Public health and economic importance of livestock diseases with the emphasis on zoonoses including brucellosis, Q-fever and Rift Valley Fever in Somali region, Ethiopia

INAUGURALDISSERTATION
zur
Erlangung der Würde eines Doktors der Philosophie

vorgelegt der
Philosophisch-Naturwissenschaftlichen Fakultät
der Universität Basel

von
Mohammed Ibrahim Abdikadir
aus Äthiopien

Basel, 2021

Genehmigt von der Philosophisch-Naturwissenschaftlichen Fakultät auf Antrag von
Prof. Dr. Jakob Zinsstag und Prof. Dr. Joerg Jores

Basel, den 18. Februar 2020

Prof. Dr. Martin Spiess,
Dekan

Dedication:

I dedicate this PhD thesis to my beloved mom, Quresh Omar who always is with me in her love, prayer and encouragement

Table of content

Contents

Acknowledgements

Praise be to Almighty Allah for making it possible to reach this stage. I sincerely, thank my family. Without their support, it would not have been possible to pursue my PhD study.
I thank my parents, Ibrahim Abdikadir, Quresh Omar, my brothers Abdullahi Ibrahim, Hassan Ibrahim, Abdisalam Ibrahim, Abdirahman Ibrahim, Omar Ibrahim, Ali Ibrahim and my sister Amina Ibrahim. I also thank my uncle, Yusuf Sh. Abdikadir who pushed me to continue my PhD after I finished my masters diploma.

I was lucky to meet very kind, humble and supportive people at the beginning of my long journey to Basel, Switzerland. These people interviewed me in my home country and trusted me to proceed my studies. These humble people were Jakob Zinsstag and Rea Tschopp. Without you, I would not be here, thank you.

I started my journey to Europe for the first time. I was feeling lonely and did not know what challenges are ahead of me. However, everything changed soon, when I joined the Swiss Tropical and Public Health Institute (Swiss TPH) family, where you never feel homesickness and since then became my second home for those years I spent in Basel. I am deeply thankful to Christine Mensch, for her kind, support and understanding. She makes you feel good even if her day is not good, what a human!

I am indebted to my supervisors, Jakob Zinsstag, Rea Tschopp and Esther Schelling who supported and guided me during the past few years. I really appreciated your support and knowledge you invested on me. You have not taught me science only but also to take responsibilities and to be an independent thinker. I would like to thank Rea Tschopp for the facilitation and introduction of the people in AHRI that allowed me to have access to all the laboratory facilities. She also granted me relevant trainings within AHRI. I would like to thank Esther Schelling who was not only my supervisor but also my mentor and helper. She was always ready to help me in ordering lab kits, data collection, data management, data analysis and writing results. She came twice during my fieldwork to make sure, how my data collection was going on as well as to establish serology lab in Jigjiga University to use for my study. I really appreciate her extraordinary knowledge and humble.

It was a privilege for me to work with Jakob Zinsstag, one of the leading experts in the field of One Health and Transdisciplinary. He taught me how important is to look at health research in a holistic way rather than focusing only on my specialty and work together with diverse disciplines.

I am grateful to Jan Hattendorf (a well-experienced statistician at Swiss TPH) whose knowledge is remarkable and has the ability to make complex statistical analysis simple for understanding and of course, his nice jokes and smiling!

My thanks also goes to Lisa Crump, in the Human and Animal Health Unit (HAHU) who helped me in editing my articles and who was always ready to help me whenever I was struggling with my writing.

Many people played a role in my professional career that deserve my acknowledgments. First, I would like to thank Dr. Abdinasir Ahmed (former Jigjiga University president and current Addis Ababa University staff). Dr. Mohammed Sanni (London School of Hygiene and Tropical Medicine and NDORMS, CSM, University of Oxford). Dr. Tesfaye Sisay (Director of Institute of Biotechnology, Addis Ababa University). Dr. Simenew Keskes (Ministry of Science and Technology, Academic and Research Director). Mr. Seid Mohammed (former Jigjiga University, Academic and Research Vice President and the current JOHI coordinator). Mr. Ismail Mohammed (Directorate Director, Community services, Jigjiga University). Dr. Abdiwasa A. Bade (State Minister, Ministry of Science & Higher Education). Dr. Berhanu Admassu (Tufts University, Regional office at Addis Ababa). Dr. Diriba Geleti (Deputy Director General, Ethiopian Institute of Agricultural Research). Dr. Getachew Gebru (Co-founder and Deputy Director of MARIL). Dr. Nesre Redi, Consultant at World Health Organization in Egypt) and Prof. Guéladio Cissé (Ecosystem Health Science Unit Head, Swiss TPH).

It was a great experience during my lab work at Armauer Hansen Research Institute (AHRI), Addis Ababa. All AHRI staff were supportive, I particularly thank to Emawayish Andargie, Azeb Tarekegn, Ashenafi Alemu, Marechign Yimer, Melaku Tilahun, Ashenafi G/giorgis, Robel Gesese, Metasebiya Tegegn, Biruk Yeshitela, Mahlet Usman, Dr. Adane Mihret and the transportation department. I also thank to Regina Oakley (from Swiss TPH) for her technical support in my molecular diagnostic tests at AHRI.

I would like to thank Gode zonal deputy administrator, Saleban. Adadle Woreda administration particularly Abdiwahab and Mohammed (Human and Livestock office heads), Kebele administrators, and all Adadle Woreda communities. I thank to the United Nations World Food

Program field office compound for allowing us putting our deep freezer due to their 24 hours electrical power service.

Although my fieldwork was a challenging, it was full of entertainment, which made it interesting. I will never forget the joys of all the trips on those months together with Seid Mohammed, Najib Sh. Abdi, Shazali Mohammed, Fikre Zerfu, Abdirazak Adem, Kadra Ali, and Mohammed Hussein.

I am grateful to the Swiss Government Excellence Scholarship (ESKAS), a competitive scholarship that helped me to understand the Swiss culture and easily integrate in the local community. My special thanks go to Ms. Andrea Delpho (ESKAS representative at University of Basel). I also thank all EPH, HAHU, JOHI team and my colleagues at Eu-83 workplace for your support and be part of my achievements.

Last but not least, I would like to thank my beloved wife Rahma Abdurahman, my daughter Nashwa and my sons Ahmed and Ibrahim who let me go far and compromised the difficulties in my absence.

Summary

Background

Horn of Africa (HoA) is the home of the largest pastoralist communities in the world. The pastoralist communities live in arid and semi-arid lands of the region characterized by harsh climatic conditions. The reality of climate change is becoming more visible in recent years. The pastoralist communities are the most vulnerable victims to climatic hazards more than any society on earth. Moreover, diseases, malnutrition, conflicts and poor health services exacerbated the threats to the livelihood of these communities.

Aims

The aim of this PhD thesis is to establish public health and economic importance of livestock diseases with the emphasis on zoonoses including brucellosis, Q-fever and rift valley fever in humans and livestock in Somali region of Ethiopia. Specifically we aimed:

- To estimate seroprevalence of brucellosis, Q-fever and rift valley fever in humans and livestock
- To identify the risk factors for transmission of zoonotic diseases between humans and livestock
- To assess community awareness on zoonotic diseases
- To investigate the risky practices among pastoral and agro-pastoral communities
- To evaluate livestock trade in Somali region
- To identify livestock diseases including zoonoses that can hinder livestock trade
- To map livestock trade routes and identify the highest concentrated livestock markets

Methods

This PhD thesis is composed of three major components. First, we estimated the seroprevalence of brucellosis, Q-fever and rift valley fever in humans and livestock in Adadle woreda of Somali region. Secondly, we assessed community awareness about zoonotic diseases, their risky practices that favor zoonotic diseases transmission and the most reported livestock diseases in the area. Finally, we studied livestock trade and its associated livestock diseases.

A multi-stage cross sectional cluster study to estimate the seroprevalence of brucellosis, Q-fever and RVF in humans and livestock. Logistic regression was used to estimate the apparent seroprevalence of humans and livestock. We also used uni and multivariable analysis to identify the predictors for seropositivity. Generalized Estimating Equation (GEE) model was

used to account the potential correlation within herds. Finally, Pearson's correlation coefficient was calculated to check the correlation between humans and livestock prevalence.

Both quantitative and qualitative methods were used to assess community awareness on zoonoses and livestock trade in the study area.

Principal findings

The individual seropositivity of Q-fever by species was 9.6% (95% CI 5.9-15.1) in cattle, 55.7% (95% CI 46.0-65.0) in camels, 48.8% (95% CI 42.5-55.0) in goats, 27.0%(95% CI 20.4-34.0) in humans and 28.9% (95% CI 25.0-33.2) in sheep. In humans, seropositivity of Q-fever in males was 28.9% vs 24.2% in females (OR= 1.3; 95% CI 0.6-2.5). Camel seropositivity of Q-fever was significantly associated with age (OR= 8.1; 95% CI 2.8-23.7). The individual apparent seroprevalence of RVF was 13.2% (95% CI 8.7-18.8) in humans, 17.9 % (95% CI 11.0-27.8) in cattle, 42.6% (95% CI 34.8-50.7) in camels, 6.3% (95% CI 3.3-11.6) in goats and 7.4% (95% CI 4.7-11.5) in sheep. Camels had the highest seropositivity of both Q-fever and RVF. The camel seropositivity was 55.7% (95% CI 46.0-65.0) and 42.6% (95% CI 34.8-50.7) for Q-fever and RVF respectively. Generally, there was only a weak correlation between human and livestock seropositivity for both Q-fever and RVF. Only cattle and camels were found seropositive for brucellosis by iELISA. The individual seroprevalence of brucellosis was 2.8(0.9-6.4) in humans, 1.5% (95% CI 0.2-5.2) in cattle and 0.6% (95% CI 0.0-3.2) in camels.

Awareness level on zoonoses in agropastoralists was relatively higher than in pastoralists. Only family size was statistically significant ($p<0.05$) in association with awareness level in multivariable analysis. About three-quarters of respondents did not know about "zoonoses". The diseases/syndromes reported as zoonoses were anthrax, cough, hemorrhagic septicemia, foot and mouth disease and tuberculosis. Raw milk consumption, animal birth assistance without protective material, and throwing aborted fetus in the field were among risky practices reported. Poor veterinary services, lack of livestock market, insufficient animal health professions and animal diseases were reported as problems in the area. Some perceptions were recorded which states that knowing about zoonoses as bad idea since people will get afraid from their livestock if they knew about zoonoses.

Small ruminant species dominated the livestock trade. Most of the traders sold their animals to near local markets. Gode, Jigjiga and Harteshek were the dominant livestock markets to sell respectively. High input trade costs were reported like transportation, broker, tax, treatment, feed, labor and personnel costs. The main factors hindering livestock trade were

drought, disease, security, conflicts, hard currency exchange rate fluctuation and poor market. The reported trade problems exacerbate if drought and/ diseases occur. Trypanosomiasis, anthrax, sheep and goat pox, helminthiasis, foot and mouth disease (FMD), tick infestation, contagious caprine pleuropneumonia, diarrhea, nasal discharge and Nairobi sheep disease were the most common outbreaks reported to hinder livestock trade.

Livestock demand increased during Arafa, Mowlid, Eid-Al Adha religious ceremonies, and during the rainy season. Gode was the main livestock market in the area and received high numbers of animals from various parts of the surrounding zones as well as neighboring Somalia. The major livestock trade destinations reported were Somaliland, Puntland, Saudi Arabia, United Arab Emirates, Oman, Qatar, Egypt and Yemen (no market currently due to war). The customs and revenue authority reported that livestock export increased during strong control of contraband activities and vice-versa. Informal livestock trade share was high in the current livestock trade. The major livestock diseases targeted by the quarantine office were; FMD, brucellosis, sheep and goat pox, camel pox, ovine and bovine pasteurollosis, and Peste des petits ruminants (PPR). Export animals were vaccinated according to the type of vaccines requested by the importing countries.

Conclusions

This study showed the exposure of RVF in humans and livestock for the first time in the country. The low awareness level on zoonoses, risky practices and misconception about zoonoses might increase the risk of zoonotic infections transmission between humans and animals in the area. Thus, community awareness and education about zoonoses is essential. Further research on socio-culture perspective on zoonoses awareness and risky practices is required. Collaboration between public and animal health sectors for further investigation on these zoonoses using the One Health concept is indispensable.

Despite the existing livestock trade challenges, livestock trade supported many poor pastoralist communities. The dominant livestock markets could be used as critical points for zoonotic disease control interventions in the future. Knowledge on livestock trade and its associated diseases, routes and systems in place can contribute to designing appropriate policies and strategies that could improve the economy, health and well-being of pastoralist communities in Somali region.

Zusammenfassung

Hintergrund

Das Horn von Afrika (HoA) ist die Heimat der größten Pastoralistengemeinschaften der Welt. Die Pastoralistengemeinschaften leben in den trockenen und halbtrockenen Gebieten der Region, die durch harte klimatische Bedingungen gekennzeichnet sind. Die Realität des Klimawandels wird in den letzten Jahren immer sichtbarer. Die Pastoralistengemeinschaften sind die verwundbarsten Opfer der klimatischen Gefahren, mehr als jede andere Gesellschaft auf der Erde. Darüber hinaus haben Krankheiten, Unterernährung, Konflikte und schlechte Gesundheitsversorgung die Bedrohung der Lebensgrundlage dieser Gemeinschaften noch verschärft.

Ziele

Das Ziel dieser Dissertation ist es, die öffentliche Gesundheit und die wirtschaftliche Bedeutung von Viehkrankheiten mit dem Schwerpunkt auf Zoonosen einschließlich Brucellose, Q-Fieber und Rift Valley Fieber bei Mensch und Vieh in der Region Somalia Äthiopiens zu ermitteln. Konkrete Ziele dieser Arbeit:

- Abschätzung der Seroprävalenz von Brucellose, Q-Fieber und Rifttalfieber bei Mensch und Vieh;
- die Risikofaktoren für die Übertragung zoonotischer Krankheiten zwischen Mensch und Vieh zu identifizieren;
- Bewertung des Bewusstseins der Gemeinschaft über Zoonosen;
- Identifizierung der risikoreichen Praktiken unter den pastoralen und agrarpastoralen Gemeinschaften;
- Bewertung des Viehhandels in der Region Somali;
- Identifizierung von Viehkrankheiten, einschließlich Zoonosen, die den Viehhandel behindern können;
- Kartierung der Viehhandelsrouten und Identifizierung der am stärksten konzentrierten Viehmärkte.

Methoden

Diese Dissertation besteht aus drei Hauptkomponenten. Erstens schätzten wir die Seroprävalenz von Brucellose, Q-Fieber und Rifttalfieber bei Mensch und Vieh in Adadle Woreda der Region Somalia. Zweitens bewerteten wir das Bewusstsein der Gemeinschaft für zoonotische Krankheiten, ihre riskanten Praktiken, die die Übertragung von Zoonosen

begünstigen, und die am häufigsten gemeldeten Viehkrankheiten in der Region. Schließlich untersuchten wir den Viehhandel und die damit verbundenen Viehkrankheiten.
Eine mehrstufige Querschnitts-Clusterstudie zur Abschätzung der Seroprävalenz von Brucellose, Q-Fieber und RVF bei Mensch und Vieh. Zur Schätzung der scheinbaren Seroprävalenz von Mensch und Vieh wurde eine logistische Regression verwendet. Wir verwendeten auch uni- und multivariable Analysen, um die Prädiktoren für die Seropositivität zu identifizieren. Das Modell der verallgemeinerten Schätzungsgleichung (GEE) wurde verwendet, um die potenzielle Korrelation innerhalb der Herden zu berücksichtigen. Schließlich wurde der Korrelationskoeffizient nach Pearson berechnet, um die Korrelation zwischen Mensch- und Viehprävalenz zu überprüfen.
Sowohl quantitative als auch qualitative Methoden wurden verwendet, um das Bewusstsein der Gemeinschaft für Zoonosen und den Viehhandel im Untersuchungsgebiet zu bewerten.

Wesentliche Ergebnisse
Die individuelle Seropositivität des Q-Fiebers nach Arten betrug 9,6% (95% CI 5,9-15,1) bei Rindern, 55,7% (95% CI 46,0-65,0) bei Kamelen, 48,8% (95% CI 42,5-55,0) bei Ziegen, 27,0% (95% CI 20,4-34,0) bei Menschen und 28,9% (95% CI 25,0-33,2) bei Schafen. Beim Menschen betrug die Seropositivität des Q-Fiebers bei Männern 28,9% gegenüber 24,2% bei Frauen (OR= 1,3; 95% CI 0,6-2,5). Die Kamel-Seropositivität des Q-Fiebers war signifikant mit dem Alter assoziiert (OR= 8,1; 95% CI 2,8-23,7). Die individuelle scheinbare Seroprävalenz von RVF betrug 13,2% (95% CI 8,7-18,8) beim Menschen, 17,9% (95% CI 11,0-27,8) beim Rind, 42,6% (95% CI 34,8-50,7) beim Kamel, 6,3% (95% CI 3,3-11,6) bei der Ziege und 7,4% (95% CI 4,7-11,5) beim Schaf. Kamele wiesen die höchste Seropositivität sowohl für Q-Fieber als auch für RVF auf. Die Kamel-Seropositivität betrug 55,7% (95% CI 46,0-65,0) und 42,6% (95% CI 34,8-50,7) für Q-Fieber und RVF. Im Allgemeinen gab es nur eine schwache Korrelation zwischen der Seropositivität von Mensch und Vieh sowohl für Q-Fieber als auch für RVF. Nur Rinder und Kamele wurden im iELISA seropositiv für Brucellose gefunden. Die individuelle Seroprävalenz der Brucellose betrug 2,8(0,9-6,4) beim Menschen, 1,5% (95% CI 0,2-5,2) bei Rindern und 0,6% (95% CI 0,0-3,2) bei Kamelen.

Das Bewusstsein für Zoonosen war bei den Agropastoralisten relativ höher als bei den Pastoralisten. Nur die Familiengröße war statistisch signifikant ($p<0,05$) in Verbindung mit dem Bekanntheitsgrad in der multivariablen Analyse. Etwa drei Viertel der Befragten wussten nichts über "Zoonosen". Die als Zoonosen gemeldeten Krankheiten/Syndrome waren Anthrax, Husten, hämorrhagische Septikämie, Maul- und Klauenseuche und Tuberkulose. Der Verzehr von Rohmilch, Tiergeburtshilfe ohne Schutzmaterial und das Werfen von abgetriebenen Föten auf das Feld gehörten zu den gemeldeten riskanten Praktiken. Schlechte Veterinärdienste,

ein fehlender Viehmarkt, unzureichende Tiergesundheitsberufe und Tierkrankheiten wurden als Probleme in der Region gemeldet. Es wurden einige Wahrnehmungen aufgezeichnet, die besagen, Wissen über Zoonosen sei eine schlechte Idee ist, da die Menschen Angst vor ihren Tieren bekommen, wenn sie über Zoonosen Bescheid wüssten.

Kleine Wiederkäuerarten dominierten den Viehhandel. Die meisten Händler verkauften ihre Tiere an nahe gelegenen lokalen Märkten. Gode, Jigjiga und Harteshek waren die dominierenden Viehmärkte, auf denen die Tiere verkauft wurden. Es wurden hohe Kosten für den Input-Handel gemeldet, wie z.B. Transport-, Makler-, Steuer-, Behandlungs-, Futtermittel-, Arbeits- und Personalkosten. Die Hauptfaktoren, die den Viehhandel behinderten, waren Dürre, Krankheiten, Sicherheit, Konflikte, harte Währungsschwankungen und ein schlechter Markt. Die berichteten Handelsprobleme verschärfen sich, wenn Dürre und/oder Krankheiten auftreten. Trypanosomiasis, Milzbrand, Schaf- und Ziegenpocken, Helminthiasis, Maul- und Klauenseuche (MKS), Zeckenbefall, ansteckende Ziegenpleuropneumonie, Durchfall, Nasenausfluss und die Schafkrankheit von Nairobi waren die häufigsten Ausbrüche, die den Viehhandel behinderten.

Die Nachfrage nach Vieh stieg während der religiösen Zeremonien Arafa, Mowlid, Eid-Al Adha und während der Regenzeit. Gode war der wichtigste Viehmarkt in der Region und empfing große Mengen an Tieren aus verschiedenen Teilen der umliegenden Zonen sowie aus dem benachbarten Somalia. Die wichtigsten Viehhandelsziele, über die berichtet wurde, waren Somaliland, Puntland, Saudi-Arabien, die Vereinigten Arabischen Emirate, Oman, Katar, Ägypten und der Jemen (derzeit kein Markt aufgrund des Krieges). Die Zoll- und Finanzbehörde berichtete, dass der Viehexport während der starken Kontrolle der Schmuggelaktivitäten zunahm und umgekehrt. Der Anteil des informellen Viehhandels war im gegenwärtigen Viehhandel hoch. Die wichtigsten Viehkrankheiten, auf die das Quarantäneamt abzielte, waren: MKS, Brucellose, Schaf- und Ziegenpocken, Kamelpocken, Schaf- und Rinderpasteurollose und Peste des petits ruminants (PPR). Exporttiere wurden den Vorgaben bezüglich Impfungen der Importländer entsprechend, geimpft.

Schlussfolgerungen

Diese Studie zeigte zum ersten Mal die Exposition von RVF bei Menschen und Vieh in diesem Land. Der geringe Kenntnisstand über Zoonosen, riskante Praktiken und falsche Vorstellungen über Zoonosen könnten das Risiko einer Übertragung von Zoonosen zwischen Mensch und Tier in der Region erhöhen. Daher ist das Bewusstsein und die Aufklärung der Bevölkerung über Zoonosen von wesentlicher Bedeutung. Weitere Forschung über die soziokulturelle Sichtweise des Zoonosenbewusstseins und risikoreicher Praktiken ist

erforderlich. Die Zusammenarbeit zwischen dem öffentlichen Sektor und dem Tiergesundheitssektor zur weiteren Untersuchung dieser Zoonosen unter Verwendung des One Health-Konzepts ist unerlässlich.

Trotz der bestehenden Herausforderungen im Viehhandel unterstützte der Viehhandel viele arme Viehzuchtgemeinschaften. Die dominierenden Viehmärkte könnten in Zukunft als kritische Punkte für Interventionen zur Bekämpfung von Zoonosen genutzt werden. Das Wissen über den Viehhandel und die damit verbundenen Krankheiten, Wege und Systeme kann dazu beitragen, geeignete Politiken und Strategien zu entwerfen, die die Wirtschaft, die Gesundheit und das Wohlergehen der Viehzuchtgemeinschaften in der Region Somalia verbessern könnten.

List of Tables

List of Figures

List of Abbreviations

AHRI	Armauer Hansen Research Institute
AIDS	Acquired Immunodeficiency Syndrome
BBC	British Broadcasting Corporation
CBPP	Contagious Bovine Pleuropneumonia
CCPP	Contagious Caprine Pleuropneumonia
CFT	Complement Fixation Test
CI	Confidence Interval
EC	Ethiopian Calendar
ELISA	Enzyme Linked Immunosorbent Assay
ESKAS	Swiss Government Excellence Scholarship
FAO	Food and Agricultural Organization of the United Nations
FGDs	Focus Group Discussions
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GEE	Generalized Estimating Equation
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
iELISA	Indirect Enzyme Linked Immunosorbent Assay
IgG	Immunoglobulin G
JOHI	Jigjiga One Health Initiative
LMB	Livestock and Meat Board
NZDs	Neglected Zoonotic Diseases
OD	Optical Density
OIE	World Organization for Animal Health
OR	Odds Ratio
PPR	Peste des Petits Ruminants
RBPT	Rose Bengal Plate Test
RVF	Rift Valley Fever
RVFV	Rift Valley Fever Virus
SDC	Swiss Agency for Development and Cooperation
Swiss TPH	Swiss Tropical and Public Health
UAE	United Arab Emirates
USD	United States Dollar
WHO	World Health Organization

Chapter One: Introduction

1.1 Background of Ethiopia

Ethiopia is a land locked country located in the Horn of Africa bordering Djibouti, Eritrea, Kenya, Somalia, Sudan and South Sudan. It is the second most populous country in Africa after Nigeria with an estimated human population of 109 million (UN DESA, 2019). Ethiopia is the fastest-growing economy in Africa and aims to be a lower-middle income country by the end of 2025 (World Bank, 2018). The government of Ethiopia utilize a federal parliamentary republic system, in place since 1995 following the end of the socialist Derg Regime in 1987. There are nine ethnic-based regional states and two chartered cities, which are semi-autonomously governed by the central government.

Ethiopia has the highest livestock population in Africa. The total livestock population is estimated to be 59.5 million cattle, 30.7 million sheep, 30.2 million goats, and 4.5 million camels (CSA, 2017). Livestock is the core of the agricultural sector contributing about 45% of agricultural GDP and 19% of national GDP (CSA, 2017). Approximately 85% of Ethiopia's population lives in rural areas, and livestock contributes to the livelihood of 80% of rural people in the country (Shapiro et al., 2017). Pastoralist communities keep about 44% of the national livestock population (cattle, sheep, goats and camels) and 100% of camels (Shapiro et al., 2017). The major pastoralist communities in the country live in Somali, Afar, Oromia, Benishangul-Gumuz, Southern Nation Nationalities and Peoples Region, Gambella regions and Dire Dawa administration (Gebremeskel et al., 2019). The pastoralist communities live in the arid and semi-arid lands (below 1500 meters above sea level) that receive annual rainfall of 200-800 mm. Other production systems besides pastoralism are hardly possible in such areas.

The pastoralist communities keep livestock mainly for milk, meat, draft power, transport, cash, social status, insurance and investment. A large part of the milk produced by households is consumed at home. With the remainder sold to earn cash. Livestock slaughter is not common in the pastoral areas, except for ceremonies such as marriage, prayer, burial and religious events (Schelling et al., 2007). Live animal sale is the most common source of cash income in pastoralist communities. It is reported that about 90% of live animals exported nationally to Gulf countries originated from pastoral areas of the country (Aklilu et al., 2013). In 2010/11, livestock exported from Ethiopia was valued at 211 million USD (Rettberg et al., 2017).

Despite their contributions, pastoral communities are among the poorest and most vulnerable rural inhabitants in Ethiopia (IFAD, 2016). Livestock traders/producers face many challenges and obstacles in livestock trade due to lack of sufficient accessible livestock markets, lack of demand, livestock diseases, conflicts, droughts, and bureaucracy or illegal animal confiscation by the Federal Customs and Revenue Authority (Fig 1).

Despite the huge livestock resources available, Ethiopia has not successfully exploited the opportunities mainly due to international market competition, poor infrastructure, weak livestock disease diagnosis, poor veterinary services, livestock disease outbreaks, low productivity performance and inappropriate livestock policies and strategies. Recently, the government designed a livestock master plan, aiming for modern technology and policies to lead Ethiopia to become Africa's largest meat exporter (IFC, 2018).

1.2 Zoonotic diseases and One Health

Zoonoses are diseases and infections transmitted naturally from vertebrate animals to humans and vice-versa. More than sixty percent of known human pathogens are animal source in origin (zoonoses). Approximately, seventy-five percent of emerging infectious diseases globally are also zoonoses (Grace et al., 2012). The recent outbreaks of zoonotic infections like West Nile Virus and the ongoing Corona virus outbreak in the developed world raises concerns for global public health (Camp and Nowotny, 2020). Many zoonotic diseases were either eradicated or well controlled in developed countries through expensive infrastructural investments and well-coordinated interventions (İnci et al., 2018; Zinsstag et al., 2005). However, the burden of zoonotic diseases remains in the developing world affecting billions of poor communities particularly where livelihoods depend on livestock and livestock related activities (Grace et al., 2012). Control strategies effective in industrialized countries and the cost of compensating farmers for culled stock are out of reach for most low-income countries. New locally adapted strategies for zoonoses control have to be developed in low-income countries. The majority of neglected pathogens are endemic zoonoses, which have tremendous health and economic impacts in developing countries but little consideration in the global health agenda (Roth et al., 2003).

Globally, 2.5 billion cases related to zoonoses were estimated every year causing about 3 million deaths (Grace et al., 2012).The direct cost due to zoonotic disease outbreaks in the last decade was estimated at 20 billion USD globally, with an additional 200 billion USD estimated indirect costs (World Bank, 2010). There is clear evidence that the economic and health impacts derived from zoonotic infections cannot be addressed effectively by only by a single sector. In 2005, Highly Pathogenic Avian Influenza pandemic threats in Asia brought all international communities together to cooperate and work for better health and well-being of global societies. Convincingly, the only way to bring all concerned bodies on board is by using the One Health approach. A One Health approach is ideal to tackle such threats by using surveillance, diagnosis and control of zoonotic diseases at the human-animal interface through coordination and communication between the human and animal health sectors (Zinsstag et al., 2016). Zoonotic infections are either under-reported or misdiagnosed in developing countries (Schelling et al., 2007). This is particularly true for pastoralist communities who have poor access to health and veterinary services (Montavon et al., 2013). The main reasons for under-reporting included unwillingness, lack of incentives, knowledge and skill gaps, economic consequences, and poor infrastructure (World Bank, 2010).

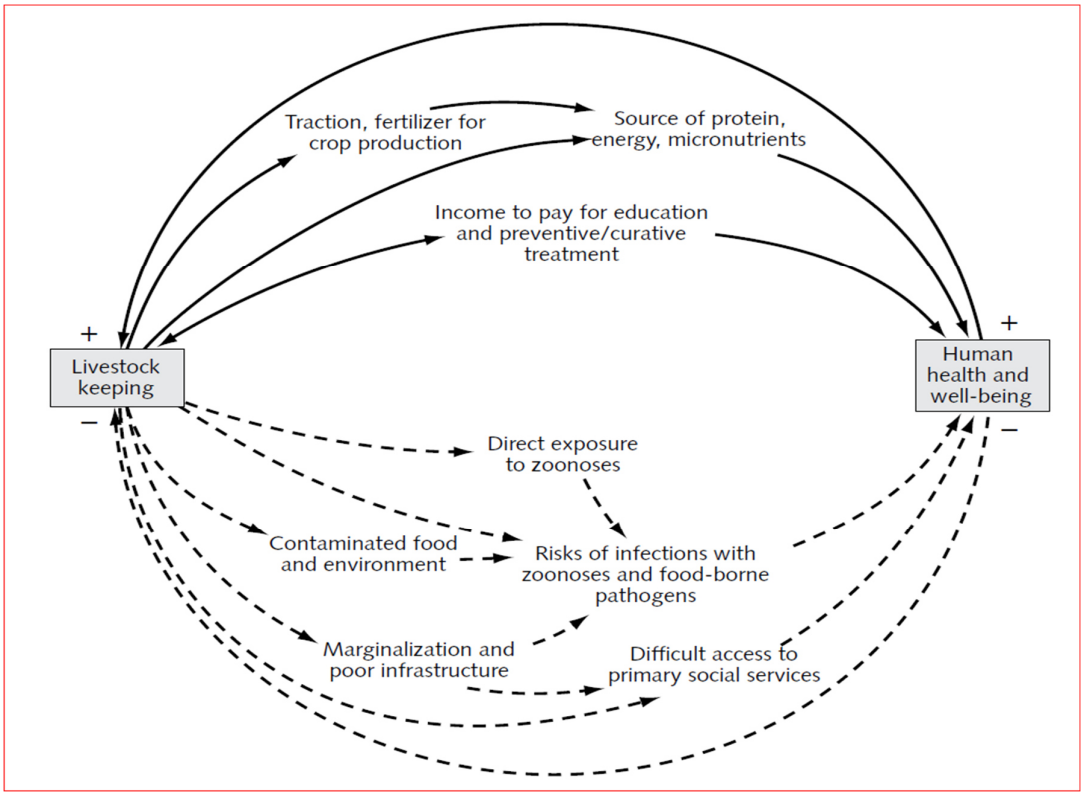

Fig 1 Positive and negative consequences of livestock keeping by pastoralist communities (Schelling et al., 2007)

1.3 Global status of brucellosis, Q-fever and Rift Valley Fever

1.3.1 Brucellosis

Brucellosis is a neglected bacterial zoonosis of global economic importance (Fig 2) (McDermott et al., 2013) caused by the genus *Brucella*. Transmission from animals to humans usually occurs due to consumption of unpasteurized milk and milk products or direct contact with infected animal especially during parturition through direct contact with placentas or aborted fetuses (Al Shehhi et al., 2016). Human brucellosis causes a chronic flu-like illness with fever, weakness, malaise, myalgia and weight loss. Human brucellosis infection cause non-specific symptoms and remains generally unnoticed or undiagnosed by medical doctors due to overlap with other febrile illnesses (Sharma et al., 2016). In livestock, *Brucella* spp cause abortion, infertility, and subsequent, reduction of milk yields (Ducrotoy et al., 2015). Brucellosis occurs globally, with higher incidences in the Middle East (Garcell et al., 2016).

