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SPATIOTEMPORAL ANALYSIS FOR FIGHTING COVID-19 IN IRAQ

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Abstract. At the end of 2019, a new form of Coronavirus (later dubbed COVID-19) emerged in China and quickly spread to other regions of the globe. Despite the virus's unique and unknown characteristics, it is a widely distributed infectious illness. Finding the geographical distribution of the virus transmission is therefore critical for epidemiologists and governments in order to respond to the illness epidemic rapidly and effectively. Understanding the dynamics of COVID-19's spatial distribution can help to understand the pandemic's scope and effects, as well as decision-making, planning, and community action aimed at preventing transmission. The main focus of this study is to investigate the geographic patterns of COVID-19 dissemination in Iraq from May 1 to July 29, 2021. The analysis was primarily based on using spatial analysis tools such as standard deviational ellipse (SDE) with in GIS environment, in addition to incidence rates calculations. The results revealed that the direction of COVID-19 spread is NW-SE. Furthermore, the findings showed that the rate of COVID-19 infections is greater at the middle and south of Iraq. This may aid decision-makers in identifying priority areas for emergency efforts.

Keywords: COVID-19, spatial distribution, GIS, spatial analysis, standard deviational ellipse, Iraq.

Introduction

For centuries, many diseases have had different effects on different facets of human well-being and have transformed the styles of cultural, financial, technological, environmental and human activity on a global and local scale. For instance, HIV/AIDS (at its peak, 2005–2012) have killed 36 million people worldwide (Hazbavi et al., 2021). Recently, the World Health Organization (WHO) obtained reports about an infection of an unknown cause from Wuhan, Hubei, China, on December 31, 2019. This virus was formally called COVID-19 on February 11, 2020, and was recognized as an infectious disease causing a public health emergency because it rapidly spread across China and to another 24 nations which are located geographically between 42.937084° N and 75.6107° E. According to COVID-19 clinical trials, the majority of patients experience respiratory difficulties and pneumonia. COVID-19 causes kidney failure, pneumonia, and even death, with symptoms similar to other coronavirus diseases such as MERS and SARS, such as cough, diarrhea, and trouble breathing due to respiratory disease. In the worst-case situation, COVID-19 causes pneumonia, kidney failure, and even death (Bashir et al., 2020).

In Iraq, the first verified case of COVID-19 was reported in Najaf governorate on 24 February 2020 for an Iranian student who had travelled from Iran, followed by four instances from one family in Kirkuk region on 25 February, all of whom had been to Iran. On February 27, a further case was reported in Baghdad for a patient who had just visited Iran (Sarhan et al., 2020). Later, the infection accelerated its spread in all governates of Iraq. Iraq's health sector looks to be among the least equipped to deal with a pandemic that is testing the world's wealthy countries' considerably more strong health-care systems. In addition to health challenges, Iraq faced the economic battle. The COVID-19 pandemic is spreading in Iraq at a difficult time. Iraq's economy is slowly recovering, following last years' decline due to the fight against ISIS. GDP grew to 4.4% in 2019 because the healthier oil production, coupled with ongoing reconstruction efforts, and improving security conditions (World Bank, 2017). In general, the world faces great challenges in responding to the COVID-19 infection. Iraq is a part of the world that is facing an outstanding test of its leadership in responding to saving the economy and protecting the lives of its people.

The survey and rendering of intangible phenomena are made possible by graphic representation. As a

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result, computer graphics and technologically advanced photography are now playing an increasingly important role in all fields that are focused on the study of events that exist in the domain and on which decision-making is based. Consequently, graphic science skills, methods, and technologies are rapidly being requested to contribute to interdisciplinary study. Health data visualisation can be a valuable tool for revealing new insights into disease spread patterns, especially in the analysis of risk factors for diseases classified as "environmental" since a significant portion of their spread can be traced to environmental factors, resulting in distribution patterns that are closely linked to the spatially centralized environment in which they are exposed. Simultaneous visualisation of health and environmental data from various sources may help researchers better interpret environmental-health relationships and create new ideas for future study. In both human and veterinary public health, diseases mapping and environmental risk assessment using digital geospatial data resources have become validated analytical tools (Cicalò & Valentino, 2019).

Indeed, health experts have long regarded traditional mapping, as well as more recently geographic information systems (GIS), as important instruments for monitoring and fighting disease. In 1694, on the topic of plague containment in Italy, the first map visualisation of the relation between place and health was made. For the next 225 years, the importance of maps as a communication method grew in the interest of recognising and monitoring infectious diseases like cholera, yellow fever, and the 1918 influenza pandemic. The possibilities for analysing, visualising, and identifying disease patterns significantly improved again in the 1960s, when automated geographic information systems were born (Kamel Boulos & Geraghty, 2020). GIS and spatial visualisation, in particular, may be critical methods for disease understanding, detection, and care. GIS technology, for example, can be used as a mapping tool to chart the disease's spatial spread, possible risk factors, and care and preventive resources. It is possible to assess disease risks, patterns in outbreaks over time and space, and infection hotspots using spatial analysis of such data. Such approaches, which are similar to one another, may contribute to the design, preparation, and delivery of international health services for care and preventive facilities, and they may help reduce the effect of intervention (Murugesan et al., 2020).

