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Mapping the Spatial Distribution of COVID-19 Incidence Using a Geographic Information System

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ABSTRACT:

Background : The outbreak of the new coronavirus, also known as COVID-19, began in Wuhan, China, in January 2020, becoming a sudden public health crisis and a severe threat to lives in most parts of the world. This study aimed to use a Geographic Information System (GIS) to study the spatial distribution of COVID-19 incidence in Ho Chi Minh city.

Methods: the histogram was first used to study the distribution of the COVID-19 cases and COVID-19 incidence. A GIS was then employed to map the spatial distribution of the COVID-19 cases and COVID-19 incidence. Finally, the study results were discussed and concluded.

Results: a large proportion of COVID-19 infections mainly appeared in districts in the eastern region, then followed by the western districts of the city, while the average rate of infections was concentrated in districts near the city center. Low rates of COVID-19 infection were detected in the northern and southern districts of the city and some central districts of the city.

Conclusions: the study results indicated the effectiveness of a GIS for mapping COVID-19 incidence. Findings in this study provide an insight into the spatial distribution of infectious diseases and make great contributions to the control of the COVID-19 pandemic.

KEYWORDS: Spatial distribution, Geographic Information System (GIS), COVID-19, Ho Chi Minh City, Vietnam.

INTRODUCTION

A novel coronavirus disease outbreak in 2019 (COVID-19) caused by the emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in China quickly spreads throughout the world (1). The COVID-19 pandemic has been a serious global danger to public health since early 2020. SARS-CoV2, the coronavirus that causes severe acute respiratory syndrome, is the cause of COVID-19 (2). Previous outbreaks of coronaviruses include acute respiratory syndrome (SARS-CoV) and Middle Eastern respiratory syndrome (MERS-CoV), previously known as risk factors for public health (3). The Coronavirus spread fast to additional nations in eastern Asia, Europe, and the rest of the world (4). The primary symptom is fever, and approximately after five days, signs of acute respiratory infection appear. Healthcare staff and those with chronic illnesses are at a high risk of the disease (5). The latest data shows that Globally, as of 3:52pm CET, 30 November 2023, there have been 772,052,752 confirmed cases of COVID-19, including 6,985,278 deaths, reported to World Health Organization (WHO) (6). Due to the increasing prevalence and growth of this disease, it is necessary to find ways to manage and cope with it. It is, therefore, mapping COVID-19 pandemic makes great contributions to the control of the COVID-19 pandemic (7,8).

The disease depends on many parameters, including spatial information, it is essential to analyze this information to predict and control it (9). Geographical factors play crucial roles in the fight against the COVID-19 pandemic (10). One useful tool is the geographic information system (GIS), which reduces costs by analyzing spatial and non-spatial data, significantly helping managers and decision-makers control the disease (11). The GIS has been used to process health data, analyze geographic distribution, disease prediction mapping, surveillance, and epidemic disease management. When the COVID-19 pandemic were discovered to be thoroughly spatial in nature (12). Lots of efforts have been made to study the COVID-19 pandemic from a geographical perspective such as the assessment of the effects of living environment deprivation on COVID-19 hotspot in Kolkata megacity, India using Getis-Ord G statistic and geographically weighted principal component analysis (13). The spatial statistics and factors affecting COVID-19 at both, prefecture and county levels were examined in Hubei Province, China (14). Exploratory spatial data analysis and the geodetector method have been also employed to analyse the spatial and temporal differentiation characteristics and the influencing factors of the COVID-19 epidemic spread in mainland China (15). The necessity of using GIS science was investigated for COVID-19 mapping (16). Spatial autocorrelation analysis was used to investigate the spatial clustering characteristics of the

COVID-19 pandemic in Beijing, China (17). Spatial analysis and GIS in COVID-19 was studied (18). In addition, GIS has been also successfully to COVID-19 studies in many countries such as to investigate the spatiotemporal interaction effect of COVID-19 transmission in the United States (19), to identify long-term exposure to air-pollution and COVID-19 mortality in England (20), to spatial autocorrelation patterns across five waves of COVID-19 in Catalonia, Spain (21), and to analyse spatio-temporal COVID-19 outbreak in Italy (22). In addition, a hot spot map of COVID-19 outbreaks was prepared in Iran (23).
The objective of this study was to employ a Geographic Information System (GIS) to study the spatial distribution of COVID-19 incidence in Ho Chi Minh city. The histogram was first used to study the distribution of the COVID-19 cases and COVID-19 incidence. A GIS was then employed to map the spatial distribution of the COVID-19 cases and COVID-19 incidence. Finally, the study results was discussed and concluded.

