Spatial epidemiological analysis of American foulbrood outbreaks over the past 18 years in Türkiye

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ABSTRACT

American foulbrood (AFB), a highly infectious and fatal disease of honey bees, is caused by Paenibacillus larvae. Despite its beekeeping and economic importance, little is known about the historical epidemiology and geographical distribution of AFB in bees. The aim of this study was to evaluate AFB clusters across Türkiye, and to see how the cluster model has changed. In this study, a retrospective analysis of AFB epidemiology in Türkiye was performed, using data from outbreaks registered with the World Organisation for Animal Health (WOAH-OIE) between 2005 and 2022. Descriptive statistical analyses were performed to evaluate the number of outbreaks and cases by region, month, year and season. Spatial statistical tests (Local Moran's I and Getis-Ord Gi*) were used to locate potential AFB epidemiological clusters, and cartographic maps were produced. During the 18-year period, 403 outbreaks and 18,483 cases were recorded. The results of this study showed an irregular trend in the spread of AFB over the period studied. The results of this study show that the highest number of outbreaks and cases were detected in summer and spring, with rates of 30.77% and 37.46% respectively. The majority of outbreaks and cases were recorded in the Black Sea Region. Moran's statistics showed a positive spatial autocorrelation in AFB cases across the country for 2008-2010 and 2014-2016. The results of this study can contribute to our understanding of the spatial epidemiology of the disease, and provide policy makers with useful data for surveillance activities.

Key words: American foulbrood; honey bee colony; paenibacillus larvae; spatial analysis; Türkiye

Introduction

American foulbrood (AFB) is a devastating disease. It is caused by the Gram-positive spore-forming bacterium, Paenibacillus larvae. This bacterium can persist for decades and produces spores that are extremely long-lived (BERTOLOTTI et al., 2021; PAPIĆ et al., 2021). The disease is particularly progressive in larvae 12 to 36 hours old (SIK et al., 2022). Within the first 36 hours after hatching, endospores begin to infect honey bee larvae. Endospores begin to grow immediately after digestion, and continue to grow in the larval midgut for several days. They then remove the epithelium and peritrophic barrier of the midgut. This creates an entry point for bacteria to pass through the haemocoel, causing the larvae to die (AL-GHAMDI et al., 2021). Bees carrying food or a beekeeper using beekeeping tools can both transmit the spores. This condition is common in beehives and causes the disease to spread rapidly

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from colony to colony, causing significant financial losses to the beekeeping industry worldwide (BĄK et al., 2022).

In order to prevent the spread of the disease, many processes and precautions must be in place after the disease is detected (LOCKE et al., 2019). The disease has a significant impact on international trade, so the export and import of honey bees is only allowed in certain regulated circumstances (TEIXEIRA et al., 2018; WOAH- OIE, 2023). Due to its significant economic and epizootiological impact on beekeeping, WOAH has identified AFB as a serious contagious animal disease (MATOVIĆ et al., 2023). On every continent where honey bees and their subspecies are reared, AFB disease has been detected in a significant number of countries (GENERSCH, 2010; WOAH- OIE, 2023) .

Türkiye, which connects Europe and Asia, is home to a wide range of ecosystems and organisms, including, but not limited to, honey bees. It was estimated that honey and beeswax sales alone would contribute approximately $584 million to the Turkish economy in 2021 (MAYACK and HAKANOGLU, 2022). Furthermore, pollination by bees is thought to produce ten to fifteen times more value than beekeeping itself (OZKIRIM, 2018). Türkiye ranks third in the world, after mainland China and India, with an estimated eight million bee hives. In addition, Türkiye is the second largest producer of honey in the world, with an estimated production of 100,000 tonnes. As Türkiye produces relatively little honey per colony compared to many other countries, it is believed that beekeeping in Türkiye has not yet reached its full potential (MAYACK and HAKANOGLU, 2022). This could be the result of deteriorating bee health, among other things (CAKMAK and CAKMAK, 2016).

Honey bee diseases are expected to have a significant impact on bee health in Türkiye, as they are a major cause of honey bee losses worldwide (HRISTOV et al., 2020; MAYACK and HAKANOGLU, 2022). Geographical information systems (GIS) and exploratory spatial data analysis methods with adequate discriminatory power are crucial for monitoring infectious disease epidemiology and epidemic investigations (CHEN et al., 2020; BAYIR, 2023; BAYIR and GURCAN, 2023). There are insufficient studies on the spatial clustering of AFB reports using clustering algorithms. With this knowledge, the aim of the present study was to assess the AFB clusters located within the Turkish provinces and ascertain how the clustering pattern has changed. In order to assist in the development of disease control measures, and ultimately the elimination of the disease, this study focuses on conducting a comprehensive historical epidemiological investigation of the spatial patterns of AFB in Türkiye. The results of this study will also serve as a basis for the development of a spatial risk-based approach to AFB control and the formulation of regulations that can minimise the harmful consequences of the disease.

