ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of GeographyVol 55, No 1 (2023): 155-166
DOI: 10.22146/ijg.73663 website: htps://jurnal.ugm.ac.id/ijg

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

The Temporal and Spatial Analysis of Corona Pandemic in Jordan using the Geographic Information System: An Applied Geographical Study

Ayed Taran[1], AbedAlhameed AlFanatseh[2], Shatha Rawashdeh[3], Faisal Almayouf[4]
[1,4]Al al-Bayt University, Department of Applied Geography, Jordan, Almafraq
[2,3]Al-hussein Bin Talal University, Department of Geography, Jordan, Ma'an

Submit : 2022-03-17
Received: 2022-04-21
Accepted: 2023-01-10

Keywords: Spatial Analysis; Temporal Analysis; Corona; Pandemic; Geographical Information Systems; Hotspot Analysis.

Correspondent email:
taran@aabu.edu.jo.

Abstract. The coronavirus disease which results from severe acute respiratory syndrome (SARS-COV-2), is considered a global challenge affecting millions of people and leading to a global increase in mortality, including in Jordan. Therefore, this study aims to analyze the temporal and spatial patterns of the prevalence and outbreak of coronavirus in Jordan during six periods, from 1, October 2020 until 31, March 2021 by applying geographical information systems. The Moran coefficient was applied in addition to the G* test and location quotient (LQ). The results showed the overall pattern for the distribution of cases affected by the virus was random since most governorates' experience increased the focus and prevalence of the pandemic. Furthermore, four hot spots were revealed, namely Amman, Irbid, Zarqa, and Balqa'. This study introduced new insights into the statistical analysis of the distribution and prevalence of coronavirus in Jordan using geographical information systems. This will help planners and decision-makers to predict the dynamics of the temporal and spatial transfer of the virus in the future. It will also explain the current situation to set the appropriate policies or measures to face the pandemic, as well as reduce its prevalence. Therefore, monitoring, evaluating, and planning the usage of geospatial analysis are essential for controlling the spread of COVID-19 in the country.

1. Introduction

The prevalence of a disease is regarded as one of the most serious challenges experienced by humanity. This is due to the negative effects on people's lives in all the environmental, technological, social, and economic domains at the national and international levels (Garchitorena et al., 2017). Also, the pandemic diseases that prevailed throughout the world during the last few centuries, such as plague, AIDS, flu, measles, and malaria have led to the deaths of millions of people (Wagner et al., 2014). Currently, the world is confronted by one of the most serious diseases ever, namely COVID-19 according to the World Health Organization (WHO). This virus first emerged on 31st December 2019 in the city of Wuhan, the capital of Hubei province. Subsequently, it spreads rapidly throughout China and to all the countries in the world, including Jordan. As a result, about 136 million cases and 3 million deaths were registered at the world level until 31st, March 2021. The rapid and wide prevalence of the virus throughout the world has become a global concern and crisis despite the increased efforts for its control. The records of the WHO suggest that North and South America registered the highest numbers of cases, followed by Europe, the Eastern Mediterranean, South East Asia, and Africa (WHO, 2021).

This rapid prevalence has resulted in considerable psychological consequences, where about (98.54%) suffered from severe anxiety and depression due to the high infection rate (Kelvin and Rubino, 2020). Furthermore, individuals whose ages range between (30-79) years are more exposed to the virus, especially when they have underlying health problems, such as cardiorespiratory diseases, diabetes, blood pressure, and cancer (Liu et al., 2020). Meanwhile, the age categories over 50 years are more exposed to death due to coronavirus as compared to the other categories (Yahya et al., 2020).

The prevalence of diseases, especially infectious ones, takes on a spatial dimension, therefore, experts in general health can determine how the infection is transmitted at the national and international levels by following the paths of human communication (Mackey et al., 2014). In this regard, the geographical information system and spatial maps are considered effective analytical tools, which can be viewed as being basic for knowledge, prevention, and therapy. These instruments can also be used as a visual representation that helps draw the maps of the geographical distribution of the pandemics and predicts the areas exposed to risks in the future in order to give priority to prevention and medical treatment. As for the spatial analysis, the risks of diseases as well as the directions of their prevalence across time and space can be evaluated, while the spots of infection and prevalence can also be determined (Kandwal et al., 2009; Lyseen et al., 2014). Furthermore, geographical information systems are considered a basic tool for several educational programs that deal with pandemic diseases, where it catalyzes the development of modern automated mapping procedures (Sithiprasasna et al., 2004). However, this tool did not attract the required attention concerning the study and analysis of corona pandemic, its distribution, or prevalence style all over the world.

The most obvious usage for the technology of geographical information systems is related to providing a graphical representation of the prevalence of a disease. Although the visual and printed media take advantage of this context, they tend to use the produced maps. For example, the BBC station uses the maps produced by the University of John Hopkins and the ESRI company to help the international community by providing data, programs, and maps to monitor as well as trace the prevalence of coronavirus through its specified entry. In addition, the British Geological Survey formed teams to respond to emergent cases in order to help the British National Health Services Committee confront the pandemic. This increased the use of digital maps and the application of (OS Maps) by 78%. It also issued licenses to developers to come up with certain services for the pandemic.

Understanding the temporal and spatial events of the corona pandemic at the national level is a very important issue since it provides a comprehensive and vital view of how the pandemic occurs, spreads, and declines. Also, Jordan is one of the countries that declared the outbreak of the virus by announcing the number of affected cases and deaths as well as the prevalence ratio in the various governorates. The Jordanian Ministry of Health reported that the first confirmed case was registered on 2 March 2020, where the total number of affected cases was 611.577 and deaths were 6858 by the end of March 2021. This negatively reflected on all the scientific, environmental, technological, social, and economic domains as several restrictions were imposed. These include social distancing, self-isolation, work from home, as well as educational institutions and business closure. Furthermore, there were movement restrictions by closing the state's local and international borders. The socio-economic fallout caused by the pandemic was a threat that affected growth at the national and global levels. The virus has not come to an end and has adversely affected the world's economy. It has led to an economic recession and hit various business areas, such as travel, tourism, aviation, and service sectors. Therefore, this study aims to (1) assess the spatiotemporal patterns of COVID-19 prevalence using the data of confirmed cases, (2) quantify temporal variations of the infection rate, (3) compare variations in the daily infection rate at the governorates' level and (4) detect space-time patterns of COVID-19 by using spatiotemporal methodologies, specifically descriptive statistical tests and ArcGIS 10.5 spatial autocorrelation indexes. This will contribute to alleviating the severity of the pandemic as well as the setting of policies at the national level to advocate the strategies specified for emergencies, treatment, and the prevention of infection.

Several studies have been conducted worldwide about the protection against coronavirus and the mechanisms of its transmission, prevalence, as well as treatment methods. For example, several statistical models were used to predict the prevalence of the pandemic based on spatial and temporal characteristics. The results showed the spatial dimension is important in predicting the directions of the disease's prevalence over time (Dickson et al., 2020). Another study determined the spatial effects and temporal styles for the prevalence of coronavirus in Italy by using several spatial statistical methods, including the Moran coefficient (Ghosh and Cartone, 2020). Also, the outbreak of the corona pandemic in India was investigated, and the results revealed that the cities of Delhi, Gujarat, Telangana, Uttar Pradesh and Rajistan were the most affected (Murugesan et al., 2020). Furthermore, the distribution of the virus and its relationship with people's immigration from the city of Wuhan was examined. The results revealed a strong correlation between people's immigration from the city of Wuhan and the number of cases in other Chinese cities (Chen et al., 2020).

A geographical database that consists of (35) variables to demonstrate the spatial variation for the prevalence of coronavirus in the United States of America was also established. The results showed four variables interpreted as a high spatial variation of infection by the virus in the country, namely family income, inequality of income, the percentage of nurses, and the percentage of black females in the population (Mollalo et al., 2020). Furthermore, the spatial distribution of corona cases in Iran was examined. The results revealed a strong relationship between the prevalence of the virus in the Iranian governorates and the following characteristics, namely aging, urbanization, the correlation between governorates, temperatures, rates of illiteracy, and number of doctors (Ramírez-Aldana et al., 2020).

