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Spatial and Temporal Distribution of Foot and Mouth Disease (FMD) Outbreaks

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ABSTRACT

Foot and mouth disease (FMD) is an economically important transboundary viral infection of cloven hoofed animals caused by foot and mouth disease virus belonging to the genus Aphthovirus & family Picornaviridae. It is a well-customary endemic infection in globally since it was firstly isolated in 1957. Ten (10) years (January 2011-December 2020) retrospective study was shepherd with key objectives of recognizing the spatial & temporal distribution and to forecasting future patterns of FMD explosions in West Hararghe Zone (WHZ) of Eastern Ethiopia using data from outbreak reports obtained from Hirna Regional Veterinary Laboratory. Totality 45 FMD upsurges were noted to occur in WHZ between 2011 and 2020 with a mean & median of 4.5 & 3.5 upsurges every year, respectively. In that period, FMD outbreak was noted at least once in each district of the Zone. The average prevalence of FMD explosions in the district area was 1.12 district year. The prevalence differed among districts, the lowest being in Anchar (0.68/10 district year) & highest in Chiro town (1.77/10 district year) and The long-period tendency of FMD explosions indicated a statistically significant increase over 10 years period ($p<0.001$). The level of outbreak reached its peak in the March & the low in June to August. The existence of FMD explosion was got to be seasonal whereby the levels of upsurges were relatively high during the hot season. The spatial & temporal disposition identified in this work showed those risky areas that are prone to the contingency of FMD upsurges & the time period in which they predominantly occur. The unregulated & frequent cattle movements could have been the likely basis of the increased level of upsurge contingency during the hot season. Therefore, animal movement biosafety regulations should be taken for the long-time benchmark of FMD in WHZ.

Keywords: Upsurge, Temporal distribution, Spatial, West Hararghe Zone, Foot & mouth disease.

INTRODUCTION:

Foot & mouth disease (FMD) is a trans-boundary disease endemic to Sub-Saharan Africa, South Asia, the Middle East, and other parts of the world. FMD is the most contagious disease affecting cloven-hoofed domestic & wild animals (Grubman *et al*., 2004). Clinically, it is characterized by pyrexia, lameness, loss of appetite, the drooling of saliva, and vesicular lesions of the tongue, feet, and teats (Alexandersen *et al*., 2003). FMD is one of the key important animal diseases blameworthy for the loss of production & productivity, trade impediment & huge control values across globally (Knight *et al*., 2016). Globally, there are seven (7) groups of FMDV sero-types, called pools that circulate in certain zones. Pools 1 & 2 (Southeast & Southern Asia) & pool 3 (Euro-Asia including the Middle East) are the first three (3) pools located in the Asia & Euro-Asia. Three circulating FMDV sero-types (O, A & Asia 1) make up these three (3) pools. Pool 4 (east part of the Africa) consists of sero-types O, A, SAT-1, SAT-2, & SAT-3. Pool 5 (the west part of Africa) contains sero-types O, A, SAT-1, & SAT-2. Pool 6 (southern Africa) comprises only the SAT serotypes. In pool 7, in South America, only serotypes A and O circulate (Logan *et al*., 2017). The causative agent of FMD is a small-sized virus with a single-strand positive sense RNA genome of the approximately 8.5 kbp (Knowles, 2003). Over 65 topo-types (geographically distinct variants) have been described so far (Carrillo *et al*., 2005). Cross protection between sero-types has not been noted. Subsequently, infections and/or vaccination don't necessarily induce protective immunity to re-infection with other sero-types (Klein, 2009; Gammada *et al*., 2022).

The world wide prevalence of FMD ranges from disease free to endemic zones. Key economically developed countries have already eradicated the infection. In the Sub-Saharan Africa, Southern & Eastern Asia, & some South American countries, the infection is endemic (OIE, 2009). In Ethiopia, FMD is a well-traditional endemic infection since it's isolated in 1957 for the first-time (Ayelet *et al*., 2012). Previous works in territory noted FMD in the different animal species with the various ubiquitye levels. For ex-ample, in cow they noted FMD ubiquity that ranges from 1.3 to 52.6% at the animal level & up to 60% at the herd level (Tesfaye *et al*., 2016), in domestic small ruminants 5 to 12%, & in ungulate wildlife 30% (Beyene *et al*., 2015). Out of the known FMD sero-types, four sero-types (A, SAT 1, O, & SAT 2) are prolonged endemically in Africa. Published papers on FMD focus that type A & O are the key sero-types responsible for the significant economic losses in territory (Gelaye *et al*., 2009).

In very recently, there is a curiosity to regulate FMD in the Ethiopia to express its live animal & meat distributes as the infection is scrutinized key parameter to the foreign trade of the livestock & their products (MoARD, 2006). Nevertheless, regulating of FMD endemic in the developing nations in general & in Africa in the peculiar is not easy work due to various reasons and these include the broad distribution of multiple sero-types & subtypes, & the presence of multiple hosts of the virus over the territory, un-controlled cattle movement & shortage of effectual & affordable FMD vaccines in huge quantities in the territory. Besides, FAO & OIE patron that the regulate of the FMD in endemic territory's like the Africa has to be done in the long-time progressive risk reduction method (Paton *et al*., 2009; Aman *et al*., 2020; Woldemariyam *et al*., 2022). Forthwith, in Africa, there is designing towards a native FMD control programme, which is a part of modern control pathway (MCP) and the Africa has been pick out to be in step one of FMD modern control pathway. The cumulative control pathway requires detail epidemiological works to locate & identify the Spatio-temporal distribution of FMD in the territory to update to the next level (Aman *et al*., 2020; Woldemariyam *et al*., 2022).

Statement of the Problem

Foot & mouth disease is the well-established endemic disease in WHZ. Study area is characterized by free grazing (desert), free movement (market), low atention of vaccination, common watering source, high population of animals are at risks. Knowledge of spatial & temporal pattern of this infection distribution is important to understand the natural history of infection in specific time & place and this in turn helps in budgeting, planning and efficient utilization of resources. In doing this, it makes it possible to develop contingency plans for different risk locations; develop a differentiated strategy of vaccination (disease map) and other control strategies and to develop preventive recommendations to reduce risk in high risk areas. Since, Africa has been mapped to be in level one of FMD PCP, particularly study area, this requires detail epidemiological works to locate & identify the Spatio-temporal dispersal of FMD in the territory to progress to the next stage and In spite of a level of the sero-prevalence the studies conducted in the different areas of Ethiopia, to date there is no a study that the scrutinized the spatial & temporal dispersal of FMD upsurge excepting that of the work of Aman *et al*. (2020) in Amhara area.

Likewise, despite there is a routine procedure of animal diseases including FMD outbreak reporting from districts to WHZ Agricultural Office and Hirna Regional Veterinary Laboratory spatial & temporal distribution of FMD outbreak remains un-investigated. Thus, risky areas and time periods remain un-known which hampers forecasting of the future shape of FMD upsurges.