In Ethiopia, livestock brucellosis is endemic (Yilma et al., 2016; Gumi et al., 2013; Tilahun et al., 2013; Haileselassie et al., 2011; Yeshwas et al., 2011). Seroprevalence of cattle in extensive production systems is lower than in intensive production systems (Adugna et al., 2013). The overall prevalence reported for brucellosis is 1.3% - 14.6% in cattle, 1.2%-11.7% in small ruminants, 0.53%-9.5% in camels and 2.2%-34.1% in humans (Degefu et al., 2011; Megersa et al., 2011; Bekele et al., 2011; Girma, 2012; Gessese et al., 2014; Bati, 2004; Tibeso et al., 2014; Genene et al., 2009).

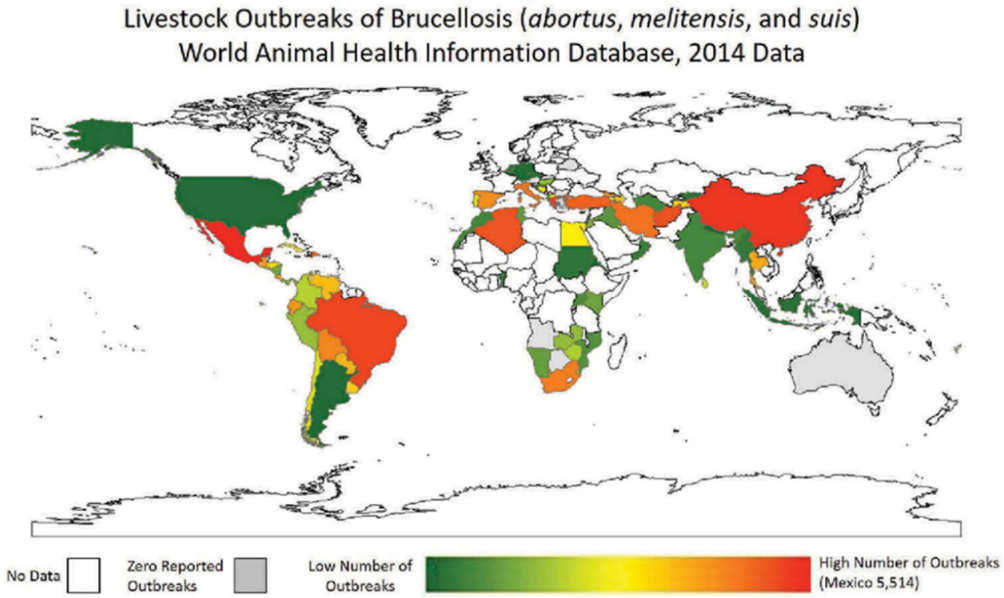

Fig 2 Global livestock brucellosis outbreaks (Hull & Schumaker, 2018)

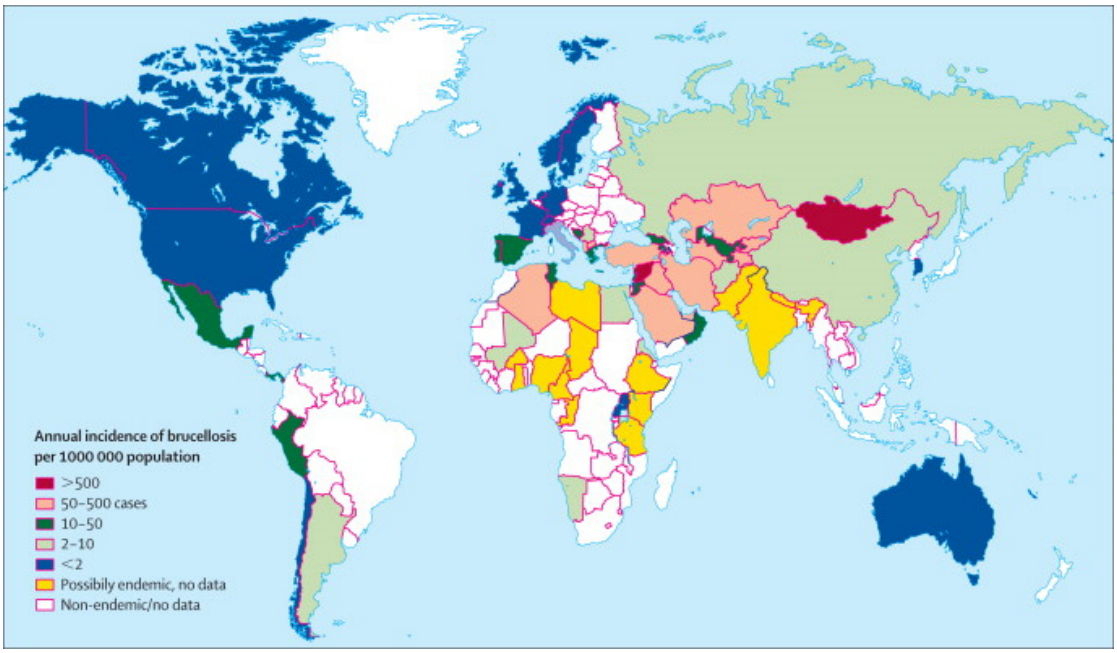

Fig 3 Worldwide incidence of human brucellosis (Pappas et al., 2006)

1.3.2 Q-fever

Q-fever is a zoonotic disease caused by *Coxiella burnetii,* which is endemic worldwide except in New Zealand and Antarctica. It affects a wide range of mammals, birds and arthropods (Bond et al., 2016). Domestic ruminants such as cattle, goats and sheep are the main reservoirs for Q-fever in humans (Brandwagt et al., 2016). Human infection occurs due to inhalation of dust contaminated by infected animal fluids, consumption of unpasteurized dairy products and contact with milk, urine, faeces, vaginal mucus or semen of infected animals. Most commonly in humans, Q-fever causes a flu-like illness, which can progress to atypical pneumonia and life threating acute respiratory distress syndrome (Dean et al., 2013).. Infection in animals is predominantly asymptomatic but has been associated with late abortions, stillbirth, delivery of weak offspring and infertility (Wardrop et al., 2016). Q-fever diagnosis is only possible through laboratory testing. Serological tests can detect antibodies against phase I and phase II antigens of *Coxiella burnetii*, and distinguish acute from chronic disease (Hoek et al., 2012).The largest Q-fever outbreak ever recorded occurred in 2007 in the Netherlands, with more than 4000 acute human cases (Hoek et al., 2012). Even though Q-fever has received attention in developed countries, reports show significant gaps in understanding the epidemiology of Q-fever infections in Africa (Wardrop et al., 2016).

Q-fever seropositivity among integrated human and animal studies was 13%, 23%, 33% and 16% in Egypt and 4%, 13%, 11% and 1% in Chad in cattle, goats, sheep and humans respectively (Nahed et al., 2012 ; Schelling et al., 2003). Seropositivity for Q-fever in camels was 80% in Chad and being a camel breeder was a risk factor for human seropositivity (Schelling et al., 2003). In Togo, people of Fulani ethnicity had greater livestock contact and a significantly higher seroprevalence than other ethnic groups (46% in Fulani vs 27% in non-Fulani) (Dean et al., 2013). The overall seroprevalence of Q-fever in Kenya was 3 % and 11%, in humans and cattle respectively (Wardrop et al., 2016). In Cote d'Ivoire, Q-fever seroprevalence was 14 % in cattle, 9 % in sheep and 12 % in goats (Kanoute et al., 2017). In Ethiopia, Gumi et al. reported seroprevalence of Q-fever as 90%, 32 % and 54 % in camels, cattle and goats respectively (Gumi et al., 2013).

1.3.3 Rift Valley Fever

Rift Valley Fever (RVF) is a peracute or acute zoonotic disease affecting ruminants and humans. It is caused by a mosquito borne virus belonging to the genus *Phlebovirus* in the family Bunyaviridae (OIE, 2016). Rift Valley Fever epidemics in East Africa occur often when there is a heavy rainfall followed by flooding in arid and semi-arid areas, which facilitates massive hatching of mosquito eggs. When these are already transovarially infected, there is rapid spread of the virus to animals and, to a lesser extent, to humans (Clark et al., 2018). The majority of animal infections are due to bites of infected mosquitoes. In humans, RVF-Virus (RVFV) is transmitted by direct contact with infectious animal tissue or by bites from infected mosquitoes (Nakoune et al., 2016). The disease in ruminants and camels is characterized by abortion, neonatal weakness or mortality and liver damage in animals. In humans, most infections are asymptomatic or a mild (flu-like) illness. In severe disease (about 7-8% of cases), it causes haemorrhage, encephalitis, visual disturbances and death (Ng'ang'a et al., 2016). The ability for RVF to spread outside traditionally endemic countries, even beyond the African continent, exists due to the extensive range of arthropod vectors capable of transmitting the virus. The presence of a wide range of hosts and vector species, and the epidemiological characteristics of RVF, led to concerns that epidemics may occur in previously undocumented regions (Tran et al., 2016). A recent Ethiopian study showed diversified primary (*Aedes spp.*) and secondary (*Culex, Anopheles, and Mansonia*) vector mosquitoes (Megarsa, 2019, doctoral dissertation) and mapped areas suitable for distribution of RVFV vector mosquitoes. It is not yet known if the virus needs to be reintroduced before an outbreak, or if undetected virus circulation in vertebrates or mosquitoes is sufficient to maintain the virus (Rissmann et al., 2019).

Seroprevalence of RVF is reported in many African countries. Cook et al., (2017) reported 0.8% in humans in Kenya (Cook et al., 2017). Seroprevalence was 3.9% in cattle, 2.4% in sheep and 0% in goats in Cote d'Ivoire (Kanoute et al., 2017). In Chad, seroprevalence of RVF was 37.8%, 18.8% and 10.8% in cattle, goats and sheep respectively (Abakar et al., 2014). Matiko et al., (2018) and Di Nardo et al., (2014) reported seroprevalence of 29.2% in cattle and 0.97% in livestock in Tanzania and Western Sahara, respectively.

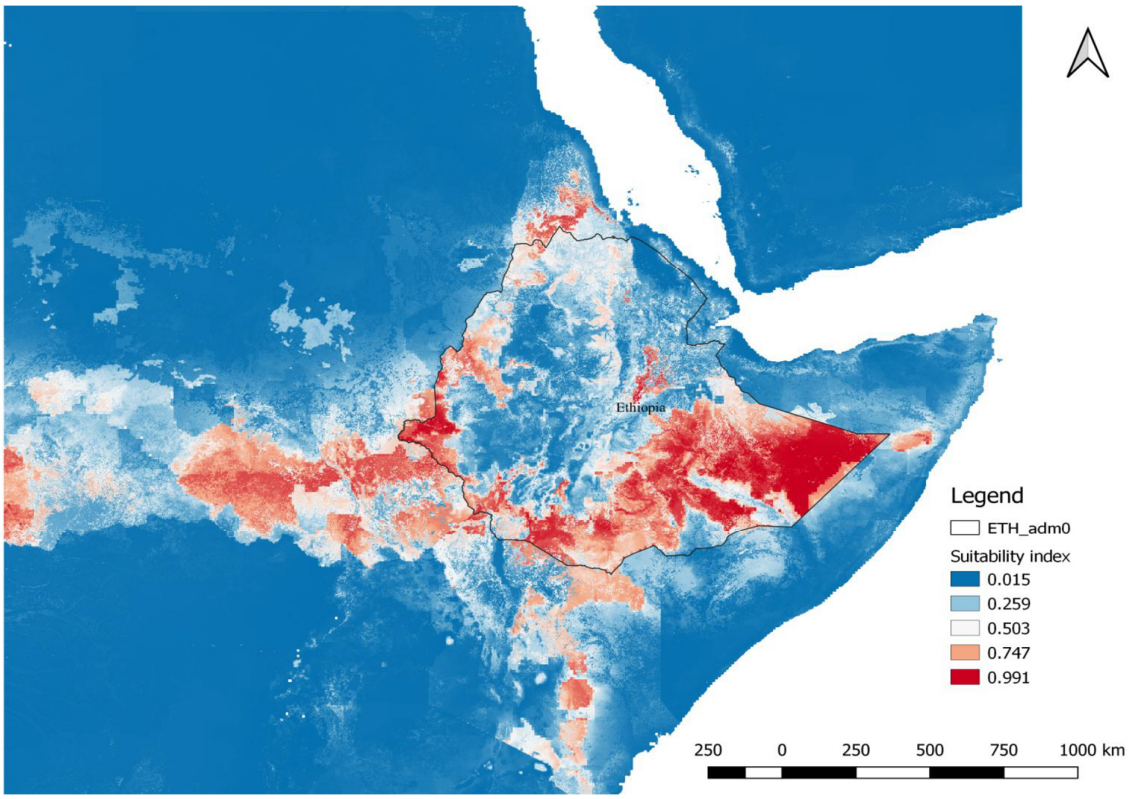

Fig 4 Predicted potential distribution of RVF vector mosquitoes in Ethiopia. (Megarsa J., 2019)

1.4 Zoonoses awareness in Ethiopia

Pastoralist communities practice traditional extensive livestock production system and have close contact with their livestock. The majority of these communities consume raw milk and assist animal deliveries with bare hands, which might increase the risk of zoonotic disease transmission. Nevertheless, community awareness about zoonotic diseases is reported to be low (Tadesse, 2016). The risky practices and low zoonoses awareness of the communities could lead to health and economic impacts caused by various zoonotic diseases.

1.5 Livestock marketing in Africa

The Horn of Africa is the largest livestock-marketing hub in Africa, with over 20 million nomadic and semi-nomadic pastoralists living in the Horn of African drylands (Venton et al., 2014). The Horn of Africa livestock export industry reportedly accounts for about 1.5 billion USD (Stem, 2016). Annual livestock trade through only the ports of Berbera and Bosaso is estimated to be 400 million USD (Eid, 2014). Formal and informal livestock trade is common in the region, with the informal accounting for a large share. About 60-80% of animals exported through Berbera port originate from the Somali region of Ethiopia (Aklilu and Catley, 2009). Most Horn of Africa countries do not exercise their full potential of livestock trade, due to diverse reasons such as poor policies and strategies, governmental negligence, inefficiencies, poor infrastructure, poor veterinary services, livestock diseases, insufficient quarantine services and lack of diagnostic facilities. The major livestock importers of the region are the Gulf countries, especially Saudi Arabia and UAE (Little et al., 2015).

In Ethiopia, livestock marketing contributes immensely to national GDP. As it is a land locked country, livestock exported from Ethiopia transit through either Djibouti or Berbera ports.

There are three types of livestock markets in Ethiopia.

1. Primary markets: these markets are small in size receiving less than 500 head of cattle per week. They are located in small villages, are not fenced and have no water or feed troughs. Main actors in these markets are primary producers, local consumers and butchers.
2. Secondary markets: These are average in size, receiving about 500-1000 head of cattle per week. They have fences, shade, water and feed troughs. They are located in larger cities, for example, capital cities of regional states. The main actors are traders and butchers, but they also supply terminal markets, live animal exporters and meat processors.
3. Terminal markets: These are located in large urban centres, like the country capital and other larger cities. They receive more than 1000 head per week. The actors are mainly medium to large-scale traders and butchers.

Chapter Two: Aims and Objectives

2.1 Rationale

Somali region hosts the largest pastoralist communities in Ethiopia. Eighty five percent of the people in the Somali region are pastoralists or agropastoralists whose livelihoods depend on livestock and livestock products. The region plays a huge role in livestock trade of the country. For example, up to 80% of Ethiopian livestock exported through Berbera port were originated from this region.

Ethiopia is among the countries with the highest zoonotic infection rates (Pieracci et al., 2016). Investigating zoonotic diseases such as brucellosis, Q-fever and rift valley fever in humans and livestock using integrated approach will provide a baseline information in the study area. It will also contribute the improvement of health and well-being of pastoralist communities and their livestock. Furthermore, assessing the awareness level of the pastoral and agropastoral communities about zoonotic diseases as well as practices related to livestock husbandry, feeding habits, and aborted material management are believed to reduce the risks of zoonotic diseases transmission if that information is obtained. Livestock trade assessment and associated livestock diseases including zoonoses also believed to improve the market demand, livestock diseases control and ultimately increase the household incomes. Finally, the outcomes of this study could be used to design effective interventions as a result; appropriate policies and strategies are developed.

2.2 Jigjiga One Health Initiative

This study was part of research and development project called Jigjiga One Health Initiative (JOHI) funded by Swiss Agency for Cooperation and Development with major partnership between Jigjiga University, Swiss Tropical and Public Health Institute and Armauer Hansen Research Institute. The goal of the project is to improve the health and well-being of pastoralist communities in the Somali region of Ethiopia. Iterative transdisciplinary participatory processes with communities, authorities and scientists identified the priorities of research and interventions. One of the components of the project was to capacitate Jigjiga University staff in masters and PhD programs at Swiss TPH. The JOHI team conducted researches based on the priorities identified by the pastoralist communities from Adadle Woreda of Somali region. The team was composed of students from different disciplines like public health, veterinary, range ecology, and nutrition. The team applied One Health approach for the first time Somali

region using same vehicle and cold chains. The studies were conducted in humans, animals and environment simultaneously in the study area.

2.3 Aim

The aim of this PhD thesis is to establish public health and economic importance of livestock diseases with the emphasis on zoonoses including brucellosis, Q-fever and rift valley fever in humans and livestock in Somali region of Ethiopia.

2.4 Specific Objectives

- To estimate seroprevalence of brucellosis, Q-fever and rift valley fever in humans and livestock
- To identify the risk factors for transmission of zoonotic diseases between humans and livestock
- To assess community awareness on zoonotic diseases
- To investigate the risky practices among pastoral and agro-pastoral communities
- To evaluate livestock trade in Somali region
- To identify livestock diseases including zoonoses that can hinder livestock trade
- To map livestock trade routes and identify the highest concentrated livestock markets

Chapter Three: Method

This PhD thesis is composed of three major components. First, we estimated the seroprevalence of brucellosis, Q-fever and rift valley fever in humans and livestock in Adadle woreda of Somali region. Secondly, we assessed community awareness about zoonotic diseases, their risky practices that favor zoonotic diseases transmission and the most reported livestock diseases in the area. Finally, we studied livestock trade and its associated livestock diseases.

3.1 Study design and Approach

For the study on seroprevalence of brucellosis, Q-fever and rift valley fever in humans and livestock, a multi-stage cross sectional cluster design study was implemented with the aim to establish the seroprevalence of zoonotic diseases including brucellosis, Q-fever and rift valley fever in humans and livestock. Six kebeles (smallest administrative unit) of Adadle woreda were selected using proportional probability to human population. The sub-kebeles were selected using simple random sampling. The households in the sub-kebeles of sedentary (agropastoral) communities were selected using spinning pen and proceeding to the direction of the pen head. For the mobile pastoralists communities, the visited camps (Reer) were asked to tell us the nearest camps with large households then we visited for sampling accordingly. Blood samples were collected from humans and livestock from May – August 2016. Blood samples were transported to Addis Ababa, Ethiopia for laboratory tests. Additionally, questionnaires survey were conducted to capture the risk factors.

For the study on Livestock health and zoonoses: Awareness and practices among pastoral and agro-pastoral communities, a multi-stage cross sectional cluster design study was implemented. Six kebeles were selected using proportional probability to human population. Semi-structured interviews and focus group discussions (FGDs) were conducted in local language (Somali) between May and August 2016. For FGDs, we consulted kebele administrators, elders and religious leaders to select community members (men and women) who had good knowledge and experience on livestock production and health. We made an audio recording of each discussion, after informed consent from all the group members.

For the study on Livestock trade and its associated livestock diseases, a multi-stage cross sectional cluster design study was implemented. Six kebeles were selected using proportional probability to human population. With the consultation of kebele administrator and elders, local livestock traders within the kebele were selected for convenience. First, we conducted In-depth interviews followed by livestock trade routes mapping using printed maps. The livestock traders used different colours for each livestock species. The interviews were audio recorded after obtaining a consent from the participants. In addition to the individual interviews of livestock traders, FGDs were conducted with Gode livestock market brokers. Lastly, we interviewed the federal customs and revenue authority and quarantine office personnel. Secondary data were received from both customs and revenue authority as well as quarantine office. All the interviews were audio recorded after consent.

3.2 Data analysis

For study one (Chapter 4): the data was entered into Microsoft Access then analyzed using STATA version 14 (Stata Corporation, College Station, TX, USA). Both descriptive and analytical statistics were used for data analysis. Logistic regression was used to estimate the apparent seroprevalence of humans and livestock. Uni and multivariable analysis was done to identify predictors for seropositivity. Generalized Estimating Equation (GEE) model for binomial outcomes were used to account for potential correlation within herds. For the correlation matrix, we calculated the pairwise Pearson's correlation coefficient for the prevalence in two different species.

For study two (Chapter 5): the individual interviews was double entered using Epi-info (Centre for Disease Control and Prevention, Atlanta GA, USA, version 3.5.1.) A single entry was made to categorize text variables using a Microsoft Excel spreadsheet. Quantitative data, including new binary variables about awareness and reported zoonoses, was analysed using STATA version 14 (Stata Corporation, College Station, TX, USA). Computed cross-tabulation statistics and logistic regression were used to determine the association between the binary variable awareness of zoonoses and the associated practices/risk factors in the study area. FGDs recordings were transcribed, translated in to English, and imported into MAXQDA 12 (VERBI GmbH Berlin, Germany) for qualitative data management and analysis. The framework method for analysis of qualitative data was used (Gale et al., 2013).

For study three (Chapter 5): the qualitative in-depth interview recordings were transcribed, translated into English then imported into MAXQDA 18 (VERBI GmbH Berlin, Germany) for qualitative data management and analysis. The framework method for analysis of qualitative data was used (Gale et al., 2013). For livestock trade routes, geographical coordinates of the major markets and cities/towns that either recorded by the researcher using global positioning system (GPS) or derived from google map was used and mapped using ArcGIS 10.6.1.

3.3 Ethical clearance

The study complied with ethical standards according to the "Ethikkommission Nordwest-und Zentralschweiz" (EKNZ) in Switzerland (BASEC UBE-req.2016-00204) and the Jigjiga University Research Ethics Review Committee (JJU-RERC002/2016). Religious leaders, elders and clan leaders together with the administrator informed the communities about the study and asked their willingness to participate the study. The researcher together with the administrator obtained oral consent from the participants. All the information about the participants were anonymous.

3.4 Study area

Somali region

Somali region is located in the most eastern part of Ethiopia. It is the second largest region and third most populous in the country with a population of 6.2 million (CIA, 2018) with Jigjiga as its capital. The region is divided into 11 administrative zones and 94 woredas (districts). It is located in the arid and semi-arid agro-ecological and climatic zone. Its altitude ranges from 400 m in the Southeast to about 1000 m in the North. It has erratic and unreliable type of rainfall. The annual rainfall is 300-500 mm. the temperature ranges from 20-45 ^{o}C. About 86% of the population lives in rural areas, and majority of them are pastoralists and to a lesser extent, agro pastoralists. Majority of the pastoralists are mobile, moving from place to place with their livestock in search of pasture and water. Camel, cattle, sheep and goat are the most dominant livestock species in the region.

Adadle woreda

Adadle woreda is situated in the Shabelle Zone of the Somali region. It is located in the lowlands of the semi-arid Wabe Shabale River sub basin (Figure 5). The mean annual rainfall based on Gode (the main town of the zone) data is about 300 mm (Gebre-Mariam, 2007). The main rainy season called "Gu" lasts from March to May and the short dry season known as

“Xagaa” from June to August. “Xagaa” is followed by the short rain “Dayr” between September and November and the long dry season “Jilaal” from December to March. The woreda is composed of 15 kebeles (the smallest administrative units) (Gebre-Mariam, 2007) with a total population of 100,000 (SRBoFED, 2014). According to data in 2000, the majority of people living in Adadle were pastoralists (60%), whereas 28% were agro-pastoralists and 10% practiced riverine cultivation as cited in (Gebre-Mariam, 2007).

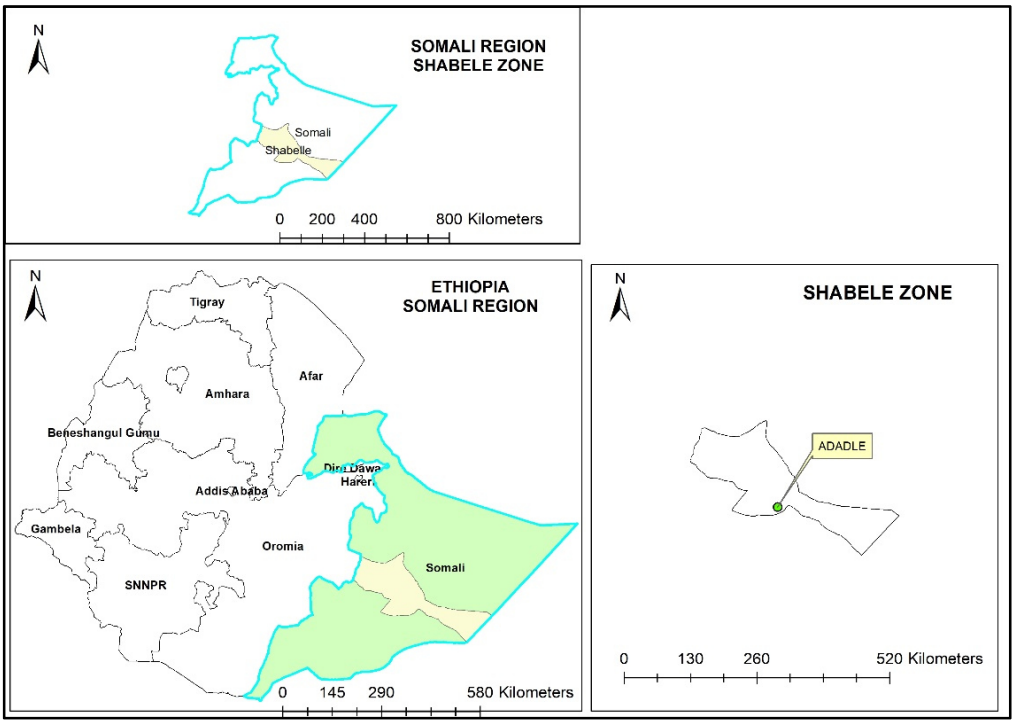

Fig 5 Map of the study area

Chapter Four: Sero-prevalence of brucellosis, Q-fever and Rift Valley Fever in humans and livestock in Somali region, Ethiopia

Sero-prevalence of brucellosis, Q-fever and Rift Valley Fever in humans and livestock in Somali region, Ethiopia

Mohammed Ibrahim[1, 2, 3], Esther Schelling [2, 3], Jakob Zinsstag [2, 3*], Jan Hattendorf [2, 3], Emawayish Andargie[4], Rea Tschopp [2, 3, 4]

1 College of Veterinary Medicine, Jigjiga University, Jigjiga, Ethiopia
2 Swiss Tropical and Public Health Institute, Department of Epidemiology and Public Health, P.O. Box, CH-4002 Basel, Switzerland
3 University of Basel, Petersplatz 1, CH-4003 Basel, Switzerland
4 Armauer Hansen Research Institute, Addis Ababa, Ethiopia

This article has been published in PLoS Neglected Tropical Diseases Journal

Abstract

Information on zoonotic diseases in humans and livestock are limited in pastoral/agro-pastoral communities in Ethiopia. A multi-stage cross sectional cluster design study was implemented with the aim to establish the seroprevalence of zoonotic diseases including brucellosis, Q-fever and Rift Valley Fever (RVF) in humans and livestock in Adadle woreda of the Somali region, Ethiopia. Blood samples were collected from humans and livestock and tested by relevant serological tests. For brucellosis, Rose Bengal test (RBT) and indirect ELISA was used for screening and confirmatory diagnosis respectively. Indirect and competitive ELISA were also used for Q-fever and RVF respectively. The individual seropositivity of Q-fever by species was 9.6% (95% CI 5.9-15.1) in cattle, 55.7% (95% CI 46.0-65.0) in camels, 48.8% (95% CI 42.5-55.0) in goats, 27.0%(95% CI 20.4-34.0) in humans and 28.9% (95% CI 25.0-33.2) in sheep. In humans, seropositivity of Q-fever in males was 28.9% vs 24.2% in females (OR= 1.3; 95% CI 0.6-2.5). Camel seropositivity of Q-fever was significantly associated with age (OR= 8.1; 95% CI 2.8-23.7). The individual apparent seroprevalence of RVF was 13.2% (95% CI 8.7-18.8) in humans, 17.9 % (95% CI 11.0-27.8) in cattle, 42.6% (95% CI 34.8-50.7) in camels, 6.3% (95% CI 3.3-11.6) in goats and 7.4% (95% CI 4.7-11.5) in sheep. Camels had the highest seropositivity of both Q-fever and RVF. The camel seropositivity was 55.7% (95% CI 46.0-65.0) and 42.6% (95% CI 34.8-50.7) for Q-fever and RVF respectively. Generally, there was only a weak correlation between human and livestock seropositivity for both Q-fever and RVF. Only cattle and camels were found seropositive for brucellosis by iELISA. The individual seroprevalence of brucellosis was 2.8(0.9-6.4) in humans, 1.5% (95% CI 0.2-5.2) in cattle and 0.6% (95% CI 0.0-3.2) in camels. This study showed the importance of zoonoses in Somali regional state and is the first published study to describe RVF exposure in humans and livestock in the country. Collaboration between public and animal health sectors for further investigation on these zoonoses using the One Health concept is indispensable.

Key words: humans, livestock, seroprevalence, Somali region, zoonotic diseases

4.1 Introduction

Zoonoses are infectious diseases transmitted between human and vertebrate animals. These diseases include those from animal sources food. Neglected zoonotic diseases (NZDs) are not addressed adequately by the international communities (World Bank, 2012). Brucellosis, Q-fever and Rift Valley Fever are among those NZDs, which are largely eliminated in developed countries but under-diagnosed and under-reported in developing countries (Kanoute et al. 2017). Effective management of zoonoses benefits from a One Health approach, creating synergistic benefits from the collaboration of human and animal health sectors (Zinsstag et al. 2015). Ethiopia is among the top five countries with the highest zoonotic infections in the world (Grace et al. 2012). Despite its burden, attention by the government rose only recently, where the five most prevalent zoonotic diseases were prioritized as following: Rabies, anthrax, brucellosis, leptospirosis and echinococcosis (Pieracci et al. 2016).

