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MORALITY BEFORE KNOWLEDGE

Spatial analysis of hepatitis A case distribution using Moran's index and LISA (local indicator of spatial association)

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ABSTRACT
Background: Hepatitis A is an infectious disease of the liver caused by the hepatitis A virus (HAV). This virus can spread from human to human by oral-fecal route, by consuming food contaminated with HAV and using drugs that are injected into the veins of people with HAV. Hepatitis A risk factors can be viewed from: (1) Factors causing (agent), (2) environmental factors (environment), (3) factor host (host). Hepatitis A occurs in several developing countries where the HAV virus is endemic. Hepatitis A occurred in Pacitan Regency in 2019 with a total of 1.314 cases of sufferers, so that the Common Laurent Incidence (KLB) of Hepatitis A was determined in Pacitan Regency. Sudimoro Subdistrict is a sub-district in Pacitan Regency with the highest number of sufferers reaching 908 patients spread across 10 villages in Sudimoro District. **Methods:** Using the Moran's Index method, LISA (Local Indicator of Spatial Association), simple linear correlation, and an overlay between the number of sufferers and the total population. The objectives of this study were (1) to examine the spatial autocorrelation of the distribution of Hepatitis A sufferers in Sudimoro District in 2019. (2) to examine the relationship between population density and the distribution of Hepatitis A sufferers in Sudimoro District, Pacitan Regency in 2019. The method used is descriptive quantitative method, which explains the results of data processing in the form of a LISA cluster map and simple linear correlation. **Findings:** The results showed that (1) There was spatial autocorrelation in the distribution of Hepatitis A patients with Sudimoro Village, Gunungrejo Village, and Pagerlor Village as the high spatial cluster and Klepu Village, Sembowo Village, and Ketanggung Village as the low spatial cluster. (2) Population density has a relationship with the distribution of Hepatitis A sufferers, meaning that the higher the population density, the higher the number of hepatitis A sufferers, and vice versa. **Conclusion:** The correlation index of 0.48 means that the relationship has moderate strength. **Novelty/Originality of this article:** This study create a spatial model of the distribution of hepatitis A sufferers as a reference to assess the spatial autocorrelation of the distribution of hepatitis A sufferers and see the relationship between population density and the number of sufferers.

KEYWORDS: hepatitis A; spatial autocorrelation; Moran's index; LISA (local indicator of spatial associaton); population density.

1. Introduction

The Geographic Information System (GIS) technology has rapidly developed in recent years. Its use is not limited to geography alone, but has expanded into various fields, including health. This technology is widely used by healthcare practitioners to analyze disparities in accessing health services, investigate outbreaks of diseases, and assess priorities for the use of limited resources to improve public health levels (Rahmanti &

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Prasetyo, 2012). The data visualization technique through mapping in GIS can be an effective way to convince policymakers at various administrative levels to prioritize health issues and select the most suitable health programs to be implemented in health institutions across regions. GIS can even be used as a learning tool to evaluate public health programs that have been applied in previous periods (Economic Report on Africa 2005 Meeting the Challenges of Unemployment and Poverty in Africa Economic Commission for Africa, 2005).

According to Cromley & McLafferty (2011), GIS can be used in healthcare to analyze and map health data, such as the geographic distribution of at-risk populations, spatial distribution of diseases and health problems, distribution of healthcare facilities, and the analysis of risk factors for disease occurrence. This technology can be utilized to assess the relationship between risk factors and the health impacts caused by environmental health issues and infectious diseases such as Hepatitis A, HIV, tuberculosis, etc. The analysis results can serve as a basis for determining the target populations and regions to prioritize for health intervention efforts. GIS can be used to map the spatial distribution of diseases by observing the similarity of phenomena between one region and another. This aligns with Tobler's statement in Anselin (1993), "Everything is related to everything else, but near things are more related than distant things." This concept forms the foundation for regional science studies, where spatial effects often occur between neighboring regions.

Hepatitis A is an infectious liver disease caused by the Hepatitis A virus (HAV). The virus can spread from person to person through the oral-fecal route, consumption of food contaminated with HAV, and the use of injection drugs from a person infected with HAV. The risk factors for Hepatitis A can be examined from three causes, namely: the agent factor, the host factor, and the environmental factor. The agent factor is the Hepatitis A virus. The host factor is influenced by age, gender, family medical history, occupation, the use of unprotected drinking water sources, food and drink acquisition methods, personal hygiene practices, handwashing with soap and water, and sexual deviance/homosexual behavior. The environmental factor is influenced by climate/season/time of examination, environmental sanitation, ownership of bathrooms and toilets, wastewater management, garbage disposal, the number of food establishments/street vendors/stalls, and population density (Pertiwi et al., 2014).

Hepatitis cases in Indonesia have been detected in all provinces, with a prevalence of 0.6% (range 0.2% - 1.9%). These cases are generally detected based on clinical symptoms, except for the provinces of East Java, South Sumatra, Central Kalimantan, and North Sulawesi, where diagnosis is made by healthcare professionals. The highest prevalence of clinical hepatitis is found in individuals aged ≥ 55 years, with higher rates in rural areas compared to urban areas, and is more common among those with lower education levels. The clinical hepatitis prevalence is evenly distributed across all levels of household per capita expenditure (Badan Penelitian dan Pengembangan Kesehatan, 2018). According to the Ministry of Health of the Republic of Indonesia (2014) and (Ministry of Health of the Republic of Indonesia, 2019), an Extraordinary Event (KLB) of Hepatitis A was reported in various provinces in Indonesia from 2013 to 2018.

