OCCURRENCE AND RISK FACTORS ASSOCIATED WITH FOOT AND MOUTH DISEASE IN SMALLHOLDER DAIRY FARMS OF NAKURU COUNTY, KENYA

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DECLARATION

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

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DEDICATION

Dedicated to my daughter Joan Machira, my wife Mary Wairimu and my mother
Cecilia Nyaguthii (Wanjira) for all your support throughout. God bless you!
ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS AND ACRONYMS

AHP – Animal Health Provider

ELISA – Enzyme linked immunosorbent assay

EuFMD - European Commission for the Control of Foot and Mouth Disease

FAO – Food and Agriculture Organisation

FMD - Foot and Mouth Disease

FMDV – Foot and Mouth Disease Virus

KES – Kenyan Shilling

KNBS – Kenya National Bureau of Statistics

NSP – Non-Structural Protein

OIE – World Organization for Animal Health

SAT -1 – Southern African Territories Serotype 1

SAT-2 - Southern African Territories Serotype 2

VP – Virus Protein
ABSTRACT

Foot-and-Mouth Disease (FMD) is a highly transmissible viral infection of cloven-hoofed animals caused by an Aphthovirus of the family Picornaviridae. In Kenya, the disease is endemic with outbreaks typically occurring throughout the year.

A cross-sectional study of smallholder dairy farmers in Nakuru County was conducted with the objectives of identifying the risk factors for FMD and estimating the 6-month period prevalence (May/June 2016 to November/December 2016). A secondary objective was to analyse retrospective data on FMD occurrence in Nakuru County for the previous 7 years (2010 to 2016) to determine temporal trends in infection. Semi-structured questionnaires were administered via personal interviews to 220 smallholder farmers, selected using random spatial sampling in November 2016. The retrospective study was conducted using data available from the Directorate of Veterinary Services for FMD occurrence in Nakuru for the period 2010-2016. Univariate and multivariate logistic regression models were used to assess the association of risk factors and the occurrence of FMD for the cross-sectional study with occurrence of FMD in the previous 6 months being the outcome variable. In addition, a spatial Bernoulli model was used to detect and quantify clusters of infection in the study area. Descriptive statistics and generalized linear models were used to analyse data for the retrospective study with the outcome variable being sample positivity.
The average size of farms was 11.0 acres (5.69-16.26, 95% CI) and the average number of cattle kept was 5.5 (4.75-6.20, 95% CI). A total of 132/220 (60%) of the respondents also owned sheep with 15% (33/220) owning goats.

The majority of respondents, 94.1% (207/220), knew of FMD and 80.2% (166/207) could correctly identify the disease based on clinical signs. About 20% (45/220) farmers had vaccinated their livestock against FMD in the previous six months.

FMD had reportedly occurred in 5.9% of the surveyed farms within the previous six months. The overall morbidity rate on affected farms in outbreaks occurring on farms in the previous 6 months was 58.0% (95% CI 38.3-77.6). Spatial clustering of FMD cases was identified in the northern part of the study area. This single disease cluster (radius = 5.32 Km) was 38.1 times more likely than any other part of the study area to experience FMD (p<0.001).

Univariate logistic regression analysis provided evidence that clinical FMD at the household level was statistically associated with the use of a shared bull, the number of cattle restocked in the previous 12 months, the restock source (with an increased risk if buying from livestock markets), grazing sheep either within towns or the compound, grazing cattle within towns, the use of a communal dip and the number of sheep present within the household (p<0.05). Vaccination in the previous six months (May 2016 – November 2017) was associated with a decrease in the risk of FMD at the household level.
On multivariate analysis, the use of a shared bull [OR=28.1 (95% CI 3.3-241.3); p=0.002], the number of sheep owned [for each additionally sheep owned OR=1.1 (95% CI 1.0-1.2); p=0.006] and the number of restocked susceptible species of animals bought in the last one year [OR=1.2 (95% CI 1.0-1.4); p=0.030] were associated with whether a farm experienced a case of FMD in the previous six months.

In the retrospective study, high proportions (63.74%) of the samples (171) were positive for FMD for the period 2010 – 2016. Serotypes detected from the samples in the seven-year period were O (25.2%, n=43/171), SAT 2 (17.5%, n=30/171), A (11.7%, n=20/171), and SAT 1 (9.4%, n=16/171). These serotypes caused multiple outbreaks within the study period (2010-2016) and occurred simultaneously. A generalized linear model revealed evidence of seasonal variability in FMD with positivity being highest in the dry season.

This study provides a clearer picture of smallholder dairy farming within Nakuru and reports on risk factors associated with FMD at the farm level in a densely populated smallholder farming area of Kenya. The results provided can be used to inform the development of a risk-based FMD control strategy and as a baseline for evaluating future interventions used in FMD management programmes.
CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Foot and Mouth Disease (FMD) is a viral disease affecting cloven-hoofed animals. The causative pathogen, the Foot and Mouth Disease Virus (FMDV) is a single-stranded positive sense virus belonging to the family Picornaviridae and genus Aphthovirus (Domingo et al., 2002). The disease is endemic in Kenya (Kibore, 2013).

In cattle, the disease causes erosions and ulcers in the oral cavity (particularly the dental pad and tongue), interdigital space and the teats (Kitching, 2002). In infected animals, the virus is shed from all body secretions including milk, saliva, urine and faeces. Direct transmission occurs when susceptible animals inhale infectious droplets exhaled by infected animals. Indirect transmission occurs when feed, water or fomites contaminated by secretions from an infected animal come into contact with a susceptible animal. Though the disease has a low case fatality rate, the high morbidity rate and impact on productivity means the disease can have a huge impact on dairy farming (Lyons et al., 2015).

Foot and mouth disease viruses occur in serotypes that have no crossover protection. These are O, A, C, Southern African Territories (SAT)-1, SAT 2, SAT 3 and Asia 1. In Kenya, outbreaks of O, A, C, SAT 1 and SAT 2 have been previously reported (Vosloo et al., 2002). Serotype C has not been detected.
worldwide since 2004 and may no longer be present (Paton, Sumption and Charleston, 2009).

From farmer descriptions foot and mouth disease outbreaks of clinical disease are common in Nakuru County although data on the potential risk factors for FMD among smallholder dairy farmers in the county are poorly documented and no study has estimated the prevalence or incidence of the disease among smallholder dairy farmers.

This study aimed to estimate the 6-month period prevalence of FMD and the risk factors for its occurrence within the County. The data on risk factors generated in this study and other studies on FMD epidemiology would be important if Kenya is to move to stage two of the Progressive Control Pathway for FMD control in endemic countries as recommended by FAO and OIE (Rweyemamu et al., 2008).

1.2 Problem statement

Foot and Mouth Disease continues to be a major source of economic losses for smallholder farmers in Kenya. Though endemic in Nakuru County the disease easily spreads into individual smallholder farms due to risky practices by the farmers. An understanding of these risk factors was lacking. In addition, the analysis of temporal trends may have provided new information critical to control of the disease. Although data on FMD occurrence in Nakuru for the past ten years were available, little had been done to properly understand the
temporal trends of the disease in this county that the data contained. This study aimed to fill these information gaps.

1.3 General Objective of the study

To determine the occurrence and risk factors associated with foot and mouth disease in smallholder dairy farms of Nakuru county, Kenya.

1.3.1 Specific Objectives

1. To determine the 6-month period prevalence and spatial distribution of Foot and Mouth Disease in Nakuru County, Kenya for the period May/June 2016 to November/December 2016.

2. To determine the risk factors of FMD in smallholder dairy farms in Nakuru County, Kenya within this period.
CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Foot and Mouth Disease virus

The Foot and Mouth disease virus (FMDV) is a single-stranded positive sense RNA virus belonging to the genus Aphthovirus and family Picornaviridae (Domingo et al., 2002). The virus is non enveloped with icosahedral symmetry and a genome length of about 8500 nucleotides (Domingo et al., 2002). The genome encodes for virus protein (VP) 1-4 as well as several regulatory proteins. The VP 1, VP 2 and VP 3 are found on the outside of the viral shell while VP 4 is found on the inside of the shell.

The viral proteins can also be divided into structural or non-structural proteins. Non-structural proteins are those found in the virus but are not part of the viral capsid. These proteins also induce antibody responses. This is utilised in serological diagnostic tests most common of which is ELISA. An overview of serology based methods for FMD detection is available (Ma et al., 2011).

The FMD viruses occur in serotypes that are immunologically independent including O, A, C, SAT 1, SAT 2, SAT 3 and Asia 1. The difference in the strains can be shown as differences in the VP1 gene of the virus (Knowles and Samuel 2003) with different serotypes showing at least 50% difference to each other. In Kenya outbreaks of O, A, C, SAT 1 and SAT 2 have been previously reported (Vosloo et al., 2002).
Usual hosts for the virus are all cloven-hoofed animals including cattle, sheep, goats, pigs, buffaloes and antelope. The virus infects the epithelium of the soft palate, pharynx, lung, feet and mouth (Kitching, 2002). It enters the cell through clathrin-mediated endocytosis. It primarily replicates in the cytoplasm where a negative strand of the positive RNA of the virus is manufactured. The negative strand is then used as the mRNA in the manufacture of viral proteins. Being an RNA virus, large numbers of mutations occur due to errors made during replication and this accounts for the huge number of subtypes of the virus (Sobrino and Domingo, 2004). After replication, the newly assembled virions are released by the cell when it ruptures. This rupturing of the cells accounts for the pathogenesis of the disease seen.

2.2 The Foot and Mouth Disease

The Foot and Mouth Disease virus causes Foot and Mouth Disease (FMD). The virus can infect all cloven-hoofed animals (Alexandersen and Mowat, 2005). Transmission is through direct and indirect modes. Indirect transmission modes include contaminated food, water or fomites or direct through infectious droplets from the breath of an infected animal through the wind. The incubation period of the disease is 2-14 days depending on the viral strain, host factors and most importantly the level of viral exposure. Transmission of the virus typically occurs in the first few days after clinical signs appear although can also occur in the 24 hour period prior to disease onset (Chase-Topping et al., 2013).
Typically after an initial fever, vesicles can appear on the gum, hard palate, interdigital cleft, teats, tongue, lips, muzzle, dental pad and coronary band (Kitching, 2002). There is a drop in milk production observed particularly in animals with higher lactation numbers and those during the first 50 days of lactation (Lyons et al., 2015). Animals may not recover this loss of production during the remaining lactation.

Cattle produce increased amounts of saliva and a nasal discharge that may later become mucopurulent due to secondary bacterial infection. Cattle are reluctant to move due to pain caused by the lesions on their feet and may shift weight from one foot to the other. Lesions on the teats may predispose a cow to developing mastitis (Nicholas A Lyons et al., 2015). The course of the disease is typically around 11-14 days whereby the vesicles in the oral cavity start healing. The disease has low mortality but morbidity may approach 100% (Chowdhury et al., 1993).

**2.3 Occurrence and Distribution of Foot and Mouth Disease**

“Every year it affects us. It has been a big problem for us.”

-A dairy farmer from Ol Banata, Nakuru County talking about Foot and Mouth Disease.

