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RETROSPECTIVE STUDY OF OUTBREAK OF CATTLE FOOT AND MOUTH DISEASE IN MOPANI DISTRICT FROM 2003 TO 2013

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DECLARATION

I hereby declare that this project is my original work and has been submitted or presented to any other institution for the award of any degree.

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LIST OF ABBREVIATION

FMD- Foot and Mouth Disease

FMDV-Foot and Mouth Disease Virus

OIE-Office International Des Epizootic

SAT- South African Territory

KNP-Kruger National Park

ABSTRACT

The research describes the retrospective study of FMD outbreak, inspection and vaccination distribution during FMD outbreaks from 2003 to 2013. The study will help understand the probability of occurrence of FMD outbreak in Mopani district. The probability of the occurrence of FMD was determined by assessing the effectiveness of vaccination and inspection, presence and elimination of challenges and predisposing factors during outbreak using available information from Mopani District Agriculture State Veterinary. The methods and results was used as an approach on the basis to determine the probability of the occurrence of the FMD outbreak. Occurrence of FMD in protection zone with vaccination is related to predisposing factors (African buffaloes, small ruminants, pigs and wild animal). The time (2.5 days) taken to respond to FMD outbreak and high percentage (82.46-95.99%) of cattle inspected during FMD outbreak portray effective control of FMD while Low percentage (30.1-43.18%) cattle of vaccination during FMD outbreak portray an ineffective control program of FMD.

The is probability of occurrence of FMD in Mopani district due to ineffectiveness of vaccination, presence of challenges and predisposing factors that influence the occurrence of FMD outbreak.

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CHAPTER ONE

1.0 Introduction

1.1 Background

1.1.1 Foot and mouth Disease and economic significance

Foot and Mouth Disease (FMD) is a severe, clinically acute, vesicular disease of cloven-hoofed animals including domesticated ruminants and pigs and more than 70 wildlife species (Coetzer *et al*., 1994). It is one of the economically important infections disease of livestock trade in animals and animal products (Li-no *et al*., 20ll) through reduction in productive indicated by reduced milk production, abortion, loss of weight and delayed conception (James and Rushton,2002). The impact of FMD on livestock production and agricultural exports makes it the most important animal disease in Southern Africa (= Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe). All these countries except Lesotho have experienced FMD outbreaks. FMD has been eradicated from North America and Western Europe, while eradication from South America is probably achievable. Eradication of FMD in Southern Africa is however not possible, due to the presence of large numbers of African buffalo, which are the maintenance hosts for SAT-types of FMDV and the undesirability of eradication of buffalo. Hence agricultural activity in Southern Africa is dependent on the control of FMD, and not the eradication thereof. Due to FMD being the economically important infections disease of livestock trade in animals and animal products, assessment of control measures during an outbreak is crucial as this as have implication of the probability of occurrence of another FMD outbreak. In this study vaccination and inspection of cattle, presence of predisposing factors and challenges during outbreak are assessed as a way of determining the probability of the occurrence of FMD outbreak in Mopani District. The results of this study will have an implication on inspection and

vaccination as control measures and predisposing factors and challenges during another FMD outbreak.

1.1.2 Significance of the study

Due to highly infectious nature of the disease and accompanying economic constraints effective control through vaccination is crucial for herd immunity against FMDV. Effectiveness of vaccination, presence of challenges and predisposing factors were assessed with the aim of determining the probability of occurrence of FMD outbreak. The results will have an implication on the vaccination protocol on number of FMD outbreak in Mopani.

1.2 Aim and objectives

1.2.1General objective

To determine number of FMD outbreak and effectiveness of vaccination.

1.2.2 Specific objective

- To determine number of FMD outbreak in FMD zones of Mopani district
- To determine the proportion of cattle vaccinated and inspected during FMD outbreak
- To determine the predisposing factors and challenges during FMD outbreak

1.3 Hypothesis

There is probability of occurrence of cattle FMD outbreak of Mopani district due ineffectiveness of cattle vaccination and inspection and lack of elimination of predisposing factors and challenges during FMD outbreak.

