Jurnal Kesehatan Lingkungan Indonesia
22 (2), 2023, 170 – 178

DOI : 10.14710/jkli.22.2.170-178

Spatial Analysis of Environmental Conditions in The Incidence of Leptospirosis in Kebumen Regency

Arief Nugroho[1,2*], **Mateus Sakundarno Adi**[3], **Nurjazuli**[3]

[1] Program Studi Magister Kesehatan Lingkungan, Universitas Diponegoro, Semarang, Indonesia
[2] Balai Besar Penelitian dan Pengembangan Vektor dan Reservoir Penyakit, Jl. Hasanudin No.123 Salatiga, Indonesia
[3] Fakultas Kesehatan Masyarakat Universitas Diponegoro, Semarang, Indonesia
*Corresponding author :ariefnugroho12@gmail.com

Info Artikel: Diterima 9 Desember 2022 ; Direvisi 7 Maret 2023 ; Disetujui 13 Maret 2023
Tersedia online : 27 April 2023 ; Diterbitkan secara teratur : Juni 2023

Cara sitasi (Vancouver): Nugroho A, Adi MS, Nurjazuli N. Spatial Analysis of Environmental Conditions in The Incidence of Leptospirosis in Kebumen Regency. Jurnal Kesehatan Lingkungan Indonesia [Online]. 2023 Jun;22(2):170-178. https://doi.org/10.14710/jkli.22.2.170-178.

ABSTRAK

Judul: Analisis Spasial Kondisi Lingkungan pada Kejadian Leptospirosis di Kabupaten Kebumen

Latar belakang: Kabupaten Kebumen tercatat ada 23 kasus leptospirosis tahun 2021 dan 37 kasus leptospirosis tahun 2022 hingga Bulan Agustus. Salah satu upaya penanggulangan dan pencegahan penyakit yaitu spasial penyakit berbasis lingkungan. GIS (*Geographic Information System*) bermanfaat untuk mengetahui pola spasial penyakit yang berkaitan dengan lingkungan. Tujuan dari penelitian ini adalah mengetahui distribusi dan melakukan analisis spasial faktor lingkungan terhadap kejadian leptospirosis di Kabupaten Kebumen.

Metode: Jenis penelitian adalah observasional analitik dengan desain secara *cross sectional* melalui pendekatan spasial. Jumlah sampel sebesar 56 kasus leptospirosis di Kabupaten Kebumen tahun 2021 dan tahun 2022 hingga bulan Agustus. Pengumpulan data titik koordinat rumah kasus menggunakan alat GPS (*Global Positioning System*). Pengambilan data dilakukan selama 2 bulan. Analisis data dilakukan melalui ArcGIS 10.3, dan SaTScan 10.1.

Hasil: Distribusi kasus leptospirosis di Kabupaten Kebumen tersebar di 20 Kecamatan, 12,5% kasus ditemukan di Kecamatan Kutowinangun, mayoritas sebesar 32,14% kasus berumur 50-59 tahun, 83,93% kasus diderita laki-laki, 48,21% kasus berpendidikan rendah (SD) dan 66,07% kasus bekerja sebagai petani. Hasil analisis spasial menunjukkan 54% kasus tinggal di wilayah dengan kepadatan penduduk rendah (417-1025 jiwa/km^2), 76,79% ketinggian tempat 0-100 mdpl, punya riwayat banjir, 80,36% di wilayah pedesaan, 57,14% kasus berada > 1 km dari sungai, 87,5% kasus berada pada radius <500 m dengan sawah, dan terbentuk pola cluster yang signifikan (*p value* = 0.0015) yang berlokasi di Kecamatan Mirit.

Simpulan: Kasus leptospirosis banyak ditemukan di wilayah pedesaan dengan kepadatan penduduk rendah, berada di wilayah dataran rendah, daerah kasus pernah mengalami riwayat banjir, lokasi kasus dengan sungai radius > 1 km, lokasi kasus dengan sawah radius <500 m, dan terjadi kluster di Kecamatan Mirit. Kegiatan pengendalian terpadu maupun pencegahan dapat difokuskan pada daerah kluster tersebut.

Kata kunci: Leptospirosis; Kebumen; spasial; klaster

ABSTRACT

Background: *Kebumen Regency recorded 23 cases of leptospirosis in 2021 and 37 cases of leptospirosis in 2022 until August. One of the efforts to overcome and prevent disease is the environment-based spatial disease. GIS*

(Geographic Information System) is useful for knowing the spatial patterns of diseases related to the environment. The purpose of this study is to determine the distribution and conduct a spatial analysis of environmental factors on the incidence of leptospirosis in Kebumen Regency.

