

## An Overview of Foot and Mouth Disease Situation in Tunisia (1975-2017)

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### Abstract

The present study provides a descriptive analysis of the episodes of foot and mouth disease (FMD) in Tunisia that can help to understand its occurrence during a period of 42 years (1975-2017). Historically, six major episodes of FMD were recorded. From 1975 to 2017, outbreaks were irregularly notified in cattle, sheep and goat with three serotypes (O, A, C). The study shows evidently that occurrences were highest in the regions that encloses livestock markets. Time of introduction of FMD played major role in disease economic impact. Illegal trade of animals from neighbouring countries was the main source of introduction of FMD in Tunisia. The rapid spread of the serotype O from Libya to Tunisia and to the others countries of the Maghreb region in 2014 reveals the failure of the strategy of the control of FMD in those countries. To fight his disease, veterinary services of Tunisia must reinforce the surveillance of FMD specially in the areas with a very high risk of introduction and spread of MFD.

**Keywords:** Foot and mouth disease; Tunisia; Epidemiology; Outbreak; Vaccination; Risk factor; Animal movement

highlighting factors involved in the spread of the disease and the control measures implemented to fight this occurrence.

### Introduction

Foot and mouth disease (FMD) is a viral disease caused by an aphthovirus within to Picornaviridae family [1]. It is a highly contagious disease causing considerable economic losses (milk losses, mortality, trade restrictions ...) [2]. FMD can be transmitted directly or indirectly to healthy animals (direct contact, contaminated objects, airborne transmission) [3]. Seven serotypes (A, O, C, SAT1, SAT2, SAT3, and Asia1) are identified to be responsible of the observed clinical signs in susceptible species [4]. These serotypes are immunologically distinct and each one requires specific vaccine strain [5]. The six serotypes besides serotype C are circulating in Africa [6]. In the Northern Africa region, FMD is not endemic and is characterized by its sporadic occurrence with epizootic episodes. From the Northern Africa region, three countries (Tunisia, Algeria and Morocco) did not record cases of FMD during fifteen-years and last outbreaks were declared in 1999. However, in 2014, FMD has occurred in Tunisia following an illegal introduction of animals. Then, disease was spread to the neighboring countries. It has been proved that illegal animal movement was responsible of the introduction and spread of FMD in these countries [7,8]. Due to its geographical localization, Tunisia combines several risk factors that can be implicated in the emergence and re-emergence of transboundary diseases such as foot and mouth disease. For this reason, official veterinary services have decided to vaccinate cattle, sheep and goats to mitigate the risk of introduction and spread of FMD. In the last years, vaccination is practiced in Tunisia for cattle against serotypes O, A and SAT2 and for small ruminants against serotypes O and SAT2 [9]. The prophylactic measures implemented are the control of animal movements, vaccination in farms and livestock markets, control in slaughterhouses. These measures have severely reduced incidence of FMD in Tunisia.

This article aims to provide an overview of the foot and mouth disease situation in Tunisia with a special focus on the episode of 2014

### Control program

FMD control program was mainly based on the annual vaccination campaign of all ruminants. Emergency ring vaccinations are implemented after occurrence of the disease. Before December 1989, vaccination was carried out only in cattle. But, since 1989, this program has been extended to small ruminants (sheep and goats). The annual vaccination campaign is executed between October and January. It is covered by the budget of the Ministry of Agriculture and realized by Veterinary Services.

### History of episodes of foot-and-mouth disease in Tunisia before 1999

Tunisia is a North African country bordered on the north and east by the Mediterranean Sea (1,148 kilometers of coastline), on the west by Algeria with 965 kilometers of common borders and on the southeast by Libya with 459 kilometers of borders (Figure 1).