This study investigates the spatial distribution pattern of COVID-19 in Iraqi governorates. It is based on spatial analysis process using GIS tools for daily confirmed cases (from May to July 2021). The findings might help policymakers better understand the dynamics and mechanisms that regulate the spread of COVID-19 in both location and time. This allows them to take more suitable steps and tactics to stop the pandemic from spreading in Iraq.

1. Related researches

In the wider literature, a substantial number of researchers have used geospatial analysis methods to study the dissemination of COVID-19 infection. For instance, Lima et al. (2021) used readily available information from the Brazilian Ministry of Health to quantify COVID-19 infection and death rates in small communities, taking into account the population's average age and gender distribution, as well as the extent of economic inequality throughout regions. In order to understand the potential association between cases and deaths from COVID-19, the number of intensive care units (ICUs) and doctors present in each city were accounted. To investigate the spatial pattern of infections and mortality, a Bayesian formulation of a spatial autoregressive model (SAM) has been used, which is useful for smoothing and stabilizing spatial estimates. The findings show that mortality and infection are geographically dispersed, producing clusters and hotspots, particularly in the Northern Amazon, the North-east coast, and the South-east of the country.

Sarwar et al. (2020) focused on analyzing the COVID-19 pattern including the use of spatial temporal model in the case of Pakistan. The paper outlined GIS methods for identifying and defining the area of inquiry, which necessitates taking into account the strengths and shortcomings of data collection instruments, the ease of collecting locational data, the precision of locational data, and relevant attributes for determining risk of disease. The paper addressed a few problems as well as possible responses; however, Pakistan will need to operate on a number of fronts: first, improving GIS capability by using GIS techniques to combat the pandemic. Second, confirm the presence of an outbreak by identifying and counting cases. Third, perform practical multi-scale dynamic mapping for epidemics. The outcomes indicated that the GIS approaches can be used to track down and treat patients in a timely manner, as well as to take preventative measures in that area to prevent the spread of COVID-19.

Silalahi et al. (2020) utilized geospatial modeling to assess demand in relation to Referral Hospital capability and to model the COVID-19 spreading situation in Jakarta, Indonesia. They performed this research in order to promote and coordinate an efficient medical system. As trusted available sources, data from local government publicity for COVID-19 were used. They measured the geographical trend of case spread using verifiable data from the local authority and observed information to determine the growing cases. In order to assess the geographic distribution of COVID-19, a service area and Origin-Destination (OD) Cost Matrix were established in collaboration of an existing referral hospital, as well as a Standard Deviational Ellipse (SDE) model. According to the findings, more than 12.4 million residents (86.7 percent) reside in the referral hospital's well-served region based on distance. The outcomes indicated that there is a need for more referral hospitals specialized in COVID-19 care, as well as a geographical analysis map of

COVID-19 case development to aid in the introduction of social distancing in Jakarta.

Kang et al. (2020) identified the spatio-temporal trend and calculated the spatial correlation of the initial stages of the COVID-19 infection in mainland China. A test was conducted to see whether there was a spatial correlation of COVID-19 infections using Moran's I spatial statistic with different meanings of neighbors. The COVID-19 pandemic's spatial distribution in China was reported. The findings revealed that, with the exception of medical-care-based interaction models, most of the models suggested a strong spatial correlation of COVID-19 infections starting about January 22, 2020. It was concluded that the understanding the dissemination of infectious diseases requires spatial interpretation, and spatial correlation was essential to the spatial spread of the COVID-19 pandemic in mainland China during its early stages.

Rezaei et al. (2020) discussed the monitoring of the COVID-19 outbreak in South Korea using GIS techniques. They stated that South Korea is now the perfect example of how to use GIS as a system to control a COVID-19 epidemic. The system, which was developed and constructed by students at Kyunghee University in Seoul, has been used by South Korean authorities since the outbreak of COVID-19 began in the region. They created a special, accurate, and quick tracking framework using GIS software and mapping systems in order to recognize, locate, and track infected patients, as well as the locations that each identified patient had been before being detected, among other controlling techniques. This mapping system also shows the number and location of reported cases, as well as the number of deaths and rescued patients in each affected area. It also contains details about the medical services that are open such as the drugstores to find mask and sanitizer and the screen clinics for test of COVID-19. This system has also provided a number of other benefits, such as allowing government to make decisions based on up-to-date and accurate information.

