

EVALUATION OF LEPTOSPIROSIS CASES IN TÜRKIYE USING A GEOGRAPHIC INFORMATION SYSTEM

Serdar Karakullukcu¹, Irem Dilaver², Husniye Ebru Colak³ and Murat Topbas¹

¹Department of Public Health, Faculty of Medicine, Karadeniz Technical University, Trabzon, Türkiye; ²Provincial Health Directorate, Trabzon, Türkiye; ³Department of Geomatics Engineering, Faculty of Engineering, Karadeniz Technical University, Trabzon, Türkiye

Abstract. Leptospirosis is a public health problem in Türkiye with cases occurring sporadically and occasionally in outbreaks. In this study we aimed to retrospectively map leptospirosis cases in Rize Province, Türkiye during 2016-2022 using a geographic information system (GIS) in order to inform leptospirosis control efforts. Data regarding numbers and locations of leptospirosis cases in the study province were obtained from an Infectious Disease Surveillance and Early Warning System and entered into GIS software and examined for spatial patterns. A total of 97 subjects were included in the study, 59% males. The mean (\pm standard deviation) age of study subjects was 59 (\pm 11) years. During the study period, the year with the largest number of leptospirosis cases was 2018 ($n = 37$) ($p < 0.001$) and the month of the year during the study period with the most cases was September ($n = 32$) ($p < 0.001$). The incidence of cases was highest during June-October ($n = 85$) ($p < 0.001$). The districts in Rize Province where the most leptospirosis cases occurred were the 3 contiguous coastal districts of Merkez ($n = 31$), Çayeli ($n = 16$) and Pazar ($n = 12$) ($p < 0.001$). Cases were also reported in Güneysu District ($n = 11$) ($p < 0.001$). The other cases of leptospirosis were distributed sporadically. In summary, leptospirosis cases in Rize Province occurred primarily in clusters in 3 contiguous provinces during the study period and were more common during 2018 and during September. We conclude these patterns need to be taken into consideration by efforts to reduce the incidence of leptospirosis in the study area. Further studies are needed to determine why there are more cases in these specific districts during September and if they have preventable origins in order to improve leptospirosis control efforts in Rize Province, Türkiye.

Keywords: leptospirosis, geographic information systems, mapping, infectious diseases

Correspondence: Serdar Karakullukcu, Department of Public Health, Faculty of Medicine, Karadeniz Technical University, Milli Egemenlik Street, Trabzon 61080, Türkiye

Tel: +90 5364475763 Email: serdar.karakullukcu@ktu.edu.tr

INTRODUCTION

Leptospirosis is a frequently neglected, important public health problem in Türkiye. It is a potentially fatal zoonotic infection caused by *Leptospira* spirochetes (Ko *et al*, 2009; Bharti *et al*, 2003; Levett, 2001). It is endemic in many tropical countries (Soo *et al*, 2020). Outbreaks may occur after heavy rains and during flooding (Lau *et al*, 2010). Numerous wild and domestic animals can act as reservoirs but the brown rat is the most common source of human infections (Haake and Levett, 2015; Calvopina *et al*, 2022). Leptospirosis cases are usually sporadic but can occur in clusters (Dhewantara *et al*, 2019b).

Geographic Information Systems (GIS) were first used by John Snow in 1849 during a cholera epidemic (Bryan and George, 2004) to enable epidemiologists to identify spatial outbreak patterns and associated health, socio-economic

and environmental variables (Glass, 2014). GIS are valuable for research, analysis and data communication regarding communicable and non-communicable diseases (Musa *et al*, 2013). The Life Fits Home (HES) application was used in Türkiye during the coronavirus-disease-2019 (COVID-19) pandemic; it gave useful information about associations between COVID-19 cases and various factors (Er and Kusak, 2023).

Identifying the geographic and chronological patterns of leptospirosis cases can inform treatment and prevention programs to allow appropriate allocation of resources (Núñez-González *et al*, 2020). Using GIS allows identification of spatial and chronological patterns and other factors (Souza *et al*, 2020; Sulistyawati *et al*, 2016).