Foot and mouth disease occurs in most parts of the world (Rweyemamu et al., 2008). Some countries, however, have been able to achieve disease free status with or without vaccination. Specific serotypes and strains are unevenly distributed among the different regions in the world. In the Middle East
serotypes incursions of SAT -1 and SAT -2 have occurred mainly due to animal movements from Africa. In Asia and India Eurasia serotypes O, A, C and Asia - 1 are most prevalent. In south America O, A and C are most prevalent. Animal movements are the most important factor in spread of the disease world-wide (Rweyemamu et al., 2008).

In Africa serotypes SAT-1, SAT – 2, SAT – 3, O and A are most common. Indian Ocean islands including Madagascar, Mauritius and the Seychelles are free of the disease. Recent studies have shown that wildlife especially the African Buffalo and impala could be reservoirs for infection with the three SAT serotypes in Africa. In addition, animal movements in search of pasture and water could contribute to introduction if FMD into new areas (Vosloo et al., 2002).

2.4 Foot and Mouth Disease in Kenya

Foot and Mouth Disease is endemic in Kenya with outbreaks thought to occur yearly. It was first demonstrated in Kenya 1932 although it is possible that livestock keeping communities might have been interacting with it for longer (Wariru, 1994). Onono et al. (2013) ranked FMD second among diseases with the most impact to pastoral livestock keepers. In Kenya outbreaks of O, A, C, SAT 1 and SAT 2 have been previously reported (Vosloo et al., 2002).

A recent study estimated the sero-prevalence of FMD within Nakuru County to be 22.7% with a national prevalence of 52.5% (Kibore et al., 2013). This study utilised serum samples collected from various counties within Kenya. The
sampling unit was divisions and farms. However, this study did not correct for clustering in individual animals within a single dairy farm.

2.5 Risk factors for foot and mouth disease

Globally there have been various studies looking at the risk factors for clinical FMD among cattle. At the time of writing this thesis (2016), fourteen papers from 10 different locations in Africa, Asia, Europe and the Middle East had been published using various methods of sampling and evidence of infection (Table 2.1). Table 2.2 shows the reported risk factors for FMD transmission in other studies.

Risk factors can vary from region to region in terms of relative importance. An understanding of these risk factors in different areas is essential in developing a national and regional control strategy.

No study has been performed in Kenya to exclusively look for risk factors to FMD among smallholder dairy farms. One study investigated the epidemiology of an FMD outbreak in a large scale farm in Nakuru (Lyons et al., 2015) and concluded that percentage of local breed present in the breeding pedigree and age were risk factors. In his study, movement of animals incubating the virus, use of a communal dip and milking parlour likely spread the disease around the farm.
Table 2.1: Summary of published literature on risk factors for Foot and Mouth Disease in various countries obtained through a literature search.

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of study</th>
<th>SS</th>
<th>SU</th>
<th>Measure of Effect</th>
<th>Sampling method</th>
<th>Collection/Analysis method</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Allepuz et al., 2015) Tanzania</td>
<td>Cohort</td>
<td>30 grids</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Bayissa et al., 2011) Ethiopia</td>
<td>Cross-sectional</td>
<td>177 animals</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Ehizibolo et al., 2014) Nigeria</td>
<td>Cross-sectional</td>
<td>198 farms</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Emami et al., 2015) Iran</td>
<td>Cross-sectional</td>
<td>8378 animals</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Ellis-Iversen et al., 2011) England</td>
<td>Case control</td>
<td>30 farms</td>
<td>OR</td>
<td>non random</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td>(Fasina et al., 2013) Nigeria</td>
<td>Case control</td>
<td>68 farms</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Dukpa et al., 2011b) Bhutan</td>
<td>Cross-sectional</td>
<td>485 farms</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Elnekave et al., 2015) Israel</td>
<td>Case control</td>
<td>44 farms</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Molla et al., 2010) Ethiopia</td>
<td>Cross-sectional</td>
<td>770 animals</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Bronsvooort et al., 2004) Cameroon</td>
<td>Cross-sectional</td>
<td>147 farms</td>
<td>OR</td>
<td>random</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td>(Muroga et al., 2013) Japan</td>
<td>Case control</td>
<td>292 farms</td>
<td>OR</td>
<td>random</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td>(Megersa et al., 2009) Ethiopia</td>
<td>Cross-sectional</td>
<td>79 farms</td>
<td>OR</td>
<td>random</td>
<td>ELISA</td>
<td></td>
</tr>
<tr>
<td>(Dukpa et al., 2011a) Bhutan</td>
<td>Cross-sectional</td>
<td>383 farms</td>
<td>OR</td>
<td>random</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td>(Cleland et al., 1996) Thailand</td>
<td>Cross-sectional</td>
<td>60 villages</td>
<td>OR</td>
<td>random</td>
<td>Questionnaire</td>
<td></td>
</tr>
</tbody>
</table>

Key: SS-Sample Size SU- Sampling unit; OR – Odds Ratio
Table 2.2: Risk factors of FMD transmission according to literature.

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharing of Water or feed areas</td>
<td>Cleland et al., 1996</td>
</tr>
<tr>
<td>Type of Livestock production system</td>
<td>Megersa et al., 2008</td>
</tr>
<tr>
<td>Proximity of livestock to wildlife especially buffalo and impala</td>
<td>Jori et al., 2009</td>
</tr>
<tr>
<td>Increased cattle movements</td>
<td>Hassig et al., 2015</td>
</tr>
<tr>
<td>Presence of calves below six months of age</td>
<td>Elnekave et al., 2015</td>
</tr>
<tr>
<td>A period of 6 months or more between vaccinations</td>
<td>Elnekave et al., 2015</td>
</tr>
<tr>
<td>Residing in an area that has had an FMD outbreak in the last 12 months</td>
<td>Emami et al., 2015</td>
</tr>
<tr>
<td>Animals owned by livestock traders</td>
<td>Emami et al., 2015</td>
</tr>
<tr>
<td>Distance of farm to major roads</td>
<td>Hamoonga et al., 2014</td>
</tr>
<tr>
<td>Mixing of cows with small ruminants</td>
<td>Hamoonga et al., 2014</td>
</tr>
<tr>
<td>Distance to major national boundaries</td>
<td>Hamoonga et al., 2014</td>
</tr>
<tr>
<td>Buying animals from livestock markets</td>
<td>Bronsvoort et al., 2004</td>
</tr>
<tr>
<td>Number of cattle bought in the previous 1 year</td>
<td>Cleland et al., 1996</td>
</tr>
</tbody>
</table>
2.6 Small holder dairy farming in Kenya

Kenya has the best developed smallholder dairy farming system in sub-Saharan Africa and the sector contributes 56% of all milk produced in the country (Odero-Waititu, 2017). There are over 600,000 smallholder farmers in Kenya (Omore et al., 1999; Odero-Waititu, 2017). Smallholder dairy farming has had varied descriptions. One author defined them as those managing 2-15 animals (Devendra, 2001) while another defined them as those having up to 50 animals (Phiri et al., 2010). The majority of the milk sold by smallholder dairy farmers is informal with only 38% being sold through cooperatives (Omore et al., 1999; Odero-Waititu, 2017).

2.7 Economic Impact of Foot and Mouth Disease

Foot and Mouth Disease causes major economic losses in dairy production. Losses can be classified as direct and indirect (Knight-Jones and Rushton 2013). Direct losses can be due to reduced milk production, death of animals and sale of sick animals. Indirect losses include lack of access to prime livestock markets and loss of customers due to unreliable milk production. One study in Ethiopia found that the losses due to reduced milk production and death could reach as high as USD 76 (KES 7600) per herd (Jemberu et al., 2014). Losses included reduced milk production, death of calves, rapid weight loss and abortions.
2.8 Progressive control pathway for Foot and Mouth Disease (PCP-FMD)

The progressive control pathway (PCP) is a plan developed by the FAO, OIE and the European Commission for the Control of FMD (EuFMD) to help endemic countries control foot and mouth disease (Rweyemamu et al., 2008). The plan consists of six stages (0-5) as outlined below.

- Countries in stage 0 have no knowledge of the FMD status within the country.
- Stage 1 consists of gathering information on the FMD status in the country. This information is collected with the aim of developing a risk-based strategic control program for the disease. After developing the plan, a country then moves to stage 2.
- In stage 2 they implement this plan with the aim of reducing the impact of the disease nationally or in a pre-identified region or sector.
- Stage 3 involves a more intensive control plan aimed at reducing viral circulation.
- Stage 4 is where a country achieves an FMD-free status with vaccination. A country can then apply to the OIE to be declared FMD-free with vaccination.
- Finally at stage 5 a country becomes free of FMD without vaccination (FAO/OIE, 2011).

The PCP-FMD is intended not to be prescriptive and countries can choose their own methods to reach their national objectives. It does not necessarily assume that the country will plan to reach advanced stages of control.
Kenya is currently transitioning between stage 1 and stage 2 whereby information is still being collected on regional distribution and risk factors for FMDV in different production systems. A control strategy has been developed but has not been fully implemented and is undergoing revision in line with the devolution of veterinary authority to the County level. There is still need for further passive and active epidemiological studies and this study aims to contribute to the body of knowledge in the country in its efforts of developing a risk-based control strategy.
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The study was conducted in Nakuru County which is one of the counties in the Republic of Kenya (Figure 3.1). It was conducted between 16th November and 1st December 2016. Nakuru County is found in the Midwest area of Kenya with an elevation of approximately 1850m above sea level with an average rainfall of 963mm per year. It is found between 35.44° E and 36.57° E longitudes and 0.21° N and 1.13° S latitudes. The area is home to a national park (Lake Nakuru National Park) and a forest reserve (Mau forest reserve) hosting wildlife. National statistics from the 2009 Kenya Housing and Population Census, reported Nakuru County as having a total of 409,836 households (Kenya National Bureau of Statistics, 2013), 439,994 cattle, 502,035 sheep, 227,037

Figure 3.1: Map of Kenya showing Nakuru County with the three sub counties within Nakuru where the study was conducted on the right.
Figure 3.2: Salmon-coloured regions indicate the location of the Nakuru County within Kenya and each of the sub-counties of Molo, Njoro and Rongai targeted
for the study. Green-shaded areas represent protected areas, whilst those in azure define lakes.

Dairy farming is an important economic activity in the County. Most of the milk was produced by small holder dairy farmers.

### 3.2 Study design

This was a cross-sectional study. Small holder dairy farms were randomly selected using a spatial randomisation protocol and the farmers then interviewed.

A retrospective study was also conducted using data available from the National FMD laboratory in Kenya on FMD occurrence in Nakuru County for the years 2010 to 2016. Only data from 2010 onwards was available.

### 3.3 Sampling

Four cooperative societies out of six operating within central and Northern Nakuru were identified purposefully based on interviews with the staff at the County Director of Veterinary Services. Of the two cooperative societies not picked, one was in a remote inaccessible area while the other supplied milk to one of the cooperative societies already included in the study. The selected societies were Gogar Farm, Rongai Dairy Small Holders Commercialization Project, Njoro Dairy Farmers’ Cooperative Society and Elburgon Progressive Dairy Cooperative Society.

