prioritized by the initiative (Dessie *et al*.,

2023) in which 15 animal diseases and five zoonotic diseases were on top agenda including control and eradication of Peste des Petits Ruminants (PPR) (MoA, 2021-2030 Plan and PPR CEP, 2020).

While there is some evidence from surveys of men's and women's perceptions of the livelihood impacts of animal diseases (Muindi *et al*., 2015), no research has documented the effects of interventions to prevent animal disease on FNS outcomes. For some major diseases, there is some evidence of negative impacts on individual animal productivity (e.g., milk yields) and herd productivity (e.g., reproduction) (Jibat *et al*., 2016; Megersa *et al*., 2011). This strongly suggests that reducing morbidity and mortality could significantly impact FNS, either through consumption or income pathways. In addition, inter-sectoral engagement to establish control and prevention strategies for prioritized zoonotic diseases will reduce the public health burden in humans and reduce the associated economic impact of the diseases at the national and household levels, while creating inter-sectoral linkages and infrastructure improvements needed to rapidly respond to newly emerging health threats (Pieracci *et al*., 2016).

Community-Based Breeding Program (CBBP) has been initiated in several communities to improve the productivity of small ruminants to ultimately contribute to income, and food and nutrition security. Reports on the impact of CBBP engagements showed that the population of small ruminants is increasing for CBBP participants, while it is decreasing for non-participants. The trend observed in CBBP participants has attracted non-participating farmers and sheep breeders' cooperatives. Successful breed improvement requires a high level of management, mostly efficient health intervention. Animal health intervention is required to reduce morbidity and mortality of improved breeds and consequently contribute to food and nutrition security (Areb *et al*., 2021). Additionally, the Health of Ethiopian Animals for Rural Development (HEARD) program has been working on animal health intervention targeting reducing morbidity and mortality. However, there is no scientific evidence on the impacts of animal health intervention on improving FNS. The lack of evidence on impacts of animal health interventions on FNS impedes linking animal health to policy issues nationally, regionally and globally. This study attempts to explore the impacts of animal health intervention on household food and nutrition security and nutritional diversity.

1.1. Statement of the Problem

Despite Ethiopia's large population of small ruminants and ongoing animal health interventions, livestock productivity and its contribution to food and nutrition security (FNS) remain suboptimal. High prevalence of diseases, limited access to veterinary services and lack of coordinated health interventions in extensive livestock systems continue to hinder household food security and economic development (Gizaw et al., 2019). Moreover, there is insufficient empirical evidence demonstrating the direct impact of animal health interventions on FNS outcomes. This knowledge gap impedes the formulation of effective policies and strategies linking animal health to improved nutrition and livelihoods. The study seeks to assess the effects of health intervention on FNS in selected Community-Based Breeding Program (CBBP) and HEARD project areas of Ethiopia.

1.2. Research Questions

The study was conducted to answer the following key questions:

- What are the types and status of animal health interventions in extensive livestock production systems?
- What are the effects of previous and ongoing animal health interventions on food and nutrition security in extensive livestock production systems?
- What additional interventions should be suggested in conjunction with promising animal health interventions to increase synergies and address trade-offs between animal health intervention and food and nutrition security?

General Objective

To assess the impact of animal health intervention on food and nutrition security in selected CBBP and HEARD project sites.

Specific Objectives

- To investigate the type and status of animal health interventions in CBBP and HEARD project areas
- To generate information on the evidence of the impacts of animal health interventions on food and nutrition security
- To explore the synergies and trade-offs between animal health interventions and impacts on FNS.

2. LITERATURE REVIEW

2.1. Literature Review Methodology

A semi-systematic literature review was conducted to examine animal health interventions and their impact on food and nutrition security in Ethiopia. The review is focus on existing documents, progress reports, and project implementation data from CBBP and HEARD initiatives. Unlike a systematic review, which follows a strict, predefined methodology for evidence synthesis, this study employed a semi-systematic approach to provide a broader exploration of the topic while maintaining critical and objective analysis (Snyder, 2019). The review was guided by the theoretical framework on *"The Impact of Animal Health Interventions on Food and Nutrition Security in Extensive Livestock Systems in Ethiopia."* It focused on key interventions including vaccination, treatment, and awareness-raising while avoiding redundant findings. The analysis synthesized existing knowledge, highlighted gaps in research, and identified areas requiring further investigation.

Data sources of information were from published literatures/articles, grey literature (including reports, policy literature, working papers, newsletters, government documents, and non-government documents), online publications through internet searches using key words and phrases on animal health interventions and their impact on food and nutrition security. The review specifically centered on small ruminants, particularly sheep, to maintain focus.

2.2. Livestock Production System in Ethiopia

Based on the Ethiopia Policy Studies Institute (PSI) of February 2023 report, the livestock population of Ethiopia is estimated at 71 million cattle, 43 million sheep, 54 million goats, 13.33 million equines, and 57 million poultry (PSI, 2023). Ethiopia has large livestock resources, and the sector plays a significant role in the livelihood and economic development of the country. Livestock not only contributes to the agricultural GDP (45%) and the overall GDP (19%) but also plays a significant role in foreign exchange earnings, accounting for 16-19% (ESS, 2022). The livestock sector analysis conducted in 2017 also estimated the contribution of livestock as high as 21% of the national GDP and 49% of the agricultural GDP, considering the contribution of processing and marketing (USD 35.6 billion) (Shapiro *et al*., 2017). The contribution of small ruminants to the national economy accounts for 2% of GDP, estimated for Ethiopia in the year 2021. Much of this was from increased stock value and live animal off-take (Jemberu *et al*., 2022).

In Ethiopia, livestock is produced under two major production systems: the sedentary mixed crop-livestock production system and the nomadic pastoral or agro-pastoral production system. The other less important, but growing, livestock production systems are small-scale peri-urban and urban production systems and medium-to large-scale commercial livestock production. The mixed crop-livestock production system is based on limited communal and/or private grazing areas and the use of crop residues and stubble. The pastoral production system is based on extensive communal grazing, while agro-pastoralists are characterized by a combination of pastoral and mixed crop-livestock production. Mixed-farm households practice both crop and livestock production (Negassa *et al*., 2012). The emergence of private intensive dairy farms of various sizes run as a business, which focused on peri-urban and urban areas in the central highlands, taking advantage of urbanized large markets and the rapidly increasing demand for animal products such as milk (Ahmed *et al*., 2004).

The percentage of farmers in Ethiopia only growing crops was 18% in 2001/02 and decreased to 9% in 2007/08, while the percentage of farmers keeping livestock only was 8% in 2001/02 and decreased to 5% in 2007/08. On the other hand, the percentage of farmers with both crop and livestock holdings was 74% in 2001/02 and this percentage increased to 86% in 2007/08. Diversification allows producers to mitigate the risk of crop failure or losses of livestock, while livestock is also an important input to crop production and vice versa. Both the mixed crop-livestock and the pastoral production systems are characterized as small-scale, low-input, and less commercially oriented, with very little or no vertical coordination. The common feature of these production systems is that livestock producers keep different livestock species for multiple uses. Recently, commercially oriented livestock production systems have begun to emerge. Private sector entries and capital investment into meat, dairy, and poultry farms have increased substantially over the last decades (Negassa *et al*., 2012).

Livestock production constitutes one of the principal means of achieving improved living standards in many regions of Ethiopia, in common with other developing countries. Livestock plays a crucial role both for the national economy and the livelihood of the rural communities. It provides draft power, milk and meat, input for crop production and soil fertility and raw material for industry. However, livestock health problems are high due to environmental factors such as high temperature and humidity, extensive nature of production systems, stress factors, drought and poor animal health services (ESS, 2022).

2.3. Small Ruminant Production Systems and CBBP in Ethiopia

According to the traditional classification of livestock production systems, there are two distinct areas in the Ethiopian livestock production system. Highland areas more than 1,500 metres above sea level (masl) cover 40% of the country and host approximately 75% of the cattle, 50% of the sheep and 30% of the goats. The lowlands are areas below 1,500 meters above sea level are mainly pastoral, covering 60% of the of the country's land mass and host 70% of goats, 50% of sheep, 24% of the cattle and nearly the whole camel population of the country. The pastoral areas have historically been the source of export animals (MoA PPR CEP Strategy, 2020).

Sheep and goats require relatively low labor input, and may be easily maintained by poor households, women and young people. Production of sheep and goats also serves as a risk-mitigation strategy, as it complements other farm activities and diversifies the household investment portfolio. Sheep are typically sold at an age between 6-12 months.

Sheep and goats are kept for cash sale, meat (especially during holiday seasons), and milk (MoA PPR CEP Strategy, 2020). Further, sheep contribute 25% of the domestic meat consumption; about half of the domestic wool requirements; about 40% of fresh skins and 92% of the value of semi-processed skin and hide export trade. Sheep also play several other important social, cultural and economic roles as they can also easily be raised by women and disadvantaged households (Hirpa and Abebe, 2008).

2.4. Small Ruminant Priority Diseases in Ethiopia

Prioritization of disease during the Livestock Master Plan (LMP) development process of the livestock sector investment and policy toolkit (LSIPT) was used to inform decision makers to prioritize diseases to focus on (MoLF, Epidemiology Directorate, 2016). The most important diseases were ranked according to their impact on rural households and their livelihoods, markets and value chains, and intensification pathways. The global scores were weighted for total numbers of households affected, total value added generated from the sub-chain, and the animal populations affected. Accordingly, for sheep and goats, the top ranked diseases taking into account household, market and value chains, and intensification are Peste des petits ruminants (PPR), sheep and goat pox (SGP) and contagious caprine pleuropneumonia (CCPP). Ranking by impact on household attributes led to CCPP first, followed by PPR and SGP.

In addition to these three diseases, brucellosis and ovine pasteurellosis are highly prevalent and affect the small ruminant population in Ethiopia. Brucellosis and SGP are also among the 15 national priority diseases. In some regions, SGP was integrated during PPR vaccination. The federal government provides CCPP and SGP vaccines free of charge and there are regular vaccination programs implemented by the sub-national governments. However, combining PPR with other small ruminant disease vaccinations is less common and needs to be strengthened. Depending on their distribution, there is some degree of integration of PPR vaccination with SGP or CCPP (MoA PPR CE Strategy, 2020). A study on livestock disease priorities and health services in the highland crop-livestock and lowland pastoral systems in Ethiopia also indicated that, the major sheep and goat diseases are Pasteurellosis, CCPP, Respiratory diseases, coenuruses, tick, lice and sheep ked, Anthrax, foot-and-mouth disease and black leg, sheep and goat pox, Orf, liver fluke, and lung worm (Gizaw *et al*., 2021).

2.5. Animal Health Service in Ethiopia

Ethiopia is endemic to several livestock diseases which continue to hinder livestock productivity and agricultural development. Of the 15 former Office International des Epizooties (OIE) list "A" (notifiable) diseases, known for their potential for very serious and rapid spread, irrespective of national borders, that are of serious socio-economic or public health consequence and that are of major importance in the international trade of animals and animal products, eight of them are endemic in Ethiopia. Whereas, of the 72 former lists "B" (non-notifiable) disease that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of animals and animal products, 20 of them are endemic in the country. The impact of animal diseases stems from direct losses due to mortality and indirect effects through slow growth, low fertility and decreased work output that result from morbidity. In addition, livestock diseases are responsible for live animal and animal product trade embargoes, limiting the county's access to international markets. The direct and indirect losses from livestock disease have significant economic, food security, and livelihood impacts on livestock keepers and the national economy (MoA Animal Health Strategy, 2012; Alemu, 2019).

The annual loss due to mortality was estimated at 8-10% for cattle, 12-14% for sheep, 11-13% for goats and 56.9% for poultry. These figures are even much higher for calves, lambs and kids. Moreover, existing data indicated that annual production losses emanating from diseases could reach 30-50%. Since young replacement stocks are more affected both in terms of mortality and morbidity, it would undermine the sustainability of developments in the livestock sector (MoA Animal Health Strategy, 2012).

Livestock diseases directly cause pre-slaughter defects on hides and skins. Cockle (an allergic dermatitis from lice and ked infestation) is regarded as an economically catastrophic disease since it causes over 50% of skin rejection or downgrading. Animal diseases also have an important impact on human health; with 60% is animal origin. Ethiopia is endemic to a wide range of zoonotic diseases. In the past two decades, emerging and re-emerging zoonotic diseases have acquired global significance for Veterinary Public Health. These developments call for increased levels of surveillance and preparedness, and for novel approaches to control and prevention. The One Health approach, which has been developed by the international community in the context of influenza pandemics, has been adopted as the global framework for streamlining this collaboration (MoA and ILRI Animal Health Strategy, 2013).

The federal veterinary service of Ethiopia is organized at State Minister level and has different specialized departments that are responsible for coordinating and implementing national policies, regulations, and strategies related to veterinary services and livestock management. The regional state veterinary service offices are also responsible for the implementation of animal health programs, control of livestock diseases, and ensuring delivery veterinary services through their zonal, district and kebele/ Peasant associations (PAs) structures. The government has established a new authority to control and administer the quality, safety and efficacy of veterinary drugs, biologicals and animal feeds. There are many veterinary schools at university level, veterinary and para-veterinary training is improving, and the National Veterinary Institute now produces 23 vaccines against livestock diseases. There are 18 regional state diagnostic laboratories nationwide. There is one recognized national Animal Health Institute implementing a ‘quality management system’ as part of its application for ISO-17025 accreditation. This national laboratory has been accredited for more than 14 tests and six diseases. Grassroots health service delivery is through district veterinary clinics and health posts.

The Ethiopian veterinary service is delivering services such as Epidemio-surveillance, disease prevention and control, veterinary laboratory services, veterinary public health and food safety, import/export quarantine and inspection services, animal health input supply and delivery, development of legal framework, animal health extension, animal welfare, human resource development, development of communication and resource mobilization strategy (MoA Animal Health Strategy, 2012). The various animal health interventions are summarized in Table 1.

To make veterinary services are accessible to remote and pastoral areas, the use of Community Animal Health workers (CAHWs) have been widely promoted and these workers have been providing basic animals services in the remote areas of the country. A number of National intuitions such as National Animal Health Institute and the National Veterinary Institute's (NVI) have been also playing a pivotal role in the implementation of national animal health programs. In particular, the National Veterinary Institute's (NVI) production of 23 livestock vaccines, disease surveillance and diagnostics supported by 17 regional and one national laboratory, and the provision of grassroots health services through health posts in most kebeles/PAs, have all contributed to the upsurge in efforts to prevent and control diseases (Shapiro *et al*., 2015). The PPR control and eradication program supported the development of decentralized National Animal Disease Surveillance System (NADSS), which comprises Animal Disease Notification and Investigation System (ADNIS) and web-based Monthly Disease Outbreak and Vaccination Activity Reporting (DOVAR). As a result, the completeness and coverage of disease reporting have improved from 45% (2016) to 72% (2023), with improved quality and timeliness. But due to conflict in Amhara region disease reporting drop to 62.1% (MoA report, 2024)

2.5.1. Experiences of animal health interventions in Ethiopia

Animal health intervention programs have been in initiated and implemented in Ethiopia, which have been engaged in wide range of activities focusing on improving livestock health and productivity across the country. These interventions comprise disease control through increasing vaccination coverage, with over 638 million doses administered, and the vaccination of nearly 694 million animals against both Transboundary Animal Diseases (TADs) and non-TADs. Participatory disease search initiatives, supported by the EU-SHARE project, have been carried out in pastoral areas, with 351 surveys conducted between 2017 and 2019. The Ministry of Agriculture has been engaged in control of PPR and a total 554 PPR outbreak investigations have conducted between 2015 and 2022. Also as indicated in table 1, over 53 million small ruminants were vaccinated against PPR during the same period. Additionally, capacity building efforts have been made focusing on training of experts, with 207 experts trained on young stock mortality, disease prioritization, and vector-borne diseases. Similarly, a total of 439 experts received training in laboratory diagnostics, sample collection, and meat inspection. Orientation sessions for 7,000 regional experts were held as part of the ongoing PPR eradication campaign. These interventions are crucial for enhancing animal health, supporting disease control, and improving food security across Ethiopia (MoA PPR Eradication report, 2015-2022).

Table 1 Summary of Animal Health Interventions in Ethiopia (MoA PPR ECP report, 2015-2023)

Intervention Type	Unit	Output/result	Location	Reference/source	Remarks
Vaccine distribution	dose	638,441,029	All region	MoA veterinary services report, 2018-2023	
Vaccination of animals	Number	694,450,852	All region	MoA veterinary services report, 2018-2023	Vaccination against both TADs and non-TADs
Participatory disease search	Number	351	All region	National PPR CEP report, 2017-2022	2017 to 2019 by EU-SHARE project
PPR Outbreak investigation	Number	554	All region	MoA veterinary services report, 2015-2022	2015-2016 from DOVAR, 2017-2019 EU-SHARE
Shoats vaccinated (PPR)	Number	53,090,534	All region	MoA veterinary services report, 2015-2022	2015-2016 from DOVAR, 2017-2019 EU-SHARE
Capacity building (experts)	Number	207	National	MoA veterinary services report, 2018	on young stock mortality, diseases prioritization and vector borne diseases
Training for experts	Number	439	National	2nd PPR eradication program, 2024	QMS, sample collection, handling, basic lab diagnostic, PDS, NADSS, GIS and Meat Inspection
Training for experts	Number	2,886			
Orientation for experts	Number	7,000	Regional	2nd PPR eradication program, 2024	On PPR vaccination

2.5.2. Impacts of animal health intervention in Ethiopia

Attempts to prevent and control diseases have been stepped up recently with improved veterinary services. Although the coverage and quality of services are less than satisfactory, provision has been expanded and improved across Ethiopia. Data on parameters specifically on numbers of vaccinated, afflicted, and treated animals were collected and summarized regularly. According to the ESS 2021/2022 report, the estimated number of vaccinated animals in the country was about 30 million. Out of these animals, about 39% were cattle, followed by goats, which took about 17.24% share. Sheep also accounted for about 13.24% of the total vaccinated animals. About 44 million animals were infected/ afflicted by different types of diseases during the specified period and about 15 million of them were treated. The cattle constituted about 39% of the total treated animals in the country and substantial numbers of sheep and goats were treated as well (ESS, 2021/2022). Based on different reports of MoA, because of the support from government and partners, morbidity and mortality of livestock are decreasing. Due to implementation of PPR CEP, the occurrences of disease outbreaks in small ruminants in Ethiopia have been decreasing dramatically.

According to MoA 2020 plan document, there is a plan to increase milk production from 3.7 billion litrers in 2020 to 10.3 billion litrers by 2030; meat from 189 million ton to 1,665 million ton. To achieve this, clinical services are expected to be improved from 83% to 90%; vaccination coverage from 89.5% to 95%; PVS from 2.65/5 to 3.5/5; young stock mortality reduction from 13% to 6% in cattle, from 24% to 13% in sheep, from 27% to 13% in goats, from 35% to 22% in camels, and from 50% to 20% in poultry; and vaccine production from 365.34 million doses to 730.68 million doses. The pooled prevalence of calf mortality in the country was 14.79%, and the pooled calf mortality estimate across studies for the entire period between 1991 to 2000; 2001 to 2010; 2011 to 2016; and 2017 to 2020 was 26.54%, 17.03%, 14.21%, and 11.23%, respectively (Tora *et al.*, 2021), showing a declining tendency.

2.5.2.1. Capacity building

The first Ethiopian Performance veterinary Services (PVS) evaluation mission was conducted in May 2011 and followed by PVS Gap analysis in 2012. Based on the findings of the PVS evaluation and Gap analysis, strategic issues were identified and a strategic plan developed in 2013 and implemented accordingly. In 2023, the Ethiopian Government has conducted PVS self-evaluation and advancement in certain critical competencies. The results of the self-evaluation showed that Ethiopia has adequate technical capacities for surveillance and control of diseases. Furthermore, implementation of different prevention and control of different diseases has improved diagnostic capacity, surveillance, reporting, and subsequent control and prevention of the diseases. Stakeholder engagement and coordination also played a vital role in different programs. One of the critical competencies is human resource development. Different trainings have been given for different professionals from federal up to PAs level in different years as indicated in Table 1.