Most studies of leptospirosis in Türkiye have been case studies or small case series studies (Yesilbas

et al, 2016, Sumbul *et al*, 2018). A literature search revealed no studies with a large enough number of leptospirosis cases necessary for public health evaluations and we were unable to identify any leptospirosis studies using GIS to map cases in Türkiye.

Serological studies of leptospirosis antibodies among humans and animals in Türkiye reveal a high prevalence of leptospirosis antibodies in coastal and agricultural Türkiye (Lelebicioglu *et al*, 1996, Gumussoy *et al*, 2009). Rize Province is in northeastern coastal Türkiye. Rize Province experiences rainfall throughout the year and has the highest precipitation levels in the country (Sensoy, 2004). Seventy percent of the land in Rize Province is agricultural or consists of meadows and forests (Abaci *et al*, 2020). This suggests Rize Province is suited for a study of leptospirosis cases.

In this study we aimed to retrospectively map out leptospirosis cases in Rize Province, Türkiye during 2016-2022 using a geographic information system (GIS) in order to inform leptospirosis control efforts.

MATERIALS AND METHODS

Study type

We conducted a retrospective study of leptospirosis cases in the study area during the study period.

Study area

The study was conducted in Rize Province, in northeastern Türkiye (between 40°-22' and 41°-28' east longitude and 40°-20' and 41°-20' north latitude). This province is comprised of primarily mountainous terrain and is bordered by the Black Sea in the north, with 80 kilometers being coastline (Fig 1).

Leptospirosis cases

We obtained data regarding the number of leptospirosis cases and their locations from the cases reported to the Rize Provincial Health Directorate, Public Health Services Directorate, Infectious Diseases Unit during 2016-2022 via the Turkish Infectious Disease Surveillance and Early Warning System. Leptospirosis is classified as a notifiable disease in Türkiye but the database regarding leptospirosis cases has only been collected since 2016.



Fig 1 - Rize Province, Türkiye

The data recorded for each leptospirosis case were subject age, gender, district of residence, occupation, year and month the case occurred, the patient's chief complaint, hospital course and case outcome.

Data mapping and interpretation

The GIS software used for this study was ArcGIS Enterprise, version 10.7 (Environmental Systems Research Institute (ESRI),

Redlands, CA). Subject addresses were converted into spatial points using Google Earth Pro software, version 7.3 (Google, Mountain View, CA). These data in Google Earth Pro were then imported into ArcGIS software to allow a continuous representation of leptospirosis case density in the study area.

Statistical analyses

Numbers and percentages

were used to describe categorical variables and medians and minimums/maximums were used to describe continuous variables. One-sample binomial test and one-sample Chi-square test were used to detect differences in the distribution of leptospirosis cases. A p -value <0.05 was considered statistically significant. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software, version 24.0 (International Business Machines Inc, Armonk, NY).

Ethical approval

Ethical approval for this study was obtained from Recep Tayyip Erdogan University, Non-Interventional Clinical Research Ethics Committee (E-71006170-050.01.04-6716 and 2022/230).

RESULTS

A total of 97 subjects were included in the study, 59% ($n = 57$) males. The mean (\pm standard deviation) age of subjects was 59 (± 11) (range: 19-88) years. Ninety-six subjects (99%) were aged >40 years. Seventy-eight subjects (80%) presented with acute and 19

(20%) with subacute leptospirosis. Eighty-seven subjects (90%) were treated as in-patients and the overall mortality rate among subjects was 2% ($n = 2$). Seventy subjects (72%) lived in detached houses.

The most common subject complaints on presentation were: loss of appetite ($n = 82$, 85%), fever ($n = 81$, 84%), myalgia ($n = 77$, 79%), headache ($n = 71$, 73%) and nausea and vomiting ($n = 63$, 65%). Fifty-seven subjects (59%) reported having a rat in the home and 55 (57%) had a history of contact with contaminated water (Table 1). There was no statistically significant difference in leptospirosis case rates between those who did and did not report having a rat in the home ($p=0.104$) and between those who did and did not report having contact with contaminated water ($p=0.223$).

Significantly more leptospirosis cases in the study period were in 2018 than in the other years of the study ($n = 37$) ($p<0.001$) and significantly more leptospirosis cases were reported in September ($n = 32$) than during the other months ($p<0.001$). The incidence of leptospirosis cases was highest during June-October ($n = 85$) ($p<0.001$) (Table 2, Fig 2).