Each cooperative society’s catchment area was mapped through discussions held with the cooperative's management. They described the boundaries of the areas
where their members came from (catchment areas) and using Google Earth (Google Inc., USA) a map of their catchment area was created. The four cooperative societies’ catchment areas bordered each other thus one large composite area map comprising all the cooperative societies’ catchment areas was created. This area straddled three sub-counties within Nakuru County namely Njoro, Molo and Rongai.

The map was exported from Google Earth and imported into QGIS. Random GPS coordinates within the mapped area were generated using QGIS and loaded onto Garmin eTrex 10 handheld GPS units. These GPS units were then used to locate the generated points on the ground.

The farm closest to the generated GPS coordinates was approached and an oral consent obtained after the project was explained to the household head or livestock manager and then a farmer information sheet (Appendix I) given to them. The information sheet explained the scope of the project, what kind of data were being collected and what it would be used for.

Farms were included in the study if:

i. Farmers orally consented to participate in the study after reading the project information sheet (Appendix I).

ii. Farmers currently owned cattle that were located within the same village

iii. The farm had at least one but no more than 50 cattle in total at the time of the interview.
iv. The farmer or farm worker was present to answer the questions

If the farm selected by spatial sampling did not match these criteria, the next closest farm was selected. Points that were located in areas where no obvious closest smallholder farm could be identified (e.g. in the centre of a large-scale farm or woodland/plantation) were removed from the study.

### 3.4 Data collection

Data were collected by use of a questionnaire (Appendix II) developed and uploaded onto EpiCollect+ (Aanensen et al., 2009). The questionnaire was then loaded onto a mobile phone and administered to the smallholder dairy farmers via personal interview. The questionnaire included both closed and open-ended questions and was pre-tested on three smallholder dairy farms prior to the study.

The primary outcome was whether the farm experienced an FMD case in the last six months. Other information collected included demographic data, data on possible risk factors for FMD occurrence, management of livestock and history of FMD in the farm.

According to the AU-IBAR (2014) a case definition for FMD was:

“Foot and Mouth Disease will be suspected in cattle, sheep, goats, pigs and other cloven-hoofed animals if any **one or more** of the following clinical signs are encountered: un-ruptured vesicles; blisters and sores in the mouth, tongue, teats and feet at the coronary band and interdigital space; lameness, salivation, discharges from the nose and the mouth.”
For the retrospective study, data on FMD occurrence in Nakuru County was collected from the Department of Veterinary Services’ National FMD control laboratory, Embakasi. These data included: date of sample submission, origin of the sample (county, sub-county, division, and serotypes isolated.

Data on confirmatory FMD diagnosis was collected from the National FMD laboratory in Embakasi. The laboratory has capacity to do various serological and molecular tests to confirm FMD and its serotypes (Namatovu et al., 2013).

3.5 Sample size determination

The sample size determination for the number of farms that needed to be interviewed was based on *apriori* prevalence of 15% established through surveys done in the area as part of EuFMD training courses (Lyons, Personal Communication, 2016).

The sample size was calculated using the formula in Dohoo et al.,(2003):

\[ n = Z_\alpha^2 \times \frac{P(1-P)}{L^2} \]

Where,

\( n \) = required sample size,

\( Z = \) the value of \( Z \) (normal deviate) that provides a 95% confidence interval (1.96),
P = expected proportion of households affected in last six months (15% (Lyons, Personal Communication 2016)),

L = precision of estimate taken as 0.05.

Thus, n= 1.96*1.96*0.15*0.85/0.05*0.05 = 197 farms.

This number was inflated by 20% to account for non-responsiveness, large scale farms and the GPS coordinates being in an inaccessible area with no obvious neighbouring smallholder. Therefore, a total of 220 GPS points were generated and visited.

3.6 Ethical considerations

The project proposal went through ethical review by the Kenyatta National Hospital/ University of Nairobi Ethical Research Committee and was approved (reference: P301/04/2016).

3.7 Data handling and analysis

Data from surveys were exported from the EpiCollect+ website as a csv file and imported into STATA version 13 (STATA Corp., College station, Texas, USA) for cleaning and analysis.

The primary outcome was whether the farm experienced an FMD case in the last six months. Farms reporting clinical cases were validated by comparison of the reported clinical signs to the AU-IBAR (AU-IBAR, 2014) case definition of FMD.
Descriptive statistics were generated and included proportions for categorical variables such as grazing methods for FMD susceptible animals, use of communal dips, use of communal watering holes among others and measures of central tendency (mean with 95% confidence intervals and medians with range) for continuous data such as age of respondents, numbers of FMD susceptible animals among others.

The 6-month period prevalence was defined as the number of farms that had experienced a case of FMD within the last six months (based on the farmer correctly identifying the disease using the stated case definition) divided by the total number of farms participating in the interview.

Univariate logistic regressions were performed with each possible risk factor being modelled against the outcome. These variables included use of a shared bull, use of artificial insemination, number of replacement cattle purchased in the last 1 year, source of replacement stock is own animals, buying replacement stock from surrounding farms, buying replacement animals from livestock markets, goats grazing in other communal places, goats grazing by road sides, goats grazing within towns, grazing goats in forests, grazing goats within the farm compound, grazing goats outside the farm compound, grazing sheep by road sides, grazing sheep within towns, grazing sheep outside the farm compound, grazing sheep within farm compound, how often cattle are grazed on communal grounds, grazing cattle in other communal places, grazing cattle by road sides, grazing cattle within towns, grazing cattle outside the farm compound, grazing cattle within the farm compound, vaccination against FMD,
the farm being next to a road, sharing of farm equipment with other farms,
employees commuting from outside farm, sharing of workers with other farms,
use of communal dips, use of communal watering holes, how often goats grazed
on communal grounds, number of goats, ownership of goats in addition to cattle,
how often sheep grazed on communal grounds, number of sheep owned,
ownership of sheep and the number of cattle below 6 months owned.

All variables in the univariable analysis with a p value of less than or equal to
0.2 were entered in a multivariate logistic regression model. Penalized likelihood
ratios would be used instead of maximised likelihood ratios in the logistic
regression modelling to reduce bias if there were low number of cases as
suggested by Firth (1993).

The final multivariate model was constructed using a backward stepwise
approach. Variables were included in the model based on the result of a
likelihood ratio test with a p-value less than 0.05. Regression diagnostics were
undertaken to evaluate potential multicollinearlity between independent
variables by post-estimating the Variance Inflation Factor (VIF). Model fitness
was assessed using the Wald $\chi^2$ test, Akaike's information criterion (AIC),
Bayesian information criterion (BIC) and McFadden’s Pseudo $R^2$ (McFadden,
1974). Linearity between the continuous independent variables and the logit of
the dependent variable was assessed by adding an interaction term calculated
by multiplying the continuous variable with its logarithm as described before
(Box and Tidwell, 1962) and checking for its significance.
A spatial Bernoulli model was used to detect potential clustering of disease events within the study area, and estimating the relative risk of a case occurring in the predicted cluster. This was done using SatScan version 9.4.4 (Kulldorff, 1997). ArcGIS was used to draw maps of the outbreak area (ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute).

Linearity between the continuous independent variables and the logit of the dependent variable was assessed by adding an interaction term calculated by multiplying the continuous variable with its logarithm as described before (Box and Tidwell, 1962) and checking for its significance. Spatial autocorrelation of reported FMD cases was assessed by further fitting a geographically weighted logistic regression model in Stata using the variables statistically provided by the final multivariate model (Brunsdon, Fotheringham and Charlton, 2018).

For the retrospective study, data were extracted from the National FMD control laboratory database as a PDF file. The data were first input into Microsoft® Excel® and then imported into STATA version 13 (STATA Corp., College station, USA) for cleaning and analysis.

The data were analysed to describe trends spatially and temporally in infection with FMD. Exploratory descriptive analysis was conducted to determine frequency distribution on year, location and serotypes detected. A Generalized Linear Model was fitted against the log of the count of the number of samples submitted per month as the outcome. The predictor variable was the month. May was chosen as the base month since it had the lowest number of submitted samples according to best practice. The year
of sampling and the sub county were also added to the model to correct for any clustering by year and sub county.
CHAPTER FOUR

4.0 RESULTS

4.1 Location of sampled farms

A total of 237 random points were generated but only 220 small-scale dairy farmers were interviewed. Seventeen (7.2%; 17/237) points were located either in inaccessible locations or with no discernible farm in the locality. The average distance of a farm from the random point generated by the software was 377.0 metres (52.6- 1201.4, 5th – 95th Percentile). A total of 20% (44/220), 24.1% (53/220), 13.6% (30/220) and 42.3% (93/220) of the farms were from Gogar, Elburgon, Rongai and Njoro cooperative societies respectively.

A total of 42.3% (93/220), 24.1% (53/220), 20.0% (44/220) and 13.6% (30/220) of the farmers came from the catchment areas of Njoro, Elburgon, Gogar farm and Rongai dairy cooperative societies respectively. The locations of the farms are shown in Figure 4.1.
4.2 Characteristics of the smallholder dairy farmers

The majority (84.1%; 185/220) of respondents were the farm owners or relatives while managers, herdsmen and farm hands represented 11.4% (25/220), 3.6% (8/220) and 0.9% (2/220) of the respondents, respectively. The average age of the respondents was 44.0 years (median=40).

The average size of the farm was 11.0 acres (5.69-16.26, 95% CI) and the average number of years that the farm had been in operation was 3.1 years (median=3). The surveyed farmers owned a total of 1205 animals with the mean number of cattle kept per farmer being 5.5 (min-max range 1-42). Majority (61%) of the animals were aged above 2 years with the least (11.2%) being in the one to two-year age group. More (56.6%) of the animals kept were female. The age and sex distribution of the cattle is shown in Figure 4.2.
4.3 Other animals kept by the farmers

A total of 60% (132/220) respondents also owned sheep while 15% (33/220), 10% (22/220) and 0.5% (1/220) owned goats, donkeys and pigs, respectively. A total of 10.9% (24/220) of the farms kept both sheep and goats in addition to cattle. Thus, cattle and sheep were the commonly kept species of animals by the farmers.
4.4 Feeding Methods

4.4.1 Cattle

The cattle feeding methods reported by participants are shown in the Table 4.1. The most popular grazing method for cattle was grazing within the household compounds which was practiced by 47.7% (105/220) of the households. Only a small proportion (5.5%; 12/220) of the households practiced stall feeding with 28.6% (63/220) grazing their animals both within the compound and communally. Many farmers [44.1% (97/220)] used communal grazing either as the sole source of pasture [15.5% (34/220)] or in addition to that available within the premises (28.6% [63/220]). Of these 97 farmers who grazed their cattle communally, the majority (29.9%; 29/97) grazed them by the road sides, 24.7% (24/97) in harvested fields and 3.1% (3/97) in forests as shown in Table 4.1.
Table 4.1: Type of grazing and locations of cattle sampled in Nakuru County, 2016. Proportions are based on choices that respondents made.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grazing type</strong> (n=220)</td>
<td>Stall feeding</td>
<td>12</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>within Compound</td>
<td>105</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td>both within compound and communally</td>
<td>63</td>
<td>28.6</td>
</tr>
<tr>
<td></td>
<td>communally alone</td>
<td>34</td>
<td>15.5</td>
</tr>
<tr>
<td><strong>Frequency of communal grazing (n=220)</strong></td>
<td>Never</td>
<td>105</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td>Rarely</td>
<td>14</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>46</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>55</td>
<td>25</td>
</tr>
<tr>
<td><strong>Cattle grazing locations (n=97)</strong></td>
<td>Forests</td>
<td>3/97</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Forests and by roadsides</td>
<td>2/97</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Forests, by roadsides and other communal places</td>
<td>4/97</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Forests and other communal places</td>
<td>1/97</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Within towns and by roadsides</td>
<td>4/97</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Within towns, by roadsides and other communal places</td>
<td>5/97</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>By roadsides</td>
<td>29/97</td>
<td>29.9</td>
</tr>
<tr>
<td></td>
<td>By roadsides and other communal places</td>
<td>24/97</td>
<td>24.7</td>
</tr>
<tr>
<td></td>
<td>Don’t Know</td>
<td>1/97</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>Other communal places e.g. harvested fields</td>
<td>24/97</td>
<td>24.7</td>
</tr>
</tbody>
</table>

A total of 29.1% (64/220) of the farmers used communal watering points for their animals.