Major objectives of the work

General Objective

1) To the identification of spatial & temporal distribution of FMD upsurge in the work area.

Specific Objectives

1) To the accession of spatial & temporal distribution of FMD upsurge in the work area.
2) To identify high risk districts in work area.
3) To the accession of cases occurrence of FMD in the work area.
4) To forecast the future pattern or tendencies of FMD upsurge.

Review of Literature

Etiology

Foot & mouth disease is an acute contagious viral infection of cloven-hooved animals with significant economic impact, in cattle & swine as well as the sheep & goats (Xu *et al*., 2013). Foot & mouth disease is associated with foot & mouth disease virus (FMDV), is classified within the *Aphthovirus* genus as a group of the *Picornaviridae* family, being small, a non-enveloped, single stranded RNA virus, icosahedral and is 26nm in diameter, which occurs as seven major serotypes, over 61 subtypes have been explained (Knowles *et al*., 2011). Due to a lack of error-correction mechanisms during genome replication, RNA viruses and particularly FMDV, have high mutation rates within the capsid coding region which is responsible for its significant anti-genic variation (Knowles and Samuel, 2003). Traditionally, FMDV had been classified according to the serological criteria by which they were classified on the basis of the lack of cross protection after infection or vaccination (Bachrach, 1968). The FMDV isolates can be grouped into seven (7) distinct serotypes and are given the names of their areas of distribution. The Euroasiatic serotypes are A, O, C & Asia-1 and the South African (SA) territories serotypes SAT-1, SAT-2, & SAT-3 (Knowles *et al*., 2007). Viruses showing partial cross protection were assigned to the same serotype but to different subtype. Over 80 sub-types have been described using genetic and immunological tests. The availability of whole genome sequences have allowed the generation of phylogenetic trees that strongly correlate with the sero-typical classification and have replaced the division into subtypes (Sahle *et al*., 2004). The virus genome is enclosed in a protein capsid (Ludi *et al*., 2017). The viral gene contains the four structural proteins which build the capsid (VP1-VP4); the VP1-3 proteins are discovering on outer layer, while VP4 is internal & ten (10) non-structural proteins (L, 2A, 2B, 2C, 3A, 3B1-3, 3C & 3D). These four (4) proteins form the capsid of the viral & are the coded for by 1D, 1B, 1C & 1A coding sequences respectively. The genome is subject to a higher rate of mutation because FMDV RNA-dependent RNA polymerase lacks proof reading ability (Mahapatra *et al*., 2017).

Aetiology of the FMD

Host Range

FMD affects varies cloven-hoofed domestic & wild mammals, including cattle, sheep, goats, deer, and pigs are susceptible to infection & can spread the disease, whereas the African buffalo (*Syncerus caffer*) is known to be the main wildlife reservoir for the SAT sero-types in the Africa based on the species & virus strain development of the infection varies. The classic severity of the disease & the level and period of infectiousness pass widely, with sheep showing less clinical evidence of the infection than the cattle, or pigs. However, horses, pet animals & birds are resistant to FMD while, camels are moderately susceptible (Chakraborty *et al*., 2014).

Spatial & Temporal Placement of the FMD

Knowledge of spatial & temporal shape of animal disease distribution is important to under-stand the natural history of infectious diseases in specific time and place. This in turn helps in budgeting, planning and efficient utilization of resources. In doing this, it makes it possible to develop contingency plans for different risk locations; develop a differentiated strategy of vaccination and other control strategies and to develop preventive recommendations to reduce risk in high risk areas (Dukpa *et al*., 2011).

Spatial Distribution

The general shapes of disease occurrence reflect the randomness or non-randomness of their distribution in the dimensions of time & space. The spatial pattern of disease is ordinarily a consequence of environmental factors including aspects of weather as well as aspects of cattle management. Geographic database system and easy access to spatial data have facilitated the ability to conduct spatial epidemiological analysis in recent years. In endemic diseases, there is clustering both in time & in the space. This means the disease affects more individuals in specific region during a specific time than would be expected (Stevenson, 2009; Aman *et al*., 2020). Globally and across multiple serotypes, there are distinct genetic & the antigenic strains of Foot & Mouth disease virus (FMDV) circulating and evolving in defined geographical regions that are hence grouped into seven regional pools. Pools 1 & 2 occur in the Asia, while pool 3 occurs in the Asia, Middle East & North Africa. Virus pool 7 is found in South America (Logan *et al.*, 2017) while Africa contains 3 different pools roughly spread across East, West and South Africa respectively (Tully, 2008). FMDV has an essentially foreign distribution, with the exception of North America & the Central America, New Zealand, Greenland, Australia, Iceland & Western Europe. The seven serotypes display different geographical distributions and epidemiology (Bronsvoort *et al*., 2004). Foot & mouth disease was first described in Africa in 1780 but the disease may have been current in the continent for centuries. Foot & mouth disease is endemic in Africa and the epidemiology of the disease is more complicated than in other parts of world. In Somalia, the FMDV sero-types are not uniformly distributed & each sero-type results in various epidemiological structures. The cumulative prevalence of FMDV sero-types show that six (6) of seven (7) sero-types of FMD (O, C, A, SAT1, SAT2 and SAT3) have arised in Africa with exception of Asia-1 (Maree *et al*., 2014). Contingent the antigenic relationship of the viral and genetic features of the FMDV in Africa, the virus distribution has been divided into three virus pools: namely, pool 4 covering East and North Africa, with predominance of sero-types A, O, SAT1, SAT2 & SAT3; pool 5 confined to West & northern Africa, with sero-types O, A, SAT1, & SAT2 & pool 6 restricted mostly to South Africa, with SAT1, SAT2, & SAT3 serotypes (Maree *et al*., 2014). The term topo-type is used to reflect the presence of genetically & geo-graphically distinct evolutionary lineages (Samuel & Knowles, 2001). In Africa, six topo-types have been identified for serotype O, two for sero-type A, three for serotype C, nine for serotype SAT1, fourteen for serotype SAT2 and five topo-types for serotype SAT3 (Sebhatu, 2014).

Temporal Dissemination

The temporal shape of disease occurrence can be described with short-term, cyclical & seasonal, and long-term trends; time steps analysis is a frequently used method to assess these temporal patterns (Thrusfield, 2018). The cyclical trends are associated with regular, periodic fluctuations in the level of disease occurrence. A seasonal trend is a special case of a cyclical trend, where the periodic fluctuations in disease incidence are related to particular seasons (Thrusfield, 2018). Seasonal variation in the occurrence of pathogenic infections is an ordinary phenomenon in both temperate & the tropical climates (Grassly, 2006).