MATERIALS

Vietnam was a remarkable COVID-19 success story, logging zero cases for months on end and keeping life close to normal for much of the population. For much of the pandemic, cases and deaths per 100,000 remained among the lowest in the world (24). But in late April 2021, the highly transmissible Delta variant began to take hold in Vietnam and Ho Chi Minh City - the country's economic engine, where 13 million people live and work - is now the locus of struggle against the virus: amid mass testing many thousands of cases are logged daily (25). Vietnam's fourth wave began on April 27. As COVID-19 spread, an infographic produced by the Ho Chi Minh City Center for Disease Control (HCDC) circulated on social media and instant messaging channels listing locations, flights and bus routes with confirmed cases and providing instructions to either isolate at home or enter a government quarantine facility depending on one's exposure to the virus (25). In this study, a dataset of COVID-19 cases and COVID-19 incidence collected from August 2021 to August 2023 in Ho Chi Minh City will be used to study the spatial distribution of COVID-19 incidence in this study.

METHODS

Histogram

Histogram is one of the most important graphical objects in statistical practice. In addition, the histogram provides a consistent estimate of any density function with very few assumptions. A histogram is an approximate representation of the distribution of numerical data. The term was first introduced by Karl Pearson (26). To construct a histogram, the first step is to "bin" (or "bucket") the range of values - divide the entire range of values into a series of intervals -and then count how many values fall into each interval. The bins are usually specified as consecutive, non-overlapping intervals of a variable. The bins (intervals) must be adjacent and are often (but not required to be) of equal size (27). If the bins are of equal size, a bar is drawn over the bin with height proportional to the frequency - the number of cases in each bin. A histogram may also be normalized to display "relative" frequencies showing the proportion of cases that fall into each of several categories, with the sum of the heights equaling one. However, bins need not be of equal width; in that case, the erected rectangle is defined to have its area proportional to the frequency of cases in the bin (28). The vertical axis is then not the frequency but frequency density - the number of cases per unit of the variable on the horizontal axis. Examples of variable bin width are displayed on Census bureau data below.
As the adjacent bins leave no gaps, the rectangles of a histogram touch each other to indicate that the original variable is continuous (29). Histograms give a rough sense of the density of the underlying distribution of the data, and often for density estimation: estimating the probability density function of the underlying variable. The total area of a histogram used for probability density is always normalized to 1. If the length of the intervals on the x-axis are all 1, then a histogram is identical to a relative frequency plot. The histogram is one of the seven basic tools of quality control (30). Histograms are sometimes confused with bar charts. A histogram is used for continuous data, where the bins represent ranges of data, while a bar chart is a plot of categorical variables. Some authors recommend that bar charts have gaps between the rectangles to clarify the distinction (31). Histograms are particularly useful for understanding the shape of a data set. The shape of a data set is a way of describing the pattern that is generated when the data are plotted using a histogram. Figure 2 below shows several common shapes of data sets.

