
Review Articles

Environmental Risk Factors of Leptospirosis: Systematic Review

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ABSTRACT

Background: Leptospirosis is a zoonotic disease caused by the bacteria *Leptospira* sp. The incidence of Leptospirosis ranges from 0.1 to 10 per 100,000 per year globally. GIS is a tool to visualize data that considers effectiveness and efficiency when determining the priority areas of particular disease control.

Method: This systematic review was based on some databases, Google Scholar, PubMed, and the BASE, for articles published from 2010 to 2020. PRISMA guideline was used during data screening.

Results: Eight articles were reviewed that showed a pattern of distribution of cases of Leptospirosis: clustered, evenly, and randomly. We also found 15 environmental factors that influence Leptospirosis distribution: the existence of the river, precipitation, sunshine, a history of the flood, the existence of the gutter, the condition of the garbage disposal, the existence of rice fields, the presence of vegetation, trap success, the existence of the road, the ownership of the pet, the presence of rats, altitudes, and land-use.

Conclusion: 15 identified environmental risk factors influence the incidence of Leptospirosis, namely the existence of rivers, history of flooding, the existence of gutters, waste disposal conditions, rainfall, the existence of rice fields, population density, the existence of vegetation, the success of traps, the existence of ponds, the existence of roads, livestock ownership, presence of rats, altitude, and land use.

Keywords: Geographic Information Systems; Spatial Analysis; Mapping; Leptospirosis; Environment.

INTRODUCTION

Leptospirosis is acknowledged as a public health issue, with several outbreaks attributed to natural catastrophes and the presence of unsatisfactory sanitary conditions. Globally, the prevalence of Leptospirosis varies from 0.1 to 10 cases per 100,000 individuals annually. In the event of an outbreak and significant exposure among vulnerable populations.¹ In Indonesia, nine provinces experienced cases of Leptospirosis in 2019; they are DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, Banten, North Kalimantan, South Sulawesi, and Maluku. The 2020 Indonesian Health Profile states that 920 cases of Leptospirosis occurred in 2019, with 122 deaths (CFR = 13.26%).²

Leptospirosis is a zoonotic disease caused by spiral-shaped and actively moving microorganisms from the pathogenic genus *Leptospira*, which is *Leptospira sp.* bacterial.³ Humans can accidentally become infected by the *Leptospira* bacteria, which naturally resides in mice as their definitive hosts. This infection is considered incidental because humans are not the primary target of this bacteria. There are two main ways humans can get infected: first, through contact with environments contaminated by mouse urine containing this bacterium, such as water or soil; second, through direct contact with tissues or organs of mice infected with the *Leptospira sp.* bacteria. In both cases, the infection occurs due to indirect interaction between humans and mice, making this process an incidental event in the life cycle of the bacteria.⁴

One step to reduce leptospirosis incidence can be utilizing geographic information systems (GIS). GIS are computerized instruments for storing, visualizing, analyzing, and interpreting geographic data.⁵ The use of GIS is presented in a spatial form to make it easier to display and compare the distribution of relationships between the locations of objects so that you can get a picture of the points or locations of the distribution of diseases and other health conditions.⁶ The environment plays a vital role in transmitting *Leptospira sp.* bacteria, so it is necessary to know the spatial description of leptospirosis cases, which is expected to identify environmental factors that influence the spread of Leptospirosis. The Geographic Information System is used to improve the health surveillance system because by using this system, it can visualize disease in space and time in the form of a map. Besides that, GIS can also be used to identify patterns of disease spread, the distance between cases, the outbreak, how long cases can spread, and which areas are included in disease-prone areas.⁷

Knowing the past research that discussed the environmental risk factor of Leptospirosis using GIS is beneficial to understanding the potential community at risk. Accordingly, it can alarm the policymaker while planning the control program. A systematic review is a research method that uses review, analysis, structured evaluation, classification, and categorization of evidence-based evidence from previous researchers. This research aimed to study the last article that addresses the environmental risk factor of Leptospirosis and analyze it using GIS.