Moreover, the prevalence in Iran was addressed and the results showed a positive relationship between the cases of infection on one hand as well as population density and mobility on the other. It also revealed a negative relationship between the number of infected cases as well as the ratio of humidity and solar radiation (Ahmadi et al., 2020).

The spatial distribution and direction of the COVID-19 prevalence in the Delta of Yangtze River in China were investigated by tracing the center of geographical concentration of the disease, calculating the spatial correlation, and applying the multiple regression coefficients to detect the temporal and spatial directions for the cases. The results showed the control procedures applied by the government were effective and the delta areas which witnessed more flow of people from the city of Wuhan were more exposed to infection (Ye and Hu, 2020). The sequence of infection cases was also explored temporally and spatially at the world level. The results revealed that the geographical environment conditions, the cultural and nutritional habits, as well as the advanced transportation means, had a prominent effect on the rapid prevalence of the pandemic. It was also suggested that the pandemic is increasingly prevailing over time (Elzeeny, 2020).

Geographical information systems have emerged as an effective tool for studying and analyzing infectious diseases as well as determining the spatial and temporal patterns of pandemics due to the development of science and technology (Comber et al., 2011). For example, the center of Johns Hopkins University for science and engineering in the United States used geographical information systems in providing new data and maps about the global spatial distribution of coronavirus, including the case of infection, recovery, and deaths all over the world (JHU CSSE, 2020). These systems were also used to improve control management for the diseases of foot and mouth in New Zealand in 1991 (Sanson et al., 1991). Furthermore, the national geographic information system for combating the SARS pandemic as well as the early warning developed by the Chinese national center for combating and preventing diseases (China CDC) played an important role in managing, analyzing, and controlling severe acute respiratory syndrome (SARS). They were also used in drawing a spatial map for the areas affected by coronavirus in Malaysia in an attempt to detect the spatial patterns and temporal directions for the prevalence of the virus (Yahya et al., 2020).

Corona pandemic resulted in several problems and adverse effects at the international level in all the technological, environmental, social, and economic life domains. A geo-epidemic study addressed the effects of the virus on the population of Brazil by analyzing the geographical distribution of the affected cases and deaths using geographical information systems. The results revealed that the most affected areas were the northern, western, and Middle regions in Brazil (Alves et al., 2021). The impact of the pandemic on the temporal and spatial characteristics of road accidents in Al-Medina Monawara was identified using the tools of geographical information systems, such as Kernel coefficient, in addition to analyzing the hot and cold spots as well as the measures of central tendency (Al-Ahmadi, 2021).

According to the literature review, different studies had been carried out on the various dimensions of COVID-19. They all emphasized the necessity of conducting more research and updating the scientific outlook on the virus. Since information from articles played an essential role in empowering authorities and people during an epidemic period, the present paper was conducted to conclude on the number, density, and trend of cases that occurred due to COVID-19 in Jordan from its emergency time up to now. Also, the use of geographical information systems would provide a geographical database concerning the spatial dynamics of the virus to set the appropriate policies and measures to confront the pandemic and reduce its prevalence. Therefore, this study focused on spatial distribution mapping of COVID-19-affected areas to regionally identify the preventive measurements. The results will help to interpret the governing spatial-temporal patterns and trends, as well as provide rapid information sources around the spatial dynamics of COVID-19.

Study Area

This study was conducted in Jordan which is situated in the southwest of Asia. Jordan is one of the countries that experienced the prevalence of coronavirus and was considerably affected by its consequences due to its strategic location that connects the three continents, namely Asia, Europe, and Africa. The country has an area of (88.794) km^2 and a population of about (10.806.000) people (Department of Statistics, 2021). Furthermore, it consists of (12) governorates as illustrated in Fig 1, these include Amman, Zarqa, Irbid, Mafraq, Jerash, Ajloun, Balqa', Madaba, Al-Karak, Tafila, Ma'an and Aqaba. Fig 2 shows the geographical distribution of the people and the population density for each governorate (Department of Statistics, 2021). Amman is the largest populated governorate, while Tafila is the least. In terms of population density, Irbid was ranked first, while Ma'an as last.

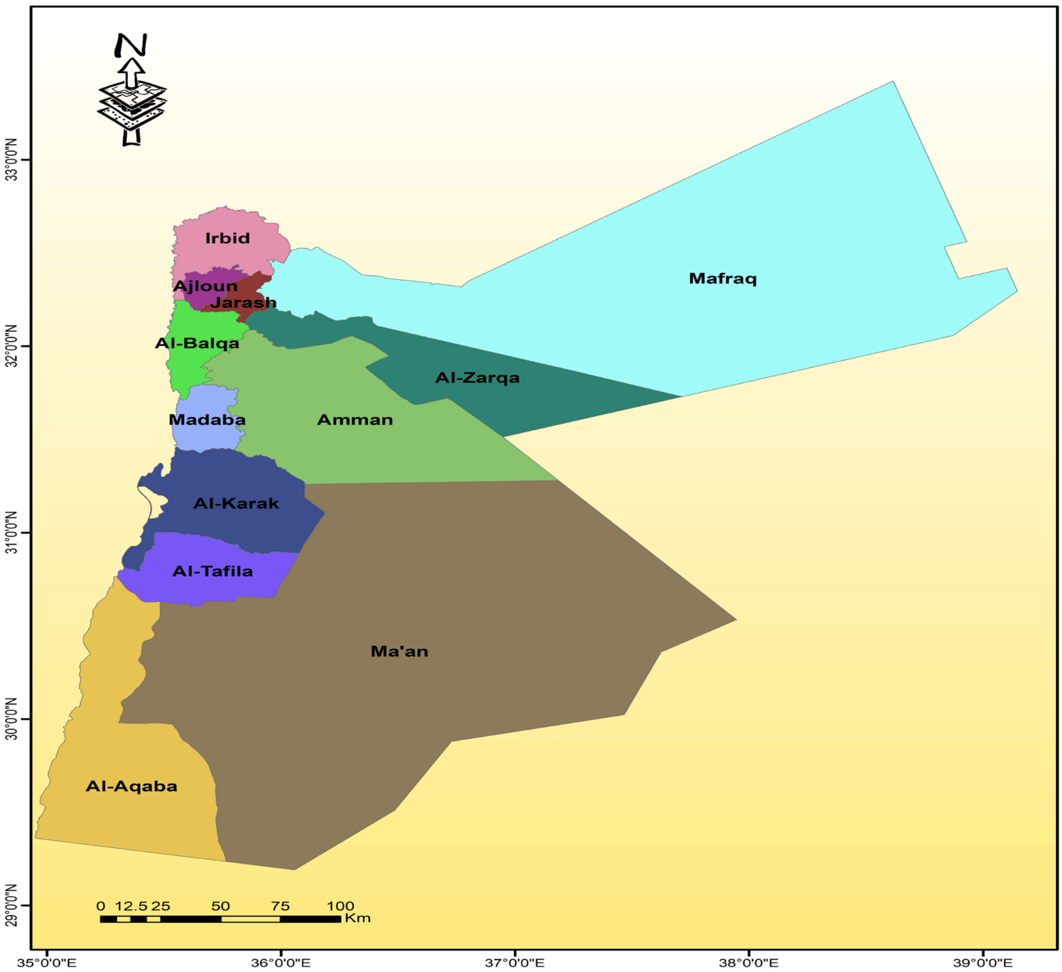

Figure 1. Study area (Source: Prepared by the researcher using GIS)