An Extraordinary Event (KLB) is the occurrence or increase in morbidity and mortality that is significant epidemiologically within a specific area over a period of time and indicates a situation that may lead to an outbreak (Ministry of Health of the Republic of Indonesia, 2011). Pacitan Regency, located in East Java, is one of the regions affected by the Hepatitis A Virus (HAV) endemic. In 2013, Pacitan Regency recorded an outbreak of Hepatitis A in Ngadirojo Subdistrict with 66 cases. In 2019, Hepatitis A outbreaks again occurred in Pacitan, with the first case of Hepatitis A detected on June 13, 2019, involving 34 patients. On June 25, 2019, the status of Extraordinary Event was declared by the Pacitan Regency Government. The spread of this virus was rapid, with the number of cases reaching 800 in less than two weeks by June 30, 2019, across eight subdistricts in Pacitan. The first cases were found in Sudimoro Subdistrict, spreading to Ngadirojo, Tulakan, Arjosari, Tegalombo, Kebonagung, Punung, and Pacitan Subdistricts. Symptoms experienced by patients included fever, dizziness, nausea, vomiting, dark-colored urine, and yellowing of the eyes and skin (Pacitan Health Office, 2019). The Extraordinary Event of Hepatitis A in Pacitan lasted for two months, with a total of 1,314 cases spread across eight subdistricts (Pacitan Health Office, 2020). The distribution of cases in each subdistrict is presented in Table 1.

Table 1. Number of hepatitis A cases per subdistrict in 2019

Num.	Subdistrict	M	F	Patient	%
1	Sudimoro	395	337	732	55.7
2	Ngadirojo	201	159	360	27.4
3	Tulakan	68	45	113	8.6
4	Arjosari	40	57	87	6.6
5	Tegalombo	8	3	11	0.8
6	Kebonagung	7	2	8	0.6
7	Punung	1	0	1	0.1
8	Pacitan	1	0	1	0.1
	Amount	721	603	1314	100

(Pacitan Health Office, 2020)

Based on Table 1, Sudimoro Subdistrict has the highest number of Hepatitis A cases, with 732 individuals, which accounts for 55.7% of the total cases. This is supported by the fact that the first cases were discovered at the Sudimoro Public Health Center (Puskesmas). Sudimoro Subdistrict also has a relatively high population density compared to other subdistricts in Pacitan Regency. Below is the population density data for Pacitan Regency.

Table 2. Number of population and population density per subdistrict in 2018

Num.	Subdistrict	Population (thousands of people)	Area (km^2)	Population density (people/km^2)
1	Arjosari	39,347	117.06	336
2	Bandar	43,200	117.34	368
3	Donorojo	34,421	109.09	316
4	Kebonagung	41,849	124.85	335
5	Nawangan	45,362	124.06	366
6	Ngadirojo	46,626	95.91	486
7	Pacitan	81,605	77.11	1,058
8	Pringkuku	29,985	132.93	226
9	Punung	33,315	108.81	306
10	Sudimoro	31,004	71.86	431
11	Tegalombo	49,747	149.26	333
12	Tulakan	77,933	161.62	482
	Amount	554,394	1 389.90	5,043

(Central Statistics Agency of Pacitan Regency, 2019)

Based on Table 2, it is known that in 2019, Sudimoro Subdistrict had a population density of 431 people per km^2 (Central Statistics Agency of Pacitan Regency, 2019). The population density in Sudimoro is relatively high compared to other subdistricts in Pacitan Regency. High population density in an area increases the risk of transmission of the HAV virus, which is the cause of Hepatitis A. This is supported by McDonald's statement in (Pertiwi et al., 2014) that the higher the number of people in a specific area, the higher the risk of Hepatitis A transmission. Given the background above, it is necessary to conduct a study on the spread of Hepatitis A using a spatial approach to serve as a reference for handling similar cases in the future. Based on the background, the research problem formulation is as follows: How does the spatial autocorrelation of Hepatitis A cases spread in Sudimoro Subdistrict in 2019? What is the relationship between population density in Sudimoro Subdistrict and the spread of Hepatitis A cases in Sudimoro Subdistrict, Pacitan Regency, in 2019?

1.1 Geographic information system (GIS)

Geographic Information System (GIS) is a computer-based information system that allows researchers to collect, store, manipulate, model, analyze, and present spatial or geographically referenced data (Lai et al., 2009). Spatial data refers to data related to locations based on geography, which includes latitude-longitude and areas. According to LeSage & Pace (2009), spatial data are the results of measurements that indicate a dependency of observations at one location (i) on the results of observations at another different location (j), where (i≠j). Bivand et al. (2013) states that there are three types of spatial data: point data, geostatistical data, and area data. Based on the above definition, spatial data is extensive, covering many objects and phenomena on the Earth's surface. Therefore, almost all visible features and phenomena that can be mapped, provided they have a geographic reference, fall under spatial data.

In 1854, John Snow manually displayed cholera outbreak information in the form of a map, allowing him to identify the source of the disease transmission without knowing the type of bacteria or the mode of transmission of the outbreak (Riner et al., 2004). The use of GIS technology in developing countries has been increasingly employed not only to assess accessibility to healthcare facilities but also for planning the locations of treatment centers, such as for infectious diseases like malaria, tuberculosis, dengue fever, and even for HIV treatment access, mental health services, and cancer treatment centers (Higgs, 2004). Although GIS was first popularized for cholera eradication, its benefits extend far beyond that (Rahmanti & Prasetyo, 2012). Spatial data analysis cannot be done globally, meaning that each location has its own characteristics. Most analytical approaches are exploratory and presented in the form of thematic maps. Thematic maps, also called statistical maps or special-purpose maps, provide a depiction of spatial usage in a specific place according to the desired theme. These maps emphasize variations in land use from a geographical distribution perspective. Geographical distribution can be in the form of physical phenomena, such as climate, population density, or health issues (Pfeiffer et al., 2008). Spatial data contains geographic information about the location of an area. According to De Mers in (Budiyanto, 2010), spatial analysis involves many operations and concepts, including simple calculations, classification, layout, geometric overlay, and cartographic modeling. According to Kosfeld (2018), location information can be obtained from two sources: adjacency relations and distance.

1.2 Spatial statistical analysis

Spatial statistics is a method used to analyze spatial data. This method has been applied in various fields, including social, economic, environmental, health, meteorology, and climatology. Spatial data contains location information, meaning it not only describes "what" is measured but also indicates the location of the data (Latimer et al., 2009). Spatial data can consist of geographic location information, such as the latitude and longitude of each region and boundaries between areas. Simply put, spatial data can be represented as address information. Another form of spatial data is presented as a grid of coordinates, such as in maps or as pixels in satellite imagery. Spatial statistical analysis can be presented in thematic maps.