**4.4.2 Small ruminants**

A total of 60% (132/220) respondents owned sheep while 15% (33/220), 10% (22/220) owned goats in addition to cattle. For those who kept sheep, the average number of sheep kept was 7.1 (6.1-8.2, 95 % CI) while the average number of goats kept was 4.8 (3.0-6.7, 95% CI) animals.
The most popular feeding method for sheep and goats was grazing within the compound which was practiced by 77.3% (102/132) and 81.8% (27/33) of the respondents, respectively. Both species were rarely stall fed.

4.5 Milk production by cattle

The average milk production in the 220 farms was 11.0 Litres (9.0-13., 95% CI) of which an average of 8.6L (64.8%) was sold with the rest being consumed within the household. Of the milk sold 40.5% (89/220) sold their milk to hawkers while 20% (44/220) sold to cooperatives. Other characteristics on milk production are summarized Table 4.2.

Table 4.2: Characteristics of milk production as reported by farmers in Nakuru County, 2016.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sells to milk hawkers</td>
<td>89/200</td>
<td>44.5%</td>
</tr>
<tr>
<td>Hawkers then sell privately</td>
<td>56/89</td>
<td>62.9%</td>
</tr>
<tr>
<td>Hawkers take to processor</td>
<td>16/89</td>
<td>18.0%</td>
</tr>
<tr>
<td>Hawkers take to cooperative</td>
<td>12/89</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

4.6 Cattle Management Practices

Several characteristics that may predispose smallholder dairy farmers to FMD are summarised in Table 4.3. Only a small proportion (6.4%; 14/220) of the farmers used communal dips. Over two thirds (66.8%; 147/220) of the farmers
replaced their stock with their own animals indicating that replacement of animals from outside was not common. Other sources of replacement stock were buying from surrounding farms (43.6%; 96/220) and buying from livestock markets (19.6%; 43/220).

A total of 40.5% (89/220) had acquired replacement stock in the previous year. Of these 89 respondents, 60.7% (54/89) had acquired only one replacement animal in the previous year while 19.1% (17/89) and 13.5% (12/89) had acquired two and three animals respectively. The rest had acquired more than three animals in the previous year.

Use of artificial insemination was the most common breeding method practiced by 52.3% (115/220) of the farmers. Some farmers (30.5%; 67/220) shared bulls with surrounding farms while only 5.5% (12/220) used their own bulls.

Sharing of workers with surrounding farms was not common (11.8%; 26/220) and only a small proportion of farms had employees commuting from outside (12.7%; 28/220). However, nearly half (46.4%; 13/28) of the commuting workers owned animals.

Almost all (93.2%; 205/220) of the farms were next to a road where people and animals frequently passed through (Table 4.3).
Table 4.3: Management practices in 220 survey farms from Nakuru County 2016. Proportions are based on choice made by respondents.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean / Proportion</th>
<th>percentage / 95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use communal dip (n=220)</td>
<td>14</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>Source of replacement stock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From my own animals</td>
<td>147</td>
<td>66.8</td>
</tr>
<tr>
<td>Buy from surrounding farms</td>
<td>96</td>
<td>43.6</td>
</tr>
<tr>
<td>Buy from livestock markets (n=220)</td>
<td>43</td>
<td>19.6</td>
</tr>
<tr>
<td><strong>Replacement animals bought in previous 1 year</strong></td>
<td>0.8</td>
<td>0.6-1.0</td>
</tr>
<tr>
<td><strong>Breeding Method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial Insemination</td>
<td>115</td>
<td>52.3</td>
</tr>
<tr>
<td>Own Bull</td>
<td>12</td>
<td>5.5</td>
</tr>
<tr>
<td>Shared Bull (n=220)</td>
<td>67</td>
<td>30.5</td>
</tr>
<tr>
<td><strong>Share farm employees with other farms (n=220)</strong></td>
<td>26</td>
<td>11.8</td>
</tr>
<tr>
<td>Employees commute from outside (n=220)</td>
<td>28</td>
<td>12.7</td>
</tr>
<tr>
<td>Commuting employees’ own cattle (n=28)</td>
<td>13</td>
<td>46.4</td>
</tr>
<tr>
<td>Farm is next to a road (n=220)</td>
<td>205</td>
<td>93.2</td>
</tr>
</tbody>
</table>

4.7 Presence of wildlife

The majority (77.8%; 130/220) of farmers had not seen or heard of reports of wildlife in the surrounding areas. A total of 12.6% (21/220) had heard of reports of antelopes while 0.6% (1/220) had heard of wild pigs in the surrounding area. Other wildlife reported included aardvarks, cheetahs, hyena, gazelles, hares, leopards, monkeys, porcupines, squirrels and wild dogs.
4.8 Knowledge on Foot and Mouth Disease

The majority (94.1%; 202/220) of the farmers claimed knowledge of FMD. The most commonly mentioned clinical sign was hypersalivation (79.2%; 160/202) followed by hoof lesions (54.6%; 111/202) and mouth lesions (54.0%; 109/202). Only one farmer associated it with mortality in adults with no farmer associating it with mortality in calves.

About 15.8% (32/202) respondents also, in addition, mentioned other clinical signs in addition to those captured in the main questionnaire. These clinical signs included a drop in milk production, lesions on the nose and weakness, weak joints, irritated eyes, rough hair coat, swelling under the jaw, swelling of lymph nodes and tongue extruding outside (Table 4.4). Eight farmers did not know of any clinical signs associated with FMD.

Table 4.4: Other signs reported by respondents as being seen in an animal with FMD by 220 survey farmers in Nakuru county 2016.

<table>
<thead>
<tr>
<th>Other Signs of FMD reported (n=32)</th>
<th>Proportion</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhoea and skin problems</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Drop in Milk yield</td>
<td>14</td>
<td>43.8</td>
</tr>
<tr>
<td>Irritated eyes</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Lesions on nose, Pain and drop in milk yield</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Problems with the ears</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Rough hair coat</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Swelling under the jaw</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Swollen lymph nodes</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Tongue outside</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Weakness</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Weak Joints</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Don’t Know</td>
<td>8</td>
<td>25</td>
</tr>
</tbody>
</table>
Using the case definition recommended by the African Union Inter-African Bureau of Animal Resources (AU-IBAR) (2014), 82.2% (166/202) of the respondents had correctly identified the disease.

Asked whether they would call a veterinarian if they suspected their cow had FMD 76.8% (169/220) said that they would, 15.9% (35/220) said that they would not while 1.4% (3/220) did not know. A total of 5.9% (13/220) did not answer.

**4.9 Foot and Mouth Disease 6-month period prevalence**

Of the 220 smallholder farmers, 13 (5.9%) reported that they had had a case of FMD in their farm in the last six months converting to a six-month period prevalence of 5.9%. All the respondents who had a case of FMD in the last six months correctly identified the disease. A total number of 60 cattle were affected in the previous six months from a total of 1205 cattle at risk. This (60/1205) gave an individual level incidence risk of 5.0% (95% CI; 3.9 – 6.4). Figure 4.3 shows the distribution of the sampled dairy farms and those that reportedly had outbreaks of FMD in the last 6 months.

Spatial clustering of FMD cases was identified in the northern part of the study area (Northern part of Rongai). This single disease cluster (radius = 5.32 Km) was described being 38.1 times more likely than any other part of the study area to experience FMD (p<0.001). A total 40.7% of the cases were reported within this cluster.
A total of 58% (4.6/8.2) of animals owned by respondents per farm were affected by the outbreak. Out of those affected 28.1% (1.2/8.2) were being milked at the time. The age group most affected in the farm outbreak were animals aged above two years (34.6%; 1.8/8.2) while those least affected were aged below 6 months (8.0%; 0.6/8.2). The characteristics of the cattle in the farms where outbreaks occurred are shown in Table 4.5.
Table 4.5: Characteristics of cattle in farms where outbreaks of FMD reportedly occurred in Nakuru County, 2016.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (95% CI)</th>
<th>As a percentage (95% CI) of cattle owned at the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cattle owned (mean)</td>
<td>8.2 (2.9-13.6)</td>
<td></td>
</tr>
<tr>
<td>Number of cattle affected (mean)</td>
<td>4.6 (0.8-8.5)</td>
<td>58.0 (38.3-77.6)</td>
</tr>
<tr>
<td>Number being milked</td>
<td>1.2 (0.9-1.3)</td>
<td>28.1 (11.7-44.4)</td>
</tr>
<tr>
<td>Affected ≤6 months</td>
<td>0.6 (0-1.2)</td>
<td>8.0 (0-17)</td>
</tr>
<tr>
<td>Affected 6 months- &lt;1 year</td>
<td>2 (0-5.3)</td>
<td>10.9 (0-22.3)</td>
</tr>
<tr>
<td>Affected 1 year – 2 years</td>
<td>0.3 (0.0-0.6)</td>
<td>11.4 (0-28.2)</td>
</tr>
<tr>
<td>Affected above 2 years</td>
<td>1.8 (1.1-2.5)</td>
<td>34.6 (17.3-51.9)</td>
</tr>
</tbody>
</table>

4.10 Foot and Mouth Disease occurrence in the study area

Outbreaks of FMD reportedly occurred in the study area in the recent past prior to the survey. Of the 220 respondent’s 20.5% (45/220) of the respondents reported having heard of outbreaks more than two years ago, 13.2% (29/220) between 6 months and 1 year, 15% (33/220) between 1 and 2 years and 15.5% (34/220) in the last 6 months. Only 11.4% (25/220) reported having never heard of an FMD outbreak in recent memory. A total of 24.6% (54/220) did not respond to the question. This is shown in figure 4.3.