Brucellosis is one of the neglected bacterial zoonoses which have economic importance globally (McDermott John, Grace Delia, and Zinsstag J 2013). This disease is caused by the genus *Brucella*. The economically most important species are *B. melitensis* and *B. abortus* having a high potential of human infection (Zinsstag et al. 2015) affecting small ruminants and cattle respectively (Ducrotoy et al. 2015). Transmission from animals to humans occurs usually due to consumption of unpasteurized milk and milk products or direct contact with infected animal especially during parturition, with direct contact with placentas or aborted fetuses (Al Shehhi et al. 2016). Human brucellosis causes a flu-like illness with a fever, weakness, malaise, myalgia and weight loss. It can be debilitating in chronic stages with serious complications (e.g. endocarditis, musculoskeletal lesions) which can be potentially fatal if not treated. In livestock, *Brucella* spp cause abortion, infertility, and as a consequence, reduction of milk yields (Ducrotoy et al. 2015). Human brucellosis infection shows non-specific symptoms and remains generally unnoticed or undiagnosed by medical doctors due to overlapping with other febrile illnesses (Sharma et al. 2016). Brucellosis occurs globally with higher incidences in the Middle East (Garcell et al. 2016).

In Ethiopia, livestock brucellosis is endemic and were reported in different studies in Ethiopia (Gumi et al. 2013; Tilahun et al. 2013; Haileselassie et al. 2011; Yilma, Mamo, and Mammo 2016; Yeshwas et al. 2011). Most studies were done in the highlands targeting urban and peri-urban dairy farms. Seroprevalence of cattle in extensive production systems is lower than that of intensive production systems (Adugna, Agga, and Zewde 2013). The highest prevalence of brucellosis was recorded in central Ethiopia followed by the southern part, whereby lower

prevalences were seen in the western and eastern parts. Camel seropositivity for brucellosis in Ethiopia ranged from 0.7 to 12% for the Rose Bengal Plate Test (RBPT) and 0.5 -10% for Complement Fixation Test (CFT) in different agro-ecologies(Yilma, Mamo, and Mammo 2016). Studies on human brucellosis in Ethiopia are sparse with less information about risk factors for human infection (Zerfu et al. 2018; Haileselassie et al. 2011).

Q-fever is a zoonotic disease caused by *Coxiella burnetii* which is endemic worldwide except in New Zealand and Antaractica. It affects a wide range of mammals, birds and arthropods (Bond et al. 2016). Domestic ruminants such as cattle, goats and sheep are the main reservoirs for Q-fever in humans (Brandwagt et al. 2016). Human infection occurs due to inhalation of dust contaminated by infected animal fluids, consumption of unpasteurized dairy products and contact with milk, urine, faeces, vaginal mucus or semen of infected animals. The most common sign of Q-fever in man is a flu-like illness which can progress to an atypical pneumonia, resulting in a life threating acute respiratory distress syndrome (Dean et al. 2013). Infection in animals is predominantly asymptomatic but has been associated with late abortions, stillbirth, delivery of weak offspring and infertility (Wardrop et al. 2016).

Even though Q-fever have been given attention in developed countries, there are reports which showed significant gaps in understanding the epidemiology of Q-fever infections in Africa (Wardrop et al. 2016). Q-fever seropositivity among integrated human and animal studies was 13%, 23%, 33% and 16% in Egypt and 4%, 13%, 11% and 1% in Chad in cattle, goats, sheep and humans respectively (Nahed and Khaled 2012; Schelling et al. 2003). The seropositivity of Q-fever in camels was 80% in Chad and being a camel breeder was a risk + factor of human seropositivity (Schelling et al. 2003). In Togo, people of Fulani ethnicity had greater livestock contact and a significantly higher seroprevalence than other ethnic groups (46% in Fulani vs 27% in non-Fulani) (Dean et al. 2013). The overall seroprevalence of Q-fever in Kenya was 3 % and 11 % in humans and cattle respectively (Wardrop et al. 2016). In Cote d'Ivoire, Q-fever seroprevalence was 14% in cattle, 9 % in sheep and 12 % in goats (Kanoute et al. 2017). In Ethiopia, Gumi et al. reported seroprevalence of Q-fever as 90%, 32 % and 54 % in camels, cattle and goats respectively (Gumi et al. 2013). Abebe reported seroprevalence of Q-fever in humans as 7 % in Ethiopia (Abebe 1990).

Rift Valley Fever (RVF) is a peracute or acute zoonotic disease affecting ruminants and humans. It is caused by a mosquitoes borne virus of the Bunyaviridae family; genus *Phlebovirus (OIE 2016).* Rift Valley Fever epidemics in East Africa occur often when there is a heavy rainfall followed by flooding in arid and semi-arid areas favoring the massive hatching of mosquitoes eggs, whereof a part is already transovarially infected, and thus lead to rapid spread of the virus to animals and to a lesser extent to humans (Clark et al. 2018). The majority of animal infections are due to bites of infected mosquitoes. In humans, RVFV is transmitted by direct contact with infectious animal tissue or by the bites of infected mosquitoes (Nakoune et al. 2016). The disease in ruminants and camels is characterized by abortion, neonatal mortality, weak-born offspring and liver damage in animals. In humans, most infections are asymptomatic or as a mild (flue-like) illness. In severe disease (about 7-8% of cases) it causes hemorrhage, encephalitis, visual disturbances and death (Ng'ang'a, Bukachi, and Bett 2016).

Seroprevalence of RVF was reported in many African countries. Cook et al., (2017) reported 0.8% in humans in Kenya (Cook et al. 2017). Seroprevalence of 3.9 % in cattle, 2.4 % in sheep and 0 % in goats was reported in Cote d'Ivoire (Kanoute et al. 2017). In Chad, seroprevalence of RVF was 37.8%, 18.8 % and 10.8 % in cattle, goats and sheep respectively (Abakar et al. 2014). (Matiko et al. 2018; Di Nardo et al. 2014) reported seroprevalence of 29.2 % in cattle and 0.97 % in livestock in Tanzania and Western Sahara respectively.

The ability of RVF to spread outside traditionally endemic countries, even out of the African continent lies in the fact that a large range of arthropod vectors are capable of transmitting the virus. The presence of a wide range of hosts and vector species, and the epidemiological characteristics of RVF, had led to concerns that epidemics may occur in previously not described regions like Ethiopia (Tran et al. 2016). In other East and central African countries such as Kenya, inter-epizootic/epidemic cases are increasingly documented for the past 10 years (Halawi et al. 2019; Sumaye et al. 2013; Britch et al. 2013; LaBeaud et al. 2015). Even though, Ethiopia remained free from outbreaks, its geographic location as well as the livestock exchanges with neighboring countries makes highly vulnerable to the disease particularly to cases that are not epidemic but occur on a more continued basis (Anyamba et al. 2009).

Somali region had the highest pastoralist communities in Ethiopia and yet, the status of the selected zoonotic diseases in humans and livestock are unknown. Thus, the aim of this study was to estimate the seroprevalence of brucellosis, Q-fever and RVF in humans and livestock and identify the associated risk factors in Adadle woreda. This study also highlighted the awareness gap of the communities against zoonoses and recommended the intervention strategies in preventing and control of zoonotic diseases in the area.

4.2 Materials and methods

This study was part of research and development project called Jigjiga One Health Initiative (JOHI) funded by Swiss Agency for Cooperation and Development with major partnership between Jigjiga University, Swiss Tropical and Public Health Institute and Armauer Hansen Research Institute. The goal of the project is to improve the health and well-being of pastoralist communities in the Somali region of Ethiopia.

4.2.1 Study area

Adadle woreda (district) is situated in the Shabelle Zone of the Somali region of Ethiopia. It is located in the lowlands of the semi-arid Wabe Shabale River sub basin (Figure 6). The mean annual rainfall based on Gode (the main town of the zone) data is about 300 mm (Gebre-Mariam 2007). The main rainy season called “Gu” lasts from March to May and the short dry season known as “Xagaa” from June to August. “Xagaa” is followed by the short rain “Dayr” between September and November and the long dry season “Jilaal” from December to March. The woreda is composed of 15 kebeles (the smallest administrative units) (Gebre-Mariam 2007) with a total population of 100,000 (SRBoFED 2014) (Figure 1). In 2000, the majority of people living in Adadle were pastoralists (60%), whereas 28% were agro-pastoralists and 10% practiced riverine cultivation as cited in (Gebre-Mariam 2007).

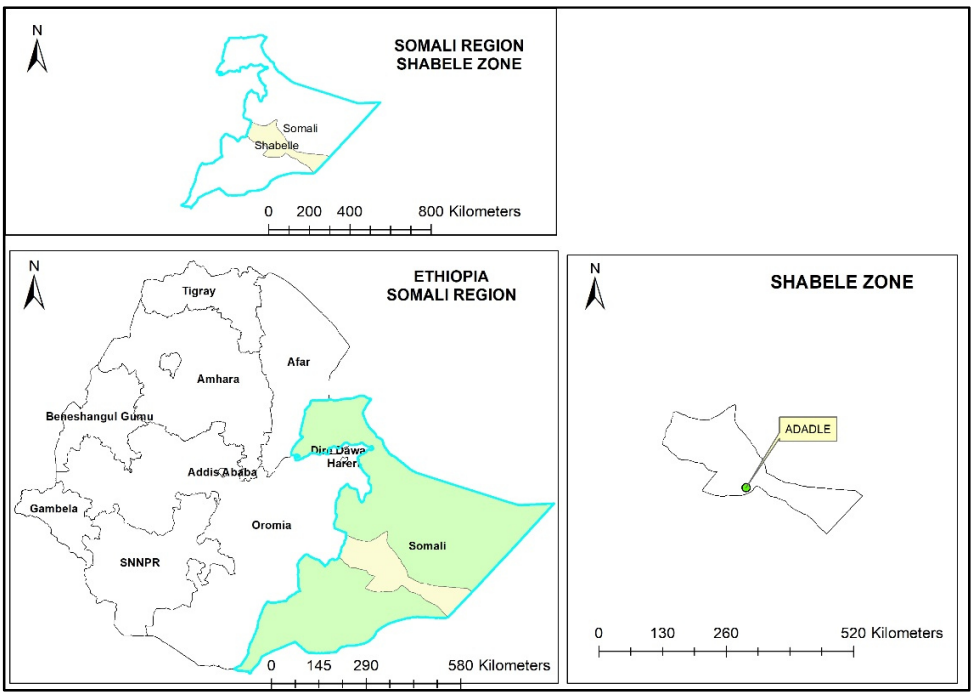

Fig 6 Map of the study area

4.2.2 Sample size calculation

Sample size determination was conducted to estimate the precision of the study with an anticipated prevalence. In pastoral and settled livestock management systems in semi-arid areas of Africa, the seroprevalence of brucellosis in cattle is usually greater than 5%, ranging from 4.8-41.0% (McDermott and Arimi 2002). The seroprevalence of brucellosis is usually much lower in small ruminants than in cattle (McDermott and Arimi 2002). Considering that in the study area livestock has never been vaccinated against brucellosis, we assumed based on data from comparable countries that brucellosis had a prevalence of 7%, 5%, 12% and 7% in humans, camels, small ruminants and cattle, respectively. The design effect D was derived from the following formula D = 1 + (b-1)rho; where b is the number of units sampled per cluster and rho (ρ) is the intra-cluster correlation coefficient (Bennett et al. 1991). A rho value for zoonoses (and infectious diseases more generally) is usually between 0.05-0.2 and rarely exceeds 0.3 with highly contagious viral infections (Bennett et al. 1991), (Otte and Gumm 1997). Thus a rho value of 0.15 was taken for initial sample size calculation. We calculated that a sample of 180 humans from 60 clusters will lead to a standard error of 2.2% of our estimate. Three hundred goats and three hundred sheep to be sampled will lead to a standard error of 2.0% of our estimate for each species. Furthermore, 150 camels to be sampled will lead to a standard error of 2.3% of our estimate.

4.2.3 Sampling procedure

Adadle woreda has 15 kebeles. Two kebeles were excluded from the study due to the lack of mobile phone network and poor accessibility. Six kebeles were selected randomly from the remaining thirteen kebeles with selection probability proportional to the human population size. Melkasalah and Harsog were pure pastoralist kebeles, whereas Boholhagare, Bursaredo, Higlo and Gabal were agropastoralist. Even though Boholhagare and Higlo were listed as agropastoralist kebeles, people were mainly depended on livestock and practice crop plantation only during rainy seasons.

A village list was available for each agropastoral kebele. All villages in the kebele were assigned numbers. Community members (kebele administrators, elders and religious leaders) drew a minimum of 8 numbers from a bag to select the villages. In each selected village, households were selected by spinning a pen and proceeding in the direction of the pen head. All households in that direction were included. The two pastoralist kebeles were selected as follows: Kebele administrators reported which villages had concentrations of mobile pastoralist camps in the vicinity. We visited all reported villages and selected the camp (Reer) with the highest number of tents. We included all households of the selected Reer. Within the selected

households, individuals who were present at the time of interview and were 16 years or older than were eligible to participate in the study.

Livestock

The sampling was conducted between May and August, 2016 from six kebeles of Adadle woreda of Somali region, Ethiopia. The animals within the herd of selected households were selected systematically using sampling interval number (total number of animals in the herd which are ≥ 6 months divided by the number of animals to be sampled within the herd). The first animal was selected randomly then every n^{th} animal until total sample size was attained. In camels, we sampled outside the barn unlike other species but with the same methodology. Within each herd, a maximum of nine from each livestock species were sampled. A total of 171 camels, 297 goats, 269 sheep and 135 cattle were sampled from six kebeles. All samples (n=872) were screened by RBPT but only 141 camels, 252 goats, 229 sheep and 108 cattle (n=730) were tested by ELISA test.

Humans

Individual people within the selected households whose animals were sampled who were ≥ 16 years and providing informed consent to participate the study were sampled. Semi-structured questionnaires were also conducted to capture the risk factors associated with the zoonoses under study. In addition to individuals within the selected households, people from the village who fulfill the criteria were voluntarily selected and sampled. A total of 190 humans were sampled from six kebeles. All the samples (n=190) were used for ELISA test but only 178 were used for brucellosis screening using RBPT.

Questionnaire administration

Households whose livestock and/people sampled were questioned about livestock health and management as well as people demographic information and their risky practices. Some of the information were used here to analyse the risk factors. The questionnaire was translated from English to Somali.

Blood samples collection

A nurse collected blood samples by venipuncture in 5 ml vacutainer tubes from humans and a veterinarian used 10 ml plain vacutainer tubes for livestock. The blood samples were labeled and kept at room temperature until clot formation. The blood samples were centrifuged at 3000

rpm for 5 minutes. Sera were separated with pasteur pipettes and placed in a labeled 2 ml eppendorf sera tubes. Sera samples were transported on ice to Gode city and stored at -20^{o}C until transported to Addis Ababa for laboratory testing at the Armauer Hansen Research Institute.

4.2.4 Serological tests

Brucellosis serology

Sera samples were first screened with the RBPT (ID. vet, Innovative Diagnostics, RSA-RB ver 0112 GB, Grabes, France). The reagents were left under room temperature for 30 minutes before testing. Equal volume of the reagent and serum (30µl) were placed on a clean plate. First, 30 µl of Rose Bengal was placed on the plate and 30 µl of serum was added then mixed thoroughly by using wooden applicator sticks and then the plate was shaken slowly with hand for about 4 minutes (OIE 2018). Any visible agglutination by naked eyes was considered as positive and lack of agglutination was considered as negative. Even if slight agglutination was observed, it was considered as a positive. Human sera which were positive in RBT (n=5) were sequentially diluted with phosphate buffered saline (PBS) to obtain dilutions from1/4 and 1/8. All sera were found reactive in 1/4 dilutions and three sera were also reactive in 1/8 dilution.
All livestock samples positive with the RBPT(n=23) were further tested by indirect ELISA (CHEKIT Brucellose Serum ELISA Test Kit, IDEXX Laboratories, ME, USA) and classified as positive or negative according to the manufacturer's recommended cut-off ranges. Samples were tested in duplicates and the mean optical density (OD) value at 450nm of each was calculated [($S_{ample}/P_{ositive}$% = mean OD sample – mean OD negative control/ (mean OD positive control – mean OD NC) x100]. Brucellosis results were interpreted as positive (S/P ≥ 80%) and negative (S/P < 80%). Results were checked for validity according to the manufacturer's recommendations. In livestock, only samples positive in iELISA were used for the data analysis whereas in humans, those samples which were positive in RBPT were used for the data analysis since iELISA kit used was only for ruminants but not for humans.

Q-fever and Rift Valley Fever serology

All ruminants and camels samples were tested using indirect ELISA for Q-fever by using *Coxiella burnetii* phase I and II strain (ID-vet, Innovative Diagnostics, FQS-MS ver 0514 GB, Grabes, France). The Panbio *Coxiella burnetii* (Q-Fever) IgG ELISA was used for human sera (Panbio diagnostics, Cat. no. 06PE10, Germany). Q-fever results of livestock were classified as seropositive and seronegative by calculating the S/P% as described above. Q-fever results

of livestock were interpreted as positive (S/P > 50%) and negative (S/P ≤ 40%). Q-fever results in humans were interpreted using an index value (IV) (IV= sample absorbance/cut-off value) as positive (IV > 1.1) and negative (IV < 0.9). All equivocal (doubtful) human Q-fever samples were re-tested. Results were checked for validity according to the manufacturer's recommendations

Competitive ELISA (ID-vet, Innovative Diagnostics, RIFTC ver 1114 GB, Grabes, France) was used for Rift Valley Fever in both humans and livestock. RVF results were classified as seropositive and seronegative by calculating the mean OD value of each sample in both humans and livestock. Results were expressed as percentage (S_{ample} /$N_{egative}$ % = OD $_{sample}$ /OD $_{NC}$ x 100) and interpreted as positive (S/N ≤ 40%) and negative (S/N > 50%).

4.2.5 Data analysis

The data was entered into Microsoft Access then analyzed using STATA version 14 (Stata Corporation, College Station, TX, USA). Both descriptive and analytical statistics were used for data analysis. Logistic regression with clustering at household level was used to estimate the apparent seroprevalence of humans and livestock. Uni and multivariable analysis was done to identify predictors for seropositivity. Age category, sex and kebele were included as categorical variables in the pre specified multivariable model. Age categories varies according to species. For sheep and goats (young= 1-2 years, adult= 3-6 and old= >6). For cattle (young= 1-3 years, adult= 4-7 and old= >7). For camels (young= 1-4 years, adult= 5-8 and old= >8). For humans (young adult= 16-31 years, middle-aged adult= 32-48 and old adult= ≥ 49).Generalized Estimating Equation (GEE) model for binomial outcomes were used to account for potential correlation within herds. For the correlation matrix in figure 8, we calculated the pairwise Pearson's correlation coefficient for the prevalence in two different species.

4.2.6 Ethical clearance

The study complied with ethical standards according to the "Ethikkommission Nordwest-und Zentralschweiz" (EKNZ) in Switzerland (BASEC UBE-req.2016-00204) and the Jigjiga University Research Ethics Review Committee (JJU-RERC002/2016). In each kebele, religious leaders, elders, and clan leaders were gathered by the administrator then explained the objective of the project and made clear that the participation of the study was voluntary. After questions and discussions, an agreement was reached. Religious leaders, elders and clan leaders together with the administrator informed the communities to participate the study.

During sample collection and questionnaire surveys, the administrator together with the researcher obtained oral consent from the participants.

4.4 Results

Descriptive analysis of the study population

About 77.4% (565/730) of the livestock were females and 22.6% (165/730) were males. The majority of livestock sampled were adults; cattle (49.1%), camels (45.4%), goats (61.1%) and sheep (0%). In human samples, 48.9% (93/190) were females and 51.1% (97/190) were males with mean age of 42 years. The mentioned zoonotic diseases by the respondents included brucellosis, tuberculosis, and anthrax.

The livestock vaccination status was based on all types of vaccines provided by the government except those against zoonotic diseases under the study (Table 1).

Table 1. Sampled household related information

Variable	Category	(%, mean, SD)
Family size	1-6	25
	7-10	54
	≥11	21
Production system	Agropastoral	38
	Pastoral	62
Livestock disease event prior to 6 months	Abortion	90
	Retained placenta	38
	Weak newborns	60
Livestock vaccination status	Non-vaccinated	41
	Vaccinated	59
Family herd size	Cattle	2.0±1.2
	Camel	1.6±1.1
	Goat	3.5±1.0
	Sheep	3.4±1.0
Milk consumption habit	Raw	87
	Boiled	13
Zoonoses mentioned among all reported herd diseases	Mentioned at least one	10
	Mentioned as zoonoses but were not zoonoses	17
	I do not know	73
Marital status	Married	99
	Single	1
Zoonoses awareness	Yes	27
	No	73
Animal delivery assistance	Yes	100
	No	0
Aborted fetus disposal	Throw in the field	100
	Burn	0
	Bury	0
	Others	0

SD= Standard deviation

Apparent seroprevalence estimates of Q-fever, RVF and brucellosis in humans and livestock in Adadle, Somali region of Ethiopia.

Table 2. Apparent seroprevalence of Q-fever, RVF and brucellosis in humans and livestock

Zoonoses	Species	n-tested	n pos	Apparent with clustering (95% CI)
Q-fever	Human	188	50	26.3(20.2-33.4)
	Cattle	108	11	9.6 (5.9-15.1)
	Camel	141	79	55.7(46.0-65.0)
	Goat	252	123	48.8(42.5-55.0)
	Sheep	229	69	28.9(25.0-33.2)
RVF	Human	190	25	13.2(8.7-19.4)
	Cattle	108	19	17.9(11.0-27.8)
	Camel	141	60	42.6(34.8-50.7)
	Goat	252	15	6.3(3.3-11.6)
	Sheep	229	17	7.4(4.7-11.5)
Brucellosis	Human	178	5	2.8(1.2-6.5)
	Cattle	135	2	1.5 (0.4-5.6)
	Camel	171	1	0.6(0.1-4.0)
	Goat	297	0	--
	Sheep	269	0	--

The apparent seroprevalence of Q-fever in humans was 27.0% (95% CI 20.4-34.0) and RVF was 13.2% (95% CI 8.7-18.8) (table 2). The apparent seroprevalence of Q-fever and RVF in livestock was 39.0% (95% CI 35.1-42.3) and 15.2% (95% CI 12.7-18.0) respectively. The apparent seroprevalence of brucellosis in humans was 2.8% (0.9-6.4) and 1.5% (0.2-5.2), 0.6% (0.0-3.2) in cattle and camels respectively (table 2).

In livestock, the highest seroprevalence of Q-fever was found in Harsog (50.0%, 95% CI 41.4-58.6) and the least in Higlo (29.1%, 95% CI 17.6-42.9). In humans, the highest seroprevalence of Q-fever was recorded in Boholhagare (42.0%, 95% CI 28.2-57.0) and the least in Gabal (5.9%, 95% CI 0.1-28.7). The highest seroprevalence of RVF in livestock was found in Bursaredo (19.6%, 95% CI 13.7-26.7) and the least in Melkasalah (9.8%, 95% CI 4.3-18.3).

The highest seroprevalence of RVF in humans was 27.5% (95% CI 15.9-41.7) and the least was 4.4% (95% CI 0.5-14.8) in Boholhagare and Harsog respectively (Fig 7).
Camels had the highest seroprevalence of both Q-fever and RVF at herd level with 55.7% (95% CI 46.0-65.0) and 42.6% (95% CI 34.8-50.7) respectively. The lowest seroprevalence of Q-fever at herd level was found in cattle with 9.6% (95% CI 5.9-15.1) and RVF in goats with 6.3% (95% CI 3.3-11.6) (table 2).

Apparent seroprevalence estimates of brucellosis in humans and livestock in Adadle, Somali region of Ethiopia.

The apparent seroprevalence of brucellosis in humans was 2.8% (0.9-6.4) and 0.3% (0.0-1.0) in livestock. Only cattle and camels were found seropositive for iELISA and all were females. The individual seroprevalence was 1.5% (95% CI 0.2-5.2) in cattle and 0.6% (95% CI 0.0-3.2) in camels. Seropositive cattle were from Boholhagare and Gabal kebeles whereas seropositive camels were only from Melkasalah kebele. No correlation was found between risk factors and brucellosis seropositivity in both humans and livestock. All seropositive samples were males in humans and females in livestock. Seropositivity of brucellosis was decreasing as age increased in humans but increased as age increased in cattle. The only positive sample for camel was in the age between five and eight years.

Risk factors associated with human seropositivity of Q-fever and RVF

In contrast to livestock, human seroprevalence was higher in males than females. Males had on average of 30% and 90% odds of seropositivity for Q-fever (OR= 1.3; 95% CI 0.6-2.5) and RVF (OR= 1.9; 95% CI 0.7-4.8) than females respectively. Human seroprevalence increased with increasing age for RVF but not for Q-fever. In multivariable analysis, there were no significant association between any risk factor variables and seropositivity of Q-fever and RVF in humans next to kebele (table 3).

Table 3. Risk factors associated with human seropositivity for Q-fever and RVF

Predictors	*Category*	*N tested*	*Q-fever*	Odds ratio (95% CI)		*N tested*	*RVF*	Odds ratio (95% CI)	
			Number (% seropositive)	Univariable analysis	*Multivariable analysis*		*Number (% seropositive)*	Univariable analysis	*Multivariable analysis*
Kebele	Boholhagare	50	21(42.0)	1	1	51	14(27.5)	1	1
	Gabal	17	1(5.9)	0.1(0.0,0.7)	0.1(0.0,0.7)	17	2(12.0)	0.4(0.1,1.7)	0.4(0.1,1.9)
	Harsog	46	11(24.0)	0.4(0.2,1.0)	0.5(0.2,1.2)	46	2(4.4)	0.1(0.0,0.6)	0.1(0.0,0.7)
	Higlo	19	6(32.0)	0.6(0.2,2.0)	0.7(0.2,2.1)	19	1(5.3)	0.1(0.0,1.2)	0.2(0.0,1.3)
	Melkasalah	41	10(24.4)	0.4(0.2,1.1)	0.5(0.2,1.1)	42	3(7.1)	0.2(0.1,0.8)	0.2(0.1,0.9)
	Bursaredo	15	1(6.7)	0.1(0.0,0.8)	0.1(0.0,0.8)	15	3(20.0)	0.7(0.2,2.7)	0.6(0.1,2.6)
Sex	Female	91	22(24.2)	1	1	93	8(9.0)	1	1
	Male	97	28(28.9)	1.2(0.6,2.3)	1.3(0.6,2.5)	97	17(18.0)	2.2(0.9,5.4)	1.9(0.7,4.8)
Age	16-31	68	17(25.0)	1	1	85	8(9.4)	1	1
	32-48	55	13(24.0)	1.0(0.4,2.1)	1.0(0.4,2.2)	40	5(13.0)	1.2(0.4,4.0)	1.0(0.3,3.6)
	≥49	65	20(31.0)	1.3(0.6,2.8)	1.3(0.6,3.1)	65	12(18.5)	1.9(0.7,4.8)	1.5(0.5,4.3)

Risk factors associated with livestock seropositivity for Q-fever and RVF

In livestock, high seroprevalence of both diseases were found in female animals than males and older age animals (except sheep). In sheep, all seropositive samples were older than six years. The cattle with age 4-7 years had almost three times higher odds of getting Q-fever infection than those less than 4 years (OR= 2.5; 95% CI 0.2-29.6). Camel seropositivity of Q-fever and RVF were significantly associated with age (OR= 8.1; 95% CI 2.8-23.7 and OR=8.4; 95% CI 2.3-30.3) respectively (Table 4).

Table 4. Risk factors associated with livestock seropositivity for Q-fever and RVF

			Q-fever			*RVF*		
				Odds ratio (95% CI)			Odds ratio (95% CI)	
Predictors	*Category*	*N tested*	*Number (% seropositive)*	Univariate analysis	*Multivariable analysis*	*Number (% seropositive)*	Univariate analysis	*Multivariable analysis*
Cattle								
Sex	Female	97	10(10.3)	1	1	19(20.0)	---	
	Male	11	1(9.1)	1.0(0.1,7.7)	2.4(0.1,47.2)	0(0.0)	---	
Cattle								
	1-3	30	2(7.0)	1	1	0(0.0)	---	---
Age	4-7	53	5(9.4)	1.7(0.3,9.6)	2.5(0.2,29.6)	11(20.8)	0.6(0.2,1.8)	1.1(0.3,3.8)
	>7	25	4(16.0)	3.0(0.5,18.0)	4.4(0.4,49.7)	8(32.0)		---
Camel								
Sex	Female	119	75(63.0)	1	1	57(48.0)	1	1
	Male	22	4(18.2)	0.1(0.0,0.4)	0.4(0.1,1.4)	3(14.0)	0.2(0.0,0.6)	0.6(0.1,2.5)
Camel								
	1-4	43	7(16.3)	1	1	4(9.3)	1	1
Age								
	5-8	64	43(67.2)	10.4(4.0,27.1)	8.1(2.8,23.7)	29(45.3)	8.3(2.7,26.0)	8.4(2.3,30.3)
	>8	34	29(85.3)	29.6(8.5,103.1)	24.0(6.1,92.4)	27(79.4)	39.7(10.6,149.4)	34.0(8.0,145.5)
Goat								
Sex	Female	181	100(55.3)	1	1	14(8.0)	1	1
	Male	71	23(32.4)	0.4(0.2,0.7)	0.5(0.3,1.0)	1(1.4)	0.3(0.0,1.5)	0.3(0.0,2.6)
Goat								
Age	1-2	49	14(28.6)	1	1	2(4.1)	1	1
	3-6	154	77(50.0)	2.5(1.2,5.0)	2.0(1.0,4.2)	3(2.0)	0.5(0.1,2.6)	0.3(0.0,2.0)
	>6	49	32(65.3)	4.8(2.0,11.2)	3.6(1.4,9.0)	10(20.4)	5.5(1.2,24.2)	3.6(0.7,19.2)
Sheep								
Sex	Female	168	52(31.0)	1	1	16(10.0)	1	1
	Male	61	17(27.9)	1.0(0.5,1.7)	1.0(0.5,1.8)	1(1.6)	0.2(0.0,1.2)	0.2(0.0,1.5)
Sheep								
Age	1-2	0		---	---	0	---	---
	3-6	0		---	---	0	---	---
	>6	229	69(30.1)	---		17(7.4)	---	

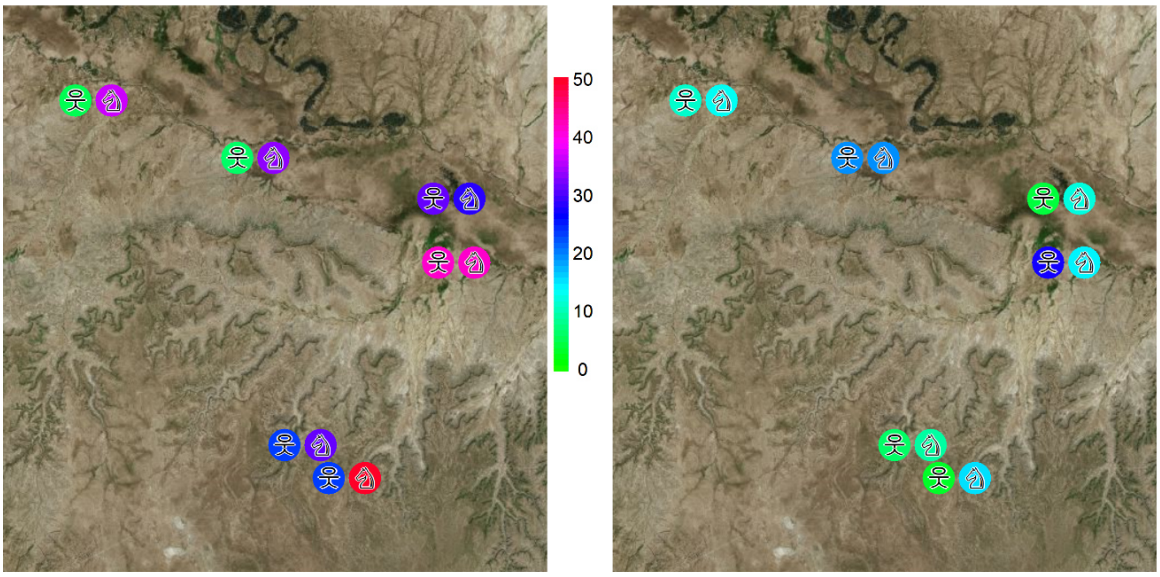

Fig 7. The apparent seroprevalence of Q-fever (left) and RVF (right) in humans and livestock in Adadle woreda, Somali region. 웃 = humans and 🐐 = livestock.