CHAPTER: TWO

2.0 Literature review

2.1Historical background of foot and mouth disease

The first written incident of FMD outbreak was reported by an Italian monk Girolamo Francastoro in 1546 (sutmoller *et al*., 2003), the causative agent was identified by Leoffler and Frosch in 1897. The agent was found to pass through very fine filters that normally do not allow the bacteria to pass through, pointing to the possibility of virus. This observation stimulated research by many scientist of FMD in animals. Since labs involved in conducting research on FMD, also used animals for other studies. FMD susceptible animals too often contracted infection resulting in the death of animals, which necessitated establishment of separate FMDlabs in institution. The first research center for FMD was established at the InselRiems, an Island in Germany in 1909 followed by similar research centers at Pirbright in England, Landholm in Denmark in 1925 and Plum Island , North Fork of Long Island in United State of America in 1954 (Brown, 2003). Hucheon made the first official record of FMD in South Africa in 1982, following an outbreak in Griqualand West (Thomson, 1994). In April 1903 FMD reappeared in South Africa through the importation of cattle from Argentina to Cape Peninsula (Thomson, 1994). South Africa was initially FMD free zone where vaccination was not practised (resolution no XIV of the OIE) was accepted by OIE In 1995 and lost the OIE free zone status after an outbreak of FMD caused by serotype O virus, was diagnosed on 14 September 2000 in the district of Camperdown in Kwa-zuluNatal. This was followed by outbreak of SAT 1 serotype virus that was diagnosed on 29 November 2000 in a cattle feedlot in district of Middleburg in Mpumalanga and the trace-back actions following the outbreak on the feedlot established that the disease originated from buffalo or cattle contact in the surveillance zone of Nkomazi, bordering the southern KNP, also in Mpumalanga province. On 1 February 2001 FMD lesion caused by serotype SAT2 virus were

detected in cattle at the dipping tank in Mhala district in Limpopo province which border the KNP.

2.2 Economic significance

FMD has worldwide economic impact which is unsurpassed by any other animal virus in the world. The FMD is on the A list of infectious disease of the OIE and it has been recognized as the most important constrains to the international trade in animals and animal products (Trautwein, 1927). The great economic losses caused by FMD are due to marked reduction in milk yield, death of young animals, abortion in advanced stage of pregnancy and reduced working ability of animals (Singh,2003) and quality and quantity of meat, reduction in fertility, loss of quality of semen in breeding bulls (Yadav, 2003). The disease also interferes with agriculture and tourism. The additional cost include application of control measures such as quarantine, slaughter, compensation, vaccination, as well as conducting scientific surveillance after an outbreak in order to prove that the disease and the virus have been eliminated (Prempeh andRobert, 2001).

2.3 Serotype and strains of FMD

FMD is caused by seven antigenically distinct serotype of genus Aphthovirus in the family of Picornaviridae (Murphy *et al*., 1999). Picornaviridae are non-enveloped virus with a single stranded RNA genome of positive polarity. Initially type O an A were identified (Valle and Carre, 1922) and few years later type C was identified (Waldmann and Trautwein, 1926). Several African field strains collected since 1931 were re-examined by Brookby in 1948 who demonstrated a new strain from the South African Territories (SAT1). Two more strains from Southern Africa (SAT2 and SAT3) were identified by (Brooskby, 1982).FMD Asia 1 was identified from sample originating from Pakistan in1957 (Brooksby and Roger, 1957). Within

each serotype there is considerable diversity and antisera against one strain of serotype may not recognize other strains of the same serotype. Isolate were classified into antigenically related subtype within serotype and each serotype contain a number of subtype (Buxton and Frazer, 1977).

2.4 Incidence and distribution

FMD is endemic in most part of Africa and epidemiology of the disease is more complicated than other part of the world (Vosloo *et al*., 2006). Geographic distribution according to Fenner *et al*., 1993 there are Asia (A, O, C), Europe (A, O, C), Africa (A, O, C) and South African Territory (1, 2, 3). Serotype A, O and C has a global distribution. Serotype distribution differs between region and intratypic variants with serotype occur (Vosloo *et al*., 2002).

2.5 Transmission, spread and excretion

The spread of FMD is through indirect or direct contact with the infected animal or with the infected environment. Directs spread involves mechanical transfer of droplets from infected animals to susceptible ones (Alexandersen *et al*., 2003) and airborne transmission over long distance has been reported from pigs that exhale large quantities of the virus and can thus pass it to susceptible ruminants. The mode of FMD spread is only true for temperate region like South Africa and is of no significance to the drier regions of east Africa (Alexandersen *et al*., 2002). Cattle and sheep can transmit the virus over a long distance (Sellers *et al*., 1971). Another direct spread is through direct contact of infected animals with susceptible animals through abrasions on the skin or mucous membrane (McKercher, 1959). Indirect spread is through contaminated personnel from infected farms who may carry the virus to susceptible animals in another farm. Horizontal transmission from mother to calve is reported

(Thomson*et al*., 1992) and sexual transmission is possible (Bastos *et al*., 1999).The pharyngeal area is the primary site of replication (Gar-land, 1974) and lung can be the primary replication side (Domanski *et al*., 1959). Incubation period can be between 2 to 14 depending of the infecting dose and route of infection (Rbino, 1946), susceptibility to the host and strain virus. FMD virus is excreted by lesion material, saliva, milk, urine, feces, semen, nasal discharge and exhaled air (Donaldson, 1983). The contagious state start 24 hours prior to onset of clinical sign and after 3-4 days after development of lesion, there is drop in viral titters and first development of antibodies (Graves, 1971).