Al-Kindi et al. (2020) investigated the spatiotemporal trends of COVID-19 distributed using information from cases reported in Oman, which increased from 2274 to 40,070 from April to June, 2020. They also compared differences in the normal infection rate at the wilayat (discrit) level and quantified seasonal fluctuations in the rate of infection. Within the environment of a Geographical Information System (GIS), five geospatial approaches were used to make the assessment. They included standard deviational ellipses, a weighted mean centre (WMC), Getis-Ord General-G high/low clustering, Moran's I autocorrelation coefficient, and Getis-Ord G^*_i statistic. This analysis showed that the directional trend of COVID-19 instances has shifted from northeast to northwest and southwest.

Martellucci et al. (2020) used GIS to create epidemiological maps of risk factors for COVID-19 in Italy based on official population data. Monitoring cases reports officially registered by the Italian medical authorities have been used to calculate cumulative occurrence rates utilizing reference census data on SARS-CoV-2 recorded infections (cases/100,000 citizens) and to create maps by provinces and cities using GIS tools. The GIS-based maps showed that the COVID-19 has expanded widely across Italy from north to south over time, with some regions reporting more than 1,000 instances per 100,000 people.

2. The spreading of COVID-19 in Iraq

Iraq is at the top of the list of Arab world countries which was affected by the emerging of corona virus (COVID-19). The number of confirmed cases and death have been increased noticeably, as shown in Figures 1 and 2. In Iraq, from 3 January 2020 to 20 August 2021, there have been 1,809,376 confirmed cases of COVID-19 with 19,958 deaths, reported to World Health Organization (WHO) https://covid19.who.int/region/emro/country/iq. The high number of infections is probably because its large population (about 40 million people), Iraq is second, after Egypt as the largest Arab countries in terms of population. In addition, in Iraq, there is great societal mixing and communication, failure to observe safety and public health guidelines and procedures, and social distancing as it should, in light of the outbreak of the epidemic. Another major reason for increasing the number of infections is that the citizens' negligence in not taking the preventive measures imposed by the Ministry of Health. The Ministry of Health is unable to reduce the rates of infections unless citizens unite to adhere to preventive measures and support them to get rid of this epidemic.

As well as the factor of extensive religious tourism in Iraq, due to the large number of places, thresholds and religious shrines in the country, which are visited by visitors from different countries of the world. While, for example, in the Kingdom of Saudi Arabia, where the Two Holy Mosques are, a strict application of precautionary measures, especially at the level of Hajj and Umrah, and the establishment of strict controls that take into account health considerations, which subsequently contributed to the lack of a large outbreak of the epidemic as is the case in Iraq, where there are no significant controls, neither in terms of controlling religious tourism, nor in terms of various facilities and aspects of life.

A comprehensive analysis of the COVID19 crisis in Iraq conducted by technical teams from various United Nations agencies (including WHO and UNICEF) emphasized that Iraq needs to adjust its preparations, and COVID-19 response operations to curb the spread of the virus and reduce cases were reported daily and ending the epidemic in the community. This includes guidelines that health authorities have emphasized more than times and procedures that many people have already followed, such as wearing masks and keeping social distances. One of the most important measures to prevent the spread of the virus is not to hold mass gatherings (such as sporting and cultural events, weddings or funerals) at this critical stage. People avoid such events for their own health and their family members and safe community (OCHA, 2020).

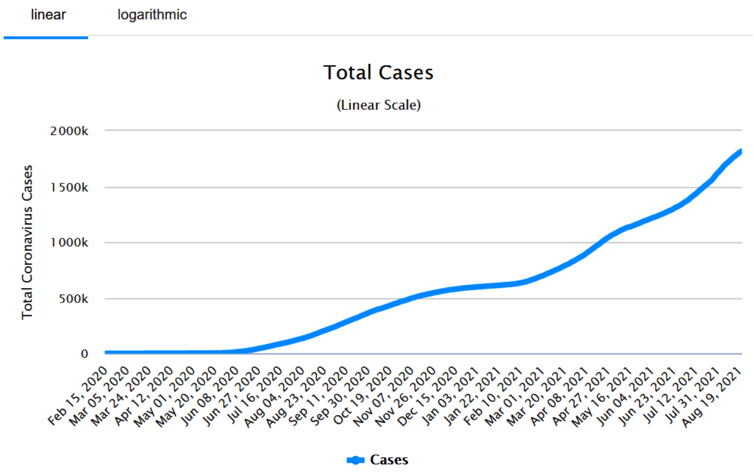

Figure 1. The total confirmed cases of COVID-19 in Iraq (Worldometer, 2021)

