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Original Article
Özgün Araştırma

Mapping and filiation of bovine tuberculosis outbreaks in Türkiye (2017-2021)

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Abstract: Since the beginning of the XXIst century, it has been seen that bovine tuberculosis (bTB) disease in Türkiye has both increased in the number of outbreaks and gradually spread throughout the country. This study aims to map the spatial distribution of bTB between 2017 and 2021 at the scale of outbreak premises. Besides, the basic data of the research, which includes the results of the filiation studies carried out in the outbreak premises, were taken from the veterinary information system. The inclusion of the geographical coordinates of each premises with a bTB outbreak in the system has enabled point mapping of the data throughout Türkiye by using geographical information systems. As a result, the spatial distribution of the number of bTB outbreaks both in Türkiye and in the province of Erzurum, annual and five-years temporal distribution patterns, filiation graphs of the disease, and animal movements in the outbreak premises were revealed. Although the number of bTB outbreaks varies according to years, thanks to the fact that the spatial scale in the data is at the premises level, the clustering areas in the country are determined in much more detail than the distribution maps according to the provinces. Two points provide as a concise summary of the findings. The first is to explain the spatial spread of bTB across the country; secondly, it is expected to guide decision-makers to identify target intervention areas in the fight against the disease and to determine the national fight strategy.

Keywords: Bovine tuberculosis, epidemiology, filiation, geographic information systems, map.

Türkiye'de sığır tüberkülozu mihraklarının haritalandırılması ve filyasyonu (2017-2021)

Özet: XXI. yüzyılın başından itibaren Türkiye'de sığır tüberkülozu (bTB) hastalığının hem mihrak sayılarında artış olduğu hem de giderek ülke sathına yayılma eğilimi sergilediği görülmektedir. Bu araştırmada bTB'nin görüldüğü mihrak işletmeler ölçeğinde 2017-2021 döneminde mekânsal dağılımının haritalandırılması amaçlanmıştır. Ayrıca mihrak işletmelerde yapılan filyasyon çalışmalarının sonuçlarının da yer aldığı araştırmanın temel verileri veteriner bilgi sisteminden alınmıştır. bTB mihrakı olan her bir işletmenin coğrafi koordinatlarının da sistemde yer alması, verilerin coğrafi bilgi sistemleri kullanılarak Türkiye genelinde noktasal haritalamasının yapılmasına imkân sağlamıştır. Sonuçta hem Türkiye geneli hem de Erzurum iline ait bTB mihrak sayılarının mekânsal dağılımı, yıllık ve beş yıllık zamansal dağılım örüntüleri, hastalığa ait filyasyon grafikleri ve mihrak işletmelerdeki hayvan hareketleri de ortaya konmuştur. bTB mihrak sayıları yıllara göre değişim göstermekle birlikte, verilerdeki mekânsal ölçeğin işletme düzeyinde olması sayesinde ülke içerisindeki kümelenme alanları illere göre dağılış haritalarından çok daha detaylı bir şekilde belirlenmiştir. Ortaya çıkan sonuçlar iki noktada özetlenebilir. Birincisi, ülke genelinde bTB'nin mekânsal yayılımını açıklamak; ikincisi ise, hastalıkla mücadelede hedef müdahale alanlarının saptanması ve ulusal mücadele stratejinin belirlenmesi için karar vericilere yol gösterici olması beklenmektedir.

Anahtar kelimeler: Coğrafi bilgi sistemleri, epidemiyoloji, filyasyon, harita, sığır tüberkülozu.

Introduction

Bovine tuberculosis (bTB) is a zoonotic disease that has significant effects on animal and human health, leading to significant economic losses due to low yields, trade restrictions and fighting and control costs (Branger et al. 2020). bTB is one of the most common bacterial infections that primarily affects cattle, domestic-wild animals, and humans (Silva et al. 2018). *Mycobacterium bovis* (*M. bovis*), a highly adaptive and successful pathogen, is spreading worldwide (Skuce et al. 2012).

Zoonotic tuberculosis (TB) is a public health problem of concern and generally, affects all countries according to their state of development (Napp

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et al. 2019). Although the prevalence of zoonotic TB is unknown in the world, a possible estimate is made (Luciano and Roess 2020). According to the 2019 global estimates of the World Health Organization (WHO), 140 thousand (1.4%) of 10 million cases are zoonotic TB patients. Globally, the number of TB strains resistant to multiple drugs/rifampicin and individuals who are positive for human immunodeficiency virus is increasing day by day (Silva et al. 2018; Anonim 2020). The interaction between people, farm animals, wildlife, and ecology involved in the epidemiology of TB makes TB an ideal target within the "One Health" approach (Good et al. 2018). In this regard, international cooperation is needed in all aspects of the fight against TB (Cosivi et al. 1998).

This zoonotic pathogen, which is at the forefront of the world stage, continues to have significant effects on reducing animal and human health as well as economic well-being (Byrne et al. 2019). bTB is one of the most complex animal health problems facing the world's cattle industry today, causing significant economic losses (Chandran et al. 2019). Therefore, the disease continues to pose an important economic animal health problem worldwide. It is estimated that more than 50 million cattle are infected worldwide. The annual socio-economic cost of this is also estimated at $3 billion (Buddle et al. 2018). Within the scope of the project carried out by Barwinek and Taylor (1996), it was reported that the socio-economic impact of bTB on both the agricultural and health sectors in Türkiye was approximately $15 to 59 million per year (Cosivi et al. 1998). The fight against disease in cattle in Türkiye is mainly based on slaughterhouse surveillance, a test-slaughter regime, and movement restrictions (Crispell et al. 2017).

The use of Geographic Information Systems (GIS) in the field of veterinary epidemiology has increased since the beginning of the XXIst century. The use of GIS in veterinary epidemiology is increasingly expanding to visualize disease data with maps and graphs, analyze complex disease problems, and plan control methods in animal disease prevention and control (Mengistu and Haile 2017; Fayisa 2020). International research on risk-based strategies and geographical distribution in France Marsot et al. (2016), England and Wales Adkin et al. (2016) and USA-Minnesota Ribeiro-Lima et al. (2016) regarding bTB points to the importance of this study's approach. The reasons for this research are the national research examining the spatial distribution of measles cases in humans in Istanbul by Ulugtekin et al. (2006) and Çiçek and Şenkul (2006) which are not directly aimed at bTB disease in Türkiye but deal with the possibilities of using GIS in the veterinary field (Çiçek et al. 2008).