2.6 Host range and clinical signs

FMD is a highly contagious disease of cloven-hoofed animals including cattle, swine, sheep and goat and more than 70 wildlife species(Coetzer *et al*., 1994) and Impala being the most susceptible wildlife animal to FMD in South Africa than kudu and vice versa is true for Zimbabwe (Messer, 1962). FMD infected cattle are characterized by high fever, hyper-salivation and appearance of vesicular lesion on the mucous membrane of the mouth, lips, tongue, epithelia of the muzzle, inter-digital space (lead to lameness) and teat and udder of infected animals (Grubman *et al*.,2004). The vesicle ruptures to produce large denued ulcerative lesions. African buffalo are main maintenances of FMD serotype (SAT 1, SAT 2 and SAT 3). In Kruger National park most buffalo calves become infected by this 3 strains prevalent this region of the content by the time they reach 1 year of age (Hedger, 1972) and Thomson *et al*., 1992 and 1994 indicated that the buffalo show no clinical sign of FMD. Rauf *et al*., 1981 noted that cattle are more susceptible to FMD than buffalo. FMD in small stock may be significantly in apparent in a proportion of animal (Donaldson and seller, 2000) and often present with mild clinical sign (Callens *et al*., 1998). Certain strains of the virus may be of lower virulence for some species than the other (Donaldson, 1998).

2.7 Carrier of FMD virus

Carrier animals are defined as those from which live virus can be isolated at 28 days later after infection (Sutmoller *et al*., 1968). The notion that FMDV can cause persistent infection was initially based on field outbreaks, but remained conjectural until (Van Bekkum *et al*., 1959) showed the continuing presence of infectious virus in the saliva of the proportion of convalescent cattle for many weeks after infection. Further studies were made demonstrating the persistence of virus in infected cattle, sheep and goat (Sulmoller *et al*., 1968). It is well established that the African buffalo can carry the disease up to 5years or more (Hedger, 1972; Thomson *et al*., 1984) and about 50-70% African buffalo are carrier (Hedger, 1972). There is evidence of transmission from carrier animals. Reports of transmission from carrier African buffalo to cattle in Zimbabwe outbreaks of 1989 (SAT1) and 1991 (SAT3), which was supported by laboratory diagnosis indicating the persistence of causal virus (Dawe *et al*., 1994). Outbreaks of the SAT2 serotype in Zimbabwe in 1989 and 1991 indicated transmission from carrier cattle to uninfected cattle (Salt, 1998 and N.J Knowles) thus the current evidence indicates that the risk of transmission from carrier buffalo to cattle is significant and that transmission from carrier of cattle to uninfected cattle cannot be excluded.

2.8 Diagnosis of FMD

Confirmatory diagnosis of FMD is by lab diagnosis since there are other viral disease that cause clinically indistinguishable (e.g vesicular stomatitis, blue tongue), though history, clinical sign and species involved can be valuable pointer to the diagnosis. The laboratory technique for detecting and confirming FMD have developed and described in the OIE manual of Diagnostic technique (OIE, 2004). This laboratory diagnosis involve range of serological test including Virus Neutralization Test (VNT), Enzyme-Linked Immuno sorbent

Assay (ELIZA)which detect antibodies against FMD viruses irrespective of Vaccination status of the animal (Berger *et al*., 1990) and it identify the strain of the virus (Sorensen *et al*., 2005). Sample collected for diagnosis should be based on the history of vesicular lesion or lameness, collect vesicular fluid, milk, blood, epithelial tissue and this sample are sufficient to confirm the diagnosis.

2.9Control of FMD in South Africa

FMD is listed as a controlled disease in South Africa in the animal Disease Act 35/1984. The choice of control policy adopted by a given country depends on its FMD status and the risks of incursions of the disease (Ahl *et al*., 1991). KNP is an FMD infected zone and it's about 350km long and 60 and 80 km wide fenced off by 2.4m electrified fence and suited in the North-Eastern part of South Africa. Regular game inspections are performed and suspected cases and are reported to the State Veterinary. Surrounding the KNP there are buffer zone that are divided into zone with and one without vaccination (directorate of Animal Health Department of Agriculture, 2006) and recent studies indicate that the buffer zone are called protection zone.Protection zone with vaccination border the Southern and Western boundary of the park, cattle are vaccinated every 6 months, vaccinated cattle are branded with an "F" on the right side and inspection for FMD is done every week. Protection zone without vaccination situated to the West and the South of protection zone with vaccination and the cattle are not vaccinated and inspection is done every 14 days. The free zone is located to the south of the protection zone without vaccination and inspection is done every 28 days. Following an FMD outbreak South Africa authorities enforce quarantine to restrict livestock and livestock products movement as the first control measure (Balinda *et al*., 2009). The movement restriction is through road blocks and Red Cross permit. This control measures are followed by inspection through mouthing and serology and vaccination within and around

area affected. The current vaccines in South Africa is trivalent vaccines that contain three serotype including SAT1, SAT2 and SAT3.

