

**FOOT AND MOUTH DISEASE IN THE BORENA PLATEAU: LIVELIHOODS
IMPACT AND VACCINATION BENEFIT - COST ANALYSIS, ETHIOPIA.**

By

TARIKU JIBAT BEYENE

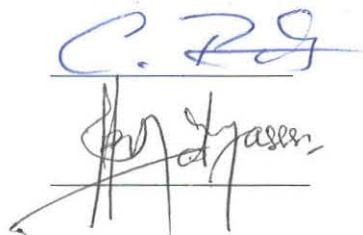
Academic advisors

Signature

Dr. Tesfaye Rufael (NADIC, Ethiopia)

Dr. Carsten Potzsch (FU-Berlin, Germany)

Dr. Berhanu Admassu (Tufts University, Ethiopia)

The image shows two handwritten signatures in blue ink. The top signature is 'C. Potzsch' and the bottom signature is 'Berhanu Admassu'. Both are written over horizontal lines.

**DECEMBER, 2011
DEBRE ZEIT, ETHIOPIA**

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SUPERVISORS

Signature

Berhanu Admassu (DVM, MSc.)

.....

Tesfaye Rufael (DVM, MSc.)

.....

Carsten Potzsch (Dr. Med. Vet.)

.....

By

TARIKU JIBAT BEYENE

Board of examiners

Signature

1. Prof. K-H. Zessin (Freie University of Berlin, Germany)

2. Dr Berhanu Admassu (FIC, Tufts university, Addis Ababa, Ethiopia)

3. Dr Tesfaye Rufael (NAHDIC, Ethiopia)

4. Dr. Khitma Hassan Elmalik (University of Khartoum, Sudan).

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ABBREVIATIONS

- AU/IBAR – African Union/Interafrican Bureau of animal resources
BZPDB- Borena Zone Pastoral Development Bureau
CBPP- Contagious Bovine Pleura Pneumonia
ELISA- Enzyme Linked Immunosorbent Assay
FAO- Food and Agricultural Organization
FMD- Foot and Mouth Disease
HIS- Heat Intolerance Syndrome
MOARD- Ministry of Agriculture and Rural Development
NAHDIC- National Animal Health Diagnostic and Investigation Center
NSP- non structural protein
OIE- Office International des Epizooties/World Organization for Animal Health
PA- Participatory Appraisal
PDS- Participatory Disease Searching
PE- Participatory Epidemiology
PP- proportional piling
RNA- Ribonucleic acid
SAT- Southern African Territories
USD- United States Dollar
VNT- Virus Neutralisation Tests
VP- Viral Protein
W- Kendal's concordance of coefficient

ABSTRACT

Foot-and-mouth disease (FMD) is an acute, highly communicable and economically important disease of livestock and wild animals. This study was conducted on FMD's livelihoods impact, trend analysis and benefit-cost ratio of vaccination in Borena zone, Oromia regional state of Ethiopia. The study used participatory appraisal methods and secondary data sources. Livestock-related livelihoods options accounted for 31% of the total means of food and income source followed by crop farming. This study clearly showed that FMD had the greatest impact on the cattle-derived benefits and the trend of outbreaks frequency and severity has been increasing with timeline from 1960 to 2007 ($r=0.612$). Furthermore, through the timeline, FMD outbreaks frequency and severity was found to be significantly correlated to length of extended dry season ($r=0.377$). In addition, FMD is ranked number one cattle disease after 1985 with significant rank change ($t=12.04$) as compared to 1984 and before. In this study area vaccination was proposed after realizing that majority of the FMD cases remain untreated and outbreaks remain uncontrolled. The benefit from FMD vaccination is found to be 9.1 times that the expenses of the vaccination indicating that the control of FMD in Borena zone by vaccination could be justified on economic grounds. The feasibility of FMD vaccination as control strategy needs to be examined in the light of FMD's significant impacts on livelihoods, its positive benefit-cost ratio for vaccination, absence of an environment suitable for FMD control through movement control, quarantine, culling and other options. The benefit-cost ratio of vaccination was less sensitive to vaccination costs change. Although it is not expected for a vaccination program to lead to a disease free status in herds in the region soon, decreased FMD incidences will lead to increased milk production and calf survival. This would imply less stress on people's lives, secure food sources and social harmony and also might increase national and international trade opportunities.

Keywords: Food security, economic modeling, participatory epidemiology, socio-economics, trend analysis.

1 INTRODUCTION

Foot and mouth disease (FMD) virus causes a highly contagious viral disease of cloven-footed animals and is one of the most important economic diseases of livestock. The disease is characterized by fever, and vesicular eruptions in the mouth and on the feet and teats. It is caused by a virus of the genus *Aphthovirus*, family Picornaviridae which has 7 immunologically distinct serotypes, namely: O, A, C, South African Territories (SAT) 1, SAT 2, SAT 3 and Asia1 (OIE, 2009). Some seroprevalence estimates for FMD available in pastoralist herds, includes Orma herds in Kenya (9%), and Maasai and Sukuma herds in Tanzania (9.5%) (Catley *et al.*, 2004), South Sudan (15.8%) (Barasa *et al.*, 2008); Borena in Ethiopia (21%) (Rufael *et al.*, 2008), 53.6 % (Mekonen *et al.*, 2011) and other non pastoral parts of Ethiopia (8% -50%) (Ayelet *et al.*, 2009; Megersa *et al.*, 2009; Molla *et al.*, 2010; Negussie *et al.*, 2011).

The disease effects are more pronounced in cattle and pig systems while the impact in goat and sheep systems tends to be low (Hughes *et al.*, 2002). The most direct economic impact of FMD in endemic countries is the loss or reduced efficiency of production, which reduces farmers' income. The impact of reduced productivity of animals can be a long lasting and diseases can have lasting effects on livestock output in a number of "hidden" ways such as delays in reproduction leading to fewer offspring and the consequences of a reduced population. These hidden losses often exceed the losses associated with clearly visible illness. At the local level, FMD reduces farmers' income and food availability for consumption. At the national level, FMD slows economic growth by severely limiting trade opportunities. Heavy losses occur in small scale mixed farming system when outbreaks affect draft oxen during cropping season. It causes considerable losses of milk yield and weight gain among dairy and fattening stock. Its role in contributing to the suffering and death of livestock particularly when affected at periods of drought by limiting their access to feed and water or at early ages can to be significant. Foot and mouth disease status of a country is an important determinant of international trade in livestock products, and the existence of FMD is an effective barrier from the markets with the highest prices for these products. The 2006 FMD outbreak detected in Egypt also became the major cause of live cattle import ban to the Egyptian markets. Ethiopia had commenced exportation of

chilled meat and live animals to different countries based on bilateral agreements. In the past few years, this exportation was banned due to suspected outbreaks of FMD occurrence in the country in association with Ethiopian imports (MOARD, 2006) and it also causes significant losses in agriculture and tourism due to restriction on human movement (James and Rushton, 2002).

The literature on pastoralism in Africa highlights the importance of milk in the diet of pastoralists. For example, for the Borena in southern Ethiopia and the Turkana in northwest Kenya, milk accounted for 55.4% and 62.0% of people's diet, respectively, in terms of gross energy intake. At household level, milk is particularly an important food for pastoralist's children and children receive preferential treatment in terms of milk consumption. Marked seasonality in human food supply is another important feature of pastoralism (Coppock, 1994; Fielding *et al.*, 2000).

Due to the comparatively low productivity of indigenous livestock and inadequate information on the impact of FMD on the livelihoods of pastoralists and agro pastoralists, control of FMD in these production systems is given very low priority by the policy makers. This status of the disease is compounded by the following factors: relatively high vaccine cost, relatively low vaccine specificity of locally available vaccines, raising cost effectiveness: questions due to short duration of conferred immunity and high mobility of pastoralists rendering movement control difficult if not impossible (Barasa *et al.*, 2008). Thus, vaccination against FMD has been given only to exotic improved breeds and their crosses and has never been seriously considered as a control option for the pastoral areas of Ethiopia (Sahle *et al.*, 2004; Ayelet, *et al.*, 2009).

The extent to which a disease is recognized as a problem is often dependent on the efficacy of the means for diagnosing it and observing its occurrence. However, in the Borena pastoral community, there is extensive body of traditional or ethno-veterinary knowledge that pastoralists have known to possess and on which they rely to diagnose, treat, prevent and control most cattle diseases (Rufael *et al.*, 2008). Veterinarians and livestock workers have used and are presently using a variety of participatory appraisal methods to investigate animal health problems (Catley, 1999).

In recent years the methods of participatory appraisal have been adapted by epidemiologists to improve understanding of livestock diseases in resource poor settings and in areas where conventional methods are difficult to use. The value of this approach is apparent from the emergence of participatory epidemiology (PE) as a distinct branch of veterinary epidemiology, and the application of PE by programmes such as the Pan African Programme for the Control of Epizootics (AU-IBAR) and the Global Rinderpest Eradication Programme (FAO) (Catley and Admassu, 2003). In addition; it is stated by Catley (2005) that participatory epidemiology can be used for research like livelihood analysis, basic research on the epidemiology of endemic and epizootic diseases, local preferences for control of animal diseases, animal health surveys and problem analysis in community based animal health projects, impact assessments of community based animal health programs, participatory disease searching and veterinary research that involve diagnostic studies and disease characterization.

It is increasingly recognized that economic analysis should inform decisions on animal disease control and that benefit-cost analysis is a commonly used analytical framework (Rushton *et al.*, 1999). Given the complexity of the epidemiology of FMD, the presence of various virus types and intratypic variants, the high cost of vaccines and the operational challenges of working in pastoral areas, the underlying logic of benefit cost analysis is well known and accepted. This assumes that investors in disease control, whether they are public, private or mixed sectors, need to understand the possible outcomes of a particular disease control option in monetary terms. A recent case study in Uganda and Sudan for benefit-cost and livelihood analysis has shown that application of FMD control measures are of considerable benefit to the national economy of the country (Rutagwenda, 2003; Barasa *et al.*, 2008).

The main objectives of this study were:

1. To assess the livelihoods impact of Foot and Mouth Disease in Borena zone.
2. To analyze the trend of Foot and Mouth Disease occurrence.
3. To estimate the benefit-cost ratio of vaccination and its sensitivity to recommend it as control strategy.

2 LITERATURE REVIEW

2.1 The Borena's livelihood

Keeping cattle as sole livelihood option called 'pastoralism' is the principal source of livelihood for Borana households. The income from pastoralism consists of the cash component generated from live animal sales, earnings from milk off-take, miscellaneous income from other animal by-product sales such as hides and skins and the in-kind source. The in-kind component of pastoral household income consists of unmarketed pastoral and farm outputs, inter-household in-kind transfers, and food aid. The cash component of pastoralist household income is similarly generated from pastoral and non-pastoral activities. The latter have become a growing source of pastoralist livelihoods in recent years. The Borana household non-pastoral cash income is generated from grain sales, various non-farm non-pastoral activities, and some cash gifts and transfers from friends and relatives. The Borana pastoralists also sell livestock for clothing, grain purchases, replacement stock and tax payment. Pastoralists practice farming primarily to supplement their subsistence diet, though it has gained some importance as a source of cash income in the relatively livestock-poor periurban areas (Berhanu and Fayissa, 2010).

2.2 Foot and mouth disease

2.2.1 Etiology

Foot and mouth disease, FMD, is caused by a virus belonging to the genus *Aphthovirus*, family *Picornaviridae*, with a number of immunologically and serologically distinct subtypes with different degrees of virulence affecting cloven-hoofed animals (Radostits, *et al.*, 2006). Picornaviruses are small RNA viruses that are enclosed within a non-enveloped protein shell (capsid). The capsid consists of polypeptides, which are devoid of lipoprotein, and hence is stable to lipid solvents like ether and chloroform. In milk and milk products, the virion is

protected, and can survive at 70 °C for 15 seconds and pH of 4.6. In meat, the virus can survive for long periods in chilled or frozen bone marrow and lymph nodes. Two percent solutions of Sodium hydroxide or Potassium hydroxide and 4% sodium carbonate are effective disinfectants for FMD contaminated objects, but the virus is resistant to alcohol, phenolic and quaternary ammonium disinfectants. The sizes of droplet aerosol also play an important role in the survival or drying out of the virus; droplet aerosol size of 0.5 - 0.7 µm is optimal for longer survival of the virus in the air, while smaller aerosols dry out (Murphy *et al.*, 1999).

Picornaviruses virions are icosahedral with no envelope and contain one molecule of infectious, positive sense, single stranded RNA (ssRNA), ranging from 7-8.5 kb in length. A viral genomic protein (VP), which is enclosed by the 3B genome region, is covalently linked to the 5' end of the genome and a poly (A) tract of variable length is located at the 3' terminus. The diameter of 22 - 25 nm capsid is composed of 60 capsomers each consisting of four proteins (VP1-4). VP1-VP3 is exposed on the surface, whilst VP4 is located internally at the pentameric apex of the icosahedrons and contains a myristic acid molecule attached to the amino terminal glycine (Murphy *et al.*, 1999).

Foot-and-mouth disease virus undergoes a high rate of mutation during replication. This is mainly due to a lack of replication error checking mechanisms. RNA viruses that exhibit such a deficiency mutate at the rate of one nucleotide base change per 10³ bases per replication cycle. Therefore, new variants of FMD viruses are continuously arising after each replication cycle, which constitute an intratypic population of FMD viruses with different degrees of genetic relationships, previously described as the quasispecies phenomena (Domingo *et al.*, 1990). One of the consequences of genetic variation through mutation, selection, and recombination is that new antigenic variants are constantly being generated. Not only is there no cross protection between FMD virus serotypes, but vaccination with one antigenic variant of serotype does not necessarily protect an animal when challenged with a different virus of the same serotype. Changes to the genes encoding capsid proteins can result in antigenic variation and evolution of new subtypes. This may give rise to immunologically distinct variants that can re-infect individuals that have been previously infected by related viruses. The degree of cross protection among different subtypes of the same serotype thus varies. Since there is continual antigenic drift

in enzootic situation this is an important factor to consider when selecting vaccine strains (Sangare, 2002).

Currently there are seven serotypes of foot and mouth disease virus, namely O, A, C, Southern African Territories (SAT) 1, 2 and 3, and Asia 1, which infect cloven-hoofed animals. Within these serotypes, over 60 subtypes have also been described using biochemical and immunological tests; and new subtypes occasionally arise spontaneously. However, at a specific time, there are only a few subtypes causing disease throughout FMD endemic areas. The importance of subtypes is that a vaccine may have to be tailored to the subtype present in the area in which the vaccine is being used (OIE, 2009). At present, a sequencing of FMD virus is increasingly being used to establish intratypic variations of FMD viruses and classifying viruses in to genotypes and lineages (Gelaye *et al.*, 2005; Negussie *et al.*, 2011).

2.2.2 Epidemiology

a. Geographic distribution

FMD is a global disease that through the years has affected most of the countries on the globe. It occurs throughout the world, most commonly in Asia, Africa, the Middle East, and parts of South America. North America, Central America, Australia, New Zealand, Chile, Japan, and most of European countries have been recognized as free, and Uruguay and Argentina have not had an outbreak since April 1994. However, Europe is essentially free of the disease but cattle imported from Eastern Europe gave rise to an epidemic in Italy during 1993. More recently, there was a massive outbreak in Britain in 2001 which spread to Ireland, France and The Netherlands and separate outbreaks in Italy and Greece. Japan has also recently eradicated outbreaks before it was eventually contained. As for North America, the last outbreak in the United States was in 1929, Canada in 1951-1952, and Mexico in 1946-1954 (Radostits *et al.*, 2006). Due to poor reporting system from the African continent, FMD is considered endemic in most of the African Countries with only Swaziland being free and Namibia and Botswana having free zone of FMD by the OIE resolution No.14 in 2011 (<http://www.oie.int/animal-health-in-the-world/official-disease-status/fmd/list-of-fmd-free-members/>).

b. Host range

Domestic animal species like cattle, pigs, sheep, goats, and buffalo are susceptible to FMD. In addition, many species of cloven-hoofed wild animals, such as deer, antelope and wild pigs, may become infected, although, apart from the African buffalo, their involvement in the epidemiology of FMD in the domesticated species is not certain (OIE, 2009). The susceptibility of these animals can vary with breed of animal and strain of virus. The disease is considerably less obvious or sub-clinical in breeds of cattle, sheep, and goats indigenous to Africa and Asia, where FMD is endemic. Studies in Kenya showed that goats were infrequent carriers, and sheep not at all (Radostits *et al.*, 2006).

c. The role of carriers and wild animals

Carrier, in FMD, is defined as an animal from which FMD virus can be isolated from the esophageal pharyngeal (OP) area, more than 28 days after infection. Although it is well established that FMD virus persists in buffalo, cattle, sheep, and goats, the mechanisms underlying persistence and the immunological pathway that eventually leads to viral clearance are not well understood. This may provide a mechanism for the maintenance of the virus in nature and the cause of acute episodes of disease and may contribute to the emergence of new antigenically variant viruses (Kitching, 1998; Radostits *et al.*, 2006).