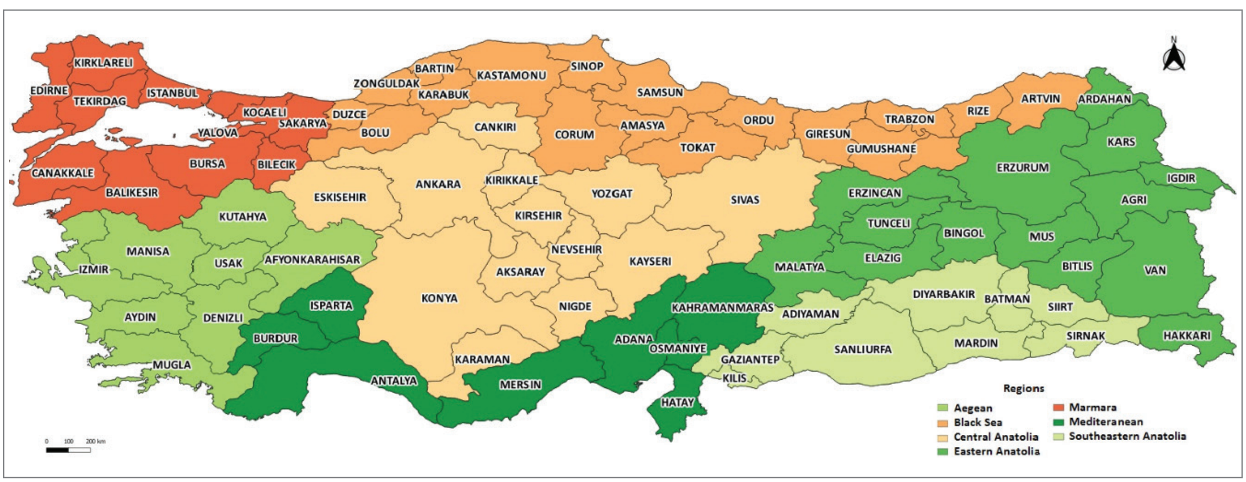

Fig. 1. The study area

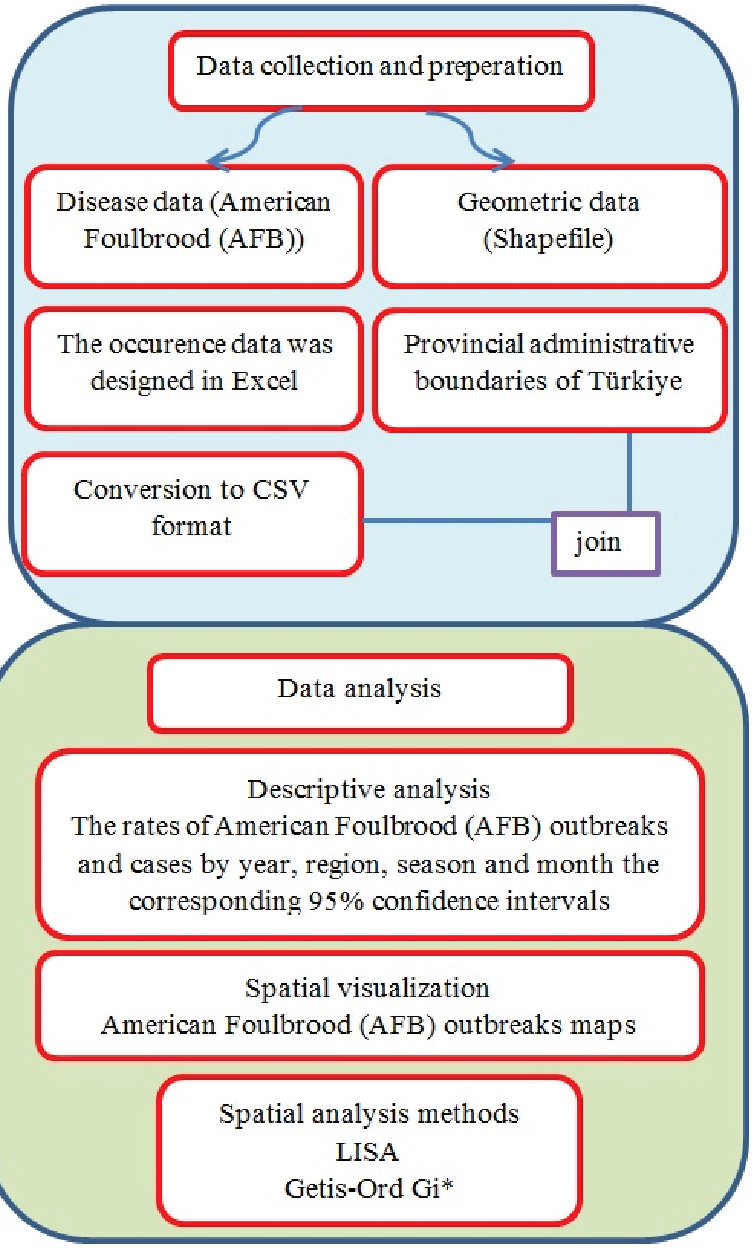

Fig. 2. The study's workflow

Materials and methods

Study Area and Framework of the Study. Türkiye is a bridge between Asia and Europe, connecting two continents. Türkiye is divided into 81 provinces. It is a nation with a population of 85,279,553 and an area of 780,580 km^2. The seven geographical regions of the nation are the Aegean, Black Sea, Central Anatolia, Eastern Anatolia, Marmara, Mediterranean, and Southeastern Anatolia (Fig. 1). The course of the study is summarised in Fig. 2.

Data Collection and Generation. In this study, geographic information showing province boundaries and information on AFB outbreaks by province were used. The number of cases and outbreaks of AFB reported annually by the World Organisation for Animal Health (WOAH-OIE) in Türkiye between 2005 and 2022 are among the AFB outbreak data considered in this study. The administrative boundaries of Turkish provinces, consisting of 81 provincial boundaries, are represented geographically using polygon shapes.

Descriptive Analysis. The study provides a summary of the proportions of AFB outbreaks and cases by region, month, season and year, with associated 95% CIs (confidence intervals) (Table 1). AFB data in Excel format were converted into CSV files. GIS was then used to create spatial maps of AFB outbreaks, and to assess the spatial spread of the disease. The whole study period was divided into six sub-periods and evaluated spatially for 2005-2007, 2008-2010, 2011-2013 and 2014-2016, 2017-2019, 2020-2022. Descriptive statistics were analysed using SPSS 23 software.