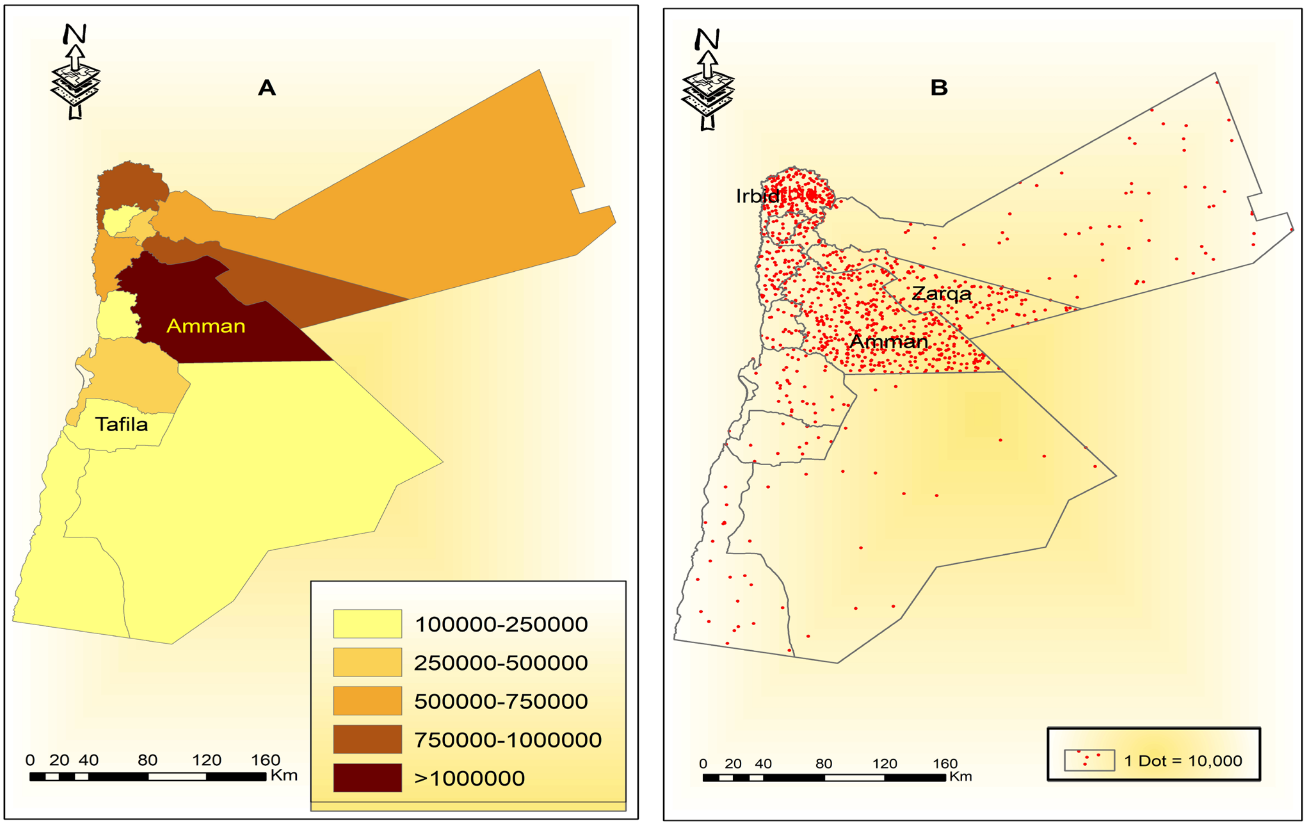

Figure 2. A. geographical distribution of the population B. the population density/km^2 in the Jordanian governorates in the 2015 estimate.(Source: Prepared by the researcher using GIS)

Table 1. The periods used for the temporal analysis of the corona pandemic during 2020-2021

Symbol	P1	P2	P3	P4	P5	P6
Period	October	November	December	January	February	March

Table 2. The spatial data and their resources

Variables	Source
Number of population	Department of Statistics
Density of population	Department of Statistics
Administrative governorates map	Royal geographical center
Jordan's map	Royal geographical center
Corona daily data	The Jordanian ministry of health and WHO

2. Methods

Data collection and preparation

This study includes a comprehensive temporal and spatial analysis of corona pandemic in Jordan. The data relating to the population at the level of the Jordanian governorates were obtained from the department of statistics according to the general census in 2015 (department of statistics, 2020). Furthermore, the data related to coronavirus, such as the number of cases and deaths were obtained from the Jordanian ministry of health, the national center for security and crisis management, as well as the WHO, from the beginning of October 2020 until the end of March 2021. This period experienced a considerable increase in the number of affected cases all over the country. This, in turn, made it possible to discover the pattern of the spatial distribution of the virus in the Jordanian governorates more precisely. Accordingly, the collected data were divided into six time periods as illustrated in Table 1.

All the collected data were inserted into (ArcGIS 10.3) software. Subsequently, the geographical databases were established, the diagrams were drawn, and the maps showing the temporal and spatial distributions were illustrated for the prevalence of the corona pandemic in Jordan. Table 2 shows the used descriptive and spatial data and their resources.

The methods of spatial and statistical analysis

The geographical information systems provide a set of spatial and statistical analysis tools that are appropriate for studying and analyzing the risks of diseases, such as the distribution, direction, as well as pattern of prevalence, correlation, and spatial gathering. In this context, the geographical information system was used to investigate the temporal and spatial variations of the pandemic. It was also used to cite a clear conceptualization of the epidemic reality, spatially trace the hot spots of the pandemic during the study period and contribute to the rapid future prediction of the pandemic in Jordan. Several spatial and statistical methods were used in order to determine the spatial patterns for the prevalence of the pandemic as follows:

Location quotient (LQ)

Location quotient (LQ) is considered an important tool to determine the areas that are characterized by a certain phenomenon at the national level. Therefore, the extent of focus for a certain phenomenon, trait, or profession in a certain area can be determined. This scale was used to measure the extent of the geographical concentration of the pandemic in Jordan at the level of each governorate. This was carried out by dividing the total number of infected cases by the number of population in that governorate and dividing that by the number of infected cases in the country as a whole relative to the population, as illustrated in the following equation (Xu et al, 2018).

$$LQ = \frac{\left(\frac{\text{Value of COVID}-19\text{ infected cases in the Governorate}}{\text{Population of the Governorate}}\right)}{\left(\frac{\text{Value of COVID}-19\text{ infected cases in the total country}}{\text{Population of the total country}}\right)} \quad (1)$$

A value of LQ>1 indicates a high prevalence of coronavirus in the area, while LQ<1 and LQ=1 indicate low and stable prevalence, respectively.

The analysis of spatial correlation using (Moran's I) coefficient

Moran's coefficient is considered one of the important scales in the geographical information system. It is used to investigate the degree of correlation between the elements of the investigated phenomenon and evaluate the pattern of their spatial distribution, either as regular, irregular, or arbitrary (Getis& Ord., 1992). Furthermore, it is used to determine similar values and collections for the geographical phenomenon by comparing the value of parameter pairs with the average value in the area. This method demonstrates the difference of values from the overall average and shows the local variation for the nature of the spatial distribution. Moran's I coefficient is calculated using the following equation:

$$I = \frac{N\sum_i \sum_j w_{i,j}(x_i-\bar{x})(x_j-\bar{x})}{(\sum_i \sum_j w_{i,j})\sum_j (x_i-\bar{x})(x_j-\bar{x})^2} \quad (2)$$

Where, I : Moran's coefficient, N: number of corona cases, XiXi: the value of the variable in site i, XjXj: the value of the variable in site j, $\bar{X}$: the variable average, Wij: the weighing values of the parameters i and j.

Moran's coefficient value ranges between (1 and – 1), where the positive value indicates an inclination towards gathering, the negative value shows an inclination towards distraction, and zero shows arbitrariness or lack of spatial correlation. The values (Z-score) and (P-value) are used to reject or accept the null hypothesis, which states that the pattern of the values' distribution is an arbitrary one. Therefore, the pattern would be gathered when (Z-score) ranged between (1.96 – 2.58) and the confidence level is between (0.01 –0.05), which means the similarity of adjacent values is either high or low. However, the pattern would be distracted when (Z-score) ranged between (-1.96) and (-2.58), indicating that the high values are by the low values and vice versa. Meanwhile, the values that range between (1.65) and (-1.65) indicate that the pattern is arbitrary (Ord and Getis, 1995).