Since the beginning of the XXIst century in Türkiye, the rise in bTB outbreaks has accelerated, especially in the last decade, increasing the concerns of dairy premises, industry stakeholders and management institutions while threatening animal and public health (Silva et al. 2018). The increase in the number of disease outbreaks, which is becoming increasingly worrisome with each passing day, has started to be the subject of new research, even in small numbers. In this context, investigations were conducted examining epidemiological infection dynamics in the field Çakır et al. (2022), temporal and spatial distribution at the provincial level Çakır et al. (2021), epidemiological problems, and solution analyses (Çakır and Diker 2021). As an epidemiological unit, the livestock premises where the outbreaks are seen directly were taken as a basis, and it was aimed to map it pointwise. In the research conducted Çakır et al. (2021), bTB outbreaks were mapped at the scale of provinces, and in this research, the spatial scale was taken to the most detailed possible detail. In this respect, the research has a unique place in Türkiye where bTB is mapped nationally at the premises level for the first time. This mapping of bTB was undoubtedly possible by including the geographical coordinates of the data sets kept at the premises level in the Ministry of Agriculture and Forestry (MoAF) information systems. Again, the filiation information included in these data sets was also used in the present research. The resulting maps are expected to be a guide for decision-makers and implementers to determine the national strategy in the fight against bTB nationwide and identify the priority cluster (hot spot) areas and make the necessary plans.

Material and Method

Legal permissions

The necessary legal permissions have been obtained from MoAF of the Republic of Türkiye, General Directorate of Food and Control, for both the provision of data and the publication of obtained results, as bTB is a disease for which notification is mandatory.

Access to data

The research is based on multiple datasets obtained from different institutions. The distribution of bTB, which is the basic data of the research, according to premises was taken from the Veterinary Information System (VETBIS) kept in a module of MoAF's agricultural monitoring and information system annually for the period 2017-2021. In addition to the province, district, village, and geographical coordinates of the outbreaks according to the premises, it also contains various information (premises number, filiation, release date, approval date, etc.). Mapping of research data was possible based on the geographical coordinates in this database. The coordinate data of each premises was checked before mapping, and some incorrect or incomplete coordinate data were corrected according to the village or neighbourhood of the respective premises. In addition, some duplicate notification reports were also removed from the data set. As a result of all these operations, the total number of bTB outbreaks for the years 2017-2021 was determined as 9,026. The filiation information in 17 titles (2 of which are "other" and "being investigated") was evaluated using this database and graphs showing all the filiation information were created according to the years. The obtained filiation data were compared with the results of the research conducted by (Çakır et al. 2022).

The premises numbers in the registered information of the outbreaks in VETBIS and the information on the animal movements of these premises in the Animal Registration System (TURKVET) database were used to obtain the second data set. Again, using the information on animal movements, the remaining 8,606 premises were accessed after subtracting the duplicate disease premises numbers. Large data sets of five-year animal movements belonging to these premises and networks related to the epidemiology of infection were evaluated.

The third part of data from the research is for the presence of cattle by districts to determine the relationship between the total number of animals and the distribution of bTB outbreaks. This data was taken from the Turkish Statistical Institute (TSI) for 2021 and mapped by districts. For the same year, the number of outbreaks was also rearranged according to the districts and the correlation coefficients were examined to determine the relationship with the number of animals.

Data analysis

A total of 6 maps were produced throughout the country, showing year by year and all years combined, using Arc GIS 10.5 according to the geographical coordinates on the basic map where the premises-based data of bTB is located on the provinces and district borders. The province of Erzurum, where the bTB outbreaks are most concentrated, has also been mapped in the same way with the idea of setting an example for closer monitoring of the spatial cover outside the national scale.

Results

Mapping of bovine tuberculosis outbreaks in Türkiye

If epidemiological mapping is to be considered as the production of the representation of the distribution of diseases in space, two basic dimensions must be determined in this process. The first is on what spatial scale (country, region, province, district, village, premises) the diseases will be mapped, and the second is how the representation will be displayed on the map according to the spatial scale to be selected. In this study, the spatial distribution of bTB outbreaks on a national scale was determined according to the premises with the smallest unit. In this respect, the distribution of the previous outbreaks according to the study according to the provincial scale by Çakır et al. (2021), was illustrated in the most detailed and realistic way possible. Each outbreak was represented with a single symbol (point) directly without any spatial scale change and displayed on the map in the mapping of the outbreaks according to the premises throughout the country. In other words, point data is shown on the map without being converted to spatial data. Thus, each premises in Türkiye where outbreak have been observed has been transferred to the map based on its geographic location on the earth.

Although bTB in Türkiye has had an up-and-down graph since the 2000s, it is known that the general trend is in the direction of increase (Çakır et al. 2021). From 2017 to 2021, year by year, the bTB outbreak was determined to be 1,220; 1,629; 2,248; 1,877[1]; 2,052 respectively (Figures 1-5). A total of bTB outbreaks was determined as 9,026. Even though a change in the number of outbreaks according to the years is observed, the distribution of the outbreaks in the country is not homogeneous.

1 The number of bTB outbreaks in Türkiye in 2020 was reported by Çakır et al. (2021) as 1,913. However, since a subsequent examination of a province's data was found to have been inadvertently entered into OIE-WAHIS by MoAF and corrected in the report, the number of outbreaks for this year was revised to 1,877 in this article.