Table 1

Subject symptoms and selected factors potentially associated with leptospirosis
(N = 97)

Variables	Frequency <i>n</i> (%)
Subject symptoms	
Loss of appetite	82 (85)
Fever	81 (84)
Myalgia	77 (79)
Headache	71 (73)
Nausea/Vomiting	63 (65)
Weakness	19 (20)
Jaundice	16 (17)
Loss of weight	13 (13)
Conjunctival tenderness	10 (10)
Hepatomegaly	7 (7)
Liver tenderness	6 (6)
Bleeding	5 (5)
Contractions	3 (3)
Rash	2 (2)
Selected factors potentially associated with leptospirosis	
Presence of rat(s) in the house	57 (59)
History of contact with contaminated water	55 (57)
History of contact with an animal at home, while traveling or at work	48 (50)
Presence of an attic, basement, barn or woodshed at home	45 (46)
History of seeing a rat or rat droppings in the house	41 (42)
Consumption of food possibly associated with rodent contact	36 (37)

The largest numbers of leptospirosis cases in the study province were reported from the 3 coastal districts: Merkez ($n = 31$), Çayeli ($n = 16$) and Pazar ($n = 12$) ($p < 0.001$). A notable number of cases were also reported in Güneysu District ($n = 11$) ($p < 0.001$) (Fig 2). The rest of the cases were distributed sporadically (Fig 3).

DISCUSSION

In our study, most leptospirosis cases occurred in three coastal districts. This may be due to several factors found in coastal environments: greater rainfall, more frequent flooding, more bodies of water and greater humidity (Gurgen, 2004; Polat

Table 2
Leptospirosis cases by months and years

Months	Years							Total
	2016	2017	2018	2019	2020	2021	2022	
January	1	0	0	0	1	0	0	2
February	0	0	0	0	0	1	0	1
March	0	0	1	1	0	0	0	2
April	0	0	1	0	0	0	0	1
May	0	0	1	1	0	0	0	2
June	0	2	5	1	0	1	1	10
July	0	0	6	0	1	2	3	12
August	1	0	5	1	1	2	4	14
September	2	3	14	8	1	3	1	32
October	0	1	4	3	1	2	6	17
November	0	0	0	4	0	0	0	4
December	0	0	0	0	0	0	0	0
Total	4	6	37	19	5	11	15	97