Exploratory Spatial Data Analysis. Exploratory spatial data analysis (ESDA) provides techniques for examining geographic clusters, detecting outliers, and displaying and illuminating data distribution (ANSELIN et al., 2006; ARAL AND BAKIR, 2022). By examining and evaluating clustered locations, it is possible to observe the spatial pattern of AFB outbreaks and how it has changed over time. ESDA was used to find differences in AFB between provinces. GeoDa spatial statistics software was used to check for spatial autocorrelation and clustering. The local Moran's I statistic was used to identify the geographical distribution of clusters, and the Getis-Ord-Gi* statistic was used to estimate the corresponding spatial distribution of hot and cold regions (MESSNER et al., 1999; ANSELIN et al., 2006).

When analysing the spatial data, a spatial weight matrix was used to determine how the provinces in the study were related to each other. The weight matrix below was used to represent the spatial relationship between the 81 provinces:

$$W = \begin{bmatrix} \omega_{1,1} & \cdots & \omega_{1,81} \\ \vdots & \ddots & \vdots \\ \omega_{81,1} & \cdots & \omega_{81,81} \end{bmatrix}$$

$\omega_{i,j}$, indicates the relationship between provinces i and j, *i, j* =1,2, …, 81. In this study, the queen contiguity matrix was used (ANSELIN, 1996).

Moran's I is a widely used statistic for examining spatial autocorrelation and detecting global spatial clusters. The local Moran's I is used to determine the strength of each parameter pattern. It examines the heterogeneity of a study area to find regional clusters and outliers. The presence of high or low values may be associated with statistically significant outliers. The cluster or outlier must have a sufficiently low p-value to be considered statistically significant (ANSELIN, 1995). The spatial autocorrelation properties of the AFB were assessed using Moran's I statistic. Moran's I statistic is expressed as follows:

$$I_i = n \times \frac{x_i \sum_{j=1}^{n} W_{ij}\left(x_j - \bar{x}\right)}{\sum_{j=1}^{n}\left(x_j - \bar{x}\right)^2}$$

local spatial autocorrelation measure; n indicates the number of provinces i and provinces j; and are the values of the variable of at provinces i and j; the matrix of spatial weight.

The range for the Moran's I statistic is -1 to +1. The distribution of the cluster score is random if the statistic is not far from zero. The distribution of all the provinces that make up the research is random when this value is zero, because there is no spatial autocorrelation and there are no clusters in the area. The value of the Moran statistic is positive when similar data are spatially clustered, and negative when there are outliers (ANSELIN, 1996).

The Getis-Ord Gi* is another common approach to estimate local spatial autocorrelation (ORD and GETIS, 1995; ANSELIN, 2019). The Gi * statistic was calculated to determine the hot and cold AFB areas. The Gi * statistic is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij}x_j - \bar{x}\sum_{j=1}^{n} w_{ij}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2\right]}{n-1}}}$$

Results

Descriptive statistics. In total, 62 provinces reported 403 AFB outbreaks and 18,483 AFB cases over the eighteen years (2005-2022). The highest number of AFB outbreaks was recorded in the month of May (12.16%) and during the summer season (30.77%). The highest number

Table 1. Distribution of American Foulbrood (AFB) data reported in Türkiye during 2005 – 2022

Year	Outbreak	%	95% CI	Case	%	95% CI
2005	6	1.49	0.50-2.73	202	1.09	0.95-1.25
2006	24	5.96	3.72-8.19	824	4.46	4.15-4.75
2007	14	3.47	1.99-5.45	605	3.27	3.01-3.57
2008	18	4.47	2.48-6.45	238	1.29	1.14-1.46
2009	19	4.71	2.73-6.70	1107	5.99	5.64-6.35
2010	11	2.73	1.49-4.47	107	0.58	0.47-0.69
2011	13	3.23	1.49-4.96	717	3.88	3.62-4.16
2012	20	4.96	2.98-7.20	526	2.85	2.62-3.09
2013	20	4.96	2.98-7.20	247	1.34	1.17-1.50
2014	8	1.99	0.74-3.72	118	0.64	0.53-0.76
2015	22	5.46	3.47-7.69	443	2.40	2.19-2.62
2016	21	5.21	3.23-7.44	528	2.86	2.61-3.11
2017	33	8.19	5.46-10.91	3440	18.61	18.03-19.19
2018	25	6.20	3.97-8.44	1616	8.74	8.35-9.15
2019	74	18.36	14.64-22.08	4125	22.32	21.72-22.94
2020	49	12.16	8.94-15.63	1788	9.67	9.27-10.10
2021	15	3.72	1.99-5.71	1370	7.41	7.03-7.79
2022	11	2.73	1.24-4.47	482	2.61	2.38-2.83
Region						
Mediterranean	44	10.92	7.94-14.14	3428	18.55	17.97-19.12
Eastern Anatolia	79	19.60	15.63-23.57	2901	15.70	15.18-16.26
Aegean	17	4.22	2.48-6.45	747	4.04	3.77-4.34
Southeastern Anatolia	3	0.74	0.00-1.74	348	1.88	1.70-2.10
Central Anatolia	51	12.66	9.43-16.13	2123	11.49	11.03-11.97
Black Sea	146	36.23	31.27-40.94	5754	31.13	30.47-31.80
Marmara	63	15.63	12.16-19.11	3182	17.22	16.71-17.72
Season						
Autumn	74	18.36	14.64-21.84	3875	20.97	20.33-21.58
Spring	121	30.02	25.81-34.24	6923	37.46	36.79-38.20
Summer	124	30.77	26.55-35.48	3373	18.25	17.70-18.79
Winter	84	20.84	17.12-25.06	4312	23.33	22.73-23.92
Month						
January	43	10.67	7.94-13.65	1634	8.84	8.46-9.28
February	29	7.20	4.71-9.68	2312	12.51	12.06-12.97
March	41	10.17	7.20-13.15	3105	16.80	16.26-17.30
Aprıl	31	7.69	5.21-10.17	1425	7.71	7.30-8.12
May	49	12.16	9.18-15.38	2393	12.95	12.44-13.41
June	47	11.66	8.68-14.89	1202	6.50	6.15-6.87
July	43	10.67	7.94-13.90	1484	8.03	7.63-8.42
August	34	8.44	5.71-11.17	687	3.72	3.47-4.01
September	27	6.70	4.47-9.18	2031	10.99	10.52-11.41
October	32	7.94	5.46-10.42	1014	5.49	5.17-5.80
November	15	3.72	1.99-5.71	830	4.49	4.20-4.80
December	12	2.98	1.49-4.71	366	1.98	1.79-2.17