METHOD

Search Strategy

Google Scholar, PubMed, and Bielefeld Academic Search Engine (BASE) were the primary source databases accessed in January-March 2021 to extract studies published in English and Bahasa that discussed the Leptospirosis Indonesian context. A set combination of keywords was used: "Geographical Information System," "Spatial Analysis," "Geographical Mapping," "Leptospirosis," and "Environment," and the keywords in English are: "Geographical Mapping," "Spatial Analysis," "Leptospirosis" and "Environment." We observed research papers published from 2010 to 2020. Title, keyword, and abstracts were screened for the first step for the relevant article, and the full paper that met our criteria inclusion was included in our analysis. Inclusion criteria: original research article, articles are published in English or Indonesian, the article aims to understand the spatial distribution, pattern of case spread, and environmental factors affecting the spatial occurrence of Leptospirosis and have published 2010-2020.

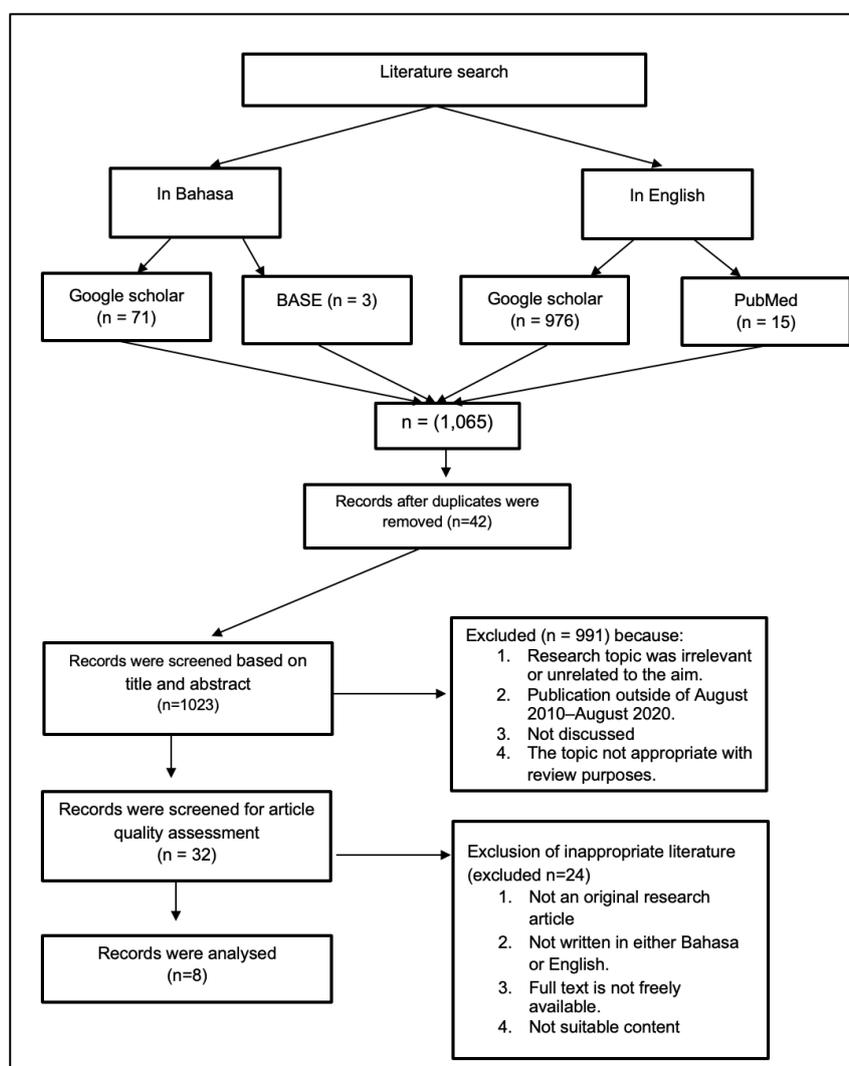


Figure 1. PRISMA Diagram

RESULTS

The final result of screening using the PRISMA diagram yielded eight articles that aligned with the predetermined topic and criteria. The last stage of the systematic review was extracting data into Microsoft Excel. Table 1 shows the search results after going through several stages.