2.5.2.2. Internal parasite control

In Ethiopia's smallholder systems, intestinal parasite infestations rank second in terms of severity after respiratory disorders. The uncontrolled and communal animal management system (communal grazing, herding, and watering points) diluted the efforts of individual progressive farmers as communal grazing lands are contaminated by untreated flocks. As a result, gastrointestinal tract (GIT) parasite control interventions implemented by individual farmers had limited impact. Access to veterinary inputs and services by individual smallholders is often difficult or uneconomical. It is thus imperative for smallholders to act as a collective entity (Gizaw. *et al*., 2019).

The Consultative Group on International Agricultural Research (CGIAR) research program in livestock launched a project with the objectives of introducing and assessing the performance and feasibility of participatory/community-based strategic helminth control programs in three regions (South Ethiopia, Oromia, and Amhara) of Ethiopia. The design involved organizing cooperative small ruminant breeding groups which share common grazing resources and watering points and are separated from other village flocks in the *kebele* to plan collective deworming action by all members of the cooperative. The intervention also included capacity building of farmers and livestock extension workers and multi-stakeholder platforms for the cooperative control of diseases (Gizaw *et al*., 2019).

The control program of parasite had been implemented in Amhara, Southern Nations, Nationalities and Peoples and Oromia regions of Ethiopia starting from 2017. As a result of the implemented activities the overall periodic prevalence of GIT parasites had been reduced, from 54.41% at the beginning of the program to 44.80%, the overall GIT parasite prevalence and mean Eggs counts Per Gram of feces (EPG) were decreasing from year to year due to continuous deworming interventions and the reduction of GIT parasites prevalence and fecal egg count contributed to improved weight gain and wool growth in the sheep and goats (Mekonnen *et al*., 2021).

Regarding deworming interventions, anthelmintic chemotherapy is widely used to control helminth infection in Ethiopia. Farmers and pastoralists are also applying deworming to their herds and flocks without the advice and prescription of trained veterinarians. For instance, Aga *et al*. (2013) reported that 95.3% of farmers use anthelmintic as a parasite control method, but 38.7% and 25.3% of the respondents select anthelmintic based on ease of administration and color and only 21.3% based their selection on prescription. Indiscriminate and widespread use of deworming has recently led to resistance to anthelminthic drugs and reduced effectiveness of helminthic control.

The principle is killing parasites within the host to reduce pasture contamination just prior to the onset of the parasite's favorable season and reduce the worm burden of the host during the peak of parasitic infestation to ease the pathology on the host. Some of the actions are administering anthelmintic to the flock prior to the onset of the wet and warm season, which is favorable for the development of parasite eggs into infective parasitic stages in the pasture, administering anthelmintic at the middle of the wet season to reduce the worm burden inside the hosts that is acquired from the infectious pasture due to the development of a high level of the infective stage by the favorable season and facilitation of movement of infective stages to the pasture herbage due to high rainfall. This deworming regime should be applied selectively for animals with clinical manifestations with positive laboratory results, high fecal egg count, or other signs such as diarrhea, coughing or bottle jaw, depending on the suspected parasite. Selective treatment should be practiced to slow development of anthelminthic resistance (Jemberu *et al*., 2022).

In Doyogena District of Kembata Tembaro Zone, the main rainy season was identified to be from April to June, the peak rain being in May. For parasite control, deworming is should be done in March just before the start of the rain to reduce pasture contamination and the second selective deworming should be done in May when high infestation is expected to occur. In Menz Mama Mider District of North Shewa zone of Amhara region, the main rainy season is from June to September, the peak rain being in July and August. For parasite control, deworming should be done in June just before the start of the rain to reduce pasture contamination. The second selective deworming for nematodes should be done in August when high infestation is expected to occur. For liver fluke, this is a common problem in the district, the second selective deworming using flukecidal drug should be done in November during when the disease starts to manifest due to its long prepatent period (Jemberu *et al*., 2022). According to the epidemiology of parasite infections in an area, strategic drenching and a combination of confined and grazing systems, improved nutrition, and controlled breeding have to be considered as the foundations for parasite control (Sani and Gray, 2004).

2.5.2.3. Ecto-parasite control

Ethiopia has been implementing the control of ecto-parasites for many years based on Small Ruminants' External Parasitic Diseases Control Strategy which was designed in 2005. In this country, ecto-parasites are a major factor in skin quality deterioration and lost production potential. In goats and sheep, the prevalence of tick infestation could reach as high as 89.9% and 87.5%, respectively (Abunna *et al*., 2009). Although, the assessment of the impacts of ecto-parasite control has not been done in Ethiopia, the evolution of tick control services in Kenya, examined by Mutavi *et al*. (2018), showed that the public control failed and this was transferred to the private sector.

2.5.2.4. Vaccination interventions

The reason for vaccinating animals is to induce strong immunity that peaks at the time of high disease risk. Vaccinating against contact diseases is mainly done ahead of the season of high inter-flock contact for grazing (e.g. after harvest season) and marketing (e.g. during festival seasons such as Easter, Mawlid, New Year, Christmas, etc.), against multifactorial complex diseases (e.g. respiratory disease complex caused by Pasteurella and others), ahead of stress time and flock mixing seasons, against soil borne diseases such as anthrax ahead of high rainfall and flooding season which exposes buried spores in the ground and are accessed by animals or during the season of deep grazing in which the animals could ingest spores from the soil (Jemberu *et al*., 2022).

The vaccination approach followed against PPR involves risk-based vaccination informed by an active disease surveillance system, participatory disease surveillance and PPR diagnoses in the field (PPR CE Strategy, 2020). Vaccination programs against Transboundary Animal Diseases (TADs) need to be implemented at a larger scale, for instance regional or continental level to be effective. As an example, PARC involved continent-wide vaccination campaigns, systematic sero-surveillance, and active investigation of outbreaks and control of animal movement wherever possible (Tambi *et al*., 1999).

Alternative methods of disease control include restricting movement of animals to and from affected areas, quarantine, elimination of contact fomites, and appropriate disposal of infected carcasses (Abubeker *et al*., 2011). Balamurugan *et al*. (2014) argue that control strategies may vary from country to country but in developing countries vaccination has become a recommended tool. Catley *et al*. (2009) attributed non-significant differences in mortality rates between vaccinated and non-vaccinated small ruminants due to inappropriate vaccines, low vaccination coverage, problems with vaccine dosing, incorrect timing of vaccination and problems with storage.

In Doyogena District of Kembata Tembaro Zone, crops are harvested off the land by December, after which there is high mixing of animals from different flocks. There is also high market animal movement starting at the end of this month for Christmas and other festivals. Based on these considerations (disease risk and availability of good nutrition for optimum immune response), vaccinations against contact diseases are good in November. Vaccination against soil borne diseases such as anthrax is in February ahead of high rain, which will expose buried spores to the surface and increase the risk. For a disease which requires biannual vaccination such as pasteurellosis, vaccination should be done preferably prior to the stress period which can be caused by different factors (Jemberu *et al*., 2022).

In common with Doyogena, the crops in Menz Mama Mider District are harvested off the land by December, followed by high mixing of animals from different flocks. Based on these, vaccination against contact diseases should be best done in November. Vaccination for soil-borne diseases such as anthrax is in the month of May ahead of high rain, which will expose buried spores and increase the risk of infection. Diseases which require biannual vaccination are managed in the same way as the same Doyogena (Jemberu *et al*, 2022). The animal health intervention calendar in selected areas is given in Table 2.

The Ethiopian Government is supporting its rural communities by providing TADs vaccines free of charge. According to the MoA Veterinary Services Report from 2018 to 2023, 638,441,029 TADs vaccines were distributed and 775,070,152 animals were vaccinated against TADs and non-TADs vaccines. The HEARD project also had been providing different animal health services in selected districts of Somali, Amhara and Oromia regions. The vaccine production capacity of Ethiopia is given in Table 3.

Table 2 Tentative intervention calendar for CBBP livestock intervention sites of Ethiopia

No	*Herd health intervention*	*Intervention sites*			
		Abergelle,	Menz	Doyogena	Bonga
1	Deworming small ruminants for GI parasites and lungworms	June, September, December & March	October, January/ February and June	October, January/Feb & June	October, March and June
2	Training farmers on control of small ruminants, GI parasitosis	November and June	September/November and December	December, January and April	December and May
3	Deworming dogs for coenurosis	NA	NA	NA	October, January, April & August
4	Vaccination (ovine pasteurellosis)	March& September	October & March/April	February& August	November& April
5	Vaccination for PPR	August	September, October & November	December	December
6	Vaccination for sheep pox	September	September–October	April	April
7	Training farmers on control of small ruminant respiratory disease	November and June	March	December and May	March
8	Targeted feeding for pregnant ewes/does	December and May	Throughout the year	March and April	May, June,August, December & May
9	Training farmers for reproductive performance	November and June	March	February and July	December and May

Source: Mekonnen *et al*. (2019)

Table 3 Small ruminant vaccine production capacity of National Veterinary Institute plan by year (2020 -2025)

No	Vaccine Type	Unit	Vaccine production Capacity					
			2020	2021	2022	2023	2024	2025
1	Bacterial Vaccines							
1.1	Anthrax	dose	15,000,000	16,000,000	18,000,000	18,000,000	21,000,000	23,000,000
1.2	Pasteurellosis	,,	15,000,000	16,000,000	16,500,000	17,000,000	17,000,000	18,000,000
1.3	CCPP	,,	7,000,000	10,000,000	10,000,000	11,500,000	13,000,000	14,000,000
	Sub Total		**100,000,000**	**100,500,000**	**106,000,000**	**118,000,000**	**127,500,000**	**138,000,000**
2	Viral vaccines							
2.1	SGP	,,	25,000,000	26,000,000	28,000,000	29,000,000	29,500,000	30,000,000
2.2	PPR	,,	26,200,000	26,000,000	27,500,000	30,000,000	30,500,000	33,000,000
2.3	PPR thermostable		20,000,000	20,000,000	21,000,000	23,000,000	22,000,000	24,000,000
	Sub Total	**,,**	**116,200,000**	**117,300,000**	**123,900,000**	**132,430,000**	**134,960,000**	**143,000,000**
	Grand Total	,,	149,700,000	**164,200,000**	**183,200,000**	**206,200,000**	**238,700,000**	**285,700,000**

The Government of Ethiopia has given attention to enhancing the contribution of the sector to economic growth, poverty reduction, and food security, as well as improving climate resilience. In line with this, a ten-year Strategic plan with ten focus areas (Ten in Ten) was designed and implemented in all parts of the country. Four of the focus areas are specific to livestock development. In addition, a National Livestock Development Initiative called 'Lemat Turufat' was launched in 2022 to enhance the production of selected commodities: milk, meat, egg, and honey. Pest des Petitis Ruminats and rabies are the top priority TADs and Zoonotic diseases, respectively (Pieracci *et al*., 2016; MoLF unpublished report, 2016) for which national control and eradication programs are in place.

The Ministry of Agriculture has projects to support the veterinary service from World Bank, African Development Bank, EU and FAO. Some of the projects that have been supporting the livestock sector of the country are LFSDP, HEARD, EU-SHARE, Regional Pastoral Livelihoods Resilience Project (RPLRP), Drought Resilience and Sustainable Livelihoods Programme (DRSLP) and Agricultural Growth Program. Some of the supports given by the partners/projects are listed below in Table 4 and 5. The Ethiopian Ministry of Livestock and Fisheries (MoLF) leads and oversees drought resilience initiatives under the Ethiopia Country Program Paper, which contributes to the Intergovernmental Authority on Development's (IGAD) Drought Resilience and Sustainability Initiative (IDDRSI) strategy, as part of its efforts to improve the livelihoods of the pastoral and agro-pastoral communities. The MoLF had been implementing the Regional Pastoral Livelihoods Resilience Project (RPLRP) in 21 districts in the target regions through a World Bank funded the project (Gebremedhin *et al*., 2017).

The Livestock and Fishery Sector Development Project financed by World Bank has been supporting animal health intervention activities in 58 target districts on PPR eradication program, Newcastle disease (NCD) control and prevention, Livestock Identification and Traceability System, disease surveillance and diagnostic. This project supports the national program to eradicate PPR across the country. This project also supports CBBP through International Center for Agricultural Research in the Dry Areas (ICARDA) (LFSDP, 2017).

Table 4 Proportion of vaccinated animals in selected regions in 2022 by RPLRP project

Region	Type of vaccines	Vaccinated animals	% vaccinated	HH Benefited
Afar	SGP, CCPP, LSD, Camel pox	517,557	56.2	21,622
Oromia	CCPP	550,000	37.22	32,900
SNNPR	CCPP, Anthrax, Bovine pasteurellosis, SGP, CBPP and LSD	1,932,809	86.1	54,256
Somali	Camel pox, SGP, CCPP፣ LSD	1,108,418	92.36	12,616
Total		**4,108,784**	**70.32**	**121,394**

Table 5 Procured drugs and vaccines by HEARD (Veterinary Services Report, 2022)

No	Type of Drugs and Vaccines	Unit	Quantity
1	Oxy TTC 10 %	Bottle	2,000
2	Oxy TTC 20 %	Bottle	8,000
3	Penicillin	Bottle	10,000
4	Pen strep	Bottle	1,500
5	Multivitamin	Bottle	2,000
6	Ivermectin 1%	Bottle	2,000
7	Albendazole 2500 mg	Bolus	100,000
8	Albendazol 300 mg	Bolus	300,000
9	Treclebendazole 250 mg	Bolus	42,730
10	CCPP	Dose	300,000
11	CBPP	Dose	500,000
12	African horse sickness	Dose	300,000
13	LSD	Dose	500,000
14	SGP	Dose	2,562,541
15	Camel Pox	Dose	250,000
16	Rabies	Dose	30,000
17	Saline water	Litter	3,500

The Lowland Livelihood Resilience Project (LLRP) is supporting communities living in the lowland part of the country, including Somali region. The project has supported the rehabilitation and equipping existing veterinary health post, animal health clinics and animal diagnostic laboratories. In addition, the project supported community animal health workers (CAHWs), both in enhancing their capacity and providing kits targeted at reducing loss of animal production and productivity due to morbidity and mortality. A total of 13 animal health posts, which is seven in Benshangul Gumuz and six in Gambella Regions were equipped and rehabilitated. Cumulatively, a total of 1,478 (159 females) and 750 youths (animal health workers) were trained and equipped with startup kits across all project regions (Table 6).

Table 6 Major animal health activities accomplished by LLRP (2013-2017 EFY report)

No	*Activities*	*Unit*	*Performance*			*Beneficiaries*		
			Plan	Achieved	%	M	F	Total
1	Rehabilitation and equipping of health post	Number	333	307	92	88132	48715	136857
2	Equipping new clinics	Number	61	59	97	24270	10659	34929
3	Equipping regional laboratories	Number	8	6				
4	Training of new CAHWs at zonal level	Number	1518	1478	97	1317	159	1478
5	Provision of equipment for the newly trained CAHWs	Number	1518	1478	97			

2.6. Impact of Zoonotic Diseases on Food and Nutrition Security

Pathogens such as rabies, tuberculosis, taeniasis, anthrax, cysticercosis and brucellosis, are the major zoonotic diseases and can spread from animals to humans by different routes (Pieracci, 2016; FAO, 2020 and Alemayehu *et al*., 2024). While many of these infectious diseases are well-known, there are also newly-emerging diseases that can harm a lot of people and animals, such as highly virulent avian influenza. Also inappropriate and overuse of antimicrobials in animal production contributes to an increase in antimicrobial resistance in human pathogens (Pieracci, 2016; FAO, 2020).

A large proportion of the population in Ethiopia is exposed to zoonotic infection because 80% of people depend on agriculture and all the agricultural activities are done by livestock or there is regular contact with domestic animals, creating an opportunity for infection and the spread of disease (Pieracci, 2016). In addition, there has been a growing demand for animal products in many urban and peri-urban communities in low- and middle-income countries that increases exposure to food-borne zoonosis. Moreover, animal production in densely populated areas has intensified, which has raised the danger of zoonotic disease infections in humans (Thornton, 2010).

Diseases can hinder the body's ability to absorb nutrients and/or result in nutrient loss, as in the case of diarrhea. Because their immune systems are still growing or have been partially inhibited, small children and breastfeeding women are more susceptible to the adverse effects of animal-derived pathogens. Growing scientific evidence indicates that dietary exposure to mycotoxins is a likely contributing factor to child stunting in exposed communities (Wild *et al*. 2015). Disease in animals can impair their productivity, which in turn negatively affects the 'consumption of ASF' and the 'income-generation' pathways. AHI such as vaccinations and deworming can prevent this.

Therefore, limiting contact with animals, maintaining good personal and environmental hygiene, and avoiding consumption of raw food of animal origin were the major prevention methods against zoonotic diseases. Consumption of raw milk and meat should be discouraged. The application of ongoing one health approach is crucially important to control zoonotic diseases, and a concerted effort among all relevant stakeholders, especially among human and animal health professionals, is highly needed to effectively control and prevent zoonotic diseases. More research regarding economic and public health impacts of zoonotic disease is necessary (Alemayehu *et al*., 2024).

2.7. Animal Health Intervention in CBBP Implementation Areas of Ethiopia

Enhancing small ruminant productivity in Ethiopia is hampered by gaps in disease control that lead to high rates of morbidity and death in both young and adult animals. A participatory epidemiology and gender survey carried out in 2015–2016 by ILRI on livestock and fish detailed the effects of diseases affecting small ruminants. The study found that the effects of animal diseases included financial and economic loss, decreased production; negative effects on human health, shift to other employment, and time wasted caring for the animals. The survey's findings showed that the farmers had little understanding of good husbandry techniques, disease prevention and control, or access to high-quality veterinary inputs, such as the use of antibiotics, or consulting services. During the study, the results of sero-surveys, literature reviews, and participatory epidemiology were used to rank respiratory diseases as the most important small ruminant diseases. Coenurosis and intestinal parasites were listed as more significant health risks associated with the production of sheep and goats. As a result, suitable control methods were defined with the intention of lessening the socioeconomic effect of these serious illnesses. Since fragmented individual interventions for animal health may not be able to generate sufficient benefits to increase production and productivity, integrated herd health interventions such as vaccination, deworming, health follow-up and treatments, and awareness creation campaigns are preferable to reduce the impact of disease (Alemu *et al*., 2019 and Mekonen *et al*., 2021).

According to the studies conducted in CBBP areas, different herd health activities were conducted in the sites comprising a herd health approach to reducing the incidence of respiratory disease, community-based gastro-intestinal parasite and coenurosis control, enhancing small ruminant reproductive performance, health certification of breeding rams and targeted feeding of pregnant ewes. Implementing animal health activities motivated the farmers to apply the other activities of SmaRT Pack (e.g. genetics, feed and forage, marketing, environmental management and gender). Based on Mekonen *et al*. (2021), morbidity reduced from year to year and as did the burden of gastro-intestinal parasites in project sites. The impact of this approach in preventing and controlling of small ruminant diseases in project sites is reflected in the vastly lower mortality and morbidity rates seen in the study sites (4.35% and 0.85%, respectively) compared to figures for such systems elsewhere in Ethiopia where mortality typically ranges from around 12% to 14% for sheep and 11% to 13% for goats (MoA and ILRI, 2013).

Again, according to the study done by Mekonen *et al*. (2021), the Key messages regarding the animal health interventions project in targeted CBBP areas (Bonga, Menz, Abergelle and Doyogena) in Ethiopia are, the calendar based herd health intervention is important in the management of small ruminant health reducing morbidity and mortality. The data from the intervention-based study showed that there was a decrease in the morbidity of animals in study sites from year to year, and overall mortality is very much lower than typically found in equivalent small ruminant systems in Ethiopia. Respiratory disease had been previously identified as a major problem in the highland agro-ecology and mixed crop–livestock production system (Alemu *et al*. 2019) and the herd health approach applied reduced this burden, not only through vaccine but also through improved provision of medicines and advice for treating sick animals. Improved treatment of sick animals reduced mortality of animals in general. The community conversations and trainings on different animal health-related activities improved the knowledge and skill of the farmers.

2.8. Food and Nutrition Security Situation and Food Consumption Patterns in Ethiopia

A significant portion of the Ethiopian population, particularly those in rural and pastoral areas faces challenges of food insecurity due to climate variability, droughts, animal health problems and other socio-economic constraints. Malnutrition also remains a major concern among children in the country (FAO, 2021). The diet is heavily reliant on staple crops like teff, maize, and sorghum, with limited diversity while intake animals source foods like meat, dairy, and eggs are so limited leading to poor nutritional outcomes (FBDG, 2022). Despite some improvements in food availability, disparities in access to nutritious food and the impacts of climate-related shocks continue to affect food and nutrition security.