FMD has been reported in several wild life species, such as African buffalo (*Syncerus caffer*), Impala (*Aepyceros melampus*), Kudu (*Tragelaphus strepsiceros*) species, Warthog (*Phacochoerus aethiopicus*) and elephants that have a role in epidemiology of the disease. Buffalo are believed to be the ultimate source of infection for livestock in southern Africa due to their ability to both maintain and transmit the disease. FMD virus can persist in an isolated herd of buffalo for up to 24 years, whilst an individual animal can maintain the infection for up to five years. Furthermore, buffalo have unequivocally been shown to be a source of infection for cattle under both natural and experimental conditions (Sangare, 2002). The mechanism facilitating SAT-type virus transmission of virus from buffalo appears to occur readily when; there is close contact between the two species during acute stage of infection and shedding large amounts of

virus. Impala (*Aepyceros melampus*) is the most frequent infected species and act as intermediaries in disease transmission was recognized. Although studies have established that individual impala do not become carriers, it appears that the disease can persist in impala populations for between 6 and 13 months Kudu (*Tragelaphus strepsiceros*) were shown to be gradually infected, with the carrier state of between 106-140 days being demonstrated. Experimental infection of warthog (*Phacochoerus aethiopicus*) with SAT 2 type virus resulted in severe clinical signs of infection, and transmission to in-contact animals. However, these animals do not excrete virus to the level of domestic pigs and are not believed to play an important role in the epidemiology of FMD in Africa (Vosloo *et al.*, 2002; OIE, 2009).

d. Mode of transmission

The main route of infection in ruminants is through the inhalation of droplets, but ingestion of infected feed, inoculation with contaminated vaccines, insemination with contaminated semen, and contact with contaminating clothing, veterinary instruments, and so on can all produce infection (Radostits *et al.*, 2006). The most important means of spread are by direct contact between infected and susceptible animals but also indirectly by exposure of susceptible animals to the excretion and secretion of acutely infected animals. A person in contact with infected animals can have sufficient FMD virus in his or her respiratory tract for 24 hours to serve as a source of infection for susceptible animals (Asseged, 2005).

When proper humidity and temperature are maintained, FMD virus can be carried up to 250 km across the sea and up to 60 km across the land. The prior condition has been held responsible for the FMD outbreak that occurred in France and then spread to United Kingdom in 1981 emphasizing the possible windborne spread of the virus under prevailing environmental conditions (Kitching, 1992). At present, there are computer models that can predict the most likely wind-borne spread of the virus from infected herds and allow the examination of a variety of control strategies (Sanson *et al.*, 1991).

2.2.3 Pathogenesis

The respiratory tract is most common route of infection in species other than pigs (Seifert, 1996). The virus primarily replicates in epithelial cells in the pharynx and upper respiratory tract (Clavijo and Kitching, 2003) and the lymphoid tissues of the pharynx (Seifert, 1996). The liberation of the virus into the efferent lymphatic system results in an initial viremia (Seifert, 1996). The viraemia then seeds infection into the epithelium tissues where secondary virus replication occurs in the *stratum spinosum*. This results in the accumulation of intracellular and extracellular fluid, leading to the development of a vesicle (Geering *et al.*, 1995). Development of characteristic vesicles in FMD is dependent on infection of the squamous epithelium and persistent local irritation or friction (Seifert, 1996). The lesions are often observed initially as blanched areas and then produce typically clear or straw-colored fluid before they burst and heal (Davies, 2002). When vesicles are ruptured, intact epidermis cells of the *stratum spinosum* and *stratum germinativum* at the base of the vesicles remain. These structures allow the complete and fast regeneration of the lesions (Seifert, 1996). Ruptured vesicles on the feet usually become infected which prolongs the healing process and in many cases chronic lameness and permanent damage to the structure of the hoof ensue (Re'mond *et al.*, 2002). Other important secondary sites of replication include the mammary gland, ruminal lymph nodes and heart. In young animals, sudden death from myocardial necrosis may occur before the development of vesicles (Geering *et al.*, 1995), resulting in high mortality from heart failure (Kitching and Alexandersen, 2002). It was suggested that heat intolerance is a sequel to FMD which is resulted of damage to the endocrine system (Radostits *et al.*, 2006).

2.2.4 Immune Response

Serotype specific immunity is based on the presence of neutralizing antibodies to one of the viral capsid protein, VP1, develops 7 to 21 days after exposure to the virus. The immunoglobulin M (IgM) is most prevalent in the early convalescent serum and is less specific to the different serotypes than Immunoglobulin G (IgG). IgG is produced in the later stage during the FMD infection and the reaction between the serotype and the homologous antibodies is highly specific.

b. Laboratory diagnosis

i. Identification of the agent:

The demonstration of FMD viral antigen or nucleic acid is sufficient for a positive diagnosis. Due to the highly contagious nature and economic importance of FMD, the laboratory diagnosis and serotype identification of the virus should be done in a laboratory that meets the OIE requirements for Containment Group 4 pathogens. Enzyme-linked immunosorbent assays (ELISA) can be used to detect FMD viral antigens and for serotyping. Lateral flow devices (LFD) are also becoming more readily available and can also be used to detect FMD viral antigens. The ELISA has replaced complement fixation (CF) in most laboratories as it is more specific and sensitive and it is not affected by pro- or anti-complement factors. If the sample is inadequate or the diagnosis remains uncertain, sample materials can be tested by Reverse Transcription Polymerase Chain Reaction (RT-PCR) and/or virus isolation using susceptible cell cultures or 2–7-day old unweaned mice to amplify any nucleic acid or live virus that may be present. The cultures should preferably be of primary bovine (calf) thyroid, but pig, lamb or calf kidney cells, or cell lines of comparable sensitivity may be used. Once a cytopathic effect (CPE) is complete in the cultures, the fluids can be tested for FMDV using ELISA, CF or RT-PCR. Similar tests can be performed on homogenized suspensions of the dissected musculo-skeletal tissues of any mice that die (OIE, 2009).

ii. Serological tests

The demonstration of specific antibodies to structural proteins in nonvaccinated animals is indicative of prior infection with FMDV. This is particularly useful in mild cases or where epithelial tissue cannot be collected. Tests for antibodies to some NSPs of FMDV are useful in providing evidence of previous or current viral replication in the host, irrespective of vaccination status. NSPs, unlike structural proteins, are highly conserved and therefore are not serotype specific and as a consequence, the detection of these antibodies is not serotype restricted. Virus neutralisation tests (VNTs) and ELISAs for antibodies to structural proteins are used as serotype-specific serological tests. VNTs depend on tissue cultures and are therefore more prone to

variability than ELISAs; they are also slower and subject to contamination. ELISAs for detection of antibodies have the advantage of being faster, and are not dependent on cell cultures. The ELISA can be performed with inactivated antigens, thus requiring less restrictive biocontainment facilities (OIE, 2009).

2.2.6 Control

The official attitude of a country regarding control of a disease depends on how seriously the disease affects the country, the financial and technical ability of the country, and what its neighbors are doing. The degree of control of FMD thus varies as follows: routine vaccination is used where the disease is endemic; in contrast, a number of disease-free countries have never vaccinated their livestock but have preferred the use strict movement controls and slaughter of infected and contract animals when outbreaks occur (Radostits *et al.*, 2006).

a. In Endemic Areas

In endemic areas, the disease is generally controlled by vaccination and movement restriction of animals. When vaccinating animals, it is important that the vaccine contain the same serotype of virus as in the area. This necessitates frequent checking of the serotype and subtype during an outbreak because FMD virus frequently changes during natural passage through various species. Protection induced by aqueous aluminum hydroxide vaccine can protect for 4-6 months while a double emulsion oil vaccine may protect for up to 1 year (Gonzalez *et al.*, 1992).

The extent of vaccination coverage is of considerable importance to the protection of livestock populations, a concept called "herd immunity". When protective levels of immunity are achieved in the majority of individuals, the establishment or maintenance of the disease within the population is unlikely to occur. For FMD, it is estimated that 80 to 85% of individuals must have protective levels of virus-neutralizing antibody to achieve herd immunity (Asseged, 2005).

b. In Disease Free Areas

i. 'Stamping out'

The more affluent FMD free nations, those with an economically significant live animal and animal product export trade, and those whose livestock are highly susceptible to FMD, have contingency plans to deal rapidly with FMD outbreaks and suspicions (Sangare, 2002). In the first instance, 'stamping out' policy, consisting of the slaughter of all affected and in-contact susceptible animals would be instigated, together with associated zoosanitary measures including, the imposition of movements restriction, to control the outbreaks. Such measures might also extend to preemptively slaughtering other herds in which there is no clinical evidence of the disease, but which have been epidemiologically linked with an outbreak, and may therefore contain infected animals. The stamping out is done with full compensation paid for animals slaughtered. The success of 'stamping out' is recognized by the OIE in its guidelines on re- establishing trade following an outbreak (Asseged, 2005).

ii. Emergency vaccination

Emergency vaccination has gained more preference in recent years, in an attempt to reduce FMD spreading and the amount of virus circulating. 'Suppressive' or 'dampening down' vaccination regime is now on the agenda of a European Commission working group setup to assist the Animal Health and Animal Welfare (AHAW) committee in establishing criteria for the eradication of certain infectious diseases including FMD. The use of emergency FMD vaccines has two clear objectives: to provide protective immunity, as rapidly as, possible to susceptible stock and to reduce the amount of virus released and thereby limit the spread of disease (OIE, 2009; Asseged, 2005).

The protective vaccination is used effectively in animals not already exposed to FMD virus. It would therefore be employed outside the 3 km protection zone and outside any predicted aerosol spread of virus from the infected premise. All vaccinates would be naive to FMD antigen, and would require a minimum of 3-4 days to develop protective immunity. This protective

vaccination would thus form a ring around the infected area, preventing diseases spread, and allows the outbreak to expire within the protection zone, where infected herds would quickly be identified and slaughtered (Asseged, 2005).

c. Requirements for Foot Mouth Disease vaccines

According to OIE terrestrial manual, inactivated virus vaccines of varying composition are available commercially. Typically, virus is used to infect a suspension or monolayer cell culture and the resulting preparation is clarified, inactivated with ethyleneimine and blended with adjuvant. Many FMD vaccines are multivalent to provide protection against the different serotypes likely to be encountered in a given field situation. The finished vaccine must be shown to be free from residual live virus. This is most effectively done using in-vitro tests on concentrated inactivated virus preparations prior to formulation of the vaccine and freedom from live virus is subsequently confirmed during in-vivo and/or in-vitro tests on the finished product. Challenge tests are also conducted in vaccinated cattle to establish a PD50 (50% protective dose) value or protection against generalized foot infection. However, a serological test is considered to be satisfactory where a valid correlation between the observed protection and the specific antibody response has been established (OIE, 2009).

d. Foot and Mouth Disease virus serotypes

Six serotypes, namely O, A, C, SAT 1, SAT 2 and SAT 3, are endemic in most sub-saharan African countries with marked differences in the distribution and prevalence of serotypes. Serotypes A and O are widespread throughout sub-saharan Africa, whilst serotype C appears to have disappeared from the world as a whole. Historically, serotype C was the rarest of the FMDV type to have occurred in Africa, having been recorded only in three countries, namely: Ethiopia, Kenya, and Angola. In Kenya, serotype C occurrence was endemic until 1988; the last outbreaks were reported in 2004. In Kenya, numerous outbreaks due to the serotypes; A, O, SAT 1 and 2 have also been reported. Type O is endemic in some countries of northern Africa, such as Egypt and Libya, while outbreaks due to this serotype have also been reported in Algeria, Morocco, and Tunisia. In central Africa, and West Africa, serotypes of O, A, SAT 1 and SAT 2

have been recorded since 1958, while most outbreaks were attributed to serotypes A and SAT 2. The three SAT serotypes are also prevalent in southern and eastern Africa, SAT 1, and SAT 2 circulate in West Africa and are the only serotypes to have made incursions into the Middle East with SAT-3 demonstrating the most restricted (Vosloo *et al.*, 2002). There is also a knowledge gap from Africa as surveillance, sample submission and reporting is on low level (FAO, 2007).

2.2.7 Foot and Mouth Disease in Ethiopia

FMD was first recorded in Ethiopia in 1957 when serotypes O and C were detected (Martel, 1975). Serotypes A and SAT 2 were not identified until 1969 and 1989, respectively. During 1988–1991, analysis of outbreak samples from Ethiopia at the National Veterinary Institute (NVI), Debre Zeit, Ethiopia, and at the Food and Agriculture Organization Reference Laboratory (WRL) indicated that FMD serotypes O, A, C were responsible for FMD outbreaks during the period 1957 to 1979 (Roeder *et al.*, 1994). The occurrence of FMD in Ethiopia has apparently increased since 1990; outbreaks throughout the country are reported frequently. FMD remains largely uncontrolled in the country because vaccination for prophylactic purpose is not being practiced except for a few dairy herds containing exotic animals. With no control and preventive measures in place, FMD causes substantial economic loss to farmers and to the nation from embargoes of livestock and livestock product trade (Megersa *et al.*, 2009). According to Ayelet, *et al.*, 2009 the virus's serotypes recovered from FMD outbreaks in Ethiopia during 1981–2007 were O, A, C, SAT 1, and SAT 2. Serotype O predominated, followed by serotype A; type C was not recognized after 1983.

2.2.8 Impacts of Foot and Mouth disease

The consequences of animal diseases can be complex and generally go well beyond the immediate effects on affected producers. These diseases have numerous impacts, including: productivity losses for the livestock sector (e.g. production losses, cost of treatment, market disturbances), loss of income from activities using animal resources (in such sectors as agriculture, energy, transportation, tourism), loss of well-being of human beings (morbidity and

even mortality rates; food safety and quality), prevention or control costs (production costs, public expenditure), suboptimal use of production potential. These economic and social effects can be classified as “direct,” “ripple” (impact on the industry’s upstream and downstream activities), “spillover” (impact on other sectors), “long-term”, or “remote” (Gall, 2006).

Worldwide, FMD is a disease of major economic importance, especially in intensive dairy and beef production system. The disease constitutes a major obstacle to international trade in livestock and livestock products in both, industrialized and developing countries. The impact of the 2001 FMD outbreak in the United Kingdom, though only estimated to be an overall 0.2% loss in Gross Domestic Product, included losses to agriculture and food chain estimated at £ 3.1 billion and losses to the tourism sector estimated at £ 2.7 -3.2 billion (Thompson *et al.* ,2001).

The disease effects are more pronounced in cattle and pig systems while the impact in goat and sheep systems tends to be low. However, some strains of FMD do cause severe disease in sheep and goats (Hughes *et al.*, 2002). The impacts also vary considerably in the different production systems of the developing world; depending on the species involved, the genotype of animal, the level of productivity, and the effectiveness of indigenous coping mechanisms for controlling the effects of FMD (Perry and Rich, 2007). High producing animals are usually more severely affected, both in terms of immediate effects on production and long-term damage leading to premature culling (James and Rushton, 2002).

The direct production effects of FMD in extensive production system include loss of milk due to udder involvement, and reduced draught animal power from lesions on the feet. FMD also causes lower rates of live-weight gain in growing animals due to reduced feed intake, and reduction in reproductive capacity by increased abortion rates of up to 10% in animals infected during pregnancy; the disease also causes up to 6% mortality in calves. Restrictions on animal movement and international trade can cause much more serious losses. The loss in animal production and international trade restriction imposed following an outbreak makes FMD of a major concern for livestock owners (James and Rushton, 2002). The eradication of FMD in sub-saharan Africa by the implementation of slaughtering is impractical for various reasons, but

vaccination with good quality FMD vaccines can help prevent losses in stock production and reduce the overall incidence of the disease (Hunter, 1998).

