



## Analyzing the Geographical and Seasonal Trends of Leptospirosis Incidence

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### Abstract

Leptospirosis, a significant zoonotic disease caused by *Leptospira* bacteria, exhibits distinct geographical and seasonal patterns influenced by various climatic, environmental, and socioeconomic factors. This review synthesizes existing research on the incidence of leptospirosis globally, with a focus on its distribution and seasonal trends. Analysis reveals that leptospirosis is most prevalent in tropical and subtropical regions, with significant hotspots in the Caribbean, Latin America, Southeast Asia, and Oceania. Seasonal peaks typically occur during the rainy season due to increased contact with contaminated water. Climatic factors such as rainfall, temperature, and humidity are critical drivers of leptospirosis transmission. Socioeconomic factors, including poor sanitation, urbanization, and occupational exposure, also significantly affect incidence rates. Understanding these patterns is crucial for developing targeted prevention and control strategies. The review concludes that continuous surveillance and targeted public health interventions are essential to mitigate the impact of this disease, particularly in high-risk regions and during peak transmission seasons.

**Keywords:** *Leptospira* bacteria, rainfall, temperature, and humidity, socioeconomic, public health interventions

### Introduction

Leptospirosis is a globally significant zoonotic disease caused by pathogenic bacteria of the genus *Leptospira*. This disease affects humans and a wide range of animals, leading to a broad spectrum of clinical manifestations, from mild flu-like symptoms to severe, potentially fatal conditions such as Weil's disease and severe pulmonary hemorrhage syndrome. Leptospirosis is transmitted primarily through direct contact with the urine of infected animals or indirectly through contact with contaminated water or soil.

Globally, leptospirosis is most prevalent in tropical and subtropical regions, where environmental conditions favor the survival and spread of *Leptospira* bacteria. The World Health Organization (WHO) estimates that there are over 1 million cases of leptospirosis annually, resulting in approximately 58,900 deaths. Regions with the highest incidence rates include the Caribbean, Latin America, Southeast Asia, and Oceania. For instance, in Brazil, annual incidence rates can exceed 10 cases per 100,000 people, particularly during the rainy season.

The geographical distribution of leptospirosis is influenced by a combination of climatic, environmental, and socioeconomic factors. Tropical and subtropical climates provide ideal conditions for the bacteria to thrive, with high humidity and frequent rainfall facilitating the spread of the bacteria through water and soil. In urban areas, poor sanitation and inadequate waste management exacerbate the risk of transmission, particularly in informal settlements where human populations are in close contact with rodent carriers of the disease.

Seasonal variations in leptospirosis incidence are closely linked to climatic conditions. The disease incidence typically peaks during the rainy season when flooding increases the likelihood of contact with contaminated water. Studies have shown a strong correlation between leptospirosis cases and rainfall patterns. For example, in São Paulo, Brazil, the incidence of leptospirosis was significantly higher during the rainy season compared to the

dry season. Similarly, in Malaysia, increased incidence rates have been observed during periods of heavy rainfall.

Socioeconomic factors also play a crucial role in the incidence and spread of leptospirosis. Populations in low-income areas with poor infrastructure are at higher risk due to inadequate sanitation, lack of clean water, and high exposure to contaminated environments. Occupational exposure is another significant risk factor, particularly for individuals working in agriculture, animal husbandry, and waste management. For instance, in Germany, a significant proportion of leptospirosis cases were linked to occupational exposures involving direct contact with animals or contaminated water.

This review aims to provide a comprehensive analysis of the geographical and seasonal trends in leptospirosis incidence, synthesizing data from various studies to highlight the key factors influencing the distribution and timing of this disease. By understanding these patterns, public health officials can develop targeted interventions to reduce the incidence and impact of leptospirosis, particularly in high-risk areas and during peak transmission seasons.

### Objective

The objective of this study is to analyze the geographical and seasonal trends of leptospirosis incidence, identifying key environmental, climatic, and socioeconomic factors that influence its distribution and timing.