Morbidity and Case Fatality Rate

Morbidity from FMD varies with the animal's species, breed and pre-existing immunity, as well as the dose of virus and other factors. The morbidity ratio can approach 100% insusceptible naive cattle, or pigs, but relatively low morbidity ratio is seen in sheep flock that the infection disappears after infecting a low percentage of cattle's. The shape of the infection is influenced by the epidemiological situation (Radostits *et al*., 2017). In adult animals, mortality due to FMD is negligible but death can occur in up to 50% of young animals due to cardiac involvement and complications such as secondary infection, exposure or malnutrition (MacLachlan and Dubovi, 2011). In lambs and suckling pigs, mortality can range from 20-75% in most extreme cases depending on the age of the cattle's. Mortality is higher in animals under 4 weeks of age infected with FMD and decrease rapidly as animals get older (Quinn *et al*., 2002).

Source of Infection & Mode of Transmission

Foot-and-mouth disease is highly infectious. The FMDV can be constructing in all secretions & excretions from really infected cattle's, including ripped air, urine, saliva, milk, feces & semen. Transmission & spread of FMD is predominantly affected by contact between infected & susceptible cattle's to excretions & secretions of acutely infected animals or contaminated food products. Animals suffering from sub-clinical infections may disseminate the disease through direct contact with susceptible live-stock, or indirectly by the transportation of the viral on inanimate objects such as the vehicles and contaminated equipment to susceptible animals (Sumption *et al.*, 2008). Airborne dissemination of infectious aerosols is also often implicated. Under certain circumstances, the virus travels over extensive distances, over water >250 km and no more than 10 km over land. The viral can spread from pigs, which can expire up to 3,000 times more viral than cattle, to more susceptible cattle hosts via aerosol (Alexandersen *et al*., 2003). Hence, transmission can occur via aerosol spread, contact or oral routes (Tomasula and Konstance, 2004). Air borne transmission via respiratory route is the major route of transmission in cattle. The unroll of the viral from sheep & goats to those susceptible species is vague. Contaminated materials (fomites) may introduce viral into the skin surface, or mucousal membranes and infection spreads (Barnett and Cox, 1999).

Carrier Mood of Animals

Animals with antibodies against FMDV are considered as potential carrier of infectious viral indicating previous exposure of replicating virus. Following the acute level of FMDV infection, a long asymptomatic persistent phase of infection, animals being viral positive for at least 29 days post-infection (dpi), could be induced in cattle, sheep & goats and that live virus could be isolated from oesophageal pharyngeal fluids of such animals (Grubman and Baxt, 2004; Cox *et al*., 2005). Pigs, although, cleared the infection in 3-4 weeks & so do not become carriers but considered as key amplifiers of the viral since they secrete large portions of viral in their expiration (Sellers and Gloster, 2008). The higher period of the carrier state that has been re-ported in cattle is 2.5 years; in sheep, 8 months; in goat, 3 months; in African buffalo, 4 years; and in water buffalo, it is un-known. Inevitably, FMD car-rier temperament is a factor that greatly influences national policies guiding FMD prevention in areas where the infection is not the endemic (Bastos *et al*., 2001; Mwanandota, 2013).

Risk Factors

A lot of risk agents were identified by various studies for spread of FMD in Somalia which include; various species of cattle's, different age level of animals, animal composition and management system, season of the year, breed, geographic location, herd size, contact at communal grazing zone, water point and market and contact with wildlife (Desissa *et al*., 2014).

Clinical Signs

Foot & mouth disease viral can be shed by breath, saliva, feces, urine, milk, & semen for up to four (4) days before clinical hints appear & based on the routes of transmission, virulence of the viral, the age & species of animals the length of incubation period varies. In susceptible cattle's it can range from two to eight days, but can be up to twenty one days post infection with the virus. Turning on the infected cattle species incubation period of FMD is; 3 to 5 days in cattle, 3 to 8 days in sheep, & 2 to 14 days in pigs. In few cases, the incubation time may be long up to two weeks. Infected animals can spread the virus one to two days prior to the onset of the clinical signs and for seven to ten days after the presentation of clinical signs (Alexandersen *et al*., 2003). Pigs have a shorter latent and incubation period than cattle, but pigs can produce approximately 3,000 times more airborne FMDV particles than do cattle, or sheep; thus, swine can considerably boost the disease. Nevertheless, the aerosol yield of infectious FMDV by the pigs differ strain by the strain (Kitching, 2005).

Control and Prevention Measures

Foot & mouth disease is subject to national & international control and the measures taken depend on whether the territory is free from the disease, is subject to sporadic outbreaks or has endemic infection (Rweyemamu *et al*., 2008). In countries free of FMD that have naive livestock populations, great attention is paid to reducing the possibility of incursions of the viral (Paton *et al*., 2009). In disease-free counties, strict movement control & slaughter of infected & exposed animals is carried out in the event of an upsurge. In endemic areas, the infection is usually controlled by vaccination & restrictions on animal movement (Asseged, 2005). Preventive measures in the absence of disease should be implemented as follows: Control of national borders to prevent significant movement of cattle's & livestock products from non-free neighbors or trade partners. For officially free countries, prohibition of imports of animals and livestock products from endemic countries in conferring with the OIE standards.

Emergency measures in the event of outbursts through: Rapid slaughter of infected cattle's, in contact animals and herds considered to have received infection by contact, to reduce the quantity of virus released policy of "stamping out", followed by cleaning and disinfection to reduce the risk of reinfection, strict movement controls, extending to movement on and off farms of livestock products. And also possible emergency vaccination is important (Ding *et al*., 2013). In the Ethiopia context control of FMD is practiced by involvement of quarantine, isolation of infected cattle's, restriction of cattle movement, vaccination programs, proper removal of infected carcass & other methods which are feasible to Ethiopian economy (Admassu *et al*., 2015). There is no country wide vaccination program aimed to control FMD and ring vaccination is carried out around an infected area. Considering the wide prevalence of sero-types of the Native Veterinary Institute (NVI) is producing an inactivated trivalent vaccine which contains O, A & SAT 2 sero-types (Tesfaye, 2014).

Status of FMD in the Ethiopia

Outbreaks and Serotypes

FMD is endemic to Ethiopia as it is in all the bordering countries like Eritrea, Sudan, Kenya and Somalia & restriction of the cattle movement is limited. The infection is widely prevalent and previously used to occur frequently in the pastoral herds of the marginal lowland areas of the territory. However, this trend has been changed and currently the disease is frequently noted in the high lands of the territory (Abdela, 2017). In Ethiopia foot & mouth disease was first noted in 1957 when sero-types O & C were found while sero-type A was identified in 1969 (Martel, 1975). The first extraction of SAT2 in the Africa was in 1989 in a sample collected from Awassa, Sidamo and Negelli Borena (Roeder *et al*., 1994). The existence of FMDV serotype SAT1 in Ethiopia was isolated and noted for the first-time in 2008 from three species of livestock's, cattle, sheep & goats (Legesse *et al*., 2013). FMD is endemic and widely prevalent and distributed in all areas of the territory (Abdela, 2017).