2.2.9 Economics of Foot and Mouth Disease control

The control of FMD in the East African region is currently treated with less priority than it deserves when compared to other diseases that are relevant to trade. The situation is characterized by frequent outbreaks of FMD with negative consequences for livestock trade and economies in East Africa. It is important to note that vaccination programs for FMD have not helped to control the disease in the East African Community (EAC) States. A project proposal by the EAC indicates the constraints experienced in transboundary livestock diseases control as: inadequate funding leading to low vaccination coverage, ineffective enforcement of legislation relating to livestock movement control, inadequate community participation in livestock disease control including unwillingness to cost share in service delivery, insufficient local disease surveillance and reporting systems to support diagnosis and control efforts; inappropriate diagnostic techniques for emerging strains and serotypes of FMD virus; lack of appropriate information on the impact of the disease on the farming and pastoral communities; droughts leading to uncontrolled and widespread movement of livestock in search of pasture and water, thereby spreading diseases; inadequate facilitation of livestock marketing and limited formal trade marketing and quarantine infrastructure; no incentive to vaccinate due to low producer prices; inadequate inter-institutional, regional and international collaboration in disease control; lack of awareness and information (extension services) of stock owners and other stakeholders on the economic importance of FMD; inadequate political goodwill and low private sector participation in FMD control management. This is in sharp contrast to the approach of western countries that have over years prioritized control of the disease due to its enormous economic impact. Radical measures have been implemented to eradicate the disease from their countries and to maintain disease free status in order to safeguard their international livestock trade opportunities (ECA, 2004).

The control of outbreak (slaughter of infected and in contact, disposal of carcass in disease free zones) and the loss due to the ban on livestock exports costs several million US dollars for a

single outbreak (Sellers and Daggupaty, 1990). A striking example was the 2001 outbreak of serotype O in Great Britain. The country had been free of FMD since 1981. This devastating epidemic spread to Ireland, France and the Netherlands. In the United Kingdom alone, about 4 million infected and in contact animals were culled (Samuel and Knowles, 2001).

Computer simulations of disease transmission can assist epidemiologists to develop disease control strategies (Catley and Mariner, 2002). Economic analysis is a valuable technique in the planning and management of animal health programmes at the national policy level and at the level of individual livestock enterprises. Considerable experience has now been accumulated in the adaptation of methods of economics to address decisions on disease control issues. Different methods are appropriate for endemic diseases, for diseases which occur intermittently as local outbreaks, and for diseases which have the potential to cause an epidemic (Morris, 1999).

2.2.10 Participatory rural appraisal

Participatory rural appraisal (PRA) is a systematic data gathering activity carried out by a multidisciplinary team to reveal the unidentified facts about a community. It was recognized in the early 1970s that formal systems of inquiry were of limited value when working with rural communities in developing countries. Over use of questionnaire surveys and poor cost effectiveness were identified as some of the key problem with formal method of data collection, particularly questionnaire survey. In response to these problems, Rapid Rural Appraisal (RRA) was developed in 1980s, which rather than attempting to collect quantitative data on problems identified by researchers, tends to focus on communities perceptions of priorities and problems and is characterized by a reliance on qualitative data and avoids statistical analysis (Lielo *et al.*, 1995).

In the late 80s, Rapid Rural Appraisal /RRA/ evolved in to Participatory Rural Appraisal (PRA), which facilitated the participation of the communities in the analysis and solving of the problems, and encouraged project beneficiaries to plan and take action. It is now widely used by development projects in both rural and urban areas of the third world and some workers are

investigating ways of combining participatory and formal approaches. Leyland (1991) has also reviewed community participation and its role in animal health services with substantial evidence that participatory appraisal methods do generate information that precisely describes local people perceptions on animal health problems. The methods are relatively resource friendly and are easily flexible according to given circumstances and information needs. In addition, since community-based programs look promising with regard to sustainability, there is an increasing interest by research centers to involve rural communities in the definition of research problems and identification of their solutions. Participatory appraisal has been used to good effect by community based animal projects and consequently, there is now potential for incorporating this method into conventional animal health data collection system (Catley and Irungu, 2000).

There is extensive body of traditional or Ethno-veterinary knowledge that pastoralists have known to possess and on which they rely to diagnose or treat many diseases. It is possible that the proper collection, collation, and analysis of data for diseases like FMD that are often under reported by conventional veterinary services would enable to formulate and implement sustainable disease control in pastoral areas. Veterinarians and livestock workers have used and are presently using a variety of PRA methods to investigate animal health problems (Catley, 1999; Rufael *et al.*, 2008).

a. Participatory appraisal tools

Participatory appraisal methods are useful in particular for veterinarians involved in community-based animal health services. However, it should be noted that participatory assessment is not only method and tool, but also requires professionals to adopt a respectful, sensitive, and open approach to work with communities. In a typical survey, the combination of tools allows cross checking or "triangulation" of results while the researchers are still in the field. Results are also cross-checked by working with both men and women, and using informants with varying experience, skills, age, social status, or wealth. When investigating subjects such as livestock disease, local experts can be identified who are respected by their communities for possessing

specialist knowledge. Several types of field data form the core of participatory appraisal study that includes spatial, temporal, social, and technical data can be collected (Catley *et al.*, 2002).

Participatory appraisal collects information using a toolkit comprising semi structured interviewing, timelines, trend analysis, seasonal calendar, proportional piling, mapping and different ranking and scoring methods.

The semi-structured interview (SSI) prompts one to have a checklist of some questions, followed by the follow-up questions for the informants for further information (Catley and Mohammed; 1996). For the visualization methods, mapping-involving construction of a map on the ground using locally available materials has been used in animal health surveys (Catley, 1999). For spatial data, maps and transects are used (Lielo *et al.*, 1995). For temporal data, the tools that have been employed are timeline, trend line, and seasonal calendars. Ranking and scoring methods have been widely used whereby informants are required to compare items or problems in pairs and decide the most important; the results are presented in a matrix with a total rank calculated (Catley, 1999). This scoring method, made visual when a matrix is drawn on the ground, with items along X-axis and indicators along the Y-axis, and stones used to score, has been used to understand associations between different types of ticks and health problems (Catley and Aden, 1996). Another visually oriented scoring method is proportional piling. The method involves the use of a large pile of counters like stones. The counters are usually 100 that the informants are asked to distribute on different items to show the relative sizes or importance. Most of participatory appraisal tools have been used to produce qualitative data and participatory appraisal survey results are presented in a descriptive rather than numerical form. However, virtually any qualitative data can provide numerical data if transformation occurs at an early stage in data collection process, by defining the number of items to be scored and the number of stones to be used for the scoring of indicators. Specific indicators could be defined by the researchers and added to those produced by the informants (Catley, 1999).

b. Indigenous knowledge as epidemiological intelligence

Pastoralists have a rich and detailed knowledge about significant health problems affecting their animals. This indigenous veterinary knowledge is based on oral tradition, shared information and the life experience of individuals. The core of this knowledge is clinical, pathological and epidemiological observations that serve to organize disease information into recognizable entities described by a traditional terminology. This information is valuable intelligence for veterinary epidemiologists. Each term has a consensus definition that can be explained during participatory enquiry. In pastoral and agro-pastoral societies, regular even daily meetings are held to discuss the health of livestock and decide how they should be managed. In part, decisions on livestock management are based on a constant reassessment of the animal health situation, including exposure to parasites on pasture, or proximity to diseased herds or wildlife (Catley and Mariner, 2002). The ability to recall events affecting the lives of individual animals, including the mothers of each live female in the herd, and animals alive up to 30 years ago, was reported for pastoralists in Kenya (Iles, 1994).

The indigenous knowledge of pastoralists on livestock diseases in the Horn of Africa was testified by some views of Veterinarians (Catley and Mariner, 2002).

Working in the Somaliland protectorate in the 1950s, the veterinarian Robert Mares noted that, "... it is surprising to find that the (Somali) nomad recognizes the flies that spread trypanosomiasis; that he has a good idea of the infective nature of disease and knows that cattle with rinderpest are dangerous to other cattle; and that he has learnt logical and effective, though very primitive, methods of immunization". Some years later, a British veterinary team working in northern Somalia between 1969 and 1972 also realized that herders possessed useful knowledge related to animal health. For example, when discussing trypanosomiasis in camels it was concluded that despite the t e a m's laboratory facilities, "...the best diagnostic tool was probably the camel owners own opinion. This is not something to be dismissed lightly because a camel owner knows his animals and the disease intimately".

Furthermore, it was the Maasai who suggested that wildebeest were associated with the epidemiology of malignant catarrhal fever. In Maa, the words for wildebeest and MCF are the same. The Maasai recognized that the wildebeest calving season was a high-risk period for the transmission of MCF and protected their cattle by avoiding wildebeest during the calving season.

c. Participatory appraisal versus conventional methods

The use of participatory appraisal tools normally generate largely a qualitative data that are detailed, dynamic and defines local peoples' problems and solutions whereas the conventional methods only yield data that are chiefly quantitative and stable. Thus, the participatory appraisal methods have been qualified as a bottom up approach compared to the top-down approach of the conventional approaches (Catley and Mariner, 2002).

The participatory appraisal approaches are holistic in nature whereby all aspects of the phenomenon in question are studied by use of multiple methods in a process referred to as "triangulation". The focus of conventional methods is usually on selected predefined variables. The community has a greater access, control, understanding, and analysis of information, when the participatory appraisal tools are employed. But in the conventional ones, the community does not apparently own the information. In addition, this makes the project unsustainable, because researchers in conventional methods are seen as 'outsiders' and decision-making is entirely from them. In contrast, the PA methods attempt to break the cultural barriers and researchers are seen as 'insiders', which in turn, lead to collection of useful information about the community, particularly with involvement of local people in decision-making (Catley and Mariner, 2002).

Typically, quantitative data driven approaches are attempted, but prove to be untenable in large pastoral areas with relatively small and mobile human population, limited modern infrastructure, and insecurity. Other problems include lack of baseline data to perform random sampling procedures and the difficulty of following the herd during longitudinal studies. Therefore, the use of standardized participatory appraisal tools, which produce quantitative data, is another option for veterinary epidemiologist for pastoral areas (Catley and Mariner, 2002).

In regard to FMD, participatory epidemiology has been used in original research, targeted assessments, economic evaluations and national surveillance programs. Documented studies include Catley *et al* (2004) who used participatory techniques to explore the association between chronic heat intolerance and FMD. In Pakistan, FMD was included as a target disease for the national PDS system (Zaruh *et al.*, 2008). Participatory impact assessment leading to a benefit-cost analysis for FMD control in a traditional livestock keeping community was also done in Southern Sudan (Barasa *et al.*, 2008). Despite the fact that PRA is valuable method in studying disease epidemiology and evaluation of control options, it is learnt that it has some drawbacks. This draw backs includes prone to biases i.e selection of informants and recall. Therefore, it is recommended to use participatory appraisal methods in combination with conventional epidemiological methods (Catley, 2006; Catley and Irungu, 2000).

3 MATERIALS AND METHODS

3.1 Study area

3.1.1 Description of the study area

The study was conducted in two districts of Borena zone of Oromia regional state, Arero and Miyo, located in the Southern part of Ethiopia (Figure 1) from February to September 2011. The Borana plateau, predominantly inhabited by the Borana Oromo pastoralists, is a vast territory in southern Ethiopia topographically characterized by altitudinal variations ranging from 1000m to 1500m in the main, but with a few exceptional peaks of up to 2000m. The area is less endowed with moisture retaining vertisols for reliable crop-based livelihoods, except for some areas in the valley bottoms (Coppock, 1994). The Borena zone is divided into 13 districts and as many as 25 pastoral associations (PA) in a district. The rainfall pattern in the zone is very erratic with a long-term annual average of 400mm. The arid and semi-arid agro-climatic characteristics of the region rather signify the importance of pastoralism as the single most important source of livelihood to the growing human population in the area. The general topography is rolling plains with undulating hills found in a few places. The vegetation is typical of lowlands, consisting mainly of acacia shrubs and grasslands. There are two rainy seasons: “Ganna” (March-May) and “Hagaya” (September/October-November). The area is sparsely populated and is characterized by moisture deficit, resulting in water shortages that reduce livestock production potential. The main livestock kept in the area include camels, cattle, sheep and goats. In addition to contributing to overall food needs, livestock have a paramount importance in generating cash income for households. The livestock populations are approximately 1.6 million cattle, 2 million sheep and goats, 700,000 camels and 64,000 equines (BZPDB, 2011). Livestock is an integral part of the Borana people that serve several purposes: as source of food, income generation and social prestige (Desta, 1999).

According to BZPDB Borena zone livelihood report, Arero district can be representative of agro pastoral and Miyo district can be representative of pastoral production system. The Borena zone

borders the republic of Kenya to the south, the Somali regional state to the east and the Southern Nation and Nationalities Regional State to the west and the Gujji Zone to the north.

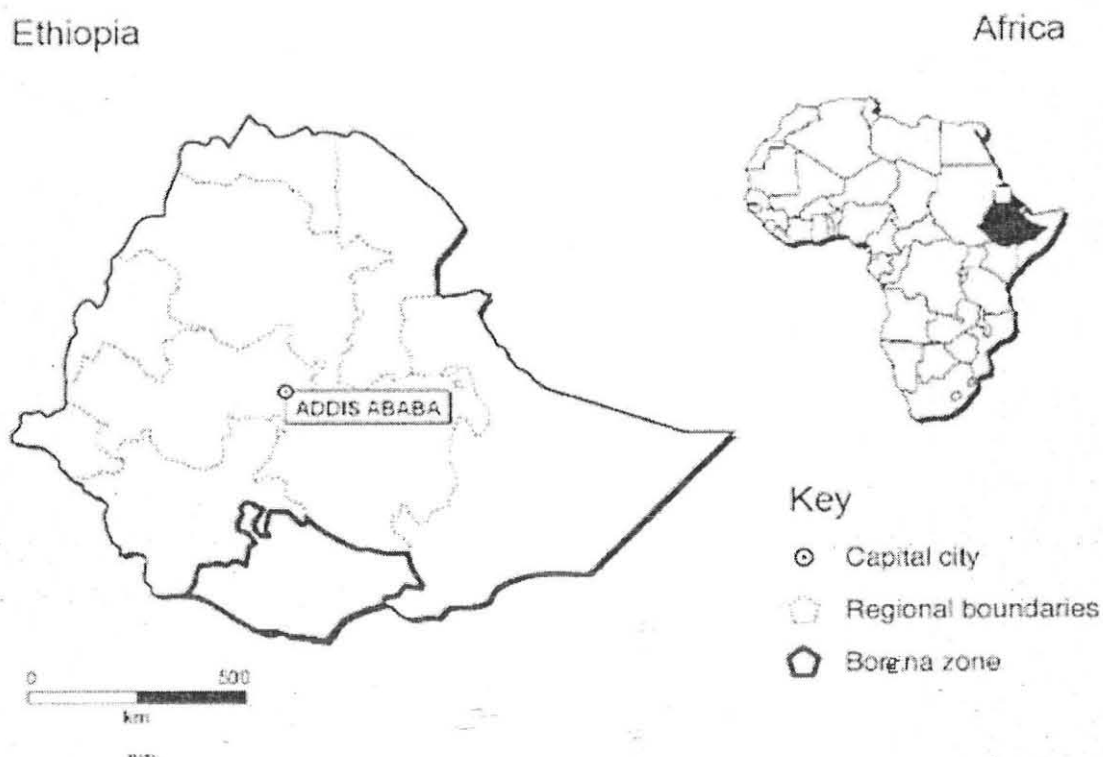


Figure 1. Map of Ethiopia showing the location of Borena pastoral area.

Source: (Chemeda *et al.*, 2007).

3.1.2 Study area and sample size determination

The research was conducted in two districts from Borena zone of Oromia regional state, southern part of Ethiopia, namely Arero and Miyo were selected purposively. The two districts are selected from the existing 13 districts of the zone based on most recent FMD outbreak history and relative lack of studied information. A Map of Ethiopia showing the location of Borana pastoral area is shown in Figure 1. From each selected districts, about 20% of the pastoral

association estimated and 5 pastoral associations from Arero and Miyo district were randomly selected. From each pastoral association about 12-15 people (herd owners) were selected for the participatory appraisal as 'informants/discussants' and 6 key informants.