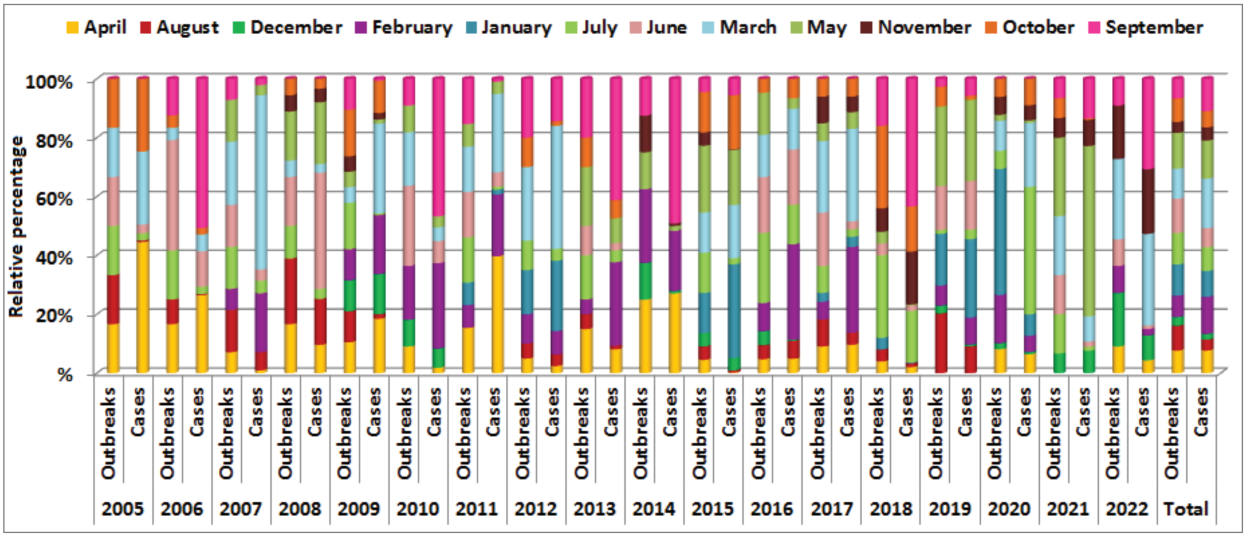

Fig. 3. Month-wise analysis of cumulative American Foulbrood (AFB) outbreaks and cases in different years in Türkiye over the 2005-2022 period

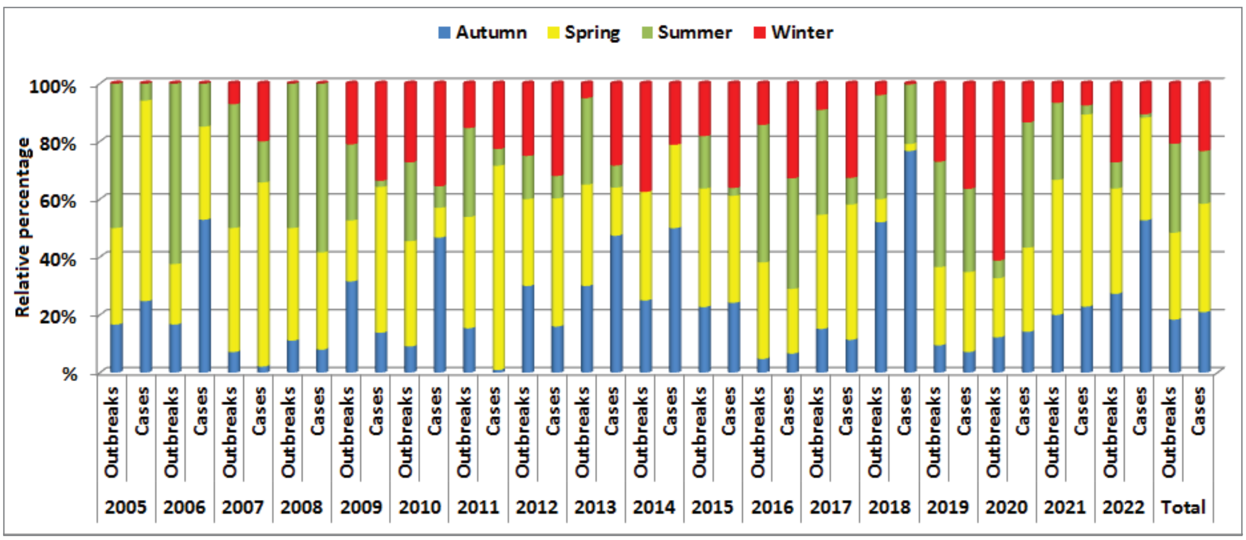

Fig. 4. Season-wise analysis of cumulative American Foulbrood (AFB) outbreaks and cases in different years in Türkiye over the 2005-2022 period