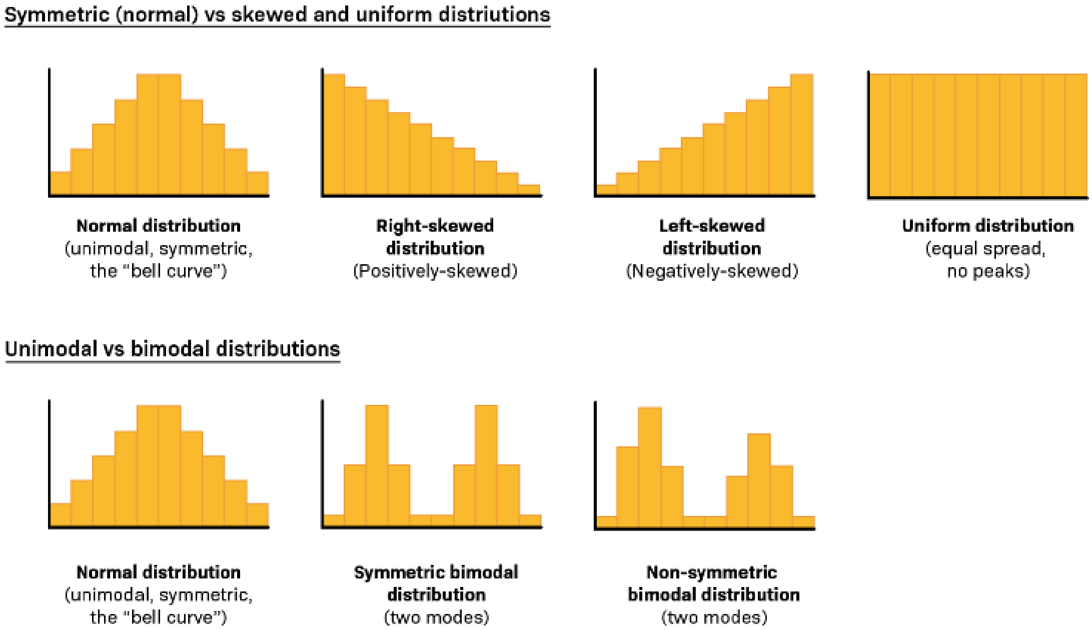

Figure 1. Examples of data shapes using histograms

A Geographic Information System

In Geographic Information System, a map projection is any of a broad set of transformations employed to represent the curved two-dimensional surface of a globe on a plane (32). In a map projection, coordinates, often expressed as latitude and longitude, of locations from the surface of the globe are transformed to coordinates on a plane (33,34). Projection is a necessary step in creating a two-dimensional map and is one of the essential elements of cartography. All projections of a sphere on a plane necessarily distort the surface in some way and to some extent (35). Depending on the purpose of the map, some distortions are acceptable and others are not; therefore, different map projections exist in order to preserve some properties of the sphere-like body at the expense of other properties. The study of map projections is primarily about the characterization of their distortions. There is no limit to the number of possible map projections (36). More generally, projections are considered in several fields of pure mathematics, including differential geometry, projective geometry, and manifolds. However, the term "map projection" refers specifically to a cartographic projection.

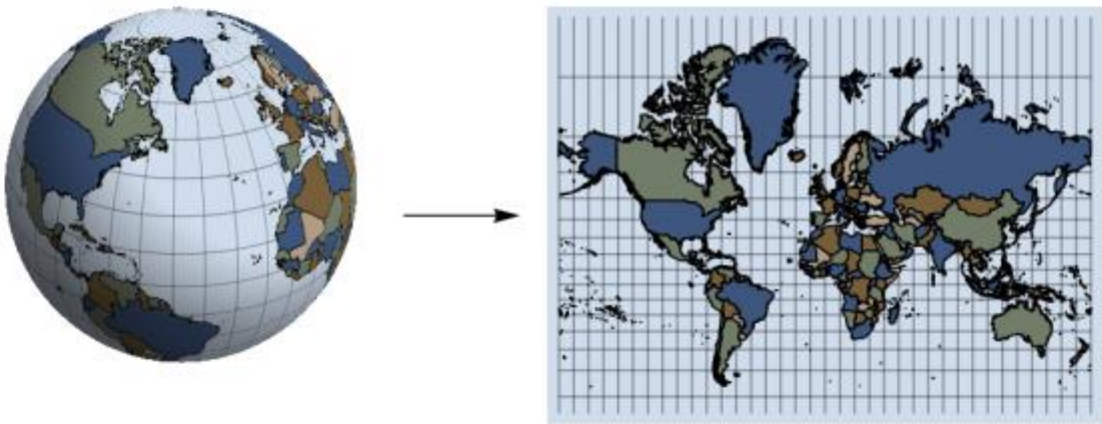

Figure 2. Projecting the Earth in a GIS.

