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Analyzing risk factors for lumpy skin disease by a geographic information system (GIS) in Turkey

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Analyzing risk factors for lumpy skin disease by a geographic information system (GIS) in Turkey

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ABSTRACT. Lumpy skin disease (LSD) is caused by the virus of the same name and has major economic impacts on cattle breeding. In Turkey, frequent cases of cattle LSD have been reported over the last years. The present study aimed to analyze potential risk factors for LSD and provide information for controlling the spread of infectious diseases by a geographic information system (GIS). The research included cross-sectional and retrospective studies with active disease follow-up and semi-structured interviews (SSI) from August 2013 to December 2014 in Turkey. Potential risk factors for LSD were evaluated based on environmental conditions and provincial demographic and epidemiological data. Of the total of 562 observed animals, 27.22% and 2.67% of cattle were sick and died due to LSD, respectively. The morbidity rate was 26.04% in mixed and 38.18% in local breeds. The animal-level prevalence significantly differed among animals of different age, sex, and with different vaccination status ($P<0.05$). It was more serious in younger animals and females and during drier weather conditions. A trend of seasonality was observed in LSD occurrence. Significant risk factors affecting the prevalence of LSD were proximity to the southern border of Turkey, animal movements, and animal markets. In this process, geographical query, analysis, and thematic map production were performed by GIS.

Keywords: LSD, Epidemiology, Risk factors, GIS, Animal Movement

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INTRODUCTION

Lumpy skin disease (LSD) is a poxviral infection of cattle caused by lumpy skin disease virus of the genus Capripoxvirus. It is a Neethling virus. This pox virus causes an acute to a sub-acute systemic disease characterized by mild to severe symptoms including fever, nodules in the skin, mucous membranes, and internal organs, and sometimes death (Davies, 1982). In general, mortality is low (1–3%), but up to 75% mortality has been reported (Babiuk et al., 2008). LSD is associated with significant production losses. It is therefore defined as a notifiable disease by the World Organization for Animal Health (OIE, 2000). LSD is related to various factors that cause significant financial losses on a national scale: restrictions on the global trade of live animals and their products (Rich and Perry, 2011, Tuppurainen and Oura, 2012).

LSD infection has a wide distribution in most African countries (Niger, Sudan, Uganda, Ethiopia, Somalia, etc.) and has recently entered into the Middle East (EFSA, 2015). In this study, we assess risk factors in the spread of LSD in Turkey from the Middle East as well as the risks of further spread. Moreover, the present study aimed to analyze potential risk factors for LSD. We address the epidemiology of LSD, its mechanisms of transmission, the potential role of risk factors in reducing spread, and currently available control strategies. The first findings on LSD in Turkey were reported in mid-2013, and potential LSD vectors, such as animal movement (Alemayehu et al., 2013) and blood-sucking insects (Tuppurainen et al., 2011), were identified. Despite this knowledge, the epidemiological status of cattle LSD in Turkey and its risk factors are not completely understood. This study aims to reveal LSD-infected cattle farm areas and analyze risk factors such as cattle sex, increasing age, cattle breed, season, and vaccination using a Geographic Information System (GIS).

MATERIAL AND METHODS

Epidemiological data and GIS

The study was conducted in nine Turkish provinces: Kahramanmaraş, Batman, Hakkari, Malatya, Adıyaman, Osmaniye, Hatay, Sivas, and Adana (Fig.1). These provinces are located along the southern border of Turkey and have a large number of family-run small- and medium-sized dairy farms. Data on LSD outbreaks, farms, and cattle movements were obtained from the animal registration system and the World Organization for Animal Health (OIE). The as-

sessment was based on a combination of active disease follow-up and questionnaire and retrospective data collection that focused on 70 pastoral and agro-pastoral farms. The study was conducted with a cross-sectional and retrospective design which employed active disease follow-up and semi-structured interviews (SSI) from August 2013 to December 2014. SSIs were used to generate information about the prevalence and history of LSD, bio-data for individual animals, and disease-related losses including death and abortion. Cattle owners were selected randomly based on the willingness to complete the questionnaire. Questionnaire interviews were carried out in these provinces face-to-face. The sample included 562 animals of different ages, sexes, and breeds (Local breeds: Eastern Anatolian Red (25), Southeast Anatolian Red (30); Mixed breeds: Holstein-Friesian (215), Brown Swiss (227), and Fleckvieh (65)). All farms were reported to have had LSD outbreaks. These provinces have a mean annual minimum and maximum temperature of -7°C and 41.3°C, respectively.