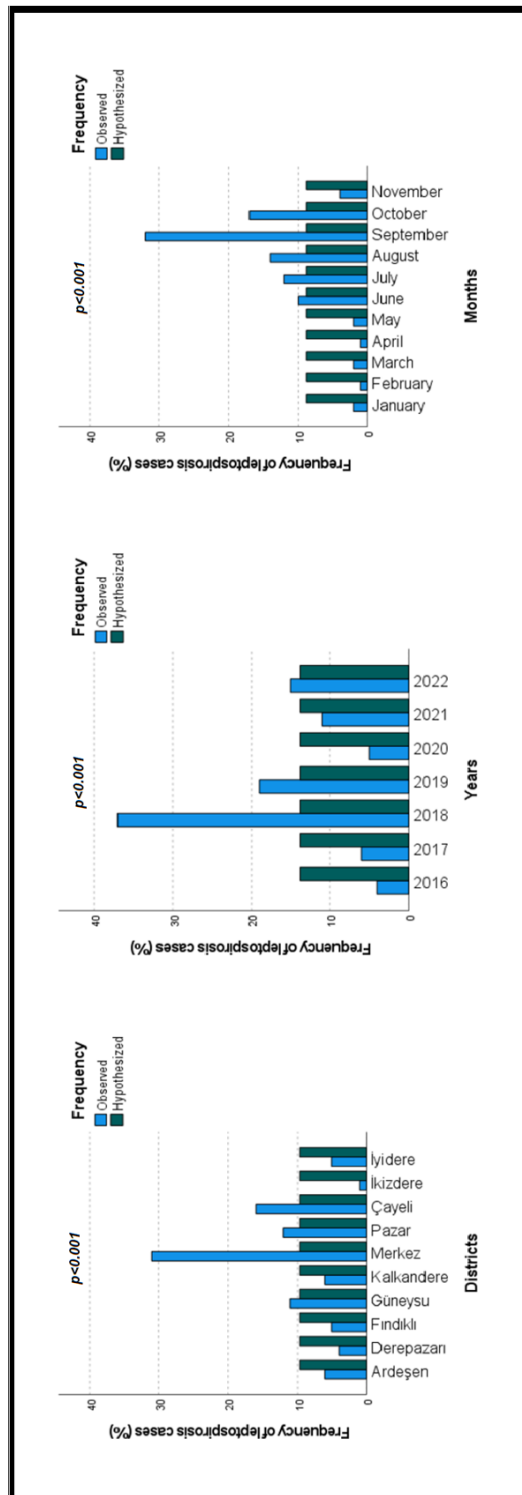


Fig 2 - Distribution of leptospirosis cases by region and time period in Rize Province, Türkiye

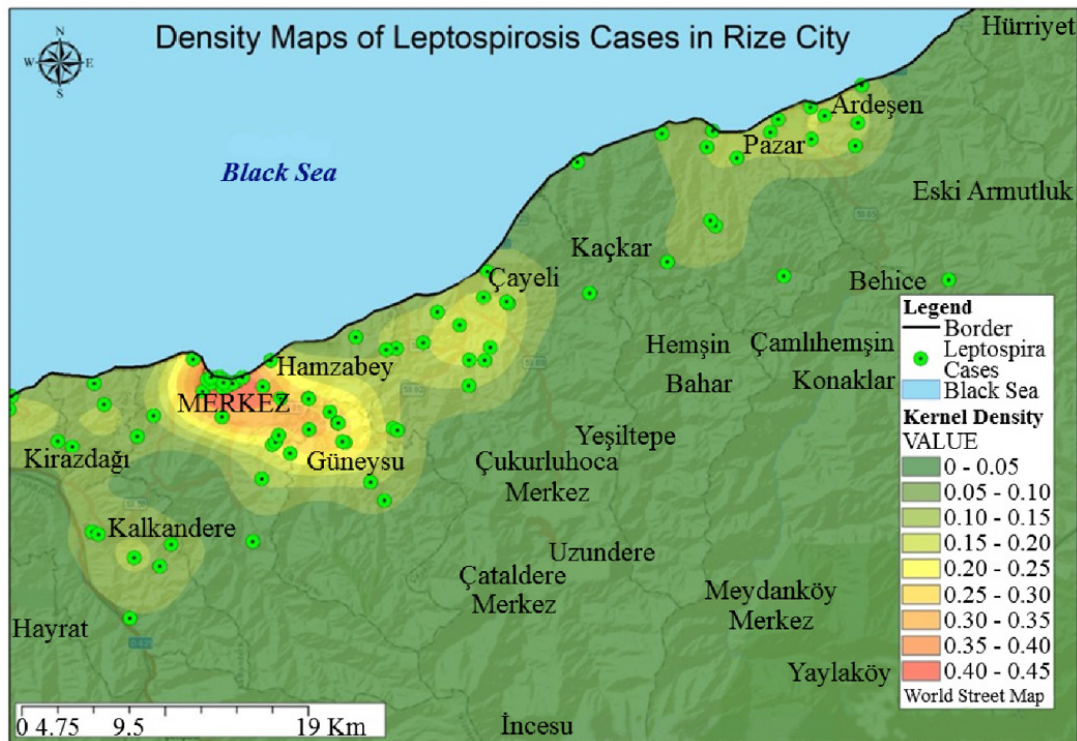


Fig 3 - Leptospirosis cases in Rize Province, Türkiye
Km: kilometer

and Sunkar, 2017; Jones *et al*, 2024; Ziliotto *et al*, 2024). A similar study from Brazil reported a greater incidence of leptospirosis in humid coastal areas (Barcellos *et al*, 2003). The clusters of cases in similar geographic areas suggests geographical and meteorological conditions may play a role in these outbreaks.