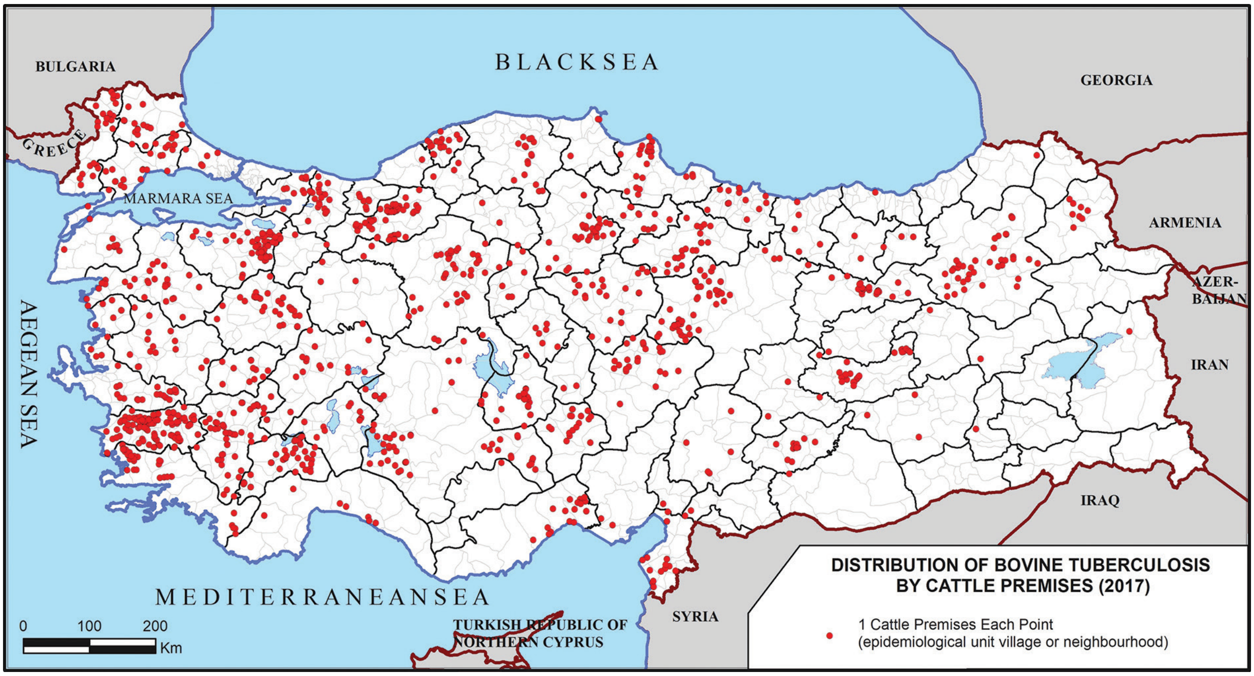

Figure 1. Annual distribution of bovine tuberculosis outbreaks in Türkiye (2017) (MoAF)

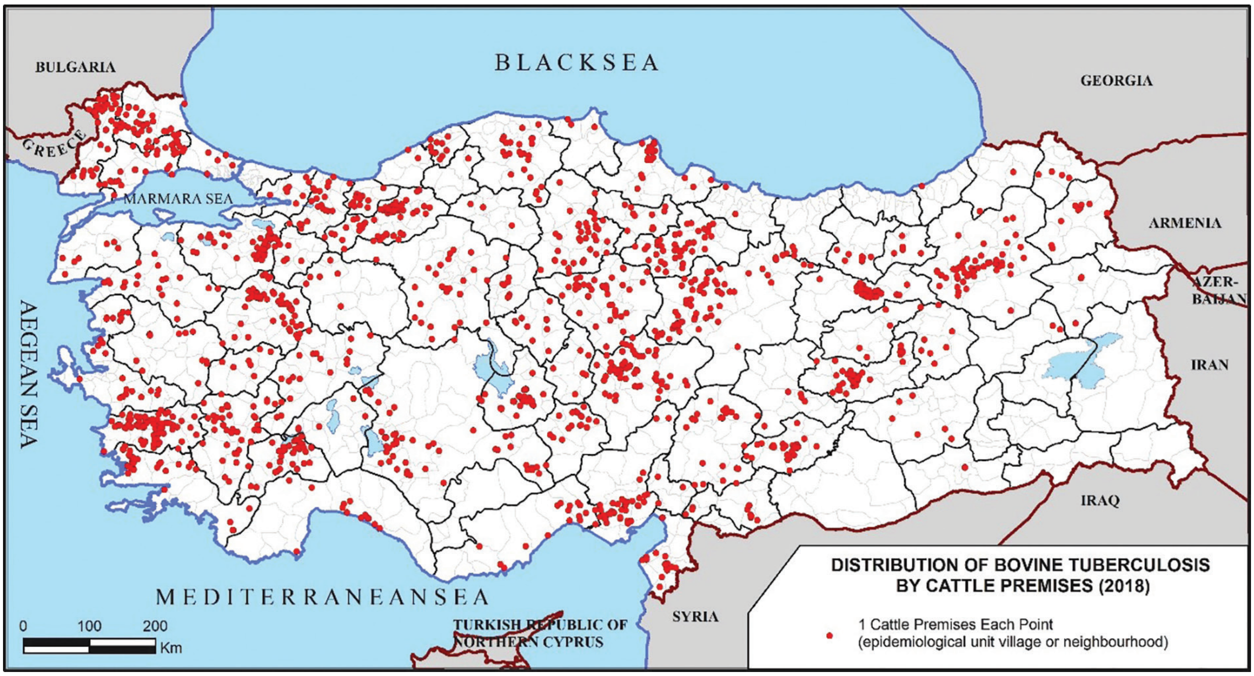

Figure 2. Annual distribution of bovine tuberculosis outbreaks in Türkiye (2018) (MoAF)

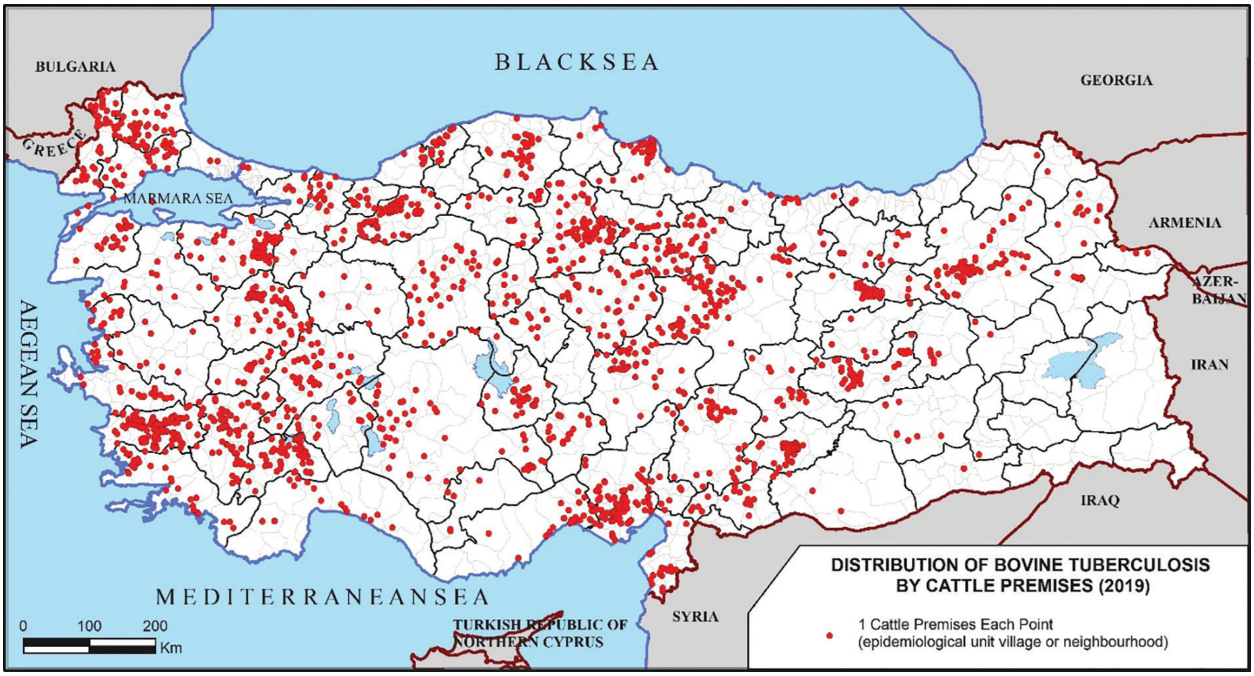

Figure 3. Annual distribution of bovine tuberculosis outbreaks in Türkiye (2019) (MoAF)