1.3 Spatial autocorrelation

Autocorrelation is used to examine whether there is a correlation between one period (t) and the previous period (t-1). In simple terms, correlation analysis is used to observe the influence of independent variables on dependent variables. In geographical studies, autocorrelation is also known as spatial autocorrelation. Spatial autocorrelation is the correlation between a variable and itself based on space or, in other words, a measure of similarity of objects within a space (distance, time, and region). If there is a systematic pattern in the distribution of a variable, spatial autocorrelation exists. The presence of spatial autocorrelation indicates that the attribute values in one area are related to those in adjacent areas (Lembo, 2006). Spatial autocorrelation at a point refers to the extent to which points are related, or how similar phenomena occurring at these points are to those at other points. Positive spatial autocorrelation indicates that neighboring distribution points share similar characteristics and are likely to be close to each other, while negative spatial autocorrelation suggests that nearby points tend to have differing characteristics.

The interrelationship between spaces in one region can be represented in an index that shows the degree of dependence or influence between a phenomenon in one area and a nearby phenomenon in another space. This is derived from Tobler's law and is referred to as spatial autocorrelation. The measurement of spatial autocorrelation for area-based spatial data can be calculated using Moran's I index, Geary's c, LISA (Local Indicator of Spatial Association), and Tango's excess (Pfeiffer et al., 2008). This study will focus on the Moran's Index method and LISA (Local Indicator of Spatial Association).

1.4 Hepatitis A and extraordinary events

Hepatitis A is an infectious disease of the liver caused by the Hepatitis A virus (HAV). Hepatitis A is caused by the Hepatitis A virus, which is transmitted through feces (fecal-oral transmission). Unlike Hepatitis B and Hepatitis C, this disease does not progress to severe and chronic stages, but HAV can cause significant economic losses and result in serious outbreaks due to its mode of transmission (Godoy et al., 2016). In epidemiological terms, fecal refers to the mouth, and oral refers to the anus, meaning the spread of microorganisms from infected feces from one person to the mouth of another person. This can happen through contaminated food and drink or through hand-to-mouth transmission after touching objects contaminated with feces. Hepatitis A risk factors can be reviewed from three causes: agent factors, host factors, and environmental factors. The agent factor for Hepatitis A is the Hepatitis A virus. Host factors include age, gender, family medical history, occupation, use of unprotected drinking water sources, food and drink acquisition methods, hygiene and health practices, handwashing with soap, and sexual behavior/ homosexuality. Environmental factors include climate/season/time of examination, sanitation, bathroom and toilet ownership, wastewater management, waste disposal, the number of food stalls/ street vendors, and population density (Pertiwi et al., 2014).

Symptoms of Hepatitis A include fever, fatigue, anorexia (loss of appetite), digestive discomfort or discomfort, especially in the liver, nausea, vomiting, dark tea-colored urine, and yellowing of the skin and eyes (Fares A, 2015). In children, the disease usually presents as subclinical anicteric, while in adults, HAV typically causes icteric hepatitis. The signs and symptoms of Hepatitis A include fatigue, nausea, vomiting, abdominal discomfort, loss of appetite, mild fever, muscle pain, and jaundice.

An Extraordinary Event (KLB) refers to an occurrence or increase in the incidence of morbidity and/or mortality that is of significant epidemiological concern in a region over a specified period, and it is a condition that can lead to an outbreak (Ministry of Health of the Republic of Indonesia, 2011). A region can be declared in a KLB state if it meets one of the following criteria: (Ministry of Health of the Republic of Indonesia, 2011). First, there is a continuous increase in morbidity over three consecutive periods in hours, days, or weeks, depending on the type of disease. Second, the incidence of morbidity increases two times or more compared to the previous period in hours, days, or weeks, depending on the type of disease. Third, the number of new cases within a one-month period shows an increase of two times or more compared to the monthly average from the previous year. Fourth, the average number of morbidity events per month over one year shows an increase of two times or more compared to the average number of morbidity events per month in the previous year. Fifth, the case fatality rate for a particular disease within a specified period shows a 50% or greater increase compared to the case fatality rate for the same disease in the previous period. Sixth, the proportion of new disease cases in one period shows an increase of two times or more compared to the same period in the previous time frame.

1.5 Previous research

Lazwardi et al. (2019) conducted a study titled "Analysis of the Metapopulation Model on the Transmission of Hepatitis A Virus (Case Study in West Java, Central Java, and East Java)". The goal was to determine the effect of vaccination programs in one region on neighboring regions and to identify the most optimal regions for mass vaccination programs. The results showed that implementing a vaccination program for Hepatitis A in East Java would reduce the number of cases in Central Java and West Java. Therefore, East Java is the most optimal region for the vaccination program.

Pratiwi et al. (2017) conducted a study titled "Identification of Hepatitis A Virus in Acute Jaundice Syndrome in Several Provinces in Indonesia in 2013", with the objective of determining the cause of acute jaundice syndrome in Extraordinary Events in four provinces: Banten, West Kalimantan, South Kalimantan, and Riau Archipelago. The study found that the cause of several cases of acute jaundice in these four provinces in 2013 was Hepatitis A virus infection.

Harisma et al. (2018) conducted research titled "Analysis of the Extraordinary Event of Hepatitis A at SMA X Lamongan District in 2018", which aimed to identify the epidemiological characteristics of the Hepatitis A outbreak at SMA X and to examine the associated risk factors. The study found that the outbreak at SMA X occurred from November 2017 to January 2018, affecting 33 students. The epidemiological curve showed a prolonged common-source outbreak. Risk factors included contact history with infected individuals, eating together in one place, sharing eating utensils, not practicing handwashing with soap (CTPS) among students, food handlers lacking access to handwashing facilities, improper food sanitation and hygiene, and inadequate well placement. Hikmah et al. (2016) conducted research titled "Mapping and Analysis of Hepatitis A Distribution Based on Risk Factors in Bondowoso District in 2016". The study aimed to map and analyze the distribution of Hepatitis A based on risk factors in Bondowoso. The research found that the outbreak in Bondowoso was caused by unhealthy behaviors, poor sanitation (open defecation in rivers), and rainfall. Population density was not considered a risk factor for Hepatitis A because the outbreak occurred in areas with low population density.