In this study, leptospirosis cases peaked during 2018 and during the month of September. In August 2018, flooding occurred in Merkez District (NTV, 2018), one of the districts in the study province reporting more cases. The peak in September may have been due to the August flooding. A study from Brazil reported a higher incidence

of leptospirosis in flooded areas (Barcellos and Sabroza, 2001). Flooding can spread infectious diseases (Barcellos and Sabroza, 2001). Another reason for the increase in cases in September in our study was increased precipitation during September. September has been reported to have an average rainfall in the study area of 258.2 mm (Meteorological Service of Turkish State, 2024). The greater rainfall creates conditions conducive to the spread of the disease (Thibeaux *et al*, 2024). Rainfall results in increased vegetation providing food for rodents, a known vector for leptospirosis (Dhewantara *et al*, 2019a). Similar studies from Thailand (Tangkanakul *et al*, 2005) and the Philippines (Hacker *et al*, 2020) also reported finding more cases of leptospirosis during the rainy season.

In this study, we found no significant association between having mice in the house and developing leptospirosis. The reason for this requires further investigation since other studies have reported finding a significant association between finding mice

and contracting leptospirosis (Gizamba and Mugisha, 2023; Rachmawati *et al*, 2023; Baharom *et al*, 2023).

In our study, most cases of leptospirosis occurred among those aged ≥ 40 years, similar to the findings of a study from Germany (Jansen *et al*, 2005) but different than the findings of a study from the United States where the most common age group was 20-40 years (Meites *et al*, 2004). The reason for this discrepancy between our study results and those from the United States could be due to differences between study populations and/or leptospirosis risk factors. The difference in age distribution could be due to differences in study populations and risk factors.

In our study, the most common presenting symptoms among our study subjects with leptospirosis were fever, myalgia, headache and anorexia, consistent with findings from other studies (Karpagam and Gannesh, 2020; Balasundaram *et al*, 2020). Since these symptoms are nonspecific, providers working in endemic areas need to have a higher index of suspicion for leptospirosis.

A strength of our study was the relatively large number of cases in our study compared to previous studies from Türkiye which included only a maximum of 12 subjects (Leblecioglu *et al*, 1996; Sagmak Tartar *et al*, 2021; Gurcuoglu *et al*, 2009). Another strength of our study was the use of the GIS to identify outbreak patterns by area. A limitation of this study was the data were obtained from a single source for a single province. Another limitation was that no data prior to 2016 were available. Another limitation of this study was we have no leptospirosis screening data to identify those with asymptomatic infection.

In summary, leptospirosis cases in Rize Province were greatest during 2018 and during September. They were more common in 3 coastal districts. We conclude these factors need to be taken into consideration by efforts to reduce the incidence of leptospirosis in the study area. Further studies are needed to determine why there are more cases in these specific districts during September and if they have preventable origins in order

to improve leptospirosis control efforts in Rize Province, Türkiye.

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CONFLICT OF INTEREST

DISCLOSURE

The authors declare that there is no conflict of interest.

REFERENCES

- Abaci NI, Keskin E, Demiryurek K. A research on determining the factors affecting organic tea production. *Anadolu J Agri Sci* 2020; 35: 430-7.
- Baharom M, Ahmad N, Hod R, *et al*. Environmental and occupational factors associated with leptospirosis: a systematic review. *Heliyon* 2023; 10(1): e23473.
- Balasundaram PK, Kanakamma LG, Jayageetha K, Selvarajan B. Epidemiological, clinical and laboratory features of leptospirosis compared to other acute febrile illnesses. *J R Coll Physicians Edinb* 2020; 50(2): 118-23.