Table 1. Extraction results

No	Author and Year	Title	Research Location	Pattern Distribution Of Cases	Method	Environmental factor
(1)	Isnaini Alfazcha Zukhruf and Dyah Mahendrasari Sukendra (2020)	Spatial Analysis of Leptospirosis Cases Based on Epidemiological Factors and Risk Factors Environment	Demak District, Central Java	Clumped	ANN	history, gutter conditions, and conditions garbage dump
(2)	Annisa Rahim and R. Yudhastuti (2015)	Mapping and Analysis of Risk Factors for Leptospirosis Based on Geographic Information Systems In Sampang Regency	Sampang Regency	Clumped	Not stated	Rainfall, altitude, history of flooding
(3)	Dewi Puspita Ningsih and Sunaryo Sunaryo (2014)	Spatial Distribution of Leptospirosis in Districts Gresik, East Java	Gresik Regency, East Java	Equally	Not stated	Trap success, Land use, rainfall, Vegetation density
(4)	Widya Hary Cahyati and Lia Diah Kumalasari (2020)	Spatial Analysis of Environmental Factors of Leptospirosis in Bonang District, Demak Regency	Demak District, Central Java	Random	ANN	History of floods, waste storage, rivers, rice fields, ponds, and population density
(5)	Maftuhah Nurbeti, Hari Kusnanto and Widagdo Sri Nugroho (2016)	Cases of Leptospirosis in the Border Districts of Bantul, Sleman, and Kulon Progo: Analysis Spatial	Bantul, Sleman and Kulonprogo Regencies, Yogyakarta	Clumped	NNA	Rice fields, rivers, roads, population density, rainfall,
(6)	Lirih Setyorini, Nurjazuli and Hanan Lanang Dangiran (2017)	Analysis of Leptospirosis Distribution Patterns in City Semarang	Semarang City, Central Java	Clumped	NNA	The existence of rivers, rubbish dumps, Drain,
(7)	Ferry Febrian and Solikhah (2013)	Spatial Analysis of the Incidence of Leptospirosis in Sleman Regency, Yogyakarta Special Region Province the year 2011	Sleman Regency, Yogyakarta	Clumped	Not state	Pet ownership, presence of rats, presence of vegetation, presence of ditches
(8)	Hasnan Arwit Hassan, et al (2018)	A Geographical Information System on Related Environmental Factors of Leptospirosis in Northeastern State Malaysia	Northeastern State Malaysia	Clumped	ANN	Existence of rivers, land use

Based on the results of the systematic review analysis that was carried out, a total of 8 articles were obtained that discussed the distribution patterns of leptospirosis cases and environmental factors that influence the spatial incidence of Leptospirosis. Articles discussing the distribution pattern of Leptospirosis cases include six articles number 1,2,5,6,7,8⁸⁻¹³ with a clustered pattern of case distribution, one article¹⁴ with an even pattern of case distribution and one article¹⁵ with a random case pattern. Of the eight articles, 5 mentioned the causes of the pattern of distribution of cases, namely due to rainfall,⁹ the presence of rice fields and ponds,^{10,15} history of flooding,^{9,15} and river flow.^{10,11} In comparison, three articles^{8,12,13} others did not mention the cause.

The method most frequently used to detect case distribution patterns from the eight articles studied, namely Nearest Neighbor Analysis (NNA), used in 2 articles, Average Nearest Neighbor (ANN) in 3 articles, Nearest Neighbor Index (NNI) method used in 1 article, and three articles did not mention the type of method used. Fifteen environmental factors play a role in the occurrence of Leptospirosis. Some of these factors include rivers,^{10,11,13,15} flood history,^{8,9,11,15} the existence of sewers,^{8,11,12} condition of waste disposal.^{8,11,15} The other result yield from the review was the presence of rice fields,^{10,15} precipitation,^{9-11,14} population density,^{10,15} presence of vegetation,¹² trap success,¹⁴ presence of ponds,¹⁵ presence of roads,¹⁰ pet ownership,¹² presence of mice,¹² altitudes,⁹ and land use.¹³