The projection shown in Figure 2 is called Mercator's projection. Mercator created his projection in space. The forward equations for the Space-oblique Mercator projection for the sphere are as follows:

$$\frac{x}{R} = \int_0^{\lambda'} \frac{H - S^2}{\sqrt{1+S^2}} d\lambda' - \frac{S}{\sqrt{1+S^2}} \ln\tan\left(\frac{\pi}{4} + \frac{\varphi'}{2}\right) \quad (1)$$

$$\frac{y}{R} = (H+1) \int_0^{\lambda'} \frac{S}{\sqrt{1+S^2}} d\lambda' + \frac{1}{\sqrt{1+S^2}} \ln\tan\left(\frac{\pi}{4} + \frac{\varphi'}{2}\right) \quad (2)$$

$$S = \frac{P_2}{P_1} \sin(i) \cos(\lambda') \quad (3)$$

$$H = 1 - \frac{P_2}{P_1}\sin(i) \quad (4)$$

Where: φ is geodetic (or geographic) latitude, λ is geodetic (or geographic) longitude, P_2 is the time required for revolution of satellite, P_1 is the length of Earth rotation, i is the angle of Earth rotation, is the radius of Earth, x and y are rectangular map coordinates.

RESULTS AND DISCUSSION:

Analysis of spatial distribution of COVID-19 cases

Vietnam was a remarkable COVID-19 success story. However, when the highly transmissible Delta variant began to take hold in Ho Chi Minh Chí Minh City - the country's biggest city in Vietnam had been the locus of struggle against the virus: amid mass testing many thousands of cases are logged daily. Social distancing measures used to control previous variants have proven ineffective against the virulent Delta strain, and this prompted the Vietnamese authorities to impose increasingly strict lockdowns and scale back contact tracing efforts to focus on treating the sick entering hospitals (25). This study was carried out after August 2021 offers first-hand observations from Vietnam's megacity as the country's fourth wave of COVID-19 hit.

Data from Figure 3 illustrates the distribution of COVID-19 cases in Ho Chi Minh City. In total there are 20 districts in Ho Chi Minh city. The smallest and largest number of COVID-19 cases are 3,164 and 61,248, respectively. The values of the first and third quartile (1-st quartile and 3-rd quartile) were of 17,626 and 31,492, respectively. Meanwhile, the mean and median number of COVID-19 infections were 26271 and 24,024 COVID-19 cases, respectively. It can be seen that the median value was larger than the average value, therefore the data on the number of COVID-19 was skewed to the right. This shows that the number of districts with many cases accounts for the majority of the entire city.

