ISSN NO: 2770-0003
Date of Publication: 04-08-2022

Applying Geographic information system (GIS) for (Covid-19) epidemic monitoring in Al-Muthanna Governorate

Nadia Hussein Ali Saoudi [1] , Ahmad Hamid Shakir [2] and Sarmed Hmzah ali [3]
[1]Department of Biology, College of Education for Pure Sciences, Al-Muthanna University, Al-Muthanna, Iraq, 66001.
[2] Students Affairs and Registration Department, College of Nursing , Al-Muthanna University, Al-Muthanna, Iraq, 66001.
[3] Computer Centre, Al-Muthanna University, Al-Muthanna, Iraq, 66001.
Corresponding Author: nadiasaoudi@mu.edu.iq

Abstract: Using GIS can assist in collecting data and displaying them to provide a complete picture about the state of disease from pandemic to epidemic. The GIS technique can, specially, help to find solutions to stop diseases and determine fast and accurately the populations exposed and expected to be infected by the contagious and endemic diseases. Mapping the disease spreading among the groups exposed to the risks and the services date can help planners determine where they can increase the precautions and medical activities immediately, as it can help in tracking of the outbreak, so that the planners could recognize the infected areas and restrict them. It also can assist in foreseeing a specific pandemic, follow and observe virus movements while spreading, specify the source of diseases and how these diseases vary from a place to another and deal with the emergencies, and, finally, diagnose and control disease vector through developing a database to those areas.

In this study, the spatial analysis techniques, with their different patterns, have been used in GIS such as spatial distribution functions: measure the average or the central feature of the phenomenon to determine and analyze the geographical distribution photograph of Covid-19 in Al-Muthanna Governorate according to the administrative units. The study shows that using the GIS technique is of high potentials in determining the areas where there are Corona virus outbreaks. Through applying the link neighboring technology, it is obvious that the pattern of Covid-19 distribution is dispersed and geometrically unorganized (close to be random) and does not submit to a particular system with less than 95% significance level in Al-Muthanna administrative units.

Also, through using GIS in measuring the directional distribution, it appears that the directional distribution of infections in the administrative units is related to the directional distribution of the population and the urbanization (Urban growth) which were witnessed by Al-Muthanna administrative units in the mentioned directions. It is indicated, though applying the standard distance scale, that there are administrative units with high numbers of Covid-19 cases, whereas others are not.

Keywords: Corona Virus (Covid-19); Geographic Information System (GIS); the Spatial Distribution; Nearest Neighbor; Standard Distance; Al-Muthanna Governorate.

1 Introduction

Corona virus, or as it called Covid-19, is considered as one of the infectious diseases which lately has been classified as a pandemic of the present time. This virus is one of the most fast and dangerous among the common viruses in terms of infection on human life. The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. You can be infected by breathing in the virus if you are close to someone who has Covid-19, or by touching a contaminated surface and then your eyes, nose or mouth. In this research , the spatial aspects of individuals are investigated and how the crowded places can influence the virus spreading.

Coronaviruses represent a large family of viruses, which may cause illness in animals or humans. In humans, several coronaviruses are known to cause respiratory infections ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS)[8]. The most recently discovered coronavirus causes coronavirus disease COVID-19. Some people become infected but do not develop any symptoms and do not feel unwell. Most people (about 80%) recover from the disease without needing special treatment. Around 1 out of every 6 people who get

ISSN NO: 2770-0003
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COVID-19 becomes seriously ill and develops difficulty of breathing. Older people, and those with underlying medical problems like high blood pressure, heart problems or diabetes, are more likely to develop serious illness. People with fever, cough and difficulty breathing should seek medical attention[2].

So, this study aims to detect the incidence of Covid-19 spread in Al-Muthanna Province during 2020.

2 Concepts and Terminology:

1. Coronavirus disease (COVID-19) is an infectious disease caused by the coronavirus which first identified in Hubei, Wuhan, China[17]. This disease was never known before, and it has been named coronavirus disease 2019 (COVID-19) – 'CO' stands for corona, 'VI' for virus, and 'D' for disease. Formerly, this disease was referred to as '2019 novel coronavirus' or '2019-nCoV, because it was discovered at the end of December 2019 and first called Chinese pneumonia or Wuhan pneumonia. Covid-19 was officially named by the World Health Organization (WHO)[7].

Corona viruses of human are sensitive to the ultraviolet radiation and heat, and they can live for years in C°60[19] . But, with the heat getting higher, the viruses get weaker and die if they are exposed to C°56 for 30 minutes. These viruses cannot live in acids and alkalis, and the best environment for them to reproduce is (7.2) PH[13].

2. Pandemic:

COVID-19 was characterized as a pandemic in March 11th of 2020 by WHO, and in the 25th of March 2020, the UN announced that Covid-19 might threaten humankind[10].

