Spatial Model to Determine Environment-Based Disease: Leptospirosis Vulnerability Zones in Bantul District, Indonesia

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Abstract. Leptospirosis is a zoonosis caused by Leptospira bacteria, transmitted through skin wounds or mucous with water or soil contaminated with leptospires from animal urine especially rodents. This paper aims to map spatially the distribution of leptospirosis and to determine a model of leptospirosis-vulnerability areas based on environment variables using the Geographic Information System. The method used was making a zoning map based on the scoring and weighting of the environmental risk variables of leptospirosis transmission. The spatial distribution of leptospirosis in Bantul District in 2019 is evenly distributed in each sub district, the most cases were in Bantul, Sewon, Kasihan sub districts. Leptospirosis vulnerability zones in the center and northern region of Bantul District. Intensive surveillance, treatment and control of leptospirosis as an early warning system in focus areas.

Keywords: Spatial, leptospirosis, vulnerability model

1. Introduction

Leptospirosis is a neglected zoonotic disease that can cause mild to severe febrile illness, renal and hepatic failure, and death [1]. Leptospirosis is transmitted during direct contact with animal reservoirs or water and soil contaminated with their urine [2]. Human leptospirosis is caused by infection with pathogenic strains of Leptospira spp. bacteria [3]. The World Health Organization (WHO) through the Leptospirosis Epidemiology Reference Group (LERG) in 2015 conducted a systematic review to obtain data on morbidity and mortality due to leptospirosis in countries in the world. It is estimated that the number of leptospirosis cases is 1.03 million cases with 58,900 deaths every year in the world. Estimates in Indonesia that the morbidity rate of leptospirosis is 39.20 and the death rate is 2.15 per 100,000 population [4]. Like other infectious diseases, leptospirosis has an epidemiological aspect and a geographical aspect in its distribution, when combined, these two aspects can be used to determine the spatial distribution of leptospirosis. Processing of epidemiological and geographic data in order to produce a spatial distribution of a disease requires an appropriate method. One of the methods that use was Geographic Information System (GIS) [5].
Geographic Information System is a computer system used to manipulate geographic data. This system is implemented with computer hardware and software that functions for: data acquisition and verification, data compilation, data storage, data change and updating, data management and exchange, data manipulation, data recall and presentation, data analysis [6]. Geographic Information System in the health sector has the meaning of a geographical program device on a computer and health data that are regularly related to each other, thus forming a complete information in the form of a visualization/map image that makes it easier for health workers to analyze data on the health situation at certain space/place/region and time [7].

GIS applications can be used to assess leptospirosis prevention programs based on endemicity strata (endemic, sporadic, potential or free areas) and can determine leptospirosis vulnerable zones. The study to describes how the process of spatially describing the distribution of leptospirosis based on epidemiological characteristics and also determining the zoning of the level of vulnerability to leptospirosis based on environmental variables [8]. This research has succeeded in obtaining new information that can be used as an update in the implementation of leptospirosis surveillance. The writing of this article is also expected to contribute to science, especially in the field of health GIS, which is one of the innovative ways of implementing surveillance and as an early warning measure for leptospirosis.

2. Data and Methods

This study was conducted in Bantul District, Yogyakarta Special Region Province, Indonesia (see Figure 1). Information on secondary data for leptospirosis cases as the dependent variable used data from 2010 and 2011. Taking the coordinates of the house for leptospirosis cases using GPS in 2019 was carried out to find out how accurate the previous prediction was. While the independent variables included: land use maps, rainfall maps, soil types maps, vegetation maps, slope/height maps. (Geospatial Information Agency). Spatial analysis was processed using Arc Gis 10.1, including: overlay method, scoring and weighting method [9,10]. Giving a value/scoring in the form of nominal numbers (30, 20 and 10) which is a function value of the level of influence on Leptospirosis. A score of 30 means the effect is large, a score of 20 means moderate and a score of 10 means low. The basis for scoring each environmental variable illustrated in Table 1 and 2.
Land use for rice fields has a high score (30), which is the biggest risk factor compared to other land uses, such as settlements, dry land. In agricultural areas such as in Bantul District with lots of rice fields both technical and non-technical irrigation, such conditions will be very favorable for the life of rat reservoir. The amount of rainfall in a location is closely related to the fluctuation pattern of Leptospirosis cases or seasonal patterns. Several studies have stated that in tropical and subtropical countries, cases of leptospirosis increase when rainfall is high [11]. Kathryn's research in Brazil and Sudarat in Thailand also stated that the increase in Leptospirosis cases was related to the rainy season. High rainfall intensity will also have an impact on flooding [12,13]. Spatial rainfall in the Bantul District tends to be more areas of moderate rainfall.