of AFB cases was recorded in the month of March (16.80%) and during the spring season (37.46%). The Black Sea Region had the highest percentage of reported outbreaks and cases (36.23%-31.13%), and the Southeastern Anatolia Region had the lowest percentage of reported outbreaks and cases (0.74%-1.88%) (Table 1). The analysis of cumulative AFB outbreaks and cases in different years in Türkiye during the period 2005-2022 by month and season is shown in Fig. 3 and 4.

Spatial Statistics. Thematic maps were produced using QGIS software (QGIS version 3.18.3). The thematic maps show AFB outbreaks in the provinces between 2005 and 2022 (Fig. 5).

This study investigated whether there was spatial correlation in AFB cases in Türkiye. Moran's I measurements were performed for the relevant time periods to assess the association between the number of AFB cases in each province and the number of cases in neighbouring provinces. The calculated Moran's I were -0.0471 (Z-score = -0.5677, P>0.05,

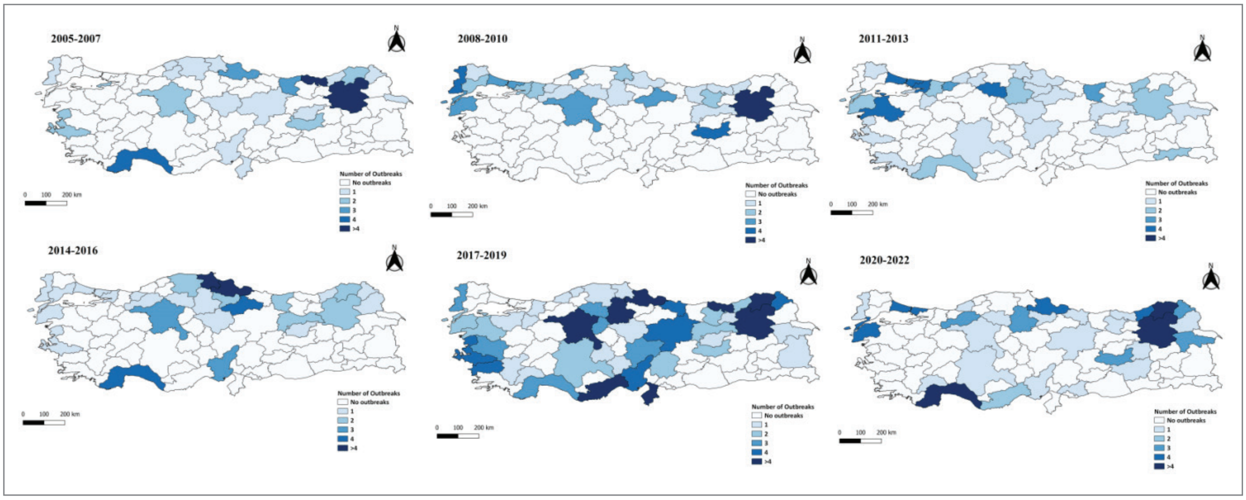

Fig. 5. Distribution of American Foulbrood (AFB) outbreaks in Türkiye over the 2005-2022 period (at province level)

random); 0.0517 (Z-score = 2.1076, P<0.05, clustered); 0.0538 (Z-score = 0.9634, P>0.05, random); 0.1539 (Z-score = 3.1132, P<0.05, clustered); 0.0078 (Z-score = 0.0478, P>0.05, random) and 0.0234 (Z-score = 0.5579 P>0.05, random), for 2005-2007, 2008-2010, 2011-2013 and 2014-2016, 2017-2019, 2020-2022, respectively (Table 2). These results indicate a positive spatial autocorrelation in AFB cases across the country for 2008-2010 and 2014-2016.

On the basis of the AFB case data for the six periods (2005-2007, 2008-2010, 2011-2013 and 2014-2016, 2017-2019 and 2020-2022), Local Indicators of Spatial Association (LISA) were calculated (Fig. 6). High-High clusters are shown in red and indicate a high number of cases in a province including a high number of cases in the neighbouring provinces, Low-Low clusters are shown in dark blue and indicate a low number of cases in a province including a low number of cases in the neighbouring provinces, High-Low outliers are shown in pink and reflect a high number of cases in a province including a low number of cases in the neighbouring provinces, Low-High outliers are shown in turquoise and reflect a low number of cases in a province including a high number of cases in the neighbouring provinces.

In order to locate the hot and cold AFB regions, the Gi* statistic was calculated. The Gi* uses information from each province affected by AFB to examine the local situation and compare it with that of the surrounding provinces. On the basis of data from 2005 to 2022, Gi* clusters indicate the risk of AFB. In this study, clusters of cold and hot spots were identified in Türkiye at both 90% and 95% confidence levels (Fig. 7).