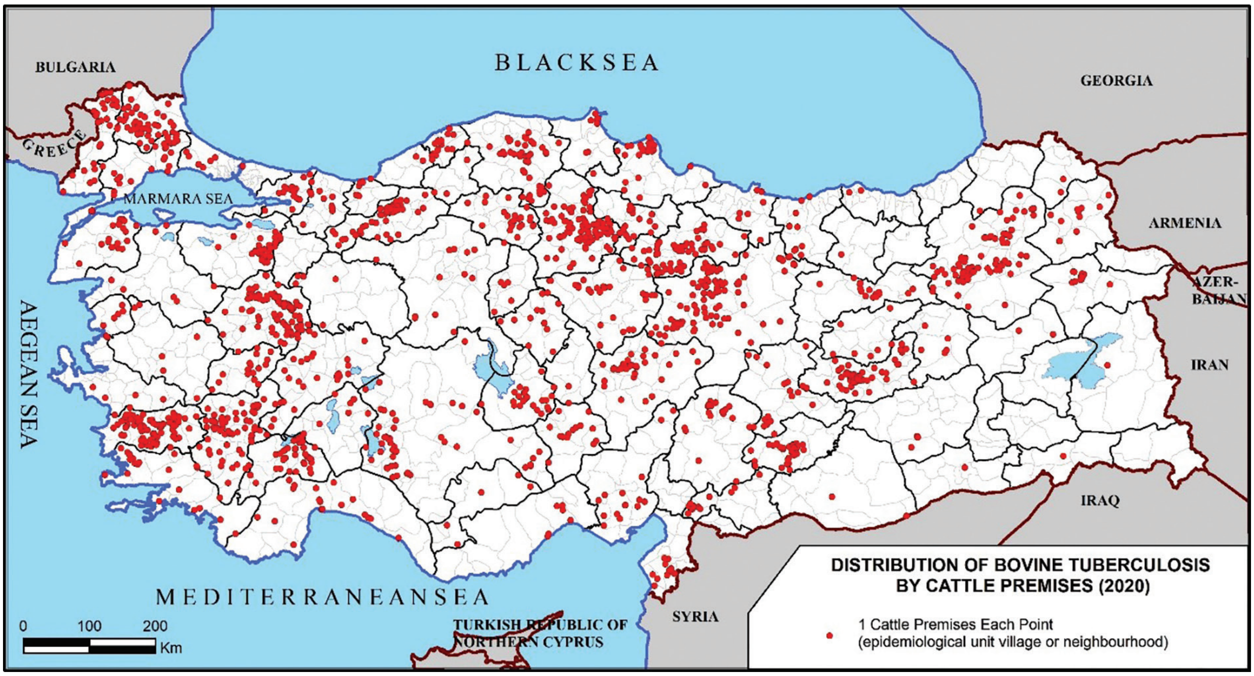

Figure 4. Annual distribution of bovine tuberculosis outbreaks in Türkiye (2020) (MoAF)

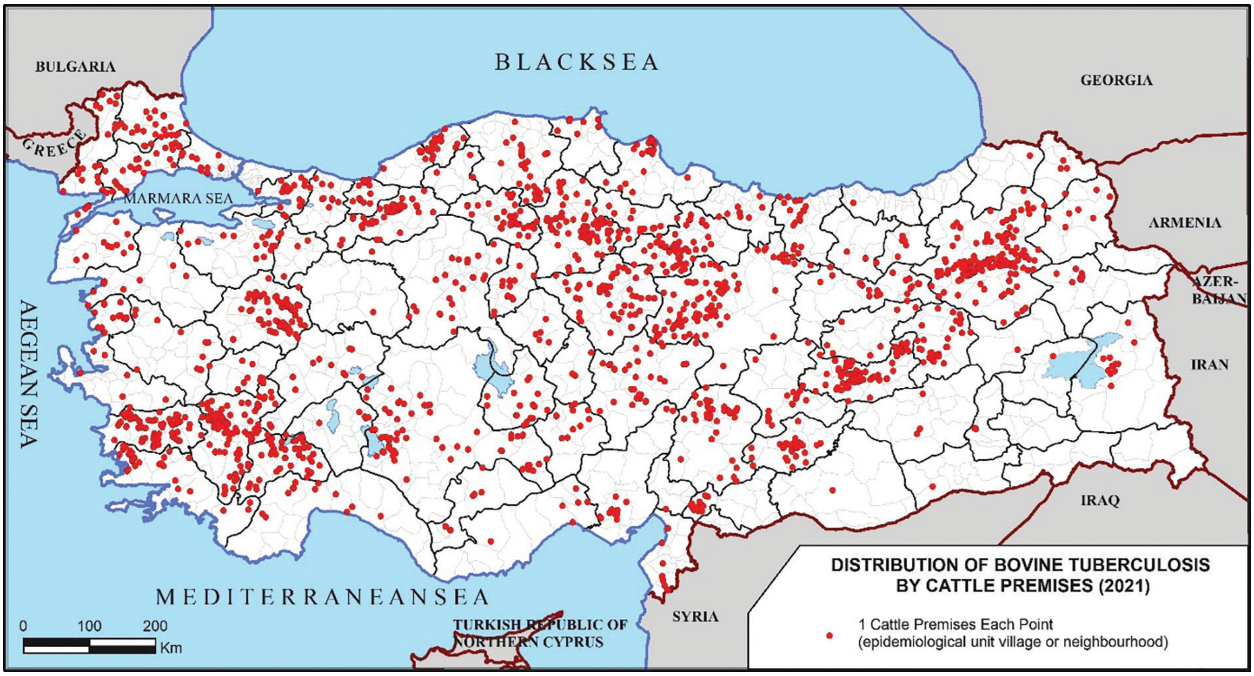

Figure 5. Annual distribution of bovine tuberculosis outbreaks in Türkiye (2021) (MoAF)

It is possible to draw conclusions based on the distribution of bTB within the country over the last five years. First of all, the distribution according to the provinces Çakır et al. (2021) demonstrates that there is no homogeneous distribution when the distribution according to the premises within the province is considered. In other words, the unequal distribution pattern within the country according to the provinces is even more irregular when the premises within the province are taken into consideration. Second, it is understood that while it is very rare or nonexistent in some regions of country, it tends to cluster in others. Thirdly, it is noteworthy that neither the clustered areas nor the extremely rare or absent areas exhibit a significant shift in the outbreaks between years. Naturally, this does not imply that the fields where bTB has been detected by year have not been expanded in any way. The appearance of clustering areas on maps, which mostly correspond to the same epidemiological areas, is consistent with the finding of at least 45.1% of bTB disease in other premises in the same settlement in another study on infection dynamics (Çakır et al. 2022). Moreover, as can be seen in the national filiation graphs, the high rate of latent/subclinical infection in the premises confirms this idea. Animal movements in these places give the impression that there is an increase in the number of outbreaks due to the increase in transmission as a result of direct or indirect contact. It is seen that bTB outbreaks are concentrated in Thrace, the east and south of the Izmit Gulf, the Big Menderes Basin in the Aegean region, the Central Black Sea, the north and east of Central Anatolia, and in areas on a diagonal line stretching from Kars to Adana. On the other hand, it is noteworthy that there are few or no some provinces in the Eastern Black Sea Region and in the provinces east of the Kars-Adana line (Figure 6).