2.10 Situation of FMD in South Africa

The first outbreak of FMD in South Africa was recorded in 1982 and South Africa lost its 0IE free zone in 2000 due to outbreak caused by serotype O virus in kwa-Zulu Natal. In South Africa the disease in endemic in KNP because of the presence of African buffaloes which are principal reservoirs of South African Territory (SAT) 1, 2, 3 of FMDV. The Outbreaks of FMD is reported in 3 provinces mainly Mpumalanga, Kwa-zulu Natal and Limpopo. Cattle of Limpopo and Mpumalanga are said to be endemic of FMD because they border the KNP. All this provinces listed above, areas are divided into three zone namely the free zone, protection zone with vaccination and protection zone without vaccination separated by geographical and physical barriers and by application of control and biosecurity.

2.11 Situation of FMD in Mopani District

Mopani District is located in Limpopo that makes Mopani District to be endemic of FMD. Mopani District is located on the Southern side of KNP some areas are regarded as protection zone with vaccination and near KNP inspection is done every 7 days, vaccination is done yearly and records on the date of vaccination, herd identification and number of cattle is kept and they are F branded if they are tested for FMD. In the Protection zone without vaccination, inspection is done every 14 days with no vaccination and free zone area the inspection is done every 28 days.

2.12 Control of FMD during outbreak in Mopani District

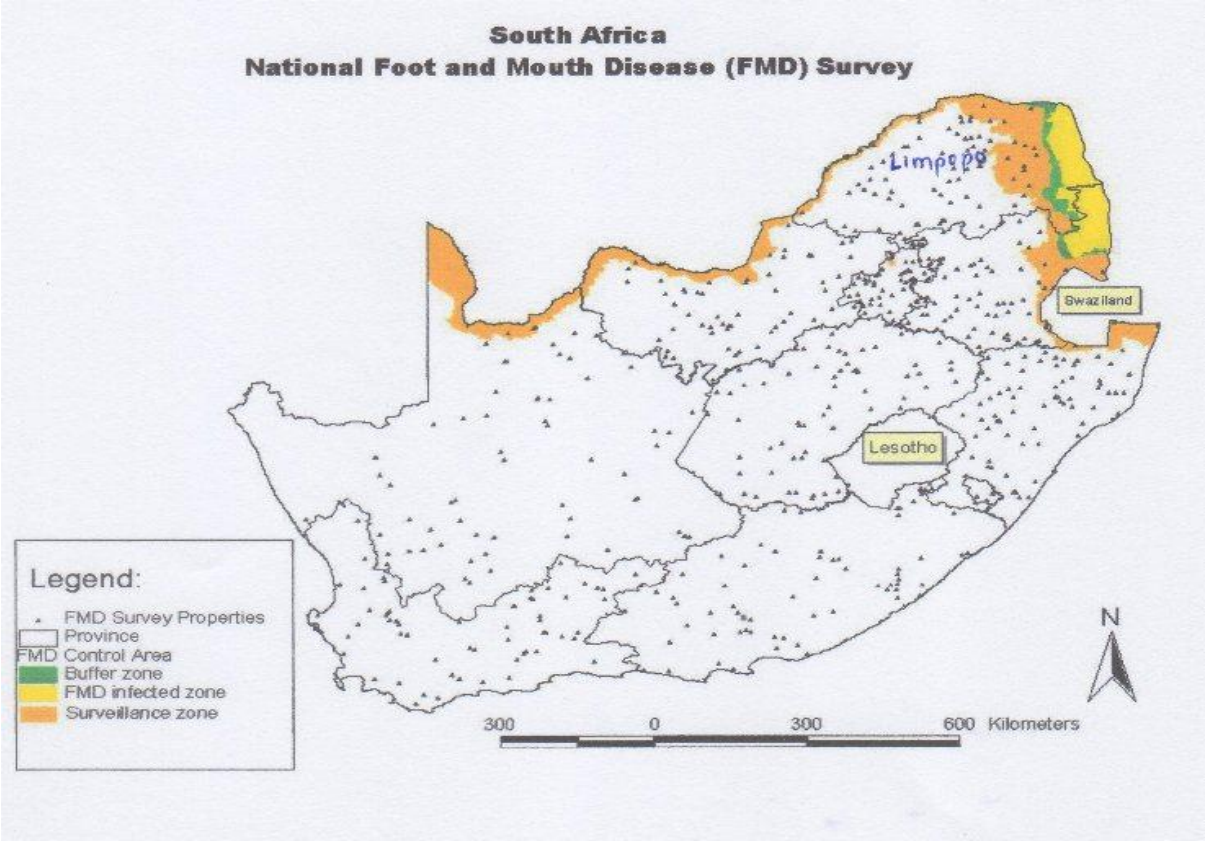
During an outbreak the area is placed under quarantine through movement control by roadblock and Red Cross permit, inspection through mouthing and serology and emergency vaccinations. Veterinary officials do surveillances on areas that are in a 10km radius around the quarantine zone.