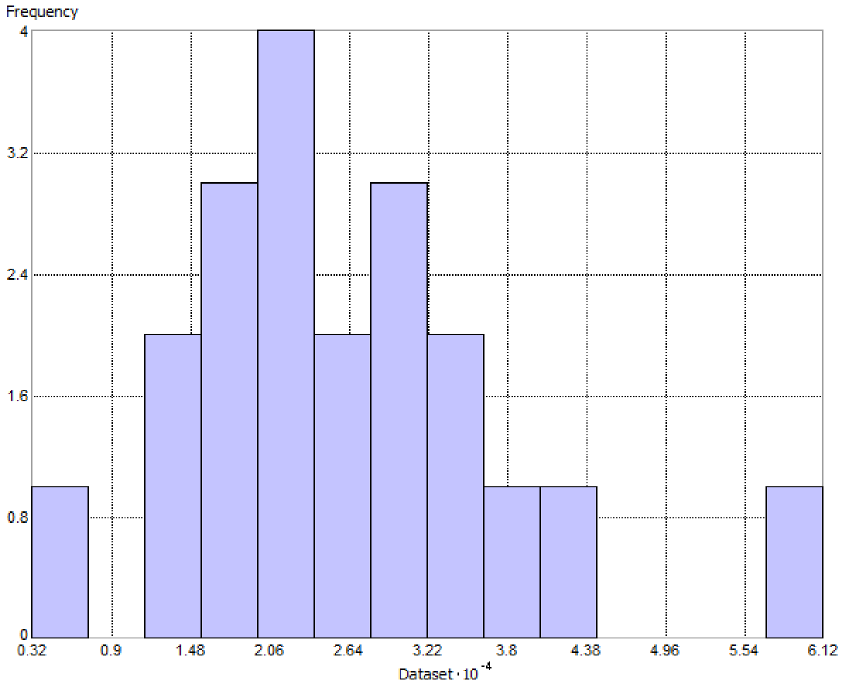

Figure 3. A histogram of COVID-19 cases in Ho Chi Minh city.

Data from Figure 4 illustrate the spatial distribution of COVID-19 incidence in Ho Chi Minh City from August 2021 to August 2023. It can be seen from Figure 2 that the number of COVID-19 infection rates were mainly found in districts in the city center, while low numbers of infection rates were mainly detected in the northern and southern districts of the city and some districts in the center of the city. Data from Figure 2 demonstrates that districts having a high number of COVID-19 cases (over 30,000 cases) included Thu Duc (61,248 cases), Binh Thanh (42,393 cases), Binh Chanh (37,357 cases), District 12 (36,042 cases). cases), Tan Binh (33,194 cases). Districts having a medium number of COVID-19 cases (ranging from 20,000 cases to 30,000 cases) included Hoc Mon (29,789 cases), District 8 (29,078 cases), District 10 (28,256 cases), District 7 (25,702 cases), District 4 (24,282), Go Vap (23,765 cases), Nha Be (23,202 cases), District 1 (23,092 cases) and District 6 (22,930 cases). Meanwhile, districts having a low number of infected cases (less than 20,000 cases) include District 5 (17,689 cases), District 3 (17,562 cases), Cu Chi (16,991 cases), District 11 (15,090 cases), Phu Nhuan (14,589 cases) and Can Gio (3,164 cases).

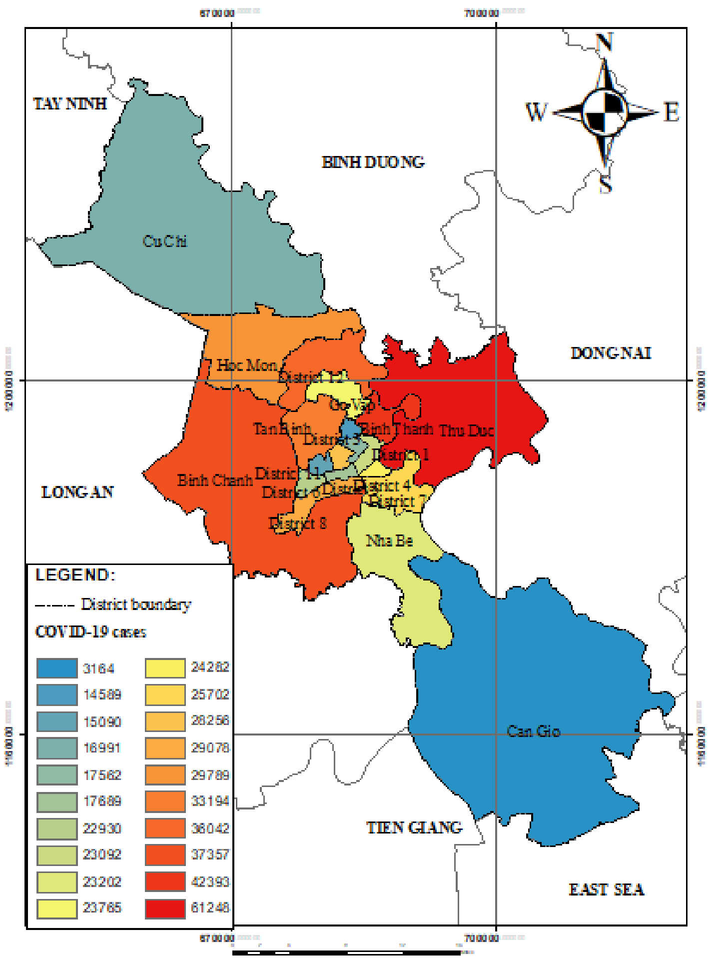

Figure 4. Spatial distribution of COVID-19 cases in Ho Chi Minh city.