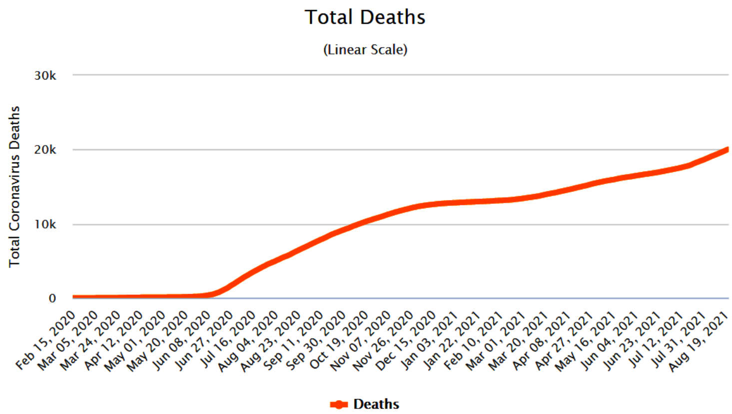

Figure 2. The total deaths of COVID-19 in Iraq (Worldometer, 2021)

3. The actions of Iraqi government against COVID-19

The current COVID-19 epidemic has put more challenges on Iraqi's health care system. Despite the limitations, the health authorities' quick and effective reaction to the epidemic, particularly during the first few months of its development in Iraq, was noteworthy. However, the situation has deteriorated in recent months as a result of a number of reasons, including the relaxation of limitations and the inability to adhere to or enforce the measures (OCHA, 2020). Therefore, the government of Iraq has worked to implement a (health emergency) that allows it to issue strict exceptional decisions and measures to limit the spread of the (Corona emerging virus), while taking some procedures that are necessary to protect human rights, including the right to life and health. For example, financial fines have been imposed for every person who does not wear a mask in public places, or in public or private transportation if it carries 4 people, with the need to open vehicle windows, and to prevent gatherings in public places (OHCHR, 2021).

In addition, imposing a curfew in order to preserve the safety of citizens from disease in line with the recommendations of the World Health Organization, that it does not include necessary products, foodstuffs, agricultural materials, movement of gasoline and derivatives tanks. The curfew also does not include pharmacies, health centers and public and private hospitals. The security agencies and service institutions that provide basic services to citizens, authorized media outlets, and diplomats do not involve as well. Further, financial fines have been imposed for every person who does not wear a mask in public places, or in public or private transportation if it carries 4 people, with the need to open vehicle windows, and to prevent gatherings in public places (OHCHR, 2021).

Another governmental step is the intensification of media channels' awareness campaign regarding the preventive measures that must be taken in schools, institutes and colleges, highlighting the commitment to the working days specified for each stage, which were approved by the Supreme Committee for National Health and Safety, and transferring accurate information from the authorized authorities and not adopting it from other parties.

The Iraqi government has also taken a number of actions regarding the Corona vaccine. The ministries of

Health and Foreign Affairs are negotiating with the countries that have announced the possibility of reaching a vaccine for Corona Virus, in order for Iraq to vaccine and medical supplies in a manner that ensures the reduction of the number of deaths according to the contexts approved by the Ministry of Health. Iraq announced the arrival of the first batch of Corona vaccines to the country on the second of March, 2021. It amounting to 50 thousand of the "Sinopharm" vaccine, a grant provided by Beijing. Iraq also received 336,000 doses of the "AstraZeneca" coronavirus vaccine on 25 of March, 2021. This is the first batch of vaccines to Iraq and there are other shipments that arrived in Iraq during the past months and will continue until covering 20% of the Iraqi population before the end of 2021.

The statistics of the Iraqi Ministry of Health showed that there was a weak demand for the vaccine at the beginning, but this demand quickly increased in recent months. For instance, the number of vaccinated people was 56,985 on March 31, 2021, while it became 2,558,730 on August 15, 2021 (https://moh.gov.iq/). It can be noticed that the number of vaccinated was increased about 45 times through three and half months. The increasing of vaccinated people rates, with adhering to preventive measures, may lead to a decrease in the rates of infection, as well as a decrease in mortality rates.

4. Materials and methods

4.1. Study area

The current study research was carried out for Iraq. The Republic of Iraq is located in the southwest of the continent of Asia and forms the northeastern part of the Arab world overlooking the Arabian Gulf. It is bordered by Turkey from the north, Iran from the east, Syria, Jordan and Saudi Arabia from the west, Kuwait and Saudi Arabia from the south. It extends between latitudes 29° and 37° north and between longitudes 38° and 48° east. Iraq officially consists of eighteen governorates, the capital of which is Baghdad (Figure 3 and Table 1). The total population of Iraq in the year 2019 is about 40 million, with a total area of 435052 km^2. Baghdad is the most densely populated Iraqi provinces, with a population of 8,340,711 people, followed by Nineveh governorate, which has a population of 3,828,197 people (Central Statistical Organization Iraq [CSO], 2021).