Correlation between human seropositivity and livestock seropositivity for Q-fever and RVF

Generally, there was only a weak correlation between human seropositivity and livestock seropositivity for both Q-fever and RVF. Human seropositivity of Q-fever was related with goats and RVF seropositivity was related with camels (Fig 8).

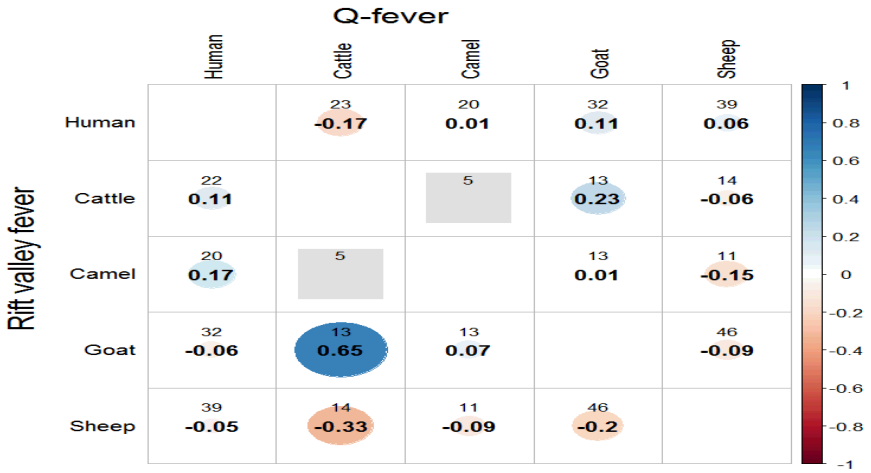

Fig 8. Correlation between humans and livestock seropositivity for Q-fever and RVF. The upper number shows herd number and the lower number shows the Pearson's correlation coefficient.

4.5 Discussion

The current findings established the seroprevalence of brucellosis, Q-fever and RVF in humans and livestock using for the first time a One Health study approach in the Somali region of Ethiopia. Mainly female animals were found in the sampled households, since pastoral communities keep animals mainly for reproduction and milk purposes. Agropastoral kebeles mostly kept small ruminants and cattle whereas in pastoral kebeles, they kept camels and small ruminants. Pastoralists had a nomadic way of life whereas agropastoralists were either transhumant or settled. Livestock abortions (90%) and weak newborns (60%) were commonly reported (Ibrahim et al., in press) and might cause negative consequences in production and economy for the households. Information about abortion incidences of pastoral livestock in Ethiopia that are vastly kept in the low lands are lacking. Abortion incidences in Ethiopia dairy cows in the highlands ranged from 2.2%-28.9% (Tulu et al. 2018).

This current finding of brucellosis seroprevalence was low. This was comparable with previous studies (Gessese et al. 2014; Gumi et al. 2013) in camels and (Terefe et al. 2017; Dirar, Nasinyama, and Gelalcha 2015; Gumi et al. 2013; Degefu et al. 2011) in cattle which reported from Somali and Oromia regions of Ethiopia. However, this study showed a lower prevalence than other previous studies in Ethiopia (Zewdie 2018; Tilahun et al. 2013; Bekele, Tessema, and Melaku 2013). This difference might be due to variation in location, husbandry and management system, breed and type of serological tests used (Terefe et al. 2017; Racloz et al. 2013). Most of the studies conducted in Ethiopia were used complement fixation test as confirmatory diagnosis unlike the current study which used iELISA. All small ruminants (n=11) which were seropositive in RBT were seronegative in iELISA. This might be that more false positives were captured by RBT but were seronegative using iELISA. Similarly (Kanoute et al. 2017; Dean et al. 2013) found 0% seroprevalence in small ruminants in Cote d'Ivoire and Togo. All seropositive were males in humans and females in livestock. Seropositivity of brucellosis in only female livestock shows their susceptibility for the infection and dominance within the herd (Zewdie 2018). The seropositivity of brucellosis had decreased as age increased in humans but increased as age increased in cattle. Higher seropositivity in older ages might be due to high risk of infection because of age and the multiple parities as they got older (ElTahir et al. 2018).

Q-fever studies in Ethiopia are rare and the few available studies focused on ticks. The present findings confirmed high Q-fever seroprevalence in humans and livestock. This is in agreement with the study (Jarelnabi et al. 2018). Camels had the highest seroprevalence for both Q-fever and RVF. Highest Q-fever seropositivity in camels was in agreement with a study from Gumi et al., (2013) in southern pastoralist livestock of Ethiopia. The seroprevalence found in camels was lower than the above cited study, which might be due to differences in the study locations (Vanderburg et al. 2014), however, was comparable to other studies (Wardrop et al. 2016; Hussein et al. 2014). Previous studies in Ethiopia showed that seroprevalence of brucellosis were lower in eastern than southern parts of the country which could hold true for Q-fever too (Yilma, Mamo, and Mammo 2016; Asmare 2014). Relatively higher Q-fever seroprevalence in both humans and livestock were recorded in agropastoral than in pastoral kebeles.

Tick infestation was reported to be higher in agropastoral than pastoral kebeles (Ibrahim et al., in press). Ticks are naturally infected by *Coxiella burnetii* and transmit the *Coxiella* from infected animals during their blood meal to other healthy animals. We have observed that the communities used ineffective diazinone as acaricide indicating that ticks were regarded by enrolled communities as a livestock health problem (Ibrahim et al., in press). The diazinone was not effective either because it was available in the market informally through from Somalia where the quality was poor as compared to the ones imported formally into the country or pastoralists used it themselves with sometimes inappropriate dilution concentration.

In agropastoral kebeles, high wind movements were observed during the dry season (June-August). Human Q-fever infection are likely to occur where livestock seroprevalence is high and such winds are common facilitating the inhalation of dust contaminated with *Coxiella* that are spread massively by livestock during abortions due to Q-fever (Kersh et al. 2010). It was common in the area to assist animal deliveries with bare hands and inappropriate management of aborted fetus, which could increase the exposure of the disease (Tschopp et al. 2013). In our study, human Q-fever seropositivity was weakly correlated with goats. This is in contrast to previous studies (Abdullah et al. 2018; Vanderburg et al. 2014; Schelling et al. 2003), but in line with recent outbreaks in Canada, Australia and Netherlands (Meadows et al. 2016; Bond et al. 2016; Enserink 2010).

Seroprevalence of Q-fever in female camels were three times higher than males. The same pattern was observed among other livestock species. Similar findings were found in various studies in the Sahel (Benaissa et al. 2017; Hussein et al. 2014).This might be due to high susceptibility of the bacteria to udder, placenta and amniotic fluids. Seroprevalence of Q-fever in camels was statistically significant associated with age ($p<0.001$). This was comparable

with the study of (Benaissa et al. 2017). Another studies showed that, like in our study-increasing age increased the seroprevalence of Q-fever in all livestock species (Klemmer et al. 2018; Browne et al. 2017; Klaasen et al. 2014) which is not surprising given the cumulative time of potential exposure. Unlike for livestock, men had twice higher seroprevalence for Q-fever than women. This might be that, males took livestock to the market and are exposed to contaminated dusts (Ibrahim et al., in press).

No Rift Valley Fever cases or seropositivity were reported in Ethiopia until today, neither in people nor in livestock. There has been recently an increasing evidence and documentation of inter-epidemic cases in East and central Africa (Halawi et al. 2019; Sumaye et al. 2013; Britch et al. 2013; LaBeaud et al. 2015). To our knowledge, this study is the first to report RVF seropositivity in humans and livestock in Ethiopia. Different models predicted the suitability of RVF occurrence in Ethiopia due to climate change, vector distribution and livestock exchanges with neighboring countries with history of RVF outbreaks (Tran et al. 2016; Anyamba et al. 2009). This study showed high seroprevalence of RVF in both humans and livestock, which lay within the ranges of reported seroprevalences in other East African countries (Clark et al. 2018). For livestock, relatively high seroprevalences of RVF were found in agropastoral kebeles for camels and cattle, but these were not significantly different to those of small ruminants. High human seroprevalence of RVF were found in our study in agropastoral kebeles. This could be due to the abundance of vectors due to closeness of these kebeles to the river (1-18 km) and main livestock species (sheep and goats) susceptibility for RVF-virus. Flooding of the Wabi-Shabele river is common in these agropastoral kebeles of Adadle woreda which might increase the suitability of amplification and transmission of RVF-Virus similar to the report by (Chevalier et al. 2010) in Madagascar. In contrast to our study, Sumaye et al., (2013) reported high seroprevalence the further away from flooding area in Tanzania.

Agropastoral kebeles were relatively nearer than pastoral kebeles to the largest livestock market (Gode) in the area. At Gode market, animals from different areas including neighboring Somalia are traded. Hence, high livestock movements for trade might increase RVFV exposure (Sumaye et al. 2013). RVF seropositivity was associated with livestock species. Among all livestock species, seroprevalence of RVF was statistically significant with increasing age only in camels. Traditionally in pastoral communities, camels were rarely sold especially females compared to other livestock species. This might increase the exposure of RVFV in female camels as they stay long in the herd. Indeed, it also shows RVFV exposure in the area since a longer time period. What seems important to highlight is the fact that in small ruminants and camels we found seropositivity also in the youngest class which suggests ongoing (inter-epidemic) transmission. The risk of human exposure during inter-epidemic

livestock infection is not yet well documented. However, one can state that an endemic situation on livestock most likely leads to endemic infection pressure in people. Unlike for livestock, men had twice higher seroprevalence for RVF than women. This was similar with the study of (Olive et al. 2016). Human seropositivity for RVF increased with age. This might be the potential risk of older people to be exposed to infected materials and vector for RVFV as in Kenya (LaBeaud et al. 2015) or the longer you live, the higher chance to get once in your life exposure to the agent.

Assessing human and livestock zoonoses seroprevalence simultaneously allowed to identify most important animal sources. In this way an added value or an integrated human and animal health approach is demonstrated. More researches is needed to use this data in view of using it to plan cost-effective intervention programs-and then to compare to other human and animal health priorities.

4.6 Conclusions

This study revealed the exposure to brucellosis, Q-fever, and RVF in humans and livestock in Adadle woreda. Our results indicated that there are several zoonotic infections in the area without clinical signs or outbreaks, including RVF transmission. The medical personnel should consider such zoonoses more carefully because most cases were either misreported or ignored at all in the daily routine diagnosis at health facilities. Hence, continuous sero-surveillance in both humans and livestock is necessary. Further researches to look more in depth into negotiating health priorities and intervention strategies in face of other prevailing health problems in people and livestock is needed. A One Health study approach as used here allowed to detect most important sources for people of three zoonotic diseases and provided evidence of needed future negotiations on potential actions in surveillance and interventions.

4.7 Acknowledgments

We would like to thank the Swiss Agency for Development and Cooperation (SDC) for funding this study. This study would not have been possible without the support of Adadle communities especially, woreda administrators, human and animal health bureaus, zonal administrators and pastoral/agropastoral communities. We would like to thank the Armauer Hansen Research Institute (AHRI) for the support with the lab analysis, particularly Robel Gesese,

Azeb Tarekegn, Ashenafi G/giorgis, Ashenafi Alemu, Mahlet Usman, Marechign Yimer, Metasebiya Tegegn, Melaku Tilahun and Biruk Yeshitela. We also thank to Shazali Mohammed and Asad Ibrahim who helped us during blood samples collection. Lastly, we would like to thank Jigjiga University and the JOHI team for their collaboration and support.

Chapter Five: Livestock health and zoonoses: Awareness and practices among pastoral and agro-pastoral communities in the Somali Region, Ethiopia

Livestock health and zoonoses: Awareness and practices among pastoral and agro-pastoral communities in the Somali Region, Ethiopia

Mohammed Ibrahim[1, 2, 3], Esther Schelling[2, 3], Jakob Zinsstag[2, 3], Jan Hattendorf[2, 3], Rea Tschopp[2, 3, 4]

1 College of Veterinary Medicine, Jigjiga University, Ethiopia

2 Swiss Tropical and Public Health Institute, Department of Epidemiology and Public Health, Basel, Switzerland

3 University of Basel, Switzerland

4 Armauer Hansen Research Institute, Addis Ababa, Ethiopia

This article has been submitted to Nomadic Peoples Journal

Abstract

Zoonoses awareness level and associated practices in pastoral/agropastoral communities was assessed in Somali region of Ethiopia. Sixty-two percent of the 100 respondents were pastoralists and 38% were agropastoralists. We used cross-tabulation statistics and logistic regression to determine the association between awareness level for zoonoses and explanatory variables. About three-quarters of respondents did not know about “zoonoses”. Risky practices reported included raw milk consumption, assist animal deliveries with bare hands and inappropriate management of aborted foetuses. Insufficient veterinary services and poor livestock marketing were reported. This study highlights the need for community awareness and education about zoonoses and livestock marketing.
Key words: awareness, marketing, pastoral, Somali region, zoonoses

5.1 Introduction

Pastoralism is a livestock production system, used by millions of people in arid and semi-arid regions worldwide (Butt 2016). Pastoralism applies where 50% or more of household gross revenue (total value of marketed production plus estimated value of subsistence production consumed within the household) comes from livestock or livestock-related activities (for example caravan trading) or where more than 15% of the household's food energy consumption comes from milk or milk products produced by the household. Agro-pastoralism applies when more than 50% of household gross revenue comes from crop-farming and 10-15% of income comes from livestock (Swift 1988). Most mobile pastoral communities remain economically, politically and socially marginalized within their countries. They utilize arid grasslands which support livestock but are not suitable for other agricultural production systems (Schelling et al. 2007). Over 20 million nomadic and semi-nomadic pastoralists live in the Horn of Africa drylands (Venton et al. 2014).

Ethiopia has the largest livestock population in Africa. The livestock sector contributes considerably to the Ethiopian economy (45% of agricultural gross domestic product (GDP), 19% of national GDP) (CSA 2017). Approximately 85% of Ethiopia's population is rural, with livestock contributing to the livelihood of 80% of rural people (Shapiro et al. 2017). There are an estimated 12-15 million Ethiopian pastoralists, primarily in the Somali, Afar, Oromia, Southern Nations Nationalities and Peoples, Dire Dawa, Benishangul, Gumuz, and Gambella regions. In 2008/09, the Intergovernmental Authority on Development estimated the contribution of the pastoral livestock population to be 1.2 billion USD out of the total national livestock value of 2.98 billion USD (Venton et al. 2014). Despite their contribution, pastoral communities were reported as among the poorest and most vulnerable rural inhabitants in Ethiopia (IFAD 2016).

Zoonoses are diseases and infections naturally transmitted between human and vertebrate animals. Effective management of zoonoses benefits from a One Health approach, creating synergistic benefits from the collaboration of human and animal health sectors (Zinsstag et al. 2015). Emerging and re-emerging diseases at the human-animal interface are increasing at an alarming rate, including those from animal source food (World Bank 2012). A One Health approach is ideal to tackle such threats by using surveillance, diagnosis and control of zoonotic diseases at the human-animal interface through coordination and communication between the human and animal health sectors (Zinsstag et al. 2016). The majority of neglected pathogens are endemic zoonoses, like brucellosis, which have tremendous health and economic impacts in developing countries despite little consideration in the global health agenda (Roth et al.

2003). These endemic zoonoses not only cause human disability but also negatively impact livestock production and subsequently pastoral community livelihoods (Maudlin, Eisler, and Welburn 2009). Zoonoses threats have increased due to pathogen evolution and adaptation to new hosts and environments with impacts on human and animal health. This increase is due to many different factors which cannot be addressed sufficiently through one individual sector (FAO, OIE, and WHO 2012). Zoonoses, particularly in developing countries, are widely unreported or underreported (Schelling et al. 2007). This is particularly true for pastoralist communities who have poor access to health and veterinary services (Montavon et al. 2013). Zoonotic disease impacts are generally high in low income countries due to lack of veterinary services, lack of adequate policies for pastoralism and regulations for zoonoses management which put the community at risk of zoonotic infections at human-animal interface (Bonfoh et al., 2016).

Ethiopia is among the countries with the highest zoonotic infection rates (Pieracci et al. 2016). The Somali regional state is the second largest region in Ethiopia, with the largest pastoral community in the country (57% of Ethiopian pastoralists) (Elias 2008). Despite the close contact between humans and animals in pastoral areas, the perception of the community on practices that favors zoonotic transmission is low (Tadesse 2016).

Most studies on zoonoses in Ethiopia consider only the animal population, and studies about awareness of zoonoses and practices in Ethiopia are rare. This study is the first to assess pastoral and agropastoral Somali community awareness on zoonoses and the associated practices that favor zoonotic infection transmission between human and animals in the Adadle woreda (district) of the Somali regional state.

5.2 Material and methods

5.2.1 Study area

Adadle woreda is in the Shabelle Zone of the Somali region of Ethiopia in the lowlands of the semi-arid WabeShabale River subbasin. The mean annual rainfall, based on Gode data, is about 300 mm (Gebre-Mariam 2007). The main rainy season, called “Gu”, lasts from March to May and the short dry season, known as “Xagaa”, is from June to August. “Xagaa” is followed by the short “Dayr” rains between September and November and the long dry season “Jilaal” from December to March. The woreda consists of 15 kebeles (Gebre-Mariam 2007), with a total population of 99,487 (SRBoFED 2014) (Figure 9). The majority of people living in Adadle are pastoralists (60%) and agro-pastoralists (28%), while 10% practice riverine cultivation (Gebre-Mariam 2007).

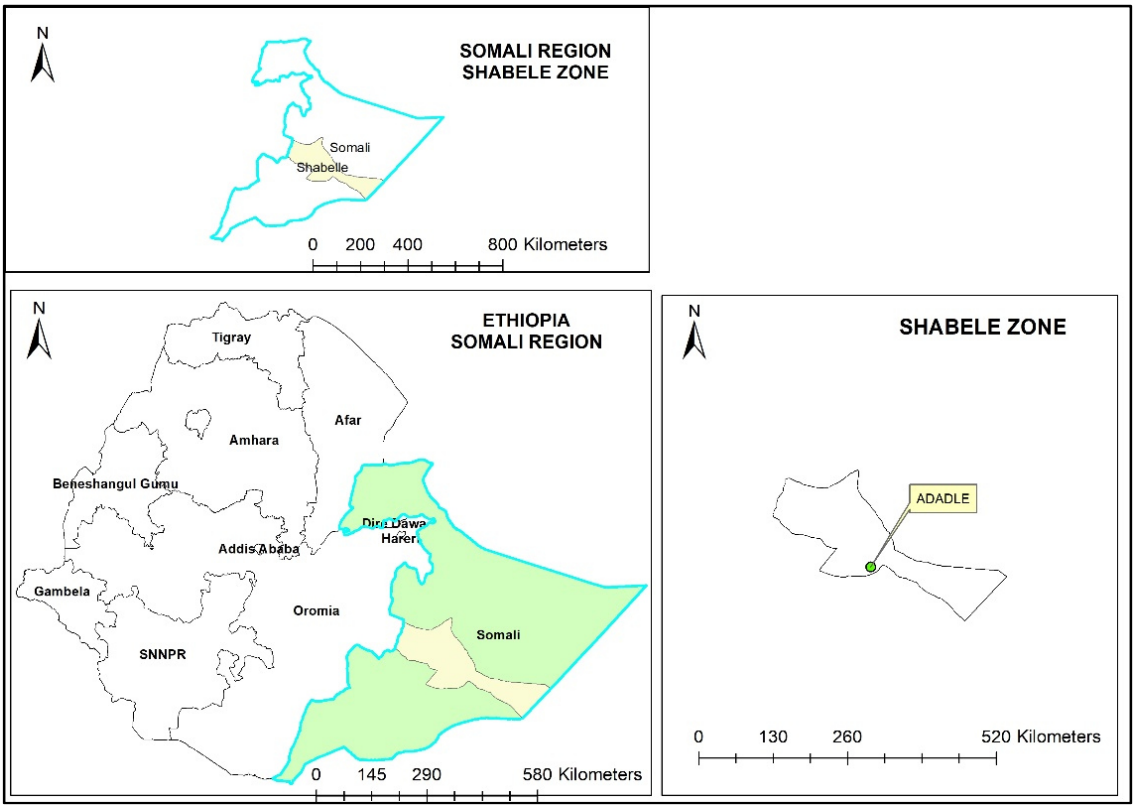

Fig 9 Map of the study area

5.2.2 Study Design and study population

A multi-stage cluster sampling technique was used to select livestock rearing households and recruit adult interviewees in pastoral and agropastoral communities. Focus group discussions (FGDs) were organized in all selected kebeles together with the kebele administrators, elders and religious leaders.

5.2.3 Sampling and data collection

Adadle woreda has 15 kebeles. Two kebeles were excluded from the study due to lack of existing mobile phone network and poor accessibility. Six kebeles were selected randomly from the remaining thirteen kebeles with selection probability proportional to the human population size. Melkasalah and Harsog were exclusively pastoralist kebeles, whereas Boholhagare, Bursaredo, Higlo and Gabal were agropastoralist, practicing both livestock and crop production. Although Boholhagare and Higlo were agropastoralist kebeles, people mainly depended on livestock, cultivating crops only during rainy seasons.

A village list was available for each agropastoral kebele. All villages in the kebele were assigned numbers. Community members (kebele administrators, elders and religious leaders) drew a minimum of eight numbers from a bag to select the villages. In each selected village, households were selected by spinning a pen and proceeding in the direction of the pen head. All households in that direction were included. We selected from the two pastoralist kebeles as follows: Kebele administrators reported which villages had concentrations of mobile pastoralist camps in the vicinity. We visited all reported villages and selected the camp ('Reer') with the highest number of tents. We included all households of the selected Reer. Within the selected households, all individuals who were present at time of interview and ≥ 16 years old were eligible to participate in the study.

We conducted semi-structured interviews and focus group discussions (FDGs) between May and August 2016. We pre-tested the questionnaire with open and closed questions in Fafan, Jigjiga zone, where livelihoods are comparable to those of Adadle woreda, and adjusted it according to the limitations and understanding of the questions. The questionnaire was translated from English to Somali. Individual interviews were 15-25 minutes long.

For FGDs, we consulted kebele administrators, elders and religious leaders to select community members (men and women) who had good knowledge and experience on livestock production and health. We conducted eight FGDs with 6-10 people, including pastoralists and

agro-pastoralists, religious leaders, local elders and community animal health workers. Six were with men and two with women. The discussions took 45-60 minutes. We made an audio recording of each discussion, following informed consent from all group members. The goal of FGDs was to obtain in-depth information about livelihoods, animal health problems, veterinary services, and zoonotic diseases awareness in areas not covered in the individual interviews. In discussions with the pastoral/agropastoral communities, we agreed to use the local phrase “Cudurada dadka iyo duunyadaba wadaagaan”, which literally means ‘diseases shared between humans and animals’ since there was no single word for zoonoses in the local Somali language. Individual interviews and FGDs were conducted in the local Somali language.

5.3.4 Data analysis

The data was double entered the individual interviews closed questions into Microsoft Access and compared entries using Epi-info (Centres for Disease Control and Prevention, Atlanta GA, USA, version 3.5.1.). A single entry was made to categorize text variables using a Microsoft Excel spreadsheet. Quantitative data, including new binary variables about awareness and reported zoonoses, was analysed using STATA version 14 (Stata Corporation, College Station, TX, USA).

Awareness was evaluated by asking whether the respondents knew/had heard about zoonoses (Yes/No). Other relevant variables were included, such as raw milk consumption, aborted fetus disposal, assist animal deliveries and mentioning zoonotic diseases. Family size was defined as husband and/or wife and their children. If a family member was not present during the interview, the member was still counted in the family size. The family herd was the number of livestock belonging to that family. ‘Herd zoonoses’ were defined as zoonotic diseases/symptoms/syndromes reported by the respondents as herd problems.

Descriptive and analytical statistics was used for data analysis. Computed cross-tabulation statistics and logistic regression were used to determine the association between the binary variable awareness of zoonoses and the associated practices/risk factors in the study area. A p-value below 0.05 was considered as statistically significant. Variables associated with awareness of zoonoses ($p < 0.2$) by the Wald test in univariable analysis were incorporated into a final multivariable model, except gender and age which were always included. The likelihood ratio test was calculated in the multivariable model analysis. FGDs recordings were transcribed, translated in to English, and imported into MAXQDA 12 (VERBI GmbH Berlin, Germany) for qualitative data management and analysis. The framework method for analysis

of qualitative data was used (Gale et al. 2013 4). Themes and codes were created within the software and related with each of the FGDs for thematic and content analysis.

The five reported herd problems, in order of judged importance from the 100 individual interviews, were further compiled into the top five diseases, according to the most frequently reported diseases and with a weighting of counts to consider if the disease was mentioned as first important (frequency multiplied by a factor of 2) or as second important (multiplication with 1.5) herd problem. Ranks 3, 4 and 5 were not weighted. For FGDs, the reported livestock diseases/symptoms/syndromes were listed according to each kebele with their frequencies.

5.3.5 Ethical approval

The study complied with ethical standards according to the “Ethikkommission Nordwest-und Zentralschweiz” (EKNZ) in Switzerland (BASEC UBE-req.2016-00204) and the Jigjiga University Research Ethics Review Committee (JJU-RERC002/2016). Oral consent was obtained from the participants.

5.4 Results

5.4.1 Findings from focus group discussions

Community livelihood

Participants of FGDs in all selected kebeles reported camels as the preferred livestock species, despite that in some kebeles they could not financially afford camels and kept only small ruminants and cattle. The main reasons included high milk and meat yield, good market prices even during drought period, means of transportation, cultural reasons, funeral use, reparation, miraculous creature mentioned in the Quran, and for attributes such as strength, beautiful walking gait, resistance to diseases and drought tolerance. Camels have many songs and poems in Somali society. Camel milk was reported to have medicinal value and was used for diseases like jaundice and constipation.

Animal health problems

During mobile pastoralist migrations, the animals encounter problems with insects/ectoparasites, like ticks, lice, flies, and mosquitoes, particularly when animals from different locations come together. The respondents reported that the acaricide diazinon was not effective in the area. A majority of the communities applied acaricide manually by rubbing it on the animals. Ticks were perceived as the major source of animal health problems in Adadle woreda and were thought to transmit most animal diseases. High mortality rates in small ruminants, especially pregnant females, were reported in Melkasalah and Higlo. The cause was reported either as unknown or diarrhea. In Boholhagare, more cattle than small ruminants experienced health problems, and among the camel diseases, respiratory disease syndrome and helminthiasis were mentioned as emerging camel diseases. Camel respiratory disease syndrome was mentioned in all areas except Higlo. The disease emerged in the area in 2006 and has since become endemic. Tetanus (Waraf), thought to be caused by tick bites, was prevalent in Boholhagare.

Diseases/symptoms/syndromes of different livestock species that were mentioned more than twice in FGDs were listed in a table 5.

Table 5. Major reported livestock diseases and syndromes/symptoms in Adadle woreda, Somali region, with Somali names in bracket.

Camel	Small ruminants	Cattle
Trypanosomiasis (Dhukaan)*	Sheep and goat pox (Caanole/Furuqa adhiga)	Anthrax (Kud)
Anthrax (Kud)	Tetanus (Waraf)	Bovine ephemeral fever (Kududiye)
Cough (Qufac/Qaaxo)	Diarrhea (Shuban/Xaar)	Foot and mouth disease (Cabeeb)
Pneumonia (Dhugato)	Foot rot (Raaf-dilaac)	Plant poisoning (Hergo)
Diarrhea (Shuban/Xaar)	Contagious ecthyma (Af-garafow/ Minja buur)	
Camel pox (Furuqa geela/Caanole)	Retained placenta (mandheer kudhag)	
Nasal discharge (Diif/Duuf)		
Nervous disorder (Shimbir)		
Camel sudden death syndrome (Goror-duuf/ Hadharqinin yayna kugu dhicin hashe)		
Helminthiasis (Caal/Gooryaan/dhuuqe)		

Wildlife attacks (Hyena, fox and crocodile), drought, and lost animals were reported as additional livestock health problems in the area.

* Dhukaan is the local name for trypanosomiasis which is used only for camels and hroughout the document, it refers to *Trypanosoma evansi*

Veterinary services

All kebeles reported that they have poor veterinary services. Even though there were annual vaccination campaigns, the services did not reach all mobile pastoralists who lived in remote areas. Due to the large territory of the woreda and the lack of sufficient community animal health workers and animal health professionals, a team from the regional bureau of livestock and pastoral development came to vaccinate livestock in the woreda but “left as soon as they finished their per diems before covering more areas”. Animal owners often bought drugs from private veterinary drug shops in Gode town and self-medicated their animals. If the animal owner did not have money to buy veterinary drugs, they sold some animals to get the needed cash. Respondents reported that the quality of products in private veterinary drugs shops in Gode was lower than those available from the woreda agriculture bureau. Respondents said that the woreda agriculture bureau received drugs by quota from the regional government, but the amount was only sufficient to serve a small proportion of the kebele total livestock population. In the past, animal owners bought inexpensive good quality veterinary drugs from a government organization in Gode, the South Eastern Rangeland Project, but it no longer exists. Respondents reported that there were no veterinary services or animal health professionals to diagnose and treat animals in their communities. Animal owners reported that, because they were not trained animal health professionals, they sometimes inadvertently killed animals through inappropriate use of drugs (administration route, dosage).

Zoonoses awareness

With the exception of Harsog, FGD participants reported that they were aware of or had heard about zoonotic diseases. People in Harsog mentioned that they were only aware of diseases that are transmitted from animals to animals but not from animals to humans. In one kebele, HIV-AIDS was thought to be the worst zoonotic disease. It was assumed that animals get infected by eating left-over food contaminated with saliva of an HIV positive person or by grazing pastures contaminated with stool from HIV positive people. The diseases, syndromes/symptoms reported as zoonoses were trypanosomiasis, cough, anthrax, malaria, fever, tuberculosis, diarrhoea, haemorrhagic septicaemia, contagious bovine pleuropneumonia, bovine ephemeral fever, and pox virus. Tuberculosis was reported as a disease easily transmitted from animals to humans.

Some respondents believed malaria could be transmitted from animals to humans through raw milk consumption. A similar perception was reported among pastoralists in Afar, Ethiopia

(Legesse et al. 2018 1). In Boholhagare, a cattle disease known as bovine ephemeral fever was mentioned as also seen in people. The human disease causes febrile illness with inability to stand or walk. Respondents reported that public health professionals said the disease is common in cattle and treating people causes sudden death. The community reported not receiving any official information to raise awareness about zoonoses, stating that our study was their first opportunity to discuss about zoonoses.

Awareness of zoonoses was reported as important because animals could be treated or disease in people could be prevented. Furthermore, owners would understand the treatment to eradicate the disease. However, after we explained about zoonoses in Harsog kebele, a participant stated that it is not good to know about zoonoses because people will fear animals when they hear that diseases can be transmitted from animals to humans.

Livestock marketing

Respondents reported that animal prices were low during the entire study period but varied between seasons, with rainy season getting better prices. Gode was reported as the only livestock market in the area. For some livestock owners in Adadle woreda, it could take up to 15 days to take animals to the Gode market. It received a large livestock population from different areas (within the woreda and regionally), and traders could buy animals at the lowest prices. Brokers further lowered prices as much as possible. Animals sometimes lost body condition during the journey to Gode, which would impact the market price. Walking camels across the bridge leading in to Gode was mentioned as problematic, as camels fear the bridge. Once arrived, they would sell all camels, even at low price, because it was perceived as impossible to drive them over the bridge again. Respondents reported that they rarely sold their animals in Ceelbarde town on the Ethiopia-Somali border. The animal owners mentioned that livestock marketing would improve if a company was buying the animals. In the past, the Livestock and Meat Board (LMB) used to weigh and tag animals and paid money accordingly. LMB was established by Emperor Haile Selassie in 1964 and functioned until the Derg regime dissolved it in 1980. The livestock market in Gode was reported as unsatisfactory since people who buy animals there have little money, buy only small numbers and take them to the Somaliland border for export.