Table 2. Spatial autocorrelation of different periods considered for hotspot analysis of the AFB using Moran's I statistics

Period	Moran's I	Z-score	P	Pattern
2005-2007	-0.0471	-0.5677	0.333	random
2008-2010	0.0517	2.1076	0.046	clustered
2011-2013	0.0538	0.9634	0.165	random
2014-2016	0.1539	3.1132	0.01	clustered
2017-2019	0.0078	0.0478	0.434	random
2020-2022	0.0234	0.5579	0.223	random

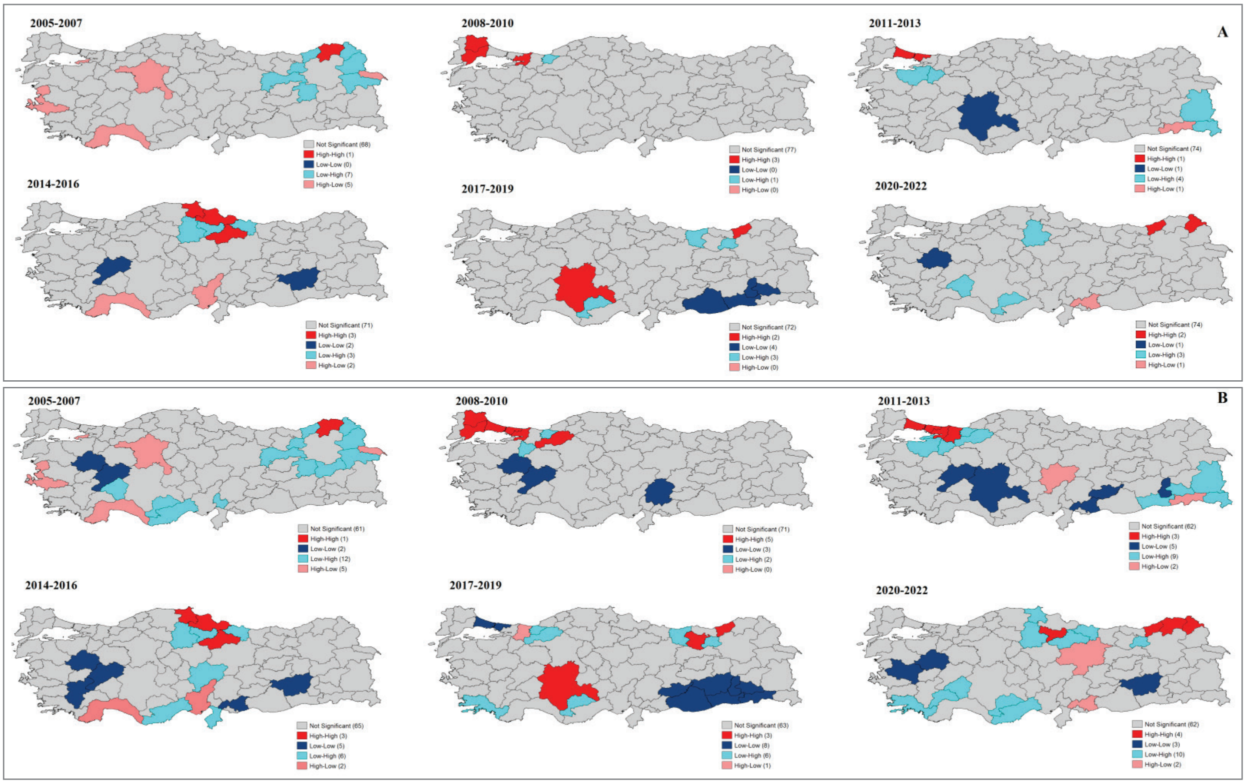

Fig. 6. Spatial clustering and outliers of American Foulbrood (AFB) using LISA clustering for the period examined (Fig A, 95% confidence interval, P-value=0.05; Fig B, 90% confidence interval, P-value=0.10)

Discussion

In view of the importance of beekeeping in Türkiye and worldwide, diseases (including parasitic, bacterial, viral and fungal infections) that affect honey bees are a crucial threat to the honey bee industry. Diseases that cause economic and production losses are the subject of extensive research on a global scale (BALKAYA, 2016). Some of the major challenges hindering the growth of beekeeping and affecting productivity are diseases and pests affecting honey bees (ALPAY KARAOGLU et al., 2023). TOMLJANOVİĆ et al. (2020) reported that 96.46% of beekeepers are in favour of early AFB diagnosis. Beekeepers stated that if they found the characteristic clinical symptoms of American foulbrood in colonies in their apiaries, most of them (55.24%) would consult a veterinarian, 34.29% would burn suspicious hives, but 7.62% stated that they could not recognise the signs of the disease.

Although bees have a very complex virosphere, most of our information on viruses and diseases in general comes from research on the domesticated western honey bee, Apis mellifera (BEAUREPAIRE et al., 2020). Information on cultivated honey bees suggests that currently known viruses appear to be globally distributed (BEAUREPAIRE et al., 2020; BONCRISTIANI et al., 2021). Climate is a factor that affects the whole bee community and its interaction with diseases. There are many studies showing that climate variables can affect both the honey bee as a host and its interactions with its (viral) pathogens (LE CONTE and NAVAJAS, 2008; APPLER et al., 2015; SWITANEK et al., 2017; DALMON et al., 2019; FLORES et al., 2019). PIOT et al. (2022) evaluated temperature and precipitation as climatic abiotic parameters and virus prevalence in wild bees, in relation to virus prevalence in sympatric honey bees as a biotic factor. Both biotic and abiotic variables were shown to influence virus prevalence in wild bee populations. There was only a weakly supported interaction effect between climatic conditions and virus prevalence in wild and sympatric bees.