Unhealthy diets add to the burden of malnutrition and diet-related non-communicable diseases (Naicker *et al*., 2015; Ronto *et al*., 2018), which are priority public health problems in low- and middle-income countries, including Ethiopia (Tebekaw *et al*., 2014; Central Statistical Agency and ICF, 2016). According to the 2016 Ethiopian Demographic and Health Survey report, the prevalence of stunting (short height-for-age, 38%), underweight (low weight-for-age, 24%) and wasting (low weight-for-height, 10%) show the poor nutritional status of children under five. The same report also indicated that 20% of women of reproductive age were underweight (Body mass index (BMI) < 18.5 kg/m^2) and 13% overweight (BMI > 25 kg/m^2). This reveals that Ethiopia faces the triple burden of malnutrition, overweight and obesity, and micronutrient deficiencies (Black *et al*., 2013).

National nutrition surveys in Ethiopia have repeatedly shown inadequate intake and deficiency of vitamin A, zinc, iodine, calcium, vitamin B12 and folate (EPHI–MoH, 2016). Similarly, deficits of most of these nutrients have been reported as public-health problems among all population groups, but especially in women of reproductive age and children under five (EPH, 2016). From study findings, reasons for this include excessive cereal consumption (teff, maize, sorghum etc.), which have a relatively low micronutrient density, and inadequate consumption of food items from other food groups such as animal-source foods (ASFs), pulses, fruits, vegetables, and nuts and seeds which are very rich in important micronutrients (Beal *et al*., 2017). The Government of Ethiopia supports Food-Based Dietary Guidelines (FBDG) implementation as an entry point to improve Ethiopia's food system to promote better diet and public health for all (FGE-MoH-EPHI, 2022).

Therefore, the Household Food Insecurity Access Scale (HFIAS) indicator is used to quantify food security and is a proxy for nutrition security, according to Coates *et al*. (2007). Food security is defined as a state in which "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". The six dimensions of food security are availability, access, utilization, stability, agency, and sustainability (WHO, 2023).

2.8.1. Global Hunger Index (GHI)

According to the GHI accounts Ethiopia continues to experience persistent challenges of food insecurity, malnutrition, and undernourishment regardless of the efforts so far made to improve food availability. In the 2024 Global Hunger Index report, Ethiopia ranks 102nd globally with a score of 26.2, suggesting a serious level of hunger in the country (GHI, 2024). The global hunger index is a means of monitoring whether countries are achieving hunger-related Sustainable Development Goals. It can be used for international ranking. The global hunger index captures three dimensions of hunger: insufficient availability of food, shortfalls in the nutritional status of children and child mortality (which is, to a large extent, attributable to under nutrition). Accordingly, the index includes three equally weighted dimensions: the proportion of people who are food energy-deficient, as estimated by FAO; the prevalence of underweight in children aged under 5 years (child wasting and stunting), as compiled by WHO; and the mortality rate of children aged under 5 years, as reported by UNICEF. The GHI score incorporates four component indicators: undernourishment, child wasting, child stunting and child mortality.

Table 7 Global Hanger Index Rank and Hunger score of Ethiopia 2000 to 2024

Year	*2000*	*2005*	*2010*	*2015*	*2020*	*2024*
GHI Score	53.5	45.8	40.4	30.3	26.7	26.2
Rank	90	90	88	85	96	102

As Table 7 indicate, Ethiopia has a level of hunger that is serious (26.2 score) but there is some improvement since 2000 (53.5 which indicates extremely alarming).

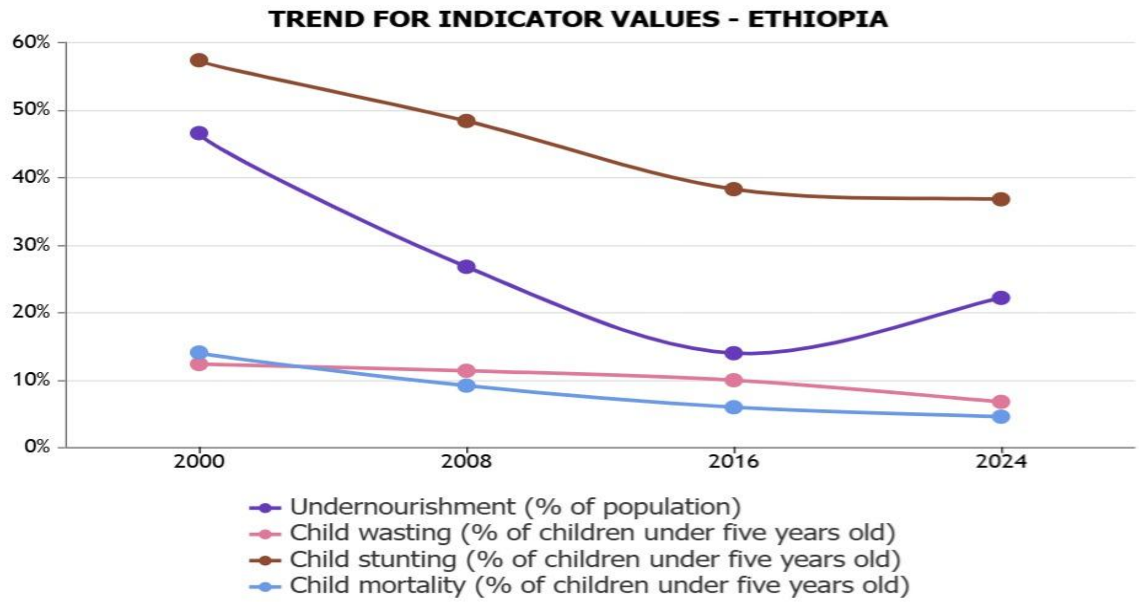


Figure 1 Trend for indicator values-Ethiopia (GHI, 2024)

Indicators in Figure 1 showed that, except for undernourishment, there is improvement in 2024 compared to the 2016 survey.

2.8.2. Livestock intervention for food and nutrition security

Animal-source foods (ASF) are a rich source of bioavailable nutrients that play an important role in reducing the risk of malnutrition (Zhang *et al*., 2016). In the context of arid and semi-arid areas with limited potential for crop agriculture, the role of livestock and ASF in supporting the livelihood and nutrition of pastoralist communities is especially critical.

The impact pathways through which livestock interventions may influence human nutrition include: (1) Increased production and consumption of ASF and hence dietary diversity at household and individual level (2) Increased household level income through sale of livestock products, which in turn translates into increased access to diverse and quality diet (Sadler K, 2012). Livestock interventions such as dairy programs, small livestock rearing, backyard poultry production, breed improvement, fisheries, and livestock transfer programs, livestock feeds improvement and livestock value chains programs, have a potential to positively influence improved dietary diversity at household level and possibly impacting the individual nutritional outcomes. However, empirical data on the net contribution of livestock intervention on nutrition in Africa is scant.

2.8.3. Importance of livestock and its products for improved nutrition

According to estimates, foods originating from livestock, or ASFs, account for 34% of the world's protein consumption and 18% of its food energy consumption (FAOSTAT, 2016). Animal source foods are a crucial part of many different diets, although consumption varies greatly. For example, the amount of meat consumed annually by each individual varies between less than 4 kg in certain countries and more than 100 kg in others. According to FAOSTAT, for Ethiopia, the recommended consumption of animal source foods kg/person/year is meat (16-31), dairy (90), (eggs 10-15) and fish (8-16), but actual consumption is 5.3 (4-12), 17 (9-19), 0.2 (0.1-1) and 0.1, respectively.

Elevated intake of specific ASF is associated with non-communicable illnesses, including heart disease and specific malignancies, and it also adds to the overall burden of disease on public health. However, poor people often consume little or no ASF for various reasons, including less availability, accessibility (including price), dietary patterns that may result from customs, religious taboos and lack of knowledge about their nutritional importance. The high potential of ASF to improve diets of vulnerable populations makes livestock an important sector for national policies and development partners' programs aiming to improve food security and nutrition. Livestock are a key resource for economic growth in many countries, both at national and household level. Animals are important assets and an essential source of income for livestock-keeping households. Moreover, livestock can also significantly influence the livelihoods of other households that do not have livestock, as well as supplying inputs for crop production such as fertilizer or animal traction (FAO, 2020).

Animal source foods are energy-dense foods. They are a good source of high-quality proteins: the proteins they contain are highly digestible and have a good profile of essential amino acids. For example, ASF generally contain high concentrations of threonine, lysine and Sulphur-containing amino acids, which are in relatively short supply in most plant-based foods. They are also a good source of several critical micronutrients, such as iron, zinc and vitamins A and B12 that are often lacking in the diets of nutritionally vulnerable populations. Red meat and offal (such as liver) contain high levels of haem iron and provide it in an easily absorbable form. Livestock-derived foods are also relatively rich in lipids, particularly saturated fatty acids and cholesterol (FAO, 2020).

3. MATERIAL AND METHODS

3.1. Description of the Study Areas

The study was conducted in two districts, namely Adiyo and Tello of Kaffa Zone of South West Regional State of Ethiopia; and Menz Mama Midir District of North Shewa Zone of Amhara Region, which have been involved in Bonga and Menz sheep production, respectively, using community-based breeding program (CBBP). In addition, Degahabur District of Somali Region, which is a pastoralist extensive livestock production system where the HEARD project had been implementing animal health interventions, was included.

Kaffa Zone is located in the south western part of the country (7º 34´N latitude and 37º 6´E longitude) and is 467 km away from the capital city, Addis Ababa. The area is characterized by mixed crop-livestock production system. It has one major rainy season that extends from May to October, and a dry season that lasts from October to April (Mirkena *et al*., 2012). The altitude ranges from 1,600 to 3,348 meters above sea level, with minimum and maximum temperatures of 14ºC and 32ºC and an average of 24ºC. The climatic conditions influence, both directly and indirectly, the productivity and reproductive efficiency of sheep, especially under small-scale extensive production system.

Menz Mama Midir is a district in the North Shewa Zone of the Amhara Region where a community-based breeding program effort for sheep genetic improvement has been implemented. It is located 222 km north east of Addis Ababa at an altitude of 3,047 masl, and at longitude and latitudes of 39° 39′41″E and 10° 07′17″N, respectively. The mean annual maximum temperature is 18.63°C and the mean annual minimum temperature is 7.26°C, with the annual rainfall of about 1,403 mm. The district is characterized by a bi-modal rainfall pattern, where the main rainy season is from June to September and an erratic and unreliable short rainy season is from February to March (Shanbel, 2019).

Another target area was a HEARD project implementing region. The HEARD project was mainly implemented in Amhara, Oromia and Somali Regions from 2018-2024. For ACIAR the project survey, due to the security reason, Somali Region was selected. The study was conducted in Degehabur District of Jarar zone in Somali Region. Degehabur town is the capital city of Jarar Zone and it is one of six self-administrated councils. Degahbur is situated about 160km southeast of the regional capital, Jigjiga. The activities of Degahbur City Administration are limited to the ten urban Kebeles (smallest administration units) in Degahbur town. This Zone has a total population of 478,168, of whom 268,006 are men and 210,162 women. While 62,584 or 13.01% are urban inhabitants, a further 223,778 or 46.8% are pastoralists. Livestock, particularly cattle, shoats and camel are important integral components of rural livelihood systems in the zones (CSA, 2016). This zone has 3,205,143 sheep and 4,778,656 goats (ESS, 2021/22) (Figure 2)

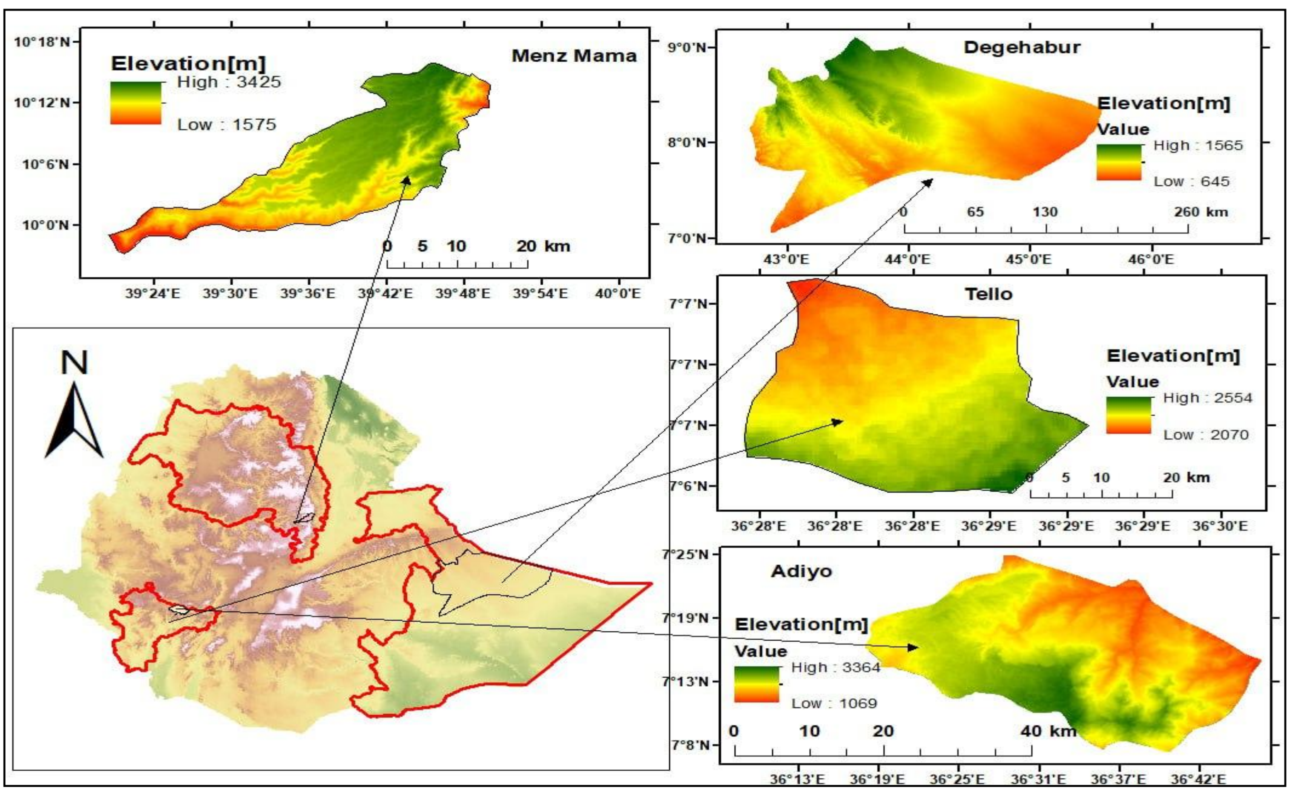


Figure 2 Map of the study districts

3.2. Description of Study Settings

Community households were involved in Bonga and Menz sheep production. HEARD project benefited households (HHs) in Degehabur district and non-participants were also taken as the study population. As Debre Birehan Agricultural Research Center (2024) data indicated, there are five cooperatives with 292 CBBP participants in Menz Mama and Menz Gera districts of N/Shewa zone of Amhara Region. The study was conducted on CBBP participants of Menz Mama District in the two target cooperatives, namely Yecha and Zeram (77 and 78 HHs respectively), giving a total 155 HHs. According to BARC, 2024, the Bonga sheep community-based breeding program was established in 2009, and currently, 1301 farmers are participating in the program in 10 cooperatives, which are in four districts of the Kefa Zone of the mixed crop-livestock production system. In Kefa zone the study was conducted in two districts (one cooperative per each district), namely Adiyo (Boqa-shuta cooperative) and Telo (Dacha cooperative) districts having 450 and 104 CBBP participants, respectively. Targeted households participating on CBBP and non-participating community were interviewed about animal health interventions and food and nutrition security and diversity based on the prepared questioner. In Degehabur District of Somali Region, the study was conducted on 19,622 HEARD project HHs. The intervention kebeles were Bulale and Lasgalol.

3.3. Description of the Interventions

3.3.1. Conceptual framework

The conceptual framework of this study is based on the premise that improved livestock health, achieved through targeted animal health interventions, can lead to better household food and nutrition security, particularly in Ethiopia’s extensive livestock systems where small ruminants play a central but underutilized role in livelihoods. The framework posits that interventions such as vaccination, deworming, treatment, training, and awareness creation (as implemented through Community-Based Breeding Programs and the HEARD project) enhance access to veterinary services, which in turn improves livestock productivity and household access to animal-source foods and income. These outcomes are expected to positively influence food security (measured by HFIAS and FCS) and nutrition security (measured by MDD-W), moderated by factors such as education and zoonotic disease awareness. By comparing intervention and non-intervention households, the study empirically tests this framework, showing clear linkages between animal health interventions and improved human food and nutrition outcomes. The conceptual framework brings together several interrelated components of core assumptions of Animal Health Interventions as listed below:

- **Animal health is a key pathway to improved livestock productivity**, which in turn influences household income, access to animal-source foods, and overall resilience.
- **Improved access to veterinary services** (e.g., vaccination, deworming, treatment, and training) enhances animal survival and productivity.
- **Better animal health contributes to increased food availability, income generation, and dietary diversity**, especially in rural, livestock-dependent households.

In general, the conceptual framework shows that animal health interventions, when effectively implemented and accessed, have a direct and measurable impact on household food and nutrition security in the extensive livestock system. The framework is empirical and systems-oriented, emphasizing the interconnectedness of animal health, livestock productivity, and household well-being. It is designed to generate evidence-based data that demonstrate the role of animal health interventions in improving food access, dietary diversity, and nutritional outcomes in extensive livestock systems.

3.3.2. Community-based breeding program

In Ethiopia, community-based small ruminant breeding programs (CBBP) has been underway with focus on improvement of local genotypes (Kosgey and Okeyo, 2007; Haile *et al*., 2023). The targets of the program are farmers within limited geographical boundaries, having a common interest and working together to improve their genetic resources (Haile *et al*., 2011; 2018). The programs focus on indigenous stock and consider farmers' needs, views, decisions and active participation, from inception to implementation, and, therefore, provide a participatory and bottom-up approach (Mueller *et al*., 2015 and Haile *et al*., 2019).

In addition to farmers, the community-based breeding program requires the active participation of different bodies such as scientists from local research centers and local enumerators for data collection and analysis for selection decisions. Extension staffs working in the development sector are also involved and they are educated on the required technical aspects to facilitate successful implementation of CBBPs (Haile *et al*., 2018, 2023).

The strategy of up-scaling by the government focuses on using the existing CBBPs as a nucleus herd where genetic improvement is generated and disseminated (Haile *et al*., 2019). Since inception, more than 150 CBBP villages on six or more sheep breeds in the Amhara, Southern, and Oromia regions have been involved (Belay *et al*., 2022; Mueller *et al*., 2023). From these villages, the Menz and Bonga sheep CBBP are well established and continued as different livestock technology testing and training sites.

3.3.3. Animal health interventions (AHI)

Two types of animal health intervention were considered for this study:

1. A package of interventions in community-based breeding programs (Areb *et al*., 2021; Mwema *et al*., 2021) (Figure 3a), including strategic deworming against internal and external parasites, vaccination for pre-identified and dominant diseases, and veterinary medicine at the breeder's cooperatives for emergency treatments. The main objective of this package is to tackle animal health problems and address intended productivity improvements.

2. The Health of Ethiopian Animals for Rural Development (HEARD) project (supported by the EU) was aimed at supporting and incentivizing young veterinarians to engage in the animal health services, improving food safety of animal origin through intervening on controlling zoonotic diseases, deliver different resources supporting animal health activities, capacity development, and disseminating best practices and research findings to district and kebele development experts.

The project was implemented in three regions of Ethiopia (Somali, Amhara and Oromia) (Figure 3b), with support of the Ministry of Agriculture (MoA) (Gizaw *et al*., 2021). In the Somali Region, the project conducted animal health interventions in sheep and goat populations at Degehabour and other districts (Tadele, 2024).