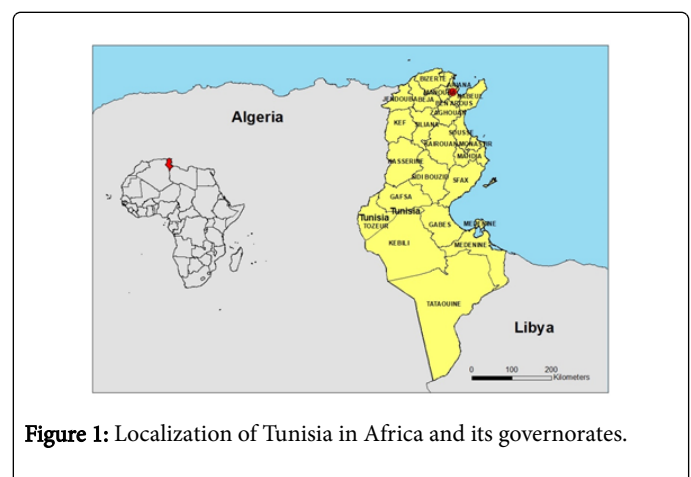


Figure 1: Localization of Tunisia in Africa and its governorates.

Tunisia has always been vulnerable to animal diseases including FMD because of its geographical position and the increase of animal trade [10]. According to FAO World Reference Laboratory, foot and mouth disease has been present in Tunisia since 1965 (serotype C) [11,12]. Since that time, several episodes of FMD have been recorded. In July 1975, serotype O was detected in cattle.

From 1975 until 2014, five episodes were reported and the last was in 1999. In March 1979, 147 outbreaks in cattle caused by serotype (A) were confirmed in 15 governorates (Tunis, Zaghuan, Jendouba, Beja, Kef, Nabeul, Sousse, Monastir, Mahdia, Sfax, Kairouan, Gafsa, Sidi Bouzid and Medenine) (Figure 2a) and 371 cases in cattle and four deaths were recorded. Emergency ring vaccination around the outbreaks was applied to fight the spread of FMD and veterinary services had vaccinated 128,584 cattle belonging to 21,825 breeders using trivalent OAC vaccine [13]. In 1982, the same serotype (A) has caused 67 outbreaks in eight governorates (Tunis, Nabeul, Zaghuan, Bizerte, Sousse, Monastir, Mahdia, Sfax) (Figure 2b). The number of registered outbreaks was less important (67 outbreaks) compared to the previous episode. An emergency vaccination with OAC vaccine was conducted by the veterinary services with a 383825 vaccinated cattle.

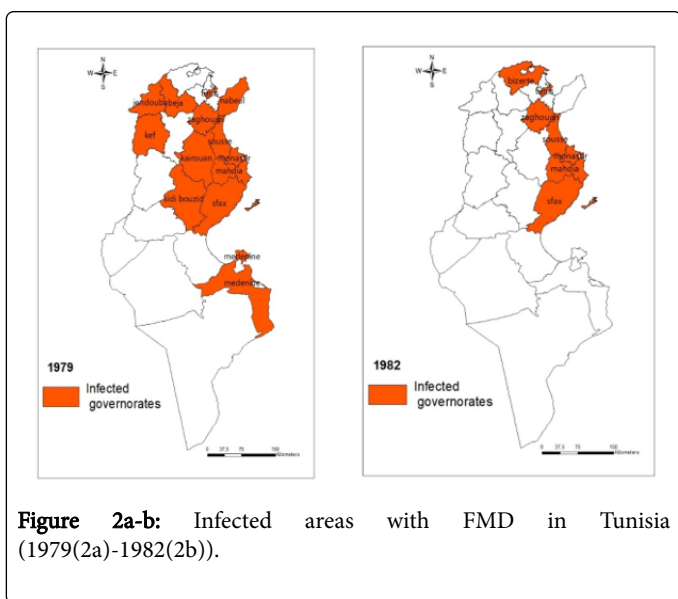


Figure 2a-b: Infected areas with FMD in Tunisia (1979(2a)-1982(2b)).