Analyzing the hot and cold spots using the Getis-OrdGi* test

This test is used to measure the gathering of high (hot spots) or low values (cold spots) to create new maps. The values of (Z-score) and (P-value) in this analysis are considered determinants upon which the null hypothesis is accepted or rejected. Therefore, a high and positive (Z-score) and the low (P-value) indicate the spatial gathering of high values (hot spots). Meanwhile, the low negative (Z-score) and low (P-value) indicate the spatial gathering of low values (cold spots), and the value of (Z-score) that approaches zero indicates the lack of spatial gathering. Gi Bin determines the statistical importance, where the values 3,-3 reflect a confidence level of 99%, 2,-2 reflect 95%, and 1,-1 reflect 90% (Getis& Ord., 1992), while the zero level does not reflect a statistical significance, as illustrated in Table 3.

The mechanism through which this tool operates is represented by measuring the statistical value of each parameter, comparing the other adjacent parameters and also comparing that with the sum of statistical values for all the elements. The existence of variation between the total values of parameters and the adjacent value as compared to the total sum of values entails considering the value as statistically significant. Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted, where (Gi*) is calculated according to the following formula:

$$Gi* = \frac{\sum_{i=1}^{n} w_{i,j}\, x_j - \bar{x}\sum_{i=1}^{n} w_{i,j}}{s\sqrt{\frac{\left[n\sum_{i=1}^{n} w_{i,j}^2 - (\sum_{i=1}^{n} w_{i,j})^2\right]}{n-1}}} \quad (3)$$

Where, x_j is the value of the parameter j, $w_{i,j}$: is the weight value between i and j, n: The sum of apparent elements, S: Distance

Table 3. The uncorrected critical p-values and z-scores for different confidence levels.

Gi_Bin	(Z-score)	(P-value)	Confidence
3	2.58+>	0.01 >	99%
2	1.96+>	0.05 >	95%
1	1.65+>	0.10 >	90%
0	0	0	no significant
-1	1.65-<	0.10 >	90%
-2	1.96-<	0.05 >	95%
-3	2.58-<	0.01 >	99%

3. Results and Discussions

The spatial analysis of corona pandemic

During the latest period, a rapid increase and a considerable prevalence in the number of cases infected with the virus were noticed in Jordan, especially with the advent of the new series of the virus. The spatial analysis showed various spatial and temporal patterns for the infected cases at the level of governorates. The results found that the most exposed regions for the infection were those with high population density. For example, during all the study periods, the capital city of Amman was ranked first in the number of infections, and the highest number was registered in March (P6) with a total of (108.611) cases, followed by Irbid and Zarqa in the second and third, respectively. This is attributed to the high population density and the constant flow of passengers from other regions as well as the concentration of industrial and commercial services and businesses in these areas. In addition, the marginal and distant regions were the least in terms of infection rates. This is due to the low population density and concentration of industrial and commercial businesses. For example, the governorates of Ma'an and Tafila had the lowest rates of infection over all the study periods. As for the other seven governorates, the numbers of infections varied from time to time. Fig 3 shows the geographical distribution of coronavirus cases in the Jordanian governorates from the beginning of October 2020 until the end of March 2021.

The analysis of the data also revealed that the peak of corona cases in Jordan was during October (P6), which reached about (223.115). This is consistent with the other results which proved the increase of infected cases during March at the world level (Mollalo, et al, 2020; Murugesan, et al 2020). It was also shown that the number of infected cases is related to the climate, such as the case in Amman and Irbid, which are characterized by low temperatures and high humidity during winter and spring. This is also consistent with (Ma et al, 2020) which linked the prevalence of coronavirus with temperatures in China. It was also noticed that the total number of infections during the study periods (P1-P6) were 64072, 223115, 32944, 40243, 146690, and 75090, respectively. The infection rates are constantly increasing, especially during the latest period, which indicates the rapid prevalence of the virus. Fig 4 shows the differences in the total number of infections in the Jordanian governorates during six periods (P1-P6).

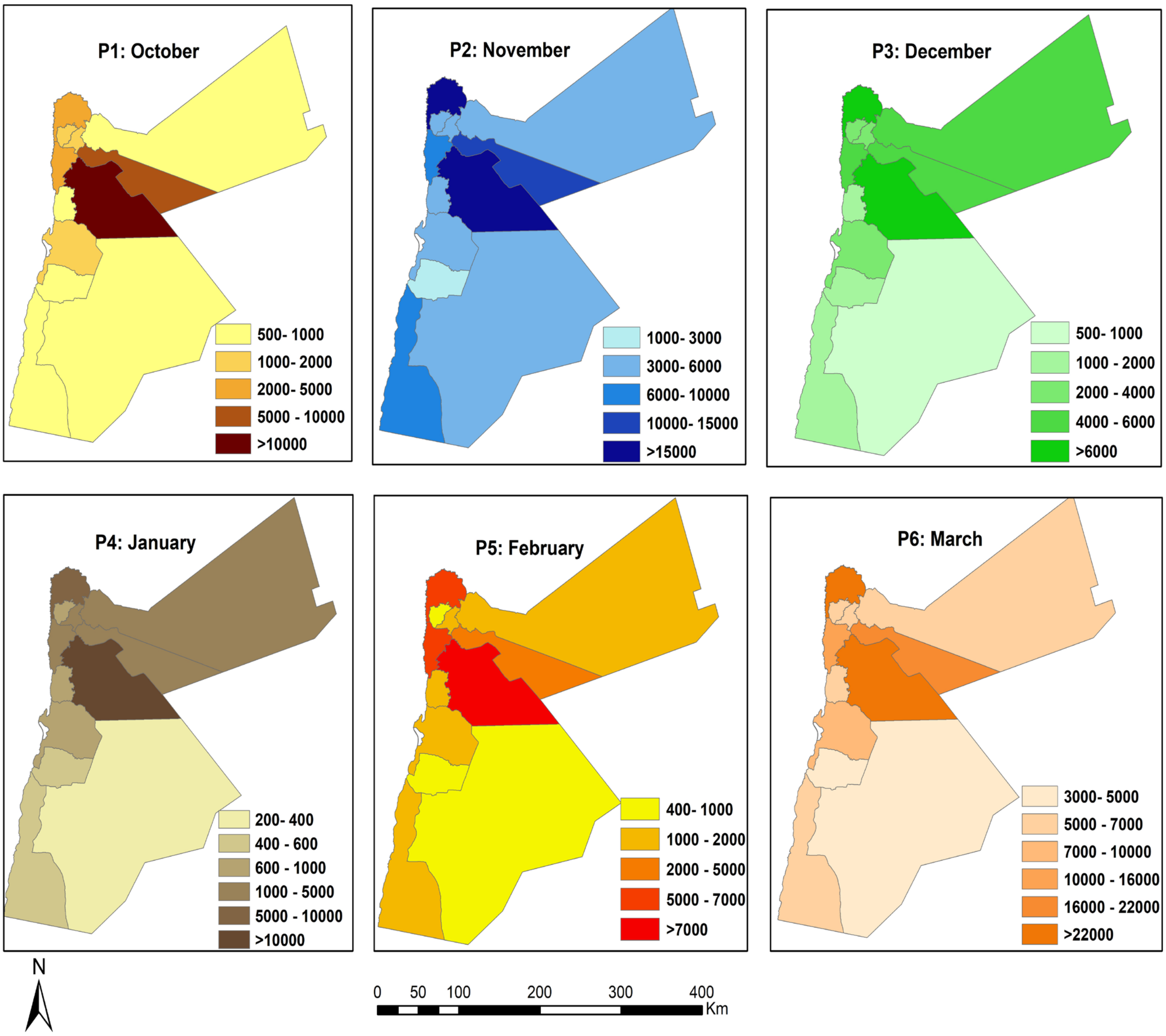

Figure 3. The geographical distribution of coronavirus cases in Jordan (October 2020 - March 2021). (Source: Prepared by the researcher using GIS)