As presented in **Table 1**, endemic distributions of five of seven sero-types of FMDV are maintained in the country & sero-types O, A, C, SAT1 & SAT2 were responsible for FMD upsurges during 1957-2021 (the data were extracted from the World Reference Laboratory for the Foot-&-Mouth Disease (WRL-FMD). From the report, sero-type O was key predominant serotype circulating in territory (Jemberu *et al*., 2016).

Table 1: Serotype-based FMD outburst reports from Ethiopia to WRFMDL in the year 1957 to 2021 (Source: WRLFMD, 2021).

Sero-types	FMD Outburst Noted Years
O	1957, 1961-1963, 1966, 1969, 1989, 1996, 2003-2018, 2020/21
A	1969, 1981, 2000-2002, 2008-2009, 2015, 2017-2018
C	1957, 1971, 1983
SAT1	2007
SAT2	1989-1991, 2007, 2009-2010, 2014-2015, 2018

Previous works have provided prove for the found of different topo-types of FMDV sero-types from the five sero-types (O, A, C, SAT1, & SAT2) noted in Ethiopia samples collected from various outbursts occurred from 1979-2021 (**Table 2**).

Table 2: Summary of topo-type and genotype distribution of FMDV sero-types in Africa from 1979 to 2021 (Source: WRL-FMD, 2021).

Serotype	Topotype	Genotypes	References
O	EA-1		Sahle, 2004, Shazali, 2021
	EA-3		Menda *et al.*, 2017
	EA-4		Beksisa, 2017
A	Africa	IV	Sulayeman *et al*., 2018
		G-IV	Negusssie *et al*., 2011
		G-VII	Metages, 2018
C	Africa		Ayele *et al*., 2009
SAT1	IX		
	IX		
SAT2	XIV		
	IV		
	XIII		Deribie *et al*., 2017
	VII	Alx-12	Sulayeman *et al*., 2018

Temporal and Spatial Distribution

Foot & mouth disease is broadly distributed in all areas of Ethiopia, although the ratio of the infection prevalence may show significant variations across the different farming systems and agro-ecological zones of territory. The infection is more prevalent in lowlands and those of pastoralist and agro-pastoralist (Megersa *et al.,* 2009). Animals from low altitude have higher seroprevalence than those from mid altitude and high altitude areas. This is due to scarcity of feed and water resources in the lowland leads increase animal movement and aggregations at water points (Yahya *et al.,* 2013). According to MoARD, division of animal & plant health regulatory directorate disease outbreaks report summary, FMD occurs at any time of the year however, the highest upsurges of the disease are observed during the heavy rain and extreme dry seasons of the years. Various researchers reported that this might be associated with factors such as drought. High FMD incident was associated with the hot season, extending from October to March. The hot season might be scrutinized as the real time for the occurrence of an FMD outburst. This timed is the time of the year where cattle's are allowed to move from one place to another, freely, in search of the pasture & water. Live stock marketing also affects animal mobility (Woldemariyam *et al*., 2022). The seasonality in the value of FMD outbursts in Africa was evident. Consequently, growing the monthly indices (the measurement of how a particular season through a cycle compares with the mean season of that cycle) showed that the hot period (October-March) was found to have a high frequency of outburst as compared to another seasons of this year. The large seasonal indices noted were for the month of March & the lowest was for May, indicating the peak in March & the lowest in the May outburst numbers (Woldemariyam *et al*., 2022).

MATERIALS AND METHODS:

Description of the Work Location

The work was completed in West Hararghe Zone (WHZ) (**Fig. 1**). West Hararghe is one of the twenty zones in Oromia Regional Zone, which is situated in the east part of the territory. This zone is located on the South by the Shebelle River which divides it from Bale, on the south-west by Arsi, on the north-west by the Afar area, on the north by the Somali area & on the east by East Hararghe. It consists of 17 woredas & two administrative zones. The administrative center of this zone is Chiro, which is 326 km from Finfine (Addis Ababa), the capital city of Africa. The total space of the zone is 16,523. 0032 square Kilometers and the population density are 69 persons per km^2 (CSA, 2021). The zone is found between 7^{0}50' 00" to 9^{0}30' 00"N latitude and 40^o 10'00" to 41^{o}45'00"E longitude. The desire annual rainfall of the area is estimated as 1290.34 mm with maximum monthly rain fall of 600 mm at August month and minimum monthly rain fall of 0 mm at January and February months on the area. More than 92% of the rain occurs from June to September; July & August being the wettest months. Months of June to August are summer (rainy seasons), months of September to November are spring, months of December to February are winter (dry seasons) while months of March to May are autumn (CSA, 2021). The work area is broadly divided into three climatic zones: "Gammoojjii" (the hot lowland zone), "Badda daree" (mid highland zone) and "Baddaa" (the cool highlands zone). It is a mountainous and highly trained with gentle and steep slopes. The elevation of the work area ranges from 1733-3,574 m above mean sea level. Maximum of land in zone is characterized with mountainous, with which Maximum of the area have an average elevation of 2271.00 m above mean sea level. The higher point in this area is mount Arba Gugu 3,574 m above mean sea level (Bekere, 2022). Sedentary (mixed crop-livestock production) and mobile livestock yield systems are practiced in the area. Small holder farmers in the work area own a variety of cattle species like cattle, sheep, goats, chickens, camels & horses.

The work area has a value of the population of 1, 255,753 cattle, 248,248 sheep, 1,049,140 goats, 216, 819 don-keys, 2,221 mules, 1,900 horse, 1,512,784 chickens, 56,537 camels, and 65,846 beehives (CSA, 2021). The work area has a lack of sufficient man power, veterinary infrastructure status of FMD vaccination is very low (WHAO, 2019; Bekere, 2022).

Target and the Study Population

The work animals were cattle of all breeds of different age groups and sex from all seventeen (17) districts of West Hararghe within 10 years.

Study Design

To determine spatial & temporal distribution outbreak of FMD a retrospective work was carried out on the contingency of FMD upsurges in goat using outbreak reports carried out from January 2011 to December 2020 in 17 districts of WHZ.

Source of the Outbreak Data

FMD upsurge data were the obtained from Hirna Regional Veterinary Lab (HRVL) and Zonal Livestock Office for the period 2011-2020 (**Table in the Appendix 1-2**). The zonal and the regional upsurge notes were the combinedly to increase the sensitivity of identifying the FMD upsurges in the zone. The records include information such as zone, species affected, indexing date, value of the cases, number of outbreaks, value of deaths, and value of animals at risk. For this work, an upsurge was defined as one (1) or more animal showing FMD signs in the district.