Respondents said if the animal owner can afford it, he takes his animals to Kebribayah, Jigjiga or Hartasheik cities where there are better markets. However, the federal custom office confiscates all animals if they try to take them to big city markets. When the market is only within country, there are not many people buying livestock. Animal health problems, security

and fluctuating demand from Arab countries were the main factors mentioned by respondents to affect livestock marketing in Adadle woreda. Lack of security was said to negatively affect marketing by causing transportation shortages. Poor veterinary services were also reported to lead to bad marketing, since people will not buy sick animals.

Demand from Arab countries has impacted the market. Livestock prices fluctuate depending on species type and age of animals desired by Arab countries and during important Muslim holidays (e.g., Eid Al-Adha and Mowlid). Respondents mentioned they were hit hard in 1998/99 and 2000/1 when Saudi Arabia banned livestock imports from Ethiopia, especially from Somali region, due to Rift Valley Fever outbreaks in neighbouring countries.

5.4.2 Findings from individual interviewees

Demographic characteristics of the respondents

A total of 68 males and 32 females participated in the interview survey. The mean age of respondents was 40 years. Ninety nine percent of respondents were married and mean family size was 8.5 (minimum of 1 and maximum of 28). Sixty-two percent of respondents were pastoralists and thirty-eight percent were agro-pastoralists. Livestock species kept by the households included sheep (92%), goats (90%), cattle (74%), and camels (37%), with mean herd sizes of 37.5, 46.8, 9.6, and 7.2, respectively. Overall composition of all reported livestock was goats (49%), sheep (20%), cattle (7%) and camels (1%). Pastoralists had higher livestock species diversity in their herds than agropastoralists.

Risky practices among pastoral and agro-pastoral community

All respondents reported that they had contact with animals and assisted animals during delivery with bare hands. All aborted foetuses were thrown in the fields without burial, burning or any other management technique. Eighty seven percent of respondents consumed raw milk regularly. All respondents mentioned using self-administered veterinary drugs for their animals. It was reported that animal owners could inadvertently kill animals they self-medicate due to inappropriate dosage and/or route of drug administration. Other treatment choices in addition to self-administered veterinary drugs included traditional medicines such as herbs and practices such as using fire to treat lung diseases (45%) and the use of the Quran (23%).

Animal health problems

The five most frequently reported livestock diseases/syndromes, in descending order, were anthrax, trypanosomiasis, foot and mouth disease (FMD), nasal discharge and diarrhoea. Other reported herd diseases/symptoms of livestock were pox virus, fever, helminthiasis and cough. Disease syndromes related to livestock reproductive problems/disorders, noted within six months prior to the interviews, included abortions (90%), weak offspring (60%) and retained placenta (38%). The diseases reported by the respondents as zoonoses included anthrax, cough, haemorrhagic septicaemia, FMD, malaria and tuberculosis.

Community awareness about zoonoses

In total, 73% of respondents had no awareness about zoonotic diseases. The awareness level was comparable in pastoral (26%) and agro-pastoral (29%) communities (Table 6). Awareness varied between kebeles, with the highest proportion found in Boholhagare (55%) (Table 6). Only 10% of respondents mentioned at least one zoonotic disease correctly, 17% did not mention any zoonotic disease at all and 73% mentioned non-zoonotic diseases. Out of 100 interviewees, 59 reported vaccinating their animals at least once during the past 3 years. Reported vaccination coverage was 7%, 6% and 1% for cattle, small ruminants and camels, respectively. The type of animal vaccine mentioned by the respondents included camel pox, sheep and goat pox, FMD, ovine pasteurellosis, anthrax and haemorrhagic septicaemia. It was said that animal health professionals did not inform owners on which vaccines were administered to their animals. Respondents brought their animals for vaccination when a campaign was held despite not knowing which vaccines were on offer. During campaigns, vaccine was provided by the government free of charge to pastoral and agropastoral communities.

Table 6. Logistic regression analysis of zoonotic diseases awareness in pastoral & agro-pastoral communities, Somali region, Ethiopia, n=100

Category	Awareness %(n/N)[a]	Univariable Unadjusted OR(95% CI)	p-value	Multivariable OR (95%CI)	LRT(p-value)
Kebele					
Boholhagare	54.6 (6/11)	1		1	
Gabal	15.8 (3/19)	0.2 (0.0,0.9)	0.03	0.2 (0.0,2.3)	
Harsog	14.3 (2/14)	0.1 (0.0,0.9)	0.04	0.2 (0.0,2.7)	
Higlo	20.0 (2/10)	0.2 (0.0,1.5)	0.12	0.3 (0.0,3.6)	
Melkasalah	25.0 (5/20)	0.3 (0.1,1.3)	0.11	0.4 (0.0,4.2)	
Bursaredo	34.6 (9/26)	0.4 (0.1,1.9)	0.26	1.5 (0.2,15.0)	0.26
Gender					
Female	21.9 (7/32)	1		1	
Male	29.4 (20/68)	1.5 (0.6,4.0)	0.43	1.9 (0.4,8.7)	0.41
Age					
16-31	19.4 (7/36)	1		1	
32-48	30.0 (12/40)	1.8 (0.6,5.2)	0.29	0.8 (0.2,3.2)	
≥49	33.3 (8/24)	2.1 (0.6,6.8)	0.23	0.6 (0.1,3.2)	0.85
Family size					
1-6	4.0 (1/25)	1		1	
7-10	29.6 (16/54)	10.1 (1.3,81.2)	0.03	39.1 (2.3,673.9)	
≥11	47.6 (10/21)	21.8 (2.5,192.2)	0.01	68.0 (3.6,1291.4)	0.001*
Production system					
Agropastoral	29.0 (11/38)	1		-	-
Pastoral	25.8 (16/62)	0.9 (0.3,2.1)	0.73	-	-
Disease event					
Disease absence	20.0 (1/5)	1		-	-
Abortion	19.2 (5/26)	1.0 (0.1,10.5)	0.97	-	-
Retained placenta	22.2 (2/9)	1.1 (0.1,16.9)	0.92	-	-
Weak calf	31.7 (19/60)	1.9 (0.2,17.7)	0.59	-	-
Vaccination					
Non-vaccinated	22.0 (9/41)	1		-	-
Vaccinated	31.0 (18/59)	1.6 (0.6,3.9)	0.35	-	-
Herd zoonoses					
Not mentioned	19.6 (10/51)	1		1	
Mentioned	34.7 (17/49)	2.2 (0.9,5.4)	0.09	0.7 (0.1,3.5)	0.66

OR= odds ratio; CI= confidence interval, n= number of respondents; N= total number of respondents; a= Awareness defined as heard about zoonoses (yes/no); 1= reference group; *= statistical significant

Univariable logistic regression analysis showed that family size and kebele (Gabal & Harsog) were statistically significant ($p<0.05$) for zoonotic diseases awareness in the area (Table 6).

The following variables with $p \leq 0.2$ by Wald test were included in the multivariable logistic regression model: kebele, gender, categorized age, categorized family size, and herd zoonoses. Only large family size was found to be statistically associated with zoonoses awareness (Table 6). (Family size 7-10: OR 39.0, 95% CI 2.3-674; family size 11 or higher: OR 68.0, 95% CI 3.6-1291)

5.5 Discussion

The present study revealed low awareness about zoonoses among pastoral and agro-pastoral communities in the study area. This result was in agreement with studies in livestock keepers done in Nepal (Kelly et al. 2018), India (Singh et al. 2019), Qatar (Alho et al. 2018), Tanzania (Mangesho et al. 2017), and Afar region, Ethiopia (Hadush Desta 2015). Zoonoses awareness was comparable in agro-pastoral and pastoral communities. Indian and Tanzanian studies reported higher awareness on zoonotic diseases in smallholder dairy as compared to traditional livestock keepers (Singh et al. 2019; Swai, Schoonman, and Daborn 2010). This might be because agro-pastoralists and small dairy farmers are sedentary and more likely to meet health professionals or people from cities who have information about zoonoses.

Livestock markets were essential for the livelihood of the communities in the area. Lack of regular local buyers and demand fluctuations from Arab countries had negative impacts on livestock trade. Confiscation of animals by the customs office and animal diseases were reported as major factors which hinder livestock marketing.

Veterinary services in general and animal vaccination campaigns specifically were infrequent in the area because of the imbalance between a huge livestock population, insufficient vaccine supply and capacity of animal health professionals to reach a reasonable coverage. The regional livestock and pastoral development bureau mentioned that the imbalance of livestock population and vaccine coverage was due to lack of funds. The bureau reported that, they requested about 33 million Ethiopian birr in 2011 (Ethiopian calendar) to reach 75% vaccination coverage but received only 9 million Ethiopian birr. Animal health professionals did not inform the pastoral/agropastoral communities about the type of livestock vaccines provided. This might be due to lack of awareness and interest of the communities. It might also be common practices for animal health professionals in the region. The few vaccines

reported by the respondents despite the availability of more vaccines in the country shows communication gaps between the communities and animal health professionals. Even though camels were the preferred species in the study area, camel vaccination coverage was the lowest (1%) compared to other livestock species (≥6%). In Kenya, the lowest vaccination coverage against Rift Valley Fever was also found in camels as compared to other livestock (1.2%) (Kimani et al. 2016). Mobile pastoralists were the only ones who could afford keeping camels, as they constantly move from place to place to access new pastures. For camels, pasture fodder includes bushes, shrubs, grasses and trees. Camel vaccines are also lacking in the country, with only camel pox vaccine readily available. The reported vaccines provided were foot and mouth disease and anthrax for cattle and ovine pasteurellosis, sheep and goat pox for small ruminants. Many more animal vaccines are produced in the country, including anthrax, black leg, bovine pasteurellosis, contagious bovine pleuropneumonia, contagious caprine pleuropneumonia, foot and mouth disease, lumpy skin disease, ovine pasteurellosis, peste des petits ruminant, sheep and goat pox, and camel pox. Virtually all livestock keepers bought veterinary drugs from private shops and self-medicated their animals due to lack of sufficient animal health professionals in the area. Ticks were reported as a major source of livestock diseases, as previously reported (Zinsstag et al. 2016). Health of animals was influenced by the occurrence of insect-vectors of diseases, the availability of quality veterinary services and access to information – and altered the possibility to sell animals and negotiate prices with the irregular buyers.

A larger family size was significantly associated with zoonoses awareness of the respondents. The larger number of household members seemingly increases the chance of someone having received information on zoonoses. This finding is in contrary to Punjab, India where lower knowledge on zoonoses was reported in bigger households (Singh et al. 2019). This might be due to different norms and knowledge sharing cultures in the two communities. The vast majority of individual interviewees reported that they had contact with and assisted animals during delivery without protective materials, consumed raw milk and disposed of aborted fetuses without burial or burning. Among diseases reported by respondents as zoonoses, only 45% of them were actually zoonoses, which indicate poor awareness and misconception about zoonoses in the communities. This is in agreement with a study in Tunisia (Khbou et al. 2019). Low awareness of the community about zoonoses and inappropriate practices reported in the area might promote/facilitate disease transmission from animals to humans.

5.6 Conclusions

Lack of regular buyers, unpredictable demand from Arab countries, animal confiscation by the customs office and livestock diseases were major factors hindering livestock marketing. Poor veterinary, information and market services were recorded in this study. These factors lead to market disruption and decrease income of the communities. Due to low awareness on zoonoses, inappropriate practices and poor veterinary services in the area, the likelihood of zoonoses transmission between humans and animals should be considered high and may favor sustained zoonotic infections in the area with subsequent decrease in household income and increased human and animal health costs. These findings highlight the urgent need for community awareness and education about marketing, livestock health and zoonoses.

Further research on socio-cultural perspectives of community health awareness and livelihood coping strategies, such as alternative incomes, is warranted, particularly in the face of climate change with more extreme weather conditions and events like prolonged drought periods in the semi-arid regions of Ethiopia. The role of camels in the livelihoods of pastoral communities in Somali region is likely to become even more important in future.

Chapter Six: Livestock trade and its associated diseases in Somali region

Livestock trade and its associated diseases in Somali region

Mohammed Ibrahim[1, 2, 3], Rea Tschopp[2, 3, 4], Jakob Zinsstag[2, 3], Esther Schelling[2, 3]

1 College of Veterinary Medicine, Jigjiga University, Jigjiga, Ethiopia
2 Swiss Tropical and Public Health Institute, Department of Epidemiology and Public Health, P.O. Box, CH-4002 Basel, Switzerland
3 University of Basel, Petersplatz 1, CH-4003 Basel, Switzerland
4 Armauer Hansen Research Institute, Addis Ababa, Ethiopia

This article is ready to be submitted to Pastoralism: research, policy and practice journal

Abstract

Livestock trade is essential for the livelihoods of pastoralist communities in the Somali region. In-depth interviews were conducted to assess livestock trade and its associated diseases in Adadle woreda of Somali region. Twenty-two local livestock traders (17 males and 5 females) were interviewed. Focus group discussions were conducted with Gode livestock market brokers. Additionally, respondents from customs and revenue authority and quarantine office were interviewed. Small ruminant species dominated the livestock trade. Most of the traders sold their animals to near local markets. Gode, Jigjiga and Harteshek were the dominant livestock markets to sell respectively. High input trade costs reported included; buying animals, transportation, broker, tax, treatment, feed, labor and personnel costs. The main factors hindering livestock trade were drought, disease, security, conflicts, hard currency exchange rate fluctuation and poor market. The reported trade problems exacerbate if drought and/ diseases occur. Trypanosomiasis, anthrax, sheep and goat pox, helminthiasis, foot and mouth disease (FMD), tick infestation, contagious caprine pleuropneumonia, diarrhea, nasal discharge and Nairobi sheep disease were the most common outbreaks reported to hinder livestock trade. Livestock demand increased during Arafa, Mowlid, Eid-Al Adha religious ceremonies, and during the rainy season. Gode was the main livestock market in the area and received high numbers of animals from various parts of the surrounding zones as well as neighboring Somalia. The major livestock trade destinations reported were Somaliland, Puntland, Saudi Arabia, United Arab Emirates, Oman, Qatar, Egypt and Yemen (no market currently due to war). The customs and revenue authority reported that livestock export increased during strong control of contraband activities and vice-versa. Informal livestock trade share was high in the current livestock trade. The major livestock diseases targeted by the quarantine office were; FMD, brucellosis, sheep and goat pox, camel pox, ovine and bovine pasteurollosis, and Peste des petits ruminants (PPR). Export animals were vaccinated according to the type of vaccines requested by the importing countries. Quarantine office reported that only male animals were allowed for export according to Ethiopian livestock trade regulations. Federal government was reported to some extent as part of the problem in the informal trade. Despite the existing livestock trade challenges, livestock trade supported many poor pastoralist communities. The dominant livestock markets could be used as critical points for zoonotic disease control interventions in the future. Knowledge on livestock trade and its associated diseases, routes and systems in place can contribute to designing appropriate policies and strategies that could improve the economy, health and well-being of pastoralist communities in Somali region.

Key words: disease, export, livestock, quarantine, trade

6.1 Introduction

Livestock is essential asset of pastoralist communities for income generation, food security and social capital (Rettberg et al. 2017 and Zinsstag et al., 2016). Pastoralist communities keep livestock mainly for milk, meat, transportation, income and social status. Cross-border livestock trade is important component for the livelihood of pastoral and agropastoral communities and supports about 17 million people in the horn of Africa (Tesfaye and Amaha 2018) (Eid 2014). The livestock sub-sector is growing at rate of 7% annually in developing countries, which is much faster than the agricultural sector as a whole and expected to become the most important sub-sector in terms of value added (Scoones and Wolmer 2006). In recent years, substantial investments in livestock trade in pastoral areas of East Africa was evident to improve the livestock export subsequent poverty alleviation. For successful poverty alleviation, understanding the livelihood of pastoralist communities is critical (Aklilu and Catley 2009). Horn of Africa countries have long standing experience in livestock trade with the Middle East mainly Saudi Arabia through complex trade routes and dealers. Thus, food safety regulations and veterinary services should be implemented to prevent damaging diseases including zoonoses who currently persist at low level (Scoones and Wolmer 2006).

Ethiopia has the largest livestock population in Africa. The livestock sub-sector contributes considerably to the Ethiopian economy (45% of agricultural gross domestic product (GDP), 19% of national GDP) (CSA, 2017). Approximately 85% of Ethiopia's population is rural, with livestock contributing to the livelihood of 80% of rural people (Shapiro et al. 2017). About 40-50% of cattle and goats supplied to domestic markets belong to pastoral communities (Aklilu and Catley 2014). It is also estimated that 90% of exported live animals (camel, cattle) and chilled meat (mutton and goat) were from pastoral areas either through formal or informal marketing channels (Aklilu et al., 2013). Despite this potentiality, the country could not exploit these resources fully because of many factors including poor livestock marketing at both domestic and international markets (Jabbar and Ayele 2004).

The Somali region of Ethiopia plays the most important role in livestock trade in the country where about 60-80% of livestock exported through Somalia came from this region (Aklilu and Catley 2009). This cross border livestock trade is the largest live animal movement route on the hoof in the world with a volume of estimated $200 million annually through Berbera, Bosaso, Kismayo and Mogadishu (Tesfaye and Amaha 2018). Livestock product processing technologies are not available in pastoral areas of Somali region in Ethiopia therefore; raw milk and live animal were the main livestock products sold for exchange of food, goods and drugs. Between 50% and 74% of annual income of poorer pastoral households comes from

the sale of livestock or livestock products (Aklilu and Catley 2009). Evidence shows that poor pastoralists benefit less from the livestock export (Rettberg et al. 2017).

Animal health protection in Ethiopia is generally poor thus; livestock disease epidemics could undermine livestock trade investments (Hurrissa and Eshetu 2002). Along with the trade value chain, diseases could encounter and subsequently might risk the health of the end consumers. The World Animal Health Organization (OIE) emphasised the control of transboundary animal diseases generally and zoonotic diseases particularly to ensure that healthy livestock or livestock products were exported. Data on livestock trade in the Somali region of Ethiopia is scant. The few available studies in the region focused only on livestock marketing structure without looking at livestock trade related diseases. Identifying the critical points of interventions in livestock disease control is important. Thus, the current study aimed to assess livestock trade and associated diseases in Somali region. Knowledge on livestock trade and its associated diseases, routes and systems in place believed to contribute designing appropriate policies and strategies to improve the economy, health and well-being of pastoralist communities in Somali region.

6.2 Material and methods

Study area

Adadle woreda (district) is situated in the Shabelle Zone of the Somali region of Ethiopia. It is located in the lowlands of the semi-arid Wabe Shabale River sub basin (Figure 10). The mean annual rainfall based on Gode (the main town of the zone) data is about 300 mm (Gebre-Mariam, 2007). The main rainy season called “Gu” lasts from March to May and the short dry season known as “Xagaa” from June to August. “Xagaa” is followed by the short rain “Dayr” between September and November and the long dry season “Jilaal” from December to March. The woreda is composed of 15 kebeles (the smallest administrative units) (Gebre-Mariam, 2007) with a total population of 100,000 (SRBoFED, 2014) (Figure 1). In 2000, the majority of people living in Adadle were pastoralists (60%), whereas 28% were agro-pastoralists and 10% practiced riverine cultivation as cited in (Gebre-Mariam, 2007).

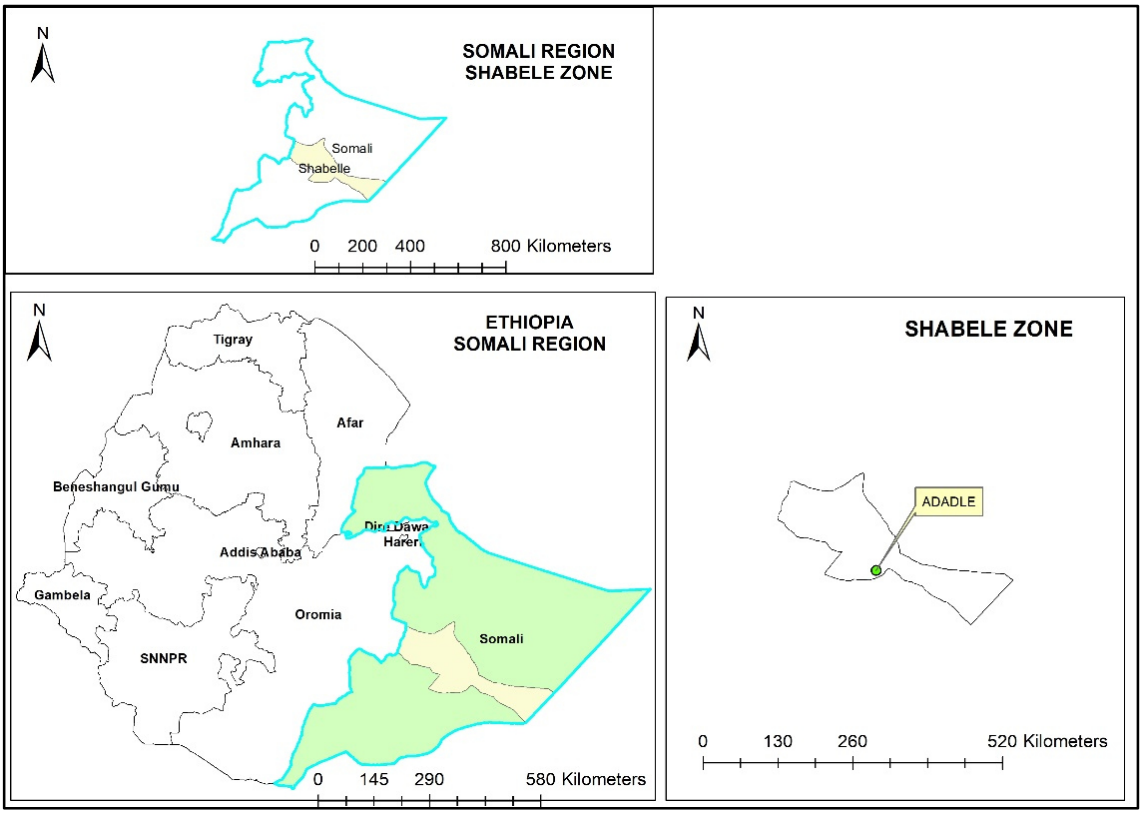

Figure 10 Map of the study area

6.2.1 Data collection procedure

Adadle woreda was selected purposely because it is a field study site of Jigjiga University. Six kebeles (smallest administrative unit) were selected proportional to human population size. Four of the selected kebeles were agropastoralist and two were pastoralist communities. With consultation of kebele administrative and elders, livestock traders were conveniently selected for in-depth interviews. The inclusion criteria were; being resident in one of the six selected kebeles, engaged in livestock trade and had experience in livestock trade. Twenty-two livestock traders (17 males and 5 females) were interviewed in Somali language. The interviewer (first author) is a native Somali speaker. Firstly, the participants were asked questions about livestock trade and its associated diseases in Adadle. After completion of the questions, each participant was requested to draw maps of livestock trade routes in and outside the Somali region on three different printed non coloured maps. The printed maps were Somali region, Ethiopia and Gulf countries. The participants used different colours for the three livestock species (cattle, small ruminants and camels). During the interview, the voice was recorded after receiving oral consent from the participants. The interview took about 45-90 minutes. Focus group discussions were also conducted with Gode livestock market

brokers. All Gode market brokers were males. The major questions asked were about; Gode livestock market animal prices, source of animals, livestock trade related costs, livestock diseases, barriers to trade, number of animals available in the market daily and major challenges in the market. The focus group discussions took about 40 minutes.

Additionally, customs and revenue authority and quarantine office representatives were interviewed. They were asked about the responsibilities of the offices, the livestock trade situation and associated diseases. Similar to livestock traders, participants from the two offices were asked to draw maps of livestock trade routes in and outside Somali region on three different printed non-coloured maps using different colours for different livestock species. During the interview, the voice was recorded after receiving written consent from the participants. The interview took about 60-90 minutes. Official quantitative data on livestock export for the last 10 years was also received from both offices and were used as secondary data source. The secondary data received from the quarantine office was not organized properly. For example, all livestock species were combined together and could not be calculated as separate species. Data on the number of animals confiscated by the law enforcement forces due to informal cross-border trade and estimated revenue lost was received from the customs and revenue authority.

Livestock trade costs included in this study were; animal cost (buying), transportation, taxes imposed by local authority, broker, treatment, feed, trekker cost, grazer cost, personal costs and benevolence. Livestock traders considered livestock actors as all people who were involved in livestock trade. Livestock diseases reported by the respondents were those diseases which either caused lack of market access or those which affected herders in the surroundings. Livestock diseases included in this study were the most frequently mentioned diseases during interview but not based on disease ranking.

Local terms used in livestock trade

Khidmaale: a person who provide service on behalf of the buyer
Dilaal: a person who provide service on behalf of the seller
Raaci: a person who takes care of animals (grazing) until the trader finishes buying animals from the market
Kaxeeye/Wadamariye: a hired laborer who treks animals to market
Jeeble: a trader who buys small number of animals from rural areas and sells to medium markets around the area (e.g. Gode)

Ganacsade: a trader who buys large numbers of animals and sells them to larger markets (e.g. Bosaso, Berbera etc)

Gaab: a grazing land kept privately for commercial purpose

Xero: a barn for rent to keep animals at night for protection

Shaxaadle: a person who stays at market and asks money whomever he knows

Limat: Amharic word for development. Here refers to the payment for development from animal buyer

Ilaaliye: a person who look after animals of the buyer inside the market until finishes buying

Calaamadeeye: a person who dyes the purchased animals using colors or henna

6.2.2 Data analysis

Qualitative in-depth interview recordings were transcribed, translated into English then imported into MAXQDA 18 (VERBI GmbH Berlin, Germany) for qualitative data management and analysis. The framework method for analysis of qualitative data was used (Gale et al., 2013). Themes and codes were created within the software and related with each of the individual interviews for thematic and content analysis. We listened the recordings again (33%) for quality assurance and double-checking with the transcripts to avoid losing important contents from the interviews. For livestock trade routes, geographic coordinates of the major markets and cities/towns that either recorded by the researcher using global positioning system (GPS) or derived from google map was used and mapped using ArcGIS 10.6.1.

6.3 Results

6.3.1 Findings from individual interviewees

Livestock trade situation in Adadle woreda

We interviewed twenty-two livestock traders. Five of the interviewed traders were females and the remaining were males. The traders had experience from 7 months to 21 years. Livestock traders from agropastoral kebeles had the longest years of trade experience. All respondents except one were engaged in small ruminants trade. Majority of the traders engaged in small ruminants either together with cattle and/with camels. The respondents reported that they either trek animals to market as individual or as group. All of the respondents said that they trek animals by themselves or by hired labor (kaxeeye). The transportation mode used was by feet. Women were actively engaged in this trade though their animals were trekked to the market by either hired laborer or their husband. The major available livestock markets reported by the respondents were Gode, Ceelbarde, Beledweyn, Harteshek, Hargeisa, Bosaso, Burco,

Kebridahar, Hargelle, Charati, Jiiq, Mandera, Wajale and Babile. Majority of the traders preferred Gode market due to its proximity, security, low input costs, availability of various food items and availability of buyers, being the only main market in the area, access of mobile network, and having relatively more relatives in the city. The respondents mentioned that livestock traders were under either one of the two categories; “Jeeble” or “Ganacsade”. The participants reported livestock trade actors as animal owner, buyer, broker, police, buyer agent, tax collector, trekker, dyer, restaurant owner, personal observer, grazer, and benevolence taker.

Reported livestock diseases affecting livestock trade

The major reported livestock diseases, which affect trade, are listed in the table below

Table 7. Reported livestock diseases affecting trade in Adadle woreda, Somali region

Small ruminants	**Cattle**	**Camel**
Plant poisoning (geed-daaq)	Bovine ephemeral fever (kududiye)	Trypanosomiasis (dhukaan)
Sheep and Goat pox (caanoole)	Nasal discharge (duuf/diif)	Anthrax (kud)
Nasal discharge (duuf/diif)	Contagious skin necrosis	Nervous disorder (shimbir)
Contagious ecthyma (minja buur)	Foot and mouth disease (cabeeb)	Mange (canbaar)
Tuberculosis (qaaxo)	Brucellosis (dhicis/buruseel)	Pneumonia (dhugato)
Tick infestation (shilin)	Anthrax (kud)	Plant poisoning (geed sagaar)
Helminthiasis (caal/dhuuqe)	Helminthiasis (caal/dhuuqe)	Cough (qufac/hergab)
Brucellosis (dhicis/buruseel)		Contagious skin necrosis (dhaleeco)
Febrile illness (qandho/xumad)		Internal parasitosis (gooryaan/cadeeye)
Diarrhoe (shuban/xaar)		Tuberculosis (qaaxo/tiibeey)
Contagious caprine pleuropneumonia (sambabka riyaha/gees-dhowr)		
Cough (qufac)		
Tetanus (qarar/waraf)		
Foot rot (raaf dilaac)		
Calf scour (fuuq dheer)		
Rift valley fever (rifti baali)		
Anthrax (kud/lugdhis)		
Lameness (lug dhutis)		

The respondents reported that some diseases had huge impact on the trade if they occur as outbreak. The common symptoms and diseases of outbreak mentioned by the respondents included; trypanosomiasis, anthrax, sheep and goat pox, helminthiasis, nasal discharge, FMD, tick infestation, diarrhea, Nairobi sheep disease, and contagious caprine pleuropneumonia (CCPP).The respondents mentioned trypanosomiasis as the worst livestock disease especially in camels. The respondents said that trypansomiasis did not affect only livestock trade but also livestock keepers in the surrounding area. The respondents reported that if trypanosomiasis occurs in one of the herds, all other camel herders move their animals from that area. Respondents from three kebeles namely; Bursaredo, Harsog and Melkasalah reported that they heard from BBC somali that Rift Valley fever was found from animals exported from Ethiopia. One respondent from Harsog kebele additionally said, a company, which exported animals to Gulf countries, reported diabetes was found in camels, which caused dramatically decline in camel price in Gode especially young camels.

The current livestock price at Gode market and costs associated with livestock trade in Adadle

The participants reported different costs associated with livestock trade at different levels throughout the market value chain. The main costs reported were; animal cost, tax, transportation, treatment, ranching, grazer, buyer agent, trekker, broker, personal cost, benevolence, watering cost, limat, loading and unloading cost. Regarding tax, respondents reported two types of taxes; municipality tax and revenue tax. One of the respondents stated that, transit letter provided by the regional revenue bureau, was used to allow traders take their animals to any market place within the country. In Gabal kebele, one respondent mentioned that traders pay different taxes in different zones within the same region. All respondents mentioned that it was important to know the daily price of livestock species at markets in order to decide whether to buy or sell animals depending on the information received from those markets. The respondents reported that they had mobile phones and call brokers at different markets in a regular basis.