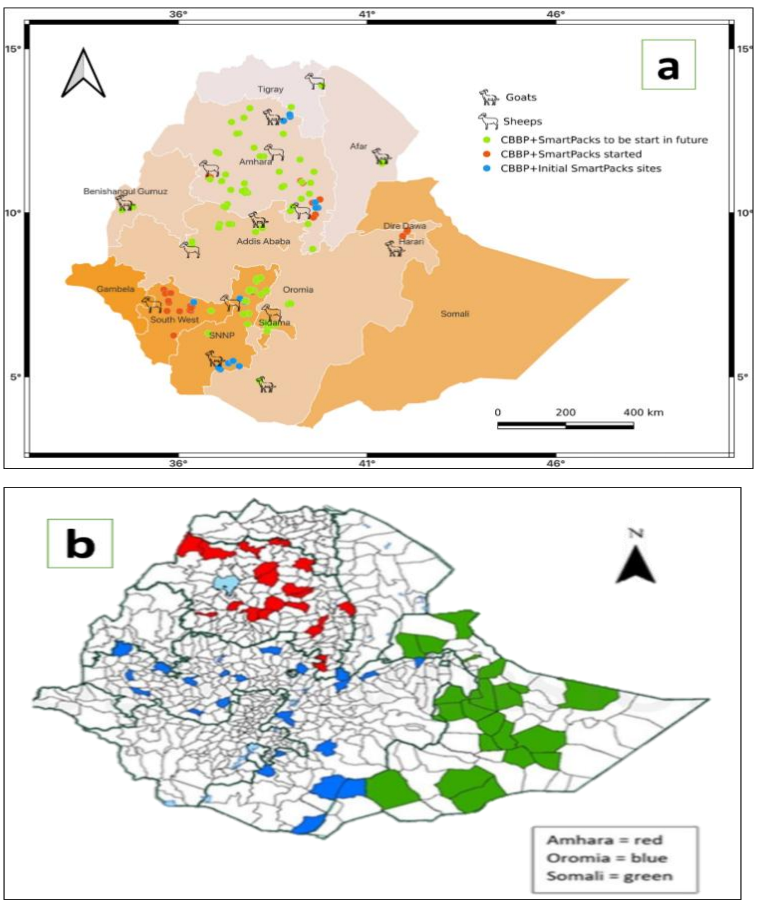


Figure 3 Animal health intervention implementing areas in Ethiopia: (a) community-based breeding program (Getachew *et al*., 2023) and (b) HEARD project (Tadele, 2024)

3.4. Sampling Method and Sample Size Determination

3.4.1. Sampling procedures

Two-stage-sampling techniques used to select study areas and representative respondent households. The working CBBP and AHI districts and villages were selected purposely from ICARDA and HEARD lists based on representativeness of the area. The non-participant villages were far from the CBBP villages and they had no information about the importance and implementation procedures of CBBP to avoid the spillover effect. Respondents who were not participating in the interventions were selected based on information obtained at the respective district offices and kebele experts. Then, from the total farmers list, the respondents were selected using simple random technique. In addition, participants for the focus group discussions (FGD) and key informant interviews (KII) selected randomly.

3.4.2. Sample size determination

Proportionate sampling size techniques were applied to select (i) farmers from each village based on proportion of active CBBP and AHI participant farmers, and (ii) to incorporate female headed participant farmers.

3.4.2.1. For CBBP (Bonga and Menz) sites

Currently there are 10 cooperatives with the total of 1,301 farmers involved in CBBP in three districts (Adiyo, Tello and Gesha) of Kefa Zone (Bonga Agricultural Research Center, 2024). Districts of Kefa Zone were purposively selected because of Bonga sheep breed production and ICARDA project areas. Out of the three districts, Adiyo and Tello districts were selected by participation with BARC. Based on sample size calculation indicated below, approximately 63 households from CBBP villages and 61 from non-participants (control) were targeted in Adiyo District. Again 51 HHs from CBBP participants were randomly interviewed from Tello District of Bonga area. In total, 175 HHs were interviewed in both districts of CBBP and non-CBBP areas of Kaffa Zone of S/W/Ethiopia. Using a two-stage sampling method, households from two CBBP cooperative/village (Boka Shuta and Dacha) and one village/ non- CBBP (Mera) sites were also randomly selected from each targeted two districts for interview using a questionnaire (one for CBBP and one for non-CBBP). Boka Shuta and Dacha CBBPs were selected randomly from Adiyo and Tello, respectively, and Mera village (non-CBBP) from Adiyo District. The sample size calculation for households was based on the variance of key indicator variables using Cochran's sample size formula (Cochran, 1977).

The Cochran formula is:

$n_o= z^2pq/e^2$

Where:

- e is the desired level of precision (i.e. the margin of error default =0.05),
- p is the (estimated) proportion of the population which has the attribute in question,
- q is 1 – p. The z-value is found in a Z table, p=estimated proportion of population to be sampled (11% of population to be sampled as reported by Habtegiorgis *et al*. (2022)), q=1-p= 1-0.11=0.89. . Now let's say we want 95% confidence, and at least 5 percent marginal error. A 95 % confidence level gives us Z values of 1.96, per the normal tables. Substituting this valve in the above equation no= $(1.96)^2$*0.11*0.89/ $(0.05)^2$ =150, so a random sample of 150 households in our target population was deemed to be enough to give us the confidence levels we needed. But for our finite population of the target districts, Cochran's sample size correction equation was applied and the above sample size can be corrected by the following Cochran's sample size correction formula for finite population.

$n=n_o/1+ (n_o-1)/N$

Here n_0 is Cochran's sample size recommendation, N is the population size, and n is the new, adjusted sample size. In this case, there were 450 (from Boka shuta CBBP) and 104 (from Dacha CBBP) households in the target CBBP villages (N=450 for Adiyo District

(Boka Shuta CBBP) and 104 for Tello district (Dacha CBBP)), we calculated 63 for Adiyo. Therefore, for this finite population, all we needed were 63 households in our sample and 61 from Mera (50% of intervention sample) for control villages in Adiyo District. For Tello District the sample size of intervention was 51 from Dacha.

For Menz areas, there were five functional CBBP cooperatives having 327 participant households (farmers) in Menz mama and Menz Gera Districts of North Shewa Zone of Amhara region (Debre Birhan Agricultural Research Center, 2024). Because of the security problem in Menz Gera Wereda, Menz Mama District was selected for the survey. From this district, Molale/Yecha and Zeram CBBP villages were selected randomly. Therefore, we used N=77 HHs for Molale/Yecha CBBP and 78 HHs for Zeram CBBP. Using the same formula of adjusting sample size for finite population, the final sample size from the intervention group in the Menz Mama District of North Shewa Zone was recalculated as: n= 51 for Molale/Yecha CBBP (intervention sample size) and n= 47 for Zeram CBBP (intervention sample size). And 50% x CBBP total= 50 sample for control (Emegua PA).

Table 8 shows number of districts, villages and sample size of the study CBBP areas

Participants sites	Bonga			Menz			Total	Grand Total
Districts	Adiyo		Telo	Menz Mama			3	
CBBP Villages	Boka-shuta	Mera	Dacha	Molale/Yecha	Zeram	Emegua	6	
HHs	450		104	77	78		709	
Intervention	63		51	51	47		212	
Non-intervention		61				50	111	
								323

Table 9 sample size in CBBP intervention and non-intervention areas

Intervention areas	*Menz Mama*	*Bonga*	*Total*
Intervention	98	114	212
Non-intervention	50	61	111
Total	**148**	**175**	**323**

3.4.2.2. For animal health interventions sites

For the AHI, an additional site was selected based on the animal health intervention implementing project in Ethiopia, i.e., the HEARD project, to know the impact of the AHI on FNS in the pastoral extensive production system as designed by the ACIAR project. Based on the discussion we had with the Somali Region HEARD project coordinator, Degehabur District was selected for the AHI survey because of its good security and HEARD project implementation area.

Table 10 Shows HHS of HEARD project districts information in the Somali region

No	*Name of District*	*Year*	*HH beneficiary*			*Remark*
			Male	Female	Total	
1	Tuliguled	2019-2023	10,836	4,644	15,480	
2	Dagahbour	2019-2023	14,520	5,102	19,622	Selected
3	Fik		17,970	4,493	22,463	

Data source (Somali HEARD project report, 2023)

Following Cochran's sample size formula (1977) like for the above CBBP areas; the sample size for the study in Degehabur district of Jerer zone was determined as follows. $no = \frac{z^2}{e^2}pq,\ q = 1 - p$. Where, no=estimated sample size, z=1.96, at 95% confidence level, e=0.05, p=estimated proportion of population to be sampled (11% of population to be sampled as reported by Habtegiorgis et al. (2022)), q=1-p= 1-0.11=0.89. Substituting this valve in above equation, no= $(1.96)^2$*0.11*0.89/ $(0.05)^2$ =150 for finite population, n= 109. Thus, 109 households (N=400) were selected from intervention kebeles of Degehabur district (Bulale and Lasgalol) and 65 samples were selected from non-intervention (control) kebeles of other district (Sasabane).

Table 11 Summary of HHs sample size for animal health interventions in Degehabur

Intervention non intervention	*kebele_name*			
	Bulale	Lasgalol	Sasabane	Total
Intervention	56	53	0	109
Non-intervention	0	0	65	65
Total	56	53	65	174

Thus, the total sample size for CBBP (323) and AHI (174) and the overall sample size was 497 (Table 12).

Table 12 Targeted households sample size in study sites

Intervention areas	*Menz Mama*	*Bonga*	*Degehabur*	*Total*
Intervention	98	114	109	321
Non-intervention	50	61	65	176
Total	**148**	**175**	**174**	**497**

3.5. Study Methodology

3.5.1. Secondary data (Documented records and literature review)

Secondary data were collected from literature and; existing records of district veterinary clinics/offices, MoA, projects, CBBP implementation sites, and ICARDA project offices using predesigned format (Annex 1 and 2). The type of veterinary services, disease reporting status, dose of distributed vaccines, number of sick and treated animals, number of dead animals, and number of sheep that received animal health services, etc. were recorded and evaluated as a supportive information to the questioner survey. The impact of animal health interventions in Ethiopia on food and nutrition in extensive livestock systems was reviewed. A literature review was conducted on animal health interventions and their impact on food and nutrition security using existing documents and progress reports in CBBP and HEARD project implementation areas of the country. A narrative review rigorously synthesizes evidence using a predefined, transparent, and replicable method to answer a specific research question, while a semi-systematic review which is used for this study offers a broader overview and exploration of a topic, often using a less structured approach (Snyder, 2019). In addition to the above sources, policy papers, working papers, newsletters, government documents, and non-government documents such as ILRI and FAO), and online data were retrieved.

3.5.2. Household questionnaire survey

The survey was conducted on CBBP and HEARD project participants and non-participant households using semi-structured questionnaires to verify the impact of animal health interventions on food and nutrition security based on literature review findings (Annex 3). The primary data were collected using a questionnaire survey (formal face-to-face interview) focus group discussions (FGD) and key informant interviews (KII). Before the actual survey, the questionnaire was pre-tested in randomly selected respondents in the study areas and ambiguities were corrected. Data on variables such as different animal health interventions and livestock productivity were collected during the survey. Data were collected using Kobo Collect v2021.2.4 from both groups of farmers (participant and non-participant) after getting ethical clearance from animal research ethical review committee of Collage of Veterinary Medicine and Agriculture of AAU. Verbal consent was obtained from the respondents, and the objectives of the study were explained to them before the start of the interview. The interviews were conducted by enumerators who know the local language. Consent letter was also written for target cooperatives and HEARD project villages and got permission for the survey.

The data collected during the interviews included socio-economic variables of households from both CBBP/HEARD project participating/cooperatives and non-participating communities, animal health status of the area, access to veterinary services, the type of veterinary services given to sheep, the number of sheep vaccinated, the number of sick sheep, the number of treated sheep/have gotten veterinary services, the number of sheep cured by treatment, the number dead, the number dewormed, and the challenges and income of households from selling of health sheep with the purpose of selling. The number of sheep owned by farmers was captured to evaluate adaptive capacity (livestock assets).

3.5.3. Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs)

In addition to the individual questionnaire survey, the study incorporated seven FGDs and KIIs to collect and validate data related to livestock health, productivity, and the impact of animal health on food and nutrition security in the study areas. Each study kebele included 8–12 FGD participants and 2–3 key informants selected based on their experience in livestock production and knowledge of essential livestock diseases, animal health services, and their effects on household well-being.

Focus group discussion participants were drawn from livestock farmers, pastoralists, and agro-pastoralists, selected to represent diverse community perspectives based on criteria such as gender, age, wealth, marital status, educational level, and social standing. Discussions focused on prevalent livestock diseases, their impact on animal morbidity and mortality, and the relationship between animal health services and household livelihoods. Key informants included experienced professionals in livestock health, production, and cooperatives, as well as community leaders and officials at kebele, district, and zonal levels. Data collection for both FGDs and KIIs utilized semi-structured questionnaires and interview guides. In addition, facilitators using questions (Annex 4) to encourage discussion and explore multiple viewpoints, with note taking employed to capture key insights guided FGDs.

3.5.4. Food and nutrition security data collection

3.5.4.1. Household food insecurity access scale (HFIAS)

The Household Food Insecurity Access Scale (HFIAS) was used to measure food and nutrition insecurity as a proxy for nutrition security using standard questionnaire described by Coates *et al*. (2007) (Annex 5). Every question on the HFIAS generic set has a four-week (30-day) recall span. First, an occurrence question was posed to the respondent, asking if the condition in question has occurred at all over the last four weeks (yes or no). If the respondent answered "yes" to an occurrence question, a frequency-of-occurrence question was asked to determine whether the condition happened rarely (once or twice), sometimes (three to ten times) or often (more than ten times) in the past four weeks. The questionnaire consists of nine occurrence questions that represent a generally increasing level of severity of food insecurity (access), and nine "frequency-of-occurrence" questions that are asked as a follow-up to each occurrence question to determine how often the condition occurred. The frequency-of-occurrence question was skipped when the respondent reported that the condition described in the corresponding occurrence question was not experienced in the previous four weeks.

The questions were directed to the person in the household who is most involved with the food preparation and meals. Most of the questions required the respondent to answer on behalf of the household and all its members. Although there were pre-coded response options, the interviewer did not read these options aloud each time but rather allowed the respondent to answer in his or her own words. The interviewer selected the most appropriate response option based on the respondent's reply. For example, if, after asking an occurrence question, the respondent says "no" but added that it only happened a few times, then the correct code is '1' (yes). The frequency-of-occurrence question was then being asked. When the respondent described a frequency that would translate to "three to ten times" in the past four weeks, the correct response selection for the frequency-of-occurrence question was "sometimes", and the correct code is '2'. When the respondent had difficulty replying then the interviewer encouraged a response by listing the set of options again.

First, a HFIAS score variable was calculated for each household by summing the codes for each frequency-of-occurrence question. Before summing the frequency-of-occurrence codes, frequency-of-occurrence coded as 0 for all cases where the answer to the corresponding occurrence question was "no" (i.e., if Q1=0 then Q1a=0, if Q2=0 then Q2a =0, etc.). The maximum score for a household is 27 (the household response to all 9 frequency-of-occurrence questions was "often", coded with response code of 3); the minimum score is 0 (the household responded "no" to all occurrence questions, frequency-of-occurrence questions were skipped by the interviewer, and subsequently coded as 0 by the data analyst.) The higher the score, the more food insecurity the household experienced. The lower the score, the less food insecurity (access) a household experienced. The food insecurity scores were finally categorized as food secure, mildly insecure, moderately insecure, or severely food insecure (Coates *et al*., 2007).

3.5.4.2. Food consumption score (FCS)

Food consumption score was targeted on identifying the major foods eaten from the nine food groups with different weighting factors (grains/staples (2), pulses (2), vegetables (1), fruits (1), meat/fish/egg (4), milk (4), sugar (0.5), oil (0.5)) for the past seven days (Annex 6). These measure the diversity, quantity and adequacy of food consumption (Sisay and Girma, 2023). While summing the scores for seven days, these ranged from 0 to 112 (0 when a household did not consume any food in the last 7 days and 112 when the household consumed each food groups every day for the last 7 days). The sum below 21 will be considered poor, and above 35 is acceptable and between both considered as a borderline (WFP, 2008).

3.5.4.3. Minimum dietary diversity for women (MDD-W) aged 15-49 years

In addition to the socio-culture impacts on the consumption pattern of women, the physiological demands of pregnancy and nursing, make women of who of reproductive age to be f at high risk of nutritional deficiencies. Pregnant and nursing women have greater nutrient requirements than adult men do. Outside of pregnancy and lactation, other than for iron, requirements for women of reproductive age may be similar to or lower than those of adult men, but because women may be smaller and eat fewer calories, they require a more nutrient-dense diet. Insufficient nutrient intake before and during pregnancy and lactation can affect both women and their infants. Yet in many resource-poor environments, diet quality for women of reproductive age is very poor, and there are gaps between intakes and requirements for a range of micronutrients. The Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) indicator defined and described here is a food group diversity indicator that has been shown to reflect one key dimension of diet quality: micronutrient adequacy, summarized across 11 micronutrients. The indicator constitutes an important step towards filling the need for indicators for use in national and subnational assessments (FAO and FHI 360, 2016).

One strategy to improve micronutrient nutrition for women of reproductive age is to promote diversified diets; in settings where other techniques are employed, additional diet quality indicators would be required. Moreover, there are other aspects to diet quality. A balanced consumption of fat, carbohydrates, and protein is another characteristic of high-quality diets, in addition to micronutrient adequacy. The MDD-W is a dichotomous indicator that indicates if women aged 15 to 49 have eaten at least five items from each of the ten food groups within the preceding day or night. One crucial aspect of food quality is micronutrient sufficiency, which can be indirectly shown by the percentage of women in a population aged 15 to 49 who meet this criterion. A woman is deemed to have minimum dietary diversity if she eats at least five of the ten food groups included in the MDD-W. The percentage of participants who consumed five or more food groups out of ten is the indicator (FAO and FHI 360, 2016). Minimum Dietary Diversity for Women aged 15–49 years is indicated in Annex 7. Interviews were conducted to know the number of food groups consumed by women of age 15-49 out of ten food groups according to this standard indicator.

3.6. Data Management and Analysis

All questionnaire survey data were captured and stored in a Microsoft Excel program and coded for analysis. Secondary data were also captured in a Microsoft Excel and analyzed accordingly. Qualitative data (KII and FGD) were narrated and explained logically. The descriptive statistic was utilized to analyze the data by STATA Version 17 software. Wilcoxon rank-sum (Mann-Whitney) test was used to know whether there is a statistically significant difference in animal health intervention between intervention and control households. A stepwise backward logistic regression analysis with a p-value threshold of 0.25 was used for variable selection to calculate the Odds ratio (OR) and to identify which predictors are significantly associated with the outcome variable**,** HFIAS Category**.** Logistic regression was used to determine which predicator variables are associated with FCS and MDD-W. Chi-square (x^2) test was used for testing. Results were considered statistically significant when *P* value is < 0.05 at a 95% confidence interval.

3.7. Ethical Clearance

Ethical clearance for this study was obtained from the College of Veterinary Medicine and Agriculture (CVMA), Addis Ababa University. Minutes of animal research ethical review committee (minutes number and date of review: VM/ERC/02/16/024, 23/01/2024) with certificate reference number VM/ERC/02/43/16/2024 are attached as Annex 8. Before starting the study, participants were made aware of its objectives, and the livestock owners provided their verbal consent and CBBP and HEARD project offices provided written signed consent for questionnaire and photograph (Annex 9 and 10).

4. RESULTS

4.1.Animal Health Services in Intervention and Non-intervention Areas/Households

Higher animal health interventions/services such as deworming, vaccinations, treatment, training opportunity, ecto-parasite control and awareness on zoonotic diseases (58.26%, 67.91%, 53.33%, 62.08%, 54.17% and 39.88%) were observed in intervention areas compared to non-intervention areas (55.11%, 53.98%, 44.25%, 24.78%, 53.98% and 36.36%, respectively (Table 13). The difference was statistically significant for vaccination (Z = -3.074; p= 0.0021) and training (z=-6.530; p=0.0000). Table 13 shows that deworming, vaccination, treatment access, ectoparasite control and awareness on zoonotic were higher in Menz Mama (88.78%, 95.92%, 85.19%, 86.42% and 60.49 %) intervention households compared to non-intervention (66.00%, 40.00%, 61.90%, 61.90% and 38.10 %), respectively. In Bonga, the animal health care provisions were not different between the intervention and non-intervention areas, except for awareness on zoonotic (32.00 vs 21.57%), while in Degehabur, all AHI were unexpectedly higher in the non-intervention households/areas.