A GIS is an information system that collects and stores data for queries, documenting (producing maps and creating tables), and spatial analysis. It has been used in various fields by many researchers, including animal health studies (Michel et al., 2002, Soumare et al., 2007, Tuma et al., 2007, Carpenter, 2011). A user interface program ensures interaction between the user and the computer. Although many processes are performed for complex spatial analysis and queries in GIS software, these processes can be executed by means of pressing a button in developed user interface programs (Türk et al., 2012). Thus, the program can be used easily without manuals, and effective and efficient results can be produced (Türk et al., 2012, Türk, 2013). Due to the fact that maps are a visual communication tool, GIS offers a means to interpret and understand the data better. For example, you cannot know the border of provinces or countries without thematic maps. Consequently, GIS users have got the possibility to access information easily via query and to analyze spatial data by GIS. In this study, a GIS-based system was created to query, analyze and document data related to animal health, so that the related institutions and users could use it. All data were integrated into the GIS environment. User interface programs were developed (Fig. 2).
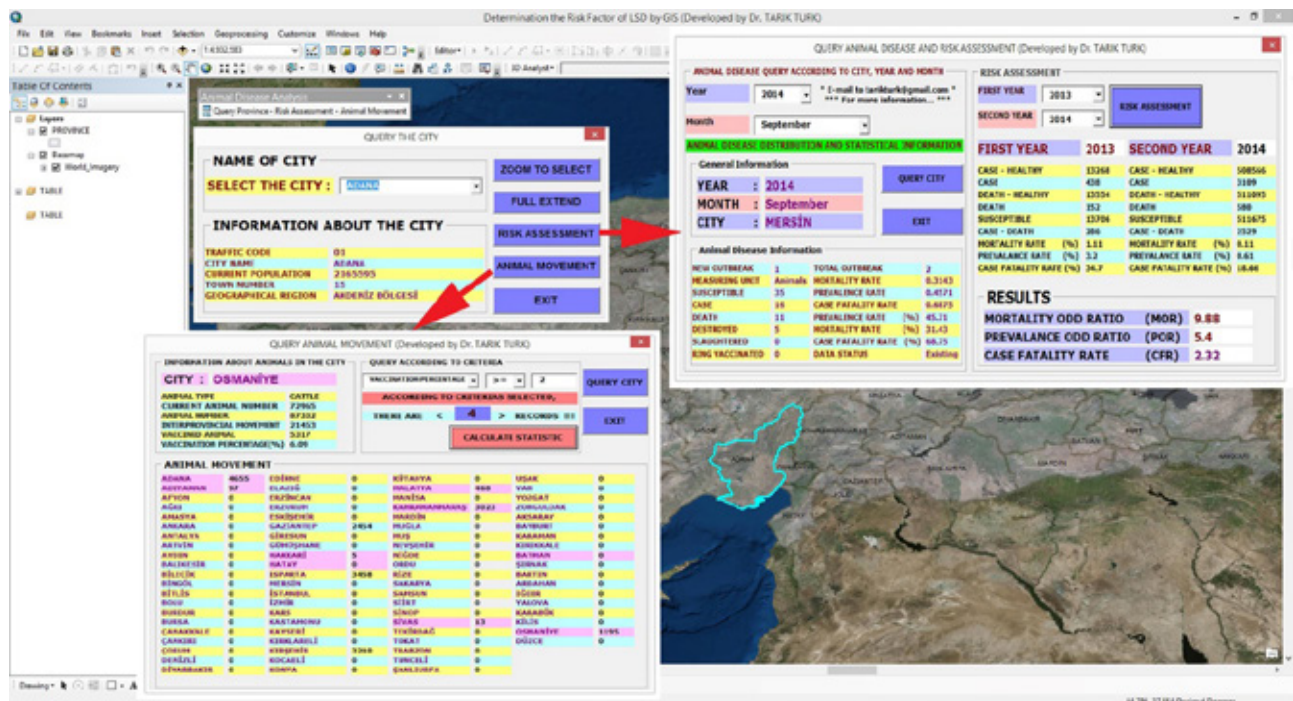
Fig 1. The study area