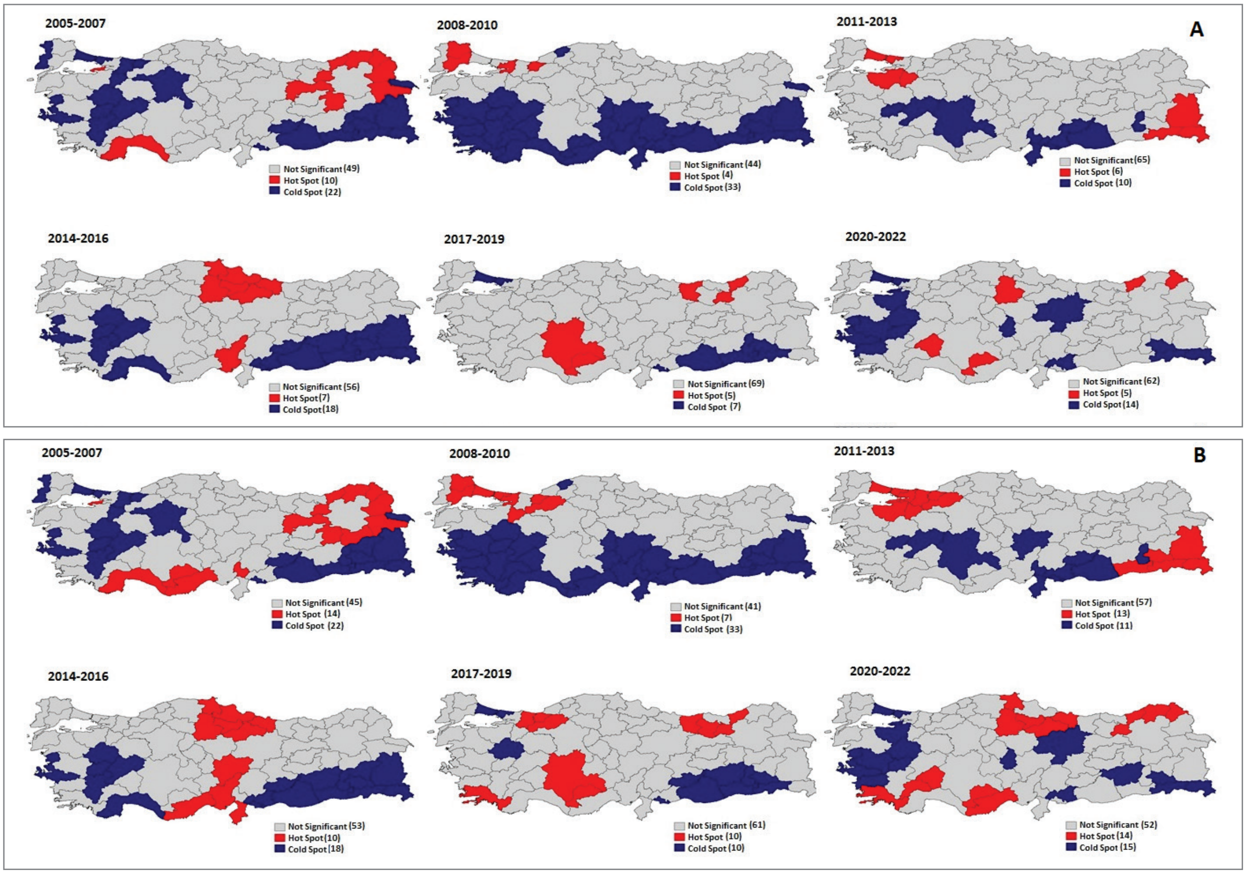

Fig. 7. Cold-hot spots of American Foulbrood (AFB) using the Gi* statistic for the period examined (Fig A, 95% confidence interval, P-value=0.05; Fig B, 90% confidence interval, P-value=0.10)

In this study, we present for the first time in Türkiye an historical epidemiological assessment of AFB disease and the spatial pattern of the disease, using exploratory spatial data analysis approaches. Evaluation of epidemic reports between 2005 and 2022 revealed a generally variable outbreak rate, with a peak in 2019 (n=74). In the last three years of the reporting period, there was a tendency for the number of cases to decrease (n = 1788 - 482). The results of this study showed an irregular trend in the spread of American foulbrood during the observation period. These findings are consistent with the results of a previous study that reported a strongly irregular trend in AFB (RUSENOVA and PARVANOV, 2016). The results of this study also show that the highest number of outbreaks and cases were detected in summer and spring seasons, with 30.77% and 37.46%, respectively. These results are in line with the conclusions of previous studies (JACQUES et al., 2017; SIK et al., 2022). AFB may be more common in summer due to parasitic mite infection, queen complications, and weaker colonies leading to dryness and increased susceptibility to disease.

This study revealed regional and provincial differences in AFB disease. The majority of outbreaks and cases were found in the Black Sea Region. Two separate studies examining the Tokat province in the Black Sea Region found that beekeepers were well aware of AFB and the disease caused major problems (PARLAKAY and ESENGUN, 2005; IVI YALCIN and ORUC BUYUKBAY, 2015). In addition, in another study investigating the Black Sea region, AFB disease was detected in the eastern Black Sea region (ALPAY KARAOGLU et al., 2023). The results obtained in this context are compatible with these studies. The fact that the Black Sea plays an important role in beekeeping and that beekeeping activities are intensive may be a cause of these epidemics. Although the Black Sea region has significant potential for beekeeping, it is one of the regions with major structural problems. According to the results of the present study, outbreaks are particularly frequent in the Black Sea region, which may be due to the persistence of structural problems there. In this study, among the data evaluated in Türkiye, the lowest number of outbreaks and cases were reported in the Southeastern Anatolia region. One of the possible reasons for this may be that beekeepers in the Southeastern Anatolia Region do not report the disease. In a study examining beekeeping activities in Southeastern Anatolia, it was stated that the effective fight against diseases and pests is in the last place of the factors affecting the yield and quality of production of honey bee products (KARAHAN and OZMEN OZBAKIR, 2020).