### Geographical Trends

#### Tropical and Subtropical Regions

Leptospirosis is predominantly found in tropical and subtropical regions where environmental conditions favor the survival and transmission of *Leptospira* bacteria. These areas provide ideal conditions such as high humidity, warm temperatures, and frequent rainfall, which facilitate the bacteria's persistence in water and soil. The Caribbean, Latin America, Southeast Asia, and Oceania are notable hotspots for leptospirosis, with Brazil, Thailand, Malaysia,

and Fiji reporting high incidence rates. In Brazil, states like São Paulo and Santa Catarina experience frequent outbreaks. São Paulo has higher incidence rates in areas with poor sanitation and inadequate waste management, particularly during the rainy season. In Santa Catarina, coastal regions exhibit higher leptospirosis incidence due to frequent flooding, which increases the risk of human exposure to contaminated water. Cuba and Puerto Rico also report high incidence rates, especially after hurricanes and tropical storms, which create conditions conducive to the spread of the bacteria. Southeast Asia is another region with high leptospirosis incidence. In Thailand, the northeastern region reports the highest rates, particularly among agricultural workers who are frequently exposed to contaminated water in rice paddies. The rainy season significantly increases the risk, with incidence rates peaking during monsoon months. In Malaysia, states like Malacca and Pahang show the highest incidence rates, with cases peaking during the monsoon season. Both urban and rural areas are affected, but the mechanisms of transmission differ. In rural areas, the disease is often linked to agricultural activities, whereas in urban areas, poor sanitation and inadequate waste management are the primary risk factors. The Philippines, particularly Manila, frequently experiences leptospirosis outbreaks following typhoons and heavy rains. Flooding leads to widespread contamination of water supplies with *Leptospira* bacteria from rodent urine. Oceania, including Fiji and the Solomon Islands, also reports high leptospirosis incidence. Fiji's warm, humid climate and frequent tropical storms create an environment conducive to leptospirosis transmission. The incidence is particularly high in rural areas where agricultural activities bring people into contact with contaminated water. The Solomon Islands face similar challenges, with high incidence rates linked to environmental conditions and poor infrastructure. Frequent flooding and inadequate sanitation systems increase the risk of disease transmission.

Socioeconomic and environmental factors significantly contribute to the risk of leptospirosis in tropical and subtropical regions. Rapid urbanization in many of these areas has led to the development of informal settlements with poor infrastructure, increasing the risk of leptospirosis transmission. Poor waste management and inadequate drainage systems in these urban slums create environments conducive to the survival of *Leptospira* bacteria. Occupational risk factors also play a significant role in the geographical distribution of leptospirosis. Agricultural workers, fishermen, and waste management workers are at higher risk due to frequent exposure to contaminated water and soil. In Germany, occupational exposure accounted for a substantial proportion of leptospirosis cases, with direct contact with animals or contaminated environments being common transmission routes. Environmental conditions such as high humidity, frequent rainfall, and the presence of standing water are crucial for the survival and transmission of *Leptospira* bacteria. In regions like Southeast Asia and Latin America, these environmental factors significantly influence the spatial distribution of leptospirosis. Studies have shown strong correlations between leptospirosis incidence and climatic variables such as rainfall and temperature. The geographical trends of leptospirosis in tropical and subtropical regions underscore the importance of environmental, climatic, and socioeconomic factors in the

transmission and spread of this disease. High-incidence areas, particularly those with poor infrastructure and high occupational exposure risks, require targeted public health interventions and improved disease surveillance. Understanding these geographical patterns is crucial for developing effective strategies to reduce the incidence and impact of leptospirosis.

### Regional Variations

The incidence of leptospirosis exhibits significant regional variations, influenced by local environmental conditions, socioeconomic factors, and specific regional practices. In Brazil, for example, the states of São Paulo and Santa Catarina report higher leptospirosis incidence rates compared to other regions. São Paulo, characterized by dense urban populations and inadequate sanitation, sees frequent outbreaks, particularly in informal settlements where waste management is poor. Santa Catarina, with its extensive coastal areas, experiences higher incidence rates due to frequent flooding, which increases human contact with contaminated water. In Southeast Asia, Thailand and Malaysia show pronounced regional differences in leptospirosis incidence. In Thailand, the northeastern region has the highest rates, often linked to agricultural practices in rice paddies, where workers are regularly exposed to contaminated water. The monsoon season further exacerbates this exposure, leading to spikes in disease incidence. In Malaysia, states like Malacca and Pahang are hotspots, with higher incidence rates during the monsoon season. Urban areas suffer from poor sanitation, while rural regions are affected by agricultural activities, both contributing to the spread of leptospirosis. In the Caribbean and Latin America, countries such as Cuba and Puerto Rico face significant challenges due to hurricanes and tropical storms, which lead to widespread flooding and create ideal conditions for the bacteria to thrive. These events result in higher leptospirosis incidence rates, particularly in areas with poor infrastructure and drainage systems. In Oceania, Fiji and the Solomon Islands experience high leptospirosis incidence due to their warm, humid climates and frequent tropical storms. Rural areas in these islands are particularly affected, as agricultural practices increase the risk of exposure to contaminated water. The lack of adequate sanitation and infrastructure further compounds the problem, making disease management challenging. Within countries, socioeconomic factors create disparities in leptospirosis incidence. Urbanization and the growth of informal settlements without proper infrastructure increase the risk of transmission. Poor waste management and drainage systems contribute to the persistence of *Leptospira* bacteria in the environment. In urban areas, the risk is heightened by the presence of rodent populations, which are common in areas with poor sanitation. Occupational exposure also plays a crucial role in regional variations. In Germany, a significant number of leptospirosis cases are linked to occupational exposure, particularly among agricultural workers, fishermen, and waste management workers who frequently come into contact with contaminated water and soil. Similar occupational risks are seen in other high-incidence regions, where certain jobs necessitate regular exposure to environments conducive to *Leptospira* transmission. Environmental conditions, including high humidity, frequent rainfall, and the presence of standing water, are critical determinants of leptospirosis