Pertiwi et al. (2014) conducted a study titled "Mapping Hepatitis A Risk Using Geographic Information System (GIS) in Jember District in 2013", which aimed to describe the distribution of Hepatitis A cases and the pattern of Hepatitis A risk distribution in 2013 using GIS. Risk factors studied included hygiene behaviors, defecation in sanitary toilets, access to clean water, toilet ownership, water sources, food stalls, and population density. The study found 183 cases of Hepatitis A in Jember in 2013. Of these, 27% (51 people) were in the 21-30 age group, and 115 were male. The areas with the highest number of cases were Sumbersari and Patrang, while the areas with the highest risk were Silo and Kaliwates. The differences in the Hepatitis A case map and the risk map were due to factors not studied, such as poor hygiene practices of food handlers and inadequate food management. Anselin et al. (2000) conducted research titled "Spatial Analyses of Crime", with the aim of examining the distribution of crime cases based on the location of events and determining whether there is a spatial relationship between events. The study concluded that crime distribution is random, but spatial factors play an important role in determining crime locations.

Nurdiansyah (2020) conducted a study titled "Spatial Analysis of Hepatitis A Distribution Using Moran's Index and LISA (Local Indicator of Spatial Association) – A Case Study of Sudimoro District, Pacitan in 2019". The aim of this study was to examine spatial autocorrelation in the distribution of Hepatitis A cases in Sudimoro District in 2019 and to analyze the relationship between population density and the distribution of Hepatitis A cases in Sudimoro. This research differs from previous studies in terms of research methods, analysis methods, and research location. The researcher referred to previous studies, including the research method from Luc Anselin and the population density variable from the research by Hikmah et al.

2. Methods

The method applied in this research is descriptive, using Geographic Information Systems (GIS) and a quantitative approach, which involves depicting the results of the Moran's I index calculation, LISA (Local Indicator of Spatial Association), and simple linear correlation. This study aims to examine the spatial autocorrelation of Hepatitis A and the relationship between population density in Sudimoro District and the spread of Hepatitis A cases in Sudimoro District in 2019. Based on this goal, the population for this study consists of 35,391 residents of Sudimoro District (BPS Pacitan Regency 2019), spread across 10 villages.

Sampling in this study aims to analyze the spatial distribution of Hepatitis A cases using the Purposive Sampling method, meaning that only the population that meets the criteria can be used as a sample. The sample criteria in this study are residents who have Hepatitis A. This research uses secondary data obtained from relevant institutions. The types of data used in this research include the number of Hepatitis A cases in Sudimoro District in 2019 and the population density data of Sudimoro District in 2019.

3. Results and Discussion

The results of this study were obtained based on secondary data collected by the researcher in accordance with the research objectives. The purpose of this study is to examine the spatial autocorrelation of the distribution of Hepatitis A patients in Sudimoro District in 2019, as well as to analyze the relationship between population density and the distribution of Hepatitis A patients in Sudimoro District, Pacitan Regency in 2019. The research findings are presented as follows.

3.1 Spatial autocorrelation of hepatitis A patient distribution

3.1.1 Spatial weighting

Spatial analysis to determine the existence of spatial autocorrelation requires the main component, which is a location map. The map is used to determine the proximity relationship between villages in Sudimoro District, thereby making it easier to assign weights to each location or village. According to the administrative map of Sudimoro District, there are 10 villages, so the spatial weight matrix will be 10x10.

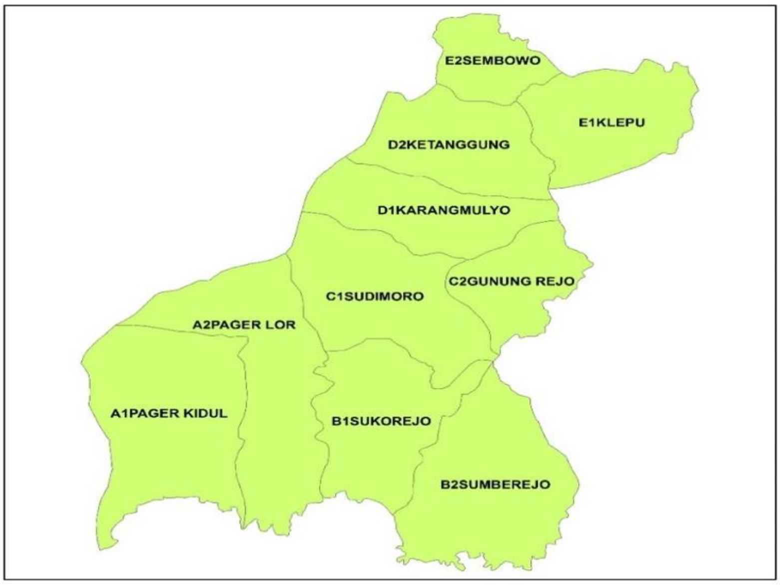

Fig. 1. Administrative map of Sudimoro District

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The matrix weighting method used is Queen Contiguity, which is a method for obtaining the spatial weight matrix based on the standardized contiguity matrix W. The standardized contiguity matrix W is obtained by assigning an equal value or weight to neighboring locations, with all other locations assigned a weight of zero. The spatial weighting matrix is as follows.