CHAPTER THREE

Methodology

3.1 Study area

Mopani district is one of the five large district of Limpopo province in South Africa. The seat of Mopani is Giyani. The districts have 5 municipalities: Greater Maruleng, Greater Tzaneen, Greater Letaba, Greater Giyani and Ba-Phalaborwa. Mopani is surrounded by Republic of Mozambique to the left, Ehlanzeni to the South, Sekhukhune to the South West, Capricon to the west and Vhembe to the North. Mopani is a district with many nature game reserves where most buffaloes are kept and is located near the KNP on the Southern section of the park and KNP is the largest nature reserve in South Africa where they keep African buffaloes.



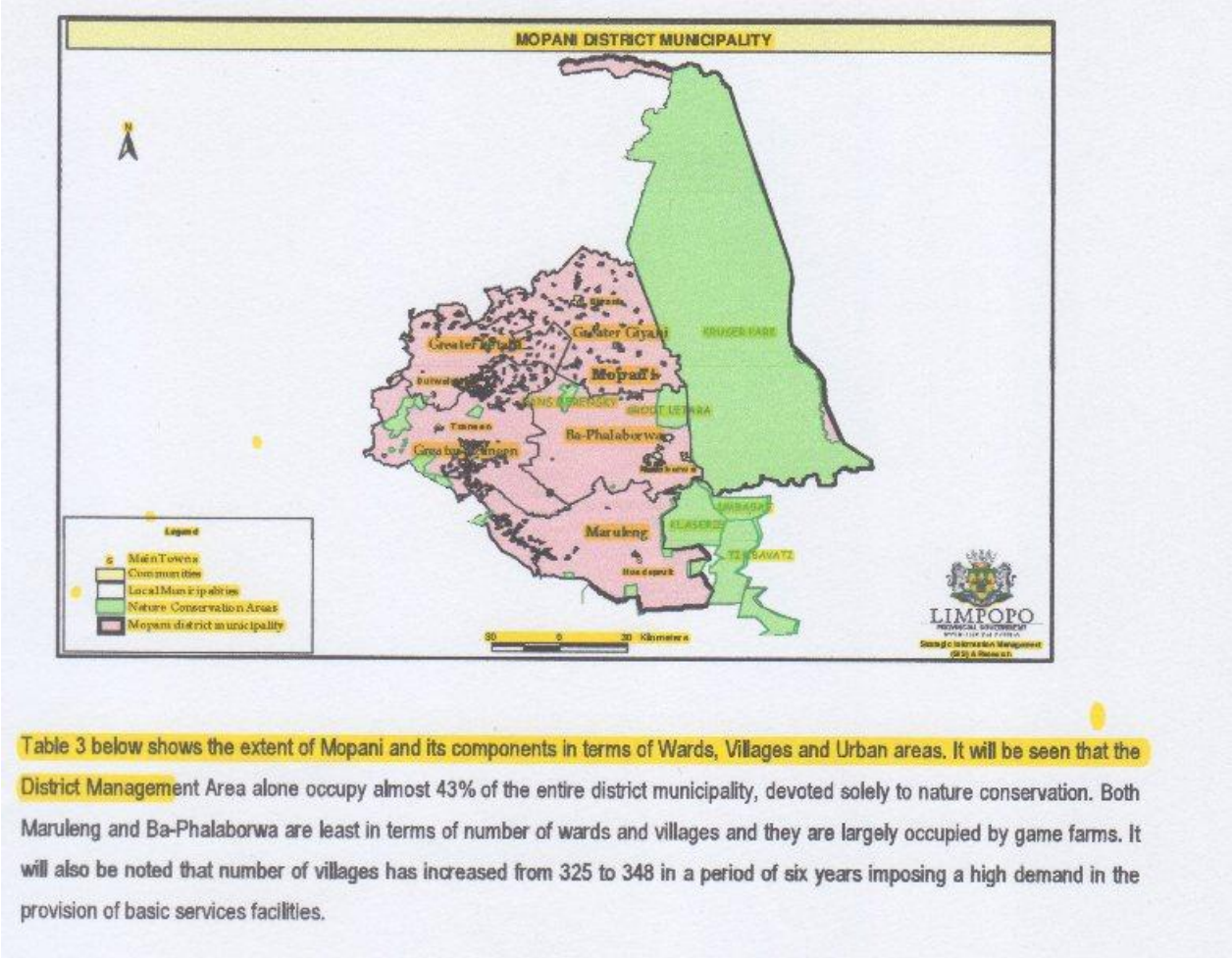


Table 3 below shows the extent of Mopani and its components in terms of Wards, Villages and Urban areas. It will be seen that the District Management Area alone occupy almost 43% of the entire district municipality, devoted solely to nature conservation. Both Maruleng and Ba-Phalaborwa are least in terms of number of wards and villages and they are largely occupied by game farms. It will also be noted that number of villages has increased from 325 to 348 in a period of six years imposing a high demand in the provision of basic services facilities.

3.2 Data source and type

3.2.1 Data on FMD

Data on FMD outbreak in Mopani district was obtained from Mopani Agriculture Veterinary State offices. Data used is for a period of 10 years (2003-2013) with the expectation that the data would provide the probability of the occurrence of FMD outbreak in Mopani District. FMD in Mopani District is a reportable disease so every outbreak is reported and any activity during the outbreak is recorded and filed and the information will reflect the cattle FMD status of the Mopani District in Limpopo Province.

Data include number of outbreak, year and month of occurrence, municipality where outbreak occurred, vaccination and inspection coverage. A set of questionnaire was developed and was administered to the Mopani State Vet officer.