DISCUSSION

Leptospirosis has been acknowledged as a public health concern, with several reported pandemics attributed to natural disasters and the prevalence of inadequate sanitation conditions. An estimated ten or more individuals per 100,000 are affected by this disease annually in tropical regions. The incidence can escalate to 100 cases per 100,000 people in a pandemic. Based on the systematic review results, GIS could recognize the distribution pattern of leptospirosis cases. The cause of this pattern formation is due to exposure to risk factors, including river flow, high rainfall, history of flooding, and the presence of rice fields and ponds. According to previous research, a spatial pattern shows the placement or arrangement of objects on the earth's surface.¹⁶ Any changes in spatial patterns will illustrate spatial processes directed by environmental and cultural factors. This aligns with another research study, which states that the pattern formed is clustered, where the same exposure to environmental risk factors, such as rice fields and puddles, causes the pattern.¹⁵

The results of the systematic review analysis show that the use of Geographic Information Systems (GIS) to detect distribution patterns of leptospirosis cases has been widely implemented in various regions in Indonesia. Despite this widespread implementation, many areas still need to utilize GIS fully in the health sector. This underutilization is partly due to the need for more human resources skilled in operating and using GIS.¹⁷ Environmental Factors that Influence the Distribution Pattern of Leptospirosis Cases can vary and are unique from one region or event to another. Spatial analysis is one method for identifying risk factor points that influence the incidence of Leptospirosis, making it easier to prevent and control areas at risk.

Existence of Rivers^{10,11,13,15}

Rivers are at risk of exposure to *Leptospira* bacteria due to the possibility of contact with the urine of infectious reservoir animals. *Leptospira* bacteria enter through the soft pores of the skin, which become permeable when in contact with water, mucous membranes, skin on the feet, hands, and any areas with abrasions or wounds.¹⁸ The distance traveled by mice is influenced by the availability of food, and the migration distance of mice reaches a distance of 1 -2 km to obtain food, so that if the distance from the house to the case's home is at that distance, there is a risk of Leptospirosis transmission. This is when compared with the research results, three articles have a distance of 1 - 2 km between the case house and the presence of a river, where this distance is the cruising range of mice, so there is a risk of Leptospirosis transmission. In contrast, 1 article shows the case house is at a distance of 3000 meters or 3 km, which means it exceeds the distance traveled by mice, suggesting that other environmental risk factors can cause this.

Flood History^{8,9,11,15}

The study showed that⁸ These results align with research conducted by Pramestuti in Pati Regency, showing that 75.7% of leptospirosis sufferers live in environments with a history of flooding.¹⁹ Flooding is a disaster that can disrupt health services and infrastructure, cause dirty water and sanitation, and damage houses. It can increase environmental exposure to pathogens.²⁰ The research results show that the research location is a coastal area, and water channels overflow when it rains, resulting in flooding and lots of standing water, which triggers the transmission of Leptospirosis. However, Leptospirosis can occur outside flood areas, where the area has experienced standing water and contains *Leptospira* bacteria. Apart from that, it can be influenced by other risk factors that influence the incidence of Leptospirosis.

Existence of gutters^{8,11,12}

Fifty-four percent of Leptospirosis cases are spread in areas with poor sewer conditions.¹² It happened when gutters in the respondents' homes did not flow smoothly, there was a lot of rubbish piling up in the gutters, the gutters overflowed when it rained, the gutters were not cleaned routinely and regularly, the gutters were made of concrete which reduced their ability to absorb water, and there were often rats—visiting the house. Previous research said that 51.4% of cases had a sewer distance of ≥ 2 meters while observed using buffer analysis.¹¹ This indicates that the distance is unrelated to Leptospirosis. The research of Priyanto et al. showed no relationship between the distance from the house and the presence of sewers on the incidence of Leptospirosis ($p = 0.789$).²¹ The proximity of a sewer to a case of Leptospirosis sufferers does not cause Leptospirosis because it depends on the condition of the sewer itself. In essence, Leptospirosis is transmitted through the sewer route if the sewer water is infected with *Leptospira* bacteria, and the respondent comes into contact with the water.