It has been mapped to explain the relationality of bTB outbreak distribution in Türkiye to the presence of cattle. For the year 2021, the presence of cattle taken from TSI according to the districts was mapped by using a color-graded legend according to the district areas(Figure7).

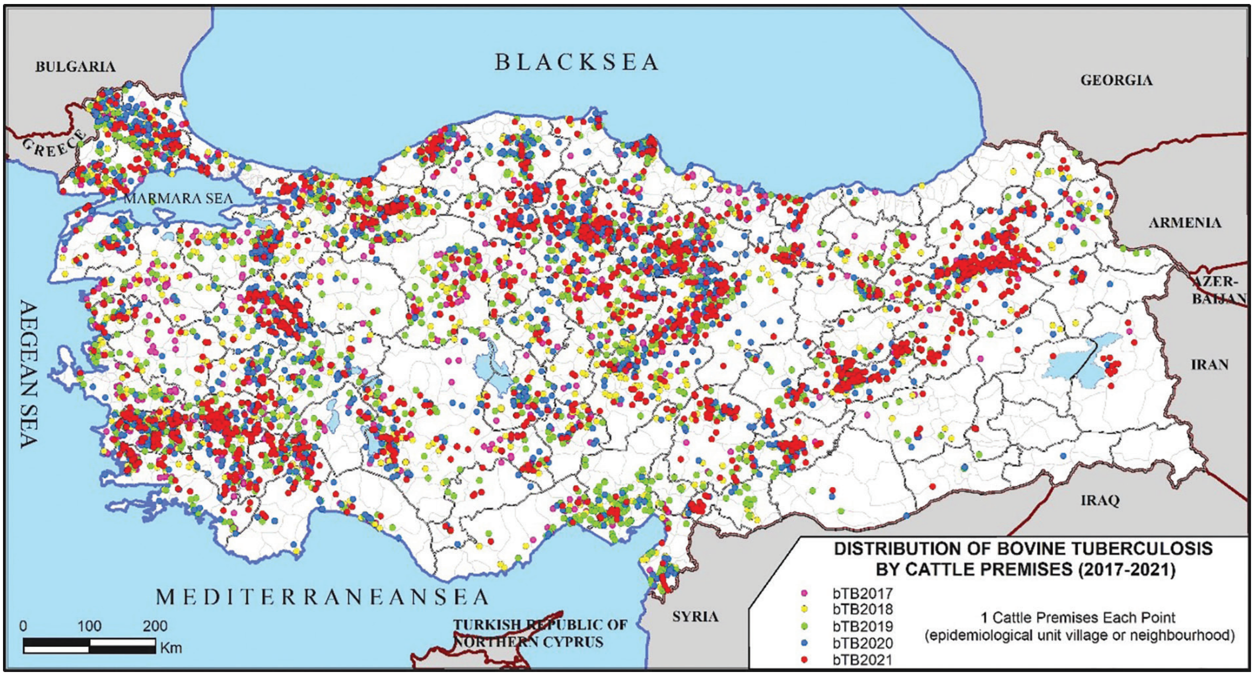

Figure 6. Total distribution of bovine tuberculosis outbreaks in Türkiye (2017-2021) (MoAF)

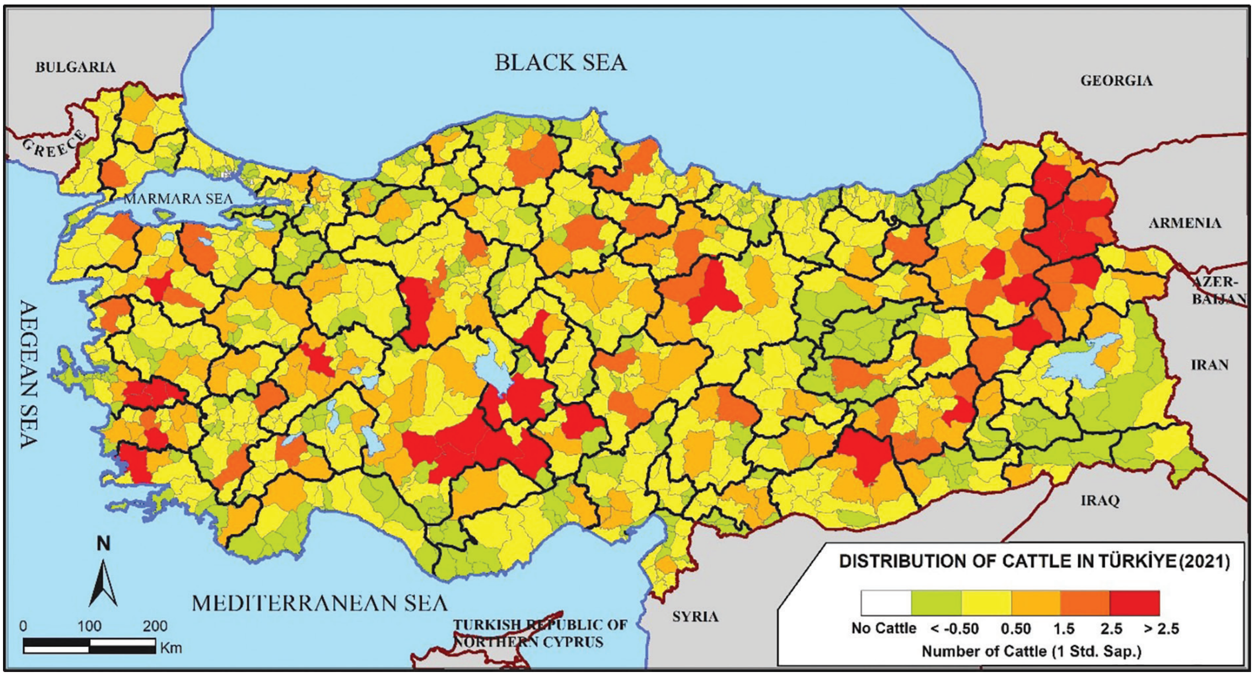

Figure 7. Distribution of cattle numbers by districts in Türkiye (2021) (TSI)