4.2. Data sources

The COVID-19 infection cases were studied from May to July, 2021 throught18 Iraqi governorates for spatial distribution. Due to the unreliable number of confirmed cases, the early months of the outbreak were not included in this analysis. The time period chosen coincided with a dramatic rise in the overall number of infected cases across the world. The data for COVID-19 cases at the governorate level was retrieved from the Iraqi Ministry of Health's official website (https://moh.gov.iq/). The archive includes case counts for Iraq at the governorate level, which are revised in tabular format on a daily basis. The population of each governorate is derived from the Central Statistical Organization of Iraq's most recent statistics (CSO, 2021). A base map (administrative map) has been imported from OpenStreetMap (OSM) project for spatial analysis process. It was downloaded from Geofabric's free download server. This server hosts data extracts from the OSM service, which are maintained on a daily basis (http://download.geofabrik.de/).

Table 1. The population of Iraqi governorates

Numbering the governorates as shown in Figure 1	Governorate Name	Population
1	Al-Anbar	1,818,318
2	Al-Qadisiyyah	1,325,031
3	Babil	2,119,403
4	Baghdad	8,340,711
5	Basra	2,985,073
6	Dhi Qar	2,150,338
7	Diyala	1,680,328
8	Duhok	1,326,562
9	Erbil	1,903,608
10	Karbala	1,250,806
11	Kirkuk	1,639,953
12	Maysan	1,141,966
13	Muthanna	835,797
14	Najaf	1,510,338
15	Nineveh	3,828,197
16	Saladin	1,637,232
17	Sulaymaniyah	2,219,194
18	Wasit	1,415,034

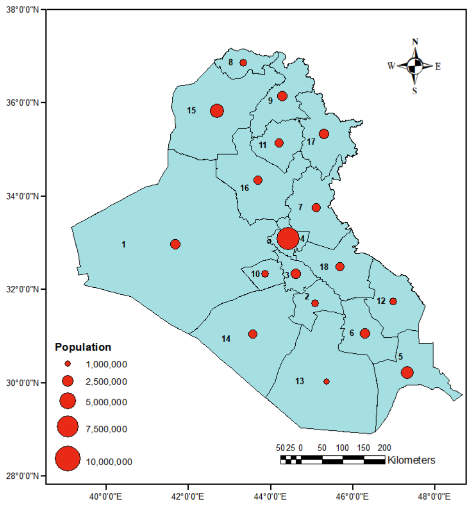

Figure 3. The distribution and the population of 18 Iraqi governorates

4.3. Spatial distribution methods

In this study, the standard deviational ellipse (SDE) model has been utilized to analyze the geographical distribution of COVID-19 cases in Iraq, specifically the dispersion pattern, movement, and direction changes. In order to obtain a better knowledge of the spatial features of the COVID-19 phenomenon, the SDE model tool in ArcGIS was adopted (Silalahi et al., 2020).

The standard deviation ellipse is usually used to describe the spatial properties of geographic variables, such as central tendency, dispersion, and directional tendencies (Wang et al., 2015). The SDEs are centered on the mean center. The mean center is required to comprehend the average location of multiple point distributions. The ellipse's long axis represents the direction with the most evenly dispersed components. The minor axis is the opposite; the greater the difference between the major axis and the minor axis, the stronger the directionality of the element. The changes in the lengths of the main and minor axes of an ellipse lead to changing the area, which reflect an expansion or contraction of a certain spatial data (Peng et al., 2016).

The azimuth represents the major pattern directions, helping to see how the feature distribution is elongated and thus has a specific direction. The rotation of the major axis, determined clockwise from north (0–360°), defines the orientation, as shown in Figure 4. SDEs can be used to describe the overall spatial dynamic mechanism by comparing them through time series (Peng et al., 2016). In this study, the SDE approach was adopted for a visual examination of shifts, expansion and contraction in COVID-19 over time in Iraq country.

The rotation angle (Azimuth angle) of the ellipse can be determined as follows (Oyana & Margai, 2016):

$$\tan\theta = \frac{\left(\sum x'^2 - \sum y'^2\right) + \sqrt{\left(\sum x'^2 - \sum y'^2\right)^2 + 4\left(\sum x'y'\right)^2}}{2\sum x'y'}. \quad (1)$$

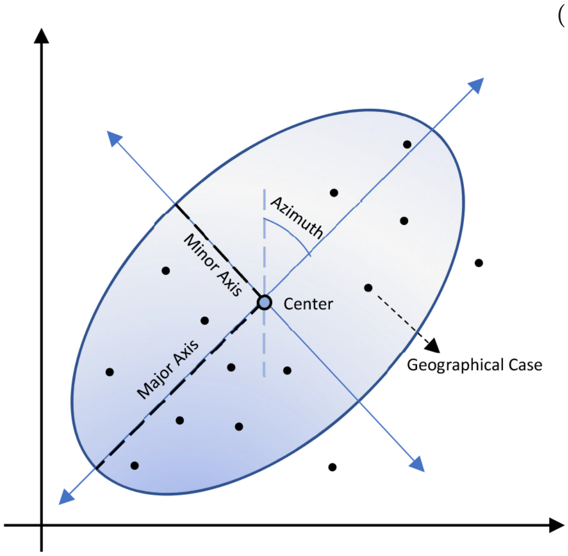

Figure 4. The parameters of standard deviational ellipse

The semi-major axis and semi-minor axis of the ellipse can be defined as follows:

$$\sigma_x = \sqrt{\frac{\left(\sum (x'\cos\theta - y'\sin\theta)\right)^2}{n}},$$
$$\sigma_y = \sqrt{\frac{\left(\sum (x'\sin\theta - y'\cos\theta)\right)^2}{n}}. \quad (2)$$