Fig 2. The GIS based system

Data management and analysis

Data were entered and stored in Microsoft Excel spreadsheets. The univariate association of potential risk factors with the animal-level prevalence of LSD and statistical significance were evaluated using the Chi-square (χ2) test. Logistic regression analysis was used to compute the strength of contribution of the risk factors to LSD occurrence. Data were analyzed in R version 3.1.2 (R Core Team, 2014) and SPSS V21. The Odds ratio (OR) was calculated for each risk factor for animals sick with LSD. In all the analyses, confidence levels at 95% were calculated, and a value of $P<0.05$ was accepted as statistically significant. The OR was calculated for the risk factors and animals sick with the disease to determine the degree of association between the risk factors and the disease. Descriptive statistics such as prevalence were used to calculate rates by dividing the number of animals sick with LSD by the total number of animals at risk. Finally, data were integrated with ESRI ArcGIS 10.1 GIS software, which was also used to query and analyze the data. Variables with P < 0.25 were shortlisted to consider in the final multivariable logistic regression analysis. The model was built stepwise by forward selection, adding shortlisted factors and removing the factors when P > 0.05. The effects of interactions among significant variables in the final model were tested by pairwise interactions in the multivariable logistic models. The model fitness was assessed by the likelihood-ratio test. The mortality odds ratio, prevalence odds ratio, and case fatality rate were determined by comparing cases/death/healthy animal number in different periods. These processes are performed automatically by the user interface program developed in the GIS-based system.

Table 1. Morbidity, mortality, case fatality rates and odds ratio of LSD for each investigated risk factors in Turkey between 2013 and 2014.

Breed	Variables	Factor Levels	No. at risk	No. of sick	No. of death	Morbidity rate	Mortality rate	Case fatality rate	Odds Ratio	95%CI	p-Value
Mixed	**Age**	<24 month *	151	93	10	61.59	6.62	10.75			
		24-48 month	174	27	3	15.52	1.72	11.11	0.11	0.06-0.19	0.001
		>48 month	182	12	0	6.59			0.04	0.02-0.08	0.001
	Sex	Female*	401	120	9	29.93	2.24	7.5			
		Male	106	12	4	11.32	3.77	33.33	3.35	1.76-6.32	0.001
	Vaccination	Vaccinated*	484	121	12	25.00	2.48	9.92			
		Non-Vaccinated	23	11	1	47.83	4.35	9.09	0.36	0.15-0.84	0,01
	Season	Autumn*	121	35	0	28.93					
		Winter	82	24	0	29.27			1.01	0.54-1.88	0.95
		Spring	30	4	0	13.33			0.37	0.12-1.16	0.08
		Summer	274	69	13	25.18	4.74	18.84	0.82	0.51-1.33	0.43
		Total	507	132	13	26.04	2.56	9.85			
Local	Age	<24 month *	7	3	2	42.86	28.57	66.67			
		24-48 month	17	5	0	29.41			0.55	0.08-3.44	0.42
		>48 month	31	13	0	41.94			0.96	0.18-5.05	0.64
	Sex	Female*	27	15	2	55.56	7.41	13.33			
		Male	28	6	0	21.43			4.58	1.4-14.90	0.009
	Vaccination	Vaccinated*	24	15	2	62.50	8.33	13.33			
		Non-Vaccinated	31	6	0	19.35			6.94	2.05-23.44	0.001
	Season	Autumn*	23	8	0	34.78					
		Winter	2	1	0	50.00			1.87	0.10-34.13	0.59
		Spring	8	2	0	25.00			0.62	0.10-3.84	0.48
		Summer	22	10	2	45.45	9.09	20.00	1.56	0.47-5.18	0.46
		Total	55	21	2	38.18	3.64	9.52			

*ref:<24-month, female, vaccinated, autumn

RESULTS

All farms were within pastoral and agro-pastoral areas. The average herd size was 15 and ranged from 5 to 42 animals. A mixture of farming systems was practiced in each province: 30% of farms in Hakkari and Batman provinces were pastoral; 40% of farms in Osmaniye, Adana, and Hatay provinces were agro-pastoral.