Table 1. Maps scoring

| No. | Maps | Scoring |
|-----|------|---------|
| 1.  | Landuse : [14] and modification |         |
|     | Paddy fields                       | 30      |
|     | Settlements                        | 20      |
|     | Dry land, swamp, forestry, open land, grassland, inland water | 10 |
| 2.  | Rainfall : [15]                    |         |
|     | 115 – 163 mm                       | 10      |
|     | 164 – 260 mm                       | 30      |
|     | 261 – 308 mm                       | 20      |
| 3.  | Type of soil :                     |         |
|     | aluvial, cambiosol                  | 30      |
|     | latosol, grumusol                   | 20      |
|     | regosol, mediterian                 | 10      |
| 4.  | Vegetation : [16] and modification |         |
|     | High density                       | 30      |
|     | Medium                             | 20      |
|     | Very rarely                        | 10      |
| 5.  | Altitude (m) asl                   |         |
|     | 0 – 50                             | 10      |
|     | 51 – 300                           | 30      |
|     | > 301                              | 10      |
| 6.  | Slope (%)                          |         |
|     | 1 – 8 %                            | 30      |
|     | 9 – 27 %                           | 20      |
|     | 18 – 51 %                          | 10      |

Table 2. Maps Weighting

| Environment variable | Weight |
|----------------------|--------|
| Landuse              | 3      |
| Slope                | 2      |
| Rainfall             | 2      |
| Type of soil         | 2      |
| Vegetation index     | 1      |
| Altitude             | 1      |

Soil type is very influential on the presence of standing water in a location. Alluvial and cambiosol soil types are soil types with low permeability/water absorption capacity, so they can withstand the
presence of floods or puddles longer than regosol and mediterranean, latosol and grumosol soil types [17,18]. The existence of standing water that lasts a long time is a vehicle for the transmission of Leptospirosis, either through puddle water contaminated with Leptospira bacteria or parts of the soil that are muddy or soft. The level of vegetation density affects the presence of a rat reservoir. Vegetation around settlements with medium density is a place to hide or nest for rats. High density vegetation such as forests, shrubs, rice fields are actually places where rats are often found, but the role of field rats and forest rats in transmitting Leptospirosis to humans is lower than house rats or sewer rats [19]. The level of altitude is very influential on the incidence of leptospirosis. Areas with an altitude between 0 m until 25 m above sea level, there is a small possibility of cases of leptospirosis, under these conditions in the Bantul area there is brackish water/sea water with high salinity levels which are not favored by leptospira bacteria, while altitudes above 400 m above sea level are unlikely the presence of leptospirosis cases. The slope closely related to the altitude, high places tend to have steep slopes, areas with low slopes allow an area to accommodate the presence of water, so that if watery areas are more at risk, low slopes have a high score. The weight of each environmental variable is determined based on the level of influence of the environmental variable on the incidence of Leptospirosis.