3.2.2 Data analysis

FMD data was obtained and entered into Microsoft excel 2013 spread sheet and descriptive statically analysis was generated. Bar graph was used to assess the proportion of cattle vaccinated and inspected during an outbreak. Pie chart created to assess the level of challenges during FMD outbreak.

CHAPTER FOUR

RESULTS

4.1 Number of FMD outbreak in different zones

There were only three outbreak reported in the study period. The highest number of FMD outbreak occurred in protection zone with vaccination (Ba-phalaborwa and Giyani) and none in protection zone without vaccination (Letaba) and none occurred in free zone (Tzaneen) indicated by table 1.

Table: 1 - Zone that reported FMD outbreak

Column 1	Column 2
Zone where outbreak occurred	Number of outbreak
Protection zone without vaccination	0
Protection zone with vaccination	3
Free zone	0

4.2 Time taken to respond to FMD outbreak through vaccination

The time from onset of FMD outbreak to response through vaccination and serotype identification is summarized in table 2, with the average time between onset of outbreak and vaccination is 2.5 days and ranged from 1-4 days.

Table: 2 Municipality that reported FMD outbreak from 2003-2013

year	Farm where outbreak occurred	Municipality where outbreak occurred	Month of outbreak	Serotype identity	Serotype vaccines	Time between outbreak and vaccination
2004	Silwane	Ba-Phalaborwa	June	SAT 2	SAT 1, 2, 3	1 day
2010	Malati	Ba-Phalaborwa	August	SAT 1, 2 ,3	SAT 1, 2, 3	4 days
2013	Makhura	Giyani	July	SAT 1	SAT 1,2, 3	3 days

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4.3 **Proportion of cattle vaccinated**

The total number of cattle vaccinated in 2004, 2010 and 2013 are 120130, 62203 and 46505 respectively, with a total cattle population of 399097,144045 and 195851 respectively.

The proportion of cattle inspected in each outbreak is > 80% while only about 40% of cattle are vaccinated indicated by figure 1.