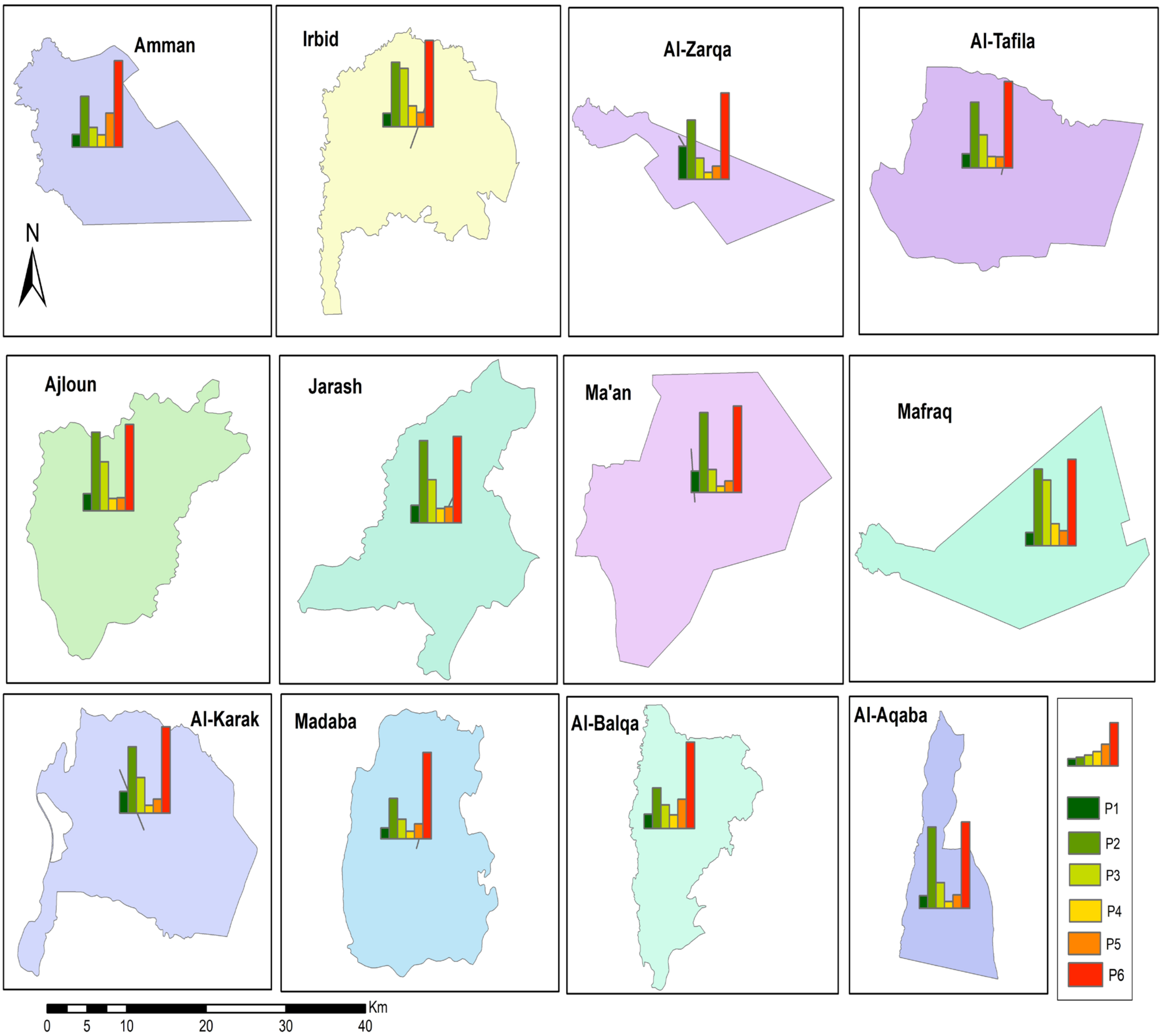

Figure 4. The difference in the number of corona cases in the Jordanian governorates during the six periods (P1-P6). (Source: Prepared by the researcher using GIS)

The analysis of location quotient (LQ)

This study addressed the relative concentration of corona pandemic in each governorate using the location quotient (LQ) analysis. The analysis illustrated in (Appendix 1) revealed that the governorates situated in the north and northwest of Jordan had a lower limit (LQ) value of more than (1), indicating the high prevalence of the pandemic. It was reported that Amman was ranked first place (1.66), followed by Balqa', Irbid, Madaba, Zarqa, Al-Karak, Ajloun, and finally Jerash, where the ratio of coronavirus focus was more than (1) (LQ>1). However, it was noticed that the focus ratio was low with less than (1) (LQ<1) in the south and northeast of Jordan, which includes Mafraq, Aqaba, Ma'an, and Tafila.

Spatial gathering and correlation of the corona pandemic

The index of auto-spatial correlation

The results of auto spatial correlation (Moran) for the Corona pandemic in Jordan from the beginning of October 2020 up to the end of March 2021 showed that all the values of the Moran index were negative and ranged between -0.0174 and -0.1358. This indicates that the general pattern for the direction of corona pandemic prevalence in Jordan is arbitrary, therefore, the null hypothesis may be accepted, since the values of the Moran index approach Zero as illustrated in Table 4. It was also noticed that the value of the Z-score differed for all the periods, however, they were not statistically significant, since they were within the critical value of -2.58 and +2.58. In addition, P-value was not statistically significant, since it was more than the adopted value of 0.05, which indicates that the value of the Moran rate concerning the total cases of coronavirus over the six months had a negative value of -0.104471. This implies that the pattern is an arbitrary one, as shown in Fig 5. The variation in the size of the Jordanian governorates in terms of the number of people as well as the fluctuation of the prevalence of corona pandemic in these governorates reflected a case of diversion between the high and

Table 4. The results of the Moran analysis during the last six months

Month	Moran's	Variance	Z-value	P-value
10	-0.0174	0.0191	0.53	0.594494
11	-0.1052	0.0159	-0.11	0.909493
12	-0.1358	0.0218	-0.30	0.761107
1	-0.1357	0.0179	-0.34	0.737574
2	-0.1149	0.0132	-0.21	0.834343
3	-0.0972	0.0149	-0.05	0.959236