Then, FMD re-emerged again in 1989-1990 with devastating consequences. The occurrence has coincided with the lambing season and epizootic started on November 1989. With the except Tataouine (Extreme south of Tunisia), FMD has been reported in all governorates with 2,315 outbreaks predominantly in sheep and serotype O was identified [14]. Geographical distribution of outbreaks revealed that Incidence of FMD was higher in the central west and central east governorates (Kasserine, Sidi bouzid, Kairouan, Sfax). The reason for the increased incidence in those governorates at that time may be related to the introduced animals from neighbouring countries. The disease spread later to the north and finally to the south (Figure 3). At this time, FMD was directly responsible of the mortality of 50677 lambs, 79 goats, 136 calves and 19 adult cattle. Similar to the number of outbreaks, highest mortality was recorded in central governorates.

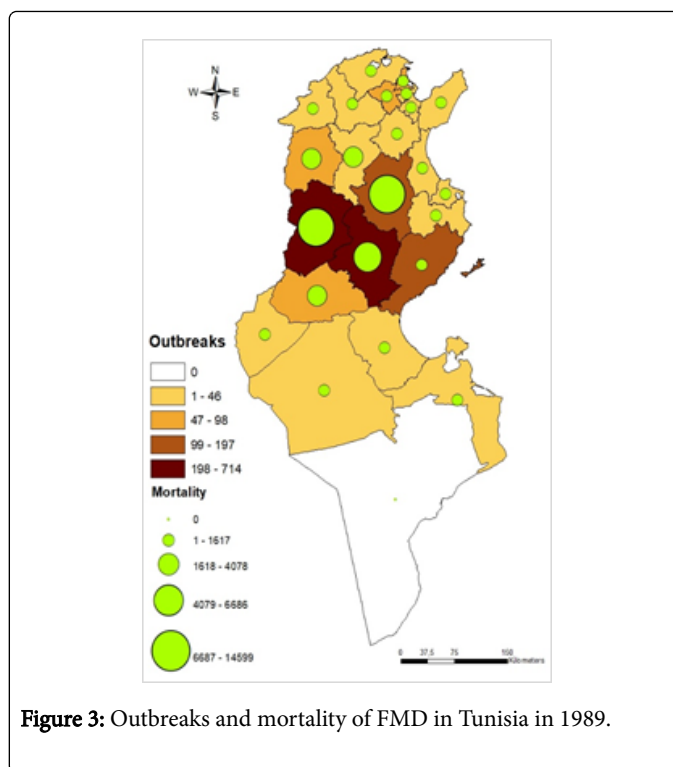


Figure 3: Outbreaks and mortality of FMD in Tunisia in 1989.

Temporal evolution of outbreak, shows that the ascending phase of the epizootic that precedes the peak has been missed by veterinary services and information about outbreaks before December 12th were not available. Until that date, incidence of FMD outbreak was decreased and the last outbreak were recorded in January 8th (Figure 4).

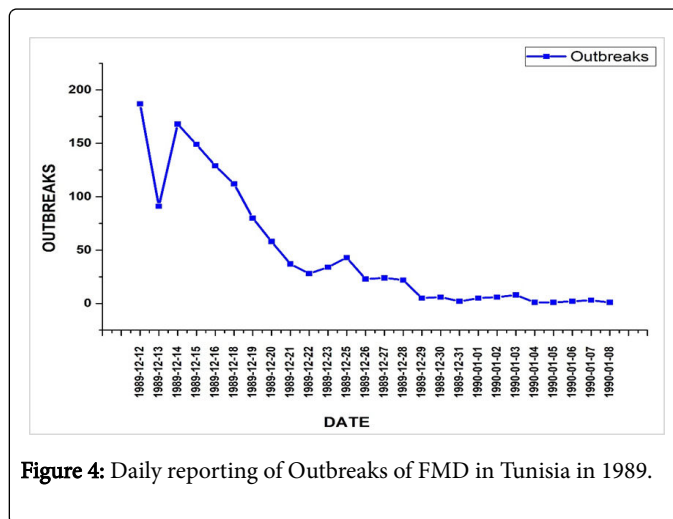


Figure 4: Daily reporting of Outbreaks of FMD in Tunisia in 1989.