Only 54 out of 562 animals were not vaccinated against LSD. It was recorded that 9.61% (54/562) of animals were affected by the disease and 2.67% (15/562) eventually died of it. Most infected animals (27.22% or 153/562) and all dead animals, except for one, were vaccinated against LSD. Breed-specific morbidity, mortality, and fatality rates were analyzed. The morbidity rate for mixed and local breeds was 26.04% (132/507) and 38.18% (21/55), respectively. The mortality and fatality rates were 2.56%, 9.85% (mixed breeds) and 3.64%, 9.52% (local breeds), respectively. In mixed breeds, the morbidity rate was 25.00% (121/484) in vaccinated and 47.82% (11/23) in non-vaccinated cattle ($P<0.05$). In local breeds, the morbidity rate was 62.50% (15/24) in vaccinated and 19.35% (6/31) in non-vaccinated cattle ($P<0.05$). In mixed breeds, the morbidity and mortality rates decreased with age. For animals under 24 months of age, they were 61.59%, 6.62%, for those aged 24–48 months, they were 15.52%, 1.72%, and in adults over 48 months of age, the morbidity rate was 6.59%, respectively ($P<0.05$). The detailed results are presented in Table 1.

A trend of seasonal distribution of LSD was observed in 2014. The month of August had the highest number of outbreak reports. Outbreaks increased from June to October 2014. The multivariable logistic regression analysis revealed that age, sex, and vaccination status were risk factors associated with the occurrence of LSD. By using the Hosmer-Lemeshow goodness-of-fit statistics, the Chi-square value was calculated as 2.15, the related significance value as 1.000, the model's Pseudo R^2 value as 0.725, and the model's overall classification ratio as 85.4%. According to the multivariable logistic regression analysis results, age and sex of animals showed a significant association with LSD. The results are presented in Table 2.

The disease was identified for the first time in Kahramanmaraş province on August 6, 2013, and spread to Batman, Hakkari, Malatya, Adıyaman, Osmaniye, Hatay, Sivas, and Adana provinces. As of June 17, 2014, it has spread to Mersin, Kayseri, and Şanlıurfa provinces. Within the framework of the EU and national legislation, there is a struggle against the disease. There were 91 outbreaks in nine provinces over the nine-month period from August 6, 2013, to May 8, 2014. Eighty-eight outbreaks (96.70%) occurred in seven provinces: Kahramanmaraş, Malatya, Sivas, Adıyaman, Osmaniye, Hatay, and Adana. The remaining three outbreaks (3.30%) occurred in two provinces: Batman and Hakkari. Eighteen outbreaks (19.78%) occurred in 2013 and 73 (80.22%) in 2014. There were 76 outbreaks (87.51%) occurred in three provinces: 45 (51.14%) in Osmaniye, 23 (26.14%) in Adana and 8 (10.23%) in Kahramanmaraş. There were outbreaks on 624 of 187.199 farms (0.33%) in all nine provinces, in which there are a total of 1.269.976 susceptible animals. In farms with outbreaks, 860 of 131.708 susceptible cattle had the disease (Prevalence Rate: 0.65%) and 249 cattle died (Mortality Rate: 0.19%) (Türkvet, 2014). Outbreak reports showed that there was a decrease in disease transmission in 2014, probably as a result of successful disease control precautions, quarantines, and vaccinations carried out in 2013. There is still a risk of the disease spreading to other provinces. The mortality, prevalence, and fatality rates observed in 2013 were higher than in 2014.

Osmaniye province had the highest rate of infected farms (1.87%) followed by Adana province (0.83%). The animal-level prevalence rates were the highest in Hakkari (28.57%) and Batman provinces (18.75%), lower in Osmaniye (0.3%) and Malatya (0.25%), and the lowest in Sivas province (0.14%).

Table 2. Values with multivariable logistic regression for investigated risk factors for LSD in Turkey between 2013 and 2014.

Factors		S.E.	Wald-value	Odds Ratio	95% CI	P- value
Age*	3.049	0.444	47.07	21.10	8.83-50.43	0.001
Sex*	2,960	1,051	7.94	19.29	2,46-151,32	0.005
Vaccination*	-2.030	0.480	17.90	0.13	0.05-0.34	0.001
Constant	-0.087	0.417	1.71	0.91		

*ref:<24 month; female, vaccinated

Regarding animal movement from infected provinces to non-infected ones, it was observed that Kayseri, Düzce, Kırşehir, İzmir, Konya, and Gaziantep provinces are under risk of transmission. Kayseri borders three infected provinces (Sivas, Kahramanmaraş, and Adana), and Gaziantep borders four infected provinces (Adıyaman, Kahramanmaraş, Osmaniye, and Hatay) (Türkvet, 2014).