It is noteworthy that the clustering areas of the outbreak numbers and the areas with positive standard deviation areas of the cattle presence are somewhat similar to each other, but this similarity is not very advanced. The provinces of Erzurum and Kars and the areas from the west of Sivas province towards Çorum can be given as examples of similar areas. In order to determine the relationship between the number of animals in the districts and the outbreaks, the number of outbreaks was rearranged according to the districts (depending on the information of which province the premises in the data are in the district), and a correlation analysis between these two data sets was performed. The correlation analysis showed that there was a slightly positive (r=0.33) relationship. This shows that the density of the bTB outbreak does not depend only on the size of the cattle presence but also other variables. Increased animal movements between premises and the activities of animal traders (cattle-dealers) in these places; the establishment of a large number of animal markets; pastures, water sources, bull use, milking units, etc. can be the result of factors like increased animal contact as a result of circumstances. It is obvious that it will not be easy to maintain the free status of the officially bTB-free (OTF) premises operating in these regions, which are important for the existence of healthy breeding cattle. In these places, disinfection and biosecurity measures will need to be further increased to prevent the transmission of OTF premises.

Mapping of bovine tuberculosis outbreaks in Erzurum province

The province of Erzurum, one of the leading provinces in terms of both the total presence of cattle and the number of outbreaks, was also mapped and the filiation indicators were examined in order to determine how the appearance is or changes in a province within the spatial distribution of bTB throughout the country. Considering the importance of animal husbandry in the economy of Erzurum province, the increasing trend of bTB outbreaks in the province recently constitutes another dimension of the province that is worth examining closely.

Erzurum province, where a total of 958 bTB outbreaks have seen between 2005 and 2021, is the province with the most outbreaks emerge in the country. In the last five years, the number of outbreaks in the province, which was 40 in 2017, increased by 5.5 times in 2021 and reached 220, indicating that the disease has gained momentum in recent years. Although the fact that there is the most outbreak emerge in Erzurum is perceived as negative at first glance, it is an indication that although the conditions in the region are difficult, serious importance is attached to the fight against the disease here. In terms of cattle presence in the province, it is seen that as of 2021 (860,404 cattle), it is in second place after Konya.

It is noteworthy that the distribution of bTB outbreaks in the Erzurum province between 2017 and 2021 does not reflect a uniform distribution throughout the region (Figure 8). Although there are no new cases of disease in Pazaryolu district, it is seen that outbreaks are very rare in the districts in the north (Olur, Uzundere) and south (Hınıs, Karaçoban) of the province and they are concentrated in Palandöken, Aziziye, Yakutiye, Pasinler, Aşkale, Narman, Köprüköy, and Horasan districts in the depression area in the east-west direction. As a matter of fact, Abdurrahman Gazi Neighbourhood (22 premises), Hüseyin Avni Ulaş Neighbourhood (18 premises) of Palandöken district and Dadaşköy (16 premises) of Yakutiye district are the epidemiological units with the most outbreaks in the province. The fact that outbreaks occur again in the same premises as of 2017-2021 causes the clustering areas on the map to show continuity in the same areas without change over the years.

These districts of Erzurum, which have been on the main transportation route in the east-west direction from past to present, are important both in terms of animal existence and animal trade. It is belived that the long, harsh winter season, which keeps the animals in enclosed environments for a long time as well as the increasing animal movements brought on by the live animal trade, increases the spread of disease in the premises because of the importance of animal husbandry for the province’s economy. Its spread among premises is considered to be due to dynamics similar to those across the country, such as undocumented animal movements, activities of animal traders, animal markets, the density of livestock, pasture livestock, and common uses. The density of the facilities related to the animal food industry in this province is also noteworthy. Considering not only its economic dimension but also its zoonotic effect in terms of public health in the province, some basic strategies should be developed in the fight against bTB. At this point, in order to prevent the spread of the disease within the province and among the provinces, it is important to monitor the infection dynamics even more closely of the premises in the district and village epidemiological units where the highest number of outbreaks in the province is concentrated.