Determine the zoning of the level of Leptospirosis vulnerability (Hazardous, Medium, Low/Safe) by overlaying several maps which are the determinants of the incidence of Leptospirosis, namely: Land use maps, slope, altitude, rainfall, soil type, index vegetation (see Figure 2 and Table 3). The final score for each environmental variable is obtained from the product of the score and the weight of each environmental variable. The overlapping process is carried out after the sum of the values of each variable. The process of dissolving in the final result of overlapping is carried out with the aim of grouping the values that have the same value in each variable, so that the area of the location of the Leptospirosis susceptibility class can be calculated. The determination of the classification of the Leptospirosis susceptibility zone (high, medium, and low susceptibility) in Bantul District is based on the sturgess formula as follows:

\[
K_I = \frac{\text{The maximum number of values} - \text{the minimum number of values}}{\text{Number of classes}}
\]

\[
K_I = \frac{340 - 135}{3} = 66.33 \\
= 66
\]

**Table 3. Potential Class/Leptospirosis Vulnerability Zone in Bantul District**

| Class | Interval | Zone             |
|-------|----------|------------------|
| 1     | 272 – 340| High Vulnerable  |
| 2     | 204 – 271| Medium Vulnerable|
| 3     | 135 - 203| Low Vulnerable   |
3. Results and Discussion

3.1 Distribution of Leptospirosis cases based on epidemiological characteristics:

Bantul District is mostly lowland area, so that landuse is mostly used as agricultural. Cases of leptospirosis are dominated by the adult male group (77%) and their work as farmers (62%), they have a greater risk of leptospirosis. The distribution of leptospirosis cases in 2019 was almost evenly distributed in every sub-district, especially the northern region. The most cases were in: Bantul, Sewon, Kasihan sub districts (see Figure 3).

![Figure 3. Distributions of Leptospirosis cases in Bantul District](image)

Land use is an important factor in transmission Leptospirosis. The use of rice fields and settlements is the largest area (see Figure 4). Bantul District is a lowland area. Therefore, the risk of occurrence Leptospirosis was greater especially in the group of adult male farmers.
Figure 4. Land use and distribution of leptospirosis in Bantul District

3.2 Leptospirosis Vulnerable Zone in Bantul District

Bantul District with an area of + 513.57 km² with 17 Sub-districts, of course, not all of them are risk areas for Leptospirosis, therefore in determining the management and intervention of Leptospirosis, it is necessary to prioritize certain zones which are vulnerable areas (see Figure 5). Leptospirosis-vulnerable areas are determined by several environmental parameters including: land use, slope, altitude, rainfall, soil type, vegetation index (NDVI) [6–8]. The scoring/assessment and weighting to each variable is based on the magnitude of the influence of these environmental variables/parameters on the incidence of Leptospirosis.

Figure 5. Leptospirosis Vulnerable zoning map in Bantul District
The results of the leptospirosis vulnerable zoning in Bantul District show that: the high vulnerable zone area is in the West and Northwest Regions, the area is 57.34 m² which includes the Bantul, Pajangan and Sedayu Sub-districts. The area of the moderate-vulnerable zone is almost evenly distributed throughout, which covers an area of 400 km². While the 55 km² free zone is in the East and the South. In general, the distribution of leptostrongilosis cases is in the high and moderate zones.

The distribution of leptospirosis cases is dominated by adult male groups of productive age, 80% of whom are farmers and workers related to livestock. These conditions indicate that farmers and livestock managers in general in the Bantul area have a high risk of leptospirosis [20]. Cases of leptospirosis tend to occur in the rainy season, this condition not only occurs in the Bantul area, but also occurs in other areas, especially areas that frequently flood, such as Jakarta City, Semarang City, Demak District, etc. In the rainy season in general the environmental conditions become muddy, there are many puddles, such conditions if there are positive rats for leptospira bacteria urinating in puddle water will be a potential source of leptospirosis transmission.

3.3 Spatial Risk Factors for Leptospirosis

The presence of rat is an important factor related to the incidence of leptospirosis. Rats as cosmopolitan animals, their lives are always close to the human environment, because rats also eat what humans eat even because of human activities so that rats will always come close to us, for example we throw food scraps in the trash, store food openly [21].