incidence. Regions like Southeast Asia and Latin America, where these conditions prevail, show strong correlations between climatic variables and disease incidence. Studies have demonstrated that rainfall and temperature significantly influence the survival and spread of *Leptospira* bacteria, leading to regional spikes in leptospirosis cases during certain seasons. Understanding regional variations in leptospirosis incidence is essential for developing targeted public health interventions. High-incidence areas require tailored strategies that address the specific environmental, socioeconomic, and occupational factors contributing to the spread of the disease. Improved disease surveillance, enhanced sanitation infrastructure, and targeted public health campaigns are crucial for reducing the incidence and impact of leptospirosis in these regions.

### Country-Specific Insights

Leptospirosis incidence varies significantly across different countries, influenced by unique environmental conditions, socioeconomic factors, and public health infrastructure.

Brazil reports some of the highest leptospirosis rates in Latin America, particularly in urban centers like São Paulo and coastal regions such as Santa Catarina. The disease peaks during the rainy season, exacerbated by frequent flooding and poor urban sanitation. Studies indicate a strong correlation between leptospirosis incidence and areas with inadequate waste management and high population density. Occupational exposure, particularly among agricultural workers and those in informal settlements, is also a significant risk factor.

Thailand has a high incidence of leptospirosis, particularly in the northeastern region, where agricultural activities in rice paddies increase exposure to contaminated water. The disease peaks during the monsoon season, with rural areas experiencing the highest rates. The Thai Ministry of Public Health has documented numerous outbreaks, emphasizing the need for continuous surveillance and targeted public health interventions.

Malaysia experiences high leptospirosis incidence, especially in states like Malacca and Pahang. The disease peaks during the monsoon season, with both urban and rural areas affected. In urban areas, poor sanitation and inadequate waste management are primary risk factors, while in rural regions, agricultural practices contribute significantly to disease transmission. Public health initiatives focus on improving sanitation and raising awareness about the risks of leptospirosis.

The Philippines, particularly Manila, frequently experiences leptospirosis outbreaks following typhoons and heavy rains. Flooding leads to widespread contamination of water supplies with *Leptospira* bacteria from rodent urine. The government has implemented public health campaigns to educate the population about preventive measures and the importance of avoiding contact with floodwaters.

Fiji and the Solomon Islands in Oceania report high leptospirosis incidence, driven by warm, humid climates and frequent tropical storms. Rural areas are particularly affected, with agricultural activities increasing the risk of exposure to contaminated water. Both countries face challenges related to inadequate sanitation and infrastructure, making disease management difficult. Public health efforts include improving sanitation and promoting preventive measures among at-risk populations.

Germany has lower leptospirosis incidence compared to tropical regions, but occupational exposure remains a significant risk factor. Agricultural workers, fishermen, and waste management workers are particularly vulnerable due to frequent contact with contaminated environments. Public health measures in Germany focus on occupational safety and improving awareness about the risks of leptospirosis among high-risk groups.

In Japan, leptospirosis incidence is higher in the southern regions, particularly in Okinawa, due to the tropical climate. The disease shows a clear seasonal pattern, with peaks during the rainy and typhoon seasons. Efforts to control leptospirosis in Japan include enhanced surveillance, public education, and improving sanitation in vulnerable areas.

India experiences significant leptospirosis outbreaks, particularly in states like Kerala and Gujarat, which are prone to heavy monsoons and flooding. The disease is prevalent among agricultural workers and residents of urban slums with poor sanitation. Public health initiatives focus on improving sanitation, enhancing disease surveillance, and raising awareness about preventive measures.