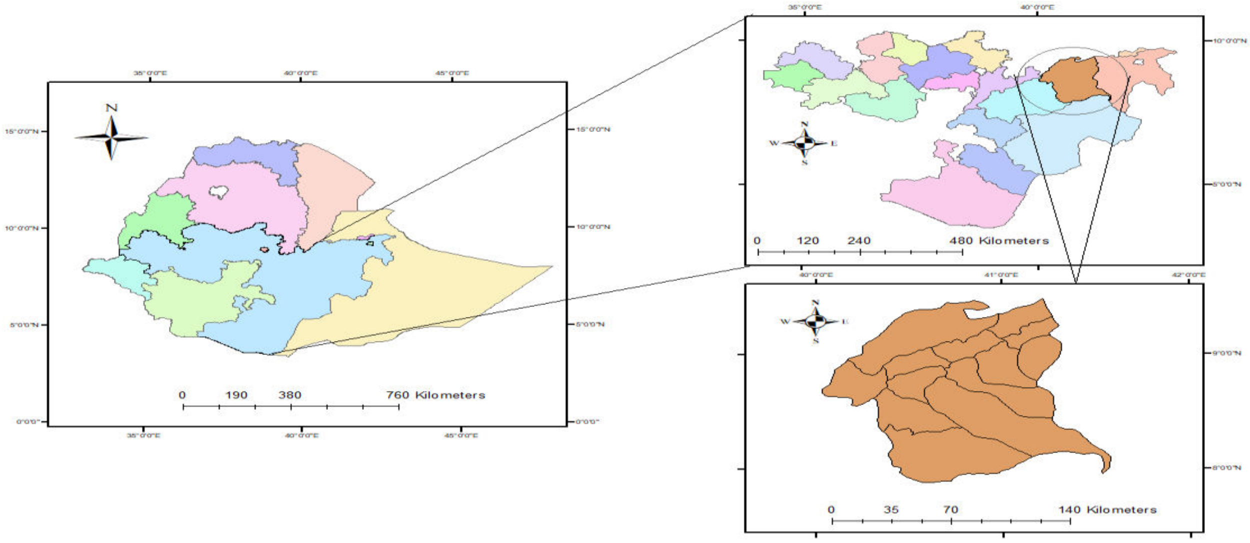

Fig. 1: Map of study area.

Consequently, the FMD upsurge incidence was computed at district (n=17) level using the 10 years (January 2011 to December 2020) upsurge data.

Analysis of the Collected Data

MS Excel spread sheets were utilized to manage data & draw graphs. Descriptive methods were utilized to calculate the incidence of upsurges. Average FMD upsurge incidence was analysed by dividing the sum of all the noted FMD the upsurges during the work time by the total value of the districts and the number of years (district year). Spatial dispersal of the FMD prevalence was drawn by districts during the work period using GIS software Arc GIS v 10.3. The values of noted FMD upsurges over the 10-years study duration were graphed to the visualize temporal trends in the disease. The figure was audited for the existence of seasonality or long term trends. Long-term trends in FMD prevalence were verified by linear-regression in the STATA version 14.2 using the value of the FMD upsurges as the outcome variable & years of outbreak as the predictor variable. Identification & analysis of the three (3) elements of the temporal additive structure; long-term trend, seasonality, and irregularity were performed by decomposing the FMD upsurge time series with label Technical Trading Rules; TTR in the R software. To analyses the seasonality of FMD upsurges, a 12-months running average was analysed & plotted using the numbers of upsurges over the 10-years work period. Moving means were utilized to the reduce random variation & facilitate detection of underlying tendencies (Thrusfield, 2018). Eventually, the run test of the randomness was utilized to verify the randomness pattern of the monthly incident of FMD upsurges (Corder, 2014).

RESULTS:

Average Incidence of the FMD upsurge

Between the year 2011 and 2020, a total of 45 FMD upsurges were noted to occur in West Hararghe Zone (WHZ). As summarized in the **Fig. 2**, average incidence of FMD upsurge in WHZ was 1.12/10 districts years. This value was above the mean incidence in Chiro town (1.78/10 district-years), & districts of Gumbi Bordode (1.6/10 district-years), Mieso (1.44/ 10 district-years) & Burka Dhintu (1.42/10 district-years) & which has low incidence from the below average was in Anchar (0.70 district-years) in **Fig. 2**.

Spatial Dispersal of the FMD upsurge

The spatial dispersal of the 10 years FMD upsurges within the WHZ is re-presented in the **Fig. 3**. Foot & mouth disease was noted from all districts (n=17) of WHZ during the session 2011-2020. From the total of 45 FMD upsurges occurred,

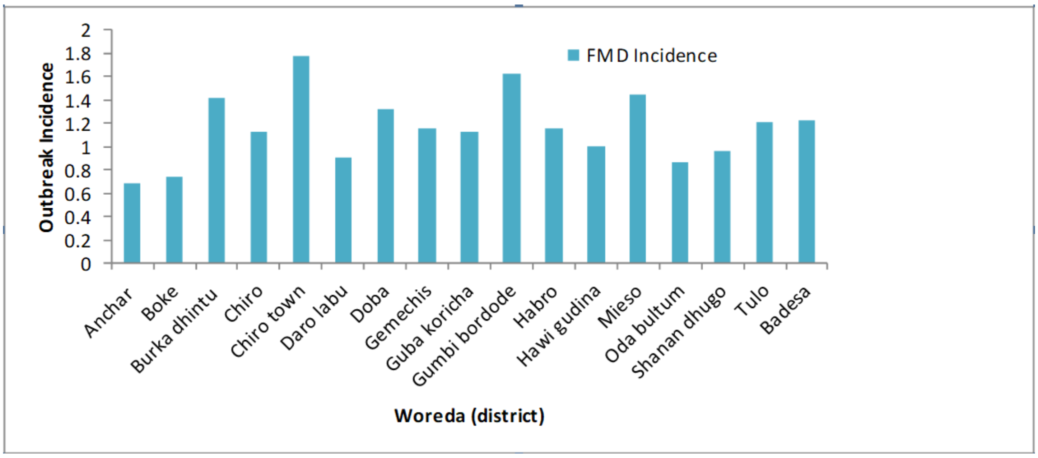

Fig. 2: The medial incidence of FMD in WHZ from 2011 to 2020.

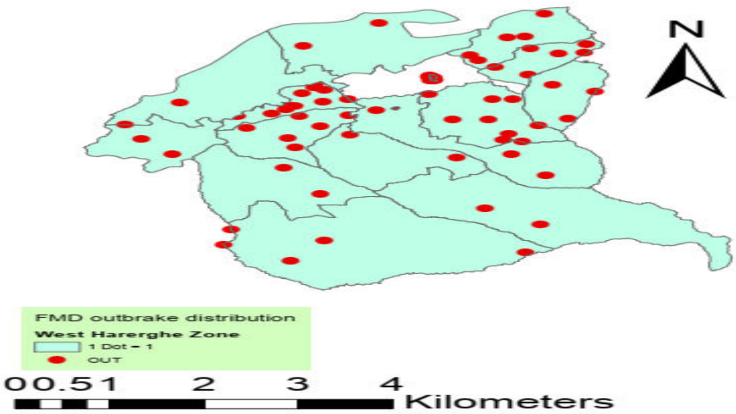

Fig. 3: Dispersal of FMD upsurges per 17 district-years in the WHZ.