- Barcellos C, Lammerhirt CB, de Almeida MA, dos Santos E. Spatial distribution of leptospirosis in Rio Grande do Sul, Brazil: recovering the ecology of ecological studies. *Cad Saúde Pública* 2003; 19(5): 1283-92. [in Portuguese]
- Barcellos C, Sabroza PC. The place behind the case: leptospirosis risks and associated environmental conditions in a flood-related outbreak in Rio de Janeiro. *Cad Saúde Pública* 2001; 17(Suppl): 59-67.
- Bharti AR, Nally JE, Ricaldi JN, *et al.* Leptospirosis: a zoonotic disease of global importance. *Lancet Infect Dis* 2003; 3(12): 757-71.
- Bryan KN, George B. Geographic information systems. In: Siegel JS, Swanson DA, editors. *The methods and materials of demography*. San Diego, CA: Elsevier Academic Press; 2004. p. 733-50.
- Calvopiña M, Váscquez E, Coral-Almeida M, Romero-Alvarez D, Garcia-Bereguain MA, Orlando A. Leptospirosis: morbidity, mortality, and spatial distribution of hospitalized cases in Ecuador. A nationwide study 2000-2020. *PLoS Negl Trop Dis* 2022; 16(5): e0010430.
- Dhewantara PW, Hu W, Zhang W, *et al.* Climate variability, satellite-derived physical environmental data and human leptospirosis: a retrospective ecological study in China. *Environ Res* 2019a; 176: 108523.
- Dhewantara PW, Lau CL, Allan KJ, *et al.* Spatial epidemiological approaches to inform leptospirosis surveillance and control: a systematic review and critical appraisal of methods. *Zoonoses Public Health* 2019b; 66(2): 185-206.
- Er B, Kusak L. Using web based maps in risk monitoring: COVID-19 web map example. *J Eng Sci Des* 2023; 11(3): 886-903. [in Turkish]
- Gizamba JM, Mugisha L. Leptospirosis in humans and selected animals in Sub-Saharan Africa, 2014-2022: a systematic review and meta-analysis. *BMC Infect Dis* 2023; 23(1): 649.
- Glass GE. Geographic information systems. In: Nelson KE, Williams CM, editors. *Infectious disease epidemiology: theory and practice*. Burlington, MA: Jones & Bartlett Learning; 2014. p.167-86.
- Gumussoy KS, Ozdemir V, Aydin F, *et al.* Seroprevalence of bovine leptospirosis in Kayseri, Turkey and detection of leptospire by polymerase chain reaction. *J Anim Vet Adv* 2009; 8(6): 1222-9.

- Gurcuoglu E, Ozturk C, Bayat N, Akalin H. Leptospirosis: three cases from Southern Marmara. *Klimik J* 2009; 22(2): 62-5. [in Turkish]
- Gurgen G. The maximum rainfalls in the eastern black sea region and their importance in terms of floods, 2004 [cited 2024 May 15]. Available from: URL: <https://dergipark.org.tr/en/download/article-file/77329> [in Turkish]
- Haake DA, Levett PN. Leptospirosis in Humans. *Curr Top Microbiol Immunol* 2015; 387: 65-97.
- Hacker KP, Sacramento GA, Cruz JS, et al. Influence of rainfall on *Leptospira* infection and disease in a tropical urban setting, Brazil. *Emerg Infect Dis* 2020; 26(2): 311-4.
- Jansen A, Schöneberg I, Frank C, Alpers K, Schneider T, Stark K. Leptospirosis in Germany, 1962-2003. *Emerg Infect Dis* 2005; 11(7): 1048-54.
- Jones FK, Medina AG, Ryff KR, et al. Leptospirosis outbreak in aftermath of Hurricane Fiona - Puerto Rico, 2022. *MMWR Morb Mortal Wkly Rep* 2024; 73(35): 763-8.
- Karpagam KB, Ganesh B. Leptospirosis: a neglected tropical zoonotic infection of public health importance - an updated review. *Eur J Clin Microbiol Infect Dis* 2020; 39(5): 835-46.
- Ko AI, Goarant C, Picardeau M. *Leptospira*: the dawn of the molecular genetics era for an emerging zoonotic pathogen. *Nat Rev Microbiol* 2009; 7(10): 736-47.
- Lau CL, Smythe LD, Craig SB, Weinstein P. Climate change, flooding, urbanisation and leptospirosis: fuelling the fire? *Trans R Soc Trop Med Hyg* 2010; 104(10): 631-8.
- Leblebicioglu H, Sencan I, Sunbul M, Altintop L, Gunaydin M. Weil's disease: report of 12 cases. *Scand J Infect Dis* 1996; 28(6): 637-9.
- Levett PN. Leptospirosis. *Clin Microbiol Rev* 2001; 14(2):296-326.
- Meites E, Jay MT, Deresinski S, et al. Reemerging leptospirosis, California. *Emerg Infect Dis* 2004; 10(3): 406-12.
- Meteorological Service of Turkish State. General statistics data for our Provinces - Rize (1928-2022), 2024 [cited 2024 May 15]. Available from: URL: <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A&m=RIZE> [in Turkish]
- Musa GJ, Chiang PH, Sylk T, et al. Use of GIS mapping as a public health tool-from cholera to cancer. *Health Serv Insights* 2013; 6: 111-6.