4.11 Identification of preventive measures of Foot and Mouth Disease

Outbreaks

Of the 207 farmers who were aware of FMD slightly more than a third (37.6%; 76/207) identified keeping cattle within the homestead compound as a method of FMD prevention. Slightly more than a quarter (28.7%; 58/207) identified
vaccination as a preventive measure against FMD. About 30.7% (62/207) respondents were not aware of any preventive measure against FMD. Other methods are shown in Table 4.6. A farmer may mention more than one measure.

**Table 4.6: Methods of preventing Foot and Mouth Disease outbreaks in livestock identified by 207 farmers in Nakuru County, 2016.**

<table>
<thead>
<tr>
<th>Preventive measure</th>
<th>Proportion (n=207)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccination</td>
<td>58</td>
<td>28.0</td>
</tr>
<tr>
<td>Keep cattle within compound</td>
<td>76</td>
<td>36.7</td>
</tr>
<tr>
<td>Do not know any prevention measure</td>
<td>58</td>
<td>28.0</td>
</tr>
<tr>
<td>Avoid other animals from entering compound</td>
<td>15</td>
<td>7.2</td>
</tr>
<tr>
<td>Keep animals away from farm boundaries</td>
<td>14</td>
<td>6.8</td>
</tr>
<tr>
<td>Don’t bring in new animals</td>
<td>9</td>
<td>4.3</td>
</tr>
<tr>
<td>Avoid use of communal dips</td>
<td>5</td>
<td>2.4</td>
</tr>
<tr>
<td>Don’t share equipment with surrounding farms</td>
<td>5</td>
<td>2.4</td>
</tr>
<tr>
<td>Keep visitors away from animals</td>
<td>4</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Other preventative measures reported included using *magadi* (Sodium Carbonate) which is a strong alkali for footbaths and as a mouth wash. Local remedies were also used with the most common being *Busaa* (a local fermented alcoholic brew which was given orally). Others were ectoparasite control, hygiene and avoiding feeds from communal areas.

**4.12 Practices with regards to vaccination by the respondents**

Although vaccination was known as a preventive measure, only 65.0% (143/220) had ever vaccinated their animals against FMD. About a third (31.7%; 51/220) of the respondents had vaccinated their cattle more than 1 year ago while
20.5% (45/220) had vaccinated their cattle 6 months to a year prior to the study. Only about 20% had vaccinated their cattle less than 6 months before the study.

A majority (59.5%; 131/220) the farmers reported vaccinating all of their animals regardless of their physiological status. Out of the 0.05% (11/220), 54.6% (6/11) and 45.4% (5/11) did not vaccinate young calves and pregnant animals, respectively.

The most popular (82.5%; 118/143) personnel who the farmers entrusted to vaccinate their cattle were government animal health providers (AHP). Private AHP’s were not popular in the area being used by only 16.8% (24/143) of the farmers. This is not surprising because FMD vaccinations are a public good and are undertaken by the government on a regular basis or whenever outbreaks occurred.

More than half (59.6%; 84/141) of the respondents took their animals to a communal vaccination point for the vaccinations. Table 4.7 shows the vaccination practices by the respondents.

The vaccination coverage at the household level based on the previous four and six months was 15.9% (35/220) and 20.5% (45/220), respectively.
Table 4.7: Foot and Mouth disease vaccination practices by 220 farmers in Nakuru County, 2016

<table>
<thead>
<tr>
<th>Vaccination Practice</th>
<th>Level</th>
<th>Proportion</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration since last vaccination (n=220)</td>
<td>&lt;5 months ago</td>
<td>35</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>5 – 6 months ago</td>
<td>10</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Above 6 months to &lt;1 year ago</td>
<td>45</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>&gt;1 year ago</td>
<td>51</td>
<td>31.7</td>
</tr>
<tr>
<td>Farmer does not usually vaccinate (n = 11)</td>
<td>Young calves</td>
<td>6</td>
<td>54.6</td>
</tr>
<tr>
<td></td>
<td>Pregnant Animals</td>
<td>5</td>
<td>45.4</td>
</tr>
<tr>
<td>Vaccinator (n=143)</td>
<td>Private AHP</td>
<td>24</td>
<td>16.8</td>
</tr>
<tr>
<td></td>
<td>Government AHP</td>
<td>118</td>
<td>82.5</td>
</tr>
<tr>
<td></td>
<td>non-veterinarian</td>
<td>1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Key: AHP – Animal Health Provider

4.13 Univariate analysis for risk factors associated with Foot and Mouth Disease

A total of 5.9% (13/220) farms had previously reported FMD outbreaks out of all that were studied.

The factors strongly associated with FMD occurrence included the use of a shared bull (OR=15.98, p=0.009), number of replacement cattle bought in the previous 1 year (OR=1.24, p=0.043), buying of replacement stock from livestock markets (OR=3.94, p=0.019), grazing sheep within towns (OR=34.5, p=0.002), grazing goats outside the compound (OR=6.09, p=0.007), grazing cattle within towns (OR=8.3, p=0.012), use of communal dips (OR=8.62, p=0.002) and
number of sheep (OR=1.08, \( p=0.025 \)). Vaccination was protective (OR=0.23, \( p=0.013 \)).

4.14 Multivariate analysis of risk factors of Foot and Mouth Disease Occurrence

Variables that were significant (\( p<0.05 \)) in the multivariate logistic regression model were use of shared bull, use of artificial insemination, number of replacement animals bought in the last 1 year, and the number of sheep owned (Table 4.8). The final multivariable model had a Wald chi-square of 16.70 with 5 degrees of freedom giving a \( p \) value of 0.005. The model had an AIC of 79.336, a BIC of 109.878 and a McFadden’s \( R^2 \) of 0.279
Table 4.8: Results from the multivariate logistic regression model of possible risk factors for an outbreak of FMD occurring in a farm in Nakuru County (2016).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Levels</th>
<th>Proportion / mean</th>
<th>Proportion with FMD</th>
<th>Odds Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of a shared bull</td>
<td>Yes</td>
<td>67/220 (30.5)</td>
<td>9/67 (13.4)</td>
<td>28.05 (3.26-241.29)</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>153/220 (69.5)</td>
<td>1/153 (1.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of replacement cattle bought in the previous 1 year</td>
<td>Continuously variable</td>
<td>0.8 (0.6-1.0)</td>
<td></td>
<td>1.19(1.02-1.40)</td>
<td>0.029</td>
</tr>
<tr>
<td>Use of Artificial Insemination</td>
<td>Yes</td>
<td>115/220 (52.3)</td>
<td>4/115 (3.5)</td>
<td>2.76 (0.59-12.93)</td>
<td>0.198</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>105/220 (47.7)</td>
<td>6/105 (5.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sheep</td>
<td>Continuously variable</td>
<td>7.1 (6.1-8.2)</td>
<td></td>
<td>1.11 (1.03-1.20)</td>
<td>0.006</td>
</tr>
</tbody>
</table>

The risk factor associated with the greatest odds of disease was the use of a shared bull (OR=28.05 (3.26-241.29), p=0.004). The wide confidences interval suggested collinearity with another predictor and VIF estimations showed use of artificial insemination and use of shared bulls to have high values (2767.66 and 2767.83, respectively). Due to variance inflator factors indicating collinearity between using AI and shared bulls, a combined variable was created containing all the breeding methods reported by the farmers. When this variable was used in the final multivariable model, the odds ratio for development of FMD when
the farm used a shared bull was 8.6 (95% CI 1.2 - 60.8; \( p = 0.031 \)) compared to those using AI.

For each additional cattle purchased in the previous year, the odds of reporting clinical FMD increased by 1.2 (95% CI 1.0-1.5, \( p = 0.05 \)). Similarly, the odds of FMD increased by 1.1 for each additional sheep owned (95% CI 1.0-1.2, \( p = 0.009 \)). The interaction terms for the two continuous variables and their logarithms in the final multivariable model were not significant (\( p = 0.195 \) and \( p = 0.810 \) for number of sheep and number of replacement animals bought in the previous one year, respectively) indicating that linearity with the logit of the dependent variable was not violated.

Spatial autocorrelation affected the relationship between the number of cattle replaced within the previous year and the reported FMD occurrence. The odds ratio for this variable in a geographically weighted logistic regression model was 1.2 (1.0 – 1.5; \( p = 0.075 \)). Parameters estimated for all other variables remained unchanged.

4.15 Retrospective data on FMD occurrence in Nakuru County

The data covering a period of seven years (2010 to 2016) showed that a total of 171 samples were submitted for FMD diagnosis.

4.15.1 Serotype confirmation of FMD virus

A high proportion (63.7%; 109/171) of the samples had at least one serotype recovered. Overall 4 serotypes were isolated from the samples as shown in Figure 4.5. Serotype O occurred at a higher frequency (25.2%; 43/171)
compared with the other three. Other serotypes detected in the samples during the seven-year period were South African Territories (SAT) subtype 2 (17.5%; 30/171), A (11.7%; 20/171), and SAT 1 (9.4%; 16/171). Ten samples (5.9%) had no virus detected (NVD) while 30.4% (52/171) had virus detected but no virus was recovered (NVR). No sample had more than one serotype recovered indicating there were no multiple (mixed) serotype infections.

A summary of the positivity of the samples by year is shown in Appendix IV.

Figure 4.4: Frequency distribution of serotypes recovered during the 7-year period (2010-2016) in Nakuru County.
4.15.2 Monthly positivity of Foot and Mouth Disease

Occurrence of FMD appeared to be uniform throughout the year although it peaked in the month of April and was lowest in the month of December (Fig. 4.5).

Figure 4.5: Proportion (%) of positive samples for FMD by month during the period 2010 – 2016 in Nakuru County.

On fitting a GLM, the relative risk for an increase in submitted suspected samples was highest in September and lowest in April. The two rainy seasons in the area generally occur in April to June and October-December. The highest relative risks were observed in the months before the beginning of a rainy season (at the end of the dry season) for each season, i.e., March and September while
the lowest relative risk was at the beginning of the rainy seasons, i.e., April and October.

The relative risk for an increase in positive samples was highest in November (5.33; 2.98-9.56, 95% CI) and lowest in July (1.33; 0.69-2.57, 95% CI). There was no observed pattern for seasonality in positivity of samples except that during the dry season (July-September) the relative risk increased.

Incidence Risk Rates (IRR) and their 95% CI are shown in the Table 4.9.

Table 4.9: Results from a Generalized Linear Model on monthly counts of submitted and positive samples of Foot and Mouth Disease.