Analysis of spatial distribution of COVID-19 incidence

The data from the histogram in Figure 5 shows the distribution of COVID-19 infection rates in Ho Chi Minh city. In total, there are 20 districts in Ho Chi Minh city. The smallest and largest COVID-19 infection rates were 0.036 and 0.132, respectively. The values of the first (1-st quartile and 3-rd quartile) and 3rd quartile ranges were 0.059 and 0.091, respectively. The values of the mean and median COVID-19 infection rates were 0.079 and 0.077, respectively. It can be seen that the median and mean values had similar values, so it can be concluded that the distribution of COVID-19 infection rate was quite balanced on both sides.

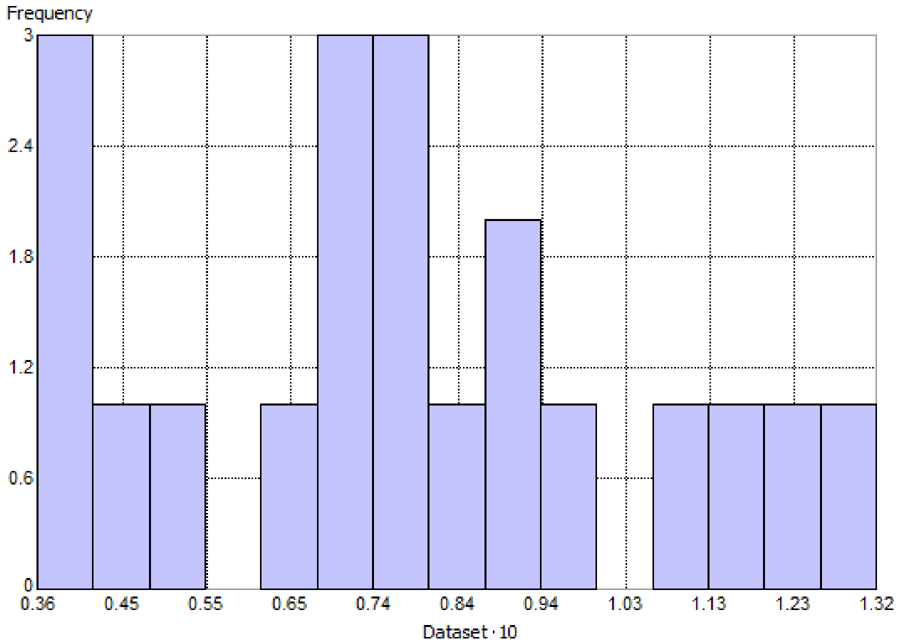

Figure 5. A histogram of COVID-19 incidence in Ho Chi Minh city.

Mapping The Spatial Distribution of COVID-19 Incidence Using A Geographic Information System

Data from Figure 6 demonstrates the COVID-19 infection rate of Ho Chi Minh City from August 2021 to August 2023. It can be seen from Figure 4 that a large proportion of COVID-19 infections mainly appeared in districts in the eastern region, then followed by the western districts of the city, while the average rate of infections was concentrated in districts near the city center. Low rates of COVID-19 infection were detected in the northern and southern districts of the city and some central districts of the city. Data from Figure 4 shows that high infection rates were detected in the eastern and southeastern districts of the city such as Nha Be (0.132), District 4 (0.119), Thu Duc (0.117), District 1 (0.113). The moderate rate of COVID-19 infection mainly appeared in districts near the city center such as District 5 (0.09), District 3 (0.089), District 6 (0.088), Binh Thanh (0.086), Phu Nhuan (0.08), District 7 (0.079), District 10 (0.076), and Tan Binh (0.07). Low-level COVID-19 infection rates were detected in the northern, southern and western districts of the city such as Go Vap (0.036), Cu Chi (0.042), Can Gio (0.042), District 11 (0.045), Binh Chanh (0.054), District 8 (0.064), District 12 (0.069) and Hoc Mon (0.07).