- NTV. A flood has occurred in Rize, 2018 [cited 2024 Jun 27]. Available from: URL: [https://www.ntv.com.tr/galeri/turkiye/rizeyi-sel-vurdu,NOFD8bXurkuvMDIbRIUKxA/Ng9d-F8s90-TankmAkw\]-w](https://www.ntv.com.tr/galeri/turkiye/rizeyi-sel-vurdu,NOFD8bXurkuvMDIbRIUKxA/Ng9d-F8s90-TankmAkw]-w) [in Turkish]
- Núñez-González S, Gault C, Granja P, Simancas-Racines D. Spatial patterns of leptospirosis in Ecuador, 2013-2018. *Trans R Soc Trop Med Hyg* 2020; 114(7): 545-8.
- Polat P, Sunkar M. The climatic characteristics of Rize and the trend analyses of long-term temperature and precipitation data around Rize, 2017 [cited 2024 May 15]. Available from: URL: <https://dergipark.org.tr/en/download/article-file/354723> [in Turkish]
- Rachmawati I, Adi MS, Nurjazuli N. Literature review: environmental risk factors of leptospirosis in Indonesia, 2023 [cited 2024 May 15]. Available from: URL: <https://jurnal.poltekkespalu.ac.id/index.php/JIK/article/download/1230/655/8353>
- Sagmak Tartar A, Asan MA, Udrugucu H, Akbulut A, Demirdag K. The overlooked zoonotic disease leptospirosis: three case reports in Eastern Turkey, 2021 [cited 2024 May 15]. Available from: URL: http://www.floradergisi.org/managete/fu_folder/2021-04/767-771%20Ayse%20Sagmak%20Tatar.pdf [in Turkish]
- Sensoy S. The mountains influence on Turkey climate, 2004 [cited 2024 Dec 10]. Available from: URL: https://www.academia.edu/8422128/The_Mountains_Influence_on_Turkey_Climate
- Soo, ZMP, Khan NA, Siddiqui R. Leptospirosis: increasing importance in developing countries. *Acta Trop* 2020; 201: 105183.
- Souza IPO, Uberti MS, Tassinari WS. Geoprocessing and spatial analysis for identifying leptospirosis risk areas: a systematic review. *Rev Inst Med Trop Sao Paulo* 2020; 62: e35.
- Sulistiyawati S, Nirmalawati T, Mardenta RN. Spatial analysis of leptospirosis disease in Bantul Regency Yogyakarta, 2016 [cited 2024 May 15]. Available from: URL: <https://journal.unnes.ac.id/nju/kemas/article/download/4615/5209>
- Sumbul HE, Gultepe BS, Buyuksimsek M, Sumbul MS, Karakoc E. A catastrophic leptospirosis case with multisystemic involvement. *J Surg Med* 2018; 2(2): 181-3.
- Tangkanakul W, Smits HL, Jatanasen S, Ashford DA. Leptospirosis:

- an emerging health problem in Thailand. *Southeast Asian J Trop Med Public Health* 2005; 36(2): 281-8.
- Thibeaux R, Genthon P, Govan R, *et al.* Rainfall-driven resuspension of pathogenic *Leptospira* in a leptospirosis hotspot. *Sci Total Environ* 2024; 911: 168700
- Yesilbas O, Kihtir HS, Yildirim HM, Hatipoglu N, Sevketoglu E. Pediatric fulminant leptospirosis complicated by pericardial tamponade, macrophage activation syndrome and sclerosing cholangitis. *Balkan Med J* 2016; 33(5): 578-80.
- Ziliotto M, Chies JAB, Ellwanger JH. Extreme weather events and pathogen pollution fuel infectious diseases: the 2024 flood-related leptospirosis outbreak in Southern Brazil and other red lights. *Pollutants* 2024; 4(3): 424-33.