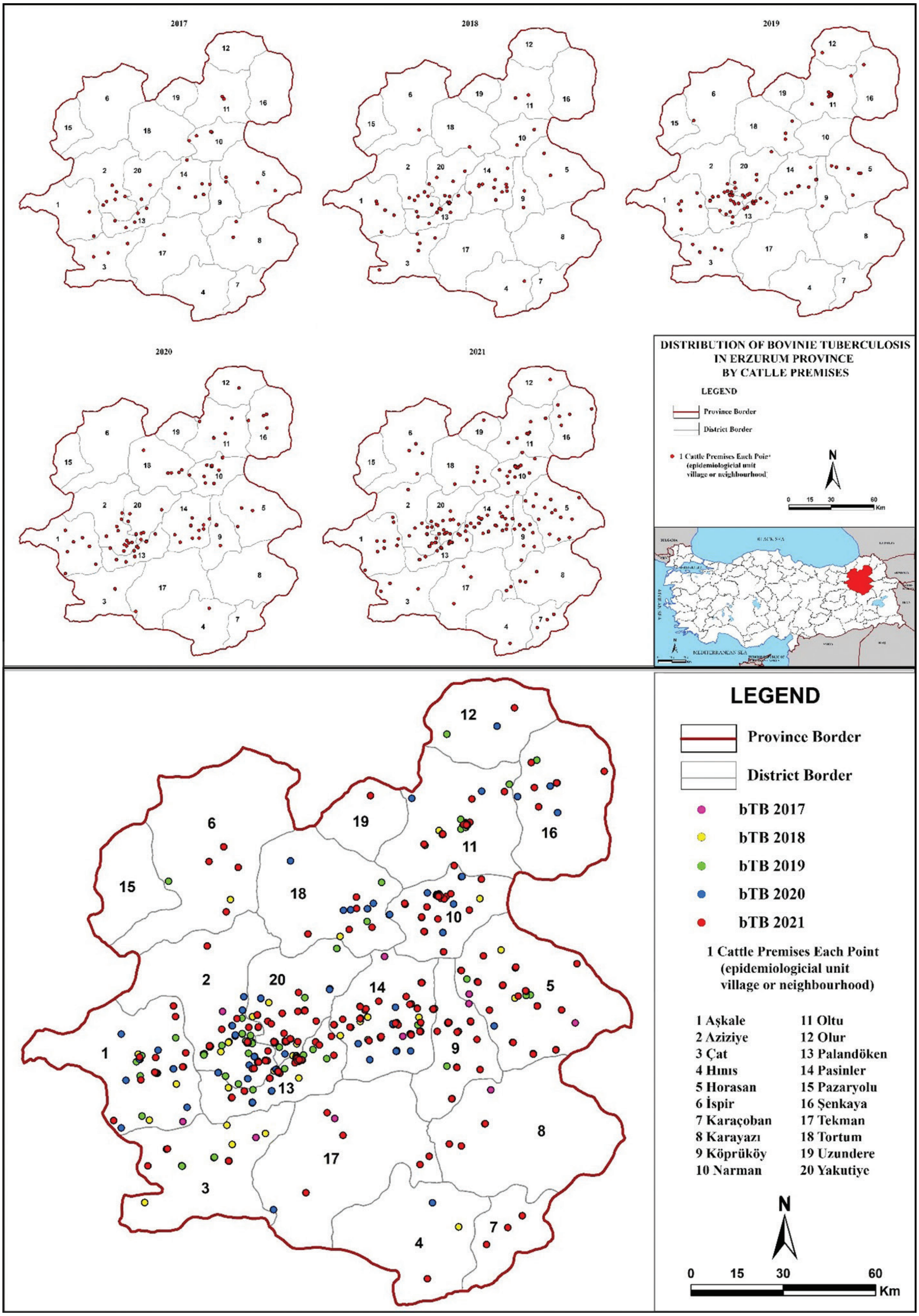

Figure 8. Distribution of bovine tuberculosis outbreaks in Erzurum province (above by years, below by 2017-2021 total) (MoAF)

Filiation of bovine tuberculosis outbreaks in Türkiye and Erzurum province

In epidemiological research, it is extremely important to monitor all stages of infection and to follow the whole process from beginning to end to determine its effects. Thus, real data collected from the field is necessary to understand the dynamics of the infection. In addition, this data is effectively used as a decision support tool in the process of determining the strategies to fight the disease, using the financial resources on-site, and putting them into practice. The data entered into the VETBIS database by the official veterinarians working in the provincial organization of MoAF provided very important information about the scope of the studies carried out on filiation. The filiation records kept on the bTB outbreaks were grouped under 17 different headings. While 7 headings from these groups stand out, under the other headings were collected because of the small value in the number of headings; the animals distributed from the young farmer project, vector transmission, infected animal feed, infected bull, iatrogenic transmission, transmission in the transport vehicle, indirect and direct contact with wildlife. Thus, it was possible to create graphs on the filiation of bTB outbreaks throughout the country (Figure 9).

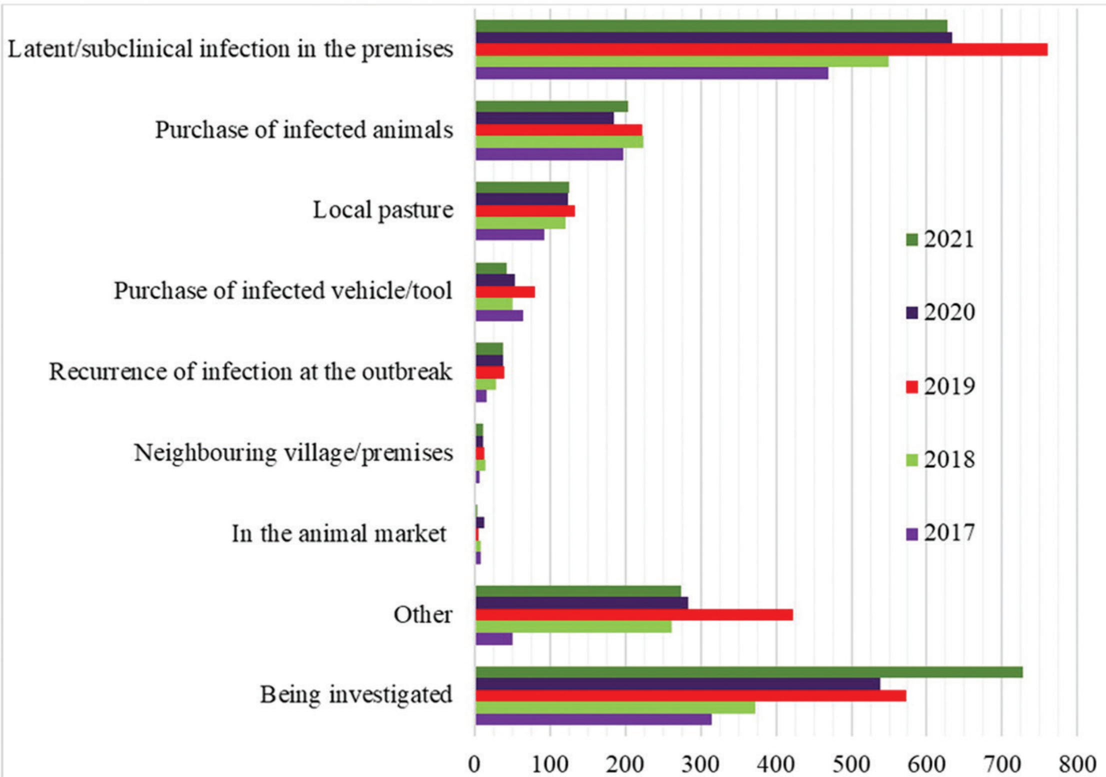

Figure 9. Comparative filiation graph of bovine tuberculosis outbreaks in Türkiye by years (2017-2021) (MoAF)

When the graph obtained from the filiation data of the bTB outbreaks across the country was examined, 28% of the 9,026 premises in total for the years 2017-2021 were classified under the heading of "being investigated" and 72% of them were determined. According to the distribution in the premises with determined filiation, the first three places are latent/subclinical infection, purchase of infected animals, and local pasture (Figure 10). This indicates that the infection continues to exist due to environmental contamination or due to the incomplete sensitivity and specificity of antemortem tests, even if the disease is extinguished in the premises. However, it should be taken into account that this distribution can vary according to the provinces.