Method: *The type of research is analytic observational with cross-sectional design through a spatial approach. The number of samples was 56 cases of leptospirosis in Kebumen Regency in 2021 and 2022 until August. Data collection of home case coordinates using GPS (Global Positioning System) tools. Data collection is carried out for 2 months. Data analysis was performed using ArcGIS 10.3, and SaTScan 10.1.*

Result: *The distribution of leptospirosis cases in Kebumen Regency is spread across 20 sub-districts, 12.5% of cases are found in Kutowinangun district, the majority of 32.14% of cases are aged 50-59 years, 83.93% of cases are suffered by men, 48.21% of cases are low-educated and 66.07% of cases of working as farmers. The results of the spatial analysis showed that 54% of cases lived in areas with low population density (417-1025 people / km^2), 76.79% of altitude of 0-100 meters above sea level, had a history of flooding, 80.36% in the rural areas, 57.14% of cases were > 1 km from the rivers, 87.5% of cases were in a radius of <500 m with rice fields, and a significant cluster pattern was formed (p-value = 0.0015) located in Mirit District.*

Conclusion: *Leptospirosis cases are found in rural areas with low population density in lowland areas, case areas that have experienced a history of flooding, case locations with rivers with a radius of > 1 km, case locations with rice fields with a radius of <500 m, and clusters occur in Mirit District. Integrated control and prevention activities can be focused on the cluster area.*

Keywords**: **Leptospirosis; Kebumen; spatial; cluster

INTRODUCTION

Leptospirosis is a zoonotic disease that has become a health problem in the global scope, especially in areas with poor sanitation and infrastructure.[1] This disease is caused by bacterial microorganisms of the genus *Leptospira*. Currently, the genus *Leptospira* has two species, namely, at least 12 species are pathogenic and 4 species are saprophytes, which have more than 250 pathogenic serovars.[2] The disease has caused cases of more than 1 million people and found at least 58,000 deaths each year in parts of the world.[3] The incidence of leptospirosis found in subtropical countries is around 0.1-1 per 100,000 inhabitants per year, while in tropical countries it is around 10-100 per 100,000 inhabitants per year.[4] The prevalence of leptospirosis in Indonesia tends to increase with case mortality rates ranging from 5 to 12%.[5]

The main transmission of leptospirosis, especially in Indonesia, is through rats. Some species of rats that are reservoirs of leptospirosis in Indonesia include Rattus *tanezumi*, Rattus *norvegicus*, *Bandicota indica*, *Rattus exculan*, *Mus musculus* and *Suncus murinus*.[6] Transmission of *Leptospira* to humans occurs directly due to exposure to fluid or urine of reservoir animals or indirectly through the medium of water, soil, and plants that have been contaminated with *Leptospira*.[7,8] Humans infected with leptospirosis will experience clinical symptoms such as acute fever, jaundice, or functional dysfunction of several organs of the body.[9] *Leptospira* bacteria enter the human body through wounds present on the skin, mucous membranes (nose, mouth, and eyes), or even through drinking water. *Leptospira* bacteria that have entered the human body will be in the blood and attack the body's tissues and organs.[6]

The incidence of leptospirosis in Kebumen Regency was first reported in 2015 as 1 case with 1 death. Leptospirosis cases were not found in 2016. The incidence of leptospirosis in Kebumen Regency has increased cases of leptospirosis where 87 cases were found with 10 deaths in 2017. Furthermore, the Kebumen District Health Office re-reported the findings of cases, namely 9 cases with 1 death in 2018, 2 cases with 2 deaths in 2019 and in 2020 no reported cases of leptospirosis. The Kebumen District Health Office again reported the findings of leptospirosis cases of as many as 23 cases with 9 deaths in 2021 and further rediscovered leptospirosis cases of as many as 37 cases with 7 deaths in 2022 until August. The emergence of leptospirosis in an area can be influenced by environmental factors, habits, work, and the presence of a source of transmission.[10] The environmental factors that affect leptospirosis include the presence of rats, the presence of farm animals, a history of contact with floods, poor sanitary conditions, and the presence of poor trash cans.[11,12]

One descriptive approach in planning disease management and prevention programs is environmental-based disease spatial. Spatial analysis in epidemiology is useful for evaluating the occurrence of differences in events by geographic area and identifying disease *clustering*.[13] Spatial analysis using Geographic Information Systems (GIS) is one of the important methods in disease surveillance. The ability of GIS to compile data into layers commonly called "overlays" can provide benefits in disease surveillance.[14] GIS is used to improve health surveillance systems that can visualize diseases in time and space with output in the form of maps.[15] GIS in the form of mapping can make it easier for health workers to see disease distribution patterns and risk factors.[16]

Based on the description above, the purpose of this study is to determine the distribution of leptospirosis cases and conduct a spatial analysis of environmental factors for the incidence of leptospirosis in Kebumen Regency in the form of land use,

population density, altitude, and flood history. The results of this study are expected to provide benefits for policymakers and leptospirosis program managers in Kebumen Regency in carrying out problem-solving and appropriate leptospirosis interventions in an area.

MATERIALS AND METHODS

This type of research is analytical observational and the research design is *cross-sectional* using spatial analysis. This research has been submitted to obtain ethical approval from the Health Research Ethics Commission (KEPK) of the Faculty of Public Health, Diponegoro University, namely No: 346 / EA / KEPK-FKM / 2022. Data collection is carried out for approximately 2 months from September 1 to October 22, 2022. The study is all leptospirosis cases recorded in the Kebumen Regency Health, Population Control, and Family Planning Office as many as 60 cases consisting of 23 cases in 2021 and 37 cases in 2022 until August. However, based on inclusion and exclusion, the total research sample was 56 cases. The inclusion criteria are leptospirosis sufferers who were found and recorded at the Kebumen Regency Health, Population Control, and Family Planning Office in 2021 and 2022 until August while the exclusion criteria were patients who had moved their homes outside Kebumen Regency and had been visited 3 times but were not successfully interviewed.