	$A1$	$A2$	$B1$	$B2$	$C1$	$C2$	$D1$	$D2$	$C1$	$C2$
$A1$	0	1	0	0	0	0	0	0	0	0
$A2$	1	0	1	0	1	0	0	0	0	0
$B1$	0	1	0	1	1	0	0	0	0	0
$B2$	0	0	1	0	1	0	0	0	0	0
$C1$	0	1	1	1	0	1	1	0	0	0
$C2$	0	0	0	0	1	0	1	0	0	0
$D1$	0	0	0	0	1	1	0	1	0	0
$D2$	0	0	0	0	0	0	1	0	1	1
$E1$	0	0	0	0	0	0	0	1	0	1
$E2$	0	0	0	0	0	0	0	1	1	0

Based on the spatial weight matrix, the number of neighboring locations for each village can be determined. The graph of the number of neighbors for each village is as follows.

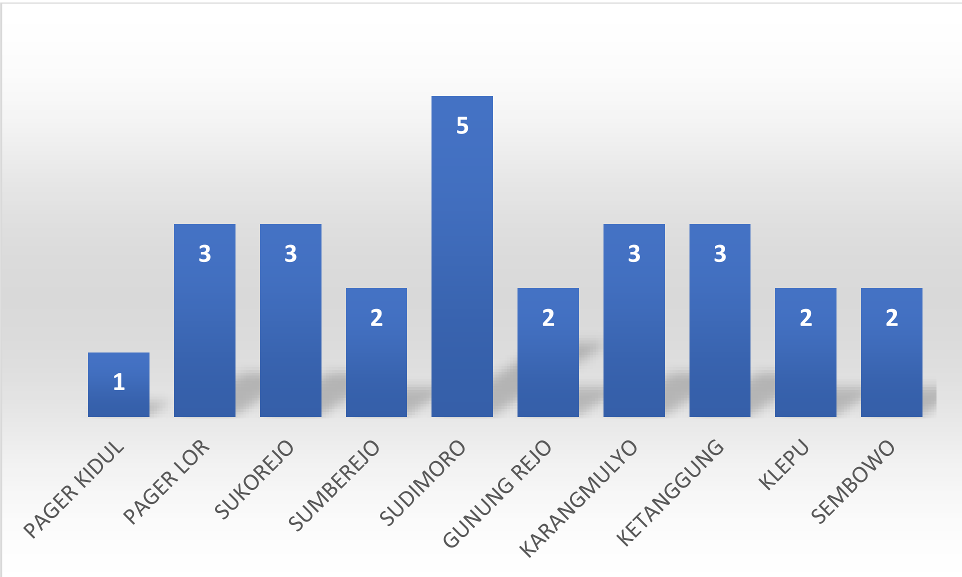

Fig. 2. Village neighbor graph

The graph of the number of neighbors illustrates the number of village locations that are directly adjacent according to the queen contiguity rule with the observed village. Based on Figure 2, it is known that the village with the most neighboring locations (neighbors) is Sudimoro Village, with 5 neighbors. The village with the fewest neighboring locations (neighbors) is Pagerkidul Village, with only 1 neighbor.

3.1.2 Moran's index

Moran's Index is a spatial analysis technique that can be used to determine the presence of spatial autocorrelation between observation locations. The value of this index ranges from -1 to 1. A value of $-1 \leq I < 0$ indicates negative spatial autocorrelation, while a value of $0 < I \leq 1$ indicates positive spatial autocorrelation. The results of the Moran's Index calculation are as follows:

Table 3. Moran's index calculation results

	Moran index
Calculation result	0.425
Variations	0.046
Statistic test Z(I)	2.41

The Moran's Index for the distribution of Hepatitis A patients in Sudimoro District can be seen in Table 3, which is 0.425, indicating a positive spatial autocorrelation in the distribution of Hepatitis A patients in Sudimoro District in 2019. The hypothesis test with H0 stating no spatial autocorrelation and H1 stating the presence of spatial autocorrelation shows that the Z(I) value = 2.41 > Z0.95 = 1.645, thus H0 is rejected.

3.1.3 LISA (local indicator of spatial association)

Based on the Moran's Index test, there is a spatial correlation in the number of Hepatitis A patients in Sudimoro District with an index value of 0.424. The Moran's Index does not reveal the relationship patterns between villages, thus, to examine local correlations, a test using LISA is necessary. Table 4.2 presents the local Moran's I index values and the P-value for the LISA test.

Table 4. LISA index calculation results

Village	LISA index	P value
Gunung rejo	1.95	0.0430
Karangmulyo	0.54	0.1010
Ketanggung	0.25	0.2240
Klepu	0.61	0.0340
Pager kidul	-0.09	0.3770
Pager lor	0.02	0.4120
Sembowo	0.65	0.0150
Sudimoro	0.41	0.0420
Sukorejo	-0.25	0.3240
Sumberejo	-0.28	0.3690

Based on Table 4, the local Moran's index for each village is provided. Unlike the global Moran's index, the local Moran's index shows the relationship values between one village and another, based on the number of Hepatitis A patients in each village.

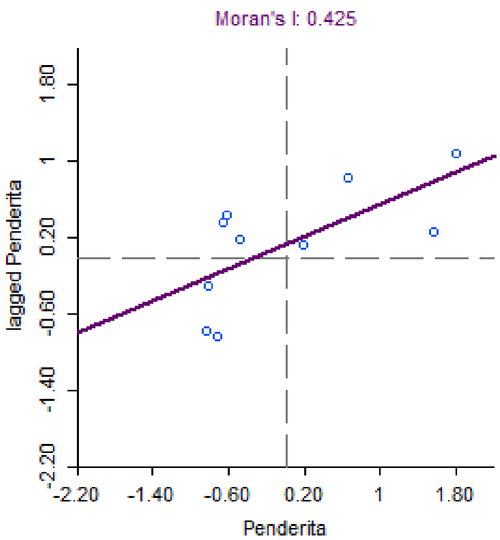

Fig. 3. Moran scatterplot

Figure 3 is the Moran's scatterplot, which illustrates the relationship pattern between the number of patients in one village and that of another. The Moran scatterplot is divided into four quadrants, showing the clustering patterns of each village's relationship.