<table>
<thead>
<tr>
<th>Month</th>
<th>Samples submission IRR (95% CI)</th>
<th>Sample positivity IRR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>4.25 (2.53 - 7.12)</td>
<td>4.33 (2.40-7.84)</td>
</tr>
<tr>
<td>February</td>
<td>2.75 (1.62 – 4.68)</td>
<td>2.67 (1.46 – 4.89)</td>
</tr>
<tr>
<td>March</td>
<td>4.75 (2.84 – 7.92)</td>
<td>3.67 (2.04 – 6.58)</td>
</tr>
<tr>
<td>April</td>
<td>1.25 (0.66 – 2.35)</td>
<td>1.67 (0.83 – 3.33)</td>
</tr>
<tr>
<td>May</td>
<td>Base month</td>
<td>Base month</td>
</tr>
<tr>
<td>June</td>
<td>3.75 (2.25 – 6.26)</td>
<td>3 (1.66-5.44)</td>
</tr>
<tr>
<td>July</td>
<td>2.25 (1.31 – 3.86)</td>
<td>1.33 (0.69-2.57)</td>
</tr>
<tr>
<td>August</td>
<td>3.75 (2.24 – 6.27)</td>
<td>3.33 (1.85- 6.02)</td>
</tr>
<tr>
<td>September</td>
<td>6.5 (3.91 – 10.80)</td>
<td>5 (2.79 – 8.97)</td>
</tr>
<tr>
<td>October</td>
<td>3.25 (1.94 - 5.46)</td>
<td>3 (1.65-5.46)</td>
</tr>
<tr>
<td>November</td>
<td>6 (3.61 – 9.97)</td>
<td>5.33(2.98-9.56)</td>
</tr>
<tr>
<td>December</td>
<td>3.25 (1.93 – 5.48)</td>
<td>2 (1.08 – 3.70)</td>
</tr>
</tbody>
</table>

IRR – Incidence Risk Rates
The result of a student’s t-test showed that the number of samples collected was significantly higher in the dry season than in the wet season (p<0.05).

**4.15.3 Patterns of occurrence of Foot and Mouth Disease serotypes**

During the period 2010 – 2016, serotype A appeared to occur in epidemics. The first major epidemic was in July 2012 lasting to January 2013. Another minor epidemic appeared in January 2016 to March 2016. The other three serotypes (O, SAT -1 and SAT -2) occurred endemically with only minor fluctuations in occurrence over the same period, (Figure 4.6).

![Figure 4.6: Patterns of FMD serotype occurrence in Nakuru County, 2010 – 2016.](image)
CHAPTER FIVE

5.0 DISCUSSION

The study results showed that the average farm size was 11.0 acres. However, a study done in a neighbouring county, Nyandarua, estimated the average smallholder dairy farm size at 8.72±7.64 acres (Muia et al., 2011). The average farm size in Nakuru in a previous study (Bebe et al., 2003) was 4.2 acres. However, in this study the farm size varied from 2.2 acres for zero grazing system to 5.9 acres in free range systems. In the study by Bebe et al. (2003), their definition of a smallholder farm was having two cows and less while in the present study smallholder farms were those with less than 50 animals.

The average number of years that the farm had been in operation was 3.08 years. This is in contrast with a study by (Gitau, 2013) in the Mauche area of Nakuru where farms had been operational for 15 years and less. The results are similar to those of another study conducted in Kiambu County where the average duration of the farm was 14.8 years (Gitau et al., 1994). These differences may be attributed to the political upheaval that occurred in Nakuru County in 2007/2008 where farmers were forcibly removed from their farms and their cattle sold or killed. Thus, the dairy enterprise in Nakuru County was recovering from the effects of this upheaval at the time of the study.

The average number of cattle kept was 5.5 but ranged from 1 to 42 cattle. This was in agreement with Phiri et al. (2010) who estimated a higher limit of 50 cattle in his study in East Africa and also with a study from Njarui et al. (2016)
who reported 5.2 animals. It was however higher than 3.2 cattle quoted in another study (Bebe et al., 2003).

Apart from keeping cattle, the small-scale farmers of Nakuru also kept goats, donkeys and pigs. This diversification of livestock was also reported by Njarui et al. (2016) in a study conducted in the highland Counties of Kenya. The same finding was also reported by Kosgei et al. (2008) in an earlier study in Nakuru, Nandi and Nyeri Counties in Kenya. In Kenya and indeed in many African countries, small stock are kept for easy cash in the face of family needs such as school fees and payment of dowry (Arasio, 2003).

The majority of farmers grazed their animals within the farm compound with only a few stall-feeding their animals. This is consistent with findings by Njarui et al. (2016) who reported a similar feeding system (stall feeding and semi-grazing) in the central highlands of Kenya.

Communal grazing grounds was also common and was in accordance with the results of a study conducted by Lukuyu et al. (2011) in the previous Rift Valley Province of Kenya. Although not investigated in the current study, farmers usually resort to grazing their cattle on communal grounds especially in the dry season when feeds are scarce (Wesonga, 2013). The results are also consistent with a study by Mwacharo and Drucker (2005) in south east Kenya. Farmers in Nakuru commonly used communal watering points. Just like communal grazing, watering points allow for mixing of animals and thus are ideal points for transmission of infectious diseases including Foot and Mouth Disease.
The average milk production in the farms was 11.0 litres. This was much lower than an average farm milk production of 18.2 litres reported in a study by Muia et al. (2011) in neighbouring Nyandarua County. In the Nyandarua study almost all the farms were on zero-grazing and thus adequate feed. Whereas in the present study pasture grazing in farm compounds was common and evidently the cows were not getting adequate feeds thus the much lower milk production. Similar to studies by Muia et al. (2011) and Omore et al. (1999) most of the milk produced was sold either to neighbours, at the market or to dairy cooperative societies. Thus, dairy cows in Nakuru, like in most other high potential areas of Kenya, are kept as a source of income for the household.

Communal dips for tick control were reportedly not used for tick control in Nakuru County. In an earlier study by Gitau et al. (1994) in Kiambu County, a huge proportion of the farmers used communal dips (42.2%) in contrast to the current study. The use of communal dips in Kenya has been decreasing over time due to challenges in managing them after the government privatised the veterinary services in the 1990s as part of the World Bank structural adjustment programs (Mugambi, 2012). Thus, communal dipping points where animals from different farms mix may not be an important factor in the transmission of FMD.

Replacement stock by the study farmers was from their own herds. Those who sourced them outside did so from neighbouring farms whose disease history was probably known. Only a few of the farmers bought replacement stocks from the markets. These practices were presumably aimed at reducing the risk of
introducing diseases from outside. Indeed, most farmers used artificial
insemination for breeding for the same reason. Similar practices of acquiring
replacement stock by smallholder holders were also reported by Bebe et al.
(2003) who found that small holder dairy farmers purchased replacement stock
from other small holders and large-scale farms with a majority depending on
their own breeding animals.

Use of AI for breeding was common in Nakuru County. Other methods of
breeding included use of communal and owned bulls. These results are in
contrast to those reported by Baltenweck et al. (2004) in an earlier study
conducted in Kirinyaga and Kisumu Counties where only 18.6% smallholder
dairy farmers used AI for breeding with the rest using communal and own bulls.
In Nakuru County AI was reportedly cheaper and readily available.

Workers in dairy farms who lived off farm would be ideal for introducing
infectious diseases in farms they work in through fomites particularly in those
farms where biosecurity measures are not instituted. Sharing of farm workers
between farms would be worse. This practice was not observed in the current
study. In a study by Gitau et al. (1994) in Kiambu County a large proportion
(42.2%) of surveyed farms had workers who lived off farm. Commuting workers
have been reported as important sources of FMD (Muroga et al., 2013).

Most of the surveyed farms were adjacent to a major road with high traffic of
human beings and animals. This was most probably due to ease of transport of
farm inputs and outputs to and from markets. A study by Staal et al. (2002) found
that increased distance to markets and urban centres reduced the uptake of dairy
farming with every increase of distance by 1 km reducing probability of cattle farming uptake by 0.6%.

Contact with FMDV susceptible wild animals is a potential risk factor for disease (Miguel et al., 2013). Farmers reported the presence of antelopes and wild pigs in the surrounding areas although the presence of wildlife in the surrounding areas was not a significant risk factor in this study. This result is not surprising since the majority of smallholder farmers in Kenya do not graze animals in protected areas where they might interact with wildlife (Bebe, 2003). In addition, Lake Nakuru National Park is fenced so likely reducing the probability of contact (Kenya Wildlife Service, 2009), confirmed by the minimal sightings of wildlife in the study area.

Most of the surveyed farmers reportedly knew about FMD. The disease has major economic implications to dairy farming (Knight-Jones and Rushton, 2013). Despite various studies (Mwacharo & Drucker 2005; Jost et al., 2007; Bedelian et al., 2007; Jost et al., 2010; Onono et al., 2013) among cattle keepers in Kenya ranking it among the most important animal diseases, no studies have been conducted to investigate the knowledge, attitudes and practices towards it among smallholder dairy farmers in Kenya.

Respondents in the present study reported hypersalivation, hoof lesions and mouth lesions in cattle as the most important signs and lesions associated with FMD. These signs and lesions are consistent with what is reported in veterinary literature (AU-IBAR) (2014). Given the endemicity of the disease and its devastating effects on the livestock sector, it was little surprising that farmers
were able to correctly identify it. Most of the study farmers would reportedly call a government veterinarian whenever an FMD outbreak occurred on their farms. Only a few would engage the services of a private veterinarian. This was so because vaccination of cattle against the major plagues is considered a public good and is undertaken by the government. In addition, FMD being a notifiable disease must be reported to the government veterinary services.

The six-month period prevalence of FMD in Nakuru was estimated at 5.9%. This differs with the results of Kibore et al. (2013) who estimated a sero-prevalence of 22.7% in a study conducted in Nakuru County. The difference in study design and the period under investigation were likely to explain this difference. The study by Kibore and colleagues utilised NSP-ELISA which relates to lifetime exposure risk. Nakuru County being an endemic area, most of the cattle will have been exposed to infection at one point in their lives. The current study utilised recall by farmers of an active clinical case of FMD in the last six months. A herd prevalence of 23.6% was reported in neighbouring Uganda (Baluka, Ocaido and Mugisha, 2014) using a case study approach while individual and herd level seroprevalence in neighbouring Ethiopia stood at 9% and 38.1% respectively (Beyene et al., 2015). These countries are immediate neighbours and are likely to have similar serotypes to those in Kenya in circulation due to unrestricted animal movements across the porous national borders. The differences in study design and area might explain the differences in prevalence seen.

The present study used clinical signs for the case definition with no laboratory confirmation. There are limitations to this approach although there was some
validation through comparing reported clinical signs to the AU-IBAR case definition (AU-IBAR, 2014). In addition, farmers who reported a case of FMD were more likely to mention more clinical signs associated with the disease. In a cross sectional study in Cambodia Bellet et al., (Bellet et al., 2012) compared participatory epidemiology tools (including farmer description of clinical signs of FMD) with serological tests. The authors found participatory methods as characterised by high sensitivity and low specificity in the identification of FMD cases. Serosurveys can also be used to estimate the burden of infection although these can be time-consuming and expensive. Moreover it is difficult to estimate the timing of infection as antibody levels can persist for years post infection (Paton et al., 2014) and previous vaccination complicates interpretation particularly if not using vaccines that have been purified of non-structural proteins (Emami et al., 2015). Surveys for clinical disease offer a cheaper alternative that is likely to be more achievable in resource poor settings although these do not replace the need for serosurveys in understanding the epidemiology of FMD. do not replace the need for serosurveys in understanding the epidemiology of FMD. However, because of the imperfectness of the case definition methodology (specificity and sensitivity is unlikely to be close to 1), both the FMD occurrence and FMD odds here reported are likely to be biased estimators of the true FMD status in the area six months prior to the study (Diggle, 2011).