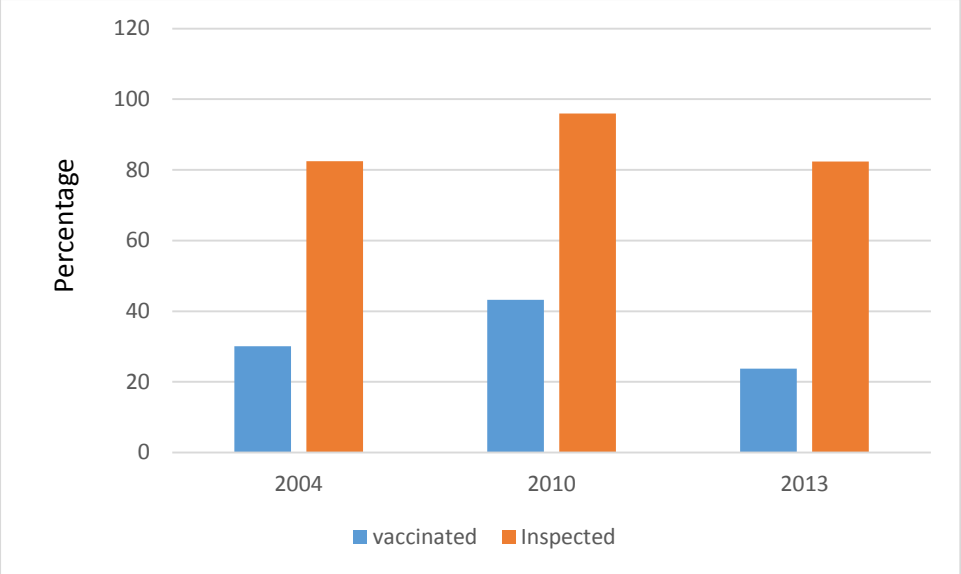

Figure 1: Proportion of cattle vaccinated per outbreak and proportion of cattle inspected per outbreak.

4.3 Challenges during FMD outbreak

The challenges during FMD outbreak are represented in figure 2.

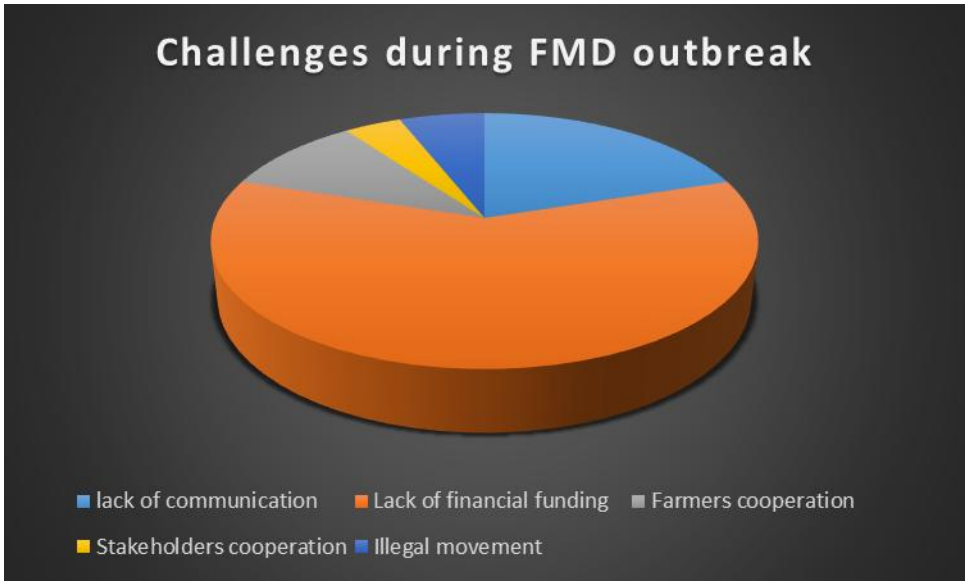

Figure 2: Challenges that occurred in all the three outbreak. The questionnaire survey in Mopani district indicates that the major challenges were financial funding

Source of data: Dr Veronica Letsoalo

CHAPTER FIVE

Discussion

5.1 Number of outbreak in different zones

Highest number of reported FMD outbreak occurred in protection zone with vaccination with none in both zone without vaccination and free zone.This indicate that the cattle in protection zone with vaccination are susceptible to FMD because they are located near the Kruger National Park and have high incident of coming into contact with FMD carrier African buffalo, which is supported by the serotypes identification that caused the 3 outbreaks in Mopani districts. Hedger 1972 established that African buffaloes can carry the disease up to 5 years and 50-70% of the African buffaloes. Dawe *et al*., 1994, reported transmission from carrier African buffalo to cattle in Zimbabwe outbreaks of 1989 (SAT1) and 1991 (SAT3), which was supported by laboratory diagnosis indicating the persistence of causal virus. Cattle in the protection zone with vaccination are infected and studies were made demonstrating the persistence of virus in infected cattle (Sulmoller *et al*., 1968), this may play a major role in the outbreak of FMD. Outbreaks of the SAT2 serotype in Zimbabwe in 1989 and 1991 indicated transmission from carrier cattle to uninfected cattle (Salt, 1998 and N.J Knowles). No records were available about FMDV vaccine in pigs and small ruminants. Thus agree with Balinda et al., 2009 who noticed that control of FMD involves vaccination in affected area leaving small stock and pigs. Small ruminants may be responsible for the maintenance of FMDV on the farm since cattle, sheep and goat most of the times reared together this may play a major role in the outbreak of FMD. Within this protection zone with vaccination FMD outbreak occurred in 2 communal farms (Silwane and Makhura farm) expect the outbreak that occurred in 2011 (Malati). This indicate that communal grazing and movement of cattle near the KNP fence,which may involve interaction of cattle with buffalo leading to FMD, occurrence and interaction with cattle from different location, increase spread of the disease