Sri Lanka is another high-incidence country, with leptospirosis outbreaks often following heavy rainfall. Agricultural workers, particularly those involved in rice farming, are at high risk. Public health measures in Sri Lanka include improving awareness, enhancing surveillance, and promoting the use of protective measures among at-risk populations.

South Africa reports lower leptospirosis incidence, but the disease remains a public health concern, particularly in the Western Cape Province. Incidence peaks during the rainy season, with rural and agricultural areas most affected. Public health efforts focus on improving sanitation, raising awareness, and enhancing disease surveillance.

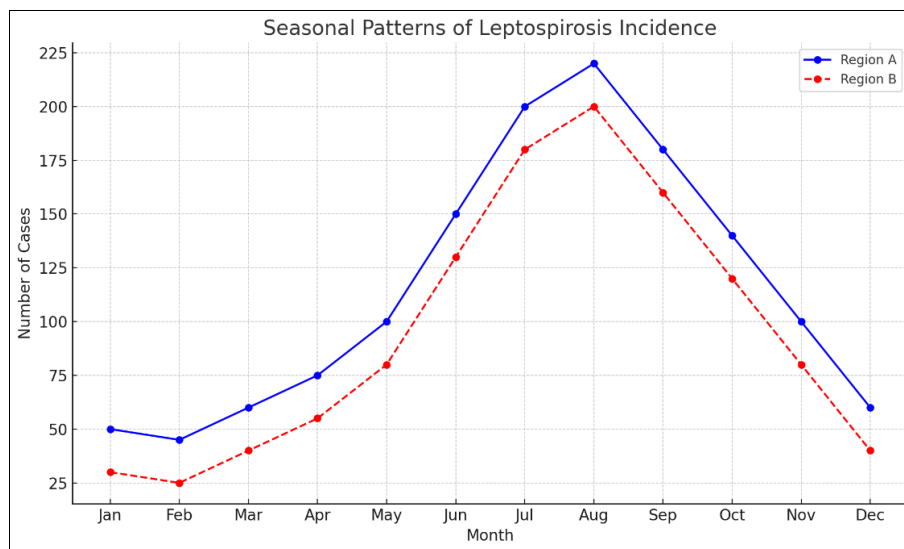
### Seasonal Trends

Leptospirosis incidence exhibits distinct seasonal trends, primarily driven by climatic conditions such as rainfall, temperature, and humidity. These factors significantly influence the survival and transmission of *Leptospira* bacteria, leading to seasonal variations in disease incidence across different regions. In tropical and subtropical regions, leptospirosis incidence typically peaks during the rainy season. Heavy rainfall and subsequent flooding increase the likelihood of human exposure to contaminated water, facilitating the spread of the bacteria. For instance, in Brazil, particularly in the states of São Paulo and Santa Catarina, leptospirosis cases surge during the rainy season due to increased contact with floodwaters contaminated by rodent urine. A study in São Paulo from 1998 to 2006 found that the incidence of leptospirosis was significantly higher during the rainy season, with 1,717 cases reported compared to 773 cases during the dry season (Soares *et al.*, 2010). Southeast Asia experiences similar seasonal patterns. In Thailand, leptospirosis incidence peaks during the monsoon season, particularly in the northeastern region where agricultural activities increase exposure to contaminated water. The Thai Ministry of Public Health has documented numerous outbreaks during the rainy season, highlighting the need for targeted public health interventions. Similarly, in Malaysia, the monsoon season exacerbates the spread of leptospirosis, with states like Malacca and Pahang reporting higher incidence rates during periods of heavy rainfall.

(Benacer *et al.*, 2016). In the Caribbean and Latin America, leptospirosis outbreaks often follow hurricanes and tropical storms. These events cause extensive flooding, creating conditions conducive to the spread of *Leptospira* bacteria. In Cuba and Puerto Rico, for example, leptospirosis incidence spikes after hurricanes, with flooding leading to widespread contamination of water supplies. Oceania, including countries like Fiji and the Solomon Islands, also experiences seasonal variations in leptospirosis incidence. The warm, humid climate and frequent tropical storms in these regions create an environment favorable for *Leptospira* transmission. Incidence rates are particularly high in rural areas during the rainy season, where agricultural activities increase the risk of exposure to contaminated water. Temperate regions such as Germany and Japan also show seasonal trends in leptospirosis incidence, though the patterns differ from tropical regions. In Germany, the incidence peaks during the summer months, which coincide with increased outdoor activities and occupational exposure among agricultural workers. In Japan, the southern regions, particularly Okinawa, see higher leptospirosis incidence