During the 1989 outbreak, emergency vaccination was performed. A total of 6270432 sheep, goats, cattle and camels have been vaccinated. Later, a control program was setup with annual vaccination that includes all ruminants.

Economic losses of FMD were estimated at 6.4 million dollars and parameters used to assess economic impact were mortality of ruminants, damages due to movement restrictions and the cost of vaccination [15].

In 1994, despite the annual vaccination, five outbreaks were confirmed by laboratory (1 outbreak in Beja and 4 outbreaks in Tataouine), which involved serotype O. 5 years later, in 1999, two outbreaks caused by serotype O (1 outbreak in Nabeul and 1 in Jendouba) were detected by veterinary services (Table 1). On March 1st 1999, 5 suspect cases with FMD-like symptoms were reported in a farm located approximately 3 km from the town of Grombalia, Nabeul governorate. 28 cattle and 110 sheep were present in the farm. Samples of vesicular epithelium and blood of bovine (13 cattle and 5 sheep) were taken and confirmation of Foot-and-Mouth Disease (virus type O) took place at the end of the afternoon of March 2nd 1999. All existing ruminants in the farm had been slaughtered. Epidemiological data showed that there was an introduction of 18 fattening bovine from two large farms on February 22nd 1999. The second outbreak was notified on Thursday March 11th 1999 after a Visit carried out by the local veterinary services. Symptoms and lesions of FMD were observed on a heifer and some sheep (lameness in the rams and a lamb). FMD was confirmed by ELISA on March 12th 1999 [16]. A booster vaccination campaign has been undertaken to revaccinate susceptible animals. On April 3rd 1999, a total of 193 686 bovines and 1 083 628 small ruminants were vaccinated with a vaccination coverage rate of 62% for bovines and 52% for small ruminants [16].

At that time, Nucleotide sequencing has revealed that the serotype O (O/TUN/1/99) and (O/TUN/5/99) were very similar (99%) to the virus that had appeared in Algeria and Morocco [11]. So, introduction of the West African topotype in North Africa can be explained by the illegal movement of animals from West Africa to Algeria [17].

		Outbreak 1	Outbreak 2	Total
<b>Gouvernorate</b>		Nabeul	Jendouba	
<b>Susceptible</b>	Bovine	28	2	30
<b>Species</b>	Ovine	110	7	117
<b>Cases</b>	Bovine	22	1	23
	Ovine	5	3	8

Table 1: Outbreaks of Foot and mouth disease in Tunisia in 1999 [16].

### History of episodes of foot-and-mouth disease in Tunisia after 1999 episode of 2014

From 1999 to April 2014, Tunisia has been considered free from FMD with vaccination [10]. Shortly after its incursion in Libya in 2013 (serotype O), the disease recurred in April 2014 in Tunisia with the same serotype. On April 24th 2014, two cows with FMD-like clinical signs were reported in the governorate of Nabeul (Sommaa sector). This first outbreak was confirmed through RT-PCR by veterinary research institution (IRVT). Rapidly, disease spread to the center and the north of the country. A few outbreaks has been recorded in the south. By November 2014, 142 outbreaks spread over 20 governorates, have been notified to the world organization for animal health (OIE) [18]. Four governorates have not recorded outbreaks of FMD (1 governorate in the center (Sousse), 3 governorates in the south (Kebili, Tozeur and Gabes)). The epidemic affected predominantly the governorate of Sidi bouzid where the highest number of outbreaks was reported (14.7% (21/142)). While, the lowest number of outbreaks was observed in governorate of Medenine and Siliana (0.7% (1/142)) (Figure 5).