Primary data in the form of measurement of coordinate points from the case house using the Garmin Monterra brand GPS (*Global Positioning System*) tool and characteristic data of respondents of leptospirosis cases by interviewing cases or families of cases. Secondary data was obtained from the Health, Population Control, and Family Office of Kebumen Regency as well as the local community health center (Puskesmas) in the form of case data and address data for leptospirosis cases, the Regional Disaster Management Agency (BPBD) in the form of flood data, the Central Statistics Agency (BPS) in the form of population density data, the Regional Development Planning Agency (Bappeda) in the form of administrative data for Kebumen Regency, land use data, and regional topographic data.

Spatial data analysis in this study used ArcGIS 10.3 and SaTScan 10.1 software. The data analysis carried out was based on overlay, buffering, and clustering analysis. Overlay analysis aims to determine the spread of leptospirosis based on data on land use, population density, altitude, and flood history. The buffering analysis aims to determine the spread of leptospirosis with spatial elements so that a certain distance area will be formed. Elements used in the buffering analysis include rivers and rice fields. Clustering analysis was performed with SaTScan 10.1 software to determine which clusters occurred using the Space-Time Permutation model method. This analysis aims to describe a significant pattern of grouping leptospirosis cases in Kebumen Regency with an aggregate time of one month.

RESULTS AND DISCUSSION

In this study, 56 cases of leptospirosis were found and 55 coordinate points of leptospirosis cases were taken because there were 2 cases living in the same house. The distribution of leptospirosis cases during 2021 and 2022 until August was found in 20 districts from 26 districts, namely Adimulyo, Alian, Ambal, Ayah, Buayan, Buluspesantren, Gombong, Karanggayam, Kebumen, Kutowinangun, Kuwarasan, Mirit, Padureso, Pejagoan, Petanahan, Poncowarno, Prembun, Puring, Rowokele, and Sempor, **(Figure 1a)**. The districts where there are many cases of leptospirosis are Kutowinangun (7 cases), Rowokele (7 cases), and Ayah (6 cases).

The results showed that leptospirosis sufferers were mostly aged between 50-59 years (32.14%) with the average age of cases being 43 years. The majority of leptospirosis cases are suffered by men (83.93%) compared to women (16.07%). Education from leptospirosis cases is mostly lower education (48.21%) and secondary to upper education (46.43%). The majority of leptospirosis cases work as farmers (66.07%) followed by self-employed (10.71%). More can be seen at Table 1.

Table1. Distribution of leptospirosis case frequency in 2021-August 2022 in Kebumen Regency

Characteristic	Category	∑ Case	%
Age	< 10 years	0	0
	10-19 years	1	1,79
	20-29 years	7	12,50
	30-39 years	16	28,57
	40-49 years	9	16,07
	50-59 years	18	32,14
	>= 60 years	5	8,93
Gender	Man	47	83,93
	Woman	9	16,07
Education	Not going to school	2	3,57
	Low (SD)	27	48,21
	Medium to upper (SMP-SMA/equivalent)	26	46,43
	High (College)	1	1,79
Occupation	Farmer/farm laborer	37	66,07
	Merchant	1	1,79
	Sand miner	2	3,57
	Coolies/Building workers	2	3,57
	Self-employed	6	10,71
	Housewives	1	1,79
	Student	1	1,79
	Government sector employees	3	5,36
	Laborer	2	3,57
	Not yet/not working/retired	1	1,79

The results of the overlay analysis of the leptospirosis case map with a population density map obtained results that leptospirosis cases were spread in areas with low population density (417-1025 people/km^2) of 54% and high population density (1154-3145 people/km^2) of 46% **(Figure 1b). Figure 1c** shows that leptospirosis cases occur in areas with land use in the form of village settlements surrounded by rice fields, yards, and gardens (80.36%). **Figure 1d** shows that most of the leptospirosis cases are at an

altitude of 0-100 meters above sea level (76.79%) found in the districts of Kebumen, Gombong, Buayan, Prembun, Puring, Alian, Adimulyo, Kuwarasan, Mirit, Ambal, Petanahan, Buluspesantren, Poncowarno, Karanggayam, and parts of Ayah, Rowokele, Pejagoan, Sempor, Kutowinangun districts. **Figure 1e** shows that areas with leptospirosis cases mostly experienced a history of flooding or inundation during the period 2021-2022 except Poncowarno and Buluspesantren Districts (5.36%).

Buffering analyses to be linked to leptospirosis cases in this study are rivers and rice fields. In **figure 2a**, the results of case buffering analysis with rivers show that leptospirosis cases in Kebumen Regency were found in a river radius of 0-1 km as many as 24 cases (42.86%) and > 1 km as many as 32 cases (57.14%). In **figure 2b** the results of the buffer analysis of the distance of leptospirosis cases with the presence of rice fields show that in a radius of up to 500 m with rice fields found 87.5% of cases were and in a radius of 500-1000 m found 12.5% of cases.