The area of the ellipse can be calculated as follows:

$$A = \pi\sigma_x\sigma_y. \quad (3)$$

The Incidence rate was also calculated and analyzed for this study. The incidence rate was chosen as a measure because it enables for easy comparison of cases across geographies and populations–particularly, total COVID-19 cases per 100,000 persons. It is a measure of how often an event (COVID-19 in this case) occurs during a particular time period (Arab-Mazar et al., 2020). In numerical terms, it is defined as the number of new cases of the disease within a given period of time, as a percentage of the number of people at risk of contracting the disease. The incidence rate can be determined through the following formula (University of South Florida, 2021):

$$(\text{Confirmed cases/ population}) \times 1\,000\,000\,. \quad (4)$$

The confirmed cases data from May 1 to July 29, 2021, officially reported by Iraqi health authorities, were used to estimate cumulative morbidity based on population data, and using ArcGIS software to create colored map by governates.

5. Results analysis

On first of May, 2021 Iraq reported 5167 confirmed cases, for a cumulative rate of 209.729 cases/100,000 population, reaching up to 13259 cases during 29 of July, 2021 for a rate of 640.528 cases/100,000 population. All governates have been affected, with rates ranging from 9.7563 (Kirkuk) to 110.73 cases/100,000 population (Duhok) (July 29, 2021). It can be seen from Table 2 and Figure 5 that there are considerable increases and changes from May 1, 2021 to July 29, 2021, in approximately three months. A third of Iraq's governorates, equivalent to six out of eighteen governorates, recorded the highest rates of incidence. These included Baghdad, Maysan, Wasit, Duhok, Dhi Qar, Karbala.

From the GIS-based maps (Figure 5), it is clear that the expansion of COVID-19 is taking place in the middle and southern regions of the country. For instance, on May 1, 2021 the percentage of confirmed cases were 79% in most of southern and middle parts while only 21% in the northern and western regions. Despite the increase in the number of infections in the subsequent months in all governorates, the middle and southern governorates still recorded the highest rates of infection compared to the western and northern governorates. From the total number of cases up to July 29, 2021, 64% were recorded

Table 2. The incidence rate of COVID- Iraq for the period between 1 May to 29 July, 2021

Governorate	Confirmed Cases							Incidence Rates						
	1-May	15-May	30-May	14-Jun	29-Jun	14-Jul	29-Jul	1-May	15-May	30-May	14-Jun	29-Jun	14-Jul	29-Jul
Baghdad	2091	914	1113	1659	1745	2172	3330	25.069	10.958	13.344	19.890	20.921	26.040	39.924
Basra	712	341	504	674	966	1175	899	23.852	11.423	16.884	22.579	32.361	39.362	30.116
Sulaymaniyah	54	45	361	273	243	425	838	2.4333	2.0277	16.267	12.301	10.949	19.151	37.761
Maysan	331	41	98	172	269	350	551	28.985	3.5902	8.5816	15.061	23.555	30.648	48.250
Diyala	325	114	107	38	214	255	390	19.341	6.7843	6.3678	2.2614	12.735	15.175	23.209
Erbil	38	44	154	107	162	380	749	1.9962	2.3114	8.0899	5.6209	8.5101	19.962	39.346
Wasit	271	74	184	389	371	600	1062	19.151	5.2295	13.003	27.490	26.218	42.401	75.051
Najaf	233	110	180	244	350	400	380	15.427	7.2831	11.917	16.155	23.173	26.484	25.159
Duhok	277	52	77	233	247	551	1469	20.881	3.9199	5.8044	17.564	18.619	41.535	110.73
Babil	114	37	130	220	318	332	259	5.3788	1.7457	6.1338	10.380	15.004	15.664	12.220
Kirkuk	127	42	72	161	133	213	160	7.7441	2.5610	4.3903	9.8173	8.1099	12.988	9.7563
Al-Qadisiyyah	77	61	96	147	275	494	250	5.8111	4.6036	7.2451	11.094	20.754	37.282	18.867
Dhi Qar	74	30	67	339	562	1058	1013	3.4413	1.3951	3.1157	15.764	26.135	49.201	47.108
Muthanna	37	26	18	42	136	227	194	4.4269	3.1108	2.1536	5.0251	16.271	27.159	23.211
Saladin	176	37	77	34	104	137	510	10.749	2.2599	4.7030	2.0766	6.3521	8.3677	31.150
Karbala	148	29	77	93	255	481	571	11.832	2.3185	6.1560	7.4352	20.386	38.455	45.650
Nineveh	61	36	104	159	168	291	411	1.5934	0.9403	2.7166	4.1533	4.3884	7.6014	10.736
Al-Anbar	21	25	55	56	40	94	223	1.1549	1.3748	3.0247	3.0797	2.1998	5.1696	12.264
Summation	5167	2058	3474	5040	6558	9635	13259	209.729	73.835	139.864	207.743	296.687	462.635	640.528