Table 8 Current livestock price at Gode market

Species	Category	Price (Ethiopian birr)	Remark
	Adult (Jar)	2700	both sheep & goats
	S*	1800-2000	both sheep & goats
	Young (Waaqle)	1300-1800	both sheep & goats
Small ruminants	She-goat (Riyaha) level-1	1800-2000	Good body weight (dhiig saaid)
	She-goat (Riyaha) level- 2	1500-1600	Normal body weight
	Ewes (Idaha) young	1000	
	Ewes (Idaha) adult	1500	
	Bull (dibi) (6-7yrs)	13000-18,000	
Cattle	Lactating cow (sac irmaan)	13000	
	Bull (dibi) (2-4yrs)	5000	
	Young camel (qaalin) (male, 4yrs)	11000	
	Young camel (qaalin) (male, 6-7yrs)	13000-14000	
	Young camel (qaalin) (female, 4yrs)	15000	
Camel	Young camel (qaalin) (female, 5-6yrs)	18000	
	Adult she-camel (hal) (7-10yrs)	18000-20000	
	Pregnant she-camel (hal riman)	25000	
	Lactating she-camel with calf (hal iyo nirigteed)	35000-40000	
	Adult male camel (Rati/Awr)	25000-30000	

1ETB= 0.034 USD during the study (Commercial Bank of Ethiopia).
*S was locally used name for middle age sheep and goats

Livestock trade challenges and opportunities

The interviewed traders mentioned that livestock trade had both positive and negative consequences. They reported factors, which might hinder the trade as security, drought, disease, poor market, tribal conflicts, market conflicts, broker conflicts, lack of demand from importing countries, lack of livestock price information at markets and hard currency exchange rate fluctuations. The respondents shared with us about the main challenges they faced during their experience in livestock trade. One of the traders stating security challenges says;

"One of the challenges I faced during my trade was when I took animals to Beledweyn then tribal conflict erupted because of revenge between one of my tribes who live in Ceelbarde and other tribe in Beledweyn. Two of my tribe men were killed. At the time of the conflict, I was in Beledweyn. I immediately took my animals back to home". (Interviewee from Boholhagare, male).

Regarding drought and disease impact, one of the respondents says;

"During the last drought (2017), I bought 32 bulls with expensive cost (11,000 birr each) then 6 of them died due to the drought. I invested all the money I had to rent farm until end of the drought". (Interviewee from Higlo, female)

“I bought bucks with all the money I had and immediately short after, drought occurred. I took them to Gode to sell but unfortunately, there was no market and I could not bring them back because of drought. Lastly, I sold some of them with half of the original price and left the rest inside the market”. (Interviewee from Melkasalah, male)

“I purchased 150 small ruminants from the market. I and other man brought our animals near the riverside, where green grasses were available and handover to a hired labor to graze them. All my animals got sick due to a disease called “Geesdhowr”. I was lucky to sell 80 animals and the rest died”. (Interviewee from Bursaredo, male)

The respondents mentioned that livestock price depends on season and demand from the buyers. Livestock demand reported high, during Arafa, Mowlid, Eid Al-Adha, rainy season, when there are demand from importing countries, during Hajj, end of rainy season (Gamasha), and early start of rainy season. Arafa and Mowlid fall under end of rainy season. Some of the respondents also mentioned that demand was high when there were low number of animals in the market.

Despite all mentioned challenges and constraints, all respondents mentioned that livestock trade was so important for their livelihood. Livestock traders created job opportunities for many people in the local community. All the respondents reported the reasons they were involved in this business, which included; family care, economy, future investment, being the only profitable type of business in pastoral areas, for insurance and being out of poverty.

Regarding the recurrent droughts and relation with trade, one of the respondents says;

“Recently, some people started losing their faith on this trade because of recurrent and long drought in the area. For me this trade is important for my livelihood because I don’t have any other experience other than livestock trade”. (Interviewee from Melkasalah, male)

“When a man is born, he must do work for living and if you do not work, you get nothing. I do not know any other job like farming or others. The only job I rely on is livestock trade to improve the life of my family and to benefit from it as long as I am a live”. (Interviewee from Harsog, male).

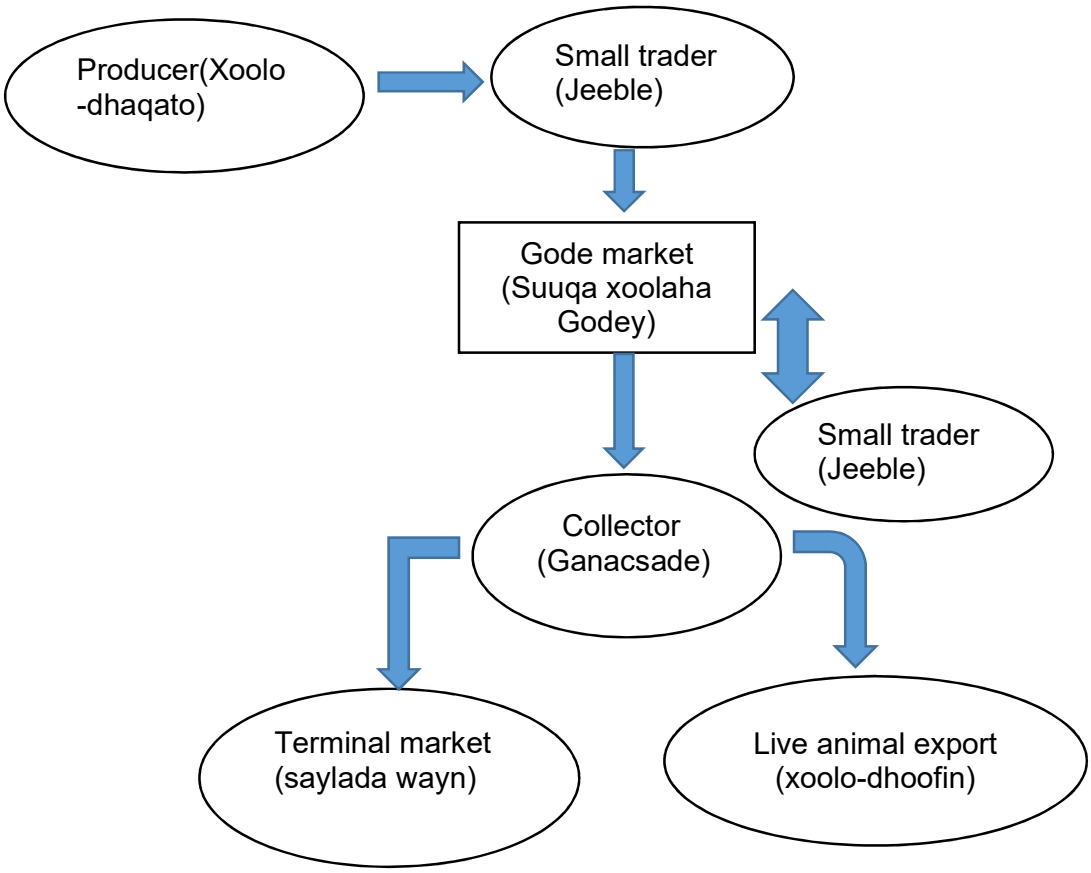

Fig 11. Schematic representation of livestock traders in Adadle woreda, Somali region

Livestock trade routes

Livestock traders purchased animals mainly from different places in Afder, Shabele and Liban zones. The traders reported that they sold their animals to Gode market but occasionally to Jigjiga, Harteshek, Ceelbarde and Beledweyn. Within the country, Gode, Jigjiga and Harteshek were the most dominant livestock markets respectively (Fig 12).

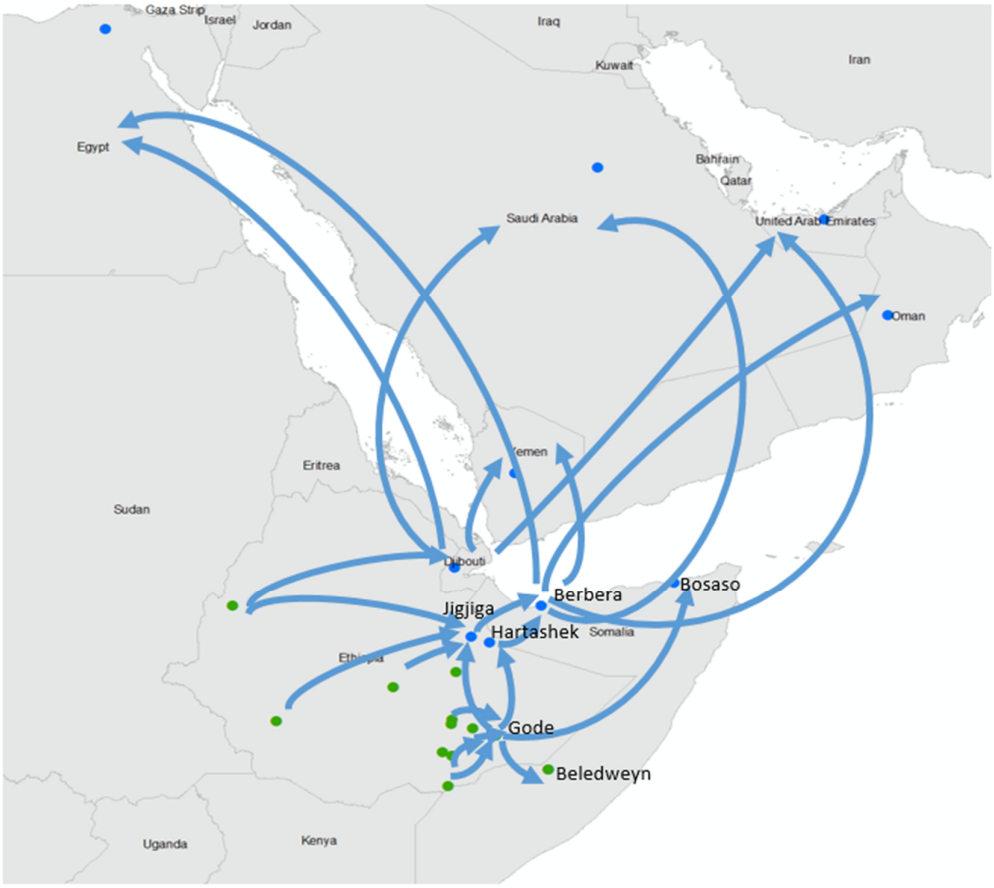

Fig 12. Livestock trade routes in and outside Ethiopia (green dot shows departure place and blue dot shows the destination place)

6.3.2 Findings from Gode market brokers

The group members reported that the market received all types of livestock, small ruminants, cattle, camels and donkeys. The members mentioned five major livestock diseases, which affected livestock trade in the area. These diseases were; FMD, contagious bovine pleuropneumonia for cattle, sheep and goat pox, contagious ecthyma for small ruminants and trypanosomiasis for camels. The major factors impacted livestock trade reported were drought and tick infestation. The reported costs related to livestock trade included broker, tax, buyer agent, grazer, henna cost and branding costs. The main livestock markets reported in the region were Gode, Degahbur, Harteshek, Jigjiga and Kebridahar. The members mentioned that Gode was the most preferable market because of its large number of animals and transportation facilities. Because of these factors, buyers preferred Gode. The members reported that animals available in Gode market were mainly from Gode surroundings, Liban zone, Afder zone, Nogob zone and Beledweyn (Somalia). Drought, security and demand from importing countries were the major factors, which could hinder livestock trade. The members

said that they were not aware of animal export destination but reported, cattle especially female ones were sold within the Somali region and some animals were taken to Burco, Bosaso and Hargeisa. During Arafa and rainy season, livestock demand was high as reported by the members. The members mentioned that the number of animals available in Gode market depends on season and demand from buyers. The members reported that, there could be about 5000 small ruminants, 5000 cattle daily and sometimes only 5 camels, and 200 small ruminants.

6.3.3 Findings from customs and revenue authority

The overall responsibilities of the office was to implement the rules and regulations of all import and export goods. Regarding livestock export, the respondents mentioned that all animal health issues like vaccination and certification is done by the quarantine office. The customs and revenue authority checks if the livestock exporter has certificates from the quarantine office as well as approval letter from National Bank of Ethiopia. The office reported that they had a good collaboration with quarantine office. Both offices have regular monthly meeting where they exchange information and how to solve the complaints of their customers. The office stated that livestock exported were mainly from Boran, Harar, Harteshek, and Wollega for cattle. Camels were mainly from Somali region and some from Babile and Bale of Oromia region. Small ruminants exported were exclusively from Somali region. The livestock were exported to the neighboring country, Somaliland. In rare cases, livestock were exported to Yemen and Djibouti. The office reported that livestock from Ethiopia to Somaliland enter the quarantine at Berbera, then being registered, inspected and certified by Somaliland government before exported to Arab countries. Therefore, Ethiopia do not export livestock directly to Arab countries.

The criteria to be fulfilled by the livestock exporter included; bank permit, commercial invoice (price agreed between the exporter and the importer), health certificates, and declaration (a registered system by the transit company that acts as facilitator between the customer and customs and revenue authority). These criteria were mandatory and only applied for neighboring countries. If the exporter wants to export directly to Arab countries, there should be ocean bill for clearance then the customs and revenue authority provided transit license. Somali region being vast, the customs and revenue authority had checkpoints at the borders like Ferfer and Gode. These checkpoints facilitate the exporters to export their livestock formally by sending their required documents to the customs and revenue authority at Jigjiga branch without traveling. The customs and revenue authority at Jigjiga sends the approved

documents to their checkpoints then the exporter export animals formally. The customs and revenue authority reported that there was no quarantine office at borders, which made traders at the border difficult to export their animals formally. Regarding profitability of formal exporters vs informal exporters, the office responded that when the contraband control is strong, formal exporters benefit and more livestock are exported through our office whereas, when the contraband control is weak, the number of livestock exported through our office decreases and more livestock are exported informally. The office mentioned that traders were competent to each other. If some of them go through formal way and others informal way and both of them take their animals to the same market, the formal traders will lose and end up with informal trade. Thus, the recommended solutions by the office for this problem were; 1. To increase the accessibility of the services in order to decrease the costs of the customer 2. To increase community awareness 3. To have a bilateral agreement with neighboring countries like Somaliland 4. To control the contraband trade. The customs and revenue authority reported that the highest export season was during Arafa.

Responding to the major challenges in livestock trade, the office said; lack of community awareness, lack of big livestock markets, high bureaucracy in getting export license and the contraband. The office reported the main causes of informal livestock trade as; 1. Failure of the custom office to control contraband 2. Trader's interest in this way since it does not cost too much 3. Lack of either awareness or due to bureaucracy requirements.

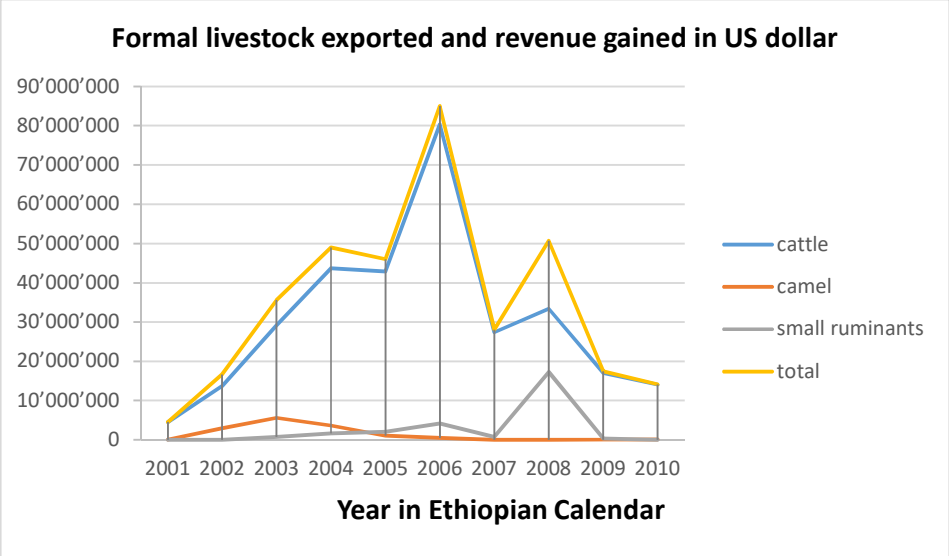

Fig 13. Formal livestock exported through Jigjiga customs and revenue authority (2001- 2010 EC)

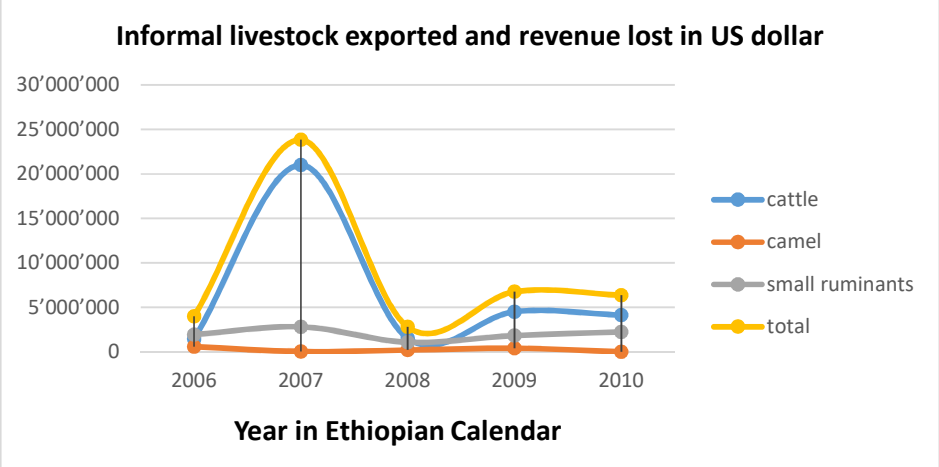

Fig 14. Informal livestock trade confiscated by Jigjiga customs and revenue authority (2006-2010 EC)

Table 9. Relationship between formal and informal export revenue (USD)

Yr_ec	Formal	Informal	Informal share (%)
2006	84'997'486	3'981'949	4.5
2007	28'102'014	23'832'110	46
2008	50'679'460	2'796'340	5
2009	17'444'570	6'752'611	28
2010	14'176'800	6'373'420	31
Total	195'400'330	43'736'430	

Yr_ec = year in Ethiopian calendar (7 or 8 years behind Gregorian calendar)
Source: Ethiopia Customs and Revenue Authority, Jigjiga branch, Somali region

6.3.4 Findings from quarantine office

The office reported that the overall responsibility is to inspect the livestock health, which are ready for export and provide certification services. The office reported that they had weekly, monthly, quarterly and yearly report. The monthly and yearly report sent to Ministry of Agriculture and copied to customs and revenue authority at Jigjiga branch and Somali regional bureau of livestock and pastoral development. The office reported that they had a good collaboration with customs and revenue authority and meet monthly. The quarantine office also provide technical assistance to the customs and revenue authority when there are animals confiscated from informal traders, which kept in the customs and revenue authority compound. According to the office report, there were 51 licensed livestock exporters from Somali region at Jigjiga-Wajale trade corridor. The office reported that customs and revenue authority, Drug Administration and Control Authority, Ethiopian Standards Agency and federal police office were their partners. The office mentioned that, they did not have a permanent office since the new office is under construction at Harre (30 km from Jigjiga) and expected to be completed in 2021.

The targeted livestock diseases reported for export trade were; FMD, brucellosis, sheep and goat pox, camel pox, ovine and bovine pasteurollosis, and PPR or shortly, transboundary diseases. The office also mentioned that they are cautious about transboundary diseases. The office had a checkpoint at Wajale (Ethio-Somaliland border) to inspect and re-check animals, which sent back to the country before allowing them to enter into the country. The office reported that importing countries had different perspectives towards livestock diseases. For example, Saudi Arabia targets diseases such as FMD, PPR and brucellosis whereas

Egypt target mainly on CCPP. The office mentioned that they provide vaccination services according to the request of importing countries. However, the office regularly vaccinated animals against six diseases; pasteurollosis, CCPP, CBPP, anthrax, black leg and sheep and goat pox. According to the office, no vaccination services provided as request for the last five years. The exporters buy vaccines by themselves and quarantine office provide services. The service charge reported was 20 birr per (1-50 head), 25 birr per (50-100 head), 30 birr per (100-150 head) etc. The office mentioned that, they write official letter for livestock traders to buy vaccines from National Veterinary Institute (NVI). The most common diseases encountered by the office were brucellosis, FMD, CCPP, CBPP, black leg, sheep and goat pox, pasteurollosis, tick infestation, injury, wound, and camel pox. The office confirmed that they did not experience livestock that returned to the country due to disease. The office did not record the most prevalent diseases from the tested samples. The office reported that only physical examination are conducted and rarely lab tests where samples sent to NVI in Debrezeit.

Small ruminants exported were mainly from Somali region (especially Garbo, Dhegahbur, Gode, Fik, Hargele and Liban) and some from Gindir and Bale of Oromia region. Cattle were from Wollega, Jimma and Chawaqa of Oromia region. The office mentioned that livestock exported to Somaliland and Djibouti but their destination were Yemen, Saudi Arabia, Egypt, Oman, Qatar, United Arab Emirates (UAE) and Kuwait. The office mentioned that there were two quarantines in Berbera and Djibouti ports controlled by two Arab traders named Abu Jabir and Abu Yasir respectively. The later had quarantines in both Berbera and Djibouti. According to the report of the office, only male animals were allowed for export. Bulls less than three years are not allowed for export. The office reported that cross bred animals were not allowed to export in the past but now is allowed even though, the amount of hard currency to be deposited is higher than the local breed (800 USD vs 600 USD). Importing countries had various preference towards the type of livestock. For example, Saudi Arabia, Qatar, UAE, and Kuwait prefer bulls and small ruminants whereas Egypt and Oman prefer only camel and bull respectively. Yemen had no specific preference and imported all types of livestock.

The criteria of the customer according to the quarantine office was to have pre-quarantine compound and license. There are two types of pre-quarantine compounds, waiting compound and fattening compound (feedlot). The office reported that there were only five fattening compounds around Jigjiga area. The other criteria was concerned by the customs and revenue authority. The office mentioned that exporters are experts in livestock marketing. When there was no contraband, they come to the office and exported formally and got profit, but when there was contraband, they used the informal way. For example, the office reported no

livestock export for the last five months. The office reported that different offices were competing to control the informal livestock trade. They said the only reason for this competition was to collect money from the traders, rather collecting revenues for the government. The office confirmed that there were complaints of traders about illegal confiscation of animals by the customs and revenue authority. The office mentioned when corruption increases and law enforcement weakened, the number of animal export decreases.

The office reported the major challenges of livestock export as hard currency deposit, contraband and the high amount of hard currency required by the national bank per head. For example, the office said that the trader has to deposit 600 USD for a bull while the price of the bull is 400 USD at the market. Recently, ethnic conflicts can also be seen as a challenge in the trade. The office mentioned that the Ministry of Agriculture has a plan to prevent and control livestock diseases in the country. The ministry planned to distribute ear tags, which has sensor/signals to their office branches in all regional states to control the number of animals coming in and going out of the country. In addition to this, the ministry was expected to bring internet-assisted apparatus that can be used for zoonotic disease reporting between the regional states and the ministry. The office mentioned that the main reasons of informal livestock trade included; the high amount of hard currency paid, lack of customs and revenue authority at the right place and weak control of contraband.

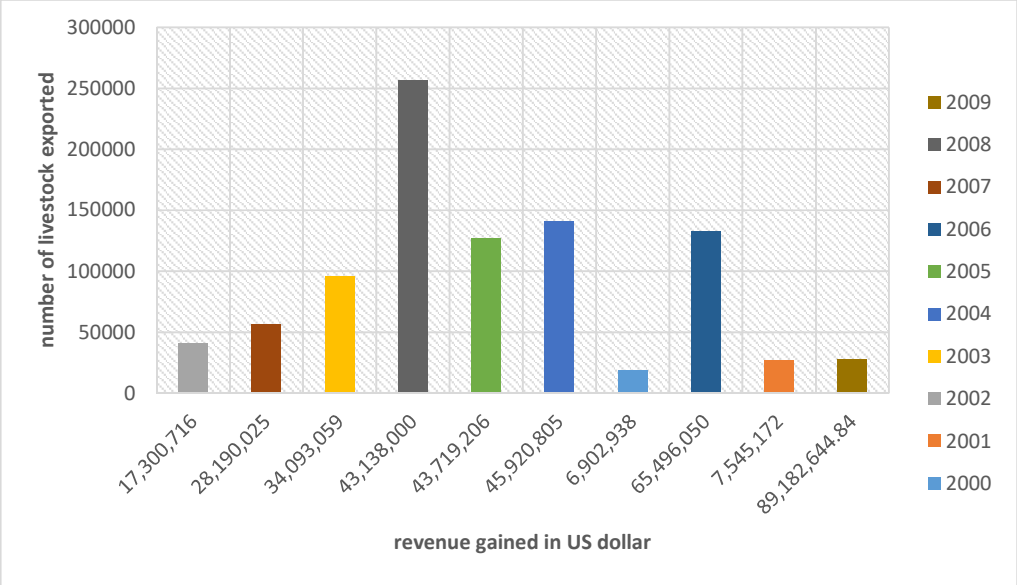

Fig 15. Livestock exported through quarantine office (2000-2009 Ethiopian calendar)

6.4 Discussion

The current study assessed the livestock trade and its associated diseases in Adadle. All the respondents engaged in small ruminants trade together with or without cattle and camels. Small ruminants were the backbone for the trade of interviewed respondents since it was the type of livestock species to start easily with this trade. This was in agreement with the study (Ibrahim et al. in press). The trade of small ruminants does not require large amount of initial capital unlike for cattle or camels. The majority of the respondents started their trade with small ruminants as starting then bought other livestock species with the cash they received from selling small ruminants. Among the interviewed livestock traders, some had experience in this trade for more than 20 years, which shows the importance of livestock trade in these communities. Women actively participated in this trade. The major livestock diseases/symptoms reported included, sheep and goat pox, contagious ecthyma, helminthiasis, ovine pasteurollosis, pneumonia, foot rot, anthrax, tick infestation, nasal discharge, cough, diarrhea, febrile illness, brucellosis and CCPP in small ruminants. Bovine ephemeral fever, anthrax, FMD, helminthiasis, brucellosis and nasal discharge in cattle and trypanosomiasis, anthrax, pneumonia, nervous disorder, helminthiasis, contagious skin necrosis, tuberculosis and mange in camels. There is clearly no diagnostic confirmation of the mentioned diseases. It is unclear to what extent the mentioned diseases reflect the true diagnostic status. Further research is needed to confirm the traders' perceptions.

During livestock disease outbreaks, traders who buy animals abandoned animals from outbreak areas. Consequently, local traders lose incomes from animal sale or even lose the animals if the disease causes high mortality. Recurrent and prolonged drought became abundant and one of the leading constraints in livestock trade. Other livestock trade constraints were disease, security and poor market/lack of demand from Gulf countries. In addition to these constraints, traders suffered high trade input costs throughout the market value chain. The major input costs involved in the trade were animal costs (buying), tax, transportation, trekker costs, feed, treatment, broker, and buyer agent costs. The seller and the buyer do not meet each other and these two people (broker and khidmaale) do the work. In Somali society, benevolence (Shaxaad) is a common culture, where you give money to relatives, friends or a person you know who is in the market when you sold your animals. Additionally, traders might sometimes travel long distance for selling animals but bring back their animals due to lack of market, which further increase the input costs. There was no case where traders brought their animals back from market because of disease. All returned animals from markets were due to lack of market. Availability of only one large livestock market in Gode city caused the traders not to look for other market options to sell. Within the country,

Gode, Jigjiga and Harteshek were the dominant livestock markets to sell respectively. These three livestock markets are critical points for zoonotic disease control interventions in the future. The traders reported that they pay multiple taxes on their way passing each zone to large markets or sometimes the federal customs and revenue authority confiscate animals. This was in agreement with (Nell 2006 and Aklilu 2002) who reported that livestock was the most taxed agricultural commodity and multiple taxation occurred in different levels within the country. The report from the quarantine office supported the traders' complaints about animal confiscation. The interviewed traders bought animals from various places within the region mainly, Afder, Liban and Shabele zones then sold to Gode market. Occasionally, they took their animals to neighboring countries, Somalia and Kenya. Gode market was the immediate trade hub for the local traders. The common market places outside the country were; Beledweyn, Bosaso, Hargeisa, Burco and Mandera. Saudi Arabia, United Arab Emirates, Oman, Egypt, Qatar, and Yemen were the importing countries even though the local traders mainly sold their animals to Gode market. Respondents reported that livestock trade demand was high during Arafa, Eid-Al Adha, Mowlid (the birth of the prophet) and during rainy seasons (long and short rainy season). The respondents mentioned that livestock trade was the only profitable and known type of business in pastoral communities, which helped to improve their income generation, social status, investment opportunities and ability to go to Hajj (Pilgrimage). This was comparable with the study of Aklilu and Catley (2014). Livestock traders also created job opportunities for many people in the local community.

The customs and revenue authority reported that their main responsibility was to regulate all kinds of import and export goods in the country. Regarding livestock export, the office ensures that livestock traders fulfilled the requirements for export. The requirements reported were; animal health certificates from quarantine office, bank permit, commercial invoice, and declaration letter for exporting to neighboring countries. If the export is directly to Gulf countries, additional to the above requirements, bill of ocean for clearance was required. The office mentioned that they had collaboration with quarantine office in livestock export where they had monthly meetings and shared reports. The office reported that since Ethiopia had no bilateral agreement with neighboring countries, livestock exported to Somaliland were re-exported to Gulf countries. This was in agreement with the study (Tesfaye and Amaha 2018). Due to informal cross-border trade, the customs and revenue authority established checkpoints at the borders. According to the office, the main purpose for the checkpoints were for facilitation to traders who are at remote near borders for ease export process without bringing animals to Jigjiga. Secondly, to promote formal livestock export. Even though the customs and revenue authority had checkpoints at remote borders, the quarantine office had no branches on those areas, which still made the livestock traders a challenge to export

formally. The customs and revenue authority reported that formal livestock export increases when the law enforcement control is strong and vice versa. Informal export was inversely proportional to formal trade as clearly showed in the data (fig 13 and 14). The informal livestock trade could hold the share as much as 85% of formal livestock export (table 3) which was a huge foreign earnings loss for the country. The total revenue gained from formal live animal export (1.04 million kg of meat) was 347 million USD for the last 10 years. According to customs and revenue authority report, the major challenges in livestock trade were; lack of community awareness, absence of larger livestock markets, high bureaucratic requirements for getting export license and contraband. Solutions recommended for these problems by the respondent were; 1.To increase the accessibility of the services to decrease customers input costs 2. To increase community awareness 3. To have a bilateral agreement with neighboring countries like Somaliland 4. To control the contraband trade.

The major responsibilities of quarantine office was the inspection and certification of live animals for export. The office mentioned that they had good collaboration with the customs and revenue authority. Currently, the quarantine office was temporary in regional veterinary laboratory compound since their new office is under construction and expected to end in 2021. Therefore, the office provided services to customers at pre-quarantine compounds owned by the traders. The office provided vaccination services according to the type of vaccines requested by importing countries. However, the office regularly vaccinated animals regardless of request from importing countries against pasteurollosis, CCPP, CBPP, anthrax, black leg and sheep and goat pox. According to office report, there was no request for vaccination from importing countries in the last five years. This shows the reluctant of importing countries for vaccination, which might be because of that, livestock from Ethiopia were re-checked and certified at Berbera and Djibouti ports. The importing countries had different preferences on targeting specific livestock diseases. For example, Saudi Arabia targeted diseases like FMD, PPR and brucellosis whereas, Egypt targeted mainly on CCPP. The most common livestock diseases or symptoms observed by the animal health professionals in quarantine office included brucellosis, FMD, CCPP, CBPP, black leg, sheep and goat pox, pasteurollosis, tick infestation, injury, wound, and camel pox.

According to the report of both customs and revenue authority and quarantine office, animals could be confiscated only if they were in the range of 15 km to the border. According to quarantine office, the major livestock trade challenges were; the high amount of hard currency required to be deposited by the livestock exporters, contraband and the recent ethnic conflicts. The office also mentioned the causes of informal livestock export as; the high amount of hard

currency paid by the livestock exporter, lack of customs and revenue authority or checkpoints at the right places and weak contraband control system.