3.2 Study methodology

The study was cross sectional and the sampling technique followed stratified purposive for sampling the districts and key informants and random sampling of pastoral associations and focus group discussants. A series of preparatory activities were undertaken before the study commences. These involved a preliminary meeting held with local administration officials and participants to introduce and explain the objectives of the study in general terms, emphasizing the livelihoods impact, losses, treatment, prevention and control options with specific reference to FMD, secondary data review and then onsite pretest of the proposed methods. The principles and methods of participatory epidemiology described by Catley, (2005); Catley and Admassu, (2003); Catley and Mariner, (2002) and later modified by Barasa *et al.*, (2008) were used to generate information on livelihoods impact of livestock diseases, severity of FMD through time and losses related to FMD. In addition, published and unpublished data were used as secondary source of information for cross checking or verification called "triangulation". FMD is most important in cattle and pigs but goats and sheep are also affected. Studies in Kenya showed that goats were infrequent carriers, and sheep not at all (Radostits *et al.*, 2006). Therefore, as FMD reduces milk production, only cattle FMD was considered.

3.2.1 Participatory appraisal methods

The participatory appraisal methods used in the study included focus group discussion, informal semi structured interview, simple scoring and pair-wise ranking, matrix scoring, proportional piling, seasonal calendar, timeline, according to Catley, (2005) and benefit-cost analysis (Barasa *et al.*, 2008). The local leaders were asked to select herd owners composing all wealth category based on social and resource possession from the targeted districts.

a. Focus group discussion and semi structured interview

During the participatory appraisal, community leaders, traditional healers, district veterinary officers, livestock and milk traders who are known to have good ethno veterinary knowledge, were chosen as key informants for the informant interview, 5-6 from each district adopted from Barasa *et al.*, (2008); Cannon and Roe, (1982). Furthermore, 3 primary and secondary district cattle and milk markets: namely “Dubluk”, “Bake”, and “Elwaya”, were visited for semi-structured interview.

Semi structured interviews were also used to collect information on the sales value of cattle of different ages and milk in local markets. To estimate milk production in healthy cattle, informants were asked to show the average daily milk production using the container which they normally used to collect milk called “Koke”. The local container was then filled with water to the mark specified by the informant, and the absolute volume of water measured with a standard liters graduated container. Informants were then asked to show the milk produced by cows suffering from acute FMD by marking the volume on the local container. Again, the absolute volume was then measured with a graduated container. Informants were also asked to specify the duration (number of days) of the disease in terms of its effect on milk production. Informal interview with Borena Zone Pastoral Development Bureau (BZPDB) officials on the experience of the costs related to the currently going on CBPP vaccination.

b. Simple and pair-wise ranking

Simple and pair wise ranking and comparison was done by asking informant groups to list and rank cattle diseases that affect their herds and compare these diseases in pairs and decide which was most important. Diseases were introduced into discussion with their local names and represented with easily memorable objects with frequent check of memory and understanding. Mortality, loss of production, involvement of more than one species of livestock, rate of transmission, difficulty to control and frequency of occurrence were some of the ranking criteria used by herders. Informants were asked why they gave priority to the selected disease and hence in addition to confirming their decision, this process was also used to generate indicators for

matrix scoring of clinical signs of the disease. The method was also used to estimate the impact of each disease on the perceived socio-economic benefits the community derives from cattle. In addition, socioeconomic impacts rank of diseases were also compared before and after 1984 which was considered as a historical time mark, even recorded in history as the major famine and death of more than a million Ethiopians as described by Adejumobi (2007) and these ranks were compared for significant differences across time.

c. Matrix scoring

Matrix scoring was used to validate qualitatively herders diagnosing ability to differentiate FMD from other cattle diseases based on the qualitative data of clinical signs and indicators of the diseases. These were compared to the diseases' signs and indicators listed on reference text books like Cynthia and Scott, (2010) and Radostits *et al.*, (2006). The six top ranked diseases including the two forms of FMD, based on the simple and pair wise ranking, were scored against a list of clinical signs and epidemiological features. Matrix scoring was standardized and repeated with 10 groups of informants. To assess the socioeconomic benefits of keeping cattle lost due to priority diseases, the diseases were represented with objects along the top of the x-axis of a matrix illustrated by line drawings on the ground while the socio-economic benefit indicators were illustrated by line drawings on cards and placed along the y-axis. A pile of 100 stones representing "100% benefit" of keeping cattle and divided in to each benefit in healthy cattle. Then, the benefit lost due to each disease was reduced from each benefit allocated and plotted on a graph to represent the relative reduction in benefit due to disease (Catley and Mohammed 1996; Barasa *et al.*, 2008).

d. Proportional piling

Proportional piling (PP) was used to gather information on livelihood means, sources of food, benefits derived from cattle, major cattle diseases, age based herd structure, disease incidences and related mortalities caused by important cattle diseases during the past one year, February 2011 to September 2011, including *heat intolerance syndrome* (chronic FMD) for comparison. Before performing the proportional piling, discussants were asked to classify the community in

to resource wealth categories and the animals into different age groups according to their production system. Discussants were allowed to maintain a pile of 100 stones for each group for livelihood options and food items across resource wealth category. The informants also divided the 100 stones to show the pattern of 'sick cattle' and 'healthy cattle' during the last year. The pile of stones representing sick cattle was then sub-divided to show the proportion of morbidity and mortality rates of the six diseases (*heat intolerance syndrome* (chronic FMD) is used for comparison plus a category called 'other diseases'). Proportional piling was also used to estimate the proportion of lactating cows in herds by dividing the piles of stones to show the relative proportions of lactating and non-lactating cows. Mean values age group specific incidence and mortality rates were calculated for each variable and used in the economic model.

The proportional piling method was also used to analyze local practice of different treatment and control methods for FMD. The disease control methods were identified by posing the question: What do livestock keepers in this area do when their animals become sick of FMD? Subsequent responses, group discussions and interviews were made to refine available options. When the informants had scored, they checked the scoring with the group and advised them that they could make adjustments to the scoring (Catley and Mohammed 1996; Barasa *et al.*, 2008).

e. Timeline

Timeline was used to gather information on the historical trend of FMD prevalence in the area over the last 48 years (six administrative periods called 'Gada' of 8 years each). This was done by focus group discussion and informal semi structured interview of 5-6 elders in the PA with a lot of experience in cattle keeping and knowledge on the history of the Borena. The group was asked to remember key natural, socio-economic and political events related to FMD outbreaks, long dry season, drought and conflict occurred in the area. Time periods were identified based on "Gada" administration system of the Borena in to Jaldessa liben (1960-1967), Goba Bule (1968-1975), Jilo Agaa (1976-1983), Boru Guyo (1984-1991), Boru Medha (1992-1999) and Liben Jeldessa (2000-2007). Each of these periods, were rated for FMD outbreak, length of long dry season, drought severity, and clans and tribal conflict number and severity from 1 to 4. The

responses related to climate were triangulated with unpublished data from the National Metrology Agency of Democratic Republic of Ethiopia.

f. Seasonal calendar

Seasonal calendars were used to describe seasonal variations in amount of rainfall, FMD incidence, calving season, cattle contact with wild life and other livelihood indicators like milk availability, grain purchase, cattle movement and trade, and socio-cultural practices related to cattle. The method was adapted from a seasonal calendar validated by Catley *et al.*, (2002) and Barasa *et al.*, (2008). The informants were asked to categorize the 12 months in a year in to seasons. These seasons were represented and placed in a row on the ground. Informant groups were asked to show the seasonal pattern of each indicator by distributing piles of 100 stones per indicator. The seasonal calendar was repeated with 10 informant groups.

Table 1. Summary of participatory appraisal methods used in the study.

Information required	PA tool and methods	Number of repetitions
<i>Resource wealth rank</i>	Focus group discussion Wealth ranking Proportional piling	Five pastoral associations per district; average of 12-15 people per Pastoral association.
<i>Age classification, livelihood means, sources of food, benefits derived from cattle, major cattle diseases, age based herd structure, disease incidences and related mortalities</i>	Focus group discussion Proportional piling Semi structured interview	Five pastoral associations per district; average of 12-15 people per pastoral association.
<i>Qualitative diagnosing ability validation and benefit loss assessment</i>	Matrix scoring	Five pastoral associations per district; average of 12-15 people per pastoral association
<i>Market value of cattle and milk</i>	Semi structured interview	Three livestock and milk markets assessment. Five pastoral associations per district; average of 12-15 people per Pastoral association.
<i>History of livestock diseases and conditions</i>	Timeline	Six key informants per Pastoral association.
<i>Ranking livestock diseases</i>	Simple and pair wise ranking	Five pastoral associations per district; average of 12-15 people per pastoral association.
<i>Seasonal variations in livestock disease</i>	Seasonal calendars	Six key informants, Five pastoral associations per district; average of 12-15 people per pastoral association
<i>General information and as part of other methods</i>	Semi structured interview probed for more information	Ad hoc for all interventions

3.2.2 Benefit-cost ratio modeling

In order to estimate the benefit-cost ratio of FMD vaccination, benefit-cost models were developed by modifying models developed by Barasa *et al.*, (2008) for FMD vaccination using measurements of FMD incidence, mortality, milk production, market values and other variables for last one year, i.e. February 2011 to September 2011, across cattle age groups. Economic models were developed and feed with data from participatory appraisal methods and unpublished data from BZPDB.

The benefits of FMD vaccination were calculated by estimating the value of the losses which occurred due to FMD during the past one year, February 2011 to September 2011. Since the losses of acute FMD and *heat intolerance syndrome* (its chronic form) were estimated as independent disease entities, financial losses attributed to each of the diseases were calculated separately. The calculation was based on the expected losses caused by losses due to mortality, losses due to reduced cattle milk production and calf crop lost due to abortion and extended calving interval. Milk losses were assumed to occur as short-term losses in cows suffering but then recovering from the disease, and as permanent losses in lactating cows killed by the disease (Barasa *et al.*, 2008). In addition, lactation length is calculated by halving the lactation length in cases of cow death and chronic FMD and the market value of cattle and milk was converted from Ethiopian birr to United States dollar. The summary of mathematical equations used for quantifying losses due to FMD was modified from Barasa *et al.*, (2008) and presented on table 3.

For the purpose of the benefit-cost analysis, the model used with the demographic features of vaccinating 85% of the cattle population in the area (Assegid, 2005) and an assumption is made that veterinary infrastructure like cold chain and vaccination equipments are not there. Costs of the vaccine purchase was asked from Kenya Veterinary Vaccine Centre, semi-structured interviews were made with BZPDB officers to estimate of costs for FMD vaccination (C^v) equipments, establishment of field camp, cold chain and its maintenance assuming the refrigerator will need kerosene for 60 days per vaccination phase, field staff perdium, supervision and management costs, fuel cost for transportation considering vehicle is available for the periods of vaccination and contingency administrative costs based on experience of

currently ongoing CBPP mass vaccination. In addition, biannual vaccination using quadrivalent FMD vaccine was assumed (constituting the serotypes: O, A, SAT1 and SAT2 that are reported in Ethiopia and responsible for FMD outbreaks during 1974–2007) (Ayelet, *et al.*, 2009; Gelaye *et al.*, 2005; Negussie *et al.*, 2011; Sahle *et al.*, 2004)) with 85% vaccination coverage.

Therefore, benefit-cost ratio for FMD vaccination from the estimates is the ratio of the potential benefits (savings on the estimated total losses due to mortality, milk production losses) to the costs (bi-annual mass vaccination) that are likely to be incurred. The calf crop losses are not included in the benefit lost because of the difficulty in estimations the calf crop lost in monetary terms but rather calculated in calve number. In addition, sensitivity analysis was modeled by feeding values in to benefit-cost model with expectation that as time advances market price of cattle and milk sales value and vaccination prices will likely increase. On the other hand, in cases of vaccination intervention, FMD incidences and related mortalities will likely decrease while FMD vaccine, cattle and milk market prices increase (Barasa *et al.*, 2008).

For the benefit-cost ratio calculation of FMD vaccination equation shown in table 2 are used and $\text{benefit-cost} = (C^{mo} + C^{mi})/C^v$

3.2.3 Secondary data review

Secondary data review was conducted on some of the variables used in the estimation of benefit cost analysis model from already published articles for triangulation of information from the participatory appraisal and bureaus like BZPDB for recent livestock population and average monthly temperature and rainfall data was collected from the National Metrology Agency of the Democratic republic of Ethiopia.

3.3 Data collection and analysis

The data collected was entered in to MS Excel sheet spread (Microsoft office Excel 2007). The results were analyzed using SPSS version 18 by descriptive statistics, Kendall's coefficient of

concordance (W), and independent t-test for correlations of different variables with FMD severity and comparison of ranks of disease used in the analysis of trends. The level of agreement among the scores of informant groups was assessed using Kendall coefficient of concordance (W) (Siegel and castellan, 1994). Consequently, evidence of agreement between informant groups was categorized as ‘weak’, ‘moderate’ and ‘strong’ according to published guidelines on the interpretation of W and the p values assigned to W by SPSS software. Accordingly, agreement was termed ‘weak’ for $W < 0.26$, $P > 0.05$; ‘moderate’ for $W = 0.26-0.38$, $P < 0.05$ and ‘strong’ for $W > 0.38$, $P < 0.01$. Furthermore, Microsoft office Excel 2007 was used for mathematical computation of sensitivity analysis using the developed models.

Table 2. Mathematical equations/models/ used in the estimation of losses due to FMD.

Mortality costs: C^{mo}	
Losses due to acute FMD affecting all age groups	$D_a^G = G^{I234} * D_a^{I234} * S^{I234}$
Losses from <i>HIS</i> chronic FMD affecting all groups	$D_c^G = G^{I234} * D_c^{I234} * S^{I234}$
Total mortality costs:	$C^{mo} = (D_a^G + D_c^G) * (N)$
Milk loss costs: C^{mi}	
Short term milk losses from acute FMD, recovering cases.	$C_a^{Mi} = (G^4 * L^4 * P_a^4 * M_i * M_d * M_s)$
Long-term milk losses due to cow deaths	$C_d^{Mi} = ((L^4 + P_r^4) * (D_a^4 + D_c^4)) * M_{l/2} * M_h * M_s$
Long term milk loss due to chronic FMD	$C_c^{Mi} = ((L^4 + P_r^4) - D_a^4) * P_c^4 * M_h * M_{l/2} * M_s$
Milk loss costs:	$C^{mi} = (C_a^{mi} + C_d^{mi} + C_c^{mi}) * N$
Calf crop losses	
Loss of calves from pregnant cows dying from acute disease	$CL^{pca} = (P_r^4 * P_r^a * Ab^{FMD}) + (P_r^4 * P_r^a * (1 - Ab^4) * Cd^{ID})$
Loss of calves from pregnant cows dying from chronic disease	$CL^{pcc} = (P_r^4 * P_r^c) + (P_r^4 * P_r^c * (1 - Ab^4) * Cd^{ID})$
Loss due to extended calving interval in calf crop	$CL^{ECI} = P_r^4 * (P_a^4 * (Ex^a / CI)) + P_c^4 * (Ex^c / CI)$
Calf crop loss, $CCL = (CL^{pca} + CL^{pcc} + CL^{ECI}) * N$	

Table 3. Summary of variables used in the calculation of estimating losses due to FMD.