3.2 Correlation between the number of patients and population density

3.2.1 Simple linear correlation

The relationship between the number of Hepatitis A patients and population density is analyzed using simple linear correlation. In this simple linear correlation test, population density serves as the independent variable (x), while the number of patients is the dependent variable (y). Table 5 below shows the number of patients and population density in each village.

Table 5. Number of patients and population density in each village

Village	Population density (X)	Patient of Hepatitis A(Y)	XY	X^2	Y^2
Gunung rejo	582	227	132114	338724	51529
Karangmulyo	682	140	95480	465124	19600
Ketanggung	596	28	16688	355216	784
Klepu	511	35	17885	261121	1225
Pager kidul	279	54	15066	77841	2916
Pager lor	361	105	37905	130321	11025
Sembowo	602	27	16254	362404	729
Sudimoro	684	209	142956	467856	43681
Sukorejo	349	40	13960	121801	1600
Sumberejo	362	43	15566	131044	1849
Amount	5008	908	503874	2711452	134938

Based on Table 5, the following correlation calculation was obtained. From Table 6, the correlation coefficient of 0.48 is derived. This indicates a correlation between population density as the independent variable (x) and the number of patients as the dependent variable (y). The correlation strength is moderate.

Table 6. Simple linear correlation calculation

Regression statistics	
R	0.48
R Square	0.23
Adjusted R Square	0.13
Standard Error	140.28
Observations	10

3.3 Spatial autocorrelation of hepatitis A patient distribution

3.3.1 Spatial weighting

Spatial weighting is used as the basis for determining the relationship pattern between one village and another. The neighborhood method is employed to identify the relationship between villages based on their proximity, while Queen Contiguity (corner sides) is used to determine the proximity of one location to another by considering both adjacent and corner neighbors, thus categorizing all adjacent areas as neighbors.

Sudimoro District, the location of this study, consists of 10 villages: Gunungrejo, Karangmulyo, Ketanggung, Klepu, Pager Kidul, Pager Lor, Sembowo, Sudimoro, Sukorejo, and Sumberejo. The use of the Queen Contiguity method reveals that the village with the highest number of neighbors is Sudimoro, which has 5 neighbors: Pager Lor, Sukorejo, Gunungrejo, Karangmulyo, and Sumberejo. This is due to Sudimoro's central location in

Sudimoro District and its historical role as the district's administrative center before it was moved to Sukorejo Village. According to Tobler's Theory, Sudimoro has a high spatial effect that influences surrounding villages. In contrast, Pager Kidul has the fewest neighbors, with only one neighbor, Pager Lor. Pager Kidul is located at the southern end of Sudimoro District and borders Ngadirojo District, resulting in a lower spatial effect on the other villages in Sudimoro District.

High spatial effects cause a location to have an impact on a wider area. This study shows that Sudimoro, with the highest number of neighbors, has a wide spatial effect, influencing neighboring villages. The first case of Hepatitis A was found in Sudimoro Village and then spread to several other villages in the district. This is attributed to Sudimoro's extensive network of neighboring villages, as well as its high population density, which increases the risk of HAV transmission. The spatial effect from Sudimoro can be observed from the distribution of Hepatitis A cases in Sudimoro and its five nearest neighbors. Sudimoro reported 209 Hepatitis A patients, making it the second-highest after Gunungrejo with 227 cases, and both are spatial neighbors. The southern part of Sudimoro borders Pager Lor with 105 cases, Sukorejo with 40 cases, and Sumberejo with 43 cases. To the north, it borders Karangmulyo with 140 cases and Gunungrejo with 227 cases. These findings show differing spatial effects, with villages in the northern part having higher case numbers (positive spatial effect) and those in the south having lower numbers (negative spatial effect).

3.3.2 Moran's index

The Moran's Index calculation results are used to examine the spatial autocorrelation of Hepatitis A patients in Sudimoro District in 2019. Spatial autocorrelation reflects the relationship between villages based on the number of patients, with the index ranging from -1 to 1. Values of ($-1 \leq I < 0$) indicate negative spatial autocorrelation, meaning that villages with high patient numbers tend to be near villages with low patient numbers, and vice versa. Values of ($0 < I \leq 1$) indicate positive spatial autocorrelation, meaning that villages with high patient numbers tend to cluster together, and villages with low numbers tend to do the same.

The Moran's Index for the spatial autocorrelation of Hepatitis A patients in Sudimoro District in 2019 yielded a value of 0.48. A hypothesis test with H0 stating there is no spatial autocorrelation and H1 stating the presence of spatial autocorrelation was conducted at a 5% significance level. With the spatial autocorrelation present, H0 is rejected if ($Z(I) > Z\_(1-\alpha)$). The results showed $Z(I) = 2.41 > Z0.95 = 1.645$, leading to the rejection of H0 and confirming the existence of spatial autocorrelation in Hepatitis A patients in Sudimoro District in 2019. The positive spatial autocorrelation is evident from the Moran's Index value ($0 < I \leq 1$), meaning that villages with high patient numbers tend to cluster, while those with low patient numbers also tend to form their own group. Spatial autocorrelation using Moran's Index is called global autocorrelation, which does not consider local aspects. This method allows for global spatial correlation but does not account for relationships between villages. To understand local spatial autocorrelation, Local Indicator of Spatial Association (LISA) is used.

3.3.3 LISA (local indicator of spatial association)

LISA is used to identify spatial dependencies or spatial dependence, which differs from Moran's Index, which produces a single index for the entire district. LISA, however, provides indices of spatial dependency for each village. Based on LISA cluster mapping, spatial dependence is evident from several villages with high numbers of patients located near each other, such as Sudimoro (207 patients), Gunungrejo (227 patients), Karangmulyo (140 patients), and Pager Lor (105 patients). According to data from Sudimoro Health Center in 2019, Hepatitis A cases in the district started with a case in Pager Lor in January, which then spread to Sudimoro and Gunungrejo. This indicates that spatial proximity plays a large role, where villages close to the initial outbreak site had higher patient numbers, while those further away had fewer cases.