Table 13 Animal health intervention in intervention and non-intervention areas of study sites

Intervention/ non-intervention	*Survey-site*	*Animal Health Intervention*														
		Deworming			Vaccination			Treatment access			Ectoparasite control			Zoonotic Awareness		
		Yes	N	%	Yes	N	%	Yes	N	%	Yes	N	%	Yes	N	%
Intervention	Menz	87	98	88.8	94	98	95.9	69	81	85.2	70	81	86.4	49	81	60.5
	Bonga	71	114	62.3	89	114	78.1	35	100	35.0	34	100	34.0	32	100	32.0
	Degehabur	29	109	26.6	35	109	32.1	24	59	40.7	26	59	44.1	22	59	37.3
	Sub-total	**187**	**321**	**58.3**	**218**	**321**	**67.9**	**128**	**240**	**53.3**	**130**	**240**	**54.2**	**128**	**321**	**39.9**
Non-intervention	Menz	33	50	66.0	20	50	40.0	13	21	61.9	13	21	61.9	8	21	38.1
	Bonga	42	61	68.9	51	61	83.6	19	51	37.3	26	51	51.0	11	51	21.6
	Degehabur	22	65	33.9	24	65	36.9	18	41	43.9	22	41	53.7	20	41	48.8
	Sub-total	**97**	**176**	**55.1**	**95**	**176**	**54.0**	**50**	**113**	**44.3**	**61**	**113**	**54.0**	**64**	**176**	**36.4**

N: Total Respondents

There were also a statistically significant difference in accessibility to the service (p=0.000) but not in affordability (p=0.286) of veterinary services between intervention and non-intervention areas.

The coefficient for the number of sick animals that got treatment is 1.06, meaning the number of survivors increased as the number of treated sick animals increased. Since this is a log-linear model, when exponentiated ($e^{1.06}$), it will become 2.894. Therefore, survived shoots by treatment were 2.894 higher than non-treated (Table 14).

Table 14 Negative binomial regression result of survived animals due to treatment in intervention areas

Number of shoats survived by treatment	*Coef.*	*Std. Err.*	*z*	*P*	*95% Conf. interval*	
Number of sick shoats got treatment	1.06	0.12	8.62	0.00	0.82	1.30
_cons	-2.65	0.23	-11.68	0.00	-3.10	-2.21
/lnalpha	1.61	0.17			1.27	1.96
alpha	5.03	0.87			3.58	7.07

4.2. Food and Nutrition Security in Animal Health Intervention and Control

4.2.1. Food secure HHs (HFIAS) in animal health interventions areas

The animal health intervention was associated with the food security levels of the intervention and control households (Figure 4). A higher proportion of households with intervention were food secure than those in non-intervention households for all animal health care practices such as deworming (74.0% versus 59.3%), vaccination (74.0% versus 45.8%), treatment of sick animals (68.0% versus 57.7%) and external parasite treatment (72.2% versus 61.5%). Overall food secure HHs that use animal health services were 72.4% compared with those in non-intervention (54.7%) areas.

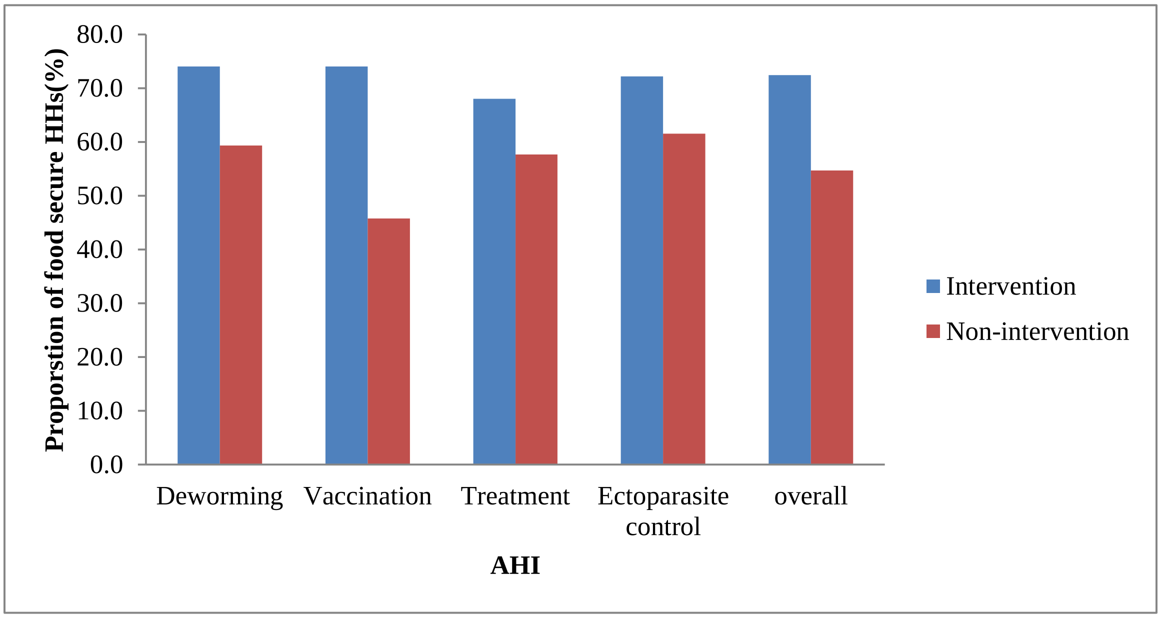


Figure 4 Proportion of food secured HHs in animal health intervention and non-intervention areas

As presented in Table 15, 85.5%, 93.6%, 87.8%, and 83.7% of households that used deworming, vaccination, treatment, and ectoparasite, respectively, in Menz intervention areas were more food secure compared to 64.3%, 39.3%, 55.6%, and 66.7% of the households that used indicated animal health interventions in non-intervention areas. Similarly, in Bonga, 97.4%, 86.8%, and 55.6% of households in intervention areas that used deworming, vaccination, and ectoparasite control were better food secured compared with 86.7%, 86.7%, and 50.0% in non-intervention areas, respectively. In Degehabur, households that used animal health services were better in food security in non-intervention areas, except for vaccination. Overall, households in target animal health intervention areas were more food secure (72.4%) compared with those in non-intervention areas (54.7%).

Table 15 Proportion of food secure households in study sites due to different animal health interventions

Study sites	*Animal health interventions*	*Intervention*		*Non-intervention*	
		Frequency	%	Frequency	%
Menz	Deworming	53	85.5	18	64.3
	Vaccination	58	93.6	11	39.3
	Treatment	43	87.8	5	55.6
	Ectoparasite control	41	83.7	6	66.7
	Total	**195**	**87.8**	**40**	**54.1**
Bonga	Deworming	37	97.4	13	86.7
	Vaccination	33	86.8	13	86.7
	Treatment	17	47.2	7	58.3
	Ectoparasite control	20	55.6	6	50.0
	Total	**107**	**72.3**	**54**	**72.2**
Degehabur	Deworming	7	22.6	4	25.0
	Vaccination	6	19.4	3	18.8
	Treatment	6	50.0	3	60.0
	Ectoparasite control	9	75.0	4	80.0
	Total	**28**	**32.6**	**14**	**33.3**
Over all		**330**	**72.4**	**93**	**54.7**

Using a stepwise backward logistic regression (Table 16), the results showed that households that practice deworming (OR = 3.6, p= 0.00) were ~3.6 times more likely to be food secure. Households linked to research center to get veterinary services (OR = 2.08, p= 0.044) were ~2.08 times more likely to be food secure. Similarly, households that used treatment against infections (OR = 2.27, p = 0.006) were ~2.27 times more likely to be food secure. Primary education levels (OR = 1.96, p = 0.023) 1.96 times more likely food security and PPR (OR=2.10, P=0.046) and Pox (OR=1.62, P=0.038) vaccination HHs were 2.1 and 1.62 times more likely food secure than those that did not use these vaccination respectively. However, households that vaccinated animals against anthrax (OR = 0.15, p= 0.000) were significantly less likely to be food secure. OR < 1, it suggests a negative association, meaning HHs that vaccinate their animals against anthrax disease were ~85% less likely to be food secure.

Table 16 Effects of selected animal health interventions and educational level on food security status of HHs based on HFIAS data (Stepwise logistic regression)

Variables	***Levels***	***Percent Food Secure (%)***	***OR***	***P-value***
Intervention	No	33.5	1.96	0.086
	Yes	40.8		
Education status	None	32.7		
	Primary	43.0	1.96	0.023
	Secondary	46.0	2.11	0.059
Anthrax vaccination	No	40.9	0.15	0.000
	Yes	16.9		
Deworming practices	No	27.2	3.61	0.000
	Yes	46.5		
Vet services from RC	No	22.7	2.08	0.044
	Yes	51.3		
Treatment of infection	No	24.0	2.27	0.006
	Yes	45.5		
SGP vaccination	No	32.3	1.62	0.038
	Yes	39.7		
PPR vaccination	No	32.1	2.10	0.046
	Yes	42.9		

OR: Odds Ration, P-value: Probability value, RC: Research Center

In general deworming, research center support, infection treatment, primary education, SGP and PPR vaccination positively impact food security.

4.2.2. Food Consumption Score (FCS) with animal health intervention in intervention and non-intervention areas

As shown in Table 17, 62.9%, 69.9%, 62.4%, and 61.8% of HHs that used deworming, vaccination, treatment, and ectoparasite control services in intervention areas were in a better acceptable FCS as compared to 61.8%, 55.3%, 49.3%, and 56.0% of HHs in non-intervention areas, respectively. Overall, 64.6% of households in animal health intervention areas were in acceptable FCS compared to those in the non-intervention group (56.3%). Similarly, 40.0% of households in animal health intervention areas were in poorer FCS than non-intervention areas (36.4%). But 48.1% of households in animal health intervention areas were in borderline FCS compared with non-intervention (51.1%).

Table 18 presents results of comparative food security among households with animal health interventions versus those without intervention across different areas. In Menz households with deworming, vaccination, treatment, and ectoparasite control interventions, higher food security percentages, ranging from 83.3% to 95.3%, were shown compared to the non-intervention group (45.0% to 72.5%). Bonga also showed a similar trend, with intervention groups having higher food security. Degehabur exhibited higher food security percentages among the intervention compared to non-intervention groups for vaccination and treatment. In general, animal health interventions have a positive impact on food security, particularly in Menz and Bonga, while a reverse effect was recorded in Degehabur for deworming and ectoparasite control.

Table 17 Proportions of Food Consumption Score with animal health services in intervention and non-intervention areas

AHI	*Intervention*						*Non-intervention*					
	N	Acceptable FCS (%)	N	Borderline FCS (%)	N	Poor FCS (%)	N	Acceptable FCS (%)	N	Borderline FCS (%)	N	Poor FCS
Deworming	229	62.9	57	56.1	35	31.4	123	61.8	26	46.2	27	33.3
Vaccination	229	69.9	57	64.9	35	60.0	123	55.3	26	61.5	27	40.7
Treatment	173	62.4	47	29.8	20	30.0	75	49.3	21	38.1	17	29.4
Ecto-parasite control	173	61.8	47	36.2	20	30.0	75	56.0	21	57.1	17	41.2
Overall	**804**	**64.6**	**208**	**48.1**	**110**	**40.0**	**396**	**56.3**	**94**	**51.1**	**88**	**36.4**

N: Total Respondent, FCS: Food Consumption Score

Table 18 Proportions of food secured household based on FCS with animal health services by areas

Survey sites	*Animal health interventions*	*Intervention*		*Non-intervention*	
		Acceptable FCs HHs	% acceptable FCs	Acceptable FCs	% acceptable FCs
Menz	Deworming	74	87.1	29	72.5
	Vaccination	81	95.3	18	45.0
	Treatment	60	83.3	12	63.2
	Ectoparasite control	61	84.7	12	63.2
	Total	**276**	**87.9**	**71**	**60.2**
Bonga	Deworming	48	72.7	31	73.8
	Vaccination	54	81.8	37	88.1
	Treatment	25	43.1	13	39.4
	Ectoparasite control	24	41.4	18	54.5
	Total	151	60.9	99	66.0
Degehabur	Deworming	22	28.2	16	39.0
	Vaccination	25	32.1	13	31.7
	Treatment	23	53.5	12	52.2
	Ectoparasite control	22	51.2	12	52.2
	Total	**92**	**38.0**	**53**	**41.4**
	Overall	**519**	**64.6**	**223**	**56.3**

Households that practice deworming were 1.96 times more likely to be in acceptable FCS category (OR=1.66, P=0.057). Similarly, households that vaccinate sheep and goats against pox (OR=1.85, P=0.042) were 1.85 times more in acceptable FCS category (food security category). Again, households that vaccinate their sheep and goats against Pasteurellosis (OR=1.63, P=0.065) were 1.63 times more likely to be in acceptable FCS category. Households that treat their small ruminants against infections (OR=1.88, P=0.023) were 1.88 more in acceptable FCS category. Households aware of zoonotic diseases (OR=3.20, P=0.000) were 3.2 times more in a higher food security category but households that vaccinate against anthrax (OR=0.51, P=0.026) were 49% less likely to be in acceptable FCS category (Table 19).

Table 19 Ordered logistic regression (ologit) of acceptable FCS category against AHI

Variables	*levels*	*Acceptable FCS (%)*	*OR*	*P-value*
Intervention	Yes	71.3	1.17	0.534
	No	70		
Deworming	Yes	77.5	1.66	0.057
	No	62		
pox vaccination	Yes	83.5	1.85	0.042
	No	63.6		
Pasteurellos vaccination	Yes	74.5	1.63	0.065
	No	62.3		
Anthrax vaccination	Yes	68.5	0.51	0.026
	No	70.8		
Treatment of infection	Yes	81.8	1.88	0.023
	No	58.9		
Awareness on zoonotic	Yes	81.8	3.20	0
	No	63.9		

Note: Odds ratios (OR) > 1 indicate an increase in the likelihood of meeting the FCS criteria, while OR < 1 indicate a decrease. OR=1 indicates no relationship, FCS: Food Consumption Score, P-value: Probability value

4.2.3. MDD-W fulfilled HHs in animal health intervention areas of study sites

A higher proportion of HHs fulfilling MDD-W in intervention areas (86.0%) were those who vaccinate their animals against diseases compared to the non-intervention households (75.7%); similarly, a higher proportion of HHs fulfilling MDD-W in intervention areas (51.1%) were using treatment for their sheep and goats against infectious diseases compared to HHs in the non-intervention areas (46.3%).

Table 20 presents MDD-W among households that received animal health interventions versus those in non-intervention areas across three study sites. In Menz, households which practice deworming, vaccination, treatment, and ectoparasite control interventions had higher Minimum Dietary Diversity for Women (MDD-W) in comparison to those which did not receive AHI, with a total of 90.8% HHs in the intervention group versus 62.0% in non-intervention areas. In Bonga it was shown that lower proportion of households who received AHIs were having MDD-W (55.2%) compared to those which did not receive AHIs (63.5%) for all AHI practices. In Degehabur, households practicing AHIs, had lower MDD-W (36.4%) compared to non-intervention households (60.7%) except for vaccination (which was 66.7% in intervention and 57.1% in non-intervention). Overall, 65.4% of households who fulfilled MDD-W were from intervention areas compared to 62.9% in the non-intervention areas.

Table 20 MDD-W among households in the study areas

Survey sites	Animal health interventions	Intervention		Non-intervention	
		N	% meeting MDD-W	N	% meeting MDD-W
Menz	Deworming	39	94.9	16	75.0
	Vaccination	39	97.4	16	50.0
	Treatment	32	84.4	9	55.6
	Ectoparasite control	32	84.4	9	66.7
	Total	**142**	**90.8**	**50**	**62.0**
Bonga	Deworming	63	58.7	47	68.1
	Vaccination	63	82.5	47	87.2
	Treatment	52	34.6	38	42.1
	Ectoparasite control	52	38.5	38	50.0
	Total	**230**	**55.2**	**170**	**63.5**
Degehabur	Deworming	12	16.7	7	71.4
	Vaccination	12	66.7	7	57.1
	Treatment	10	30.0	7	57.1
	Ectoparasite control	10	30.0	7	57.1
	Total	**44**	**36.4**	**28**	**60.7**
	Overall	**416**	**65.4**	**248**	**62.9**

N=Total Respondent, MDD-W: Minimum Dietary Diversity for Women.

Women in the households that vaccinated their animals were 2.02 times more likely to meet the MDD-W (OR = 2.02, p = 0.043). Similarly, households that vaccinated against Pasteurellosis were also 2.49 times more likely to meet the MDD-W (OR = 2.49, p = 0.009). Also, households with primary education (OR=2.97, p= 0.000) were 2.97 times more likely to meet MDD-W than those with no education; and those with secondary education and above (OR= 3.38, p=0.002) were 3.38 times more likely to meet MDD-W. Anthrax Vaccination (OR = 1.47, p = 0.185) had a statistically non-significant effect (p = 0.185). Individuals that used vet services from research centers were 53.0% less likely (1 - 0.47) to achieve MDD-W; and training/awareness and ectoparasite control service had no effect on MDD-W (Table 21).

Table 21 Logistic regression of MDD-W with selected variables

Variables	levels	% HHs fulfilled MDD-W	OR	P
Education level	Non	34.05		
	Primary	56.77	2.97	0
	Secondary and above	62.26	3.38	0.002
Research Centre	No	47.73		
	Yes	50.40	0.47	0.017
Anthrax	No	44.84		
vaccination	Yes	60.00	1.47	0.185
Pasteurellos	No	30.61		
vaccination	Yes	57.56	2.49	0.009
Training/awareness	No	41.93		
	Yes	56.08	1.59	0.176
Practice	No	26.61		
vaccination	Yes	56.13	2.02	0.043
Ectoparasite control	No	48.60		
service	Yes	49.07	0.64	0.12
_cons			0.19	0

HHs: Households, OR: Odds ratios, MDD-W: Minimum Dietary Diversity for Women, P-value: Probability value

4.3. Secondary Data

Between 2018 and 2023 vaccines have been provided to smallholder farmers against TADs as presented in Table 22. The number of animals vaccinated against different diseases has been increasing from year to year as depicted in figure 5. The number of animals vaccinated in 2020 was less due to restriction of movement during COVID-19 pandemics.

Table 22. Distributed TADs vaccine (MoA Veterinary Services Report, 2018-2023)

Year	Types of vaccines	Distributed Dose	Remarks
2023	CBPP, CCPP, LSD,	120,352,750	
2022	SGP, PPR, African	129,632,941	
2021	horse sickness, Camel	123,271,068	
2020	Pox and NCD	6,500,000	COVID-19 time
2019		117,984,270	
2018		140,700,000	

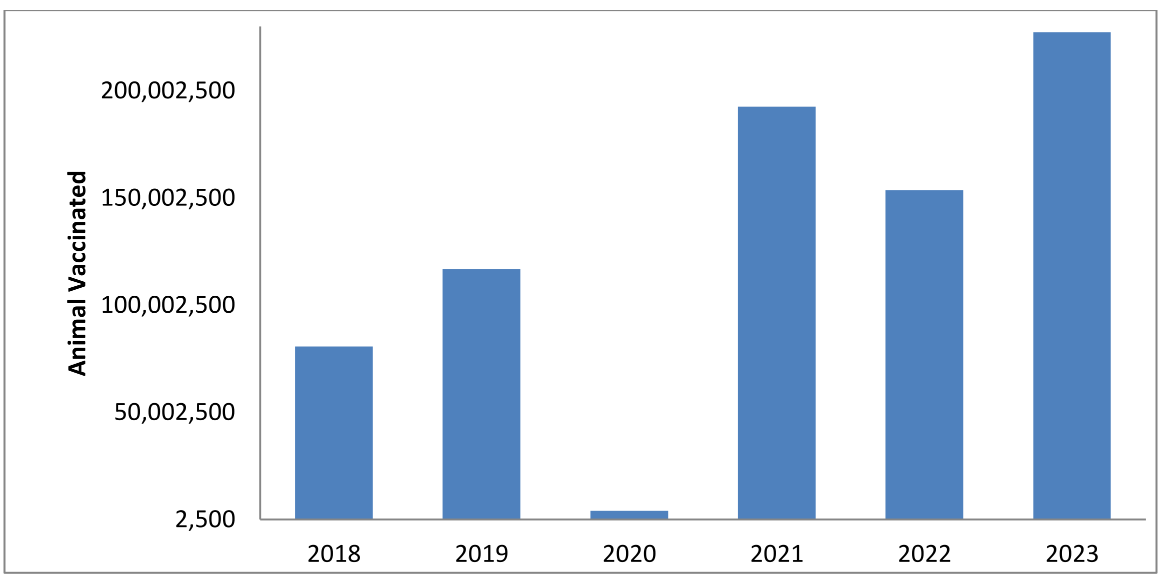


Figure 5 Number of vaccinated animals from 2018 to 2023

The federal government of Ethiopia has been working towards eradication of PPR by 2027 with the support from Livestock and Fisheries Sector Development Project (LFSDP) and HEARD. Eradication of rabies has also been planned to be effected by 2030. The PPR outbreak investigation, participatory disease search, vaccination and surveillance conducted by the program are indicated in Table 23.