in southern and middle regions and 36% in the northern and western parts.

A possible explanation for this might be that Baghdad is the capital of Iraq, and it is the economic, administrative and educational center of the country. In addition, the city of Baghdad is suffering at the present time from the increasing population and urban growth due to the large migration it witnessed, whether from rural areas or from other governorates or from outside Iraq. In addition, it contains the largest international airport in Iraq which is considered the main entry for the travelers from the world. Further, most of the southern governorates are located beside Iraqi border with neighboring countries. This makes them a crossing point for the entry of travelers and goods, especially from Iran, through which the first case of Corona virus was transferred to Iraq. Also, governorates such as Najaf and Karbala are historical and holy religious cities in Iraq, where thousands of visitors, every year from inside and outside Iraq, visit them.

Table 3 presents the parameters of standard deviational ellipse. The azimuth (rotation angle) of the ellipse's major axis have been used to examine the changing of

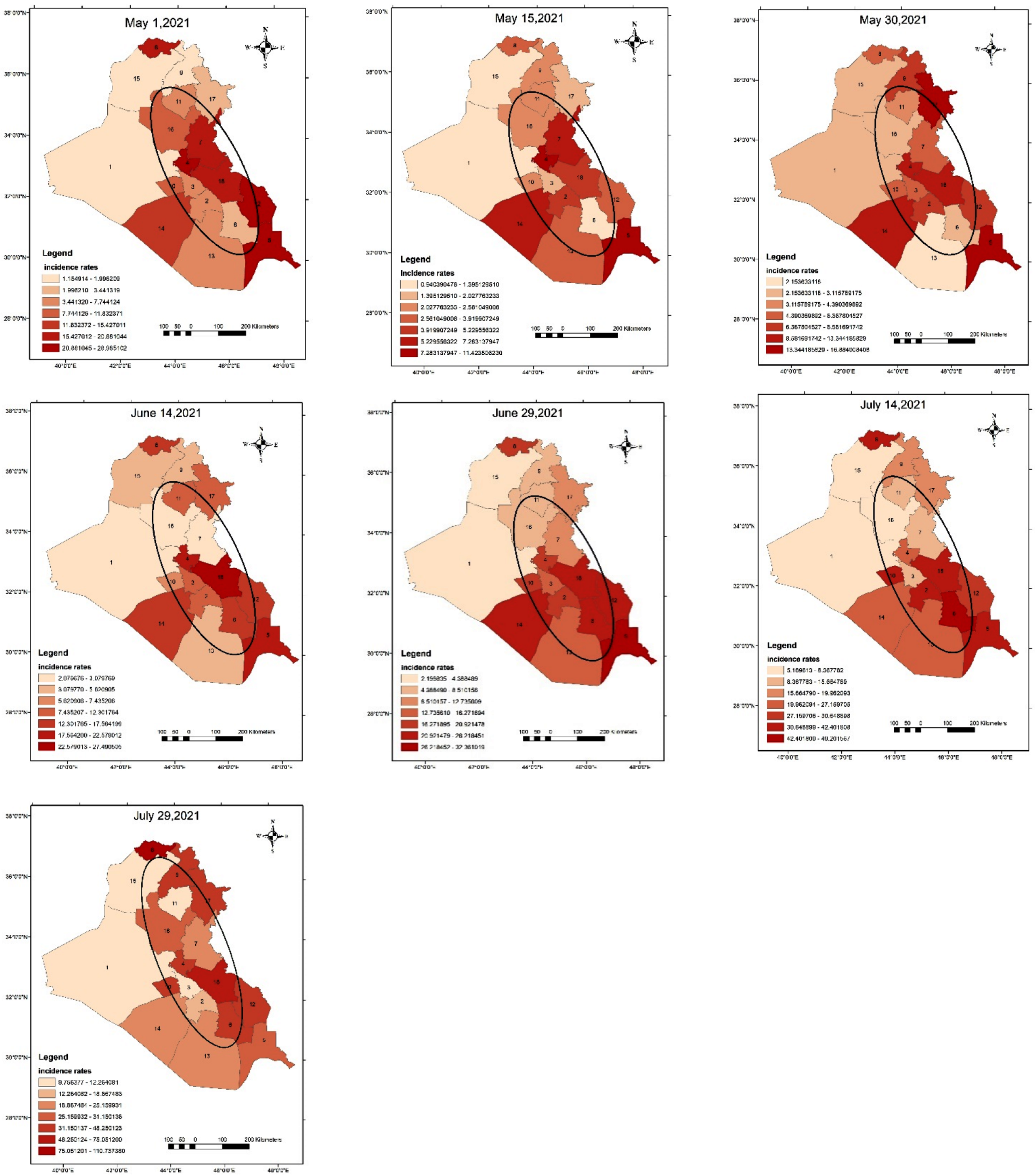

Figure 5. The distribution of COVID-19 infected Iraqi governorates, on May 1, May 15, May 29, June 14, June 29, July 14, July 29

Table 3. Standard dviational ellipse parameters of COVID-19 cases

Date	Major axis (m)	Minor axis (m)	Azimuth (°)	X_{Centre}	Y_{Centre}	Area (km^2)
1-May	336 655.723	135 595.157	152.5	509 205.563	3 652 733.834	143 391
15-May	328 894.627	146 189.283	154.8	502 670.793	3 627 687.452	151 033
30-May	331 831.827	155 821.409	158.9	502 355.714	3 667 947.130	162 424
14-June	345 150.769	141 566.572	156.0	508 398.636	3 647 532.072	153 484
29-June	328 339.873	140 377.736	156.0	514 182.174	3 614 336.690	144 784
14-July	350 672.728	135 878.2438	157.6	505 027.458	3 638 481.822	149 672
29-July	374 693.729	133 784.859	158.2	478 524.637	3 724 205.713	157 457

COVID-19 direction. It is apparent from this table that the azimuth raised from May 1 to May 30, 2021 with an average offset angle of 6.4°. For the period between June 14 and June 29, 2021, a slight decrease in the azimuth arisen with the azimuth was likely to maintain 156°. Then the azimuth grew again for the next month to be 158.2° on July 29, 2021. These findings suggest that in general the direction of COVID-19 in Iraq tends to be oriented around the long axis from southeast to northwest, as shown in Figure 5.

The area of the ellipse represents the distribution density or concentration of COVID-19 infection. It can be noticed from Table 3 that the there is significant increasing in the values of the areas from May 1 to 30 May, 2021, then theses values gradually decreased for the next month. The areas grew up again for the period between 14 July to 29 July, 2021. In general, therefore, it seems that the areas discrepancies illustrate that COVID-19 dispersion varies by time periods, with the most dispersion in May 30, 2021 and the most concentration in May 1, 2021.