Low patient villages also form clusters, such as Klepu with 35 patients, Ketanggung with 28 patients, and Sembowo with 27 patients—all neighboring villages in the northern part of Sudimoro District. In the southern part, villages with lower patient numbers also form clusters, such as Pager Kidul (54 patients), Sumberejo (43 patients), and Sukorejo (40 patients). Spatial dependencies can also be observed in the Moran Scatterplot, which divides the relationship between villages into quadrants. Quadrant 1 (HH): Sudimoro, Pager Lor, Karangmulyo, and Gunungrejo—villages with high Hepatitis A patient numbers clustered together. Quadrant 2 (LH): Sumberejo, Pager Kidul, and Sukorejo—villages with low patient numbers near villages with high patient numbers. Quadrant 3 (LL): Klepu, Ketanggung, and Sembowo—villages with low patient numbers near other low patient villages.

This study is supported by findings from the Pacitan District Health Office, which reported drought and water scarcity in Sudimoro District, compounded by the discovery of E. coli contamination in local water sources. This contamination is believed to have contributed to the spread of the HAV virus, especially during the Idul Fitri holiday, when the local population traditionally visits neighbors and family, possibly facilitating the transmission of the virus.

3.4 Correlation between the number of hepatitis a patients and population density

The correlation coefficient indicates the strength of the relationship between two variables. The coefficient ranges from -1 to 1. The closer the value is to 1 or -1, the stronger the relationship between the variables; conversely, the closer the value is to 0, the weaker the relationship, possibly indicating no correlation at all. A negative correlation coefficient indicates a negative relationship, while a positive value suggests a positive correlation (Budiyono, 2009). Based on the calculation of the simple linear correlation coefficient, with population density as the independent variable (X) and the number of patients as the dependent variable (Y), the result shows a correlation coefficient of 0.48. This indicates that there is a positive correlation between population density and the number of Hepatitis A patients. Specifically, as population density increases, so does the number of patients. Furthermore, a correlation coefficient of 0.48 suggests a moderate strength of the relationship between the two variables.

The correlation can be observed in villages with high population density, which tend to have a high number of Hepatitis A cases. Conversely, villages with lower population density have fewer patients. The following is a classification of population density and the number of patients with corresponding class intervals:

Table 7. Classification of population density and number of patients

Class population density		Class number of patient	
Interval	Description	Interval	Description
279-414	Low	27-94	Low
415-549	Medium	95-161	Medium
550-684	High	162-228	High

Based on the classification in Table 7, the distribution of villages by population density and the number of Hepatitis A patients is shown in Table 8. The following observations can be made:

Table 8. Classification of population density and hepatitis A patients by village

Village	Population density (X)	Description	Patient of Hepatitis A (Y)	Description
Sembowo	602	High	27	Low
Klepu	511	Medium	35	Low
Ketanggung	596	High	28	Low

Karangmulyo	682	High	140	Medium
Gunung rejo	582	High	227	High
Sudimoro	684	High	209	High
Pager lor	361	Low	105	Medium
Pager kidul	279	Low	54	Low
Sumberejo	362	Low	43	Low
Sukorejo	349	Low	40	Low
Amount	5008		908	

From Table 8, it can be concluded that villages with higher population densities tend to have a higher number of Hepatitis A patients, while villages with lower population densities have fewer patients. This is consistent with the result of the simple linear correlation calculation, which indicates a positive correlation with a moderate strength between population density and the number of patients in each village.

For example, Gunungrejo Village, which has the highest number of Hepatitis A patients, also has a high population density. On the other hand, Sembowo Village has the lowest number of patients (27 cases), yet also has a relatively high population density. This discrepancy can be explained by the fact that simple linear correlation ignores spatial aspects. In Sembowo's case, while it has a high population density, the village does not have neighboring villages with high numbers of Hepatitis A cases, which may reduce the likelihood of further spread in that area. In contrast, villages like Pager Kidul, Sumberejo, and Sukorejo have both low population density and fewer patients, reinforcing the idea that lower population density is linked to fewer cases.

4. Conclusions

The calculation results of Moran's Index show that there is spatial autocorrelation in the distribution of Hepatitis A cases, with an index value of 0.48. This spatial autocorrelation is positive, meaning that villages with a high number of cases tend to form clusters, as do villages with a low number of cases. The results of the Local Moran's Index (LISA) calculation show that there is spatial dependence between Sudimoro Village and Gunungrejo Village, where both villages are close to each other and have a high number of cases. Meanwhile, Sembowo Village and Klepu Village also exhibit spatial dependence, where both villages are close to each other and have a low number of cases. The spatial distribution pattern of Hepatitis A cases in Sudimoro District in 2019 is divided into several quadrants, based on the Moran scatterplot. There are three spatial relationship patterns:

HH (High-High: This includes Sudimoro, Pager Lor, Karangmulyo, and Gunungrejo Villages. These villages have a high number of Hepatitis A cases and are located near other villages with a high number of cases. LH (Low-High): This includes Sumberejo, Pager Kidul, and Sukorejo Villages. These villages have a low number of Hepatitis A cases and are located near villages with a high number of cases. LL (Low-Low): This includes Klepu, Ketanggung, and Sembowo Villages. These villages have a low number of Hepatitis A cases and are located near other villages with a low number of cases. The results of the simple linear correlation calculation show that there is a correlation between population density and the number of Hepatitis A cases, with a positive correlation. This means that the higher the population density, the higher the number of Hepatitis A cases. The correlation coefficient is 0.47, indicating that the correlation is of moderate strength, as the value of the coefficient is close to 0.

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Author Contribution

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References

Anselin, L. (1993). *Exploratory Spatial Data Analysis and geographic Information Systems*. National Center for Geographic Information and Analysis.

Anselin, L., Jacqueline, C., David, C., & Wilpen, G., (2000). Spatial Analyses of Crime. *Measurement and Analysis of Crime And Justice Spatial*, 27(2), 213–262. https://www.ojp.gov/criminal_justice2000/vol_4/04e.pdf.

Badan Pusat Statistik. (2019). *Kabupaten Pacitan dalam Angka*. Badan Pusat Statistik Kabupaten Pacitan.