(Ayebazibwe, Mwine and Alexandersen, 2010). The current vaccines used for cattle, strains of all three SAT serotypes of FMDV in an aqueous-based vaccine with aluminium hydroxide gel-saponin as adjuvant. The vaccine has several deficiencies that include the induction of short lived antibody responses and the consequent need for frequent application of the vaccine (Hunter, 1998). In Mopani the vaccination of FMD is annually which is results in decrease herd immunity and cattle being susceptible of FMDV.

5.2 Time taken to respond to FMD outbreak through vaccination

The time between outbreaks and onset of vaccination ranged from 1 day to 4 days. The average time for onset of vaccination of reported FMD outbreak was 2.5 days. According to Chowell *et al*., 2005 it is within the normal range, thus time taken to respond to outbreak of FMD through vaccination is highly significant for the effectiveness of FMD control because it will reduce the spread of the disease and reduce the carrier load in the field (Aderson *et al*., 1976). Most animals should therefore be vaccinated before fifteenth day of the outbreak (chowell *et al*., 2005). It has been suggested by Dawe and Howell, 1978 and it is widely believed that outbreak of FMD in Southern Africa occur frequently in periods of water scarcity where both wildlife and domestic animal tend to congregate at the water point. Water scarcity in South Africa occurs during winter from June to august due to no rainfall.

All FMD outbreak reported in Mopani district occurred between June and August which is dry season and none occurred during wet season thus this indicate the ispossible association between occurrence of FMD in Mopani district and the generally dry periods.

5.3 Inspection and vaccination coverage

The proportion of cattle vaccinated and inspected during outbreak statistically significant for the occurrence of subsequent of outbreaks. Vaccination and inspection programs are effective

when large proportion of population of cattle is involved. For effective control of FMD about 60-80% of cattle need to be covered under vaccination so as to control the outbreak of disease (Singh B, 2007). Percentage of cattle inspected is higher than cattle vaccination in all the years. Low level of cattle vaccinated during FMD outbreak can be due to poor record keeping on vaccination, lack of supply of enough amount of vaccines due to financial funding. About 80% of cattle herd are found on communal land thus effectiveness of vaccination depend of farmers cooperation, cattle are vaccinated at dip tanks and is dependent on the commitment of communal farmers to take their cattle to their deigned dip tanks (Steven K.B and Vosloo W, 2007).

5.4 Probability of occurrence of FMD outbreak.

The is probability of occurrence of FMD outbreak in Mopani district due to low percentage rate of cattle vaccination as a results of presence and lack challenges faced during an outbreak and presence of predisposing factors. Vosloo, 2007 indicated that the main limitation of FMD eradication is lack of effective vaccination designed for the purpose, vaccines does not only protect against clinical sign but can actually prevent infection thus the occurrence of FMD is FMD endemic area are dependent of the effectiveness of vaccination. Shanker, 2004 indicated that was no FMD outbreak in organized farm due to regular and proper vaccination. Eradication of FMD in Southern Africa is however not possible, due presence of large number of African buffalo, which are the maintenance host for SAT-types of FMDV, and the undesirability of eradication. Hence agricultural activity in Southern Africa is dependent on the control of FMD and not the eradication thereof (Sutmoller, 1978).

CHAPTER: SIX

6.1 Conclusion

1. Outbreaks of FMD occur in protection zone with vaccination due to infectiveness of annually vaccination and have high risk of coming incontact with FMD carriers African buffaloes and other wildlife animals like Impala.
2. Ineffectiveness of cattle vaccination during FMD outbreak occur due to lack of financial funding by the government to provide vaccines and hire adequate number of veterinary staff.

6.2 Recommendation

1. Practice of effective vaccination by Use of oil-adjuvanted vaccine, they can act as a slow release of vaccines, thus provide longer lasting protection than the aqueous vaccine, which means that annual vaccination can be implemented in the FMD control zone of Mopani District instead of the current double initial vaccination and 6-monthly booster required with aqueous vaccine (Hunter, 1998). Although vaccines does not prevent the development of carrier state in an animal exposed to live virus, it reduce the prevalence of carrier in the field by decreasing the overall level spread of the virus to other cattle
2. The state must effectively fund the control program of FMD to hire more veterinary staff and purchase enough vaccine.
3. Improvement on trace of the main cause of FMDoutbreak.

CHAPTER SEVEN

7.1 References

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