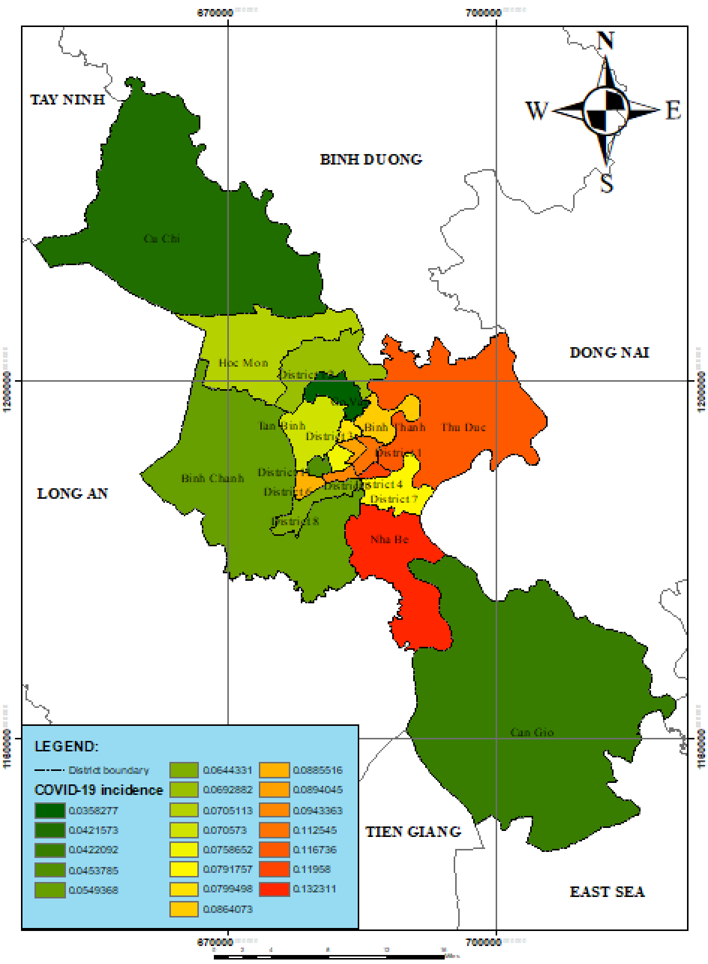

Figure 6. Spatial distribution of COVID-19 incidence in Ho Chi Minh city.

CONCLUSION

Relatively high levels of public anxiety around COVID-19 in Vietnam have been captured in surveys. The spread of coronavirus in many parts of the world, including Vietnam, has caused significant public health problems. Therefore, management and planning to address and reduce diseases are needed. The purpose of this study was to employ a Geographic Information System to study the spatial distribution of COVID-19 incidence in Ho Chi Minh city. The histogram was first used to study the distribution of the COVID-19 cases and COVID-19 incidence. A GIS was then employed to map the spatial distribution of the COVID-19 cases and COVID-19 incidence. Finally, the study results was discussed and concluded. This study aimed to analyze the spatial clustering of COVID-19. It was found that a large proportion of COVID-19 infections mainly appeared in districts in the eastern region, then followed by the western districts of the city, while the average rate of infections was concentrated in districts near the city center. Low rates of COVID-19 infection were detected in the northern and southern districts of the city and some central districts of the city. The study results indicated the effectiveness of a GIS for mapping COVID-19 incidence. Findings in this study provide an insight into the spatial distribution of infectious deseases and make great contributions to the control of the COVID-19 pandemic. The results of this investigation have a significant impact on the fight against the COVID-19 pandemic.

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CONFLICT OF INTEREST : None

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