The change in the site of the COVID-19 pandemic's case concentration was studied using the ellipse mean centre. Table 3 shows the changes in the geographic mean centre of the COVID-19 spreading. At the beginning of May 2021, the mean centre was south of Baghdad, then it was moved to south east of Baghdad towards Wassit governorate, except for the end of July, the geographical mean center of the pandemic was shifted into Baghdad. Hence, these results support the idea that the geographical mean center of the pandemic became densely distributed on south east of Baghdad.

Conclusions

The COVID-19 outbreak has been impacting countries around the world, and the World Health Organization (WHO) has labelled it a global health emergency of international significance. In this research a GIS-based spatial analysis tool using the standard deviational ellipse was adopted. In addition, incidence rates of confirmed COVID-19 cases were determined to create colored map by governates. Based on the data of COVID-19 in Iraq from May 1 to July 29, 2021, the analysis was achieved at governorates level every 15 days.

The findings revealed that during the whole pandemic period studied, the observed infection propagation rate was not consistent across the country. According to GIS-based maps, COVID-19 has expanded significantly across the governates, specially at middle and south parts of Iraq. The concentration of infection is steadily migrated to the middle and south of Iraq. Differences in incidence rates by governates would be caused by various social and economic factors. For instance, these governates have a huge population and many companies and shopping centers that failed to obey the health officials' orders to stop the virus from spreading. Further, as the crisis worsened, large numbers of Iraqis, including religious pilgrims and businesspeople, were evacuated from Iran by bus and air to Baghdad, where only a limited number of patients from their communities are being treated in public hospitals.

The results also showed that the principal direction of COVID-19 spread is NW-SE. A possible explanation for this might be that the main roads and communications, and the distribution of population, follows a NW-SE trend. The findings of this research allow health and government decision-makers to predict occurrences and establish preemptive strategies to battle the disease, as well as request international aid if the health crisis spirals out of control. The outcomes of this research may also be useful to enable the government to rehabilitate and develop health institutions in the places with the most infections, as well as increase the number of vaccination centers and encourage citizens through the media and social media on the need to take the vaccine in order to limit the spread of the virus.

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