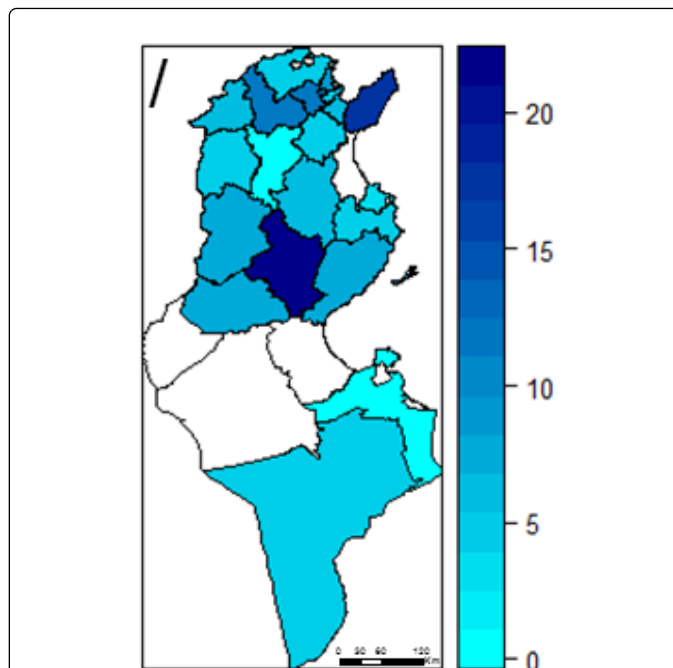


Figure 5: Outbreaks of Foot and mouth disease in Tunisia in 2014.

Spatial clustering analysis is so useful to study the spread of the disease, in order to identify the governorates in which an additional surveillance is required and to improve strategy of control. So, to test the hypothesis of spatial clustering of FMD outbreaks in 2014, the Moran I test was used to evaluate whether outbreaks were clustered, dispersed, or randomized [19,20]. The result, as shown in Figure 3, indicated that there was a significant clustering of outbreaks in space (Moran I test=1.068218, z-score=4.70+797 and p=0.000003) (Figure 6).

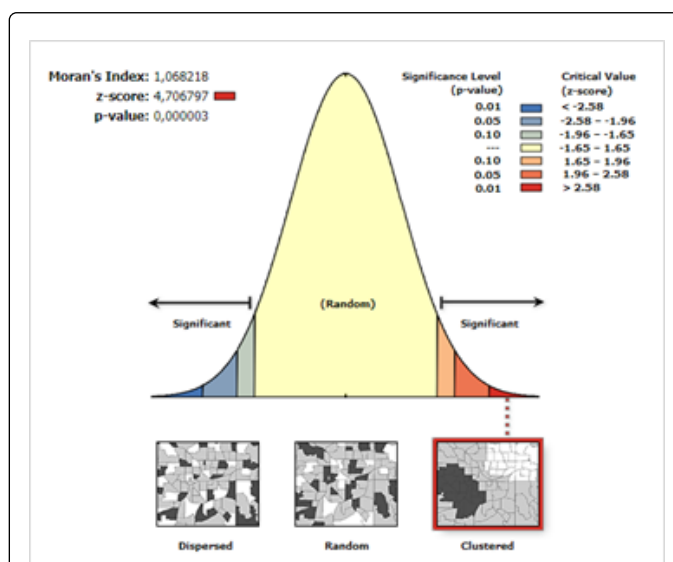
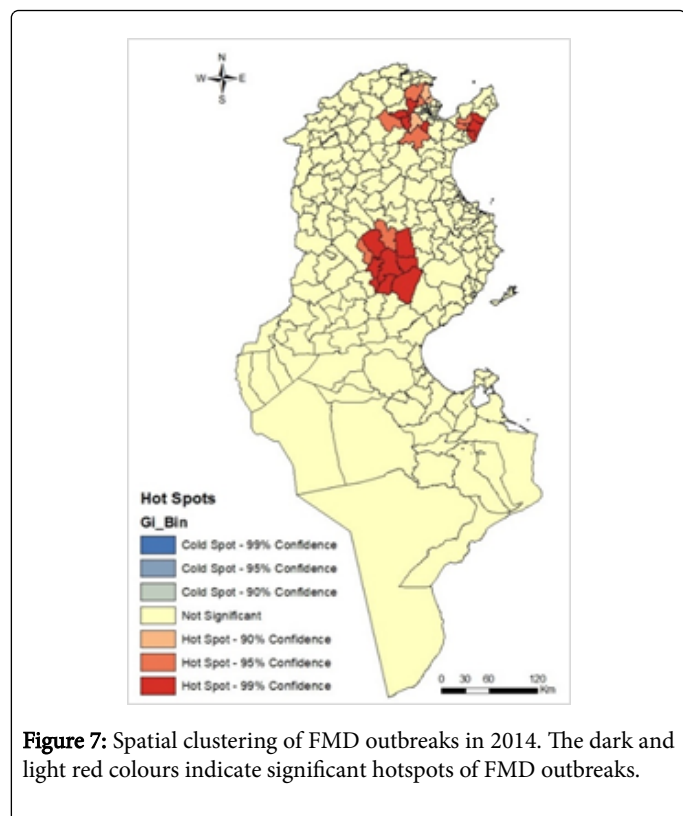