In the present study, the association between AFB cases in a province and AFB cases in neighbouring provinces was examined by first calculating Moran's I coefficients. Spatial autocorrelation showed whether AFB cases are associated with nearby locations. The Moran's statistics calculated showed clustering of AFB cases across the country for 2008-2010 and 2014-2016, and randomness in AFB cases for other years. Across the country, local clusters and outliers can be found using local spatial autocorrelation analysis. In this study, the number of High-High clusters showed diversity across the six periods, and the local correlation characteristics changed spatially over time. Throughout the period in Türkiye, High-High clusters were observed in the Black Sea region in 2014-2016 and in the Marmara region in 2008-2010 at 90%-95% CI. According to the Gi* cluster results, hotspots emerged in all regions of the country, and changes in hotspots over time were shown. Similarly, a study of AFB clustering in England and Wales found that the majority of clusters did not persist in all years (MILL et al., 2014). The irregular trend in the spread of American foulbrood can be explained by drifts in apiaries. This is because drift is a common phenomenon in apiaries, and the type of colony, the colour of the hive, and the environment all affect the intensity of drift. While GOODWIN et al. (1994) reported an AFB transmission rate of up to 8% in nearby healthy colonies when the amount of drifting was low, HORNITZKY (1998) reported no apparent risk of disease spread by drifting forager bees.

The current study has a number of limitations. Due to the semi-annual format of the available data, it was not possible to obtain immediate AFB outbreak reports. It would therefore be beneficial for future research if the data generated by the WOAH-OIE were made available immediately. In addition, it is important to note that clustering results need to be evaluated carefully. Since AFB outbreaks may not be reported to the appropriate authorities at certain times, the reports used in this study may not accurately reflect reality. The study is also limited by the lack of point data. Environmental risk factors and AFB outbreaks can be linked using spatial models.

Conclusions

Our results provide important new information on the epidemiology of AFB and show local clusters of AFB in Türkiye over the past 18 years. These epidemiological findings are crucial for the development of an infectious disease control plan. In light of the study's findings, it is considered crucial to focus on control and protection efforts, especially in areas where disease outbreaks are more likely to occur. Avoiding the use of antibiotics, working with genetically disease-resistant breeds and queens, educating beekeepers on how to manage the disease well, knowing that it is more dangerous than and different from other bee diseases, and frequently inspecting hives for early diagnosis are the most effective methods of control and protection. In the fight against this disease, adherence to protective and control measures is essential. In our nation, burning diseased colonies to ashes is the most permanent and efficient way to eradicate the disease. With the use of a blowtorch, the hive body should pass through the flame to stop the disease from spreading. Beekeeping supplies and equipment, such as feeders, queen bee grills, hand irons, masks, and bellows, should be thoroughly cleaned. Quarantining diseased colonies, destroying diseased hives and honey, and not transferring combs, bees and equipment from one colony to another prevent the spread of the disease. Nevertheless, it was concluded that the use of different spatial statistical approaches, and the improvement of epidemic data and changes for future studies are needed.

Declaration of competing interest

No potential conflicting interest was reported by the authors.

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BAYİR, T., U. USLU: Prostorna epidemiološka analiza izbijanja američke gnjiloće u proteklih 18 godina u Turskoj. Vet. arhiv 95, 99-112, 2025.

SAŽETAK

Američku gnjiloću (AFB), visoko infektivnu i smrtonosnu bolest medonosne pčele, uzrokuje larva *Paenibacillus*. Unatoč važnosti za pčelarstvo i gospodarstvo u cjelini, o epidemiologiji i rasprostranjenosti AFB-a u pčela malo se zna. Cilj istraživanja bio je procijeniti žarišta AFB-a diljem Turske i uočiti kako se model formiranja tih žarišta promijenio. Provedena je retrospektivna analiza epidemiologije AFB-a u Turskoj, u kojoj su korišteni podaci o izbijanju bolesti Svjetske organizacije za zdravlje životinja (engl. World Organisation for Animal Health, WOAH-OIE) između 2005. i 2022. godine. Deskriptivnom statističkom analizom procijenjen je broj izbijanja bolesti te broj slučajeva po regijama, mjesecima, godinama i sezoni. Primijenjena je prostorna statistička analiza (testovima Local Moran's I i Getis-Ord Gi*) kako bi se locirala potencijalna epidemiološka žarišta AFB-a te su izrađene odgovarajuće karte. Tijekom 18-godišnjeg razdoblja zabilježena su 403 izbijanja i 18 483 slučajeva bolesti. Rezultati istraživanja pokazali su neravnomjerno širenje bolesti u promatranom razdoblju. Najveći broj izbijanja bolesti i najveći broj slučajeva zabilježeni su u ljeto i proljeće, sa stopama pojavnosti od 30,77% za ljeto i 37,46% za proljeće. Većina je slučajeva i izbijanja bolesti zabilježena u crnomorskoj regiji. Moranova statistika pokazala je pozitivnu prostornu autokorelaciju u slučajevima AFB-a diljem zemlje za razdoblja 2008.- 2010. i 2014.- 2016. Rezultati istraživanja mogu pridonijeti razumijevanju prostorne epidemiologije američke gnjiloće u pčela i pružiti korisne podatke za izradu strategija praćenja ove bolesti.

Ključne riječi: američka gnjiloća; medonosne pčele; larva *Paenibacillus*; prostorna analiza; Turska