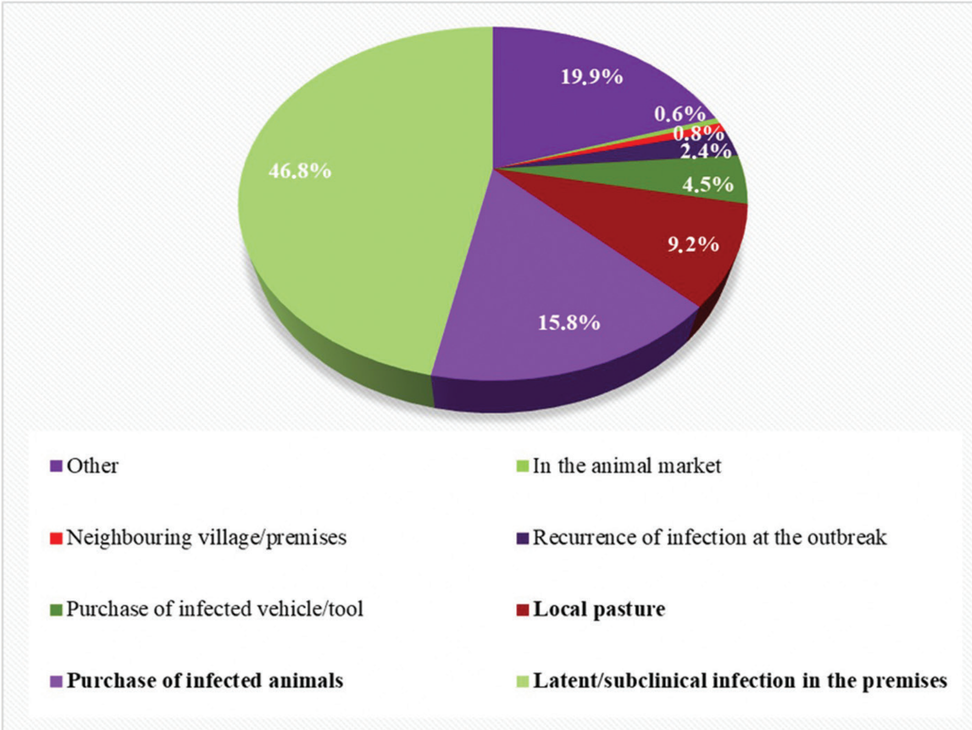

Figure 10. Filiation graph of bovine tuberculosis outbreaks in Türkiye with percent distribution (2017-2021) (MoAF)

The five-year filiation data reported from Erzurum province reveals that 92.3% of the filiation detections are made once the "being investigated" heading is excluded from the grouping. Compared to the Türkiye-wide filiation data, in the first three headings that constitute 69.3% of the graph; the purchase of infected animals ranks first with a rate of 52.6%, latent/subclinical infection in the premises ranks second with a rate of 11.1% and the purchase of infected vehicle/tool ranks third with a rate of 5.6%. When these data are properly examined, it is determined that the purchased infected animal is the main source of infection transmission to the premises in Erzurum province. This determination coincides with the determination of the purchase of infected animals as the main source of infection transmission to the premises in the research conducted according to the data collected from the field by (Çakır et al. 2022).

With the increase in animal movements on the premises, the risk of transmission of the infection to the premises increases in direct proportion. So, the entry of infection into the premises is largely through the purchase of infected animals. Between 2017 and 2021, a total of over 2 million animal movements were made in the form of departures (live, dead) and arrivals (live, dead) to 8,606 premises with bTB outbreaks. During this period, there were over 150 thousand animal movements in Erzurum province in the same way. Animal movements in these premises are included before the outbreak of the disease, animals sent to slaughter during the quarantine period, and all movements made after the disease's extinction. This situation shows how animal movements are an important risk factor for the spread of the disease. When bringing animals to the premises, this risk should be considered in light of the dynamics of bTB infection transmission, and if at all possible, purchasing animals from OTF premises should be chosen. Another important risk factor for the transmission of infection is indirect environmental interaction between susceptible animals and infected animals in nearby pasture. Contact with other herds and animals should be avoided as much as possible to reduce the risk of environmental contamination. Contact with wildlife, which is common in many nations, may be another way for the pasture to transmit the disease, but there is no scientific evidence for this in Türkiye.

Discussion and Conclusion

The increasing number of bTB in Türkiye since the beginning of the XXIst century reveals the importance and justification of epidemiological research on this subject. At this point, epidemiological dynamics of infection Çakır et al. (2022) and causalities in disease emergence and strategies for resolution Çakır and Diker (2021), as well as a spatial distribution of the disease and its change over time Çakır et al. (2021) are important. Considering the dynamics of the transmission of the disease, the spatial spread should be closely monitored at varying scales. In particular, to determine the strategies and clustering areas in the fight against the disease, it is possible to extend the scale spatially beyond the provincial level by most realistically mapping the distribution. In this study, thanks to the geographical coordinates kept in VETBIS, it was possible to map the bTB outbreaks at each premises level, and thus the most detailed pattern of the disease was revealed. In addition to determining the distribution on a national scale, the distribution was also mapped on a local scale in the Erzurum province sample. Besides, graphs of epidemiologically precious filiation data in the same dataset were created.

In the mapping of bTB both at the national scale and in the province of Erzurum, it has been clearly revealed that it tends to cluster in certain areas. It is also noteworthy that this trend is continuous without showing great changes over the years. Considering that there are several factors that are effective in shaping the emerging patterns, the clustering areas to fight the disease have been clearly determined. When the dynamics of the spread of infection and its filiation are considered together, it requires determining the strategies to be applied by taking into account the spatial clustering areas and following them more strictly. The reflections of other transmission risks such as the establishment of many animal markets, especially the live animal trade, and the increase in common contact among animals in these designated cluster areas should be closely monitored to control the disease. At this point, there is a need for other datasets on a national scale, both to understand the emergence and spread of the disease and to achieve success in the fight on the field. Besides, research needs to be further deepened with a multidisciplinary approach to make a meaningful contribution to epidemiological research in the fight against the disease.

In the world today, GIS is used in much of research effectively in the decision-making processes of the fight against TB in both domestic and wildlife (Çiçek and Şenkul 2006; Marsot et al. 2016; Adkin et al. 2016; Ribeiro-Lima et al. 2016). The use of GIS in veterinary epidemiology is critical both in determining the emergence and spread of the disease by revealing its spatial appearance and temporal spread direction and for taking into account the spatial dimension in the strategies to fight the disease. With this research, thanks to the geographical coordinate data of the bTB outbreak premises kept in VETBIS for the first time in Türkiye, the spatial pattern of the bTB outbreaks at the most detailed scale was illustrated with maps using GIS, and the filiation data was visualized by transferring them to graphs. Thus, it is expected to be an effective decision support tool in determining the five-year spatial and temporal dimension of the disease and determining its filiation and forming strategies in the national fight against the disease, the correct allocation of public funding, taking and implementing managerial decisions (Çiçek and Şenkul 2006; Çiçek et al. 2008; Mengistu and Haile 2017; Fayisa 2020).

In a sense, this research will be a guide in terms of laying the groundwork and directing other research to be done on this subject in the future. It will be important in terms of epidemiological observation to create spot maps with color indicators on the instant VETBIS with data on the locations of the outbreaks determined by GPS, and their active and extinguished states. *M. bovis* strains isolated from bTB outbreaks can be made in more advanced studies by spoligotyping by molecular methods (such as VNTR, MLVA, and WGS), by extracting the phylogenetic tree, and by network analysis according to the time of disease emergence.

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