In this study, a GIS-based system was created by the integration of all data. Geographical queries and analysis were performed by user interface programs developed using ArcGIS 10.1 GIS software (Fig. 2). The risk assessment in different periods and queries were implemented by pressing one button after entering the necessary parameters. Additionally, thematic maps such as prevalence, case fatality, and mortality rates were produced for facilitating interpretations about animal health by the GIS-based system (Fig. 3).
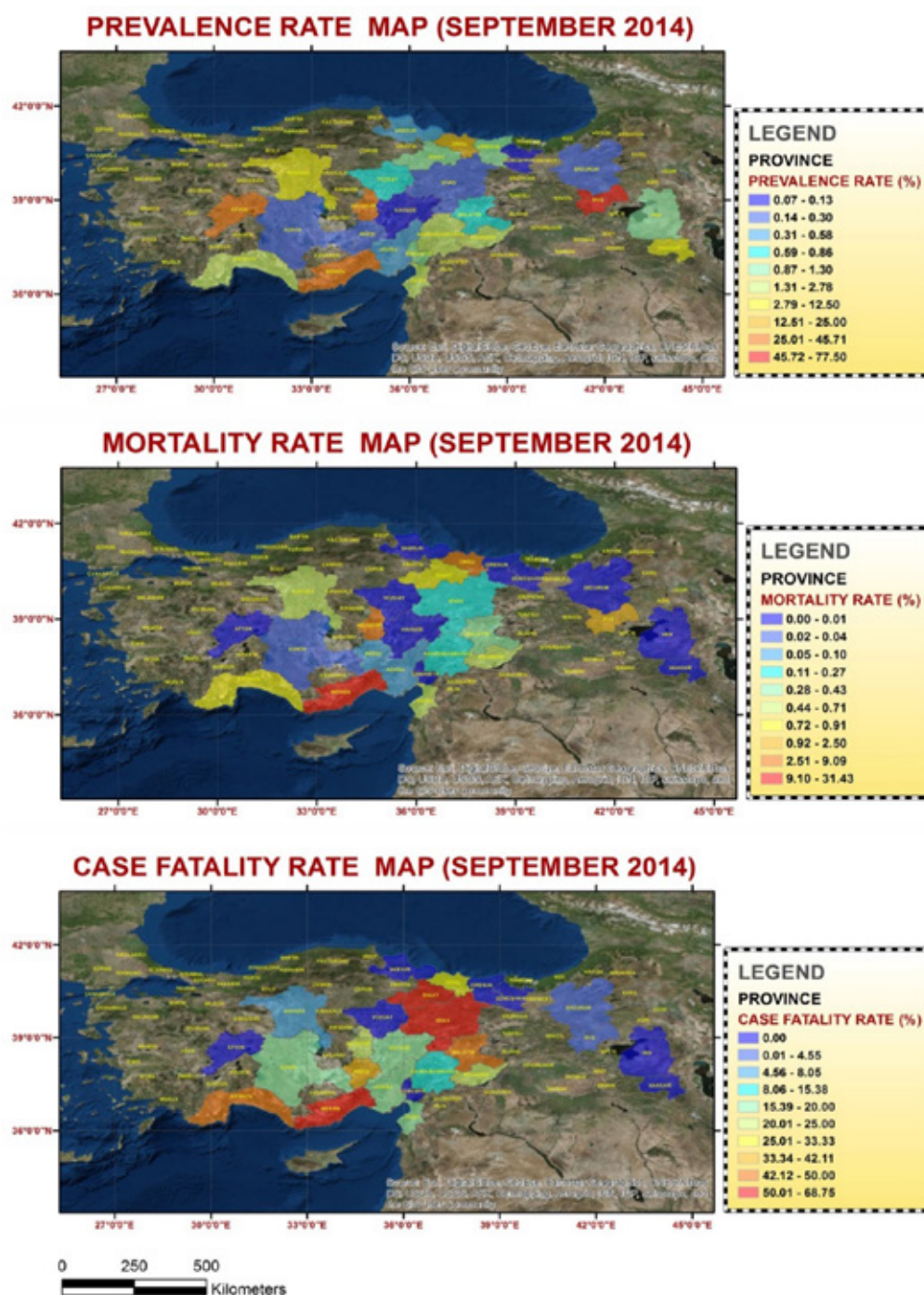

Fig 3 Prevalence Rate (PR), Mortality Rate (MR) and Case Fatality Rate (CFR) maps produced by GIS platform.

DISCUSSION

LSD prevalence and its association with different risk factors were analyzed. Mixed and local breeds of cattle were examined in terms of variable morbidity and fatality rates. Mixed and local breeds had almost the same rate, 26.04% and 38.18%, respectively. LSD morbidity ranged from 3% to 85%, and mortality was limited to 3% (Babiuk et al., 2008, Tuppurainen and Oura, 2012, Alemayehu et al., 2013).