Badan Penelitian dan Pengembangan Kesehatan. (2018). *Hasil Utama Riset Kesehatan Dasar (Riskedas)*. Kementrian Kesehatan Republik Indonesia.

Budiyanto, E. (2010). *Sistem Informasi Geografis dengan ArcView GIS*. Andi Yogyakarta.

Bivand, R. S., Pebesma, E., & Gomez, V. (2013). Applied Spatial Data Analysis with R. *Biometrics*. Springer.

Dinas Kesehatan Kabupaten Pacitan. (2020). *Infodatin Hepatitis A*. Dinas Kesehatan Kabupaten Pacitan.

Dinas Kesehatan Kabupaten Pacitan. (2019). *Profil Kesehatan Kabupaten Pacitan 2018*. Dinas Kesehatan Kabupaten Pacitan.

Economic Commission for Africa. (2005). *Economic Report on Africa Meeting the Challenges of Unemployment and Poverty in Africa*. Economic Commission for Africa.

Fares, A. (2015). Seasonality of hepatitis. *J Family Med Prim Care*, 4(1), 96-100. https://pubmed.ncbi.nlm.nih.gov/25810997/.

Godoy, P., Broner, S., Manzanares-Laya, S., Martínez, A., Parrón, I., & Planas, C. (2016). Outbreaks of hepatitis A associated with immigrants travelling to visit friends and relatives. *Journal of Infection*, 72(1), 112–115. https://pubmed.ncbi.nlm.nih.gov/26404744/.

Harisma, F. B., Syahrul, F., Mubawadi, T., & Mirasa, Y. A. (2018). Analisis Kejadian Luar Biasa Hepatitis A Di SMA X Kabupaten Lamongan Tahun 2018. *Jurnal Berkala Epidemiologi*, 6(2), 112-121. https://doi.org/10.20473/jbe.V6I22018.112-121.

Higgs, G. (2004). Health Services and Outcomes Research. *Methodology*, 5(2), 119–139. https://link.springer.com/journal/10742/volumes-and-issues/5-2

Hikmah, F., Nuraini, N., & Sari, P. E. (2016) Mapping an Analysis of Hepatitis A Disease Distribution Based on Risk Factors in Bondowoso District. *Jurnal Kesehatan*, 14(3), 303-310. https://doi.org/10.15294/kemas.v14i3.11246.

Pertiwi, A.I.P., Ramani, A., & Ariyanto, Y. (2014). Pemetaan Risiko Hepatitis A dengan Sistem Informasi Geografis (SIG) di Kabupaten Jember Tahun 2013. *Pustaka Kesehatan*, 2(2), 361–368.

Cromley, E.K. & McLafferty, S.L. (2011). *GIS and Public Health*. Guilfold Press.

Kementrian Kesehatan Republik Indonesia. (2011). *Peraturan Menteri Kesehatan Republik Indonsesia Nomor 2046/MENKES/PER/XII/2011. Jenis Penyakit Menular Tertentu Yang Dapat Menimbulkan Wabah Dan Upaya Penanggulangan*. Kementrian Kesehatan Republik Indonesia.

Kementrian Kesehatan Republik Indonesia. (2019). *Indonesian Health Profile Data and Information 2018*. Kementrian Kesehatan Republik Indonesia.

Kosfeld, R. (2018). *Spatial Econometrics with R* . General Public License.

Lai, P. C., So, F. M., & Chan, K. W. (2009). *Spatial Epidemiological Approaches in Disease Mapping and Analysis*. CRC Press.

Latimer, A. M., Banerjee, S., Sang, H., Mosher, E. S., & Silander, J. A. (2009). Hierarchical models facilitate spatial analysis of large data sets: A case study on invasive plant species in the northeastern United States. *Ecology Letters*, 12(2), 144–154. https://doi.org/10.1111/j.1461-0248.2008.01270.x.

Lazwardi, R. T., Zulkarnaen, D., & Sukaesih, E. (2019). Analisis Model Metapopulasi Pada Transmisi Virus Hepatitis A (Studi Kasus di Jawa Barat Jawa Tengah dan Jawa Timur). *Kubik*, 4(1), 149—155. https://doi.org/10.15575/kubik.v4i1.5675.

Lembo, A. J. (2006). *Spatial Autocorrelation*. Cornell University.

Lesage, J., & Pace, R. K. (2009). *Introduction to spatial econometrics*. CRC Press.

Pfeiffer, D. U., Robinson, T. P., Stevenson, M., Stevens, K. B., & Rogers, D. J. (2008). *Spatial Analysis in Epidemiology United Kingdom*. Oxford University Press.

Pratiwi, E., Soekarso, T., Adam, K., & Setiawaty, V. (2017). Identifikasi Virus Hepatitis A pada Sindrom Penyakit Kuning Akut di Beberapa Provinsi di Indonesia Tahun 2013. *Global Medical and Health Communication*, 5(3), 199-204. https://doi.org/10.29313/gmhc.v5i3.2386.

Pusat Data dan Informasi Kementrian Kesehatan RI. (2019). *Data dan Informasi Profil Kesehatan Indonesia*. Kementrian Kesehatan Republik Indonesia.

Rahmanti, A. R. & Prasetyo, A. K. N. (2012). Sistem Informasi Geografis: Trend Pemanfaatan Teknologi Informasi Untuk Bidang Terkait Kesehatan. *Seminar Nasional Informatika Medis II*I. Magister Teknik Informatika Universitas Islam Indonesia.

Nurdiansyah, R. (2020). Spatial Analysis of Hepatitis A Distribution Using Moran's Index and LISA (Local Indicator of Spatial Association) – A Case Study of Sudimoro District, Pacitan in 2019. *Undergraduate thesis*. Universitas Muhammadiyah Surakarta.

Riner, M. E., Cunningham, C., & Johnson, A., (2004). Public Health Education and Practice Using Geographic Information System Technology. *Public Health Nursing*, 21(1), 57—65. https://pubmed.ncbi.nlm.nih.gov/14692990/.

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