Table 23 Implementation of PPR CEP activities (MoA PPR CEP Report, 2015-2022)

Year	*Types of Activities*						
	PDS conducted		Outbreak investigated		Number of Shoats	Sero- Surveillance & Monitoring	
	Number of PDS	% positive	Number of outbreak	% positive	Vaccinated	% Prevalence	% Sero Monitoring
2015			31		143,528		
2016			30		1,755,323	24.48	84.86
2017	59	45.76	59	45.76	6,213,580	82.8	46.41
2018	93	54.84	93	54.84	11,290,617	44.3	49.3
2019	162	32.72	162	32.72	11,160,699	Not done	Not done
2020	97	46.39	86	66.28	5,366,654	13.33	76.21
2021	83	21.69	38	71.05	4,046,214	9.6	78.2
2022	171	23.39	55	56.36	13,113,919	19.9	71.8
Total	351	29.34	554	44.40	53,090,534		

Note: Serological surveillance/sero-surveillance: is the collection and testing, in a statistically significant manner, of serum samples from animal populations at risk of infection in order to provide data about specific diseases. **Sero-monitoring**: is an activity which also involves the collection of sera in a statistically significant manner with the intention of defining the immune status of a vaccinated population (EU-SHARE PPR Surveillance Manual, 2016). The results of sero-monitoring were promising for PPR. Existing clinics and AHI in Degehabur district is also assessed (Annex 11 and 12).

5. DISCUSION

5.1. Animal Health Services and Food and Nutrition Security in Intervention and Non-intervention Areas

The Government of Ethiopia has prioritized improvement of livestock sector to achieve food and nutrition security, as reflected in strategic initiatives such as the ten-year "*Ten in Ten*" plan and the '*YeLemat Tirufat'* initiatives. These efforts aim to enhance production and mitigate disease-related losses. High disease prevalence and mortality are impacting productivity at both individual animal and herd/flock level (Megersa *et al*. 2011, Jibat *et al*. 2016). This strongly implies that FNS could be greatly impacted by lowering morbidity and mortality. While reports suggest that animal health interventions increase the consumption of animal-derived foods and improve livelihoods, scientific evidence is lacking particularly in rural Ethiopia. The findings of this study support the national efforts to strengthen livestock strategies, optimize economic benefits, and reduce the burden of zoonotic diseases through a One Health approach.

Animal health (AH) interventions have the potential to improve the availability and accessibility of animal source foods, thereby enhancing the nutritional security and livelihoods of livestock rearing communities. Animal health interventions can also increase household income, ultimately improving the purchasing power for other food items. Given the lack of synthesized empirical evidence on the impact of AHI on diets and human nutritional status in Africa (Muema *et al*., 2023), generated evidence-based data. It highlights the critical role of AH interventions in improving food and nutrition security in extensive livestock production systems within selected CBBP and HEARD project areas in Ethiopia.

5.1.1. Status of animal health services in intervention and non-intervention areas

The higher proportion of households receiving AH services in intervention areas compared to non-intervention and their awareness of zoonotic diseases highlights the importance of targeted animal health programs in preventing and controlling animal diseases. The past study in CBBP areas also showed that, veterinary and breeding interventions have significantly increased the production and the number of sheep and goats off take due to market (Kassie *et al*., 2021). Study conducted by Moliso *et al*. (2024) also supports this survey result in CBBP area. Deworming had similar effects with the observations of Molla and colleagues (2023) in Menz, Adiyo and Doyogena intervention areas. According to the secondary data from MoA, increased veterinary input and improved services (especially TADs vaccination) had greatly contributed to the animal health status of smallholder farmers in CBBP households.

Observed significant differences in vaccination and training access between intervention and non-intervention areas suggest that these services are key packages of improved animal health care, which in turn positively impact household food security. The result is similar to that of the study conducted by Mekonnen *et al*. (2021), in which vaccination of ovine pasteurellosis in Bonga and Menz and vaccination of cattle in CBBP were found to be better in intervention areas. Vaccination and deworming were conducted based on the designed calendar and similar with the results of the study done by Temesgen *et al*. (2022).

For every additional sick animal treated, the expected number of survivors increases by approximately 2.9 (treated animals survived more than non-treated by 2.9). It shows provision of the necessary treatment to sick animals is vital for continual production in addition to the improving welfare of animals. This finding is similar to the lower mortality and morbidity recorded due to animal health intervention (4.35 and 0.85%, respectively) reported earlier by Mekonnen *et al*. (2021) and the use of preventive herd management to increase lamb survival (Tibbo *et al*. 2003; Holmøy *et al*. 2012). The effects of preventive herd management on lamb mortality have also been reported by the study conducted in Menz and Horro by Genfors *et al*. (2023). Again, during the questionnaire survey, the FGD and KII participants (especially in Menz) reported improvements in the productive and reproductive performance of sheep and goats in intervention areas, as well as a decrease in the incidence of various diseases due to the better AH intervention such as vaccination and deworming practices.

In Menz Mama, intervention households showed higher proportion of deworming (88.78%), vaccination (95.92%), treatment (85.19%), ectoparasite control (86.42%), and awareness of zoonotic diseases (60.49%) compared to non-intervention households (66.00%, 40.00%, 61.90%, 61.90%, and 38.10%, respectively). These findings align with previous studies, such as the vaccination of ovine pasteurellosis conducted from 2019 to 2021 in Bonga and Menz, which revealed better vaccination rates in CBBP intervention areas (Mekonnen *et al*., 2021) than control areas. According to MoA PPR eradication program, most of administrative zones in Ethiopia submit monthly disease outbreak reports, indicating that livestock disease surveillance and reporting are better, unlike in the previous study by Shapiro *et al*. (2015). Similarly, a study on veterinary service delivery in central Ethiopia found that 76.3% of dairy farmers were satisfied with veterinary professionals' skills and their animals' post-treatment recovery (Kebede *et al*., 2025). The small ruminant flock health intervention calendar in Menz and Doyogena supports this finding (Temesgen *et al*., 2022).

According to FGD and KII participant's response, in the Menz mama district intervention area, enhanced sheep breeding, reduced mortality, and better animal health and feed management were reported, yet high veterinary costs, resource limitations, and insufficient training for women remained concerns. The Bonga intervention area (Boka-Shuta Kebele) saw gains in sheep productivity, income, and women's empowerment, while the non-intervention area (Mera Kebele) relied on traditional practices with limited access to modern veterinary services, training and market linkages. According to the results of questionnaire survey, in Bonga the animal health care provisions were not different between the intervention and non-intervention areas, except for awareness on zoonotic diseases. This might be due to cross contamination of experience and knowledge of AH interventions. Local societies have their own information management system in which they share experiences among each other. That is, household in the non-intervention areas can acquire knowledge from adjacent intervention households and practice those AH interventions they learned from their neighbors.

In Degehabur, the proportion of households receiving AHI was unexpectedly higher in the non-intervention area. In the Somali region, animal health services were scarce, expensive, and inaccessible for pastoralists, compounded by drug shortages, a lack of skilled personnel, and high treatment costs as evidenced from FGD and KII. Previous studies also revealed that services are least accessible to pastoral production systems, while improved access was noted in crop livestock (Dejenu, 2004 and Gizaw *et al*., 2021). Additionally, the veterinary services are intended to be delivered as one component of extension packages that have been designed for crop-livestock systems. This system has been found unsustainable and impractical for pastoral system contributing to inaccessibility of veterinary services (Dejenu, 2004; Bekele and Admasu, 2018). The mobility of pastoralists, the remoteness of the area, and inadequate infrastructure that prevents professionals from working in arid, isolated, and marginal pastoral areas are the other factors contributing to the poor access to veterinary services in pastoral areas. Poor access to veterinary services in the nation's pastoral areas is a result of a number of issues, including limited funding, inadequate infrastructure, and a lackluster institutional structure (Bekele *et al*., 2014 and Gizaw *et al*., 2021). Based on FGD and KII result, the gaps of infrastructure, access to vet services and drugs in control areas were high.

5.1.2. Effects of AHI on household food and nutrition security

Significantly higher proportion of households that receive AHI such as deworming, treatment, vaccination and advice from research centers were food secure than those in the non-intervention sites. Based on the Household Food Insecurity Access Score (HFIAS), greater proportions (72.4%) of households in intervention areas were food-secure as compared to 54.7% in non-intervention area, which is in agreement with the report of FAO (2020). Our observation is in consent with reports Haile *et al*. (2020) who reported significant difference in the consumption of mutton between CBBP participants and non-participants as a result of good management including animal health interventions in Bonga and Menz. Moreover, our findings are in agreement with the observations of Megersa *et al*. (2011) and Jibat *et al*. (2016) who strongly suggest improving AHI could significantly impact food and nutritional security. The results of meta-analysis also showed that nutrition-sensitive livestock interventions increased odds of consuming ASFs (Muema *et al*., 2023). Previous study showed that keeping small ruminant in one of the study area (Degehabur) is for income generation, milk production, social function, and meat production purpose (Fikru & Gebeyew, 2015).

In general, the study findings support previous research, highlighting the positive link between animal health interventions and improved food security. It emphasizes the significant role of improved animal health service delivery such as deworming, vaccination, and veterinary treatments directly impacting food security. But households with anthrax vaccination (OR = 0.15, p= 0.000) were surprisingly less likely to be food secure which may be due to improper vaccination or less vaccination coverage (Feyisa and Shene, 2021; Catley et al., 2009)); community treating animals by themselves due to their mobility to less accessible areas for the vet services (Gizaw *et al.*, 2021).

In Menz, intervention area households that used deworming, vaccination, treatment, and ecto-parasite were in a better food security when compared with non-intervention households. Similarly, Bonga households in intervention areas that used AHIs were in a better food security compared with those in non-intervention areas. This is in agreement with the study done by Haile *et al*. (2020). However, in Deghabur, for example, only 22.6% of food-secure households in intervention areas were impacted by deworming services, compared to 25.0% in non-intervention areas.

The Food Consumption Score (FCS) analysis also revealed significant differences between intervention and non-intervention areas due to AHI. This result is supported by evidence generated by report on the positive role of livestock related intervention on food and nutritional security (FAO, 2020). Also livestock interventions influence human nutrition (Sadler, 2012). According to estimates, foods originating from livestock, or animal-source foods (ASF), account for 34% of the world's protein consumption and 18% of its food energy consumption (FAOSTAT, 2016). The survey result is also in line with the study that says vaccination programs and an adequate supply of veterinary extension services are essential to protect a household's productive assets, improve productivity, avoid harmful side effects on human health and nutrition, prevent the spread of new animal diseases (biosecurity), and prevent the transmission of zoonosis (Gijs, 2021).

Households that practice deworming were 1.66 more likely to be in acceptable FCS category (OR=1.66, P=0.057) and while those that vaccinate sheep and goats against pox (OR=1.85, P=0.042) were 1.85 times more likely in acceptable FCS category (food security category). Again, households that vaccinate their sheep and goats against Pasteurellosis (OR=1.63, P=0.065) were 1.63 more likely to be in acceptable FCS category. Households that treat their small ruminants against infections (OR=1.88, P=0.023) were 1.88 more in acceptable FCS category. Households aware of zoonotic diseases (OR=3.20, P=0.000) were 3.2 times more in a higher food security category. This also supports the study conducted by Muema *et al.* (2023) and Bonde (2016).

Livestock with better animal health intervention significantly contributes to nutrition security by enhancing household diets through the consumption of home-produced ASF, enabling the purchase of nutritious foods (pulses, nuts, fruits, vegetables), non-food essentials (soap, health services), and serving as a critical asset during crises. Additionally, livestock supports income generation via the sale of live animals, ASF (meat, milk, cheese, eggs), by-products (skins, wool, manure), and use the income to buy other food items (Gijs, 2021).

When the impact of AHI by specific sites on FNS using FCS indicator is reviewed in Menz, households with deworming, vaccination, treatment, and ectoparasite control interventions showed higher food security percentages, ranging from 83.3% to 95.3%, compared to the non-intervention group (45.0% to 72.5%). This result is similar to that of the study conducted by Haile *et al*. (2020). Degehabur exhibited higher food security percentages among the intervention compared to non-intervention groups for vaccination and treatment.

Regarding Minimum Dietary Diversity for Women (MDD-W), a higher proportion of households fulfilling MDD-W were in vaccination intervention areas (86.0%) compared to non-intervention households (75.7%). Similarly, 51.1% of intervention households used treatment for infectious diseases, compared to 46.3% in non-intervention areas. In Menz, households that used animal health services in intervention households showed significantly higher food security (90.8%) compared to non-intervention households (62.0%). In Bonga, intervention households had lower overall food security (55.2%) than non-intervention households (63.5%), though specific interventions such as vaccination showed relatively high food security (82.5%) compared to other services in intervention areas. In Degehabur, intervention households generally had lower food security (36.4%) compared to non-intervention households (60.7%), except for vaccination, which showed a positive impact (66.7% vs. 57.1%). Overall, 65.4 Vs., 62.9%. In general, previous studies show that the good amino acids profile and high micronutrient density make ASF very efficient for improving the quality of diets, especially during periods of high nutritional demand such as pregnancy, lactation, early infancy and childhood, and adolescence (Iannotti *et al*., 2008). Therefore, it is crucial to improve production of livestock products by improving service deliveries such as veterinary services.

Women in the households that vaccinate their animals were 2.02 times more likely to meet the MDD-W (OR = 2.02, p = 0.043). Similarly, households that vaccinate against Pasteurellosis were also 2.49 times more likely to meet the MDD-W (OR = 2.49, p = 0.009). Households with primary education (OR=2.97, p= 0.000) were 2.97 times more likely to meet MDD-W than those with no education; and those with secondary education & above (OR= 3.38, p=0.002) were 3.38 times more likely meet MDD-W. This result is in line with study conducted by Muema *et al*. (2023). This confirms that programs such as vaccination and adequate supply of veterinary extension services are essential to protect a household’s productive assets, improve productivity and avoid harmful side effects on human health and nutrition (e.g. spread of new animal diseases, transmission of zoonoses) (FAO, 2020). A similar study in Mali in communities experiencing shortage of food (mainly women and children), provision of improved crop seed, goats and hens with better support from agronomists and veterinarians, improved dietary diversity and income of the targeted households (Bonde, 2016). Anthrax Vaccination (OR = 1.47, p = 0.185) had a non-significant effect (p = 0.185) in some areas, which warrants further investigation. Also training/awareness and ectoparasite control service had no strong effect on MDD-W. Findings from FGDs and KIIs in Ethiopia's Menz Mama District, Bonga area, and Somali region revealed that animal health interventions have significantly improved sheep productivity, animal health, and household livelihoods, though challenges persist.

The limitation of this study was based on past and ongoing AHIs implemented by different stakeholders but was not based on controlled trials and matching of households among control and intervention areas. Additionally, the interventions were implanted by two different institutions, namely the HEARD project in the Somali Region and the CBBP project in the Bonga and Menz areas, which also may vary by their intervention package contents. Thus, these limitations might affect the findings of this study.

5.1.3. Synergies and trade-offs between AHI and food and nutrition security

The synergies and trade-offs between animal health interventions and food and nutrition security are evident in the study. **Synergies** include improved livestock health through interventions like deworming, vaccination, and treatment, which enhance productivity, increase household income, and improve dietary diversity. For example, households with AH interventions showed higher food security (72.4% vs. 54.7%) compared with non-intervention areas and better access to animal-source foods (ASFs), contributing to improved nutrition. Deworming appeared especially impactful; households that dewormed their animals were 3.6 times more likely to be food secure than those that did not (using HFIAS indicator). Livestock health also had direct economic effects. Households with healthier herds had more reliable income from livestock sales, enabling them to purchase a wider variety of foods and maintain consistent access to animal-source foods (ASF) like milk and meat.

Additionally, AH interventions like vaccination against PPR and Pasteurellosis were positively associated with higher food consumption scores (FCS) and minimum dietary diversity for women (MDD-W). Disease control can reduce the risk of zoonotic diseases, improving human health and indirectly contributing to FNS. Animal health interventions also contributed to food system stability. Feeding the world in 2050: trade-offs, synergies and tough choices for the livestock sector, support this study (Smith *et al*., 2013), study on role of ASF on health and environment (Beal *et al*., 2023) and study on dairy sector by Ayantunde *et al*. (2025). Programs like the Community-Based Breeding Programs (CBBP) facilitated synchronized deworming and vaccinations, which not only improved animal survival and flock sizes but also promoted community knowledge-sharing and coordination. These efforts enhanced household resilience to shocks such as disease outbreaks or climate-related disruptions.

Trade-offs includes challenges such as inconsistent service delivery in pastoral areas, where AHIs did not uniformly improve FNS due to limited access, mobility, and infrastructure. Anthrax vaccination showed a negative association with FNS indicators, possibly due to low coverage or improper implementation. In areas like Menz, the high cost of vet services was a barrier; households that described services as "expensive" or had no access at all were more likely to experience food insecurity. Labor demands posed another challenge households caring for sick animals often had to divert time away from farming or other income-generating activities, leading to temporary reductions in food availability. Similar study conducted on dairy sector by Ayantunde *et al*. (2025).

Furthermore, where disease outbreaks occurred particularly in households reporting more than one sick or dead animal, food security metrics declined noticeably. Another concern was the unregulated use of veterinary drugs such as antibiotics and anthelmintics. In many cases, farmers administered these drugs without veterinary oversight, increasing the risk of antimicrobial resistance, which could undermine long-term animal and human health. Also supported by study on influence of ASF on nutrition and trade-offs by Grace *et al*. (2018).

Table 24 Summary of synergies and trade-offs –animal health vs.Food & nutrition security

Dimension	Synergies	Trade-offs
Livestock Productivity / Protein Production	• Reduced morbidity and mortality, increased milk/meat/offspring yields. • Improved survival, growth, & off-take of healthier.	• High cost of veterinary services. • Drug resistance risks from indiscriminate use of antibiotics and anthelminthic.
Household Income / Access to ASF	• Improved animal health increases sales of animals and household purchasing power.	• Over-reliance on livestock income amid market/disease. • ASF commercialization may limit access for poorer.
Dietary Diversity / Utilization of ASF	• Improved ASF availability and healthier livestock, better dietary diversity (HFIAS, FCS & MDD-W).	• Poor hygiene/handling of ASF may cause zoonoses, reducing net nutritional benefits.
Health and Nutrition	• Reduction in zoonoses through vaccinations, deworming → better human health.	• Misuse of health interventions (e.g., antibiotics) → antimicrobial resistance.
Community Capacity / Stability	• Community-based breeding and herd health programs foster cooperation and resilience.	• Sustainability depends on long-term training and support, which may not be locally maintained.
Climate & Shock Resilience / Sustainability	• Healthier animals more resilient to climate stress & disease. One Health supports sustainable systems.	• Resources may be diverted from other priorities; sustainability threatened by limited national veterinary coverage.
Policy and Institutional Impact	• Supports national policies like 'YeLemat Tirufat'.	• Reliance on donor-funded projects and limited national budget threaten long-term impact.
Area Equity / regional disparities	• Success in areas like Bonga and Menz shows scale-up potential.	• Uneven impact across regions; e.g., limited effectiveness in Degehabur due to structural barriers

5.2. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that animal health interventions such as, deworming, vaccination, training /extension services, and treatment had a significant positive impact on food and nutrition security in extensive livestock production areas of Ethiopia. The findings highlight the importance of integrating improved animal health services with broader food security strategies, particularly in regions where livestock play a central role in household economies. AHI offer substantial synergies, when implemented as part of integrated livestock development programs. Overall, animal health interventions are a vital component of strategies to enhance food and nutrition security in Ethiopia's extensive livestock production systems. By addressing the barriers to effective implementation and tailoring interventions to local contexts, these programs can significantly contribute to improving the livelihoods of livestock-dependent households. Further research is needed to assess the long-term impacts of these interventions and identify additional factors influencing food and nutrition security in extensive livestock systems.