during the rainy and typhoon seasons, with peaks observed in the warmer months when conditions are ideal for bacterial survival. In India and Sri Lanka, leptospirosis outbreaks are closely linked to the monsoon season. In India, states like Kerala and Gujarat report significant increases in leptospirosis cases during the monsoons, with agricultural workers and residents of urban slums at higher risk due to flooding and poor sanitation. In Sri Lanka, the disease peaks during the rainy season, particularly affecting those involved in rice farming and other agricultural activities. In South Africa, leptospirosis incidence shows seasonal variation with peaks during the rainy season. The Western Cape Province, for instance, reports higher incidence rates during periods of increased rainfall, affecting rural and agricultural areas the most. Public health efforts in these regions focus on improving sanitation, raising awareness, and enhancing disease surveillance to mitigate the impact of leptospirosis.

### Seasonal Patterns



**Fig 1:** seasonal pattern of Leptospirosis incidence

Leptospirosis incidence exhibits distinct seasonal patterns, primarily influenced by climatic conditions such as rainfall, temperature, and humidity. These factors significantly affect the survival and transmission of *Leptospira* bacteria, resulting in seasonal fluctuations in disease incidence.

In tropical and subtropical regions, leptospirosis cases typically peak during the rainy season. Heavy rainfall and subsequent flooding increase human exposure to contaminated water, facilitating the spread of the bacteria. For instance, in Brazil, especially in states like São Paulo and Santa Catarina, leptospirosis cases surge during the rainy season due to increased contact with floodwaters contaminated by rodent urine. A study in São Paulo from 1998 to 2006 reported significantly higher incidence during the rainy season, with 1,717 cases compared to 773 cases during the dry season (Soares *et al.*, 2010). Southeast Asia experiences similar seasonal patterns. In Thailand, leptospirosis incidence peaks during the monsoon season, particularly in the northeastern region where agricultural activities increase exposure to contaminated water. The Thai Ministry of Public Health has documented numerous outbreaks during the rainy season, emphasizing the need for

targeted public health interventions. Similarly, in Malaysia, the monsoon season exacerbates the spread of leptospirosis, with states like Malacca and Pahang reporting higher incidence rates during periods of heavy rainfall (Benacer *et al.*, 2016). In the Caribbean and Latin America, leptospirosis outbreaks often follow hurricanes and tropical storms. These events cause extensive flooding, creating conditions conducive to the spread of *Leptospira* bacteria. In Cuba and Puerto Rico, leptospirosis incidence spikes after hurricanes, with flooding leading to widespread contamination of water supplies. Oceania, including countries like Fiji and the Solomon Islands, also experiences seasonal variations in leptospirosis incidence. The warm, humid climate and frequent tropical storms in these regions create an environment favorable for *Leptospira* transmission. Incidence rates are particularly high in rural areas during the rainy season, where agricultural activities increase the risk of exposure to contaminated water. In temperate regions such as Germany and Japan, seasonal trends in leptospirosis incidence are also evident, although the patterns differ from those in tropical regions. In Germany, incidence peaks during the summer months,

coinciding with increased outdoor activities and occupational exposure among agricultural workers. In Japan, the southern regions, particularly Okinawa, see higher leptospirosis incidence during the rainy and typhoon seasons, with peaks observed in the warmer months when conditions are ideal for bacterial survival. In India and Sri Lanka, leptospirosis outbreaks are closely linked to the monsoon season. In India, states like Kerala and Gujarat report significant increases in leptospirosis cases during the monsoons, with agricultural workers and residents of urban slums at higher risk due to flooding and poor sanitation. In Sri Lanka, the disease peaks during the rainy season, particularly affecting those involved in rice farming and other agricultural activities. In South Africa, leptospirosis incidence shows seasonal variation with peaks during the rainy season. The Western Cape Province, for instance, reports higher incidence rates during periods of increased rainfall, affecting rural and agricultural areas the most. Public health efforts in these regions focus on improving sanitation, raising awareness, and enhancing disease surveillance to mitigate the impact of leptospirosis.

### Conclusion

Leptospirosis is a complex zoonotic disease with distinct geographical and seasonal trends driven by a combination of climatic, environmental, and socioeconomic factors. Understanding these patterns is crucial for developing targeted prevention and control strategies, particularly in high-risk regions and during peak transmission seasons. Continuous surveillance, improved sanitation, and targeted public health interventions are essential to mitigate the impact of leptospirosis and protect vulnerable populations. Enhanced awareness and education about the risks and transmission routes of leptospirosis are also vital for reducing the disease burden and preventing outbreaks.

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