6.5 Conclusions

Livestock trade was essential component for the livelihood of pastoralist communities in Adadle. Drought, livestock diseases and poor livestock market were the major hindrances faced by the livestock traders. In addition to relatively high livestock trade input costs, the local government was reported to impose multiple taxes on livestock trade through market value chain, which hampered more on local traders. Livestock diseases associated with livestock trade were included both infectious and non-infectious diseases that affected both the production and market. Livestock demand was depend on importing countries and rainy seasons. Knowledge on livestock trade and its associated livestock diseases, routes and systems in place believed to contribute designing appropriate policies and strategies to improve the economy, health and well-being of pastoralist communities in Somali region. Livestock diseases prevention and control programs should be improved in order to minimize their effects on trade as well as the economy of households involved in this trade. The local government should improve the availability, accessibility and quality of the available and new livestock markets in the region. Finally, there should be a mechanism, which allows livestock traders to get daily livestock price information from markets.

Chapter Seven: General Discussions

General discussions

The Somali region has the highest number of pastoralist communities in Ethiopia. Direct contact between the people and their livestock is common. Generally, there are poor basic health services and infrastructure in pastoral areas compared to other parts of the country. Furthermore, recurrent droughts and livestock diseases have become part of normal daily life in these areas. Climate change related factors such as heavy rainfall and flooding are increasing recently. These circumstances create a suitable environment for zoonotic infections, particularly vector-borne diseases and increase the chance of zoonotic disease transmission between humans and livestock. As a result, the public health and economic impacts of such zoonoses will become evident. Taking these into account, this PhD thesis was designed to establish the public health and economic importance of livestock diseases with the emphasis on brucellosis, Q-fever and Rift Valley Fever in Somali pastoral and agropastoral communities in Ethiopia.

A One Health approach was implemented for the first time in Somali region to investigate the prevalence of zoonotic diseases in humans and livestock simultaneously. Serological studies are fundamental to obtain high quality baseline information on zoonoses. Such approaches help to capture the exposure to specific pathogens in humans and livestock populations. It is essential to bear in mind that exposure does not necessarily mean the current presence of the organism, but rather that an exposure to a pathogen occurred in the population either recently or over a long time. Further research is needed to characterize species and phylogenetics of prevailing zoonotic pathogens in the region.

7.1 Prevalence of brucellosis, Q-fever and RVF in humans and livestock

Relatively, high seroprevalence of Q-fever and RVF were recorded in this study in both humans and livestock. This shows that there are many zoonotic infections circulating within the population, which are either not investigated or misdiagnosed. In livestock, camels were the principal species for both Q-fever and RVF, with the highest seroprevalence for both diseases. Previous research showed that sheep, goats and cattle are more susceptible to Q-fever and RVF. In contrast, our study showed that camels seem to be more exposed than small ruminants and cattle. Klemmer, Mobarez and Faye reported similar studies (Klemmer et al., 2018; Mobarez et al., 2017; and Faye et al., 2014). This might be due to the fact that camels travel longer geographical distances than other livestock species and might cross the

border to neighboring countries where such diseases are endemic or frequent outbreaks occur (Bett et al., 2019).

The weak correlation of Q-fever and RVF seropositivity between humans and livestock, as presented in chapter 4, could be because of temporarily different transmission cycles between livestock and humans and the small geographical scale of our study. The correlation of human and animal zoonotic infections like brucellosis becomes better for higher geographical scales like provinces rather than at the village or district level scale (Bonfoh et al., 2012; Zolzaya et al., 2014). Our findings showed that human seropositivity for Q-fever and RVF had a weak correlation with the seropositivity of goats and camels, respectively. This contrasts with some previous studies (Abdullah et al. 2018; Vanderburg et al. 2014; Schelling et al. 2003) but is in line with other studies (Meadows et al. 2016; Bond et al. 2016; Enserink 2010).

The seroprevalence of Q-fever and RVF in humans and livestock showed an association with age and sex, but age was found statistically significant only for camels. This might be because camels stay longer in the herd than other livestock species given the cumulative time for potential exposure. In livestock, females were more exposed than males. The pastoralist communities keep more female animals than males because the main reasons for keeping livestock are breeding and milk production. It could also be due to susceptibility of the pathogens to the udder, placenta and amniotic fluids. Unlike for livestock, men were more exposed to Q-fever and RVF infections than women. This could be because men are responsible for trekking live animals to markets, which exposes them to contaminated dust and for assisting animal deliveries without protective materials particularly in the case of camels. In small ruminants and camels, seropositivity of RVF in young animals shows that there might be ongoing (inter-epidemic) transmission in the area. The maintenance of RVFV between inter-epidemic periods requires at least 5 years, but some of the positive animals in our study were as young as 2 years.

Different models predicted the suitability and risk of RVFV occurrence in Ethiopia due to the distribution of the vast range of competing mosquito vectors and climate change. Recently, (Megarsa, 2019, doctoral dissertation) identified the primary (Aedes spp) and secondary (Culex, Anopheles, and Mansonia) mosquito vectors for RVFV transmission as well as risk areas in Ethiopia. He reported the Somali region as the highest suitable/risk region for RVFV occurrence in the country. This highly supports our findings and makes our study the first RVFV exposure report in humans and livestock in Ethiopia.

The current findings showed low seroprevalence of brucellosis in humans and livestock. In livestock, only cattle and camels were found to be positive. For humans, we reported here only the positive results from the Rose Bengal Tests. Even though brucellosis was endemic in the country, the low seroprevalence found in our study might be due to difference in geographical location, animal husbandry, animal breed, and type of tests used (Tschopp et al., 2015; Gumi et al., 2013). In the Somali region, pastoralist communities raise only one type of breed in each livestock species, which might decrease risk of introduction of infected exotic or non-local breeds into the area. Our study also showed that livestock trade occurred mainly within the region, with only local breeds being exchanged between the local communities. Mixing livestock species was also uncommon in the study area, unlike most of the other pastoral areas like Afar. Tschopp et al., (2015) reported the highest prevalence of brucellosis in livestock ever reported in Afar, Ethiopia. All *Brucella* positive animals in our study were female, which was in agreement with (Nthiwa et al., 2019; Zewdie, 2018). This might be because female animals were dominant in the herd and the exposure of *Brucella* for placenta and reproductive organs due to the presence of erythritol, a sugar produced in foetal tissues of ruminants could lead more female animals to be exposed (Coelho et al., 2015). In livestock, as age increased, seropositivity of brucellosis also increased. This could be because the older the animals get, the longer they are in contact with infected animals in the herd. Also the higher the animal parity, the higher likelihood the udder teat canals become wider, possibly increasing the exposure to bacteria (Coelho et al., 2015). In Ethiopia, there is no brucellosis vaccine available for livestock, which could hinder the efforts for disease control programs. Unlike for livestock, we found that as age increased seropositivity of brucellosis decreased in humans. This might be because older people were not involved in animal handling and rearing, thus exposure to pathogens decreased. In Somali pastoralist communities, older men are more involved in conflict resolution, family management, marriage ceremonies and religious issues. This was in agreement with a study conducted in Turkey (Buzgan et al., 2010).

Serological tests used in this study were only validated in countries where disease prevalence was low. This was a limitation of our study, and commercially available diagnostic kits should be validated in the country in the future to improve performance of the tests against these diseases. In Ethiopia, the complement fixation test was widely used as a brucellosis confirmation test, unlike our study, which used indirect ELISA. All small ruminant samples positive for brucellosis by RBT tested negative using the indirect ELISA. This could be due to the failure of sera dilution according to OIE procedure, or perhapy *B. melitensis* was not circulating in the study area. Recent evidence showed increased infection of *B. melitensis* in camels (Foster et al., 2018).

The low seroprevalence of brucellosis in the face of high abortion rates reported in the study area (Ibrahim et al, press) raises a concern that further research should be conducted to investigate other diseases, which cause abortions in livestock.

7.2 Livestock health and zoonoses: Awareness and practices among pastoral and agropastoral communities

The awareness level about zoonoses was different during individual interviews and focus group discussions. This might be because during focus group discussions, participants did not want to reveal to others that they did not know about zoonoses, and therefore, they acted as if they all knew about zoonoses. In contrast, the individual interviews showed low awareness level about zoonoses. Family size was the only variable statistically associated with zoonoses awareness level. This could be explained by assuming that the more the family size increases the higher the chance that family members get information about zoonoses. Zoonoses awareness was comparable in pastoral and agropastoral communities. In pastoral kebeles, the majority of the people were mobile pastoralists who move frequently with their livestock from place to place in search of pasture and water. Thus, the chance of meeting with other people from towns/cities or health professionals to hear about zoonoses was rare.

Astoundingly, HIV-AIDS and malaria were reported by the community as zoonotic diseases. Although HIV-AIDS has a zoonotic origin, transmission is essentially human to human. The communities assumed animals could become infected by eating leftover food contaminated with saliva of an HIV positive person or by grazing pastures contaminated with stool from HIV positive people. They did not elaborate on clinical signs and symptoms of animals with HIV-AIDS. It was mainly a perception. Legesse et al., (2018) also reported that Afar pastoralist communities believe that malaria could be transmitted by consuming raw milk from infected animals. Tuberculosis was reported as the most transmissible disease between humans and livestock, although there is very little animal-human transmission in Ethiopia (Gumi et al., 2012). Anthrax, cough, haemorrhagic septicaemia, foot and mouth disease, malaria and tuberculosis were the diseases/syndrome reported as zoonoses. Among these, only anthrax and tuberculosis are zoonotic diseases. This shows the low awareness or knowledge of the community towards zoonoses. However, all kebeles highlighted the importance of knowing about zoonoses. The exception was Harsog where it was stated that it was not good to know about zoonotic disease because people become afraid of their livestock. These perceptions are evident in pastoral communities where, for example, raw milk consumption was high (87%) and there is strongly held the belief that if milk is boiled/pasteurized, particularly camel milk, it

loses its medicinal value. Other risky practices that favour zoonotic disease transmission included assisting animal deliveries, and disposing of aborted foetuses in the fields.

Participants reported poor veterinary services in the study area. There was not a single veterinary doctor in the whole woreda. In the kebeles, there are few animal health technicians, and a relatively large number of community animal health workers (CAHWs) were not on duty. The regional livestock and pastoral development office trains CAHWs with funds received from various non-governmental organisations. However, there was no follow up by the office to make sure that workers were on duty to provide veterinary services to the community. Other challenges were that the government did not recognise CAHWs under the governmental structure and non-governmental organisations continue training new ones without evaluating the existing workers. The CAHWs were only active during vaccination campaigns or mass livestock treatments.

Animal health clinics/posts in the study area were absent, insufficient or not functional. Due to this reason, animal owners were purchasing vet drugs from nearby cities then self-medicating their animals. Sometimes animal owners inadvertently killed their animals due to inappropriate drug dosage or route of administration. The government provided livestock vaccines to pastoralist communities cost free, but a limitation of livestock vaccination programs was the imbalance between livestock population and amount of vaccine supplied. Although, the general livestock vaccination coverage was low, camels were the least vaccinated livestock species (1%) compared to cattle (7%) and small ruminants (6%). Kimani et al. (2016) similarly reported the lowest vaccine coverage in camels compared to other livestock species in Kenya. This might be due to the fact that a large proportion of camels were kept by mobile pastoralists who move seasonally from place to place, making it difficult for service providers to reach. It could also be due to less available camel vaccines in Ethiopia. In our study, the most frequently reported livestock diseases/syndromes were anthrax, trypanosomiasis, foot and mouth disease, nasal discharge and diarrhoea in descending order. It is worth noting that the respondents reported syndromes like nasal discharge and diarrhoea as diseases but did not know the aetiologies of such syndromes.

7.3 Livestock trade and its associated diseases

As presented in chapter 6, live animal sale was the major cash income for pastoral and/agro-pastoral communities. The interviewed local small livestock traders in Adadle engaged in all types of livestock species but mainly small ruminants. The trade of small ruminants was dominant because of their low capital requirements and easy management. Women were actively involved in this trade, and their livestock were trekked by either a hired labourer or their husband. No transportation was available in the area, so all livestock were trekked on foot to market by hired labourer or the animal owner. The time needed for livestock to reach the market depended on the origination kebele. For some kebeles, it was up to 15 days since animals were allowed to rest and graze during the journey. Gode livestock market was the main market where the traders sold their livestock. Gode livestock market received livestock from the Somali region of Ethiopia and also from neighbouring Somalia due to attractive prices. This is an opportunity, which creates employment for the locals but also increases risk of disease transmission through livestock movement. Many big traders come to Gode to buy livestock for export to the Gulf countries. The small local livestock traders rarely sold their livestock to big markets and neighbouring Somalia/Kenya because of the high input costs, security and fears of livestock confiscation by the federal revenue and customs authority.

The local livestock traders complained about multiple taxation, lack of alternative livestock markets, poor market demand and insufficient infrastructure and services. In addition, livestock diseases and droughts exacerbated the burden of livestock trade. The major livestock diseases/syndromes considered to affect the livestock trade were sheep and goat pox, trypanosomiasis, foot and mouth disease, anthrax, contagious caprine pleuropneumonia, contagious ecthyma, diarrhoea and nasal discharge. Some of these diseases affect not only the trade but also herders in the surroundings particularly diseases like trypanosomiasis, sheep and goat pox, foot and mouth diseases and anthrax. The livestock market price was influenced by the season, religious ceremonies, demand from the Gulf countries, livestock disease outbreaks, security and number of animals in the market.

7.4 Findings from the customs and revenue authority

The responsibility of the federal customs and revenue authority was to regulate all the import and export goods as well as live animal exports. The authority established checkpoints at remote areas near the borders to facilitate easy livestock export through formal channels. However, there were no quarantine checkpoints on those borders to provide livestock health

certificates. Therefore, the customs and revenue authority checkpoints were not effective. Live animal export was the second largest trade to earn hard currencies after khat/qat (*Catha edulis)* according to the customs and revenue authority report. The customs and revenue authority of Jigjiga branch were closely working with the quarantine office to provide services that ensure healthy and formal livestock export. Despite the facilitation of the authority, a high number of livestock were reported to cross the border informally (up to 46%) as presented in table 9 due to weak control systems, bureaucracy, high payments and other costs.

According to the authority, there was a huge gap working with the regional sector bureaus and other concerned bodies to encourage formal livestock exports and create community awareness. The lack of bilateral agreements between Ethiopia and Gulf countries was also a major challenge reported in livestock export. Somaliland acted as an intermediary with livestock from Ethiopia exported to Somaliland and then further exported to Gulf countries as though originating in Somaliland, even though 60-80% of these animals came from Somali region of Ethiopia (Aklilu and Catley, 2009).

7.5 Findings from the quarantine office

The quarantine office is under the federal government with the mission to inspect the health of live animal exports and provide health certificates. There was only one quarantine compound, which is still under construction, in the entire Somali region. Importantly, this is where the largest pastoralist communities of the country live and the source of about 80% of live animals exported from Berbera port (Aklilu and Catley, 2009). Currently, the quarantine office personnel provided their services to customers at waiting/feed-lot compounds owned by the livestock exporters. All the live animal exports to Somaliland go through Wajale corridor. This shows how busy a hub it is for live animal export, despite the absence of a federal quarantine compound. The high number of livestock exported through Wajale corridor and the absence of adequately functioning quarantine with a skilled work force could encourage informal livestock export and risk livestock trade disruption in the future.

The quarantine office mainly conducted physical examination of live animals, only in rare cases accompanied by diagnostic tests. This is a critical concern because conducting only physical examination and providing certification of good health to the livestock exporters could lead to loss of credibility of the origin country when livestock diseases appear in the importing countries.

The importing countries had different concerns in terms of livestock diseases. For example, Saudi Arabia targeted FMD, PPR, and brucellosis, whereas Egypt targeted mainly CCPP. For this reason, the quarantine office provided livestock vaccines according to the requests of the importing countries even though there were no vaccination requests for the last five years. Nevertheless, the office reported that they regularly vaccine livestock against six diseases: pasteurellosis, CCPP, CBPP, sheep and goat pox, anthrax and black leg. The livestock species preference was also different between importing countries. For example, Saudi Arabia, Qatar, UAE and Kuwait preferred bulls and small ruminants, whereas Oman and Egypt preferred bulls and camels. Unfortunately, the office did not keep records about the prevalent diseases of live animals exported through Wajale corridor. This makes it difficult to effectively plan for and implement disease control interventions.

Due to lack of bilateral agreements between Ethiopia and the destination countries (Gulf countries), it would be quite challenging to identify the source of a positive animal for a specific disease since Somaliland assigns its own identification number before re-exporting to Gulf countries.

7.6 Implication and future research

Pastoral and agropastoral communities experienced hardships due to climatic variability, droughts and conflicts. Additionally, they have been marginalized with poor basic health services. Despite their contributions to the national economy, information about the health and economy of these communities and their livestock are limited.

Zoonotic diseases affect the livelihood of pastoral and agropastoral communities, causing morbidity and mortality in both people and their livestock. It also results in economic consequences because of household income loss derived from livestock and livestock products.

Therefore, important questions to consider include: What is the current burden of zoonotic diseases in this community? How aware are the communities of zoonoses? What efforts have been undertaken so far by the government and other concerned bodies to support these communities?

There are government efforts to tackle livestock diseases at the national and regional level. Unfortunately, most of those diseases only affect livestock, such as CCPP, CBPP, PPR, and FMD. However, zoonotic diseases not only affect the economy, like the above-mentioned diseases but also the health of the people. There is much evidence to show that, pastoral and agropastoral communities are one of the most affected and vulnerable to zoonotic infections, more so than any other society in the world (Kizito et al., 2012).

7.7 Future research opportunities

- Identification of *Brucella* strains circulating in the study area
- Study on the proportion of Q-fever, brucellosis and RVF within febrile illnesses
- The economic impacts of brucellosis and Q-fever
- Entomological study on potential mosquito vectors for RVFV maintenance and transmission in Somali region
- The contribution of ticks to Q-fever transmission in livestock
- Characterization of livestock marketing and performance in the region

7.8 Recommendations

- Create community awareness and education about zoonoses and risky practices
- Establish and strengthen collaboration between human, animal and environmental health sectors
- Continuous capacity building for human and animal health professionals at zonal and woreda levels
- Validation of basic serological tests in Ethiopia
- Establish well equipped and functional diagnostic centres at zonal level
- Translate research findings into policy
- Collaboration between Ethiopia and Somaliland in livestock tracing and identification to prevent livestock disease risks

7.9 Final conclusions

This PhD thesis established the public health and economic importance of livestock diseases with an emphasis on brucellosis, Q-fever and RVF in Somali region. It highlighted community awareness on zoonoses, the major livestock diseases and other challenges in the area. Finally, it assessed the livestock trade situation, livestock trade routes and livestock diseases that influence livestock trade in Somali region. These findings provide a holistic picture about the prevalence of the selected zoonotic diseases, community awareness, challenges and livestock trade that can be used as evidence to design effective interventions and be further translated into policy. Improving health services and supplies, establishing zonal diagnostic centres, improving livestock marketing and integrated human and animal health research need be considered in the future.

Chapter Eight: References

References

Abakar, M. F., Nare, N. B., Schelling, E., Hattendorf, J., Alfaroukh, I. O., & Zinsstag, J. (2014). Seroprevalence of Rift Valley fever, Q fever, and brucellosis in ruminants on the southeastern shore of Lake Chad. *Vector Borne Zoonotic Dis, 14*(10), 757-762. doi:10.1089/vbz.2014.1585

Abdullah, H., El-Shanawany, E. E., Abdel-Shafy, S., Abou-Zeina, H. A. A., & Abdel-Rahman, E. H. (2018). Molecular and immunological characterization of Hyalomma dromedarii and Hyalomma excavatum (Acari: Ixodidae) vectors of Q fever in camels. *Vet World, 11*(8), 1109-1119. doi:10.14202/vetworld.2018.1109-1119

Abebe, A. (1990). Prevalence of Q fever infection in the Addis Ababa abattoir. *Ethiopian medical journal, 28*(3), 119-122.

Adugna, K., Agga, G., & Zewde, G. J. R. S. T. (2013). Seroepidemiological survey of bovine brucellosis in cattle under a traditional production system in western Ethiopia. *32*(3), 765-773.

Aklilu, Y., and A, Catley (2014). Pastoral livestock trade and growth in Ethiopia. J. Policy Brief-Future Agricultures.

Aklilu, Y., Little, P. D., Mahmoud, H., & McPeak, J. (2013). Market access and trade issues affecting the drylands in the Horn of Africa. *Brief prepared by a Technical Consortium hosted by CGIAR in partnership with the FAO Investment Centre. Technical Consortium Brief*, *2*.

Aklilu, Yacob, and Andy, Catley (2009). Livestock exports from the Horn of Africa: an analysis of benefits by pastoralist wealth group and policy implications. J Medford: Feinstein International Center, Tufts University.

Aklilu, Yacob. (2002). An audit of the livestock marketing status in Kenya, Ethiopia and Sudan: Volume II: issues and proposed measures.

Al Shehhi, N., Aziz, F., Al Hosani, F., Aden, B., & Blair, I. (2016). Human brucellosis in the Emirate of Abu Dhabi, United Arab Emirates, 2010-2015. *BMC Infect Dis, 16*(1), 558. doi:10.1186/s12879-016-1900-9

Alho, A. M., C. Lima, V. Colella, L. Madeira de Carvalho, D. Otranto, and L. Cardoso. (2018). Awareness of zoonotic diseases and parasite control practices: a survey of dog and cat owners in Qatar, *Parasit Vectors*, 11: 133.

Anyamba, A., Chretien, J.P., Small, J., Tucker, C. J., Formenty, P. B., Richardson, J. H., Linthicum, K. J. (2009). Prediction of a Rift Valley fever outbreak. *106*(3), 955-959.

Asmare, A. (2014). Seroprevalence of Brucellosis in Camels (Camelus dromedaries) in South East Ethiopia. *Journal of Veterinary Science & Medical Diagnosis, 03*(01). doi:10.4172/2325-9590.1000127

Bati, B. M. (2004). Sero-Epidemiological study of brucellosis in camels (camelus dormedarius) in Borena lowland pastoral areas, southern Ethiopia [master's theses]. *Addis Ababa University*.

B. Bonfoh, G. Fokou, L. Crump, J. Zinsstag, E. Schelling. (2016). Institutional development and policy frameworks for pastoralism: from local to regional perspectives. *Rev. Sci. Tech. Off. Int. Epiz.*, 2016, 35 (2), 499–509.

Bekele, M., Mohammed, H., Tefera, M., & Tolosa, T. (2011). Small ruminant brucellosis and community perception in Jijiga district, Somali Regional State, Eastern Ethiopia. *Tropical Animal Health and Production*, *43*(4), 893-898.

Bekele, W. A., Tessema, T. S., & Melaku, S. K. (2013). Camelus dromedarius brucellosis and its public health associated risks in the Afar National Regional State in northeastern Ethiopia. *55*(1), 89.

Benaissa, M. H., Ansel, S., Mohamed-Cherif, A., Benfodil, K., Khelef, D., Youngs, C. R., Ait-Oudhia, K. (2017). Seroprevalence and risk factors for Coxiella burnetii, the causative agent of Q fever in the dromedary camel (Camelus dromedarius) population in Algeria. *Onderstepoort J Vet Res, 84*(1), e1-e7. doi:10.4102/ojvr.v84i1.1461

Bennett, S., Woods, T., Liyanage, W. M., & Smith, D. L. (1991). A simplified general method for cluster-sample surveys of health in developing countries.

Bett, B., Lindahl, J., Sang, R., Wainaina, M., Kairu-Wanyoike, S., Bukachi, S., Grace, D. (2019). Association between Rift Valley fever virus seroprevalences in livestock and humans and their respective intra-cluster correlation coefficients, Tana River County,Kenya. *Epidemiology and Infection, 147*, E67, 1–9.

Bond, K. A., Vincent, G., Wilks, C. R., Franklin, L., Sutton, B., Stenos, J., Firestone, S. M. (2016). One Health approach to controlling a Q fever outbreak on an Australian goat farm. *Epidemiol Infect, 144*(6), 1129-1141. doi:10.1017/S0950268815002368

Bonfoh, B., Kasymbekov, J., Durr, S., Toktobaev, N., Doherr, M.G., Schueth, T., Zinsstag, J., Schelling, E.(2012). Representative seroprevalences of brucellosis in humans and livestock in Kyrgyzstan. EcoHealth 9, 132-138.

Brandwagt, D. A., Herremans, T., Schneeberger, P. M., Hackert, V. H., Hoebe, C. J., Paget, J., & W, V. D. H. (2016). Waning population immunity prior to a large Q fever epidemic in the south of The Netherlands. *Epidemiol Infect, 144*(13), 2866-2872. doi:10.1017/S0950268816000741

Britch, S. C., Binepal, Y. S., Ruder, M. G., Kariithi, H. M., Linthicum, K. J., Anyamba, A., Wilson, W. C. (2013). Rift Valley fever risk map model and seroprevalence in selected wild ungulates and camels from Kenya. *PLoS One, 8*(6), e66626. doi:10.1371/journal.pone.0066626

Browne, A. S., Fevre, E. M., Kinnaird, M., Muloi, D. M., Wang, C. A., Larsen, P. S., Deem, S. L. (2017). Serosurvey of Coxiella burnetii (Q fever) in Dromedary Camels (Camelus dromedarius) in Laikipia County, Kenya. *Zoonoses Public Health, 64*(7), 543-549. doi:10.1111/zph.12337

Butt, Bilal. (2016). Ecology, mobility and labour: Dynamic pastoral herd management in an uncertain world.

Buzgan, T., Karahocagil, M. K., Irmak, H., Baran, A. I., Karsen, H., Evirgen, O., & Akdeniz, H. (2010). Clinical manifestations and complications in 1028 cases of brucellosis: a retrospective evaluation and review of the literature. *International journal of infectious diseases*, *14*(6), e469-e478.

Chevalier, V., Pépin, M., Plee, L., & Lancelot, R. J. E. S. (2010). Rift Valley fever-a threat for Europe? *, 15*(10), 18-28.

CIA (2018). The World Factbook.

Clark, M. H. A., Warimwe, G. M., Di Nardo, A., Lyons, N. A., & Gubbins, S. (2018). Systematic literature review of Rift Valley fever virus seroprevalence in livestock, wildlife and humans in Africa from 1968 to 2016. *PLoS Negl Trop Dis, 12*(7), e0006627. doi:10.1371/journal.pntd.0006627

Coelho, A. C., Díez, J. G., & Coelho, A. M. (2015). Risk factors for Brucella spp. In domestic and wild animals. *Updates on brucellosis*.

Cook, E. A. J., Grossi-Soyster, E. N., de Glanville, W. A., Thomas, L. F., Kariuki, S., Bronsvoort, B. M. C., Fevre, E. M. (2017). The sero-epidemiology of Rift Valley fever in people in the Lake Victoria Basin of western Kenya. *PLoS Negl Trop Dis, 11*(7), e0005731. doi:10.1371/journal.pntd.0005731

CSA. (2017). Federal Democratic Republic of Ethiopia. Central Statistical Agency. Agricultural Sampling Survey 2016/17. Livestock and Livestock Characteristics.

Dean, A. S., Bonfoh, B., Kulo, A. E., Boukaya, G. A., Amidou, M., Hattendorf, J., Schelling, E. (2013). Epidemiology of brucellosis and q Fever in linked human and animal populations in northern togo. *PLoS One, 8*(8), e71501. doi:10.1371/journal.pone.0071501

Degefu, H., Mohamud, M., Hailemelekot, M., & Yohannes, M. (2011). Seroprevalence of bovine brucellosis in agro pastoral areas of Jijjiga zone of Somali National Regional State, Eastern Ethiopia. *15*(1).

Di Nardo, A., Rossi, D., Saleh, S. M., Lejlifa, S. M., Hamdi, S. J., Di Gennaro, A., Thrusfield, M. V. (2014). Evidence of Rift Valley fever seroprevalence in the Sahrawi semi-nomadic pastoralist system, Western Sahara. *BMC Vet Res, 10*, 92. doi:10.1186/1746-6148-10-92

Dirar, B. G., Nasinyama, G. W., & Gelalcha, B. D. (2015). Seroprevalence and risk factors for brucellosis in cattle in selected districts of Jimma zone, Ethiopia. *Trop Anim Health Prod, 47*(8), 1615-1619. doi:10.1007/s11250-015-0910-8

Ducrotoy, M. J., Ammary, K., Ait Lbacha, H., Zouagui, Z., Mick, V., Prevost, L., Benkirane, A. (2015). Narrative overview of animal and human brucellosis in Morocco: intensification of livestock production as a driver for emergence? *Infect Dis Poverty, 4*, 57. doi:10.1186/s40249-015-0086-5

Eid, Abdurehman (2014). Jostling for trade: The politics of livestock marketing on the Ethiopia-Somaliland border, J Future Agricultures 75.

Elias, Eyasu. (2008). Pastoralists in Southern Ethiopia: Dispossession, access to resources and dialogue with policy makers. Drylands Coordination Group.

ElTahir, Y., Al Toobi, A. G., Al-Marzooqi, W., Mahgoub, O., Jay, M., Corde, Y., Johnson, E. H. (2018). Serological, cultural and molecular evidence of Brucella melitensis infection in goats in Al Jabal Al Akhdar, Sultanate of Oman. *Vet Med Sci*. doi:10.1002/vms3.103

Enserink, M. (2010). Questions abound in Q-fever explosion in the Netherlands. In: American Association for the Advancement of Science.

FAO, OIE, and WHO. (2012). High-Level Technical Meeting to Address Health Risks at the Human-AnimalEcosystems Interfaces. Food and Agriculture Organisation of The United Nations. World Organisation For Animal Health. World Health Organisation.

Faye, O., Ba, H., Ba, Y., Freire, C., Faye, O., Ndiaye, O. Sall, A. A. (2014). Re- emergence of Rift Valley Fever, Mauritania, 2010. *Emerging Infectious Diseases*, *20*(2), 300-303.

Foster, J. T., Walker, F. M., Rannals, B. D., Hussain, M. H., Drees, K. P., Tiller, R. V., & Saqib, M. (2018). African lineage Brucella melitensis isolates from Omani livestock. *Frontiers in microbiology*, *8*, 2702.

Gale, N. K., G. Heath, E. Cameron, S. Rashid, and S. Redwood. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research, *BMC Med Res Methodol*, 13: 117.

Garcell, H. G., Garcia, E. G., Pueyo, P. V., Martin, I. R., Arias, A. V., & Alfonso Serrano, R. N. (2016). Outbreaks of brucellosis related to the consumption of unpasteurized camel milk. *J Infect Public Health, 9*(4), 523-527. doi:10.1016/j.jiph.2015.12.006

Gebre-Mariam, A. (2007). *The Critical Issue of Land Ownership. Violent Conflict between the Abdalla Tolo-mogge and the Awlihan in Godey Zone, Somali Region, Ethiopia* (Vol. 11): NCCR North-South Dialogue.

Gebremeskel, E. N., Desta, S., & Kassa, G. K. (2019). Pastoral Development in Ethiopia.

Genene, R., Desalew, M., Yamuah, L., Hiwot, T., Teshome, G., Asfawesen, G., & Smits, H. L. (2009). Human brucellosis in traditional pastoral communities in Ethiopia. *International Journal of Tropical Medicine*, *4*(2), 59-64.

Gessese, A., Mulate, B., Nazir, S., & Asmare, A. J. J. V. S. M. D. (2014). Seroprevalence of brucellosis in camels (Camelus dromedaries) in South East Ethiopia. *1*, 2.

Girma, Y. (2012). epidemiological investigations of brucellosis in ruminants and humans in yabello district of borena pastoral area, oromia national regional state, southern Ethiopia. *Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Tropical Veterinary Epidemiology*.

Grace, D., Mutua, F., Ochungo, P., Kruska, R., Jones, K., Brierley, L., Phuc, P. (2012). *Mapping of poverty and likely zoonoses hotspots*.