Figure 6: Global Moran's I statistic results generated by the Spatial Autocorrelation tool in ArcMap.

However, hot spot analysis test (Getis-Ord  $G_i^*$  statistic) must be performed using GIS software ArcMap 10.4 to explore the distribution mode of outbreaks within a particular area. This test detect significant spatial clustering patterns qualified as “hot spots” and “cold spots” over the entire study area [21]. The result revealed the presence of three hot spot areas (the most prevalent areas): the first was located in the center, represented by the governorate of Sidi Bouzid. The second and third ones were situated in the north covering governorates of Manouba, Ariana, Zaghouan and Nabeul (Figure 7).



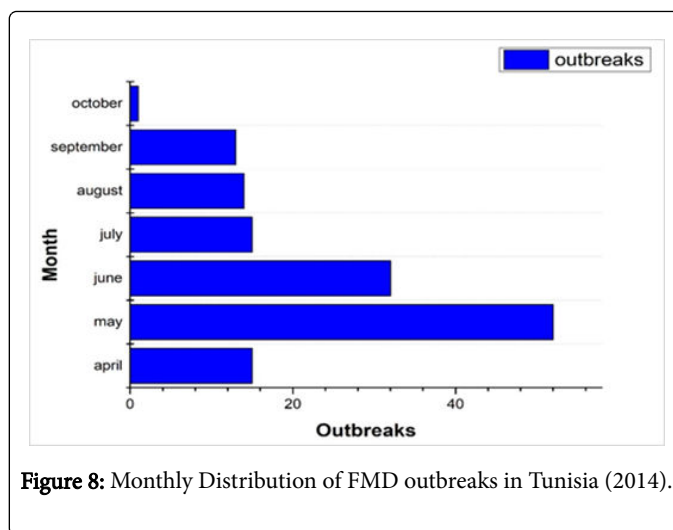
**Figure 7:** Spatial clustering of FMD outbreaks in 2014. The dark and light red colours indicate significant hotspots of FMD outbreaks.

Among the total of 142 outbreaks, 93 (65.4%) outbreaks were confirmed in small ruminants, however, the number of cases (710/8027) 8.8%) was not significant if compared to that recorded in cattle (460/2590)17.7%). In addition, difference between morbidity rate in cattle and in small ruminants was statistically significant ( $p=0.000000$ ) (Table 2).