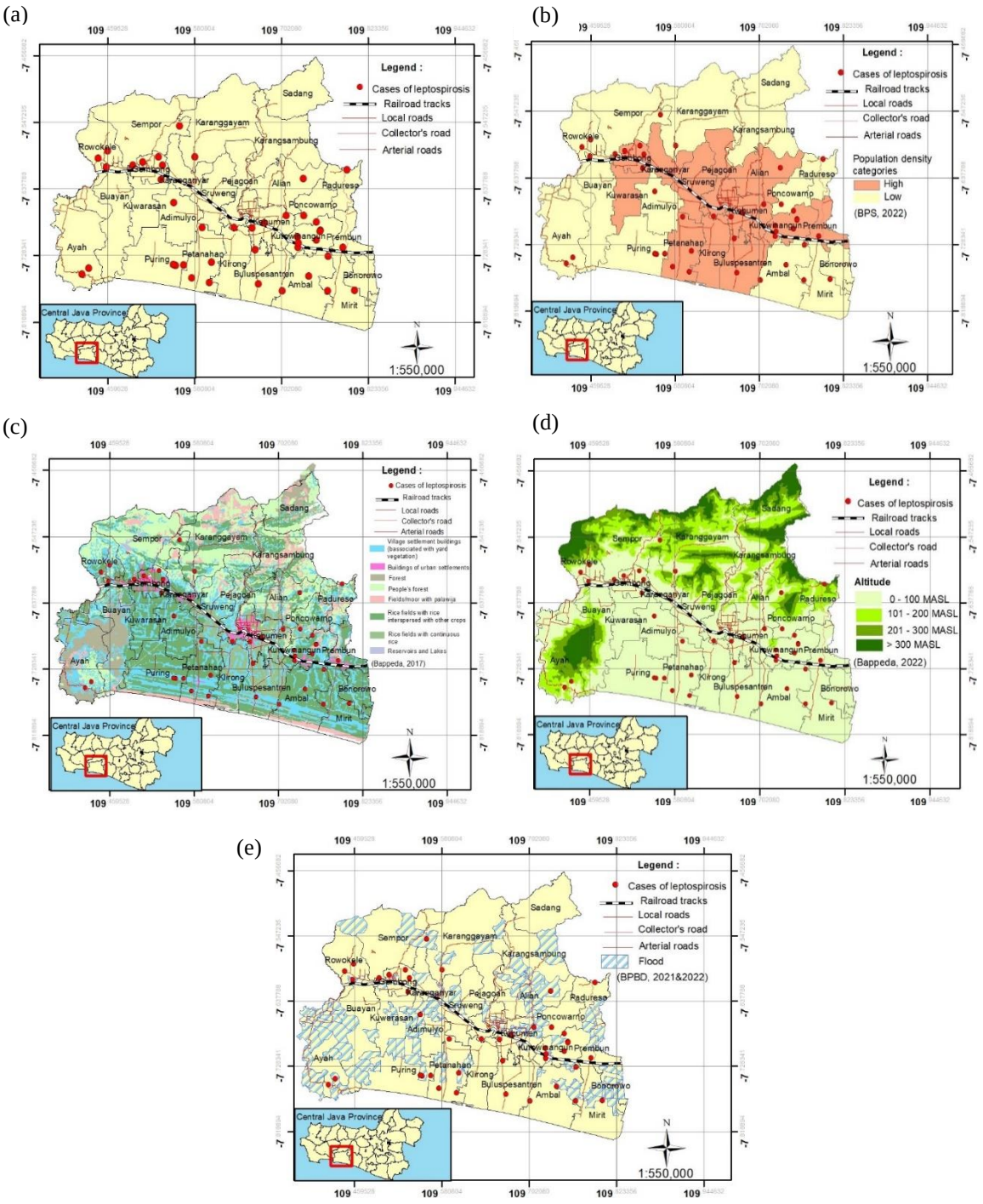

Figure 1. (a) Distribution map of leptospirosis cases. Overlay a map of the distribution of leptospirosis cases with (b) population density, (c) land use, (d) the altitude of the premises, and (e) flood history

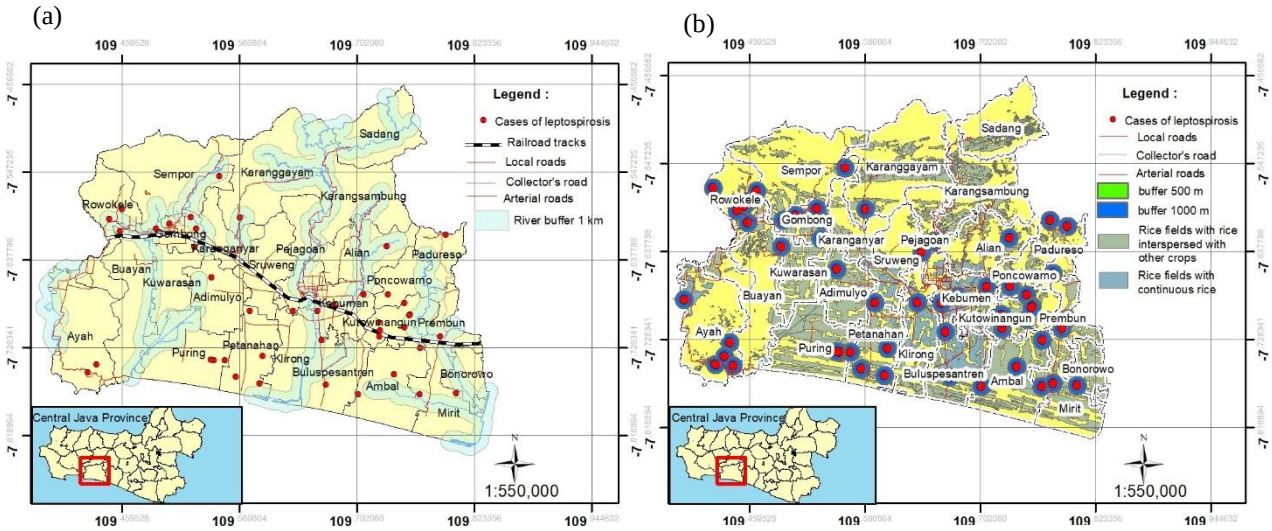

Figure 2. Buffer map of leptospirosis cases with (a) rivers, and (b) rice fields

Table 2. Results of Leptospirosis Incidence Clustering Analysis with an Aggregate period of One Month