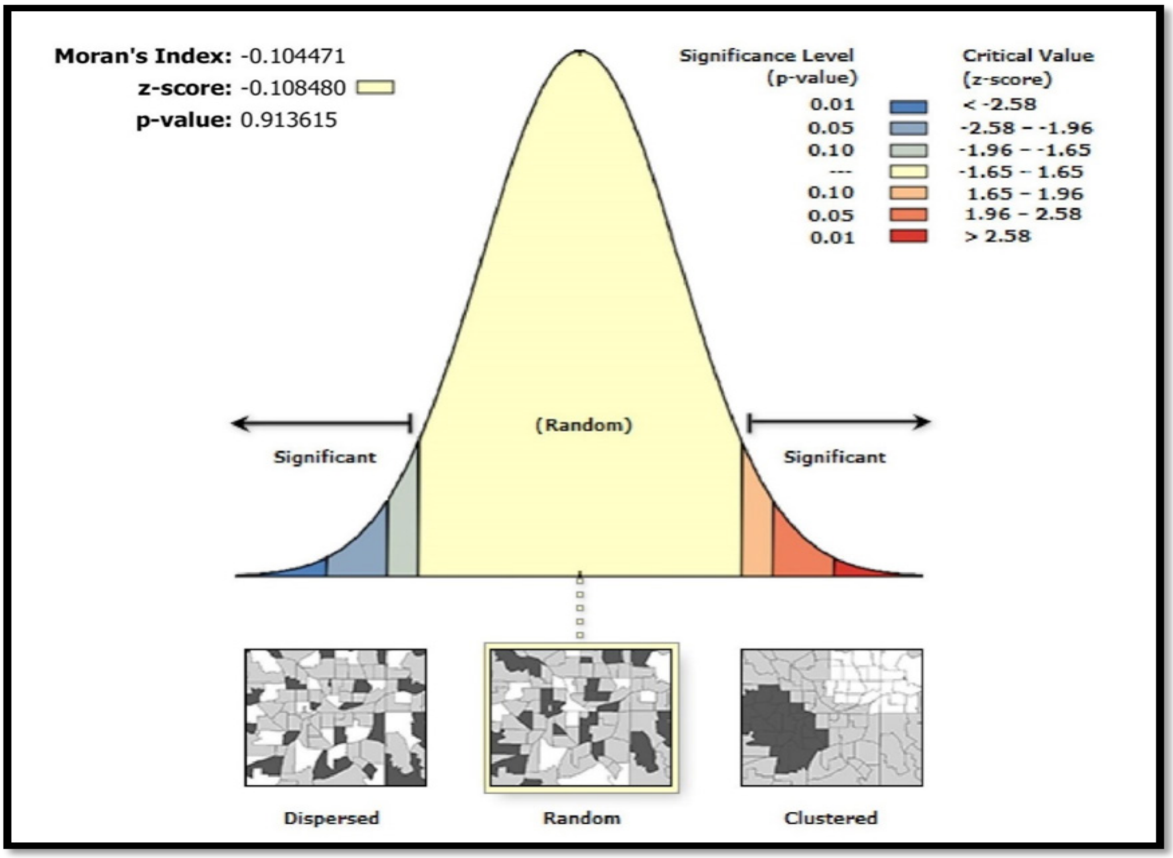

Figure 5. The values of the Moran index for the total cases of coronavirus in the Jordanian governorates at the end of March. (Source: Prepared by the researcher using GIS)

low values of corona cases. This indicates arbitrariness in their distribution, which, in turn, reflects the absence of planning and managerial sense as well as a lack of responsibility-taking in dealing with the pandemic.

Investigating the hot spatial points

The method of analyzing the gathered data of a certain phenomenon is considered a good way for investigating the values related to the elements. This is viewed as one of the most important objectives of spatial analysis, where it takes into consideration the proximity of phenomena and the proximity of the values of these characteristics in order to determine the estimations of similar values (Ordand Getis, 1995). The approximate and different site values of the phenomenon in the study area are demonstrated and represented on the map. Therefore, the hot and cold spots for the values of the investigated phenomenon can be determined. The getis-Ord GI* test was used to analyze and determine the hot and cold spots of corona cases in order to shed light on another aspect relating to the nature of corona distribution in Jordan. The results showed some Jordanian governorates had higher prevalence rates of corona pandemic than others during the study period as illustrated in Fig 6. For example, Amman had the highest rates of coronavirus prevalence during the study period that extended over six weeks with a statistical confidence level of 95%, followed by Irbid, which registered high rates during November, December, January and March at 90%. Furthermore, the governorate of Zarqa had a high statistical confidence percentage of 90% at the end of October, while Balqa' was also added as a high-risk area at the end of February with a statistical confidence of 90%. This case demonstrates the correlation between the prevalence of a coronavirus pandemic and large population size or density. This can be attributed to the high degree of overcrowdedness, the active service, commercial, and economic activities as well as the lack of commitment to the conditions of general health. The other governorates didn't represent concentration areas of the pandemic, therefore, they were considered cold spots.

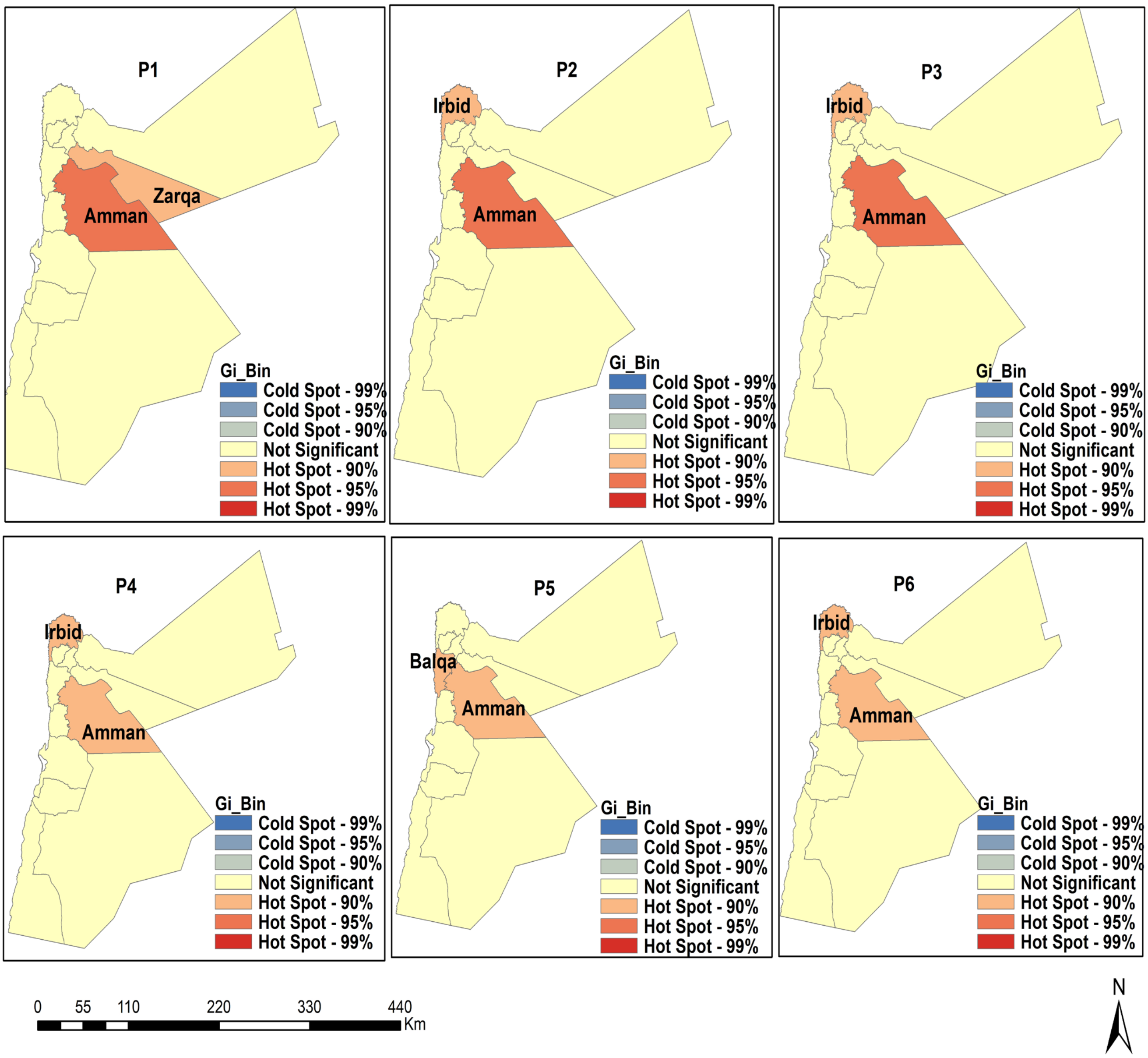

Figure 6. The results of applying Geris-OrdGi* for the number of coronavirus cases in the Jordanian governorates. (Source: Prepared by the researcher using GIS)

After applying Getis-OrdGi* to the total number of coronavirus cases in the Jordanian governorates starting from 1 October 2020 to 31 March 2021, the results were cited as illustrated in Table 5 and Fig 7 and stated that:

1. The high values (hot spots) of coronavirus cases were recorded in Amman, where the Z-score ranged between 1.44 – 2.53 at a statistical significance of 0.01% and reflected a confidence level of 95%. High values were also reported in Irbid, Zarqa, and Balqa', where they were gathered at the significance level of 0.05 which reflects a confidence level of 90%. These results showed the governorates are the central ones, as they have more focused services and work opportunities that attract more residents from the other governorates.
2. The approach of Z-score to the value of zero in most governorates showed no spatial gathering of values. This means there was an arbitrary distribution of low and high values related to coronavirus cases.
3. The lack of gathering for the low values (cold spots) in coronavirus cases at the level of the Jordanian governorates indicates a variation in the prevalence of the pandemic and a difference in the rates of infection.