<i>Variable</i>	<i>Methodology</i>
G^{1234} = Mean proportion (%) of cattle in age group 1 to 4.....	PP/proportional piling/
Losses due to mortality	
D_a^{1234} = Acute FMD mortality (%) in cattle age groups 1 to 4.....	PP
D_c^{1234} = Chronic FMD mortality (%) in cattle age groups 1 to 4.....	PP
S^{1234} = Sales value (USD) of cattle in age groups 1 to 4.....	Informal/ semi structured interview
Losses from milk production	
L^4 = Mean proportion (%) of lactating cows in group 4.....	PP
Pr^4 = Mean proportion (%) of pregnant in group 4.....	PP
P_{ac}^{1234} = Incidence of acute/chronic FMD across age group.....	PP
M_d = Volume of milk loss (liters) per day per acute FMD cases.....	Informal and semi structured interview.
M_t = Duration (days) of reduced milk production per acute FMD case.....	informal and semi structured interview.
M_h = Daily volume (liters) of milk produced per healthy cow.....	Informal and semi structured interview.
M_l = Lactation period (days).....	Informal and semi structured interview
M_s = Sales value of milk (USD/liter).....	Informal/semi structured interview
N = Cattle population in Borena zone.....	BZPDB unpublished data
Calf crop loss	
P_r^{ac} - Incidence of acute/chronic FMD in pregnant cows.....	PP
Ab^{FMD} - Abortion rate in the herd due to FMD.....	PP
Ab^4 - Usual abortion rate in the herd without FMD.....	Informal and semi structured interview
Cd^{ID} - Proportion of calves die in the first days of life after born from infected dam	PP
Ex^{ac} - Average calving interval extended days due to acute/chronic FMD.....	Informal interview
CI - Normal calving interval.....	Informal and semi structured interview

4 RESULTS

4.1 Livelihood options and food sources for the Borena people.

Livelihood options were analyzed to understand the relative importance of livestock. Livestock-related livelihood options accounted for 31.8% of the total means of food, income source and other socio-economic purposes. Whereas, farming, petty trade and food aid contributed 21%, 14.9% and 14.3% respectively. In addition, mining, charcoal, employment are also mentioned as means of living (figure 2). Various sources of food were analyzed with informant groups (n=10) to show the contribution of livestock as a source of food to households. Likewise, the most important food items consumed at the household level were milk and butter accounting for 41.6%, grain for 35.2%, meat 9.7%, vegetables and fruits 4.1% and others 9.4 % (figure 3).

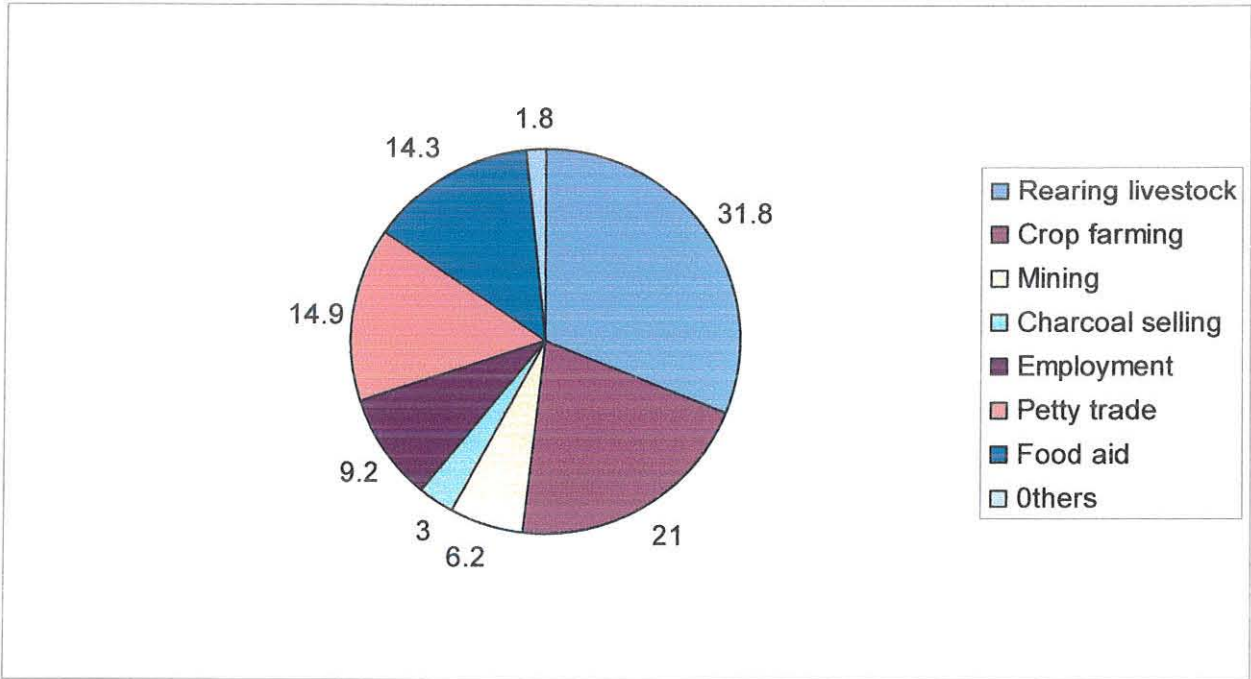


Figure 2. Livelihood options for the Borena people.

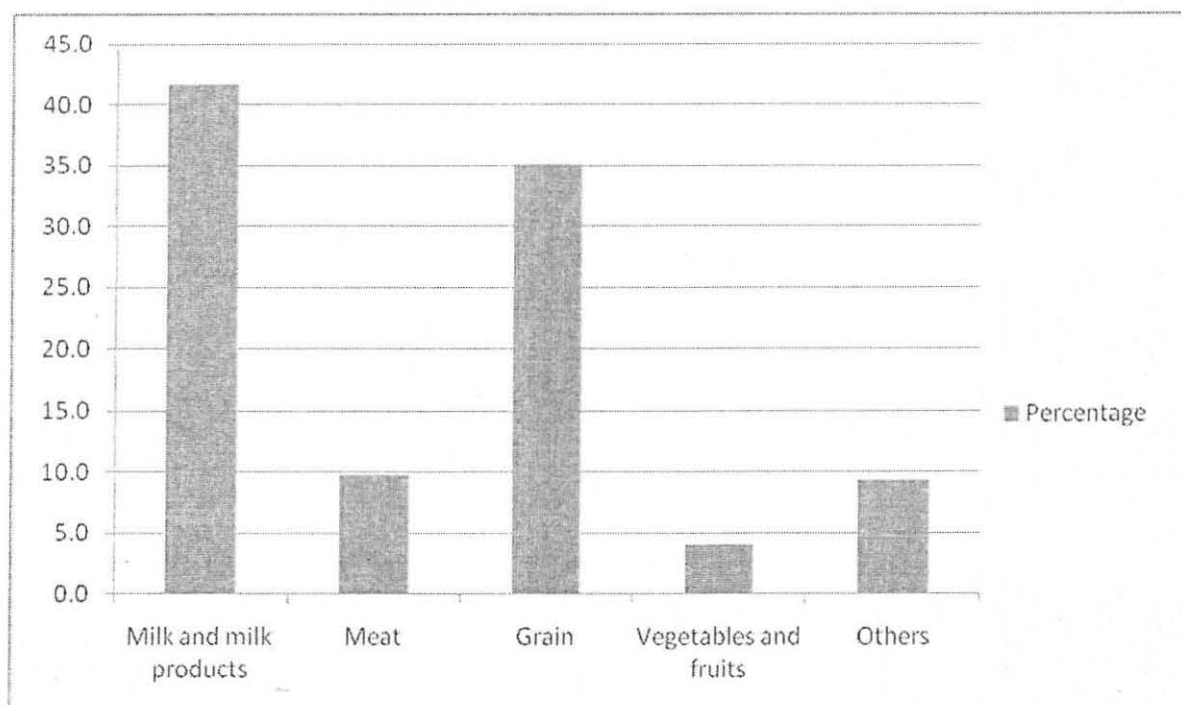


Figure 3. Relative importance of food consumed by the Borena people.

4.2 Disease characterization by clinical signs

Based on the simple and pair wise ranking, six major cattle diseases; Acute FMD, CBPP, Pasteurelosis, Tick, Blackleg and *heat intolerance syndrome* (Chronic FMD), were identified. The result of matrix scoring of the diseases and clinical signs is summarized in Table 4. Strong agreement ($W=0.58$ to 0.94 ; $P=0.000$) was observed among the 10 informant groups for all disease indicators. All the informant groups recognized acute and *heat intolerance syndrome* chronic forms of FMD as different cattle diseases called locally “Hoyalee” and “Gaandilee” respectively. According to informants, the clinical signs and indicators of acute FMD were “kissing sound”, salivation, lameness/foot sore, mouth lesion and contagiousity and hair overgrowth, seeking shade and panting for *heat intolerance syndrome* (chronic FMD). Allocation of scores for acute and *heat intolerance syndrome* (chronic FMD) showed a clear understanding of the clinical signs of the diseases.

Table 4 Summarized matrix scoring of major clinical signs cattle disease and Kendal's coefficient of concordance for median.

Indicators/ Clinical signs	W ^{P values}	Acute FMD	Chronic FMD	CBPP	Pasteurelosis	Tick	Blackleg
Mortality	0.865***	1 (0,2)	0 (0, 1)	7 (6,9)	6 (6,9)	1 (0,4)	9 (3,10)
Milk reduction	0.783***	7 (5,10)	6 (4,8)	4 (0,5)	4 (3,5)	2 (0,3)	4 (1,4)
Lameness /footsore	0.769***	16(10,20)	0 (0,6)	1 (0,3)	0 (0,0)	3 (0,10)	5 (3,9)
Nasal discharge	0.904***	0 (0,2)	0 (0,0)	6 (3,14)	18 (14,20)	0 (0,4)	0 (0,0)
Abortion	0.768***	12 (5,20)	6 (2,10)	2 (0,6)	1 (0,5)	2 (0,5)	1 (0,2)
Seeking shade	0.809***	2 (0,5)	19 (10,20)	2 (0,5)	2 (0,5)	0 (0,0)	0 (0,0)
Hair overgrowth	0.821***	0 (0,5)	25 (20,25)	0 (0,2)	0 (0,0)	0 (0,0)	0 (0,0)
Sudden death	0.943***	0 (0,1)	0 (0,0)	4 (3,7)	5 (3,8)	1 (0,2)	15 (8,16)
Salivation	0.783***	18 (12,25)	0 (0,3)	2 (0,4)	4 (0,9)	0 (0,5)	0(0,2)
Mouth lesion	0.883***	20 (6,25)	0 (0,8)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)
"Kissing sound"	0.788***	23 (18,25)	0 (0,2)	0 (0,5)	0 (0,6)	0 (0,0)	0 (0,0)
"Panting"	0.806***	5 (2,6)	13 (12,20)	5 (2,8)	1 (0,3)	0 (0,2)	0 (0,4)
Morbidity	0.699***	10 (2,15)	1 (0,2)	5 (2,8)	5 (2,7)	2 (2,5)	2 (1,8)
Contagiousity	0.841***	12 (10,14)	1 (0,4)	5 (3,10)	4 (3,5)	2 (1,3)	2 (0,3)
Emaciation	0.581***	10 (4,10)	5 (0,8)	5 (0,7)	3 (0,5)	6(2,7)	0 (0,2)

Note: Minimum and maximum scores in bracket.

Weak agreement: $W < 0.26$, $*P > 0.05$; moderate agreement: $W = 0.26-0.38$, $**P < 0.05$; strong agreement: $W > 0.38$, $***P < 0.01$ (Siegel and Castellan, 1994).

4.3 Benefit lost due to major cattle diseases

The overall values of livestock to pastoralist’s livelihoods referred as “basic contribution/benefits of cattle” reduction from the benefits as a result of major cattle diseases is shown in figure 4. The average loss of benefits compared to the basic contribution due to the six major diseases is estimated at 70% of the total benefits. On individual disease basis, acute and *heat intolerance syndrome* (chronic FMD) reduced benefits at about 76% and 79% respectively. Furthermore, acute and *heat intolerance syndrome* (chronic FMD) diseased cattle are not used for any social and cultural purposes, like bride price, that contribute 21% to basic contribution/benefits of cattle (Figure 4). This represented the most important impact of FMD on cattle derived-benefits and the opportunity for social and cultural practices is almost entirely lost when FMD outbreaks occur.

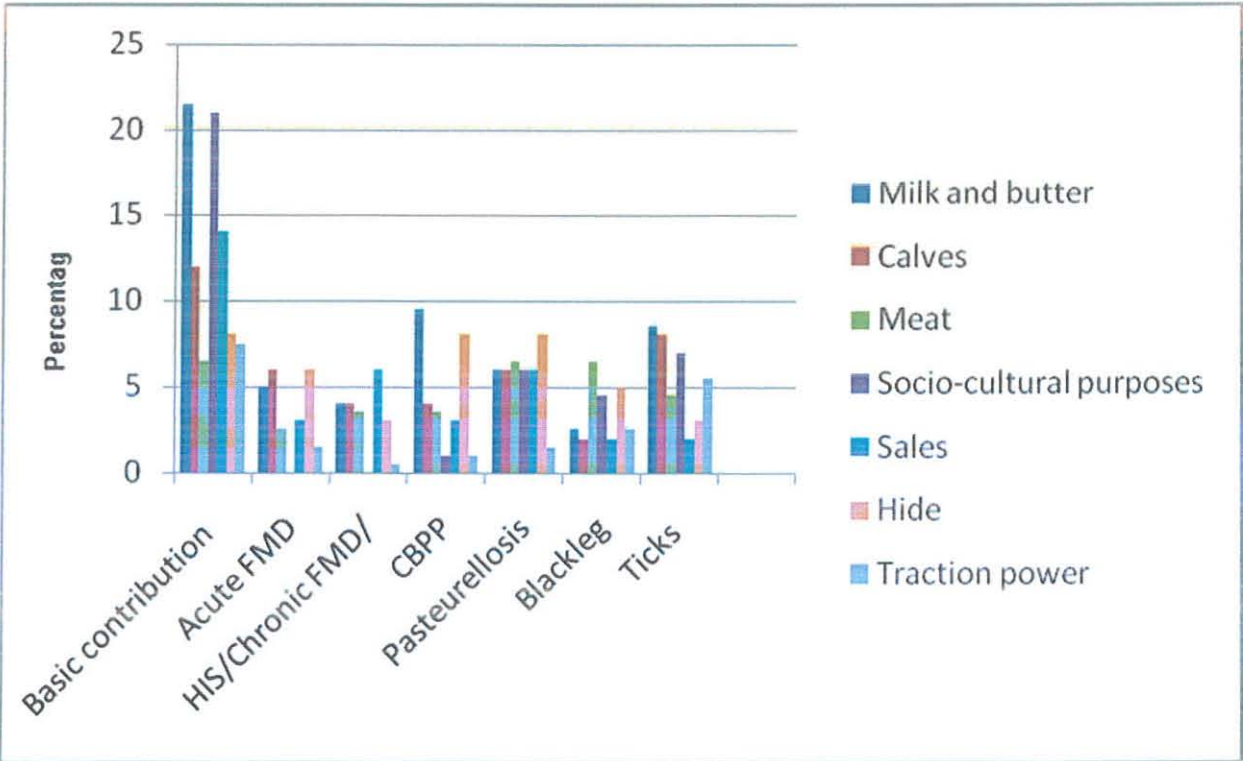


Figure 4. Cattle benefits lost due to major diseases.

4.4 Seasonal calendar

The seasonal calendar demonstrated the variations in amount of rainfall, incidence of FMD, and other livelihood variables like grain and milk availability across seasons of the year. Four distinct seasons were identified namely: “*Bona-hagayaa*” /long dry season/ December to February/, “*Ganna*” /long rainy season /March to May/, “*Adollessa*” /short dry season/June to August/ and “*Hagayya*” /short rainy season /September to November/. Socio-cultural practices related to cattle, cattle trade and movement in search of pasture and water reaches highest in the long dry season that coincides with highest FMD incidence. Milk availability was found to be in similar pattern with rainfall amount but opposite to FMD incidence. The seasonal calendar also demonstrated opposite pattern of FMD seasonal incidence with rainfall amount (figure 5).