Recommendations:

- Given the positive impact of animal health interventions on food and nutrition security, these interventions should be scaled up, especially AHI like in CBBP·
- Strengthen the link between animal health services and broader food and nutrition security initiatives that can create synergies that benefit vulnerable households.
- Nutrition-sensitive activities should include livestock intervention programs in the selection of dietary diversification strategies.
- Improve awareness of communities on the importance of consumption of ASF.
- Veterinary services cost and accessibility barriers should be addressed to maximize synergies between AHI and food and nutrition security.
- Further experimental research should be conducted to strengthen the role of animal health intervention on food and nutrition security by implementing selected animal health services and considering socioeconomic factors.

6. REFERENCES

Abubakar M, S Ashiq, AB Zahoor, MJ Arshed and AC Banyard, 2011. Diagnosis and control strategies for peste des petits ruminants virus: Global and Pakistan perspectives. *Pak Vet J*, **31**(4): 267-274.

Abunna, F., Kasasa, D., Shelima, B., Megersa, B., Regassa, A., & Amenu, K. (2009). Survey of tick infestation in small ruminants of Miesso district, West Harergie, Oromia Region, Ethiopia. *Tropical animal health and production*, **41**, 969-972.

Aga, T. S., Tolossa, Y. H., & Terefe, G. (2013). Parasite control practices and anthelmintic efficacy field study on gastrointestinal nematode infections of Horro sheep in Western Oromiya, Ethiopia. *African Journal of pharmacy and pharmacology*, **7**(47), 2972-2980.

Ahmed, M. A., Ehui, S., & Assefa, Y. (2004). *Dairy development in Ethiopia*. Intl Food Policy Res Inst.

Alemayehu, K. D., Mitiku, B. A., Alemu, Y. F., & Nibret, T. B. (2024). Knowledge, attitude, and prevention practices towards common zoonotic diseases in and around Bahir Dar city, north western Ethiopia. *Transboundary and Emerging Diseases*, **2024**(1), 6642766.

Alemu, B., Desta, H., Kinati, W., Mulema, A. A., Gizaw, S., & Wieland, B. (2019). Application of mixed methods to identify small ruminant disease priorities in Ethiopia. *Frontiers in veterinary science*, *6*, 417.

Areb, E., Getachew, T., Kirmani, M., & Haile, A. (2021). Farmers' perception on the effect of community-based sheep breeding program for smallholder production system-a case of bonga sheep in Ethiopia. *International Journal of Livestock Research*, **11**(11), 1-10.

Ayantunde, A. A., van der Lee, J., Ebro, A., Ndambi, A., van Scheltinga, C. T., Dijkshoorn-Dekker, M., & van Berkum, S. (2025). Trade-offs and synergies in food system transition: case of the Ethiopian dairy sector. *Food Security*, 1-14.

Balamurugan, V., A. Sen, G., Venkatesan, V., B. hanuprakash, R. K. Singh. 2014. Protective immune response of live attenuated thermo-adapted peste des petits ruminant vaccine in goats. *Virus disease*, **25** (3):350–357.

Beal, T., Massiot, E., Arsenault, J.E., Smith, M.R. and Hijmans, R.J. 2017. Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. *PloS One* **12**(4): e0175554.

Beal, T., Gardner, C. D., Herrero, M., Iannotti, L. L., Merbold, L., Nordhagen, S., & Mottet, A. (2023). Friend or foe? The role of animal-source foods in healthy and environmentally sustainable diets. *The Journal of nutrition*, **153**(2), 409-425.

Bekele, G., Esmael Tessema Ali, Genene Regassa and Nicoletta Buono. 2014. Impact of goat feeding and animal healthcare on child milk access in Ethiopia. Field Exchange, 47: 72

Bekele G, Admasu B. Veterinary Service Delivery Strategy in Pastoral Production Environment (2018).

Belay, B., Getachew, T., & Haile, A. (2022). Climate-Smart Small Ruminant Innovations (Smart Pack) Implemented by Universities. Implementation Report. Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA).

Béné, C., Newsham, A., Davies, M., Ulrichs, M., & Godfrey-Wood, R. (2014). Resilience, poverty and development. *Journal of international development*, **26**(5), 598-623.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet*, **382**(9890), 427-451.

Bonde, D. (2016). Impact of agronomy and livestock interventions on women's and children's dietary diversity in Mali.

Catley A, Abebe D, Admassu B, Bekele G, Abera B, Eshete G, Rufael T, Haile T. 2009. Impact of drought-related vaccination on livestock mortality in pastoralist areas of Ethiopia. *Disasters*, **33**(4):665-85.

Coates, J., Swindale, A., & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3.

Cochran, W. G. (1977). *Sampling techniques*. john wiley & sons.

CSA (Central Statistical Agency) and ICF. 2016. *Ethiopia Demographic and Health Survey 016.* CSA and ICF: Addis Ababa, Ethiopia, and Rockville, Maryland, USA.

Dejenu A. A Retrospective study on the impact of Community-based animal health service delivery system in Shinile zone, Somali national regional state of Ethiopia. Thesis of MSc in Tropical Veterinary Epidemiology, Debrezeit, Ethiopia, 2004.

Dessie, T., Zewdie, Y., Yilma, Z., Ayalew, W. and Haile, A. (Eds.). 2023. Yelemat Tirufat: An Overview of the initiative and lessons of experience from selected livestock development interventions in Ethiopia. Nairobi, Kenya: ILRI.

EPHI (Ethiopian Public Health Institute). 2016. *Ethiopian National Micronutrient Survey Report.* Addis Ababa, Ethiopia: Ethiopian Public Health Institute.

EPHI–MoH (Ethiopian Public Health Institute and Ministry of Health). 2016. Ethiopian National Micronutrient Survey 2016. Addis Ababa, Ethiopia: EPHI–MoH.

Ethiopian statistics service (ESS), agricultural sample survey (2021/22 (2014 E.C.)), Volume II. Report on livestock and livestock characteristics

FAO. 2020. Nutrition and livestock– Technical guidance to harness the potential of livestock for improved nutrition of vulnerable populations in program planning. Rome. https://doi.org/10.4060/ca7348en

FAO and FHI 360. 2016. Minimum Dietary Diversity for Women: A Guide for Measurement. Rome: FAO.

FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO.

FAOSTAT Database. 2016. http://www.fao.org/faostat/en/#search/Protein%20consump

Federal Government of Ethiopia, Ministry of Health, Ethiopian Public Health Institute (2022). Ethiopia: Food-Based Dietary Guidelines–2022. Addis Ababa, Ethiopia.

Feyisa, D. H., & Shene, L. (2021). Retrospective study of livestock vaccine coverage and trend in Lemu and Bilbilo Woreda, Arsi Zone, Ethiopia. *International Journal of Veterinary Science and Research*, **7**(2), 144-150.

Fikru, S., & Gebeyew, K. (2015). Sheep and goat production systems in Degehabur Zone, Eastern Ethiopia: Challenge and opportunities. *J Adv Dairy Res*, **3**(134), 2.

Gebremedhin, Berhanu, M. Woldehanna, Fiona E. Flintan, Barbara Wieland, and Elizabeth J. Poole. "Baseline Survey Report for the Regional Pastoral Livelihoods Resilience Project in Ethiopia." *ILRI Project Report* (2017).

Genfors, E., Magnusson, U., Moliso, M. M., Wieland, B., König, U., Hallenberg, G. S., & Båge, R. (2023). Preventive herd management practices and their effect on lamb mortality in Ethiopia. *Tropical Animal health and production*, **55**(1), 42.

Getachew, T. (2023). Unpublished. Map of Community based breeding program (CBBP) sites distribution monitored by ICARDA, Addis Ababa, Ethiopia.

Gijs van't Klooster. WVA Food Security virtual seminar on the 29th April 2021. Contribution of Animal Health Services for Food and Nutrition Security in Ethiopia.

Gizaw, S., Desta, H., Berhanu, D. and Wieland, B. 2019. A narrative review of animal health interventions for designing herd health interventions for Ethiopia. Joint ILRI and EVA Project Report. Addis Ababa, Ethiopia.

Gizaw, S., Woldehanna, M., Anteneh, H., Ayledo, G., Awol, F., Gebreyohannes, G., & Wieland, B. (2021). Animal health service delivery in crop-livestock and pastoral systems in Ethiopia. *Frontiers in Veterinary Science*, *8*, 601878.

Global Burden of Animal Diseases 2022. Ethiopia Case Study. https://gbadske.org/dashboards/ahle-casestudy/

Global Hunger Index, 2024

Godde, C.M., Boone, R.B., Ash, A.J., Waha, K., Sloat, L.L., Thornton, P.K. and Herrero, M., 2020. Global rangeland production systems and livelihoods at threat under climate change and variability. *Environmental Research Letters*, **15**(4), p.044021.

Grace, D., Domínguez Salas, P., Alonso, S., Lannerstad, M., Muunda, E. M., Ngwili, N. M., ... & Otobo, E. (2018). The influence of livestock-derived foods on nutrition during the first 1,000 days of life.

Habtegiorgis, K., Getachew, T., Haile, A., Kirmani, A., Jimma, A., & Gemiyo, D. (2022). Farmers' Perceptions to Community-Based Breeding Programs: A Case Study for Doyogena Sheep in Ethiopia. Asian Journal of Animal Sciences, **16**(2), 45–54. https://doi.org/10.3923/ajas.2022.45.54

Haile A., Wurzinger M., Mueller J., Mirkena T., Duguma G., Rekik M., Mwacharo J., Mwai O., Sölkner J. & Rischkowsky B. (2018). Guidelines for Setting Up community-based small ruminants breeding programs in Ethiopia. ICARDA—Tools and guidelines No.1. Beirut, Lebanon: ICARDA.

Haile, A., Getachew, T., Rekik, M. & Rischkowsky, B. (2019). Upscaling of community-based breeding programs in Ethiopia: process followed. ICARDA, Research Report, Addis Ababa, Ethiopia, ICARDA.

Haile, A., Wurzinger, M., Mueller, J., Mirkena, T., Duguma, G., Mwai, O., Sölkner, J. & Rischkowsky, B. (2011). Guidelines for Setting up Community-based Sheep Breeding Programs in Ethiopia. ICARDA - tools and guidelines No.1. Aleppo, Syria, ICARDA.

Haile, A., Getachew, T., Mirkena, T., Duguma, G., Gizaw, S., Wurzinger, M., & Rischkowsky, B. (2020). Community-based sheep breeding programs generated substantial genetic gains and socioeconomic benefits. *Animal*, **14**(7), 1362-1370.

Haile, A., Getachew, T., Rekik, M., Abebe, A., Abate, Z., Jimma, A., ... & Rischkowsky, B. (2023). How to succeed in implementing community-based breeding programs: Lessons from the field in Eastern and Southern Africa. *Frontiers in Genetics*, *14*, 1119024.

Hirpa, A. and Abebe, G. (2008) Economic Significance of Sheep and Goats. In: Yami, A. and Merkel, R.C., Eds., Sheep and Goat Production Handbook for Ethiopia, Branna Printing Enterprise, Addis Ababa, 2-24.

Holmøy, I. H., Kielland, C., Stubsjøen, S. M., Hektoen, L., & Waage, S. (2012). Housing conditions and management practices associated with neonatal lamb mortality in sheep flocks in Norway. *Preventive Veterinary Medicine*, *107*(3-4), 231-241.

Iannotti, L., Barron, M., & Roy, D. (2008). Animal source food consumption and nutrition among young children in Indonesia: Preliminary analysis for assessing the impact of HPAI on nutrition. *DFID Pro-poor HPAI Risk Reduction Strategies Project Research Report*.

Izzo, T. C. (2017). CFS Global Strategic Framework for Food Security and Nutrition 2017.

Jemberu, W.T., Lemma, M. and Knight-Jones, T. 2022. Ethiopia small ruminant flock health intervention calendars. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Jibat, T., Mourits, M.C. and Hogeveen, H., 2016. Incidence and economic impact of rabies in the cattle population of Ethiopia. *Preventive Veterinary Medicine*, **130**, pp.67-76.

Kassie, G. T., Asnake, W., Haile, A., Mengistu, T. G., Gizaw, S., & Rischkowsky, B. (2021). Welfare impact of community-based veterinary and breeding services on small ruminant keepers. *Frontiers in Veterinary Science*, *8*, 610610.

Kebede, G., Moje, N., Shafi, A., Kassahun, R., Merera, O., Leta, S., & Amenu, K. (2025). Investigation of veterinary service delivery and service providers on dairy cattle farms in central Ethiopia. *BMC Veterinary Research*, **21**(1), 125.

Kosgey, I. S., & Okeyo, A. M. (2007). Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant Research*, **70**(1), 76-88.

Livestock and Fisheries Sector Development Project (LFSDP), November 17, 2017.

Megersa, B., Biffa, D., Abunna, F., Regassa, A., Godfroid, J. and Skjerve, E., 2011. Seroprevalence of brucellosis and its contribution to abortion in cattle, camel, and goat kept under pastoral management in Borana, Ethiopia. *Tropical animal health and production*, **43**(3), pp.651-656.

Mekonnen, M., Assefa, A., Nane, T., Ayele, F., Arke, A., Elias, B. and Wieland, B. 2019. Small ruminant health intervention calendar in Ethiopia. Nairobi, Kenya: ILRI.

Mekonnen, M., Lemma, M., Haile, A., Rischkowsky, B.A. and Knight-Jones, T. 2021. *Integrated interventions for small ruminants transformation in Ethiopia (SmaRT Pack): Community-based small ruminants' herd health interventions.* Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Mirkena, T., Duguma, G., Willam, A., Wurzinger, M., Haile, A., Rischkowsky, B., Okeyo, A. M., Tibbo, M. & Solkner, J. (2012). Community-based alternative breeding plans for indigenous sheep breeds in four agro ecological zones of Ethiopia. *Journal of Animal Breeding and Genetics*, **129**(3), 244–253. 10.1111/j.1439- 0388.2011.00970.x

MoA(Ministry of Agriculture), I. L. R. I. (2013). Animal health strategy and vision for Ethiopia. Addis Ababa: Ministry of Agriculture and International Livestock Research Institute.

MoA, Animal Health Strategy Document (2013-2015)

MoA, Ethiopian National PPR CEP (2020). National Strategy for Progressive Control and Eradication of Peste Des Petits Ruminants (PPR) from Ethiopia. Aligned with global and Continental PPR control and eradication program Strategy.

MoA, Ethiopia's National Agriculture Investment Plan (NAIP) 2013-2022 EFY (2021-2030 GC).

MoA PPR CEP Report *(2015-2022). PPR eradication program implementation report.*

MoA PPR CEP Report *(2020-2023). PPR eradication program implementation report from 2020 to 2023.*

MoLF (Ministry of Livestock and Fisheries). Epidemiology Directorate. National Priority Animal Diseases of Socio-Economic & Trade Significance Including Those Transmissible To Humans. 2016 (Unpublished report)

Moliso, M. M., Molla, W., Arke, A., Nana, T., Ayele Zewudie, F., Tibebu, A., & Knight-Jones, T. (2024). The impact of the herd health interventions in small ruminants in low input production systems in Ethiopia. *Frontiers in Veterinary Science*, *11*, 1371571.

Molla, W., Moliso, M. M., Gizaw, S., Nane, T., Arke, A., Ayele, F., & Knight-Jones, T. (2023). Ovine gastrointestinal parasite burden and the impact of strategic anthelmintic treatment in community-based breeding sites in Ethiopia. Frontiers in Veterinary Science, 10, 1094672.

Mueller, J.P., Rischkowsky, B., Haile, A., Philipsson, J., Okeyo, A.M., Besbes, B., Valle Zárate, A., Tibbo, M., Mirkena, T., Duguma, G., Solkner, J. & Wurzinger, M. (2015). Community based livestock breeding programmes: Essentials and examples. Journal of Animal Breeding and Genetics **132**(2):155–168.

Mueller, J., Haile, A., Getachew, T., Santos, B., Rekik, M., Belay, B., Solomon, D., Yeheyis, L., & Rischkowsky, B. (2023). Going to scale—from community-based to population-wide genetic improvement and commercialized sheep meat supply in Ethiopia. Frontiers in Genetics, 14, 1114381.

Muema, J., Mutono, N., Kisaka, S., Ogoti, B., Oyugi, J., Bukania, Z., & Thumbi, S. M. (2023). The impact of livestock interventions on nutritional outcomes of children younger than 5 years old and women in Africa: a systematic review and meta-analysis. *Frontiers in Nutrition*, *10*, 1166495.

Muindi, P., Waithanji, E. and Bukachi, S., 2015. Gendered effects of contagious bovine pleuropneumonia (CBPP) occurrence and control in a pastoral community in Ijara sub county, northeastern Kenya. ILRI, Nairobi.

Mutavi, Faith, Noelle Aarts, Annemarie Van Paassen, Ignas Heitkönig, Barbara Wieland. 2018. Techne meets Metis: Knowledge and practices for tick control in Laikipia County, Kenya. NJAS - Wageningen *Journal of Life Sciences*, 86–87: 136-145.

Musau, E. M., Boukpessi, G., Mukiri, J., Getachew, T., Wamatu, J., Rischkowsky, B. A., & Notenbaert, A. M. O. (2021). Assessing the environmental impacts of SmaRT intervention packages in small ruminant production systems in Ethiopia.

Naicker, A., Venter C.S., MacIntyre, U.E. and Ellis S. 2015. Dietary quality and patterns and non-communicable disease risk of an Indian community in KwaZulu-Natal, South Africa. *Journal of Health, Population and Nutrition* **33**(1): 12.

Negassa, A., Rashid, S., Gebremedhin, B., & Kennedy, A. (2012). Livestock production and marketing. *Food and agriculture in Ethiopia: Progress and policy challenges*, 159-189.

Otte, J., Pica-Ciamarra, U., & Morzaria, S. (2019). A comparative overview of the livestock-environment interactions in Asia and Sub-Saharan Africa. *Frontiers in Veterinary Science*, **6**, 37.

Pieracci, E. G., Hall, A. J., Gharpure, R., Haile, A., Walelign, E., Deressa, A., & Belay, E. (2016). Prioritizing zoonotic diseases in Ethiopia using a one health approach. *One Health*, **2**, 131-135.

PSI (Policy Studies Institute) by Desalegn Begna (2023). The current Situation of the Livestock in Ethiopia: Summary of Draft Research Findings.

Ronto, R., Wu, J.H. and Singh, G.M. 2018. The global nutrition transition: Trends, disease burdens and policy interventions. *Public Health Nutrition* **21**(12): 2267–2270.

Sadler, K., Mitchard, E., Abdi, A., Shiferaw, Y., Bekele, G., & Catley, A. (2012). Milk matters: The impact of dry season livestock support on milk supply and child nutrition in Somali Region, Ethiopia. *F Exch-Emerg Nutr Netw ENN*, *44*, 8-11.

Sani, R. A., Gray, G. D., & Baker, R. L. (2004). *Worm control for small ruminants in tropical Asia*. Australian Centre for International Agricultural Research.

Shanbel, B. (2019). Evaluation of Artificial Insemination in Menz Sheep Following Estrus Synchronization with Progestogen and Prostaglandin-based Synchronization Protocols. MSc thesis, College of Agriculture, Hawassa University, Ethiopia.

Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Negussie, K., Aboset, G., & Mechal, H. (2015). Ethiopia livestock master plan: Roadmaps for growth and transformation.

Sisay, K., & Girma, M. (2023). Food and nutrition security status in Southwest region of Ethiopia: evidence from Kaffa zone. *Journal of Agriculture and Food Research*, *14*, 100717.

Smith, J., Tarawali, S., Grace, D., & Sones, K. (2013). Feeding the world in 2050: trade-offs, synergies and tough choices for the livestock sector. *Tropical Grasslands-Forrajes Tropicales*, **1**(2), 125-136.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of business research*, *104*, 333-339.

Tadele, H. (2024). HEARD Project Final Evaluation Validation Workshop: Draft Report. https://www.ilri.org/knowledge/publications/health-ethiopian-animals-rural-development-heard-project-final-evaluation

Tambi, E.N. W . Maina, A.W. Mukhebi & T.F. Randolph. 1999. Economic impact assessment of rinderpest control in Africa. *Rev. Sci. tech. Off. Int. Epiz,* **18** (2):458-477.