Gumi, B., Firdessa, R., Yamuah, L., Sori, T., Tolosa, T., Aseffa, A., Schelling, E. (2013). Seroprevalence of Brucellosis and Q-Fever in Southeast Ethiopian Pastoral Livestock. *J Vet Sci Med Diagn, 2*(1). doi:10.4172/2325-9590.1000109

Gumi, B., Schelling, E., Berg, S., Firdessa, R., Erenso, G., Mekonnen, W., Hailu, E., Melese, E., Hussein, J., Aseffa, A., Zinsstag, J. (2012). Zoonotic transmission of tuberculosis between pastoralists and their livestock in South-East Ethiopia. Ecohealth 9, 139-149.

Hadush Desta, Angesom. (2015). Public Awareness and Practices of Pastoral and Agro Pastoral Community Towards Zoonotic Brucella Infection in Afar Regional State of North East Ethiopia, *European Journal of Preventive Medicine*, 3.

Haileselassie, M., Kalayou, S., Kyule, M., Asfaha, M., & Belihu, K. (2011). Effect of Brucella infection on reproduction conditions of female breeding cattle and its public health significance in Western tigray, northern ethiopia. *Vet Med Int, 2011*, 354943. doi:10.4061/2011/354943

Halawi, A. D., Saasa, N., Pongombo, B. L., Kajihara, M., Chambaro, H. M., Hity, M., Simulundu, E. (2019). Seroprevalence of Rift Valley fever in cattle of smallholder farmers in Kwilu Province in the Democratic Republic of Congo. *Trop Anim Health Prod, 51*(8), 2619-2627. doi:10.1007/s11250-019-01978-z

Heo, J., Choi, Y., Kim, E. *et al.* Clinical characteristics of acute Q fever patients in South Korea and time from symptom onset to serologic diagnosis. *BMC Infect Dis* 19, 903 (2019). https://doi.org/10.1186/s12879-019-4479-0

Hoek, W., Schneeberger, P. M., Oomen, T., Wegdam-Blans, M. C., Dijkstra, F., Notermans, D. W., & Kampschreur, L. M. (2012). Shifting priorities in the aftermath of a Q fever epidemic in 2007 to 2009 in The Netherlands: from acute to chronic infection.

Hull, N. C., & Schumaker, B. A. (2018). Comparisons of brucellosis between human and veterinary medicine. *Infection ecology & epidemiology*, *8*(1), 1500846.

Hurrissa, Belachew, and Jemberu Eshetu (2002). Challenges and opportunities of livestock marketing in Ethiopia. In *Proceedings of the 10 th annual conference of the Ethiopian Society of Animal Production (ESAP). Addis Ababa, Ethiopia*, 1-13.

Hussein, M. F., Alshaikh, M. A., Al-Jumaah, R. S., GarelNabi, A., Al-Khalifa, I., & Mohammed, O. B. (2014). The Arabian camel (Camelus dromedarius) as a major reservoir of Q fever in Saudi Arabia. *Comparative Clinical Pathology, 24*(4), 887-892. doi:10.1007/s00580-014-2002-y

IFAD. (2016). Federal Democratic Republic of Ethiopia. Pastoral Community Development Project II. Project Performance Assessment. International Fund for Agricultural Development.

IFC (2018). International Finance Cooperation.

İnci A, Doğanay M, Ozdarendeli A, Duzlu O, Yıldırım A (2018). Overview of Zoonotic Diseases in Turkey: The One Health Concept and Future Threats. Turkiye Parazitol Derg. 42:39-80

Jabbar, Mohammad A, and Gezahegn Ayele (2004). Livestock marketing, food security and related issues in Ethipia.

Jarelnabi, A. A., Alshaikh, M. A., Bakhiet, A. O., Omer, S. A., Aljumaah, R. S., Harkiss, G. D., Hussein, M. F. (2018). Seroprevalence of Q fever in farm animals in Saudi Arabia. *29*, 895-900.

Jeremy V Camp & Norbert Nowotny (2020). The knowns and unknowns of West Nile virus in Europe: what did we learn from the 2018 outbreak? Expert Review of Anti-infective Therapy.18:2, 145-154.

Kanoute, Y. B., Gragnon, B. G., Schindler, C., Bonfoh, B., & Schelling, E. (2017). Reprint of "Epidemiology of brucellosis, Q Fever and Rift Valley Fever at the human and livestock interface in northern Cote d'Ivoire". *Acta Trop, 175*, 121-129. doi:10.1016/j.actatropica.2017.08.013

Kelly, T. R., D. A. Bunn, N. P. Joshi, D. Grooms, D. Devkota, N. R. Devkota, L. N. Paudel, A. Roug, D. J. Wolking, and J. A. K. Mazet. (2018). Awareness and Practices Relating to Zoonotic Diseases Among Smallholder Farmers in Nepal, *Ecohealth*, 15: 656-69.

Kersh, G. J., Wolfe, T. M., Fitzpatrick, K. A., Candee, A. J., Oliver, L. D., Patterson, N. E., Massung, R. F. (2010). Presence of Coxiella burnetii DNA in the environment of the United States, 2006 to 2008. *Appl Environ Microbiol, 76*(13), 4469-4475. doi:10.1128/AEM.00042-10

Khbou, Médiha Khamassi, Khawla Najahi, Lilia Zribi, Karim Aoun, and Mohamed Gharbi. (2019). Knowledge and attitudes of Tunisian dog owners regarding leishmaniasis, *Parasite Epidemiol Control*, 5: e00098.

Kimani, T., E. Schelling, B. Bett, M. Ngigi, T. Randolph, and S. Fuhrimann. (2016). Public Health Benefits from Livestock Rift Valley Fever Control: A Simulation of Two Epidemics in Kenya, *Ecohealth*, 13: 729-42.

Kizito, James, Miriam Kayendeke, Christine Nabirye, Sarah G. Staedke, and Clare I. R. Chandler (2012). Improving access to health care for malaria in Africa: a review of literature on what attracts patients, *Malaria Journal*, 11.

Klaasen, M., Roest, H. J., van der Hoek, W., Goossens, B., Secka, A., & Stegeman, A. (2014). Coxiella burnetii seroprevalence in small ruminants in The Gambia. *PLoS One, 9*(1), e85424. doi:10.1371/journal.pone.0085424

Klemmer, J., Njeru, J., Emam, A., El-Sayed, A., Moawad, A. A., Henning, K., El-Diasty, M. M. (2018). Q fever in Egypt: Epidemiological survey of Coxiella burnetii specific antibodies in cattle, buffaloes, sheep, goats and camels. *PLoS One, 13*(2), e0192188. doi:10.1371/journal.pone.0192188

LaBeaud, A. D., Pfeil, S., Muiruri, S., Dahir, S., Sutherland, L. J., Traylor, Z., King, C. H. (2015). Factors associated with severe human Rift Valley fever in Sangailu, Garissa County, Kenya. *PLoS Negl Trop Dis, 9*(3), e0003548. doi:10.1371/journal.pntd.0003548

Legesse, M., G. Medhin, M. Bayissa, and G. Mamo. (2018). Knowledge and perception of pastoral community members about brucellosis as a cause of abortion in animals and its zoonotic importance in Amibara district, Afar Region, Ethiopia, *PLoS One*, 13: e0206457.

Little, P. D., Tiki, W., & Debsu, D. N. (2015). Formal or informal, legal or illegal: the ambiguous nature of cross-border livestock trade in the Horn of Africa. *Journal of Borderlands Studies*, *30*(3), 405-421.

Mangesho, P. E., M. O. Neselle, E. D. Karimuribo, J. E. Mlangwa, K. Queenan, L. E. Mboera, J. Rushton, R. Kock, B. Hasler, A. Kiwara, and M. Rweyemamu. (2017). Exploring local knowledge and perceptions on zoonoses among pastoralists in northern and eastern Tanzania, *PLoS Negl Trop Dis*, 11: e0005345.

Matiko, M. K., Salekwa, L. P., Kasanga, C. J., Kimera, S. I., Evander, M., & Nyangi, W. P. (2018). Serological evidence of inter-epizootic/inter-epidemic circulation of Rift Valley fever virus in domestic cattle in Kyela and Morogoro, Tanzania. *PLoS Negl Trop Dis, 12*(11), e0006931. doi:10.1371/journal.pntd.0006931

Maudlin, I., M. C. Eisler, and S. C. Welburn. (2009). Neglected and endemic zoonoses, *Philos Trans R Soc Lond B Biol Sci*, 364: 2777-87.

McDermott John, Grace Delia, & Zinsstag J. (2013). Economics of brucellosis impact and control in low-income countries. *32*(1), 249-261.

McDermott, J., & Arimi, S. (2002). Brucellosis in sub-Saharan Africa: epidemiology, control and impact. *90*(1-4), 111-134.

Meadows, S., Jones-Bitton, A., McEwen, S. A., Jansen, J., Patel, S. N., Filejski, C., & Menzies, P. (2016). Coxiella burnetii (Q Fever) Seropositivity and Associated Risk Factors in Sheep and Goat Farm Workers in Ontario, Canada. *Vector Borne Zoonotic Dis, 16*(10), 643-649. doi:10.1089/vbz.2015.1909

Megarsa B (2019). Detection of Rift Valley Fever virus from mosquito vectors and Mosquito distribution model Based Rift Valley Fever Risk Mapping in Ethiopia (Doctoral dissertation, Addis Ababa University).

Megersa, B., Biffa, D., Niguse, F., Rufael, T., Asmare, K., & Skjerve, E. (2011). Cattle brucellosis in traditional livestock husbandry practice in Southern and Eastern Ethiopia, and its zoonotic implication. *Acta Veterinaria Scandinavica*, *53*(1), 24.

Mohabbati Mobarez A, Bagheri Amiri F, Esmaeili S (2017) Seroprevalence of Q fever among human and animal in Iran; A systematic review and meta-analysis. PLoS Negl Trop Dis 11 (4): e0005521.

Montavon, A., V. Jean-Richard, M. Bechir, D. M. Daugla, M. Abdoulaye, R. N. Bongo Nare, C. Diguimbaye-Djaibe, I. O. Alfarouk, E. Schelling, K. Wyss, M. Tanner, and J. Zinsstag (2013). Health of mobile pastoralists in the Sahel-assessment of 15 years of research and development, *Trop Med Int Health*, 18: 1044-52.

Nahed, H. G., & Khaled, A. J. (2012). Seroprevalence of Coxiella burnetii antibodies among farm animals and human contacts in Egypt. *8*, 619-621.

Nakoune, E., Kamgang, B., Berthet, N., Manirakiza, A., & Kazanji, M. (2016). Rift Valley Fever Virus Circulating among Ruminants, Mosquitoes and Humans in the Central African Republic. *PLoS Negl Trop Dis, 10*(10), e0005082. doi:10.1371/journal.pntd.0005082

Nassef, M., Anderson, S., & Hesse, C. (2009). Pastoralism and climate change: enabling adaptive capacity. *ODI, London*.

Nell, Arend Jan (2006). Quick scan of the livestock and meat sector in Ethiopia: Issues and opportunities. Wageningen University and Research Centre, Wageningen International.

Ng'ang'a, C. M., Bukachi, S. A., & Bett, B. K. (2016). Lay perceptions of risk factors for Rift Valley fever in a pastoral community in northeastern Kenya. *BMC Public Health, 16*, 32. doi:10.1186/s12889-016-2707-8

Nthiwa, D., Alonso, S., Odongo, D., Kenya, E., & Bett, B. (2019). Zoonotic Pathogen Seroprevalence in Cattle in a Wildlife–Livestock Interface, Kenya. *EcoHealth*, *16*(4), 712-725.

OIE. (2016). World Organisation for Animal Health.

OIE. (2018). World Organisation for Animal Health. OIE Terrestrial Manual. Retrieved from https://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/3.01.04_BRUCELLOSIS.pdf.

Olive, M. M., Chevalier, V., Grosbois, V., Tran, A., Andriamandimby, S. F., Durand, B., Heraud, J. M. (2016). Integrated Analysis of Environment, Cattle and Human Serological Data: Risks and Mechanisms of Transmission of Rift Valley Fever in Madagascar. *PLoS Negl Trop Dis, 10*(7), e0004827. doi:10.1371/journal.pntd.0004827

Otte, M., & Gumm, I. J. P. V. M. (1997). Intra-cluster correlation coefficients of 20 infections calculated from the results of cluster-sample surveys. *31*(1-2), 147-150.

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. doi:10.1016/j.onehlt.2016.09.001

Racloz, V., Schelling, E., Chitnis, N., Roth, F., & Zinsstag, J. (2013). Persistence of brucellosis in pastoral systems. *32*(1), 61-70.

Ran, X., Cheng, J., Wang, M., Chen, X., Wang, H., Ge, Y.,& Wen, X. (2019). Brucellosis seroprevalence in dairy cattle in China during 2008–2018: A systematic review and meta-analysis. *Acta tropica*, *189*, 117-123.

Rettberg, Simone, Gabriele Beckmann, Margitta Minah, and Anja Schelchen (2017). Ethiopia‘s Arid and Semi-Arid Lowlands:Towards Inclusive and Sustainable Rural Transformation. Albrecht Daniel Thaer-Institut für Agrar-und Gartenbauwissenschaften.

Rissmann, M., Stoek, F., Pickin, M. J., & Groschup, M. H. (2019). Mechanisms of inter-epidemic maintenance of Rift Valley fever phlebovirus. *Antiviral Research*, 104692.

Roth, Felix, Jakob Zinsstag, Dontor Orkhon, G. Chimed-Ochir, Guy Hutton, Ottorino Cosivi, Guy Carrin, and Joachim Otte (2003). Human health benefits from livestock vaccination for brucellosis: case study. In *Bulletin of the World Health Organization 2003, 81 (12)*.

Schelling, E., Diguimbaye, C., Daoud, S., Nicolet, J., Boerlin, P., Tanner, M., & Zinsstag, J. (2003). Brucellosis and Q-fever seroprevalences of nomadic pastoralists and their livestock in Chad. *Prev Vet Med, 61*(4), 279-293. doi:10.1016/j.prevetmed.2003.08.004

Schelling, Esther, Delia Grace, A Lee Willingham III, and Tom Randolph (2007). Research approaches for improved pro-poor control of zoonoses, *Food and Nutrition Bulletin*, 28: S345-S56.

Scoones, Ian, and William Wolmer (2006). Livestock, disease, trade and markets: policy choices for the livestock sector in Africa.

Shapiro, Barry I, Getachew Gebru, Solomon Desta, Asfaw Negassa, Kidus Nigussie, Gezahegn Aboset, and Henok Mechale (2017). Ethiopia livestock sector analysis: A 15 year livestock sector strategy.

Sharma, H. K., Kotwal, S. K., Singh, D. K., Malik, M. A., Kumar, A., Rajagunalan, & Singh, M. (2016). Seroprevalence of human brucellosis in and around Jammu, India, using different serological tests. *Vet World, 9*(7), 742-746. doi:10.14202/vetworld.2016.742-746

Singh, B. B., R. Kaur, G. S. Gill, J. P. S. Gill, R. K. Soni, and R. S. Aulakh (2019). Knowledge, attitude and practices relating to zoonotic diseases among livestock farmers in Punjab, India, *Acta Trop*, 189: 15-21.

SRBoFED. (2014). Somali Region Bureau of Finance Economic and Development Data Collection Created In ArcGIS 9.3 Using ArcMap.

STEM (2016). Horn of Africa Livestock Export A-bussines at a crossroads.

Sumaye, R. D., Geubbels, E., Mbeyela, E., & Berkvens, D. (2013). Inter-epidemic transmission of Rift Valley fever in livestock in the Kilombero River Valley, Tanzania: a cross-sectional survey. *PLoS Negl Trop Dis, 7*(8), e2356. doi:10.1371/journal.pntd.0002356

Swai, E. S., L. Schoonman, and C. J. Daborn (2010). Knowledge and attitude towards zoonoses among animal health workers and livestock keepers in Arusha and Tanga, Tanzania, *Tanzan J Health Res*, 12: 280-6.

Swift, Jeremy. (1988). Major issues in pastoral development with special emphasis on selected African countries.

Tadesse, G. (2016). Brucellosis Seropositivity in Animals and Humans in Ethiopia: A Meta-analysis, *PLoS Negl Trop Dis*, 10: e0005006.

Terefe, Y., Girma, S., Mekonnen, N., & Asrade, B. (2017). Brucellosis and associated risk factors in dairy cattle of eastern Ethiopia. *Trop Anim Health Prod, 49*(3), 599-606. doi:10.1007/s11250-017-1242-7

Tesfaye, Angassa, & Negassi, Amaha (2018). A Review on Cross-Border Livestock Trade Across Dry Land Borders of Ethiopia: The Trends and Implications, Journal of Scientific, and Innovative Research 7: 36-42.

Tilahun, B., Bekana, M., Belihu, K., & Zewdu, E. (2013). Camel brucellosis and management practices in Jijiga and Babile districts, Eastern Ethiopia. *5*(3), 81-86.

Tran, A., Trevennec, C., Lutwama, J., Sserugga, J., Gely, M., Pittiglio, C., Chevalier, V. (2016). Development and Assessment of a Geographic Knowledge-Based Model for Mapping Suitable Areas for Rift Valley Fever Transmission in Eastern Africa. *PLoS Negl Trop Dis, 10*(9), e0004999. doi:10.1371/journal.pntd.0004999

Tschopp, R., Abera, B., Sourou, S. Y., Guerne-Bleich, E., Aseffa, A., Wubete, A., & Young, D. (2013). Bovine tuberculosis and brucellosis prevalence in cattle from selected milk cooperatives in Arsi zone, Oromia region, Ethiopia. *9*(1), 163.

Tschopp, R., Bekele, S., Moti, T., Young, D., & Aseffa, A. (2015). Brucellosis and bovine tuberculosis prevalence in livestock from pastoralist communities adjacent to Awash National Park, Ethiopia. *Preventive veterinary medicine*, *120*(2), 187-194.

Tulu, D., Deresa, B., Begna, F., & Gojam, A. (2018). Review of common causes of abortion in dairy cattle in Ethiopia. *10*(1), 1-13.

United Nations Department of Economic and Social Affairs, Population Division.

Vanderburg, S., Rubach, M. P., Halliday, J. E., Cleaveland, S., Reddy, E. A., & Crump, J. A. (2014). Epidemiology of Coxiella burnetii infection in Africa: a OneHealth systematic review. *PLoS Negl Trop Dis, 8*(4), e2787. doi:10.1371/journal.pntd.0002787

Venton, Courtenay Cabot, Catherine Fitzgibbon, Tenna Shitarek, Lorraine Coulter, and Olivia Dooley (2014). The Economics of Early Response and Disaster Resilience: Lessons from Kenya and Ethiopia.

Wardrop, N. A., Thomas, L. F., Cook, E. A., de Glanville, W. A., Atkinson, P. M., Wamae, C. N., & Fevre, E. M. (2016). The Sero-epidemiology of Coxiella burnetii in Humans and Cattle, Western Kenya: Evidence from a Cross-Sectional Study. *PLoS Negl Trop Dis, 10*(10), e0005032. doi:10.1371/journal.pntd.0005032

World Bank (2018). https://www.worldbank.org/en/country/ethiopia/overview.

World Bank. (2012). *People, Pathogens and our Planet. The Economics of One Health* (69145-GLB).

World Bank (2010). People, Pathogens, and Our Planet. Volume 1: Towards a One health approach to controlling zoonotic disease. Report No. 50833-GLB

Yeshwas, F., Desalegne, M., Gebreyesus, M., & Mussie, H. (2011). Study on the seroprevalence of small ruminant brucellosis in and around Bahir Dar, north west Ethiopia. *15*(2), 35-44.

Yilma, M., Mamo, G., & Mammo, B. (2016). Review on Brucellosis Sero-prevalence and Ecology in Livestock and Human Population of Ethiopia. *Achievements in the Life Sciences, 10*(1), 80-86. doi:10.1016/j.als.2016.05.008

Zerfu, B., Medhin, G., Mamo, G., Getahun, G., Tschopp, R., & Legesse, M. (2018). Community-based prevalence of typhoid fever, typhus, brucellosis and malaria among symptomatic individuals in Afar Region, Ethiopia. *PLoS Negl Trop Dis, 12*(10), e0006749. doi:10.1371/journal.pntd.0006749

Zewdie, W. (2018). Review on Bovine, Small ruminant and Human Brucellosis in Ethiopia. *J Vet Med Res 5(9): 1157.*

Zinsstag, J., E. Schelling, B. Bonfoh, L. Crump and S. KrAtli (2016). "The future of pastoralism: an introduction." Rev Sci Tech 35(2): 335-355.

Zinsstag, J., E. Schelling, D. Waltner-Toews, M. Whittaker, and M. Tanner (2015). *One Health: The theory and practice of integrated health approacches* (CABI).

Zinsstag, J., M. F. Abakar, M. Ibrahim, R. Tschopp, L. Crump, B. Bonfoh, and E. Schelling (2016). Cost-effective control strategies for animal and zoonotic diseases in pastoralist populations, *Rev Sci Tech*, 35: 673-81.

Zinsstag, J., Schelling, E., Wyss, K., & Mahamat, M. B. (2005). Potential of cooperation between human and animal health to strengthen health systems. *The Lancet*, *366*(9503), 2142-2145.

Zolzaya, B., Selenge, T., Narangarav, T., Gantsetseg, D., Erdenechimeg, D., Zinsstag, J., Schelling, E.(2014). Representative seroprevalences of human and livestock brucellosis in two Mongolian provinces. Ecohealth 11, 356-371.

Chapter Nine: Appendix

Appendix

9. 1 Field photos

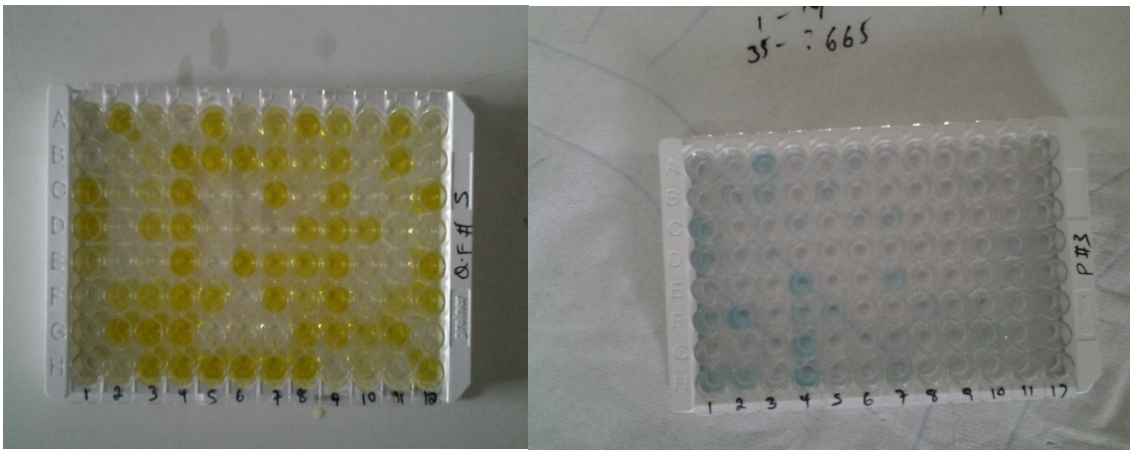

Fig 16 serological tests results (indirect ELISA (left) for Q-fever and competitive ELISA (right) for RVF. The color change shows positive

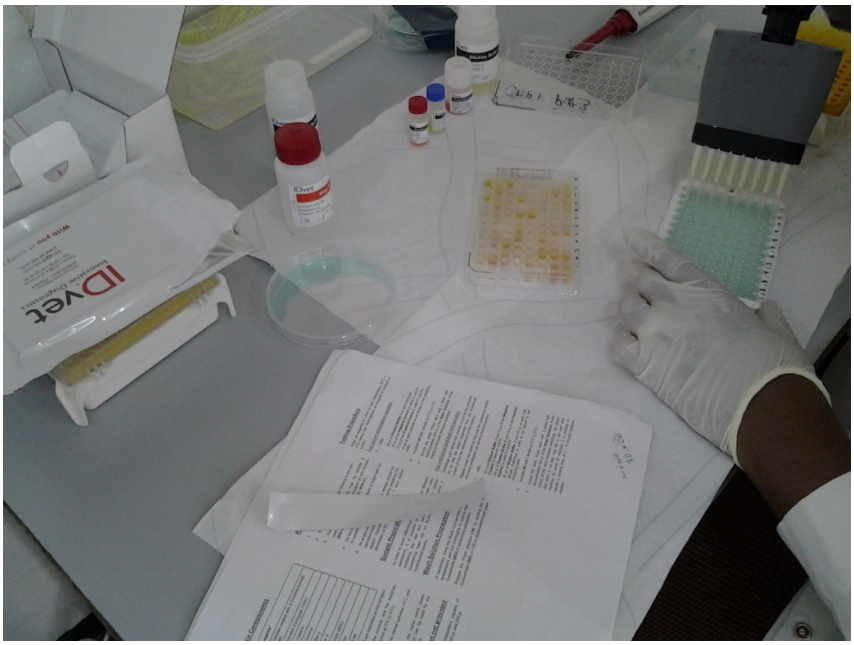

Fig 17 serological tests (ELISA)

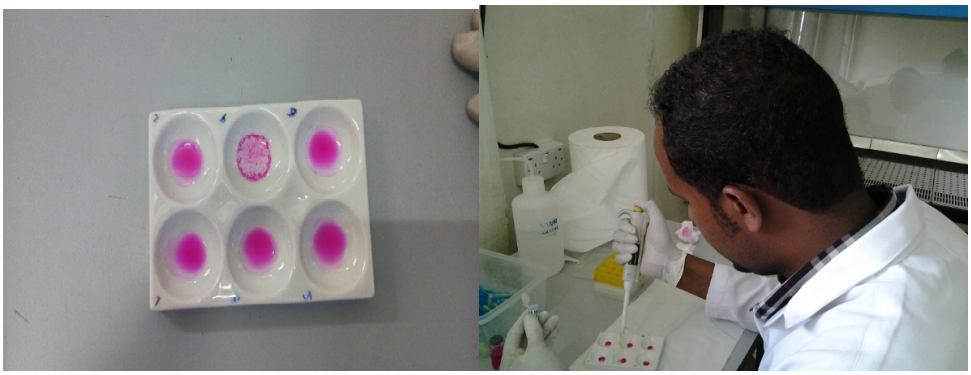

Fig 18 Rose Bengal Test (the agglutination at the left top middle shows positive)

Fig 19 the author taking blood sample from camel (left) and goat (right)

Fig 20 a nurse taking blood sample from women and the author records the information


Fig 21 focus group discussion session with the author (men and women are separated)


Fig 22 Individual interview session


Fig 23 integrated One Health training for human and animal health workers from all kebeles in Adadle Woreda

Fig 24 partial view of Gode livestock market

Fig 25 kids fetch water by donkey

9.2 Curriculum Vitate

Curriculum Vitae
Mohammed Abdikadir

Education

2015- present	PhD candidate in Epidemiology Swiss Tropical and Public Health Institute, University of Basel, Switzerland Thesis: Public health and economic importance of livestock diseases with the emphasis on zoonoses including brucellosis, Q-fever and Rift Valley Fever in Somali region, Ethiopia
2011-2013	Master in Tropical animal production and health Addis Ababa university, Ethiopia Thesis: Ccharacterisation of production systems and reproductive performances of *Camelus Dromedarius* in selected districts of Somali region, Ethiopia Excellent grade
2003-2008	Doctor of Veterinary Medicine (DVM) Haramaya University, Ethiopia Thesis: Survey on prevalence of mange mites in camels in Fafan area, Eastern Ethiopia

Professional experience

2013-2015	Chairperson Research ethics committee Jigjiga University, Ethiopia
2013-2014	Coordinator Common course on pastoralism and pastoral policy in Ethiopia Jigjiga University, Ethiopia
2010-2011	Regional coordinator Animal health research Somali Region Pastoral and Agro-pastoral Research Institute, Jigjiga, Ethiopia
2008-2010	Veterinarian Somali Region Pastoral and Agro-pastoral Research Institute, Jigjiga, Ethiopia

Publications

Journal Articles

Tamar E. Carter, Solomon Yared, Araya Gebresilassie, Victoria Bonnell, Lambodhar Damodaran, Karen Lopez, Mohammed Ibrahim, Seid Mohammed, Daniel Janies (2018). First detection of Anopheles stephensi Liston, 1901 (Diptera: culicidae) in Ethiopia using molecular and morphological approaches. https://doi.org/10.1016/j.actatropica.2018.09.001

Lidya Ketema, Zerihun Ketema, Bitsu Kiflu, Haile Alemayehu, Yitagele Terefe, Mohammed Ibrahim, and Tadesse Eguale (2018). Prevalence and Antimicrobial Susceptibility Profile of *Salmonella* Serovars Isolated from Slaughtered Cattle in Addis Ababa, Ethiopia. https://doi.org/10.1155/2018/9794869.

Jakob Zinsstag, Lisa Crump, Esther Schelling, Jan Hattendorf, Yahya Osman Maidane, Kadra Osman Ali, Abdifatah Muhummed, Abdurezak Adem Umer, Ferzua Aliyi, Faisal Nooh, Mohammed Ibrahim Abdikadir, Seid Mohammed Ali, Stella Hartinger, Daniel M¨ausezahl,Monica Berger Gonzalez de White, Celia Cordon-Rosales, Danilo Alvarez Castillo, John McCracken, Fayiz Abakar, Colin Cercamondi, Sandro Emmenegger, Edith Maier, Simon Karanja, Isabelle Bolon, Rafael Ruiz de Castan˜ eda, Bassirou Bonfoh, Rea Tschopp, Nicole Probst-Hensch and Gu´eladio Ciss ´e (2018). Climate Change and One Health. http://orcid.org/0000-0002-8899-6097.

J. Zinsstag, M.F. Abakar, M. Ibrahim, R. Tschopp, L. Crump, B. Bonfoh & E. Schelling (2016). Cost-effective control strategies for animal and zoonotic diseases in pastoralist populations. *Rev. Sci. Tech. Off. Int. Epiz.*, 2016, 35 (2), 673–681. doi: 10.20506/rst.35.2.2548.

Simenew Keskes, Mohamed Ibrahim, Tesfaye Sisay Tessema, Berhan Tamir, Fekadu Regassa, Tesfu Kassa, Fufa Dawo (2013). Production systems and reproductive performances of *Camelus dromedarius* in Somali regional state, eastern Ethiopia. JAEID 2013, 107 (2): 243 – 266. DOI 10.12895/jaeid.20132.166.

Mohammed Ibrahim, Esther Schelling , Jakob Zinsstag , Jan Hattendorf , Emawayish Andargie, Rea Tschopp.. Sero-prevalence of brucellosis, Q-fever and Rift Valley Fever in humans and livestock in Somali region, Ethiopia (published in PLoS Neglected Tropical Disease Journal).

Mohammed Ibrahim, Esther Schelling , Jakob Zinsstag , Jan Hattendorf , Rea Tschopp. Livestock health and zoonoses: Awareness and practices among pastoral and agro-pastoral communities in the Somali Region, Ethiopia (submitted to Nomadic People Journal).

Mohammed Ibrahim, Rea Tschopp, Jakob Zinsstag, Esther Schelling. Livestock trade and its associated diseases in Somali region, Ethiopia (in press)

Mohammed Ibrahim, Abdifatah Muhummed, Seid Mohammed, Hamere Melaku, Jakob Zinsstag, Rea Tschopp. Perception of wildlife among Somali pastoralists in Adadle woreda, Eastern Ethiopia (in press).

Leadership

2014-2015	Dean School of Graduate Studies Jigjiga University, Ethiopia
2013-2014	Officer Academic and Research Vice President Office Jigjiga University, Ethiopia
2013-2014	Officer Community Service Office Jigjiga University, Ethiopia
2008	Center manager Fafan Integrated Livestock Research Center Fafan, Ethiopia

Membership

2010-present	Ethiopian Veterinary Association
2013-present	Ethiopian Society for Animal Production