Table 5. The results of applying (G*) to the total number of coronavirus cases in Jordan

(Gi Bin)	z-score	p-value	Confidence
2	(1.44 – 2.53)	0.01	95%
1	(1.72 – 1.94)	0.05	90%
0	Close to zero	More than 0.01	Not significant

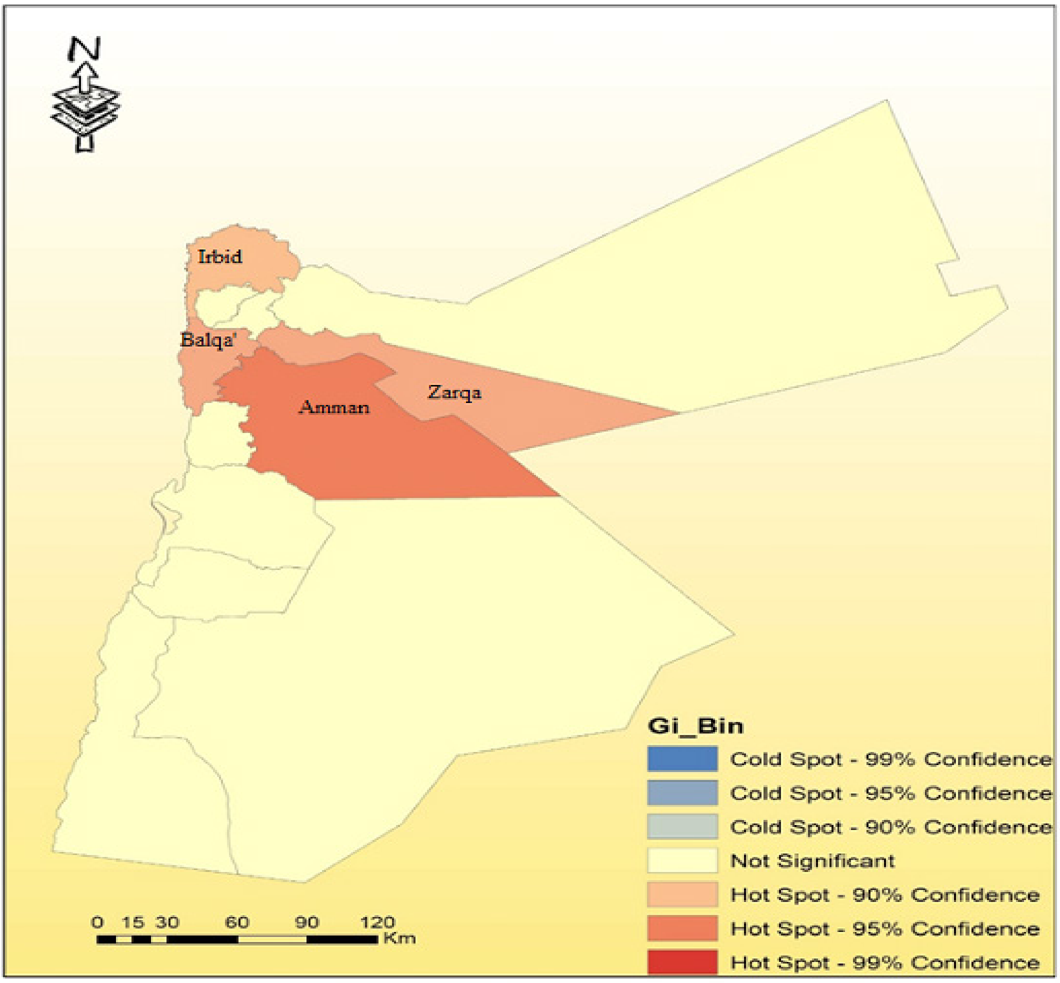

Figure 7. The results of applying Getis-OrdGi* to the total coronavirus cases in the Jordanian governorates on 31 March, 2021. (Source: Prepared by the researcher using GIS)

4. CONCLUSION

This study systematically addressed the temporal and spatial variation of the corona pandemic in Jordan using geographical information systems. The total number of coronavirus cases in October and November was 186.933), where the highest was registered in Amman with 79.754, and the lowest in Tafila with 3.236. Furthermore, Amman had the highest number of cases with 39.921, while Ma'an had the lowest with 1.152 from a total of 108.034 registered in December and January. In February, the total cases reached 64.072, where Amman registered the highest number with 42.842 and Tafila had the lowest with 443. A considerable increase in the corona cases was noticed in March with a total of 223.115, where Amman had the highest number with 108.611, and Ma'an registered the lowest with 3410.

Furthermore, the results showed the total number of coronavirus cases distributed across all the governorates in Jordan during the six months was 582.127. The highest number was reported in Amman, followed by Irbid, Zarqa, and Balqa' in the second, third, and fourth ranks, respectively. However, it was noticed that some governorates were characterized by a low number, especially Tafila and Ma'an which had the lowest during all the study periods, since they are distant and have low population density.

The results of location quotient (LQ) analysis revealed that most governorates were characterized by a high concentration of corona virus, especially in Amman, Irbid, Zarqa, Balqa', Madaba, Jerash, Karak and Ajloun, while Tafila, Ma'an, Aqaba, and Mafraq were characterized by low concentration. Also, the Moran index showed the general pattern for the prevalence of the pandemic in the study area was arbitrary due to the variation in the size and density of the population, and that corona was a global pandemic that rapidly affected all the regions. In addition, testing the analysis of cold and hot spots (G*) showed there were hot spatial areas that demonstrated a high probability of infection. These areas were characterized by a widespread of corona, particularly in Amman, Irbid, and Zarqa, which may be due to being a historical and busy trade centers.

One probable reason for the continuous increase in COVID-19 infections and the vicissitudes as well as the shifts between Governorates stated in this study is the imperfection of the control strategies currently being practiced for restricting the spread of the virus. Another potential reason could be that COVID-19 community transmission in certain regions may have been overlooked or not classified as risk areas. Nevertheless, the current data and the limited study period may not be enough to discover the valid reasons for the high concentrations of COVID-19 infections.

Geographical information systems and modern techniques are regarded as important tools used in studying disasters. This is due to the ability to create databases and provide the required analysis for temporal and spatial data as well as an analysis for the patterns of the spatial distribution of the phenomena relevant to corona pandemic. This provides scientific perspectives on the way of understanding the complex international or societal issues and dealing with them using the various tools given by geographical information systems. These applications require promoting the institutional abilities to take advantage of the techniques relating to geographical information systems in the various studies that enables communities to face this pandemic. Finally, future technological innovations should focus on the lessons learned from this pandemic in order to easily provide techniques to conduct research, cite plans or strategies, and make decisions at the international level. The decision-makers can utilize Esri's geographic information system technology to visualize the spread of the diseases. Furthermore, they can map disease response centers, the availability of medical supplies or preventative resources, such as testing locations and isolation areas. The results obtained could offer valuable information or statistics to support government monitoring and effective policy-making of associated agencies in medical, social, economic, and environmental aspects.

References

Ahmadi, M., Sharifi, A., Dorosti, S., Jafarzadeh, S., andGhanbari, N. (2020). Investigation of effective climatology parameters on COVID-19 outbreak in Iran. *Science of the total environment*. 729: 138705.https://doi.org/10.1016/j.scitotenv. 2020.138705.

Al-ahmadi, A. (2021). The impact of the Corona pandemic on the temporal and spatial characteristics of traffic accidents in the Kingdom of Saudi Arabia (2019-2020) (The city of Medina as a model). *The Arab Journal of Geographical Studies*, 4(8), 1-36.

Alves, J., Abade, A., Peres, W., Borges, J., Santos, S. andScholze, A. (2021). Impact of COVID-19 on the indigenous population of Brazil: A geo-epidemiological study. *Epidemiology & Infection new*, 149(e185), 1-11, https://doi.org/10.1017/S095026 8821001849.

Chen, Z.L., Zhang, Q., Lu, Y., Guo, Z.M., Zhang, X., Zhang, W.J. Guo, C., Liao, C.H., Li, Q.L., Han, X.H., andLu, J.H. (2020). Distribution of the COVID-19 epidemic and correlation with population emigration from Wuhan, China. *Chinese Medical Journal*. 133(9), 1044-1050. https://doi.org/10.1097/ CM9.0000000000000782.