Waste disposal conditions^{8,11,15}

97.5% of Leptospirosis cases have poor waste disposal sites.²² This is reinforced by

Rusmini, who states that poor rubbish dumps are a risk factor for Leptospirosis because the intermediary vector of *Leptospira* bacteria, especially rats, really like places with piles of rubbish.²³ Meanwhile, research stated that a distance radius between case houses with rubbish dumps shows that 91.8% of cases are located at a distance of less than 500 meters.¹¹ This is in line with research, which showed that 90% of cases were at a distance of ≤ 500 meters.²⁴ The research results show that respondents still use open rubbish bins such as buckets, plastic, and sacks, and some don't have rubbish bins at home, resulting in rubbish strewn all over the yard. This will undoubtedly invite the presence of mice, making the place a food source and shelter for mice. The proximity of a house to a rubbish dump means that mice can enter the house and urinate everywhere. If a rat is infected with *Leptospira* bacteria and excretes infective urine, the waste likely contains *Leptospira* bacteria.

*Rainfall*⁹⁻¹¹

Leptospirosis often occurs with rainfall above 177.6 mm, nine while others say that Leptospirosis often occurs in areas with rainfall of 2000 mm/year,¹⁰ and 101 – 300 mm/month.¹¹ According to Sunaryo and Marbawati, the incidence of Leptospirosis will increase with high rainfall.²⁵ Several studies have shown that the rainfall index is a risk factor influencing the incidence of Leptospirosis. High rain causes flooding and is a good and optimal condition for mice to reproduce, thereby increasing the risk of transmission of *Leptospira* bacteria.

The existence of rice fields^{8,10,15}

38% of cases reside in residences more than 200 meters from rice fields. One study found that 7 cases were documented, while another found that all cases occurred in dwellings within a 0-1 km radius of rice fields.¹⁵ The validity of these findings is enhanced by buffer analysis measures, which indicate that 52.5% of the cases reside in dwellings within a range of 0 - 1 km from rice fields. These two research findings suggest a correlation between the proximity of a house to rice fields and the incidence of Leptospirosis. Specifically, the chance of acquiring Leptospirosis increases as the distance between the house and the rice fields decreases. The findings of this study are consistent with the research carried out in Banyumas Regency, which indicates that all reported cases were within a range of 0 - 1 km from rice fields.²⁶

Population Density^{10,15}

Villages with high density have several cases of 4%, villages with medium density have several cases of 80%, and low density have several cases of 16%.¹⁵ Meanwhile, the research using an overlay of a population density map with a map of Leptospirosis cases showed that population density was not accompanied by an increase in the number of cases, and the most significant number of cases was not found in areas with high population density.¹⁰ This shows that population density does not necessarily affect the incidence of Leptospirosis. These results do not align with Stein, C. et al. that population density is one factor influencing the transmission of Leptospirosis in Southeast Asia.²⁷ Densely populated environments tend to be dirty and have a high rat

population due to poor sanitation, making it easier for *Leptospira* bacteria to spread. Other environmental factors may influence these differences. The research results stated that at the research location, the land used was not only for residential areas but also for agricultural land, plantations, and ponds, which were quite extensive. Thus, it can increase the risk of transmitting Leptospirosis apart from population density. If the population density is high but the sanitation conditions are reasonable, it can minimize the occurrence of leptospirosis transmission.

*Presence of vegetation*¹²

100% of Leptospirosis incidents occur in locations with three or more vegetation types.¹² These results align with previous research, which found that 53.8% of Leptospirosis cases had vegetation ≥ 3 types around the house.²⁸ The diversity and density of vegetation are a source of food and shelter for mice. Several plants that contribute to the existence of mice include bushes, shrubs, and plants with branches. An environment that is dirty and covered with grass or bushes is a place that mice like.

*Trap success*¹⁴

The results of the research show that most of the five sub-districts have a trap success percentage value of $> 7\%$ inside and outside the house, meaning that there are a lot of mice in that area, and this is a potential location for mouse habitat as a reservoir for *Leptospira* bacteria. Research mentioned that the criteria for successful trapping in the house are if $>7\%$ is categorized as having lots of mice and $<7\%$ is classified as having few mice.²⁹ The success of catching mice can describe the density of mice in a place or environment. High trap success can be caused by several things, such as lack of cleanliness, poor sanitation, scattered or piled-up rubbish, and sewer water that does not flow.