The mortality and fatality rates were 2.56% and 9.85%, respectively, which showed that mixed breed was more resistant than local breed against the disease. In the present study, an attempt was made to compare the susceptibility of the mixed and local breeds of cattle raised in the same farming system. Analysis of the association among age, sex and vaccination status of animals sick with LSD revealed statistically significant results. This agrees with previously conducted studies on breed-specific LSD tendencies (Woods, 1988, Davies, 1991, Ayelet et al., 2013).

Vaccinations with the SP(Bk) sheep pox vaccine strain were used to control LSD. There were various reasons for failure of vaccination such as a low titer of the vaccine, different field and vaccination strains, vaccination of calves with maternal antibodies, and mishandling of vaccines in transport or storage. In reports from Israel (Brenner et al., 2006) and Egypt (Fayez and Ahmed, 2011), results are similar.

In terms of age, morbidity was higher in 24-month-old cattle, 24-48-month cattle, and cattle older than 48 months in mixed breeds. The results agree with those from Israel (Fayez and Ahmed, 2011) and Egypt (Ayelet et al., 2013). Morbidity is higher in females because the lactation or pregnancy period causes physiological stress and lowers immunity. Another attempt was made in the present study to compare the season during which an outbreak of the disease can occur. It was high in the summer season (45.45%) and the lowest in the spring season (13.33%) in the area. LSD outbreaks occurred during dry seasons and were more common while traveling at long distances (Brenner et al., 2006, Kumar, 2011, Magori-Cohen et al., 2012), similarly to the 2014 outbreaks in Turkey. LSD appeared in Egypt and then spread to the Middle East and Israel (Tuppurainen and Oura, 2012) as well as Kuwait, Lebanon, the UAE, Israel, and Oman in 1990. The occurrence of the disease depends on factors such as animal movements, immune status, wind, and the amount of rainfall (Brenner et al., 2006). According to the OIE reports, legal or illegal animal movements in Azerbaijan, Iran, Lebanon, Egypt, and Palestine are likely to have caused the virus to spread after the 2014 outbreaks (EFSA, 2015).

Analyses of morbidity risk factors showed that cattle purchased from other farms are at risk. For the transmission of LSD among farms, the most significant factor was cattle movement. The transmission of the disease to Turkey may be from Syria and Iraq since there is a movement of live animals across the Syria–Iraq border. Furthermore, the first outbreak near the border enables airborne vectors. According to the study, LSD prevalence was significantly associated with purchasing infected animals that were not tested or quarantined. This situation is similar to the situation in Ethiopia (Gari et al., 2010, Gari et al., 2011, Gari et al., 2012) and Egypt (Salib and Osman, 2011).

It is likely that live animal movements and smuggling occur across the south-eastern border with Syria and Iraq. This study's results agree with those from Jordan (Abutarbush et al., 2013).

The results of the present study are consistent with those that have been previously reported. LSD occurs based on factors such as the prevalence of insect vectors, number of livestock and transportation of animals that have not been tested (Ali et al., 1990, Tuppurainen and Oura, 2012). It is more likely to occur via animal movements than through arthropod vectors (Tuppurainen and Oura, 2014).

Hence, the main factor in LSD distribution is animal and insect movement. Importing infected animals is the main cause of LSD, so the disease has begun to spread over long distances. Further spread can be prevented by stopping the movement of sick animals to unaffected areas (Işıdan et al.,2014).

According to the 2014 reports (Işıdan et al., 2014), disease outbreaks in Sivas province, 400 km north of the initial outbreak, supported the possibility that LSD spread depending on arthropod vectors and illegal animal movements. The illegal movement of sick or asymptomatic infected animals was the possible cause (EFSA, 2015).

CONCLUSIONS

In conclusion, control strategies for LSD infection on farms should focus on these risk factors. These risk factors could relapse the spread of LSD, and it could be found spreading to new regions that have been pre-

viously considered as a free region and will be a major livestock breeding health problem. The findings of this study also attach attention to the distribution of LSD in the area and can assist decision-makers, planners, and researchers in their efforts. Briefly, all queries, spatial analysis, and documentation processes can be performed on the GIS-based system devel-oped. Thus, risk assessments and evaluations about animal health can be performed easily and effectively by GIS.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

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