Bantul District which is mostly rice fields, both wet and dry fields, is a good place for rats to live. The rats will be lack of food, when the rice fields are not in the rice season, the rats look for food around the housing because the distance between houses and rice fields is very close, on average only 10 m. Several studies, both overseas and domestically, state that flooded areas are one of the important factors for the incidence of Leptospirosis: that in areas with a lot of flooding due to high rainfall, cases of Leptospirosis increase. Research by using Meta analysis of observational study conclude that flooding was was associated with the risk occurrence of leptospirosis. Flood in Pakistan is also as a risk factor for leptospirosis. This is different rom what happened in Bantul District. Generally, Bantul District does not have a history of flooding, since the last few years there have also been no reports of flooding, only in areas near the sea, because seawater overflows have occurred in the southern part of Bantul.

The altitude based on kriging analysis, the Bantul District area is divided into several altitude areas including altitudes below 50 meters above sea level which is a lowland, an altitude of 51 meters above sea level to 200 meters above sea level is a medium altitude area, a little inundation and some areas are quite high with an altitude of 201 to 400 masl. In areas with such conditions, it becomes an obstacle in the management of rainwater or household waste water. Drainage will become obstructed, supported by the behaviour of people who throw garbage in waterways, thus making the channel clogged, during the rainy season the water will overflow into the road and cause unpleasant odors. In conditions such as the above, there is a high risk of transmission of Leptospirosis, preventive measures to avoid contracting Leptospirosis are not playing in water with open wounds, wearing boots when working in water, cleaning/bathing with soap all the limbs after activities in water as above [1].

Land use has a close relationship with the spread of Leptospirosis, it concerns the life of the reservoir (rodent) and a potential place for the survival of Leptospira bacteria under certain conditions. Wetland rice fields close to residential areas are suitable habitats for rats.

3.4 Leptospirosis Vulnerability Zone in Bantul District.

The percentage of accuracy of the Leptospirosis distribution point in 2019 with the Leptospirosis vulnerable zone is as follows: high vulnerable zone reaches 17%, medium vulnerable zone 83%. If grouped between high vulnerable zones and moderate vulnerable zones into a class of Leptospirosis vulnerable areas, while the low vulnerable zones become Leptospirosis free areas, in general (with accuracy reaching 90 %) Leptospirosis cases are spread in Leptospirosis hight vulnerable areas.

High vulnerable zones and moderate vulnerable zones, must be taken seriously by the regional government, as well as the community around the area. Because the problem of Leptospirosis is closely related to the environment, such as housing conditions close to rice fields, poor sanitation facilities
(garbage disposal, sewerage), the role of the department of agriculture in handling rice field rats, the department of public works designs a network of sewerage channels, the design of making garbage bins temporary around settlements. The Health Office, Hospitals and Community Health Centers carry out surveillance and treatment of leptospirosis sufferers actively around the community in the vulnerable zone area to capture patients who have not or do not want to seek treatment at health services. The implementation of these activities is most appropriate at the beginning of the rainy season and before the dry season. Another form of intervention that leads to communities in vulnerable zones is counseling about Leptospirosis and counseling about environmental hygiene. Counseling by showing films about prevention of Leptospirosis at night in high-risk zones, placing posters of Leptospirosis in public places, and distributing Leptospirosis leaflets is necessary to provide basic understanding and knowledge about the causes and transmission of Leptospirosis. Environmental intervention efforts that must be carried out by the community are scheduled environmental clean activities such as clean Fridays. Mass movement of catching residential rats in various ways, such as life traps, snap traps and then burying or burning the carcasses of the caught rats, administering disinfectant (Sodium Hypochlorite 1 gram/100 lt) to all consumption water reservoirs and also administering chlorine to any permanent puddles or administering chlorine diffusers.

4. **Conclusion**

The spatial distribution of leptospirosis cases in Bantul District in recent years is evenly distributed in each sub district, especially the northern region. The most cases were in: Kasihan, Pandak and Bantul sub districts. Leptospirosis vulnerability zones areas are dominated in agricultural by technical irrigated rice fields. Intensive surveillance, treatment and control of leptospirosis in focus area.

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