Comber, A.J., Brunsdon, C.H., andRadburn, R. (2011). A spatial analysis of variations in health access: linking geography, socio-economic status and access perceptions. *International Journal of Health Geographics*, 10(44), 1-11, doi:10.1186/1476-072X-10-44.

Department of Statistics, (2021). Published data, estimated population numbers for the Kingdom by governorate, community, gender and families for the year 2020.

Dickson, M.M., Espa, G., Giuliani, D., Santi, F., andSavadori, L. (2020). Assessing the effect of containment measures on the spatiotemporal dynamic of COVID-19 in Italy. *Nonlinear Dynamics 101*, 1833–1864. https://doi.org/10.1007/s11071-020-05853-7.

Elzeeny, S. (2020). Temporal and Spatial Analysis of the sequence of coronavirus infection cases in the world: A study in medical geography, *The Egyptian journal of Environmental change*, 12(4), 31-44. 10.21608/EGJEC.2020.120041.

Garchitorena, A., Sokolow, S.H., Roche, B., Ngonghala, C.N., Jocque, M., Lund, A., Barry, M., Mordecai, E.A., Daily, G.C., Jones, J.H., Andrews, J.R., Bendavid, E., Luby, S.P., LaBeaud, A.D., Seetah, K., Guégan, J.F., Bonds, M.H., andDe Leo, G.A. (2017). Disease ecology, health and the environment: a framework to account for ecological and socio-economic drivers in the control of neglected tropical diseases. *Philos Trans R SocLondSer B BiolSci*, 372(1722). https://doi.org/10.1098/rstb.2016.0128.

Getis, A., andOrd, J.K. (1992). The Analysis of Spatial Association by Use of Distance Statistics." Geographical Analysis, 24(3), 189-206. http://dx.doi.org/10.1111/j.1538-4632.1992.tb00261.x.

Ord, J.K.andGetis, A. (1995). Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. Geographical Analysis, 27(4), 286-306. https://doi.org/10.1111/j.1538-4632.1995.tb00912.x

Ghosh, P., andCartone, A. (2020). A Spatio-temporal analysis of COVID-19 outbreak in Italy. *Regional Science Policy & Practice*, 12(6), 1047-1062. doi.org/10.1111/rsp3. 12376.

Kandwal, R., Garg, P., andGarg, R.D. (2009). Health GIS and HIV/AIDS studies: Perapective and retrospective. *Journal of biomedical information*. 42(4), 748-755. https://doi.org/10.1016/j.jbi.2009.04.008.

Kelvin, D. J., andRubino, S. (2020). Fear of the novel coronavirus. The Journal of Infection in Developing Countries (JIDC). 14(1), 1-2. doi: 10.3855/jidc.12496.

Liu, Z., Bing, X., andZhi, X.Z. (2020). The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China. *Chinese Center for Disease Control and Prevention*, 41(2), 145–151. https://doi.org/10.3760/cma.j.issn.0254-6450.2020.02.003.

Lyseen, A.K., Nohr, C., Sorensen, E.M., Gudes, O., Geraghty, E.M., Shaw, N.T., andBivona-Tellez, C. (2014). A review and framework for categorizing current research and development in health related Geographical Information Systems (GIS) studies. *Yearb Med Inform*, 23(1), 110–124.https://doi.org/10.15265/IY-2014-0008.

Ma, Y., Zhao, Y., Liu, J., He, X., Wang, B., Fu, S., Yan, J., Niu, J., Zhou, J., andLuo, B. (2020). Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China. *Science of the Total Environment*, 724:138226.https://doi.org/10.1016/j.scitotenv.2020.138226.

Mackey, T.K., Liang, B.A., Cuomo, R., Hafen, R., Brouwer, K.C., andLee, D.E. (2014). Emerging and reemerging neglected tropical diseases: a review of key characteristics, risk factors, and the policy and innovation environment. *Clinical Microbiology Rev*, 27(4), 949–979. https://doi.org/10.1128/CMR.00045 -14.

Mollalo, A., Vahedi, B., andRivera, K.M. (2020). GIS-based spatial modeling of COVID-19 incidence rate in the continental United States. *Sci Total Environ*, 728:138884, 1-8. DOI: 10.1016/j.scitotenv.2020.138884.

Murugesan, B., Karuppannan, S., Mengistie, A.T., Ranganathan, M., andGopalakrishnan, G. (2020). Distribution and trend analysis of COVID-19 in India: geospatial approach. *Journal of Geographical Studies*, 4(1-2), 1–9.https://doi.org/10.21523/gcj5.20040101.

Ramírez-Aldana R., Gomez-Verjan, J.C., andBello-Chavolla, O.Y. (2020). Spatial analysis of COVID-19 spread in Iran: Insights into geographical and structural transmission determinants at a province level. *PLoSNegl Trop Dis*, 14(11): e0008875. https://doi.org/10.1371/journal.pntd.0008875.

Sanson, R.L., Liberona, H., andMorris, R.S. (1991). The use of a geographical information system in the management of a foot-andmouth disease epidemic. *Preventive Veterinary Medicine*, 11, 309-313. doi:10.1016/S0167-5877(05)80017-0.

Sithiprasasna, R., Patpoparn, S., Attatippaholkun, W., Suvannadabba, S., andSrisuphanunt, M. (2004). The geographic information system as an epidemiological tool in the surveillance of dengue virus-infected Aedes mosquitos. *Southeast Asian J Tropical Med Public Health*, 35(4), 918–926.

Wagner, D.M., Klunk, J., Harbeck, M., Devault, A., Waglechner, N., Sahl, J.W., Enk, J., Birdsell, D.N., Kuch, M., Lumibao, C., Poinar, D., Pearson, T., Fourment, M., Golding, B., Riehm, J.M., Earn, D.J.D., DeWitte, S., Rouillard, J.M., Grupe, G., Wiechmann, I., Bliska, J.B., Keim, P.S., Scholz, H.C., Holmes, E.C., andPoinar, H. (2014). Yersinia pestis and the plague of Justinian 541-543 AD: a genomic analysis. *The Lancet Infect Dis*, 14(4), 319–326. https://doi.org/10.1016/S1473-3099(13)70323-2.

World Health Organization (WHO). (2021). Coronavirus disease (COVID-19) situation reports. Accessed 31 March 2021. https://www.who.int/ar/emergencies/diseases/ novel-coronavirus-2019.

Xu, N., Cheng, Y., andXu, X. (2018). Using Location Quotients to Determine Public–Natural Space Spatial Patterns: A Zurich Model. *Sustainability*, *10*(10), 3462. https://doi.org/10.3390/su10103462.

Yahya, M., Safian, E., andBurhan, B. (2020). The Trend Distribution and Temporal Pattern Analysis of COVID-19 Pandemic using GIS framework in Malaysia, AIJR Preprints, version 1, 1-14, https://preprints.aijr.org/index.php/ap/preprint/view/174.

Ye., L., andHu, L. (2020). Spatiotemporal distribution and trend of COVID-19 in the Yangtze River Delta region of the People's Republic of China. *Geospatial Health*, 15(1), 25-32. doi:10.4081/gh.2020.889.

Appendices

Appendix 1. Changes in location quotient (LQ) for the total number of coronavirus cases in the Jordanian governorates

Number	Governorate	Number of population	Number of infected cases	LQ
1	Amman	4536500	271128	1.66
2	Irbid	2003800	92125	1.25
3	Zarqa	1545100	55626	1.17
4	Balqa'	556600	38207	1.27
5	Madaba	214100	14432	1.25
6	Mafraq	622500	20915	0.62
7	Karak	358400	20490	1.06
8	Ajloun	199400	15675	1.05
9	Jerash	268300	18256	1.06
10	Tafila	109000	8995	0.53
11	Aqaba	213000	17261	0.92
12	Ma'an	179300	9017	0.93
Total		10806000	582127	