No	Cluster	Time	Number of cases	Cluster location		Coordinate center		Radius (Km)	*P-value*
				District	Village	X	Y		
1	Cluster 1	2021/3/8 – 2021/5/7	12	Mirit	Wirogaten	109.766850 E	7.776667 S	10.59 km	0.0015
2	Cluster 2	2022/3/8 – 2022/4/7	3	Sempor	Sidoharum	109.494767 E	7.605617 S	4.48 km	0.681
3	Cluster 3	2022/1/8 – 2022/3/7	2	Pejagoan	Jemur	109.653583 E	7.627383 S	1.87 km	0.981
4	Cluster 4	2021/10/8 - 2022/1/7	2	Petanahan	Munggu	109.577250 E	7.758600 S	2.28 km	0.997
5	Cluster 5	2022/7/8 - 2022/8/7	2	Adimulyo	Caruban	109.551800 E	7.656300 S	3.99 km	0.997
6	Cluster 6	2022/4/8 - 2022/7/7	5	Padureso	Sendangdalem	109.775833 E	7.606000 S	8.84 km	0.997

Information:
P-value <0.05 means significant
P-value >0.05 is not significantly meaningful

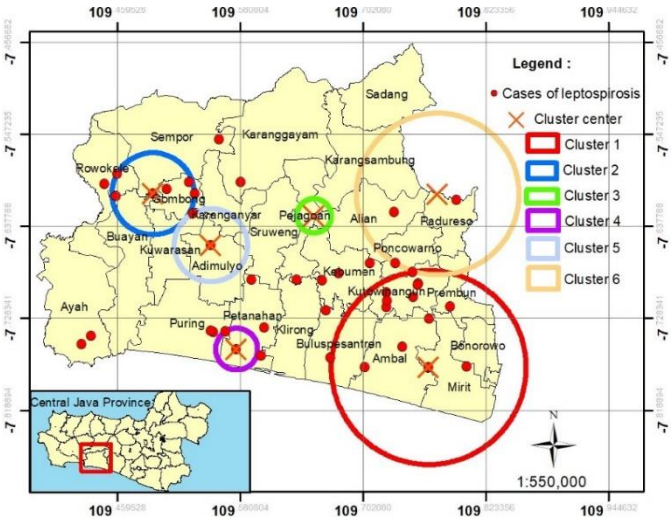

Figure 3. Cluster map of leptospirosis cases in Kebumen Regency

The results of *clustering* analysis using Satscan with an aggregate time of one month in leptospirosis cases from 2021 to August 2022 showed that there were six clusters of leptospirosis infection sources as shown in **Table 2** below.

Based on the results of the satscan analysis, it shows that there is one significant meaningful cluster (*p-value* = 0.0015) which occurred on March 8, 2021 – May 7, 2021, located in Mirit District, Wirogaten Village with a coordinate center (109.766850 E, 7.776667 S) with a radius of 10.59 km. Meanwhile, the other five clusters formed are not significantly meaningful (**Figure 3**).

The incidence of leptospirosis in Kebumen Regency from 2021 until August 2022 spread in 20 districts from 26 districts. This is possible because the condition of the Kebumen Regency area, which has many rice fields, gardens, and settlements, is very supportive of rat habitat. According to Joharina's research, in 2019 the percentage of *Leptospira*-positive rats was found in many residential habitats, rice fields, and gardens.[17] In addition, leptospirosis cases in Kebumen Regency are dominated by farmer workers because when doing activities in environments such as rice fields and gardens, they often do not wear footwear so that *Leptospira* bacteria have the potential to enter the body.[18] This result is following research in Banyumas which states that in leptospirosis cases as many as 62.1% are men and the majority worked as farmers (40%).[19]

Overlay results on population density in Kebumen Regency show that leptospirosis cases tend to be found more in low-population density areas. In addition, the results of overlays with land use show that the majority of leptospirosis cases occur in village settlement areas that are surrounded by rice fields, yards, and gardens. The land use map obtained from the Regional Development Planning Agency (Bappeda) is the result of satellite imagery in 2017. Rural areas where there is a lot of agricultural land, yards, and plantations in Kebumen Regency, especially in areas with low population density, will be the optimal place for rat breeding. This result is following Nurbeti's research, 2016 which states that the most cases of leptospirosis are not found in areas with the highest population density.[20] These results are different from studies in Banyumas and Semarang that leptospirosis cases occur in areas with moderate to high densities where there are many residential areas.[19,21] These results show that the transmission of leptospirosis is not only in densely populated settlements such as urban areas, but can also occur in rural areas where there are many agricultural areas such as rice fields, gardens, mangroves, and forests.[17]