1 Dot = 1 outbreak (OUT), 2 Dots = 2 outbreaks, 3 Dots = 3 Outbreaks, 4 Dots = 4 Outbreaks, 5 Dots = 5 and above Outbreaks. The mean and median number of upsurges per year were 4.5 and 3.5, respectively. In the ten (10) year period, FMD upsurge was noted at least once in all districts (n=17) of the Zone. Maximum of the upsurges were noted from Guba Koricha (16%), Gemechis and Chiro (13%), Tulo and Habro (9%) and Doba, Oda bultum and Hawi Gudina (7%) (**Fig. 4**).

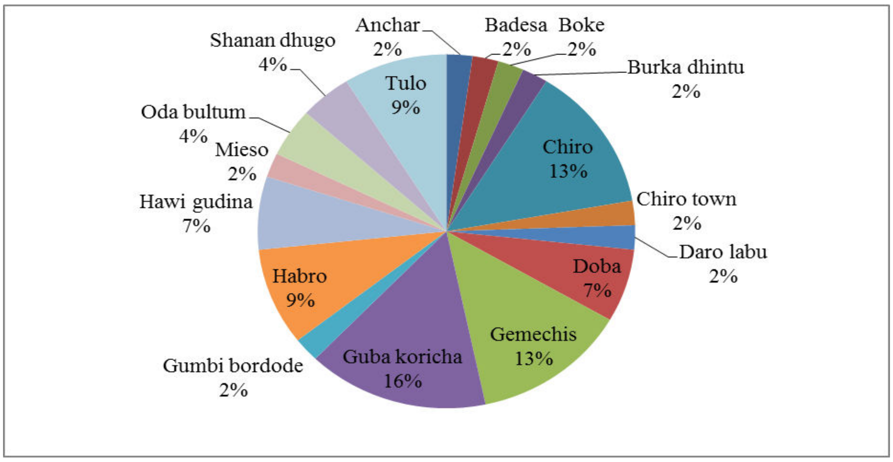

Fig. 4: Dispersal of FMD upsurges (n = 17) over districts of the West Hararghe Zone.

The lowest percentage (%) of upsurges were noted as 2% from Mieso, Anchar, Badesa, Boke, Burka Dhintu, Daro labu, Chiro town and Gumbi bordode.

Temporal trends of the FMD upsurge Occurrences

Within the session of January 2011 to December 2020, the highest numbers of FMD upsurges were noted in 2017 (n=12 outbreaks) followed by 2016 (n=7) while the lower numbers of upsurges were noted in 2011 and 2014 (n=2) (**Fig. 5**).

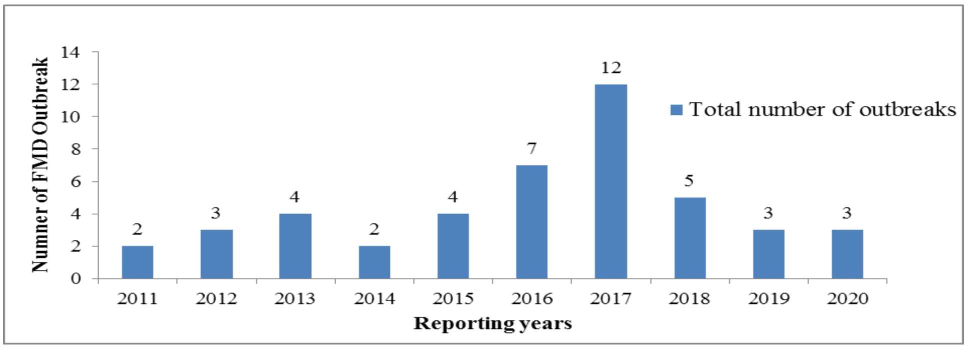

Fig. 5: Annual FMD upsurges in the West Hararghe Zone.

The tendency of incident of FMD outburst showed slight increment in the 10 years' work period. It revealed slight rise in the 2013 year and reached at its peak in the 2017 year decreased in the rest of the years. On monthly basis, the higher number of outbreaks was the noted in the March month (n=14 across all years), which counted for 31% of all reported outbursts and & lower in May, September & October (n=1), accounting for 2% of all noted outbreaks, and no outburst was reported in June to August (n=0; **Table in the Appendix 1**). The trendency & monthly distribution of FMD outbursts presented in the **Fig. 6**.

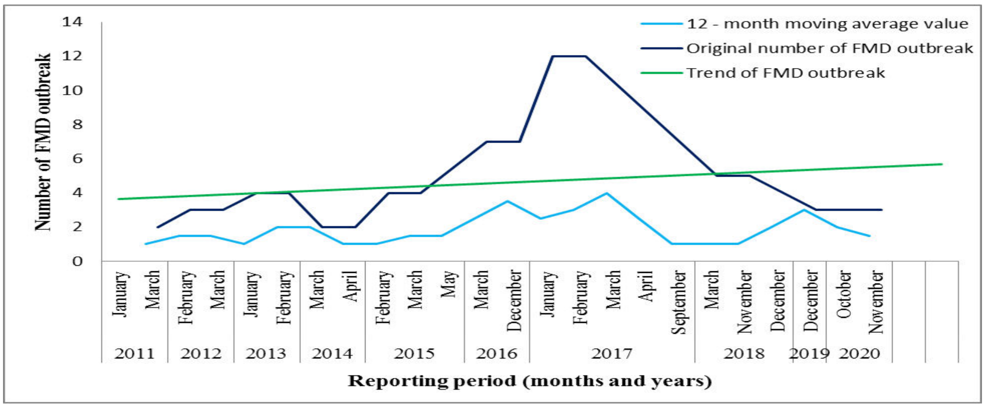

Fig. 6: Monthly outburst and tendency of FMD outburst.

Seasonality in the value of outbursts was evident as it can be seen in **Fig. 7**. Run tests for randomness tests indicated that the temporal dispersal of FMD outbursts was not random. Tendency, seasonal & random elements were analysed by decomposing the FMD prevalence time waves (**Fig. 7**). From the tendency component, FMD outbursts appear to have periodic cycles of two to four years with peaks in 2013 & 2017) (**Fig. 7**). The incidence pattern of degenerative FMD outbursts showed a light demonized in the value of outbursts from month to month (**Fig. 7**), which was statistically important (P<0. 001).

Furthermore, plotting monthly indices of the value of outbursts showed a high frequency of outbursts in hot season months than in other seasons, demonstrating statistically important seasonality of FMD outbursts (**Fig. 8**). The large incidence was the reported for March (about 1.28) & the lower for June to August (about 0), indicating that the value of FMD outbursts peaked in March & became lower in June to August (**Fig. 8**). Usually, the value of FMD out-bursts was far above mean from January to March & far below mean from April to August (**Fig. 8**).