	Outbreaks	Cases	Susceptible	Morbidity rate
<b>Small ruminants</b>	93	710	8027	8,8
<b>Bovine</b>	49	460	2590	17.7
<b>Total</b>	142	1170	10617	11

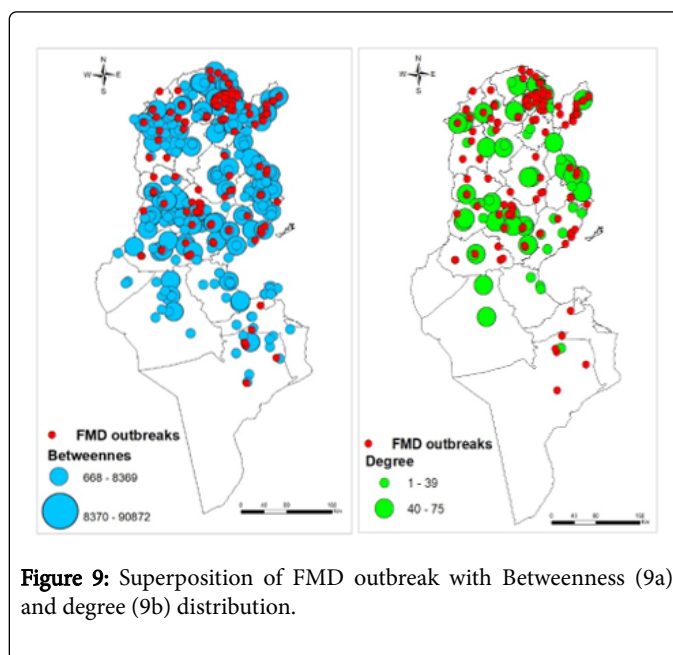
**Table 2:** Distribution of FMD outbreaks in affected species.

Monthly distribution of outbreaks revealed that the disease was reported for 7 months, but not uniformly distributed (Figure 8). A higher number of outbreaks was reported in May (36.6% (52/142) and June (22.5% (32/142)) and a lower number of outbreaks was recorded in October (0.7% (1/142)).



**Figure 8:** Monthly Distribution of FMD outbreaks in Tunisia (2014).

The sequencing of the isolated strain has identified toptotype O/ MESA/Ind 2001d, which is closely related (99%) to the virus from Libya (LIB/2/2013 and Saudi Arabia (SAU/3/2013) [22,23]. It has been shown that more than 12 million small ruminants (mainly sheep) have been traded during the period preceding the Eid al-Adha [10]. Therefore, FMD outbreaks in 2014 were probably attributable to animal movements [24]. The result of a study on animal movement shows that outbreaks of FMD had occurred in area with a high value of degree and betweenness (Figures 9a and 9b).



**Figure 9:** Superposition of FMD outbreak with Betweenness (9a) and degree (9b) distribution.

Studies showed that areas with a high degree and high betweenness are potential hubs for diseases spread [25].

It is evident that FMD incidence depends on several factors such as the characteristics of the breeding, livestock management, the climatic factors... Understanding the epidemiology of FMD incursion in Tunisia including risk factors was fundamental to increase vigilance and to derive an effective surveillance. An investigation was carried out from April 29th to May 30th 2014. A total of 41 surveys were conducted in 10 governorates (Ariana, Bizerte, Jendouba, Kasserine,



Kef, Monastir, Nabeul, Sfax, Sidi Bouzid and Tataouine). Data analysis has revealed that most FMD outbreaks appeared in farms having introduced animals within 15-20 days of the onset of clinical signs. The relationship between animal introductions in farm and the source of infection has been investigated by calculating the time interval between the introduction of animals and the appearance of clinical signs. Results presented in Table 3 offer some evidence for the original source of infection. The occurrence of FMD in the farm with imported animals provided strong evidence for the introduction of the disease through new introduced animal.