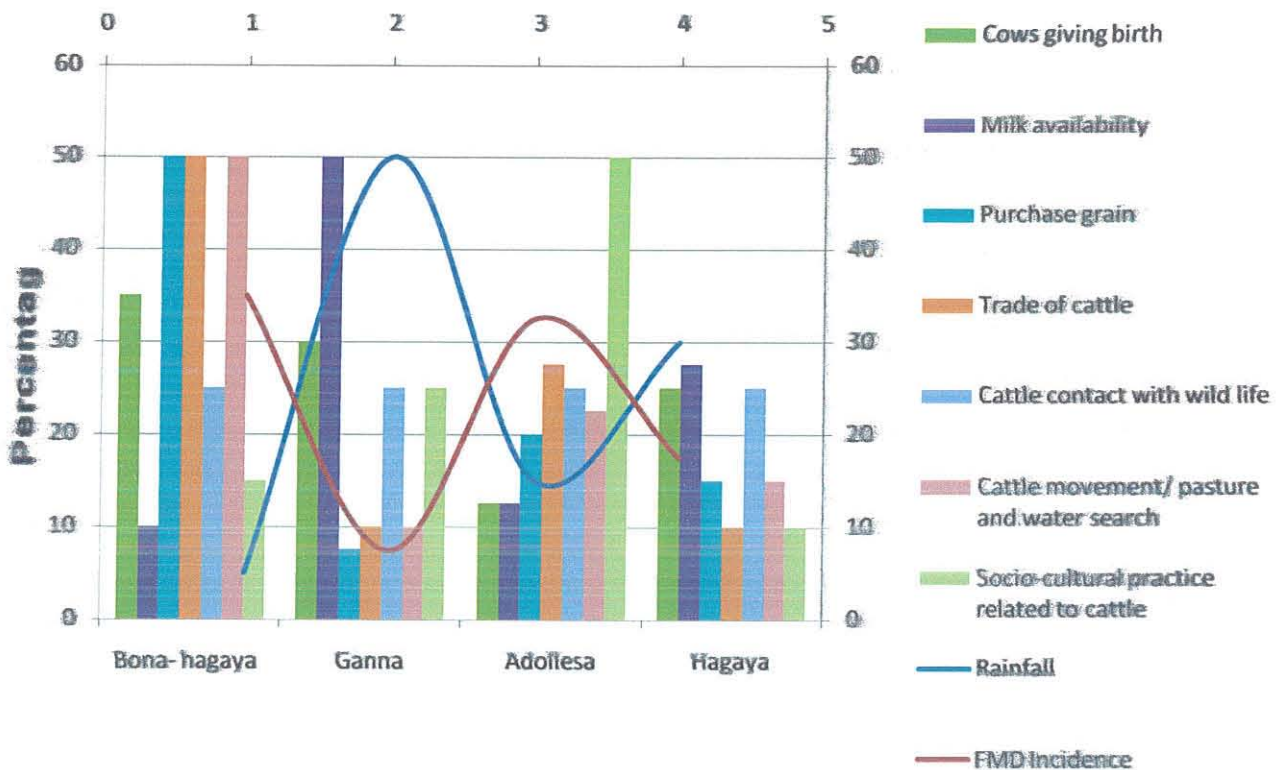


Figure 5: Seasonal calendar for FMD incidence, rainfall amount and some indicators.

4.5 Trend analysis of cattle diseases

The comparison of the rank of the most important cattle diseases before 1984, which was considered as a historical time mark and after 1985, is summarized in table 5. Rinderpest was identified and ranked first before 1984 based on its impact. It was not mentioned as major disease after 1985 as its impact was reduced as the result of the control and eradication program. FMD was ranked number one cattle disease after 1985 with significant rank change ($t=12.04$) while diseases like Blackleg changed the rank negatively because of ongoing vaccination ($t=-2.29$). The informants indicated that FMD is a disease that is well known to them and has been occurring in increasing frequency in their herds. Table 6 also demonstrates the trend of FMD outbreaks frequency and severity and extended long dry season with timeline, with correlation coefficient of 0.612 and 0.568 respectively, from 1960 to 2007. Furthermore, through the timeline, FMD outbreaks frequency and severity was found to be significantly correlated to length of extended dry season with correlation coefficient of 0.377. However, FMD was found to be in weak correlation with drought ($r=0.169$) while significantly correlated with clan and tribal conflicts occurrence and severity ($r=0.261$).

Table 5. Trend analysis of mean rank of cattle diseases

Disease	1984 and before	1985 and after	t-value	P-value	SE
CBPP	2.9	2.4	1.41	0.18	0.35
Blackleg	3.3	4.5	-2.29	0.03	0.52
Pasteurelosis	3.7	4.0	-0.71	0.49	0.42
Trypanosomosis	5.5	4.2	1.43	0.17	0.91
FMD	5.6	1.2	12.05	0.00	0.36
Rinderpest	1.0	-	-	-	-

Table 6. Correlation of FMD severity with other variables.

		Timeline 1960-2007	Drought	Long dry season	Conflict	FMD
Timeline	Pearson Correlation	1	0.205	0.568**	0.239*	0.612**
1960-2007	P-value		0.089	0.000	0.046	0.000
Drought	Pearson Correlation		1	0.559**	-0.068	0.169
	P-value			0.000	0.578	0.161
Long dry season	Pearson Correlation			1	0.157	0.377**
	P-value				0.193	0.001
Conflict	Pearson Correlation				1	0.261*
	P-value					0.029

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

4.6 FMD treatment and control options

Focus group discussions on the treatment and control options of FMD have revealed that, livestock keepers commonly use traditional methods, antibiotic treatment, or simply “taking no action”. Most (68%) of FMD outbreaks left uncontrolled with no action (Figure 6). Traditionally, the Borena cattle keeper had been treating their animals from FMD infection by using locally available unprocessed salt called “*Kula*” with a belief that the salt would reduce severity of the FMD infection. However, all of the respondents indicated that they never vaccinated cattle against FMD

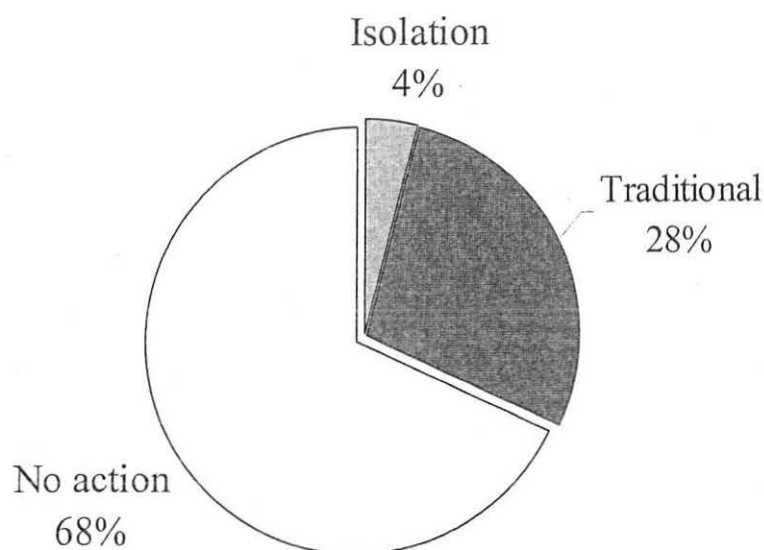


Figure 6. Current prevention/control practice/options for FMD in Borena zone.

4.7 Cattle age classification

The focus group discussants categorized their cattle herds into four exclusive age groups as “Jabi/Watiye” (calves <1 year old), “Agoro”(young 1-2 years old), “Lamacha” (2-4 years old) and “Korma Sanga/Hawicha” (adult >4 years old). Cattle herd structure by locally defined age groups and the sales value of each age group is shown in Table 7.

Table 7. Age structure of cattle herds and estimated sales value.

Age group (Local name)	Age structure by mean proportion (%) (95% CI)	Sales value (USD) (%) (95% CI)
Group 1 (Jabi/Watiye) (<1 yr)) G1	16.1 (13.4, 18.8)	14.8 (7.3, 22.3)
Group 2 (Agoro) (1-2 yrs)) G2	17.1 (16.3, 19.9)	42.9 (34.1, 51.7)
Group 3 (Lamacha) (2-4 years)) G3	20.3 (17.6, 23.0)	124.7 (96.7, 152.7)
Group 4 (Korma Sanga/Hawicha) (>=4 yrs)) G4	46.0 (39.8, 52.2)	238.2 (201.9, 274.6)
1 USD=17 Ethiopian Birr		

4.8 Incidences and mortality due to FMD

Table 8 presents incidences, mortalities and other variables related to milk production in healthy cows and milk losses due to FMD in adult lactating cows above 4 years of age. The largest age group comprised adult cattle >4 years of age (46% of a herd). The mortality due to acute FMD decreases as age advances, 29.6% to 3.7%. However, mortality due to chronic FMD was not reported in all age groups.

4.9 Benefit-cost and sensitivity analysis

Estimates of the variables used for the benefit-cost and sensitivity analysis of FMD vaccination are presented in Tables 7-11. Table 9 shows the estimated costs of FMD vaccination. The highest cost was vaccine procurement, which represented 92% (3,274,153.00 USD) of the direct costs of vaccination (32,488,399.90 USD). Two third (67.7%) of the direct losses are attributed to milk loss while mortality contribute the rest one third (33.3%). The annual calf crop lost due to both acute and chronic FMD in the Borena zone is calculated to be 113,379 calves (Table 10). The benefit-cost ratio and sensitivity analysis for FMD vaccination are presented in Table 11, with a current benefit-cost ratio of 9.1. The sensitivity analysis showed that reductions in FMD

incidence and mortality of by 25%, 50% and 75% reduced 34%, 55% and 78% in benefit-cost ratio respectively. Increases in market values of milk and cattle by 25%, 50%, 75% and 100% produced 25%, 50%, 75% and 100% increment in the benefit-cost ratio respectively. The benefit-cost ratio of vaccination was less sensitive to vaccination costs as vaccination cost doubles the benefit-cost ratio reduced only by 50%. The calf crop lost responds with similar percentage as FMD incidence and mortality decreases.

Table 8. Incidences, mortalities and other variable figures used in estimating losses.

Variable	Mean (%) (CI) (95%)
Overall incidence (all age groups) acute FMD	22.1 (18.8, 25.4)
Overall incidence (all age groups) chronic FMD	4.9 (2.4, 7.3)
Incidence of acute FMD G4 age group	13.3 (10.0, 16.6)
Incidence of chronic FMD G4 age group	6.6 (3.8, 9.4)
Overall mortality (all age groups) acute FMD	8.5 (7.7, 9.2)
Overall mortality (all age groups) chronic FMD	0.0 (0.0, 0.0)
Mortality due to acute FMD by age group:	
Jabi/Watiye (<=1 yr))	29.6 (22.3, 26.8)
Agoro (1-2 yrs))	9.7 (5.5, 13.8)
Lamacha (2-4 years))	4.3 (2.2, 6.4)
Korma Sanga/Hawicha (>=4 yrs))	3.7 (1.8, 5.5)
Mean proportion of lactating cows in the herd	40.2 (33.7, 46.7)
Mean proportion of pregnant cows in G4	66.5 (60.2, 72.0)
Mean proportion of pregnant in the herd	30.7 (25.8, 35.6)
Normal calf survival rate	86.0 (81.0, 91.0)
Mean proportion of abortion	43.0 (31.8, 54.2)
Mean calving interval (month)	19.6 (14.3, 24.9)
Mean volume of milk loss (liters) per day per acute FMD case.	0.9 (0.7, 1.3)
Mean daily volume (liters) of milk produced per healthy cow.	1.35 (1.1, 1.6)
Duration (days) of reduced milk production per acute FMD case.	34.0 (22, 45)
Lactation period (days)	234 (163, 306)
Sales value of milk (USD/liter)	0.7 (0.6, 0.9)

Table 9. Estimated costs of biannual foot-and-mouth disease vaccination.

Item	Cost (in USD)
Vaccine cost ^a	3,274,153.00
Vaccination equipment	25,111.00
Cold chain equipment and maintenance	40,450.80
Field staff, supervisor and management per diem	15,077.70
Transportation	5,980.00
Establishment and support to field camp	31,484.70
<i>Sub-total</i>	3,392,257.28
<u>Operational contingency 5%</u>	<u>169,612.86</u>
<u>Total</u>	<u>3,561,870.14</u>

^aAssumes the use of quadrivalent FMD vaccine for serotypes SAT 1, SAT 2, A and O, and biannual vaccination from Kenya veterinary vaccine center (For the entire cattle population of 1,604,977).

Table 10. Summary of losses related to FMD and cost of vaccination.

Summary variable	Cost (USD) (% of direct loss)
Losses	
Losses due to mortality:	
Acute FMD	10,799,081.32
Chronic FMD	0.00
Total loss from mortality (33.3)	10,799,081.32
Losses due to reduced milk production:	
Recovering acute FMD	970,875.10
Recovering chronic FMD	3,715,226.92
Long term due to cow death	17,003,216.56
<u>Total loss from milk reduction</u>	<u>21,689,318.58 (67.7)</u>
Total value of all losses	32,488,399.90
Calf crop loss	113,379 calves
Costs	
<u>Total cost of vaccination program</u>	<u>3,561,870.14</u>

Table 11. Sensitivity analysis of benefit-cost ratio of vaccination.

Benefit-cost of FMD vaccination (positive/negative proportional change relative to current field model in bracket)						
Changes in disease severity and vaccination costs	Current field model	Market values of cattle and milk increase by				Calf crop lost in number
		25%	50%	75%	100%	
Field model	9.1	11.40(25)	13.68(50)	15.96(75)	18.24(100)	113,379 calves
FMD incidence and mortality						
Reduced by 25%	6.05(-34)	8.55(-6)	10.26(13)	11.97(32)	13.68(51)	83,578(-25)
Reduced by 50%	4.03(-55)	5.71(-37)	8.5(-7)	7.1(-4)	9.12(0)	55,725(-50)
Reduced by 75%	2.02(-78)	2.86(-68)	7.1(-21)	7.26(-20)	7.47(-18)	27,943(-75)
Vaccination costs						
Increased by 25%	7.30(-20)	9.12(0)	10.95(20)	12.77(40)	14.59(60)	
Increased by 50%	6.08(-33)	7.60(-16)	9.12(0)	10.64(17)	12.16(34)	
Increased by 75%	5.21(-43)	6.52(-28)	7.82(-14)	9.12(0)	10.42(15)	
Increased by 100%	4.56(-50)	5.70(-37)	6.84(-25)	7.98(-12)	9.12(0)	

5 DISCUSSION

This study indicates that livestock contribute 31% to livelihood means as a source of food, income and other socioeconomic purposes. Milk and milk products contributes 41.6% of the household food source (figures 2 and 3). This result is in agreement with a similar study by Cossins and Upton (1987) reporting milk accounts for 55.4% of the diet of Borena people. However, a loss of 1 liter milk per cow in a day as a result of an acute FMD can have severe impacts on the food security of pastoral families. At household level, milk was particularly an important food for pastoralist's children and children receive preferential treatment in terms of milk consumption (Coppock, 1994; Fielding *et al.*, 2000). On the other hand, at times of less milk availability, such as FMD outbreak that affects milk production, vulnerability to malnutrition is more critical among children and also older people. These severely compromise the nutritional status and affect child growth and life expectancy. However, the adults can relatively withstand it by feeding grains as substitute (Barasa *et al.*, 2008).

This study was conducted during the extended long dry season /*Bona-hagaya*/, when there was no crop cultivation and was difficult to assess the impact of FMD on traction power. However, in the recent years crop cultivation has increased in the Borena livelihood that uses oxen to plough and harvest crop (Solomon *et al.*, 2007). As one of the manifestations of FMD is lameness, cattle lose their ability for hard labor when affected by FMD (Radostits *et al.*, 2006). This would bring food security and socio-economic problems. A study done by Bayissa *et al.*, (2011) in Borena described that FMD affected oxen do not plough for one crop season. In addition, oxen affected by *heat intolerance syndrome* (chronic FMD) are not used for ploughing any longer probably due to the heat intolerance symptom of the disease. This study found that FMD caused loss of 113,379 calves annually due to abortion and extended calving interval. Although, the incidence of FMD in the adult productive age group is found to be 13.3%, recovered cows may also suffer serious sequels, such as infertility and *heat intolerance syndrome* (also known as “panthers”) that contributes to the calf crop loss. Due to the low productivity of pastoral herds as compared to commercial or semi-commercial dairy units, FMD infection in pastoral areas is perceived relatively as minor disease. However, the findings of this study as indicated on figures 2 and 3

confirm the findings of Rufael *et al.*, (2008) that pastoralist severely suffer by the impact of the disease.

The strong agreement ($W=0.58$ to 0.94 ; $P=0.000$) observed among the 10 informant groups in describing FMD's clinical signs and epidemiological features proves the indigenous knowledge of diagnosing cattle diseases by pastoralists. In addition, clinical signs described for acute and *heat intolerance syndrome* (chronic FMD) is similar to clinical signs and indicators described in veterinary literature and textbooks (Cynthia and Scott, 2010; Radostits *et al.*, 2006). The good diagnostic skills of pastoralists were also confirmed by FMD serology in a study of Rufael *et al.*, (2008); and it was demonstrated that pastoralists can diagnose both acute and heat intolerance syndrome (chronic FMD) with a positive predictive value of 93.1%.