The results of overlaying leptospirosis cases with altitudes in Kebumen Regency show that many cases are found at altitudes of 0-100 meters above sea level. Low-lying areas tend to cause a lot of waterlogging and flooding, especially when the rainy season arrives. The existence of standing water has the potential to be a source of indirect transmission to humans if it has been contaminated by rat urine containing *Leptospira* bacteria. The results of this study are in line with several other studies such as in the provinces of South Sumatra, Sampang, and Demak which show that cases of leptospirosis or mice that are positive for *Leptospira* are found in areas with an altitude of <100 meters above sea level.[22–24] The results of studies in Pati Regency showed that rats were widely caught in low-lying areas.[25] Studies state that the altitude of a place ≤100 meters above sea level has a 2.3 times higher risk of being infected with *Leptospira* compared to an altitude of 101-600 meters above sea level.[26] The results of the overlay of cases and flood history in Kebumen Regency show that the majority of leptospirosis cases occur in flooded areas. Flood conditions will make rat nests waterlogged so that rats will come out of hiding places and move to human settlement environments where this is a chance of developing a risk of leptospirosis transmission due to contact with rats. After the flood, there will be a lot of puddles that have not receded, mud, or muddy soil so it can be a risk factor for humans to be exposed to water and soil that has contained *Leptospira* bacteria.[27] These results are in line with research in Karangtengah District, Demak which shows that as many as 61% of cases occur in areas that have experienced floods.[28] The presence of contact with flooding is a significant factor in the occurrence of leptospirosis (OR: 2.19, 95% CI: 1.48–3.24, I 2:86%).[12]

Cases of leptospirosis in Kebumen Regency are widely found to be related to the presence of rivers. The existence of rivers is one of the risk factors for the occurrence of leptospirosis, rivers can be a medium of indirect transmission of *Leptospira*.[29] Rivers in Kebumen Regency in some places found garbage scattered on the banks of the river so that potentially rats forage for food so it is feared that the river is polluted by rat urine containing *Leptospira*. Some studies state that the influence of the distance between the river and the residents' homes can be a risk factor for leptospirosis. Research in the Gajahmungkur Subdistrict area of Semarang City stated that many cases of Leptospirosis were found in a river buffer radius of 50-300 meters. Areas adjacent to the river have the potential to be exposed to river overflows due to flooding during the rainy season where the river water may have been infected with *Leptospira*.[30] Another study in Malaysia stated that as many as 90.2% of leptospirosis cases were found to be 3 kilometers away from the river.[31]

Cases of leptospirosis in Kebumen Regency are also found in a radius of up to 500 m with rice fields. These results are following research in Banyumas Regency, all cases of leptospirosis were found at a distance of 0-1 km from rice fields.[32] Kebumen Regency area has found many rice fields so it has the potential to become a place of transmission. According to BPS data in 2021, it was recorded that land use for rice fields amounted to 31.30% of the total land. Rice

fields are a suitable place for rats to get the availability of feed so it becomes one of the habitats preferred by rats. Mice in search of food can explore up to a radius of 1-2 km. In this study, many cases were found at a radius of 0-1 km from the rice fields so that they still corresponded to the home range of rats. This of course risks the transmission of leptospirosis in rice fields. Mice in their foraging range will secrete urine that potentially contains *Leptospira* along the way. The existence of rice fields can be a means of transmitting *Leptospira* bacteria indirectly. The existence of transmission through rice fields is related to the activities of residents in Kebumen Regency, most of whom work as farmers and do not wear PPE when working in the rice fields.[29]

The results of the Satscan analysis obtained 6 (six) groupings of sources of infection. The cluster radius formed from the results of the satscan analysis is the radius of the risk of transmission.[14] Significant cluster locations are in Wirogaten Village. This shows that there is transmission in the village so if there are sufferers in the village, people who live up to a radius of 10.59 km have the potential to have a risk of contracting leptospirosis. The results of the Satscan analysis were used to see the grouping pattern of the source of leptospirosis infection. The existence of a strong and significant cluster grouping indicates the suspected spread of mice and *Leptospira* bacteria in the *cluster* so that it has the potential to be a source of leptospirosis infection and has a high risk in the population living in the area.[33] The existence of strong and significant *clusters* identified in this study can be used by health policymakers to carry out integrated control, prevention, and health promotion activities in the area to break the chain of transmission of leptospirosis.

CONCLUSIONS AND SUGGESTIONS

The incidence of leptospirosis in Kebumen Regency is spread across 20 districts with the most cases in Kutowinangun and Rowokele districts. Characteristic cases of leptospirosis occur most at the age of 50-59 years, male sex, poorly educated, and working as farmers. The results of spatial analysis of environmental conditions show that the incidence of leptospirosis at the study site is mostly found in areas with low population density (417-1025 people/km^2), altitudes of 0-100 meters above sea level, flood history, land use in the form of village settlements surrounded by rice fields, yards, and gardens, the distance of houses to rivers > 1 km and the distance of houses to the rice fields < 500 m. A cluster of significant cases suspected to be the source of leptospirosis transmission is in Mirit District. The results of this study can be information for health policymakers to carry out integrated control, prevention, and health promotion activities in Kebumen Regency, especially in areas that are suspected to be clusters of sources of transmission.