Morbidity of FMD as reported by the farmers in the last six months before the study begun was (58.0%). This was in accord with results reported by Miller (1979) with predicted attack rates of 56% through mathematical modelling.
However, they contrast with another study (Young et al., 2013) who reported morbidities of up to 77.3% in studies conducted in Cambodia. This study was conducted among smallholder farmers using a questionnaire type methodology similar to the present study. The differences may be attributed to different virus serotypes, geographical location and different socio-economic conditions.

The majority of cattle affected at the time of the study were aged between 6 months and 1 year and those above two years. This is the period after which maternal antibodies wane and the farmers may still consider them too young to be vaccinated.

A higher proportion of farmers reported having heard of FMD reported in the area less than six months earlier compared to those that actually experienced an outbreak in their farms. The actual mode of information dispersal was not investigated in this study. However, this might indicate that outbreak reporting in the area is good and susceptible farms might use this information to institute preventive measure in their farms. An almost equal proportion of farmers reported having heard of FMD reported in the study area either less than six months or more than two years before the study was conducted. This might be confirmed by the history of FMD prevalence at high and low levels in different locations within the Nakuru County. In fact, the clustering, and therefore the high prevalence reported in one part of the study area, is most likely due to the identified area lying in a transit route for nomadic pastoralists, likely spreading the disease while moving their infected herds (Rufael et al., 2008). Although pastoralist routes within the study area have not been mapped, many farmers
suggested that outbreaks of the disease coincided with the arrival of Maasai pastoralists in the area. This occurs during the dry season as they move in search of food and water and may spread the disease.

Vaccination was considered by farmers as an effective measure for prevention of FMD infections. Reduction of contact between animals was also a popular prevention method. These control strategies for FMD have long been recognised as the most suitable for the control of FMD outbreaks (Hunter, 1998; Vosloo et al., 2002). However, outbreaks of FMD have occurred in vaccinated herds as happened in one large scale farm in Nakuru County (N A Lyons et al., 2015) and Saudi Arabia (Woolhouse et al., 1996). This was attributed to vaccine mismatch.

Despite vaccination being reported as the most commonly employed preventive measure (45%), the reported coverage in the last six months was lower (20.5%) and the percentage of farms that had ever vaccinated was markedly higher (65%). The former indicates either a lack of knowledge over the necessary schedules for preventive vaccination or poor availability to employ preventive vaccination as the main policy is to use vaccination reactively after outbreak confirmation. The latter may indicate that some farmers were unaware of the purpose of vaccination or they may have been remembering a different vaccine being used. Government vaccination programs are heavily subsidised to reduce cost burden to livestock keepers. Quantifying and maintaining vaccination coverage is an essential component of any FMD control programme in an endemic setting. The confusion and inability to accurately quantify vaccination coverage needs to be addressed through improved record keeping that could
involve the use of vaccination record cards. However, this study was not designed to evaluate vaccine effectiveness, therefore no reliable assessment of vaccine performance can be made.

Although young calves (Kitching, 2002) and pregnant animals (Stone and DeLay, 1960) can get infected with the FMD virus, some of the farmers did not offer these animals for vaccination. It is also known that vaccination of calves with the same serotype as antibodies passed down by the dam is not effective until serum antibodies in the calf reach low levels (Graves, 1963). This practice may increase the risk of the disease occurring in such farms.

Factors such as the use of shared bulls, number of replacement cattle bought in the previous 1 year, buying of replacement stock from livestock markets, source of replacement stock, grazing sheep within towns, grazing sheep within the compound, grazing cattle within towns, grazing cattle outside compound, use of communal dips, number of sheep were risk factors for FMD occurring while vaccination was protective. These practices all allow the mixing of cattle from different sources and therefore increase the risk of FMD infection. These results are consistent with those of other studies conducted elsewhere (Cleland et al., 1996; Bronsvoort et al., 2004; Hamoonga et al., 2014; Elnekave et al., 2015; Hassig et al., 2015).

However, in the multivariate analysis only the use of shared bull, number of replacement animals bought and the number of sheep owned were retained in the final multivariate model. This was an indication of confounding by the factors that lost significance. Confounding occurs when a potential risk factor is
associated with both the independent variables (e.g. use of a communal bull) and the dependent variable (FMD occurrence) and can mask the association between the two (Dohoo, Martin and Stryhn, 2009). Indeed, a farm that shared breeding bulls was 15.98 (OR=15.98) times more likely to get an FMD case in the univariate analysis relative to those that did not use shared breeding bulls. However, in the multivariate analysis the strength of association increased from an odds ratio of 15.98 to 28, evidence that there was confounding by factors either included in the model or other unmeasured factors. Mixing cattle with small stock was a risk factor for FMD outbreaks on a farm. This agrees with a study by Megersa et al. (2009) who found that in Ethiopia, keeping cattle with small ruminants especially sheep was a risk factor. Small stock may harbour FMDV asymptotically and act as a source of infection to cattle. In a study by Anderson et al (1976) on the role of sheep and goats in FMD epidemiology in Kenya, a high seropositivity level was reported thus indicating likely exposure in small ruminants. Observations from the study area indicated that mixed cattle-small ruminant farms were often managed differently to farms that only kept cattle. This may include factors that increase the risk of exposure to FMD virus in small ruminants (e.g. communal grazing over wider areas and for longer periods), which could be transmitted to cattle where disease is more apparent. Small ruminants are commonly excluded from vaccination strategies (including Kenya) though their inclusion could be beneficial by reducing interspecies transmission. Although challenge studies have indicated a limited role for sheep in FMD transmission to cattle (Bravo de Rueda et al., 2014), further evidence
derived from field conditions are required so support their inclusion in vaccination strategies.

Also, the practice of replacing animals from outside the farm was a risk factor for FMD outbreaks and is consistent with findings of Cleland et al. (1996) in Thailand. The replacement animals especially from farms where FMD occurs regularly may act as sources of infection.

For the retrospective data the overall positivity of the samples on PCR for FMDV was 63.7%. Several factors might affect the positivity of laboratory samples including type of sample collected, handling of the samples, tests conducted and the viral load in the sample. All samples were collected from FMD suspect cases.

The most common viral serotypes isolated in the year 2010 – 2016 were SAT 2 and O. Serotypes A and SAT 1 were also isolated though less frequently. This agrees with findings by Sangula (2006) in a country wide analysis of samples submitted for diagnosis at the FMD diagnostic laboratories. Thus like in the rest of Kenya serotypes SAT 2 and O were endemic in Nakuru County.

There appeared to be seasonal bia in sampling collection. The FMD prevalence is thought to be higher in the dry season than in the rainy season coinciding with pastoralist movements in search of food and water (Rufael et al., 2008). However, this seasonality was weakly observed for positivity of the samples.

The number of samples collected was higher in the dry season compared to the wet season. This was probably because a greater number of FMD outbreaks are thought to occur in the dry season. Although this is some form of sampling bias,
control of this is usually impossible for passive surveillance systems. Intermittent active surveillance activities can be scheduled in seasons of low incidence to complement the passive surveillance systems. Alternatively, introduction of sentinel herds into high risk areas so as to observe for development of clinical infections, serotypes involved and seasonality of infections

Sample positivity was highest in Njoro and Rongai and lowest in Nakuru town. Njoro and Rongai are at the border with Kericho County and Baringo County, respectively. They lie directly on the livestock trade stock routes. The relationship between livestock movement routes and FMD incidence has also been reported by Kibore (2013) with higher incidence occurring in areas where cattle pass through. However, no study has been conducted in Kenya to investigate the role of animal movements in FMD occurrence.

Temporal analysis showed that more than one serotype circulated at the same time in the region each year. Immunity to one serotype does not confer protection to a different serotype. Serotype A had 3 distinct outbreaks during the 7-year period. This is consistent with the finding by Sangula (2006) that this serotype only causes intermittent outbreaks.
CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions can be drawn from this study.

- Majority of the farmers keep mixed herds of cattle and small ruminants
- Grazing of cattle within the compound of the farms was the most common feeding method by the farmers.
- Most of the milk produced by smallholder dairy farmers in Nakuru County was sold mostly to neighbours and nearby markets.
- Almost half of the farmers bought replacement stock from surrounding farms and livestock markets though they bred their own replacement stock using AI and communal bulls.
- Majority of the farmers know FMD well enough to positively identify it and would call a veterinarian if they had a suspected case of FMD.
- Most of the affected cattle were above two years of age.
- Keeping cattle within the compound (movement control) was the most preferred preventative method of FMD followed by vaccination.
- FMD is endemic in Nakuru but farmers only vaccinate their cattle when outbreaks occur. Given the endemic occurrence of the disease, there is need for regular vaccinations of the cattle populations in Nakuru County.
- Four serotypes of FMD that had caused FMD outbreaks in Nakuru County in the past 7 years were O, A, SAT – 1 and SAT – 2.
6.2 Recommendations

- Although knowledge on FMD in the area is high, farmer education needs to be conducted on vaccinating all animals not just some.

- Since the government Animal Health Providers are the most preferred vaccinators, government sponsored vaccinations every six months may prove effective.

- Education on the importance of using AI instead of shared bulls, proper screening of replacement animals and reducing risky practices in small ruminants (such as communal grazing) needs to be passed on to the farmers.

- It is recommended that vigilance during the dry season be increased, vaccinations in Nakuru be conducted prior to the dry season and animals belonging to pastoralists entering Nakuru county be vaccinated and checked for infections.

- Further studies need to be conducted in the entire country to investigate how the virus is introduced into new areas in order to effectively curb its spread.
CHAPTER SEVEN

7.0 REFERENCES


**Gitau, G. K., O’Callaghan, C. J., McDermott, J. J., Omore, A. O., Odima, P. A.,**


Miguel, E., Grosbois, V., Caron, A., Boulinier, T., Fritz, H., Cornélis, D., Foggin, C.,


[Accessed 11 February, 2016].


Appendix I

Project Information Sheet in English

Project Information Sheet v2.3 final (Consent Form)

Project Title: Use of pooled milk for surveillance of foot-and-mouth disease (FMD)

About the project:
This is a project organised by the Pirbright Institute and the University of Nairobi with the Department of Veterinary Services. The aim of the project is to investigate the use of pooled milk for the surveillance of FMD. We are collaborating with your local dairy cooperative. Alongside taking the milk samples from them, we will be doing surveys of smallholder farmers in the catchment area. We expect the study to last for up to two years and we will be interviewing farmers periodically about their experience with FMD. Information gained during this study will help find better ways of diagnosing and controlling the disease in the area and Kenya in general. The results of the study will be published in academic journals and presentations conducted.

Who is responsible for the data collected in the study and what is involved?
We are a team of people from the University of Nairobi, Pirbright Institute (UK) and Department of Veterinary Services. We will be responsible for administering a questionnaire intended to collect information of FMD in the area.

We will ask you about the animals on your farm, the milk produced, and your knowledge of FMD. This will be through an electronic or paper questionnaire administered by members of the project team. All answers will be anonymous and shall not be attributed to you without your express permission.