The average loss of values of cattle due to the major six diseases mentioned is estimated at 70.25%, while on individual disease basis, acute and *heat intolerance syndrome* (chronic FMD) reduced benefits at about 76% and 79% with a incidence of 22.1% and 4.9% respectively (see figure 4 and table 8). The average benefit loss is lower than specific diseases' figure, i.e. acute and *heat intolerance syndrome* (chronic FMD), showing that these diseases cause benefit loss relatively higher than the other major diseases. Similarly, this study found that FMD reduced the basic contribution/benefits of cattle to the livelihood. The Borena people's life is highly linked to social and cultural practices like "Jila" titling son's name, "marriage" bride price, "Busa Gonofa" and others to which 21% of cattle keeping values/benefits belong. In addition, the community do not use cattle affected by FMD signifying the disease's impact on social and cultural harmony when outbreak occurs. Furthermore, livestock also plays a very important role in the social and kinship ties and settling of disputes as fine in the Borena community.

According to the result from seasonal calendar (figure 5), FMD outbreaks occur mostly in the dry season when pasture is dry and reduced, water is scarce and the ground is very hard for cattle with foot lesions to move. Severely affected cattle become recumbent, lose body condition rapidly and consequently milk is least available for consumption. Outbreaks of FMD during this time can inflict severe stress on household food security due to its effects on milk production. As

a result it can be said that seasonal variations influence the livelihood means of the community and their coping strategies. During the long dry season, cattle movement peaks due to cattle trade and migration in search of pasture and water. This movement pattern is believed to be partly responsible for the introduction and spread of FMD. Informants described that there is no a seasonal variation in contact between cattle and wildlife. However, Molla *et al.*, (2010) described that there is significant variation in cattle seropositivity based on different contact pattern of wild animal-cattle in South Omo zone. In addition, Megersa *et al.*, (2009) described that the existence of more possibilities of livestock wildlife interfaces in pastoral systems may signify the potential role of wildlife in the epidemiology of the disease.

According to findings of this study, Rinderpest was the most important disease before 1984 based on its impacts but it was not in the list of major diseases after 1985 as it was controlled and eradicated latter (Adejumobi, 2007; OIE, 2011). FMD replaced the rank of Rinderpest and ranked number one cattle disease after 1985 with significant rank change while diseases like Blackleg and Pasteurelosis which changed the rank negatively because of vaccination going on. This indicates that FMD is a disease that is left without intervention and has been occurring in increasing frequency in the Borena.

The trend analysis in table 6 showed that the number of outbreaks and severity of FMD as well as length of the long dry season are increasing and strongly correlated with the timeline findings. This goes in agreement with the report of frequent occurrence of extreme and unpredictable weather conditions in the pastoral areas of East Africa (Abule *et al.*, 2005). In Borana pastoral area, FMD outbreaks are known to occur two to three times per year, especially during the dry period when cattle have to move long distance in search of pasture, water and conflicts that suppress their immunity and increase chance of animal contacts. Grimble and Wellard (1997) and Conroy *et al.*, (1998) described that access to water, grazing land resources and territory are the major source of conflicts between clans and ethnic groups in the pastoral areas of Ethiopia.

With regards to prevention and control of FMD, this study revealed that, cattle keepers uses traditional methods, modern treatment such as antibiotics or simply “taking no action”. It is found that majority of the FMD cases remain untreated and outbreaks remain left uncontrolled.

Disease control options like movement control, quarantine and isolation measures seems to be difficult in regions with very porous borders where legal enforcement is difficult and requires collaboration with neighboring regional states and countries. The growing international concern on the importance of FMD has led animal health requirements set by importing countries getting more and more stringent from time to time (MOARD, 2006). Moreover, the growing private investment on the livestock and meat industry will not get confidence unless animal health measures that are comparable to other exporting countries competing with Ethiopia are put in place. It was also reported that 14.7% of cattle fattened by private fattening business projects to be exported live to Middle East countries (sourced mainly from Borena) through Adama federal quarantine station of Ethiopia was found to be FMD seropositive. Furthermore, these were banned from being exported; affecting cattle price in local markets and reduces the benefit of private investors engaged in fattening beef cattle for live animal export (Bayissa *et al.*, 2011).

FMD vaccination has never been included in a regular animal health program in Ethiopia and particularly in pastoral areas. This is partly due to low budget allocation, poor emphasis given to the animal health sector, relatively expensiveness of FMD vaccines, lack of infrastructures like cold chain facilities, the existence of multiple FMD virus serotypes and involvement of wildlife (MOARD, 2006; Rufael *et al.*, 2008). This might be exacerbated by genetic shift and drift of the FMD virus that may result in new antigenic variant of the virus (Ayelet, *et al.*, 2009; Negussie *et al.*, 2011). However, demand for FMD vaccination by people in the study area is becoming an issue as FMD vaccination is run by Northern Kenya bordering Borena.

In developing countries like Ethiopia, FMD eradication might not be feasible but controlling the disease with vaccination seems economical as it reduces the related impact. Based on this study, the benefit from vaccination is 9.1 times that of the expense of the vaccination indicating that the control of FMD in Borena zone by vaccination could be justified on economic grounds. The highest cost was found to be vaccine cost. This represented 92% of the direct costs of vaccination embarking the question that who will pay for the vaccine. Two third of the direct losses are attributed to milk loss while one third the direct loss is contributed by mortality. These strengthen the idea of Radostits *et al.*, (2006) that FMD is a disease severely affecting milk production.

The sensitivity analysis modeling considered reductions in FMD incidence and related mortalities but increment in cattle and milk price, as time advances. The reduction in FMD incidence and mortality by 25%, 50% and 75% reduced 34%, 55% and 78% in benefit–cost ratio respectively. Even if, the incidence and mortality of FMD is reduced by 75%, the benefit–cost ratio of vaccination would be 2.02 and still economical. An increase in market price of milk and cattle by 25%, 50%, 75% and 100% produced similar percentage increment in the benefit–cost ratio showing that the ratio is sensitive to cattle and milk price but less sensitive to vaccination costs. As vaccination cost doubles the benefit-cost ratio reduced only by 50%. The calf crop lost responds with similar percentage as FMD incidence and mortality decreases (table 11). The benefit-cost ratio is relatively lower in this study as compared to the study in South Sudan by Barasa *et al.*, (2008) probably because the calf crop loss was converted in to monetary term in the study. However, in this study, the calf crop losses are not included in the benefit lost because of the difficulty in estimations the calf crop lost in monetary terms but rather calculated in calve number. The calculation did not include losses related to international trade and costs like surveillance and monitoring costs.

A successful vaccination campaign would require good quality vaccine, trained animal health workers, vaccination equipments, cold chain facilities, other operational costs include transport, personnel cost and general administrative functions (Barasa *et al.*, 2008). Similarly, this hypothetical analysis took in to account of administration of a cocktail of quadrivalent vaccine, maintenance of cold chain, transportation, field camp and contingency budget. Furthermore, the feasibility of FMD vaccination strategy needs to be examined in the light of its significant impacts on livelihoods, its positive benefit-cost ratio, absence of an environment suitable for FMD control through livestock movement control, quarantine, culling and other options. However, the cost of FMD vaccination is comparatively expensive and many cattle keepers may not be willing to pay or if willing, may not afford if it is declared as a private good. A vaccination program that is supported by a joint private-public sector initiative would be beneficial (Barasa *et al.*, 2008).

Although mass vaccination program against FMD is found to be cost effective, a targeted vaccination approach might be considered. To achieve this, high risk cattle sub-populations need to be identified in epidemiological investigations as recommended by FAO (2009). In addition, this study shows the disease is becoming increasingly important in frequency of occurrence and the severity of its impact complemented with extended dry seasons, making it impossible for policy makers and local administrators to ignore it.

However, the scope of this study was limited to a very small area of the total pastoral community in Ethiopia. This study also showed only for the first year or base year benefit cost ratio and further study is needed on modeling of the next years using the concept of discount rate.

6 CONCLUSION AND RECOMMENDATIONS

Foot and mouth disease is a disease that causes losses associated with the death of animal, production and affects people's social as well as economic well-being. Similarly, this study showed that FMD impacts the livelihoods of Borena people. Although it is not expected for a vaccination program to lead to a disease free status in herds in the region soon, reduced calf mortality rates and disease incidence in adult animals will lead to increased calf survival and less impact on milk production. This would imply less stress on people's lives, secure food sources and socio-cultural harmony. In addition, the control of FMD through mass vaccination as shown in this study could be justified on economic grounds and adopted as a viable control strategy. It is therefore high time to give sufficient consideration and start concerted effort that can minimize its impacts in impairing local food security as a result of production loss and protect the national livestock economy from losing access to international markets.

Based on the above conclusion, the following recommendations were forwarded:

- Better organization of the veterinary services through concerted effort of stakeholders for constant surveillance, serotyping, mapping of the circulating virus and vaccine matching towards realizing the effectiveness of the proposed FMD control strategy.
- Government and private companies have to strengthen their capacity to produce cost-effective and efficient FMD vaccines.
- Animal movement control and market chain analysis is recommended for a better outbreak investigation and prevention measures.
- The veterinary service authorities can rely on the results of this study to allocate funds to carry out vaccinations. However, need to provide a clear disease control policy and strategy.
- Similar studies on impact and benefit-cost analysis of vaccination could be carried out in other pastoral areas and diverse production systems of the country to demonstrate more clearly the importance of the disease that informs a country wide FMD control strategy.

7 REFERENCES

- Abule, E., Snyman, H.A., Smit, G.N. (2005): Comparisons of pastoralists perceptions about rangeland resource utilization in the Middle Awash Valley of Ethiopia. *Journal of Environmental Management*, **75**: 21–35.
- Adejumobi, S. A. (2007): The history of Ethiopia. Greenwood Publishing Group, Inc. Westport, USA. 132.
- Asseged, B. (2005): Review of Foot and Mouth disease: An in depth discourse of Global, Sub-Saharan and Ethiopian status. Addis Ababa University, Faculty of Veterinary Medicine, Research, and Graduate studies. Debre Zeit, Ethiopia. 3-49.
- Ayelet, G., Mahapatra, M., Gelaye, E., Berhe, G., Rufeal, T., Sahle, M., Ferris, N., Wadsworth, J., Hutchings, G., and Knowles, N.J. (2009): Genetic characterization of Foot-and-Mouth Disease viruses, Ethiopia, 1981–2007. *Emerging Infectious Diseases*, **15**: 1409–1417.
- Barasa, M., Catley, A., Machuchu, D., Laqua, H., Puot, E., Tap, D. Kot. and Ikiror, D. (2008): Foot-and-Mouth Disease Vaccination in South Sudan: Benefit–Cost Analysis and Livelihoods Impact. *Transboundary and Emerging Disease*, **55**: 339-351.
- Bayissa, B., Ayelet, G., Kyule, M., Jibril, Y. and Gelaye, E. (2011): Study on seroprevalence, risk factors, and economic impact of Foot-and-Mouth Disease in Borena pastoral and agro-pastoral system, southern Ethiopia. *Tropical Animal Health and Production*, **43(4)**: 759-766.
- Berhanu, W. and Fayissa, B. (2010): Analysis of the household economy and expenditure patterns of a traditional pastoralist society in Southern Ethiopia. Department of economics and finance working paper series. Middle Tennessee State University, USA.
- BZPDB (Borena Zone Pastoral Development Bureau) (2011): unpublished data.
- Chemeda, D., Bekele, S., Ensermu, R., Singh, M., and Das, A. (2007): Indigenous Systems of Conflict Resolution in Oromia, Ethiopia. In Community-based Water Law and Water Resource Management Reform in Developing Countries. CAB International: 148.
- Cannon, R. M. and Roe, R. T. (1982): Livestock disease surveys: A field manual for veterinarians, Australian bureau of animal health, Canberra, Australia.

- Catley, A. (1999): Methods on the move. A Review of veterinary uses of participatory approaches and method focusing on experience on dry land Africa. International Institute for Environment and Development (IIED), London.
- Catley, A. (2005): Participatory Epidemiology: A Guide for trainers. African union/ Inter African Bureau for animal resources, Nairobi.
- Catley, A. (2006). The use of participatory epidemiology to compare the clinical and veterinary knowledge of pastoralists and veterinarians in East Africa. *Tropical Animal Health and Production*. **38**, 171-184.
- Catley, A. and Aden, A. (1996): Use of participatory appraisal (PRA) tools for investigating tick ecology and tick borne disease in Somaliland. *Tropical Animal Health and Production*, **28**: 91-98.
- Catley, A. and Mariner, J. (2002): Where there is no data: Participatory approaches to Veterinary Epidemiology in pastoral areas of the horn of Africa. International Institute for Environment and Development (IIED). Dry land program, Issue paper No.110, London.
- Catley, A. and Mohammed, A. (1996): The use of Livestock disease- scoring by a primary animal health project Somaliland. *Preventive Veterinary Medicine*, **28**: 175-186.
- Catley, A. and Admassu, B. (2003): Using Participatory Epidemiology to Assess the Impact of Livestock diseases. FAO-OIE-AU/IBAR-IAEA Consultative Group Meeting on Contagious Bovine Pleuropneumonia in Africa, 12-14, November 2003, FAO Headquarters, Rome, Italy.
- Catley, A. and Irungu, P. (2000): Participatory research on Bovine Trypanosomiasis in Orma cattle, Tana River District, Kenya. International Institute of for Environment Development and KETRI, 5-9.
- Catley, A., Chibunda, R. T., Ranga, E., Makungu, S., Magayane, F. T., Magoma, G., Madege, M. J. and Vosloo, W. (2004): Participatory diagnosis of heat intolerance syndrome in Cattle in Tanzania and Association with Foot and Mouth Disease. *Preventive Veterinary Medicine*, **65**:17-30.
- Catley, A., Osman, J., Mawien, C., Jones, B. A., and Leyland, T.J. (2002): Participatory analysis of seasonal incidences of diseases of cattle, disease vectors and rainfall in Southern Sudan. *Preventive Veterinary Medicine*, **53**: 275-284.
- Clavijo, A. and Kitching, P. (2003): The nature and diagnosis of Foot-and-Mouth Disease. National Centre for Foreign Animal Disease, Winnipeg, Manitoba, Canada. *Clinical Microbiology Newsletter*, **25** (11): 81-88.

- Conroy, C., Rai, A., Singh, N. and Chan, M.K. (1998): Conflicts affecting participatory forest management: some experiences from Orissa. Revised version of a paper presented at the Workshop on Participatory Natural Resource Management in Developing Countries, Oxford, UK, 6–7, April 1998.
- Cynthia, M. and Scott, L. (2010): Merck Veterinary manual, 10th ed, Merck Publishing Group, USA.
- Coppock, D. (1994): The Borena plateau of southern Ethiopia: Synthesis of Pastoral Research Development and change, 1980-1991. ILRI, Addis Ababa, Ethiopia.
- Cossins, N. and Upton, M. (1987): The Borana Pastoral System of Southern Ethiopia. In: *Agricultural Systems*. **25 (3)**:199-218.
- Davies, G. (2002): Review on Foot-and-Mouth Disease. *Research in Veterinary Science*, **73**: 195–199.
- Desta, S. (1999): Diversification of Livestock assets for risk management in the Borena pastoral system of Southern Ethiopia, PhD thesis, Utah State University, Logan, Utah. 10-31.
- Diego, A., Brocchi, E., Mackay, D. and Simone, F. (1997): The use of non- structural polyprotein 3ABC of FMD virus as a diagnostic antigen in ELISA to differentiate infected fro vaccinated cattle. *Archives of virology*. **142**: 2021-2033.
- Doel, T.R. (2003): Review on FMD vaccines. *Virus Research*, **91**: 81-99.
- Domingo, E., Mateu, M. G., Martinez, M. A., Dopazo J., Moya A. and Sobrino F. (1990): Genetic variability and antigenic diversity of foot-and-mouth disease virus. *Applied Virology Research*. **2**: 233-266.
- ECA (East African Community Secretariat). (2004): Project Proposal on the Control of Transboundary Animal diseases in the Community, Arusha, Tanzania.
- FAO (2007): FAO/EMPRES bulletin. Focus on Foot-and-Mouth Disease. No. 1.
- FAO (2009): FAO/OIE/AU-IBAR/GF-TADS Workshop on the development of a long term action plan (roadmap) for improved surveillance and control of foot-and-mouth disease in Africa held in Nairobi, Kenya 26-30th. January, 30-39.
- Ferris, N. (2004): FMD ELISA kit bench protocol: liquid phase blocking ELISA for Detection of FMD virus serotypes O, A C and SAT2 for Ethiopia. Institute for animal health, Pirbright laboratory, UK. 3-42.