Governorate	Date appearance of clinical signs	Date of animal introduction	Time interval
Ariana	17-05-2014	14-05-2014	3
Ariana	18-05-2014	14-05-2014	4
Kasserine	28-04-2014	20-04-2014	8
Nabeul	24-04-2014	17-04-2014	7
Nabeul	25-04-2014	24-04-2014	1
Nabeul	08-05-2014	01-05-2014	7
Nabeul	15-05-2014	08-05-2014	7
Sfax	01-05-2014	20-04-2014	11
Sidi bouzid	15-04-2014	01-04-2014	14
Sidi bouzid	09-05-2014	27-04-2014	12
Tataouine	09-05-2014	01-05-2014	8

**Table 3:** Distribution of FMD outbreaks in affected species.

### Episode of 2017

On March 2017, veterinary services had implemented several sanitary measures following the occurrence of FMD in Algeria on March 2017. These measures were not enough to stop the spread of the disease in Tunisia. Consequently, an outbreak of FMD serotype A was confirmed on April 27th 2017 after the previous day's notification of vesicles in the mouth and teats from a cattle farm in Bizerte (north of Tunisia). Later, a second outbreak was reported in the same region [26,27].

The virus strain identified is identical to the one circulating in Algeria since late March 2017. This strain has been genotyped as topotype Africa, lineage G-IV, closely linked to Nigerian strains collected in 2013 and 2015.

### Discussion

In this study, data were collected from different sources. Details were not available for episodes before 2014. For this reason, a brief description of these episodes was conducted.

This study shows that FMD is not endemic in our country and its occurrence was sporadic [28]. First detection of FMD (serotype C) in Tunisia was in 1965. The second episode was in 1975 and cases were reported in 15 governorates. At this time, the large spread FMD can be explained by the absence of control program of FMD. In 1989, FMD was introduced by infected sheep [29] and was declared for the first

time in sheep and significant economic losses have been recorded. The high number of reported outbreaks can be explicated by the occurrence of FMD during the lambing period [30]. At this year, Veterinary services had set up control program of FMD based on vaccination and animal movement control [31] that is why low number of outbreaks in the following episodes (1990, 1994 and 1999) was observed. Tunisia was free of FMD during 15 years and last outbreaks was reported in 1999. In 2014, 142 outbreaks were notified to the OIE. The reasons of this emergence of FMD could be multiple. Firstly, the failure to control introduced animal might lead to the introduction of FMD from infected neighbouring countries (Libya). It has been demonstrated that four serotype are circulating in Libya [32] which increases the risk of introduction of FMD in Tunisia. Secondly, Maghreb countries had implemented different strategies to fight FMD, only cattle were vaccinated in Algeria and no vaccination campaign was carried out in Morocco [10,33]. During these episodes, cattle were the main affected species and sheep have been slightly affected by the disease, this result was observed in neighbouring countries [8]. Phylogenetic analysis shows that strain isolated form confirmed outbreaks was similar to the strain identified in Libya [34,35]. Most of outbreaks was declared in May and June. During this period, movement of livestock increased and small ruminants and cattle are used for fattening for Aid el Eidha. Spatial analysis revealed the presence of three cluster in the north and the center of Tunisia. The first one was located in Sidi bouzid, this governorate hosts the most important livestock markets and animals from secondary livestock markets are usually imported from this region. The second cluster was identified in Nabeul governorate, it has been proved that animals from Libya were directly introduced to the livestock market of Nabeul [36]. Ariana, Zaghouan and Mannouba governorates also contain important livestock markets that play an important role in animal movement.

Cattle were the most affected species during the episodes of FMD. This could be explained by the fact that cattle are indicative of the FMD whereas the clinical signs are unremarkable in small ruminants [37]. It has been demonstrated that some serotypes are more virulent in cattle than sheep and goat [38].

Introduction of FMD in Tunisia has been associated to the illegal trade. Therefore, in 1989, 1999, 2014 and 2017, introduced animals from neighbouring countries were considered the main source of introduction of FMD in Tunisia and the phylogenetic results of isolated strain confirm this hypothesis.

In conclusion, FMD is an important disease of livestock and still a priority for veterinary services in Tunisia.. The circulation of many serotypes in the Maghreb region make Tunisia in a permanent risk of the occurrence of FMD. For this reason, strategy of the control of this disease must be reinforced by implementing of the risk-based surveillance to improve the early detection and to mitigate the risk of introduction and spread of FMD.

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