Tebekaw, Y., Teller, C.and Colón-Ramos, U. 2014. The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health* **14**(1): 1126.

Temesgen, W., Lemma, M., & Knight-Jones, T. J. (2022). Ethiopia small ruminant flock health intervention calendars.

Thornton, P. K., van de Steeg, J., Notenbaert, A., & Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural systems*, **101**(3), 113-127.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **365**(1554), 2853-2867.

Tibbo, M., Mukasa-Mugerwa, E., Woldemeskel, M., & Rege, J. E. O. (2003). Risk factors for mortality associated with respiratory disease among Menz and Horro sheep in Ethiopia. *The veterinary journal*, *165*(3), 276-287.

Tora, E., Shrube, M., Kaba, T., & Seyoum, W. (2021). Prevalence of Calf Mortality in Ethiopia: A Systematic Review and Meta-Analysis. *Veterinary Medicine International*, **2021**(1), 6677986.

Wild, C.P., Miller, J.D. and Groopman, J.D., eds. 2015. *Mycotoxin control in low- and middle-income countries.* IARC Working Group Reports, No. 9. Lyon, France, International Agency for Research on Cancer. 66 pp. (available at http:// publications.iarc.fr/Book-And-Report-Series/Iarc-Working-Group-Reports/ Mycotoxin-Control-In-Low--And-Middle-income-Countries-2015).

WFP (2008) Food Consumption Analysis Calculation and Use of the Food Consumption Score in Food Security Analysis. Version I

WHO (World Health Organization). (2023). The State of Food Security and Nutrition in the World 2023: Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum (**Vol. 2023**). Food & Agriculture Org.

Zhang Z, Goldsmith PD, Winter-Nelson A: The Importance of Animal Source Foods for Nutrient Sufficiency in the Developing World: The Zambia Scenario. *Food Nutr Bull.* 2016; **37**(3): 303–316. PubMed Abstract | Publisher Full Text.

7. ANNEXIS

Annex 1Animal health intervention data format for wereda veterinary office

Name of district___________________Lattituid____________________Longitude___________________ Name of recorder and signature ________________________________Date__________________											
No	Year	Livestock population	Sheep Population	Common small ruminant diseases	Conducted animal health interventions/vet services provided	No of sheep get vet services	No of sheep sick	No of sheep survived	No of death	Challenges encountered	Remarks

Annex 2 Data sheet for Animal health interventions format for MoA and Projects

No	Year	Conducted animal health interventions/vet services provided			Region/zone/Wereda	Remarks
		Type of interventions/Activities	Plan	Achieved		

Annex 3 Questioner for animal health intervention for both CBBP participants and non-participants survey

QUESTIONNAIRE NO______________________________

Enumerator name ___________________________________ Date ____________________

Respondent's Name _________________________________ Sex ___________________

Woreda __________________________ Kebele ____________ Village _______________

Name of CBBP coop. _______________ Establishment year of the CBBP _________________

Agro-ecology: ________latitude; ____________ longitude; __________altitude

1. General household characteristics of the respondent

No	Question	Answers
1.1	Age of the respondent	________ year
1.2	Sex of the respondent	1)Male ; 2) Female
1.3	Education status	1. Illiterate___, 2. Grade 1-6____3 Grade 6-12___, 4. Higher education __
1.4	Marital status	1) Single; 2) Married; 3) Divorced; 4) Windowed
1.5	Family size	Male ____; Female ____; Total _____
1.6	Source of income	1) Crop production; 2) Livestock production; 3) Daily laborer; 4)Petty trade; 5) 1&2; 6) Any other choice----------

2. Food and non-food consumption expenditures (Food consumption expenditure per month)

No.	Food Items	Own production	Purchased (ETB per year)	Food aid	Transfer
1	Teff (kg)				
2	Wheat (kg)				
3	Maize (kg)				
4	Barely (kg)				
5	Rice (kg)				
6	Potato (kg)				
7	Onion (kg)				
8	Tomato (kg)				
9	Beans and peas (kg)				
10	Lentil (kg)				
11	Vegetables (kg)				
12	Dry pepper (kg)				
13	Edible oil (liter)				
14	Milk (liter)				
15	Butter (kg)				
16	Meat (kg)				
17	Sugar (kg)				

3. Animal health interventions

6.1. Do you have a separate housing/ stable for your sheep? 1) Yes; 2) No

6.2. If yes for question 6.1, how frequently do you clean the stable? 1) Every day; 2) every other day; 3) once a week; 4) above a week; 5) other please specify

6.3. Who identifies sick animals from the flock? 1) Family members 2) animal health professionals 3) Both

6.4. Who looks at sheep flock regularly (multiple choose)? 1) Husband 2) Wife 3) Jointly 4) children 5) all family

6.5. What do you do if your sheep becomes sick/diseased (multiple choose)? 1) Left as it is 2) Forced to sell 3) Took to clinics 4) Treat by myself 5) Slaughter for home consumption 6) traditional medicine

6.6. Do you practice traditional treatments of sick animals? 1) Yes; 2) No (if No, skip to next question)

6.7. If yes for question 6.6, what type of treatment do you practice? Please list ____________

6.8. Do you vaccinate your animals for the last 12 months? 1) Yes 2) No (if No, skip to next question)

6.9. If yes for question 6.8, number of shoats vaccinated for 1) prophylaxis/prevention __, 2) control of outbreaks __

6.10. If yes for question 6.8, does the vaccination program contribute to lower disease incidences/ mortality? 1) Yes; 2) No

6.11. Do you practice ecto-parasite control/deworming of your sheep? 1) Yes; 2) No (if No, skip to next question)

6.12. If yes for question 6.11, what is your reason for deworming? (multiple choose) 1) to improve their performance; 2) regular deworming for prevention; 3) to treat diagnosed parasite; 4) Other specify (narrative option) ______

6.13. Is there any cultural norm that affects men and women's access to animal health programs? 1) Yes 2) No

6.14. If yes for question 6.13, please describe them? ___________________________________

6.15. Do you have access to veterinary services in your locality? 1) Yes; 2) No (if No, skip to next question)

6.16. If yes for question 6.15, who delivers these services? (Multiple choice) 1) Government vet services/ clinics; 2) Non government; 3) Research center; 4) Private service deliveries; 5) Own intervention

6.17. If yes selected for service delivering agent for question 6.15, please respond for the following questions

Type of animal health services in relation to your sheep	1=Yes 2= No	Frequency of the service 1= every 1 months; 2= every 3 month; 3= every 6 months; 4= every one year; 5= when needed; 6= irregularly; 7= other specify ---	Satisfaction level to the service				
			Very dissatisfied	Dissatisfied	Neutral	Satisfied	Very satisfied
Deworming services							
Vaccination services for Pox							
Vaccination services for PPR							
Vaccination services for Pasturolosis							

Vaccination services for Anthrax							
Treatment of diseased flocks against infectious diseases							
Training/advice on animal health management							
External parasite control							
Overall services							

6.18. How do you rate accessibility of animal health services in your area? 1) Not accessible 2) neutral 3) accessible

6.19. How do you rate affordability of AHI? 1) Very Affordable 2) Affordable 3) Neutral 4) Expensive 5) Very Expensive

6.20. Do veterinary services in general contribute to improved animal health/less diseases/ lower mortality/ higher weight of animals? 1) Yes, 2) No (if No, skip to next question).

6.21. If yes, please specify ___________________________________

6.22. How do you evaluate AHI after the start of CBBP/projects? 1) Very good; 2) good; 3) better, 4) no change

6.23. How is sheep disease occurrence after CBBP/ project? 1) Decreased; 2) Increased; 3) no change

6.24. How do you handle animals during parturition? 1) Bare hand 2) any materials like plastic 3) Protective gloves

6.25. Do you know about zoonotic disease (disease transferred from animal to human due to consumption of raw meat and milk, contact and other reasons)? 1) Yes 2) No (if No, skip to next question (6.28))

6.26. If yes for question 6.25, have you/family member encountered the problem? 1) Yes; 2) No.

6.27. If yes for question 6.25, what effects were observed on you or your family members? ________________

6.28. Have you encountered any sheep health problems/outbreaks that affects your flock of sheep within 12 months? 1) Yes; 2) No (if No, skip to next section)

6.29. If yes for question 6.28, please list name/type of diseases/problems ________________

6.30. If Yes, for question 6.28 and listed diseases under question 6.29

Name of Diseases	Population at risk	Number of shoats sick	Number of shoats dead	Number shoats Recovered	Number of shoats treated from sick	Number of shoats survived by treatment
A)PPR						
B)pox						
C) Pasturolosis						
E)Anthrax						

6.31. Do you perceive that use of animal health services allows you to improve your household food and nutrition security? 1) Yes 2) No (if No, skip to next question)

6.32. If yes for question 5.16, in what way? ______________________________

Annex 4 Checklists for Focus Groups Discussion

Date of Discussion____________ Place of discussion: ____________Number of target people participating on discussion: _____________

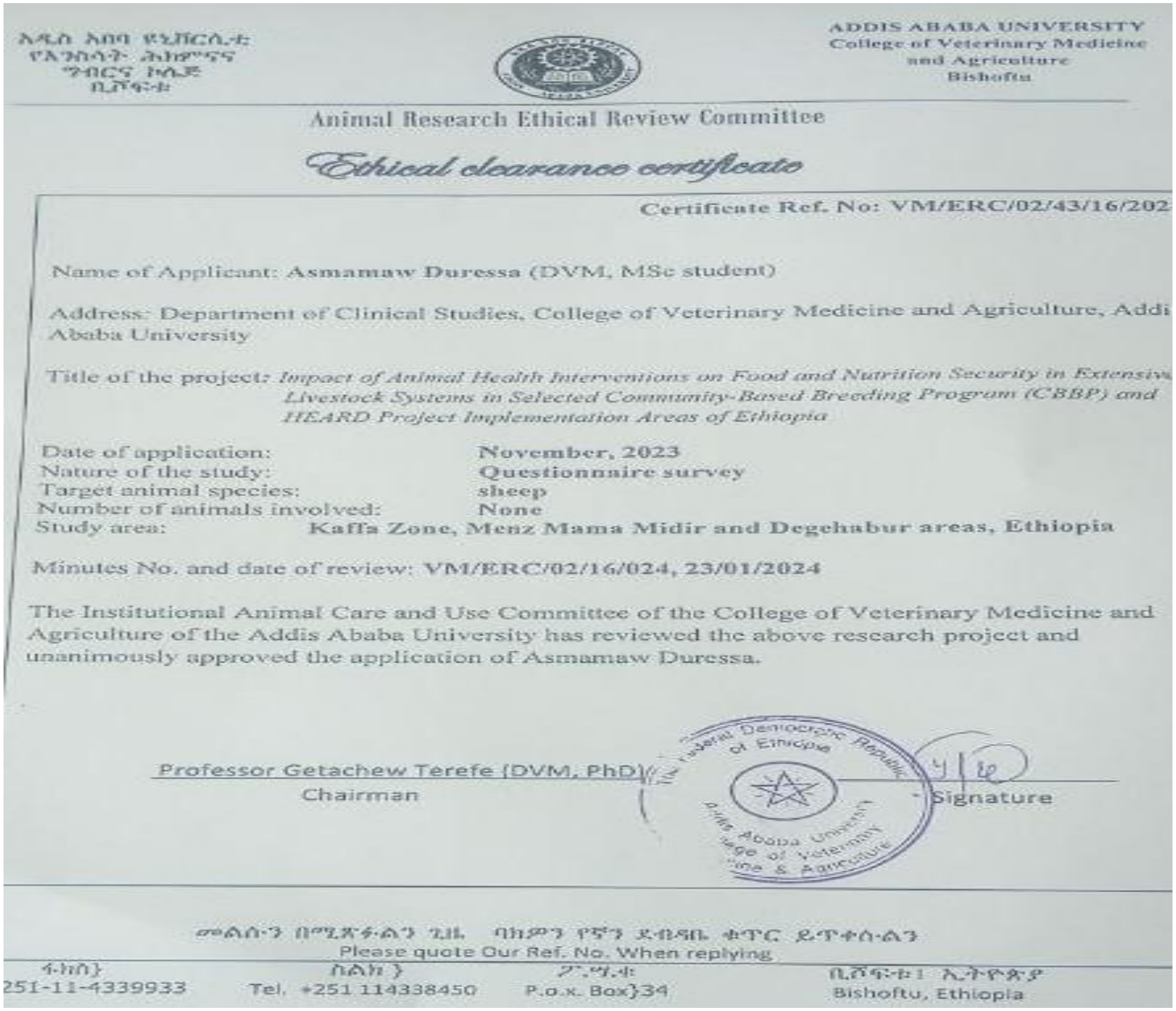
1. Discussions on livestock diseases and AH intervention
2. General discussion on impact of AHI on Food and Nutritional security
3. Support of government and others on animal health services delivery
4. Awareness creation work on AHI
5. Quality of services and capacity of professionals
6. Illegal animal health delivery
7. Disease reporting responses. Government or services provider receive disease outbreak report from the community and early responses
8. Coordination of stakeholders on AHI

Annex 5 Household Food Insecurity Access Scale (HFIAS) measurement tool (http://www.fantaproject.org.)

Annex 6 Food Consumption Score (FCS) indicators (https://doi.org/10.3390/economies7040103.)

Annex 7 Minimum dietary diversity for Women (MDD-W) aged 15-49 Years (https://inddex.nutrition.tufts.edu/data4diets.)

Annex 8 Ethical Clearance Certificate



አዲስ አበባ ዩኒቨርሲቲ
የእንስሳት ሕክምናና
ግብርና ኮሌጅ
ቢሾፍቱ

ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu

Animal Research Ethical Review Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/02/43/16/202

Name of Applicant: **Asmamaw Duressa (DVM, MSc student)**

Address: Department of Clinical Studies, College of Veterinary Medicine and Agriculture, Addi Ababa University

Title of the project: *Impact of Animal Health Interventions on Food and Nutrition Security in Extensive Livestock Systems in Selected Community-Based Breeding Program (CBBP) and HEARD Project Implementation Areas of Ethiopia*

Date of application:	**November, 2023**
Nature of the study:	**Questionnaire survey**
Target animal species:	**sheep**
Number of animals involved:	**None**
Study area:	**Kaffa Zone, Menz Mama Midir and Degehabur areas, Ethiopia**

Minutes No. and date of review: **VM/ERC/02/16/024, 23/01/2024**

The Institutional Animal Care and Use Committee of the College of Veterinary Medicine and Agriculture of the Addis Ababa University has reviewed the above research project and unanimously approved the application of Asmamaw Duressa.

Professor Getachew Terefe (DVM, PhD)
Chairman

Signature

መልሱን በሚጽፉልን ጊዜ ባክዎን የኛን ደብዳቤ ቁጥር ይጥቀሱልን
Please quote Our Ref. No. When replying

ፋክስ 251-11-4339933 | ስልክ Tel. +251 114338450 | ፖ.ሣ.ቁ P.o.x. Box}34 | ቢሾፍቱ ኢትዮጵያ Bishoftu, Ethiopia

Annex 9 Consent Letter to CBBP/HEARD project participant and Non-participant Villages

Title: Impact of Animal Health Interventions on Food and Nutrition Security of Extensive Livestock Systems in Selected Sheep Community-Based Breeding Program Implemented Areas of Ethiopia.

Date: _______________

To: ___________ CBBP cooperative/HEARD village

Issue: **Invitation to enroll your cooperative in a research study**

Dear Cooperative Leader/Village Representative,

I want to invite your cooperative/village to be included in a study entitles as "Impact of Animal Health Interventions on Food and Nutrition Security of Extensive Livestock Systems in Sheep Community-Based breeding Program Implemented Areas of Ethiopia". My name is **"Asmamaw Duressa Reje"** and I'm the principal investigator of the study. The primary objective of the study is to assess the impact of animal health intervention on food and nutritional security in Sheep community-based breeding program sites. If you agree that your village will take part in this study, ______ households or farmers will be interviewed from the village, about key performance indicators of animal health interventions, livestock production and productivity as well as about major determinants of food and nutritional security. All the information obtained during this study will be kept strictly confidential and the name of each participant farmer will not be given to anyone outside the researcher and also not used in the presentation and publication of results. The participation of every household in this study is strictly voluntary and a participant may refuse to participate and can discontinue their participation at any time without obligatory preconditions.

With best regards

Asmamaw Duressa (Researcher)

Cooperative Leader/Village Representative

Name _________________ Signature _________________

Annex 10 Consent Form

My name is _______________________________ I am working as a data collector in the survey conducted by Australian Centre for International Agricultural Research (ACIAR) project. These questionnaires are prepared to evaluate **the impacts of CBBP, Animal health and Marketing on Food and Nutrition security, Women empowerment, Greenhouse gas emission, and Adaptive capacity** at the ongoing CBBPs done on Bonga and Menz sheep production; and on HEARD animal health interventions on pastoral areas of the Somali regions of Ethiopia.

This study is designed to generate information for PhD/MSc graduation. To attain this purpose, your honest and genuine participation by responding to the questions prepared is very important. If you have been interviewed, you will not be interviewed again and will send you off with thanks. If not, I request you to respond to my questions genuinely.

Confidentiality and consent

We would like to inform you that some personal issues, your answers and ideas are completely confidential and secured. If you are not comfortable, you can refuse to answer a single question and even to the extent of stopping the interview at any time. We appreciate your kindness to be part of the study. The interview will take about -----to----- minutes.

Are you willing to participate? If the answer,

Yes ☐ Continue

No ☐ Stop

Thank you very much!

Annex 11 Animal health interventions in Degehabur district

Table 5. Animal health interventions (From Districts/cooperatives).

No	Region	Zone	District/kebele	Year	Total livestock population by spp.	Breed/spp of animals	Common small ruminant diseases	Type of animal health interventions	Unit of measurement	Plan	Achieved	Implemented by*	Intervention strategies	Prevalence/status of health problems: Before interventions	Prevalence/status of health problems: After interventions	HHs Benefited: M	HHs Benefited: F	Remarks/ challenges
1	Somali 05	Jarar	d/bour	2016	725,000	local	Shoats	Deworming	Number of small ruminants	150,000	150,000	district AHP						lack of drug
2								Ectoparasite	Number of small ruminants	154,520	154,520	AHP						"
3								Treatment	Number of small ruminants	235540	135540	woreda						-
4								vaccination	Number of small ruminants	190,000	190,000	districts						
5								Training	Number of experts	10	5	DBS						

Annex 12 Number of clinics, manpower and vaccine given by year in Degehabur district

Table 6. Animal health facilities and intervention methods data collection format.

No	Name of district/kebele	Number of villages	Public Clinics	Public Health posts	Private Clinics	Private Health posts	Private Drug shops	Veterinarians	Animal health assistants	CAHWS	Remark
	d/bour	16	1	15	—	—	2	31	6	15	

Table 7. Type of vaccination intervention and prevalence

Year	Type of disease	Unit of measurement	Plan	Achievement	Prevalence Before (%)	Prevalence After (%)	Remark
2019	PPR	Number of small ruminants	300,000	276210	83%	92%	
	CCPP						
	Ovine pasteurellosis						
	Sheep and goat pox						
	Anthrax						
	Other						
2020	PPR		60,000	50,000	—	58.33%	
	CCPP		100,000	50,000	—	50%	
	Ovine pasteurellosis		40,000	30,000	—	75%	
	Sheep and goat pox		—	—	—		
	Anthrax						
	Other		—	—	—		
2021	PPR		30,000	30,000	~~100%~~	100%	
	CCPP		30,000	27000		90%	
	Ovine pasteurellosis				—		
	Sheep and goat pox		20,000	20,000	—	100%	
	Anthrax		—	—	—	—	
	Other						
2022	PPR		—	—	—	—	
	CCPP		60,000	60,000	—	100%	
	Ovine pasteurellosis		30,000	30,000	—	100%	
	Sheep and goat pox		70,000	70,000		100%	
	Anthrax		20,000	15000	—	75%	
	Other		—	—	—	—	
2023	PPR		—	—	—	—	
	CCPP		70,000	70,000	—	100%	
	Ovine pasteurellosis		50,000	40,000		80%	
	Sheep and goat pox		—	—	—	—	
	Anthrax		25,000	15000	—	60%	

Annex 13 Pictures during data collection