*Existence of ponds*¹⁵

The research using buffer analysis shows that the highest number of houses with cases are located within a distance of > 2 km from the pond, with a percentage of 62%. This is in line with research showing that the distance between the case house and the pond is > 700 meters with a percentage of 85.3%.³⁰ The research results are inversely proportional to Mwachui's statement that low-lying areas along riverbanks, ponds, or beaches are highly vulnerable to flooding during the rainy season.³¹ This difference can be caused by other supporting environmental risk factors. This research explains that the research location is a slum and densely populated, and rubbish is piling up. This triggers the presence of a reservoir (rodent).

*Road Existence*¹⁰

The buffer analysis research shows that the highest number of houses with leptospirosis sufferers are within a distance of 0 - 50 m from the road at 82.97%. In this study, it needs to be explained in detail why this distance influences the incidence of Leptospirosis. However, it was explained that there are still many wastewater disposal facilities along the road, and people still have the habit of throwing rubbish or dead rats

at that tunnel. Most of the disposal tunnels are still open.

*Pet ownership*¹²

The research showed that 59.1% of Leptospirosis cases occurred in locations where animals, such as dogs, cows, pigs, goats, cats, or others, were owned. This research is in line with research conducted by Ramadhan in determining the condition of the homes of leptospirosis sufferers, showing that 95% of cases have pets.³² Pets that can become intermediate hosts and transmit Leptospirosis to humans are dogs, goats, cats, cows, pigs, or birds.³³ Leptospirosis exposure is primarily in tropical countries, including developing countries, but it is most likely in humans due to infection from livestock, domestic animals, and wild animals.³⁴

*Presence of mice*¹²

The study results showed that 85.2% of cases of Leptospirosis occurred in locations where rats were in the house. This is in line with previous research showing that 73.3% of cases occurred in places where rats were present.³⁵ Rats are essential in transmitting Leptospirosis because >50% of rats can continuously excrete *Leptospira* bacteria through urine without symptoms.²³ Apart from that, it is closely related to environmental conditions. Rats in or around the house are caused by rubbish that is not managed correctly, lack of lighting, and poor environmental conditions.

*Altitudes*⁹

The study results showed that Leptospirosis occurred frequently in Sampang District from 4 sub-districts with altitudes below 47 meters above sea level, with a total of 103 cases. This aligns with Sunaryo's research that Leptospirosis cases are more common in altitude areas below 47 meters above sea level.³⁶ This low altitude has the potential for flooding, which can become a medium for transmitting *Leptospira* bacteria. Areas that have a low altitude of 5m to 10m above sea level are unlikely to have cases of Leptospirosis; this is because, in these conditions, there are areas where there is seawater/brackish water with a high level of salinity, which is not liked by *Leptospira* bacteria. Meanwhile, a height between 31m and 50m above sea level is the ideal height area for the life of *Leptospira* bacteria.

*Land use*¹⁴

The research results show that most cases live on agricultural land with a percentage of 67.1%, including horticulture, rubber, rice, gardens, and other crops. These results are reinforced by the fact that 35.4% were included in the high-risk occupational group in the research area, including farmers. Land use is closely related to the spread of Leptospirosis because it can indicate the potential places for *Leptospira* bacteria to survive under certain conditions and the residence and breeding place for the reservoir itself.

CONCLUSION

This study aims to identify the environmental risk variables that influence leptospirosis incidence based on previously published publications that used GIS as the research method. It is known that 15 identified ecological risk factors influence the incidence of Leptospirosis, namely the existence of rivers, history of flooding, the existence of gutters, waste disposal conditions, rainfall, the existence of rice fields, population density, the existence of vegetation, the success of traps, the existence of ponds, the existence of roads, livestock ownership, presence of rats, altitude, and land use. It is clear that when one or more of these risk variables exist in a location, there is a risk of Leptospirosis happening, allowing local authorities to design prevention initiatives.

Declarations

Authors' contribution

DS and SS were responsible for the research design and data collection, MM provided a data analysis review, and WKW reviewed the manuscript.

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Conflict of interest

There is no conflict of interest in this research.

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