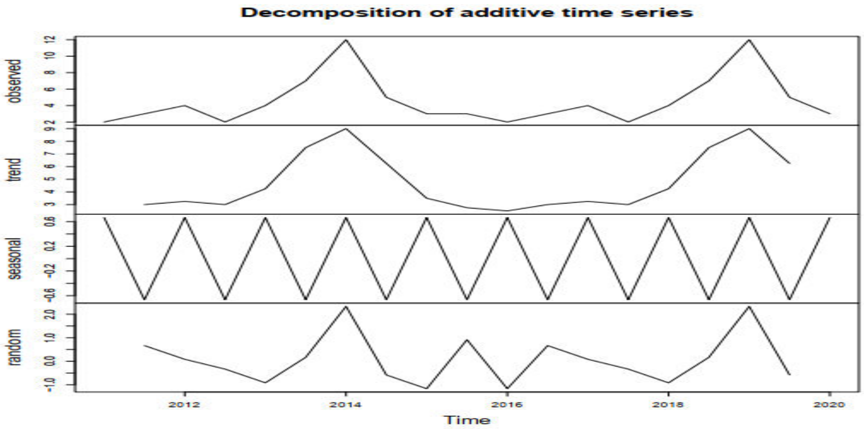

Fig. 7: Putrefaction of the visualized temporal structure of FMD outbursts (top panel) into 3 elements of the time series: tendency, seasonal, & random.

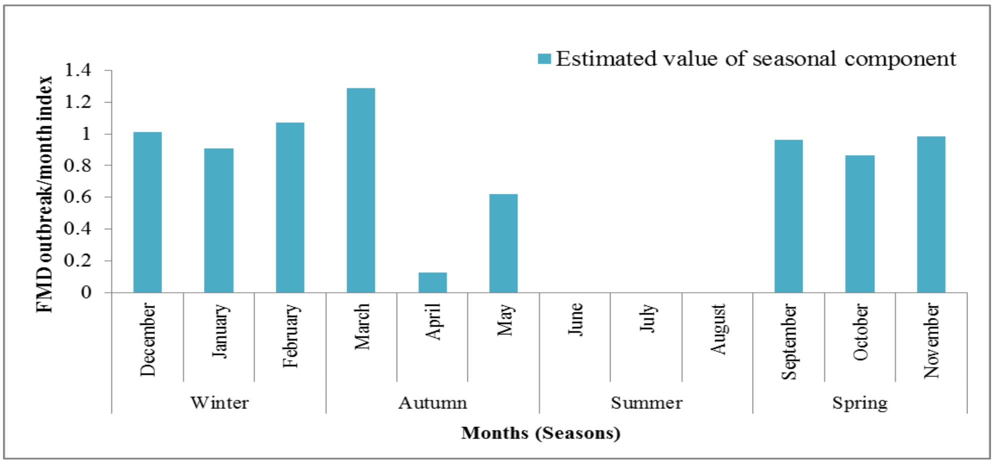

Fig. 8: Seasonal implications of monthly FMD outbursts.

Case Dispersal of FMD

Totally of 14,404 cases (a specific animal with a suspected clinical sign of foot & mouth disease) and 4 deaths were noted over the time-period between 2011 & 2020 from 17 districts of WHZ (**Table 3**). From this types of cases, 15% (n=2,148) occurred in the Guba Koricha as the highest, and 2% (n=243) in Anchar as the lower (). In entitles of year, the year 2017 had the higher number of the cases (4,265) reported & the 2011 year had the lower (430) cases. The mean morbidity, mortality & case fatality rate of FMD were 11.22%, 0.03% & 0.03% respectively within ten (10) years period (**Table 3**).

Table 3: Case dispersal of foot & mouth disease by years.

Year	No. of cases	Risk population	Number of death	Morb. Rate (%)	Mort. Rate (%)	Case Fat. Rate (%)
2011	430	6,481	0	6.63	0	0
2012	771	7,777	0	9.91	0	0
2013	1252	11,559	0	10.83	0	0
2014	620	4,631	0	13.39	0	0
2015	1258	9,321	0	13.50	0	0
2016	2276	20,858	2	10.91	0.01	0.09
2017	4265	33,503	1	12.73	0.003	0.02
2018	1523	14,356	1	10.61	0.007	0.06
2019	1106	11,451	0	9.66	0	0
2020	903	8,453	0	10.68	0	0
Total	**14404**	**128390**	**4**	**11.22**	**0.03**	**0.03**

No.: Number; Morb. Rate: Morbidity Rate; Mort. Rate: Mortality Rate; Case Fat. Rate; Case Fatality Rate.

DISCUSSION:

This work is the first retrospective study to note the spatial & temporal dispersal of FMD outbursts in the zone unlike some previous FMD works in the WHZ, which were cross-sectional sero-prevalence works. This study highlights the incidence as well as temporal & the spatial dispersal of FMD outbursts. The study indicated that frequent FMD out-breaks occurred in WHZ every year with 45 total outbursts in 10 years. During this time, on mean 4.5 FMD out-bursts were noted to occur annually. The higher number of outbursts were noted in 2017 (n=12) which agrees higher or less with the note of Ministry of Livestock & Fishery Ethiopia (2017) that showed the continual occurrence of FMD outbursts in the East Oromia (which include the western Hararghe) part of the territory & high value of the FMD outburst at the native level (Woldemariyam *et al.* 2022).

Foot & mouth disease outbursts were noted from all districts of WHZ during the ten (10) years' work time, with the higher value of outbursts (n = 7) in the Guba Koricha district & six outbreaks in each of Chiro and Gemechis districts. The high frequency of occurrence outbursts in these districts might be due to communal grazing, travelling long distance to the search for water (Woldemariyam *et al.*, 2022), unrestricted cattle movement from Somali & Afar region for grazing and watering during dry season by crossing the border of Oromia region, & lack of prophylactic vaccination (Yahya *et al.,* 2013, Woldemariyam *et al*., 2022). The present work noted that all of the districts in the zone noted at least one FMD outbursts in ten (10) years (100%), which is higher than that of the note ten (10) zones Amhara regional Republic ranging from 2% to 43% (Aman *et al*., 2020) & 73% of findings of another work by Jemberu *et al.* (2016) in this region.