ACKNOWLEDGEMENTS

The author expresses his gratitude to the Department of Health, Population Control, and Family Planning; Regional Disaster Management Agency; the Central Statistics Agency; and the Regional Development Planning Agency Kebumen District. The author also expressed his gratitude to Diponegoro University, friends, respondents, and all those who have helped in this research.

BIBLIOGRAPHY

1. Costa F, Graco CZ, Ribeiro GS, Santos N, Reis RB, Martins RD, et al. Household rat infestation in urban slum populations : Development and validation of a predictive score for leptospirosis. PLoS Neglected Tropical Diseases. 2021;(March):1–13. Available from: http://dx.doi.org/10.1371/journal.pntd.0009154
2. Adler B, de la Peña Moctezuma A. *Leptospira* and leptospirosis. Veterinary Microbiology. 2010 Jan;140:287–96. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0378113509001163. https://doi.org/10.1016/j.vetmic.2009.03.012
3. Costa F, Hagan JE, Calcagno J, Kane M, Torgerson P, Martinez-Silveira MS, et al. Global Morbidity and Mortality of Leptospirosis: A Systematic Review. PLoS Neglected Tropical Diseases. 2015 Sep 17;17(september):1–19. Available from: https://dx.plos.org/10.1371/journal.pntd.0003898
4. WHO. Human Leptospirosis : Guidance for Diagnosis, surveillance and control. Malta : WHO. 2003.
5. Notobroto HB, Mirasa YA, Rahman FS. Sociodemographic, behavioral, and environmental factors associated with the incidence of leptospirosis in highlands of Ponorogo Regency, Province of East Java, Indonesia. Clinical Epidemiology and Global Health. 2021;12:1–5. Available from: https://doi.org/10.1016/j.cegh.2021.100911
6. Widjajanti W. Epidemiologi, diagnosis, dan pencegahan Leptospirosis. Journal of Health Epidemiology and Communicable Disease. 2020;5(2):62–8. https://doi.org/10.22435/jhecds.v5i2.174
7. Schneider AG, Casanovas-Massana A, Hacker KP, Wunder EA, Begon M, Reis MG, et al. Quantification of pathogenic *Leptospira* in the soils of a Brazilian urban slum. PLoS Neglected Tropical Diseases. 2018 Apr 6;12(4):1–15. Available from: https://dx.plos.org/10.1371/journal.pntd.0006415. https://doi.org/10.1371/journal.pntd.0006415
8. Thibeaux R, Geroult S, Benezech C, Chabaud S, Soupé-Gilbert M-E, Girault D, et al. Seeking the environmental source of Leptospirosis reveals durable bacterial viability in river soils. PLoS Neglected Tropical Diseases. 2017;11(2):1–14. Available from:

https://dx.plos.org/10.1371/journal.pntd.0005414. https://doi.org/10.1371/journal.pntd.0005414
9. Haake DA, Levett PN. Leptospirosis in Human. Vol. 387, Current Topics in Microbiology and Inmunology. 2015. 65–97 p. Available from: http://link.springer.com/10.1007/978-3-662-45059-8. https://doi.org/10.1007/978-3-662-45059-8_5
10. Sakundarno M, Bertolatti D, Maycock B, Spickett J, Dhaliwal S. Risk factors for leptospirosis infection in humans and implications for public health intervention in indonesia and the Asia-Pacific region. Asia-Pacific Journal of Public Health. 2014;26(1):15–32. https://doi.org/10.1177/1010539513498768
11. Haq A, Anggraini S, Masnarivan Y. Environmental Factors Related to Leptospirosis in Indonesia: A Systematic Review. In: Proceedings of the Third Andalas International Public Health Conference, AIPHC 2019. 2020. p. 1–6. https://doi.org/10.4108/eai.9-10-2019.2297166
12. Naing C, Reid SA, Aye SN, Htet NH, Ambu S. Risk factors for human leptospirosis following flooding: A meta-analysis of observational studies. PLoS One. 2019;14(5):1–15. https://doi.org/10.1371/journal.pone.0217643
13. Rejeki DSS, Murhandarwati EH, Kusnanto H. Analisis Spasial Malaria di Ekosistem Perbukitan Menoreh: Studi Kasus Malaria Bulan September-Desember 2015. Kes Mas: Jurnal Fakultas Kesehatan Masyarakat. 2018;12(2):120–32. https://doi.org/10.15294/kemas.v12i1.4030
14. Sulistyawati S, Nirmalawati T, Mardenta RN. Spatial Analysis of Leptospirosis Disease in Bantul Regency Yogyakarta. Jurnal Kesehataan Masyarakat. 2016;12(1):111–9. https://doi.org/10.15294/kemas.v12i1.4615
15. Pramatama S, Wijayanti M, Octaviana D, Anandari D. Aplikasi Tehnologi Sistem Informasi Geografis Untuk Meningkatkan Sistem Surveilans Penyakit Menular Di Kabupaten Banyumas. Jurnal Abdimas. 2019;22(2):221–6.
16. Idayani TN, Windraswara R, Prameswari GN. Analisis Spasial Faktor Risiko Lingkungan Dengan Kejadian Kusta Di Wilayah Pesisir. Higeia Journal of Public Health Research and Development. 2017;1(4):120–30.
17. Joharina AS, Pujiyanti A, Nugroho A, Martiningsih I, Handayani FD. Peran Tikus Sebagai Reservoir Leptospira di Tiga Ekosistem di Kabupaten Bantul, Yogyakarta. Buletin Penelitian Kesehatan. 2019;47(3):191–8. https://doi.org/10.22435/bpk.v47i3.1885
18. Pratamawati S, Ristiyanto R, Handayani F, Kinansi R. Faktor Risiko Perilaku Masyarakat Pada Kejadian Luar Biasa Leptospirosis Kabupaten Kebumen Tahun 2017. Vektora: Jurnal Vektor dan Reservoir Penyakit. 2018;10(2):135–42. https://doi.org/10.22435/vk.v10i1.1079
19. Janah M, Rejeki DSS, Nurlaela S. Analisis Kondisi Lingkungan pada Kejadian Leptospirosis di Kabupaten Banyumas dengan Pendekatan Spasial. ASPIRATOR - Jurnal Penyakit Tular Vektor. 2021;13(2):89–100. https://doi.org/10.22435/asp.v13i2.4837
20. Nurbeti M, Kusnanto H, Nugroho WS. Kasus-Kasus Leptospirosis Di Perbatasan Kabupaten Bantul, Sleman, Dan Kulon Progo: Analisis Spasial. Jurnal Kesmas. 2016;10(1):1–14.
21. Sholichah Z, Ikawati B, Marbawati D, Majid M, Ningsih P. Peran Tikus Got (*Rattus norvegicus*) dari Kelompok Tikus dan Suncus sebagai Penular Utama Leptospirosis di Semarang. Jurnal Vektor Penyakit. 2021;15(1):53–62. Available from: http://ejournal2.litbang.kemkes.go.id/index.php. https://doi.org/10.22435/vektorp.v15i1.2607
22. Supranelfy Y, Suryaningtyas NH, Oktarina R. Analisis Faktor Lingkungan terhadap Distribusi Jenis Tikus yang Terkonfirmasi sebagai reservoir Leptospirosis di Tiga Kabupaten di Provinsi Sumatera Selatan. Vektora. 2019;11(1):31–8. https://doi.org/10.22435/vk.v11i1.1144
23. Rahim A, R.Yudhastuti. Pemetaan dan analisis faktor risiko lingkungan kejadian leptospirosis berbasis sistem informasi geografi (SIG) di Kabupaten Sampang. Jurnal Kesehatan Lingkungan. 2015;8(1):48–56. https://doi.org/10.20473/jkl.v8i1.2015.48-56
24. Rahayu S, Adi M, Saraswati L. Pemetaan Faktor Risiko Lingkungan Leptospirosis Dan Penentuan Zona Tingkat Kerawanan Leptospirosis Di Kabupaten Demak Menggunakan Remote Sensing Image. Jurnal Kesehatan Masyarakat Universitas Diponegoro. 2017;5(1):218–25.
25. Sholichah Z, Wijayanti T, Raharjo J, Widiastuti D, Ningsih DP, Priyanto D, et al. Spot Survei Reservoir *Leptospira* di Daerah Dataran Rendah dan Dataran Tinggi. Jurnal Litbang: Media Informasi Penelitian, Pengembangan dan IPTEK. 2020;16(2):129–38. https://doi.org/10.33658/jl.v16i2.162
26. Ikawati B, Widiastuti D. Dominant factors influencing *Leptospira* sp infection in rat and suncus. Health Science Journal Indonesia. 2012;3(2):27–30.
27. Barragan V, Olivas S, Keim P, Pearson T. Critical knowledge gaps in our understanding of environmental cycling and transmission of *Leptospira* spp. Applied and Environmental Microbiology. 2017;83(19):1–10. https://doi.org/10.1128/AEM.01190-17
28. Zukhruf IA, Sukendra DM. Analisis Spasial Kasus Leptospirosis Berdasar Faktor Epidemiologi dan Faktor Risiko Lingkungan. Higeia Journal of Public Health Research and Development. 2020;4(4):587–98.
29. Cahyati WH, Kumalasari LD. Analisis Spasial Faktor Lingkungan Leptospirosis di Kecamatan Bonang Kabupaten Demak Tahun 2018. Visikes: Jurnal Kesehatan Masyarakat. 2020;19(1):196–

211.
30. Nurhandoko F, Arum Siwiendrayanti. Zona Kerentanan Kejadian Leptospirosis Ditinjau dari Sisi Lingkungan. Higeia Journal of Public Health Research and Development. 2018;2(3):498–509.
31. Hassan HA, Daud A, Ismail AF, Aziz NRA, A F, Shafei MN, et al. A Geographical Information System on Related Environmental Factors of Leptospirosis in Northeastern State Malaysia. International Journal of Rural Development, Environmental and Health Research. 2018;2(1):26–36. https://doi.org/10.22161/ijreh.2.1.4
32. Rejeki DSS, Nurlaela S, Octaviana D. Pemetaan dan Analisis Faktor Risiko Leptospirosis. Kesmas: Jurnal Kesehatan Masyarakat Nasional. 2013;8(4):179–86. https://doi.org/10.21109/kesmas.v0i0.397
33. Deshmukh P, Narang R, Jain J, Jain M, Pote K, Narang P, et al. Leptospirosis in Wardha District, Central India—Analysis of hospital based surveillance data. Clinical Epidemiology and Global Health. 2019;7(1):102–6. Available from: http://dx.doi.org/10.1016/j.cegh.2018.02.005