- Fielding, W., Gullick, C., Coutts, P., and Sharp, B. (2000): An Introduction to the Food Economy Research in Southern Sudan 1994–2000. World Food Programme and Save the Children UK, Nairobi.
- Gall, F. (2006): Economic and Social Consequences of Animal Diseases, Speak note By Dr. Francois Le, Lead Livestock Specialist, World Bank. June 12, 2006.
- Geering W., Forman A., Nunn M. (1995): Exotic Diseases of Animals: A field guide for Australian veterinarians. Australian Government Publishing Service, Canberra, Australia, 29-34.
- Gelaye, E., Beyene, B. and Ayelet, G. (2005): Foot and Mouth Disease virus serotype identified in Ethiopia. *Ethiopian Veterinary Journal*, **9**, 7–9.
- Gonzalez, M., Mateu, M.G., Martinez, M.A., Carrillo, C., and Sobrino, F. (1992): Comparison of capsid protein VP1 of the viruses used for the production and challenge of Foot and Mouth Disease vaccines in Spain. *Vaccine*, **10**: 732-734.
- Grimble, R. and Wellard, K. (1997): Stakeholder methodologies in natural resource management: a review of principles, contexts, experience and opportunities. *Agricultural Systems*, **55**, 173–193.
- Hughes, G., Mioulet, V., Kitching, R., Woolhouse, M., Andersen, S. and Donaldson, A. (2002): Foot-and-Mouth Disease virus infection of sheep: Implications for diagnosis and control. *The Veterinary Record*, **150**: 724-727.
- [Http://www.oie.int/animal-health-in-the-world/official-disease-status/fmd/list-of-fmd-free members/](http://www.oie.int/animal-health-in-the-world/official-disease-status/fmd/list-of-fmd-free-members/)
Accessed on November 25, 2011.
- Hunter, P. (1998): Vaccination as a means of control of foot-and-mouth disease in sub-saharan Africa. *Vaccine*, **16** (2/3): 261-264.
- Iles, K. (1994): The progeny history data collection technique: A case study from Samburu District, Kenya. *RRA IIED*, London. *Notes*, **20**: 71-77.
- James, A. and Rushton, J. (2002): The economics of Foot and Mouth Disease. *OIE Scientific and technical review*, **21** (3): 637-644.
- Kitching, R. (1992): Foot and Mouth Disease. In: Viral diseases, edited by A.H. Andrews, R.W. Blowey, H. Boyd and R.G. Eddy. Blackwell Scientific Publications Ltd., Oxford, UK, 537-543.
- Kitching, R. (1998): A recent history of Foot-and-Mouth Disease. *Journal of Comparative Pathology*, **118**: 89-108.
- Kitching, R. and Alexandersen, S. (2002): Clinical variation in Foot and Mouth Disease: pigs. *OIE Scientific and Technical Review*, **21**(3): 499-503.

- Kitching, R., Knowles, N., Samuel, A. and Donaldson, A. (1989): Development for Foot and Mouth Virus strains characterization. A review. *Tropical Animal Health Production*, **21**: 153-166.
- Leyland, T. (1991): Participation in the 80s and 90s: Who ask the questions in livestock Development? MSc thesis, University of Edinburgh, Edinburgh, UK.
- Lielo, F., Ayieco, J., Makenzi, P., Muhia, N., Njeremani, D., Muiruri, H., Omollo, J. and Ochola W. (1995): PRA filed handbook for participatory rural appraisal reactionaries. PRA program, Egerton University, Njoro, Kenya. 10-24.
- Mackay, D., Forsyth, M., Davies, P., Berlinzani, A., Belsham, G., Flint, M. and Ryan, M. (1998): Differentiating infection from vaccination in Foot-and Mouth Disease using a panel of recombinant nonstructural proteins in ELISA. *Vaccine*, **16(5)**, 446–459.
- Megersa, B., Beyene, B., Abunna, F., Regassa, A., Amenu, K., Rufael, T. (2009): Risk factors for Foot and Mouth Disease seroprevalence in indigenous cattle in Southern Ethiopia: the effect of production system. *Tropical Animal Health Production*. **41**:891–898.
- Mekonen, H; Beyene, D; Rufael, T; Feyisa, A. and Abunna, F. (2011): Study on the prevalence of Foot and Mouth Disease in Borana and Guji Zones, Southern Ethiopia. *Veterinary world*, **4(7)**: 293-296.
- MOARD (Ministry of Agriculture and Rural Development) (2006): Foot and Mouth Disease Control Plan. Addis Ababa, Ethiopia.
- Molla, B., Ayelet, G., Asfaw, Y., Jibril, Y., Ganga, G. and Gelaye, E. (2010): Epidemiological Study on Foot-and-Mouth Disease in Cattle: Seroprevalence and Risk Factor Assessment in South Omo Zone, South-western Ethiopia. *Transboundary and Emerging Diseases*. **57**: 340–347.
- Morris, R. (1999): The application of economics in animal health programmes: a practical guide. *OIE Scientific and technical review*. 1999, **18 (2)**, 305-314.
- Murphy, F., Gibbs, E., Horzinek, M. and Studdert, M. (1999): *Veterinary Virology*, 3rd ed. USA. Academic press. 412- 421.
- Negussie, H., Kyule, M., Yami, M., Ayelet, G., Jenberie, S. (2011): Outbreak investigations and genetic characterization of Foot-and-Mouth Disease virus in Ethiopia in 2008/2009. *Tropical Animal Health Production*, **43**:235–243.
- OIE (2009): Foot and Mouth Disease. In: OIE terrestrial manual. Manual of standards for diagnostic tests and vaccines. Chapter 2.1.5. Version adopted by the World Assembly of Delegates of the OIE in May 2009.

- OIE (2011): Rinderpest eradication. *OIE bulletin* No. 2011-2.
- Pereira, H.G. (1981): Foot and mouth disease. In: *Virus Diseases of food animals*, volume 11 Academic Press Inc. (London) Ltd., UK. 333-358.
- Perry, B. and Rich, K. (2007): Poverty impacts of Foot-and-Mouth Disease and the poverty reduction implications of its control point of view. *The Veterinary Record*, **160**, 238-241.
- Radostits, O., Gay, C., Hinchcliff, K. and Constable, P. (2006): *Veterinary Medicine, A text book of the diseases of Cattle, Sheep, Goats, Pigs and Horses*. 10th edition. London: Bailliere Tindall. 1223-1231.
- Re'mond, M., Kaiser, C. and Lebreton, F. (2002): Diagnosis and screening of Foot-and-Mouth Disease. *Comparative Immunology, Microbiology and Infectious Disease*, **25**: 309-320.
- Rufael, T., Catley, A., Bogale, A., Sahle, M. and Shiferaw, A. (2008): Foot and Mouth Disease in the Borena pastoral system, southern Ethiopia and implications for livelihoods and international trade. *Tropical Animal Health Production*, **40**: 29-38.
- Rushton, J., Thornton, P. K. and Otte, M. J. (1999): Methods of economic impact assessment. *OIE Scientific and technical review*, **18**, 315-342.
- Rutagwenda, T. (2003): Draft consultancy report submitted to the FAO Regional Office Kampala Uganda: The implications and consequences of Foot and Mouth Disease outbreaks on food security and household incomes in selected districts in Uganda, Faculty of Veterinary Medicine, Makerere University, Kampala.
- Sahle, M., Venter, E.H., Dwarka, R.M. and Vosloo, W. (2004): Molecular epidemiology of serotype O Foot-and-Mouth Disease virus isolated from cattle in Ethiopia between 1979-2001. *Onderstepoort Journal of Veterinary Research*, **71**: 129-138.
- Samuel, A. R. and Knowles, N. J. (2001): Foot-and-Mouth Disease virus: Cause of the recent crisis for the UK livestock industry. *Trends in Genetics*, **17**(8): 421-424.
- Sangare, O. (2002): *Molecular Epidemiology of Foot and Mouth Disease virus in West Africa*. University of Pretoria, South Africa. PhD, thesis. 10-37.
- Sanson, R., Liberona, H. and Morris, R. (1991): The use of geographical information system in the management of a Foot and Mouth Disease epidemic. *Preventive Veterinary Medicine*, **11**: 309-313.

- Sanz-Parra, A., Sobrino, F. and Ley, V. (1998): Infection with Foot and Mouth Disease virus result in a rapid reduction of MHC class I surface expression. *Journal of General Virology*, **79**: 2327-2333.
- Seifert, H. (1996): Tropical Animal Health. Kluwer Academic Publishers, Dordrecht/ Boston/ London. 324-435.
- Siegel, S. and Castellan, N. J. (1994): Non- parametric statistics for behavioral science. 2nd ed. McGraw-Hill, New York, USA, 399.
- Sellers, R. and Daggupaty, S. (1990): The epidemic of Foot and Mouth Disease in Saskatchewan, Canada. *Canadian Journal of Veterinary Research*, **54**: 457-464.
- Solomon, T., Snyman, H. and Smit, G. (2007): Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management*, **82**, 481–494.
- Thompson, D., Muriel, P., Russell, D., Osborne, P., Bromley, A. and Rowland, M. (2001): Economic costs of the Foot and Mouth Disease outbreak in the United Kingdom in 2001. London, UK.
- Vosloo, W., Bastos, A.D.S., Sangare, O., Hargreaves, S.K., Thomson, G.R. (2002): Review of the status and control of Foot and Mouth Disease in sub-Saharan Africa. *OIE Scientific and technical review*, **21**, 437–449.
- Zahur, A., Irshad, H., Hussain, M., Ullah, A., Jahangir, M., M., Khan, Q., Farooq, M. (2008): The epidemiology of Peste Des Petits Ruminants /PPR/ in Pakistan. *OIE Scientific and technical review*, **27(3)**, 877-884.

8 ANNEX

Annex 1: Matrix scoring of major cattle disease signs, Kendal's coefficient of concordance for median (minimum and maximum scores in bracket).

Clinical signs /Indicators/	FMD <i>Hoyalee</i>	Chronic FMD <i>Gaaandile</i>	CBPP <i>Sombessa</i>	Pasteurelosis <i>Sillisa</i>	Ticks <i>Silmi</i> <i>Dirandisa</i>	Blackleg <i>Harkaa</i>
Mortality	•		••••••••	••••••••	•	••••••••••
0.865***	1 (0,2)	0 (0, 1)	7 (6,9)	6 (6,9)	1 (0,4)	9 (3,10)
Milk reduction	••••••••	••••••••	•••••	•••••	••	•••••
0.783***	7 (5,10)	6 (4,8)	4 (0,5)	4 (3,5)	2 (0,3)	4 (1,4)
Lameness /footsore	•••••••• ••••••••		•		•••	••• ••
0.769***	16 (10,20)	0 (0,6)	1 (0,3)	0 (0,0)	3 (0,10)	5 (3,9)
Nasal discharge			••••••••	•••••••••• ••••••••••		
0.904***	0 (0,2)	0 (0,0)	6 (3,14)	18 (14,20)	0 (0,4)	0 (0,0)
Abortion	••••••••					
0.768***	••••••••	••••••••	••	•	••	•
	12 (5,20)	6 (2,10)	2 (0,6)	1 (0,5)	2 (0,5)	1 (0,2)
Seeking shade	••	••••••••				
0.809***		••••••••	••	••		
	2 (0,5)	••• 19 (10,20)	2 (0,5)	2 (0,5)	0 (0,0)	0 (0,0)

Hair	••••••••••					
overgrowth	••••••••••					
0.821***	••••••••					
	0 (0,5)	25 (20,25)	0 (0,2)	0 (0,0)	0 (0,0)	0 (0,0)
			••••••••	••••••••		
Coughing			••••••	•••••		
0.914***	0 (0,1)	0 (0,2)	12 (2,15)	11 (10,23)	0(0,0)	0 (0,0)
Salivation	••••••••••					
0.783***	••••••••••		••	•••••		
	18 (12,25)	0 (0,3)	2 (0,4)	4 (0,9)	0 (0,5)	0(0,2)
Mouth lesion	••••••••••					
0.883***	••••••••••					
	••					
	20 (6,25)	0 (0,8)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)
“Kissing	••••••••••					
sound”	••••••••••					
0.788***	••••••••					
	23 (18,25)	0 (0,2)	0 (0,5)	0 (0,6)	0 (0,0)	0 (0,0)
“Panting”	••••••	••••••••••	••••••	•		
0.806***		••••••				
	5 (2,6)	13 (12,20)	5 (2,8)	1 (0,3)	0 (0,2)	0 (0,4)
Morbidity	••••••	•	••••••	••••••	••	••
0.699***	10 (2,15)	1 (0,2)	5 (2,8)	5 (2,7)	2 (2,5)	2 (1,8)
Contagiousity	••••••••	•	••••••	•••••	••	••
0.841***	••••••					
	12 (10,14)	1 (0,4)	5 (3,10)	4 (3,5)	2 (1,3)	2 (0,3)

Weak agreement: $W < 0.26$, $*P > 0.05$; moderate agreement: $W = 0.26-0.38$, $**P < 0.05$; strong agreement: $W > 0.38$, $***P < 0.01$ (Siegel and castellan, 1994).

9 CURRICULUM VITAE

Personal data

First Name: Tariku Jibat Beyene

Sex: Male

Date of birth: 23rd April 1983.

Place of birth: East Wollega, Ethiopia Nationality: Ethiopian

Languages: Afan Oromo, Amharic and English

Contact address

Addis Ababa University, School of Veterinary Medicine, P.O.Box 34,

Debre zeit, Ethiopia. E mail- tarikuj@yahoo.com, jibattariku@gmail.com,

Phone: +251911974262.

Education

- 2001 to 2006- Addis Ababa University, Faculty of Veterinary Medicine, Doctor of Veterinary Medicine (DVM) degree awarded with distinction.
- 1996 to 1999- Nekemte Comprehensive High School, Grade 9-12, Ethiopian School Leaving Certificate Examination (ESLCE), with great distinction.

Work experience

- Since 2007- Addis Ababa University, Faculty of Veterinary Medicine, as lecturer.
- September 2006 to December 2007- University of Gondar, Faculty of Veterinary Medicine, as lecturer.

Research focus/ interest

- To work in the area of epidemiology, disease control, health economics and related areas.

Professional membership

- Full member of the Ethiopian veterinary association (EVA), International society of infectious disease (ISID) and American society of microbiology (ASM).

Publications

- **Jibat, T. et al.**, (2008): Causes of organ and carcass condemnation in sheep and goats slaughtered at HELMEX abattoir, Debre zeit Ethiopia. *Rev med vet.* 156(8):308-311.
- Mulisa Megersa, Ashenafi Feyisa, Anteneh Wondimu and **Tariku Jibat** (2011): Herd composition and characteristics of dairy production in Bishoftu Town, Ethiopia. *Journal of Agricultural Extension and Rural Development.* 3(6):113-117.
- Sisay Girma, Girma Zewde, Ketema Tafess, **Tariku Jibat** (2011): Assessment of Awareness and Use of Veterinary Public Health in and Around Addis Ababa, Ethiopia. Proceeding of First *International Congress on Pathogens at the Human--Animal Interface (ICOPHAI): Impact, Limitations, and Needs in Developing Countries.* September 2011, United Nations conference Center, Addis Ababa, Ethiopia.
- **Jibat, T.** (2007): Major parasitic causes of organ and Carcass condemnation and its direct economic impact in small ruminants slaughtered at HELMEX abattoir, Ethiopia. Proceeding of *17th Annual research conference, University of Gondar*, held on June 29-30. Vol. 8.

10 STATEMENT OF DECLARATION

I declare that the information presented here in my thesis is my original work, has not been presented for a degree in any other University, all sources of materials used for the thesis have been duly acknowledged and my supervisors had gone through and approved it.

Name: Tariku Jibat Beyene

Signature: 

Date of Submission: 20/12/2011