The causes for the disparity between the present & the previous works could be due to differentiate in the length of the work period, work site & data sources. The previous work (Jemberu *et al*., 2016) was basis on short & the recent period outbursts history collected from the districts and the study of Aman *et al*. (2020) was in different location & not recent while the current work was basis on long time, recent, official outbursts reports from zonal office, regional lab (from OIE reporting papers & online) by cross checking among districts, zone & regional lab files. This study finding indicated that the incident of FMD outbursts at district level is epidemic which is in consensus with Woldemariyam *et al.* (2022), who had noted the epidemic nature of FMD in the zones of Oromia area. However, endemicity of FMD is regulated in the zone, as the outbursts in different districts of the zone do not occur at the similar time. The mean time for the re-occurrence of the infection in the same districts was 5.29 years. The re-occurrence period of FMD varies across the work districts. The few districts re-ported outbursts after one year of quiescence, whereas others noted an outburst of FMD after a long time (up to nine (9) years) of dormancy and the differ in re-incident time between districts could be due to the differ in the value of cattle movement, the animal husbandry system, level of the geo-graphical isolation by the natural physical covers, & level of herd immunity (Aman *et al*., 2020, Woldemariyam *et al*., 2022). Generally, in WHZ, the value of FMD outbreaks the significantly increase in 2-4 years cycle. This result is accordant with research re-ported by the Belayneh *et al.* (2019) & Aman *et al*. (2020) who culminated that increased value of FMD epidemics occur in other region of Africa on mean every two (2) years & 2-6 years respectively. The epidemic cycle focused in this work is also in line with the epidemic cycle range- of 3-6 years re-ported by the previous study from the other endemic territory (Gallego *et al*., 2007). Temporal shapes of infection outbursts were de-composed into long-term (secular), cyclical & seasonal trends. The decomposed temporal shapes demonstrated a statistically significant seasonality for the occurrence of FMD outbursts, which is in line with Aman *et al*. (2020) & Abdela, (2017) results who noted out season as a risk points for the emergence of FMD outbursts. In differ to the findings of the present work; Jemberu *et al.* (2016) reported that the instance of the FMD outbreaks has neither long-term nor seasonal tendency in Africa. In the current work, the peak FMD outbreaks were re-corded in the March (the hot season) & the lower in June to August (the wet season) which is in concurrence with Aman *et al.* (2020). The diversity of FMD outburst in season might be related to the variation in cattle movements. Outburst values increased during December-March (reaching peak in the March). The key husbandry system practiced in many of districts in the west Hararghe is extensive with free cattle movement, which favors conditions for the spread of viral. In the addition, west Hararghe incurs the free & unrestricted flow for grazing & watering of animals from neigh-boring agro-pastoral and pastoral Somali & Afar states, which may have contributed to the high outburst noted in hot season (Yahya *et al*., 2013; Wubshet *et al*, 2019). Additionally, in most mid land & high land parts of WHZ, during the wet season of the years wide zones of farm land are harvested with crops, as a finding the movement of domestic animals is restricted & kept confined on the tiny plots of grazing soils, which could be the reason for lower incidence of FMD outbursts in this period (Yahya *et al*., 2013). The trend of FMD outbursts from January 2011 to December 2020 indicates statistically significant increase over the time. The observed increase in FMD outbursts occurrence in WHZ in the last years could be due to un-restricted animal grazing in the zone & from neighboring regions that resulted in increased free movement of cattle's. In addition, lack of prophylactic vaccination & veterinary infrastructure to handle the outburst on a large scale greatly contributes to the frequent incident of the infection & also makes the FMD regulate extremely challenging. The probability of increasing outburst reporting ratio by the districts can't also be theory out. Hence, it requires further work to conclude that the long term tendency of the infection is increasing & to know the reason of the increasing tendency. The findings of this work might possibly be biased by the outburst re-porting rate of the districts. Jemberu *et al.* (2016) have already documented a serious under-reporting of FMD outbursts in Ethiopia. The smack of under-reporting will have more bias, if the under-reporting is various across districts & time. In the addition, the noted outbursts are mostly treated basis on the clinical signs except the confirmatory clinical tests, which may impact the real of the reported outburst incidences. Even though this work might have the above mentioned limitations, it generally attempted to generate quite necessary epidemiological information about the spatial & the temporal dispersal of FMD in the work area, which could be valuable inserts to support the zone, regional & the national decision-making regarding FMD regulate.

CONCLUSION AND RECOMMENDATIONS:

Foot & mouth disease is widespread & well established in WHZ. The incidence of the occurrence of FMD outburst between the year 2011 & 2020 was found to be moderate. The FMD outbursts occurred in all districts & all of the districts of area have experienced at least one FMD outburst in the ten (10) years' work period. Outbursts were observed to be seasonal & occurred extra often in the months of the hot season (January, February & March). Increased numbers of outbursts occur in the area with epidemic cycle of 2 to 4 years. A huge value of animals were hinge to exhibit clinical signs of FMD although the mortality & case fatality rates were hinge to be very lower. Recognition of temporal patterns & spatial dispersal can indicate particular times & areas when & where attention should be given to control & prevent the infection in cost effective ways. Depend on the above conclusion the following recommendations are forwarded:

1) Work needs to be under taken on outburst investigation, economic analysis of FMD outburst.
2) Strategic & pro-phylactic immunization of cattle's should commence at the beginning of the hot season.
3) Risk factors of FMD needed to identify.
4) Reason of increasing of FMD outbursts needed to identify.

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CONFLICTS OF INTEREST:

The author's declare that there are no potential conflicts in the work.

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APPENDIX

Table 1: Number of FMD outbursts noted monthly.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	1	0	1	0	0	0	0	0	0	0	0	0	2
2012	0	2	1	0	0	0	0	0	0	0	0	0	3
2013	1	3	0	0	0	0	0	0	0	0	0	0	4
2014	0	0	1	1	0	0	0	0	0	0	0	0	2
2015	0	1	2	0	1	0	0	0	0	0	0	0	4
2016	0	0	4	0	0	0	0	0	0	0	0	3	7
2017	2	4	4	1	0	0	0	0	1	0	0	0	12
2018	0	0	1	0	0	0	0	0	0	0	1	3	5

2019	0	0	0	0	0	0	0	0	0	0	0	3	3
2020	0	0	0	0	0	0	0	0	0	1	2	0	3
Total	**4**	**10**	**14**	**2**	**1**	**0**	**0**	**0**	**1**	**1**	**3**	**9**	**45**

Table 2: Number of FMD outbreaks reported yearly from districts.

District	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Anchar	0	0	0	0	0	0	0	1	0	0	1
Badesa	0	0	0	0	0	1	0	0	0	0	1
Boke	0	0	0	0	0	0	0	0	1	0	1
Burka dhintu	0	0	0	0	0	0	0	0	0	1	1
Chiro	0	0	1	0	2	1	2	0	0	0	6
Chiro town	0	0	0	0	0	1	0	0	0	0	1
Daro labu	0	0	0	0	0	0	0	1	0	0	1
Doba	0	1	0	0	0	1	1	0	0	0	3
Gemechis	0	0	1	1	2	1	1	0	0	0	6
Guba koricha	1	0	0	0	0	1	4	1	0	0	7
Gumbi bordode	0	0	0	0	0	0	0	1	0	0	1
Habro	0	0	0	0	0	1	2	0	1	0	4
Hawi gudina	0	0	0	0	0	0	0	1	0	2	3
Mieso	0	0	0	0	0	0	1	0	0	0	1
Oda bultum	1	0	0	0	0	0	0	0	1	0	2
Shanan dhugo	0	1	1	0	0	0	0	0	0	0	2
Tulo	0	1	1	1	0	0	1	0	0	0	4
Total	**2**	**3**	**4**	**2**	**4**	**7**	**12**	**5**	**3**	**3**	**45**

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