The study team will visit farms in this area every three to four months for the next 1-2 years. At the end of the study we will arrange for some local meetings which will be advertised in advance.
Rights of participants

Taking part in the study is voluntary. You may choose not to take part or subsequently cease participation at any time.

You are in no way obliged to answer any of the questions and you can halt the interview at any time without providing a reason.

For more information:
This research has been reviewed and approved by the Kenyatta National Hospital/University of Nairobi - Ethics and Research Committee and a permit has been provided by the National Commission for Science, Technology & Innovation (NACOSTI). If you have any further questions or concerns about this study, please contact:

Dr. Dickson Machira
Masters Student at the University of Nairobi.
Mobile: +254 704 670 347
Email: dmachira@students.uonbi.ac.ke
You can also contact the supervisor:
Dr. Nicholas Lyons
Pirbright Institute
Mobile: +254 700 126 250 or +44 797 6540031
Email: nick.lyons@pirbright.ac.uk
You may also wish to contact your local sub-county veterinary officer who is aware of the project.

SCVO name: 
______________________________________________

SCVO phone number: 
______________________________________________

Thank you for your participation.
Appendix II

Questionnaire for dairy farmers

Farm ID:  
Date:  

Survey Questionnaire: BSv1.6

Prevalence and Risk Factors for Foot and Mouth Disease in Smallholder Dairy Farmers in Nakuru County and its Environs

Baseline Data

1. Position at the farm: (please circle the correct choice)  
   a. Owner  
   b. Employee  
   c. Milker  
   d. Herdsman  
   e. Manager  
   f. Other

2. GPS coordinates:  
   longitude__________  
   latitude___________

3. Age in years: ______________

4. Level of education?  
   a. None  
   b. Primary  
   c. Secondary  
   d. Certificate  
   e. Diploma  
   f. Degree  
   g. Post graduate
5. How many years have you been doing dairy farming? ______________
6. What is the size of farm (where the cattle are) in acres? ______________
7. What other species are found in your farm (state number):
   a. Goats _________
   b. Sheep_________
   c. Pigs___________
   d. Donkeys________
8. How many cattle are currently on the farm? ______________
   Please complete the following grid to give the sex and age categories for cattle on the farm:

<table>
<thead>
<tr>
<th>Age of cow</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-12 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;2 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Risk factors

9. What grazing methods do you use for your animals?
   a. Stall feeding
   b. Semi grazing (Animals allowed to graze but additional food is given by stall feeding)
   c. Pasture grazing only
10. Do you use communal grazing fields to feed your animals?
    a. Yes
    b. No
    c. Don’t know

Please complete table showing how grazing varies for each species:

<table>
<thead>
<tr>
<th>Species</th>
<th>Grazing method</th>
<th>Communal grazing?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Zero; 2 = semi grazing; 3 = pasture only</td>
<td>Y=Yes; N=No</td>
</tr>
<tr>
<td>Cattle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. Do you use communal watering facilities to water your animals?
   a. Yes
   b. No
12. If you do semi or full time grazing, do you ever graze your animals in
   (yes or No):
   a. Forests________
   b. Within towns________
   c. By roadsides________
   d. Near livestock markets or slaughterhouses________
13. Do you buy unprocessed animal feeds (hay, grass etc.) from outside your
    farm?
   a. Yes
   b. No
14. Do you share workers with other surrounding farms?
   a. Yes
   b. No
   c. Don’t know
15. Do employees commute from outside the farm?
   a. Yes (go to question 16)
   b. No (go to question 17)
   c. Don’t know (go to question 17)
16. If yes to the question above, do any of the commuting workers own
    animals?
   a. Yes
   b. No
   c. Don’t know
17. Do you share equipment with surrounding farms?
   a. Yes
   b. No
   c. Don’t Know
18. Is your farm next to a road (where animals and/or people pass through)?
   a. Yes
   b. No
19. In the surrounding areas have there been reports of presence of buffaloes,
    antelopes, wild pigs or other wild animals? Please complete grid,

<table>
<thead>
<tr>
<th>Species</th>
<th>Yes/ No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffalo</td>
<td></td>
</tr>
<tr>
<td>Antelope</td>
<td></td>
</tr>
<tr>
<td>Wild pigs</td>
<td></td>
</tr>
<tr>
<td>Other (please state)</td>
<td></td>
</tr>
</tbody>
</table>
20. Where do you get your replacement stock?
   a. Buying from cattle markets
   b. Buying from surrounding farms
   c. From my own animals
   d. Other (please state)
21. If you buy your replacement stock, what number of cattle did you buy in the last 1 year? ________

Knowledge and occurrence of FMD

22. Have you heard of foot and mouth disease?
   a. Yes (go to question 23)
   b. No (go to question 24)
23. What signs do you see in animals affected with foot-and-mouth disease?
   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________
   e. ______________________
24. Do you call a veterinarian/animal health assistant when there is a case of foot and mouth disease on your farm?
   a. Yes
   b. No
   c. Don’t know
25. When there is a foot and mouth disease case do you report it to the veterinary authorities?
   a. Yes
   b. No
   c. Don’t know
26. Have you had any cases of foot and mouth disease in the farm in the last 6 months?
   a. Yes
   b. No
   c. Don’t know
27. When did you last have a case of FMD in your farm? (Month/year)
   a. ___________/________________
   b. Can’t remember
28. How many animals did you have at the time (if don’t know, write “DK”)?
   __________
29. How many animals were affected (if don’t know, write “DK”)?
   __________
30. Were the affected animals being milked at the time?
   a. Yes (If yes, how many__________)
   b. No
   c. Don’t know
31. Of the animals affected how many were:

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-12 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;2 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32. When was the last time you heard of any foot and mouth disease case in your village? __________ weeks/months/years ago (delete as appropriate)

33. Do you undertake any activities to prevent entry of FMD into your farm?
   a. Yes (go to question 31)
   b. No (go to question 33)

34. What activities do you normally undertake to prevent foot and mouth disease occurring at your farm (when there is no outbreak in the area)?
   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________
   e. ______________________

35. What additional activities do you undertake when there is an outbreak?
   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________
   e. ______________________

36. Do you usually vaccinate your animals for FMD?
   a. Yes
   b. No (go to question 34)
   c. Don’t know (go to question 34)

37. How many times in a year do you usually do this? __________

38. At what age (in months) do you start vaccinating your animals? __________months

39. Who usually vaccinates your animals?
   a. Private veterinarian
   b. Private animal health assistant
   c. Government veterinarian
   d. Government animal health assistant
   e. Other (please state) ______________________

40. When did you last vaccinate for FMD? (mm/yy)? _______/_________

Milk Production and Delivery
41. How much milk did your farm produce today? _________ litres
42. How much of this did you (or will you) sell? _________ litres
43. Do you sell milk to a cooperative society?
   a. Yes - please provide name
   b. No
   c. Don’t know
44. How is the milk transported from the farm?
   a. Farmer delivers direct to dairy
   b. Farmer leaves at a collection point
   c. Milk is collected at farm gate by dairy
   d. Milk is collected at farm gate by hawker
   e. Other (please state) ______________________________
45. How do you preserve the milk until delivery to the dairy?
   a. Refrigeration
   b. Addition of chemicals. If so which ones?
                  ______________________________
   c. Immersion in cold water.
   d. No action taken
46. What do you do with the milk during a foot and mouth disease outbreak?
   a. Sell it to the cooperative society
   b. Consume it at home
   c. Sell it to others
   d. Dispose of it
   e. Other (please specify) ______________________________
Appendix III

Results of univariate logistic regression for risk factors of Foot and Mouth Disease infection in Nakuru County, 2016.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>N (Col %)</th>
<th>Proportion (%) with FMD</th>
<th>Odds ratio (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of a shared bull</td>
<td>Yes</td>
<td>67/220 (30.5)</td>
<td>9/67 (13.4)</td>
<td>15.98 (1.98-129.33)</td>
<td>0.009*</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>153/220 (69.5)</td>
<td>1/153 (1.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial Insemination</td>
<td>Yes</td>
<td>115/220 (52.3)</td>
<td>4/115 (3.5)</td>
<td>0.30 (0.08-1.11)</td>
<td>0.072*</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>105/220 (47.7)</td>
<td>6/105 (5.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of replacement cattle purchased in the last 1 year.</td>
<td>Continuous variable</td>
<td>147/220 (66.8)</td>
<td>6/147 (4.1)</td>
<td>1.24 (1.01-1.54)</td>
<td>0.043*</td>
</tr>
<tr>
<td>Source of replacement</td>
<td>Yes</td>
<td>147/220 (66.8)</td>
<td>6/147 (4.1)</td>
<td></td>
<td>0.113*</td>
</tr>
<tr>
<td></td>
<td>Animal source</td>
<td>Yes</td>
<td>No</td>
<td>Odds Ratio</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------</td>
<td>-----------</td>
<td>--------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>is own animals</td>
<td>No</td>
<td>73/220 (33.2)</td>
<td>7/73 (9.6)</td>
<td>0.40</td>
<td>(0.13-1.24)</td>
</tr>
<tr>
<td>Buying replacement from farms</td>
<td>Yes</td>
<td>96/220 (43.6)</td>
<td>6/96 (6.3)</td>
<td>1.11</td>
<td>(0.36-3.43)</td>
</tr>
<tr>
<td>buying from livestock markets</td>
<td>No</td>
<td>124/220 (56.4)</td>
<td>7/124 (5.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buying replacement animals from</td>
<td>Yes</td>
<td>43/220 (19.6)</td>
<td>6/43 (14.0)</td>
<td>3.94</td>
<td>(1.25-12.40)</td>
</tr>
<tr>
<td>markets</td>
<td>No</td>
<td>177/220 (80.4)</td>
<td>7/177 (4.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goats grazing in other communal</td>
<td>Yes</td>
<td>11/21 (52.4)</td>
<td>1/11 (9.1)</td>
<td>4.29</td>
<td>(0.37-50.20)</td>
</tr>
<tr>
<td>places</td>
<td>No</td>
<td>10/21 (47.6)</td>
<td>3/10 (30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>7/21 (33.3)</td>
<td>1/7 (14.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goats grazing by road sides</td>
<td>No</td>
<td>14/21 (66.7)</td>
<td>3/14 (21.4)</td>
<td>0.61 (0.05-7.24)</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------------</td>
<td>---</td>
</tr>
<tr>
<td>Goats grazing within towns</td>
<td>Yes</td>
<td>2/21 (9.5)</td>
<td>½ (50)</td>
<td>5.33 (0.26-110.80)</td>
<td>0.279</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>19/21 (90.5)</td>
<td>3/19 (15.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grazing goats in forests</td>
<td>Yes</td>
<td>2/21 (9.5)</td>
<td>1/2 (50)</td>
<td>5.33 (0.26-110.80)</td>
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Appendix IV

Retrospective data: Percentage of serotypes detected for all submitted samples between 2010-2016 in Nakuru County by year and sub county

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<th>Year (Number of samples collected)</th>
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<th>SAT-2</th>
<th>Overall Positivity</th>
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<td>6/30 (20)</td>
<td>3/30 (10)</td>
<td>3/30 (10)</td>
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