The word Pandemic : is an epidemic of an infectious disease that has spread across a large region, for instance multiple continents or worldwide, this means that Covid-19 is a pandemic of a new factor that causes disease, and it spreads easily from one to another among the world. A widespread endemic disease with a stable number of infected people is not a pandemic[9], HIV, H1N1, and Covid-19 were classified as pandemics .

3. Epidemic:

The cases of the patients can be characterized as pandemic or epidemic according to the extent of spreading. Outbreak is a sharp increase in the number of people infected with one disease, epidemic is a sharp increase or rise in the number of the infected people witch continue increasing for a large area[14].

3 Kinds of Corona Virus:

There are seven variants of corona that infect the human beings:

1. Corona virus (E229 or HCOV229E).

E229 is one of the infectious viruses, which can infect humans and bats, (HvoC-229E) stands for this kind. It is surrounded by (membrane) and it is anode (positive) and has Ribonucleic Acid (ssRNA).

2. Coronavirus ocy3 or HCOV-ocy3.

3. Coronavirus NL 63 or HCOV-NL63.

4. Coronavirus HKU1 or HCOV-HKU1. The HCov-HKU1 is one of the most prominent coronaviruses, which were originated from the infected rats. The symptoms appeared on the infected people range from respiratory disease with colds symptoms. The virus was first discovered in January 2005, then the later researches detected that this kind had a wide spreading and earlier existence.

5. **Coronavirus linked to severe acute respiratory syndrome or SARS-COV.** In 2003, and after SARS outbreaks, which started in Asia, and the secondary cases in other places of the world, WHO released a statement reporting that a new Corona virus had been detected in several labs and this one was a pathogenic factor in SARS. It was officially named SARS Corona virus (SARS-CoV), 8000 people were infected and about 10% of them died[16].

6. **Coronavirus linked to Middle East** respiratory syndrome (MERS-CoV) on September 2012, a new kind of Corona virus was identified and named Corona 2012 first, and then this name was changed into MERS-CoV.

7. New 2019 Coronavirus or (nCov-2019 as it was called previously). In December 2019, viral pneumonia outbreak was reported in Wuhan, China. In 31st December 2019, this outbreak was linked to a new variant of Coronaviruses, which was officially named nCov-2019 by WHO. As it was reported that

ISSN NO: 2770-0003
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HcoV-229, NL63[4], OC43 and HKU1 of Coronaviruses spread constantly causing a respiratory infection among adults and children across the globe.

4 Research Problem:

1. What is the pattern of Covid-19 distribution in Al-Muthanna Province? and are there certain reasons caused this pattern to dominate in the distribution?
2. What is the capability of GIS in recognizing the present pattern of the spatial distribution of Covid-19 and representing it in maps and charts?
3. How dispersed or concentrated is Covid-19 in Al Muthanna Province from its Mediterranean center and what is the direction of the spatial distribution ?

5 Research Method: the descriptive and analytical methods were followed because they depend on studying the phenomenon as it is on the ground, to answer the question set in the research problem and detect the spatial relations in the phenomenon elements and link them spatially to clarity and analysis, and to prove how far the assumption of the research is achieved. These approaches were also adopted to determine the track and the direction of the virus spreading through using figures and maps as a means to recruit these data for its temporal and spatial analysis. The spatial analysis method has been used through applying the suitable analysis function provided by GIS to identify the spatial variations of the virus positions, to find an explanation and analysis for these spatial variations.

The research importance: the research importance appears in having the advantages of GIS applications which help to identify the areas where there is high prevalence rate of the epidemic, as the relevant parties are enable to take the necessary measures to contain the outbreak and vaccinate people in the infected areas so that the outbreak could be ceased.

6 The spatial and temporal boundaries:

The area of the study is Al-Muthanna province. The spatial boundaries are represented in South-West border of the Middle Euphrates territory. It is bordered on its North by Al-Qādisiyyah, East by Di Qar, West by Al-Najaf, and the South –southwest by Saudi Arabia. As shown in (Figure. 1). It extends between latitudes 29° 4 11'-31 43.49" N and longitude 43° 48' 23-46 40 19" E. It has 5 districts with 7 sub-districts, the districts are Al-Samawa, Al-Rumaitha, Al-Khudhir, Al-Salman and Uruk, the size of their areas varies.

7 Research objectives:

The present study aims at the following:

1. To know the benefits of GIS in studying the status of Covid-19 distribution in Al-Muthanna.
2. To recognize the patterns of Covid-19 the current geographical distribution and represent it in figures and charts.
3. To prepare a suggested geographical database that contains the infected areas.
4. To follow the spatial diseases in public health.
5. To show the activity of GIS in assisting the decision makers.
6. To show GIS ability in applying the methodology of Covid-19 spatial analysis in Al-Muthanna in terms of the administrative units through using the spatial analysis tools.
7. To set proper suggestions and recommendations for the decision makers to take under consideration.

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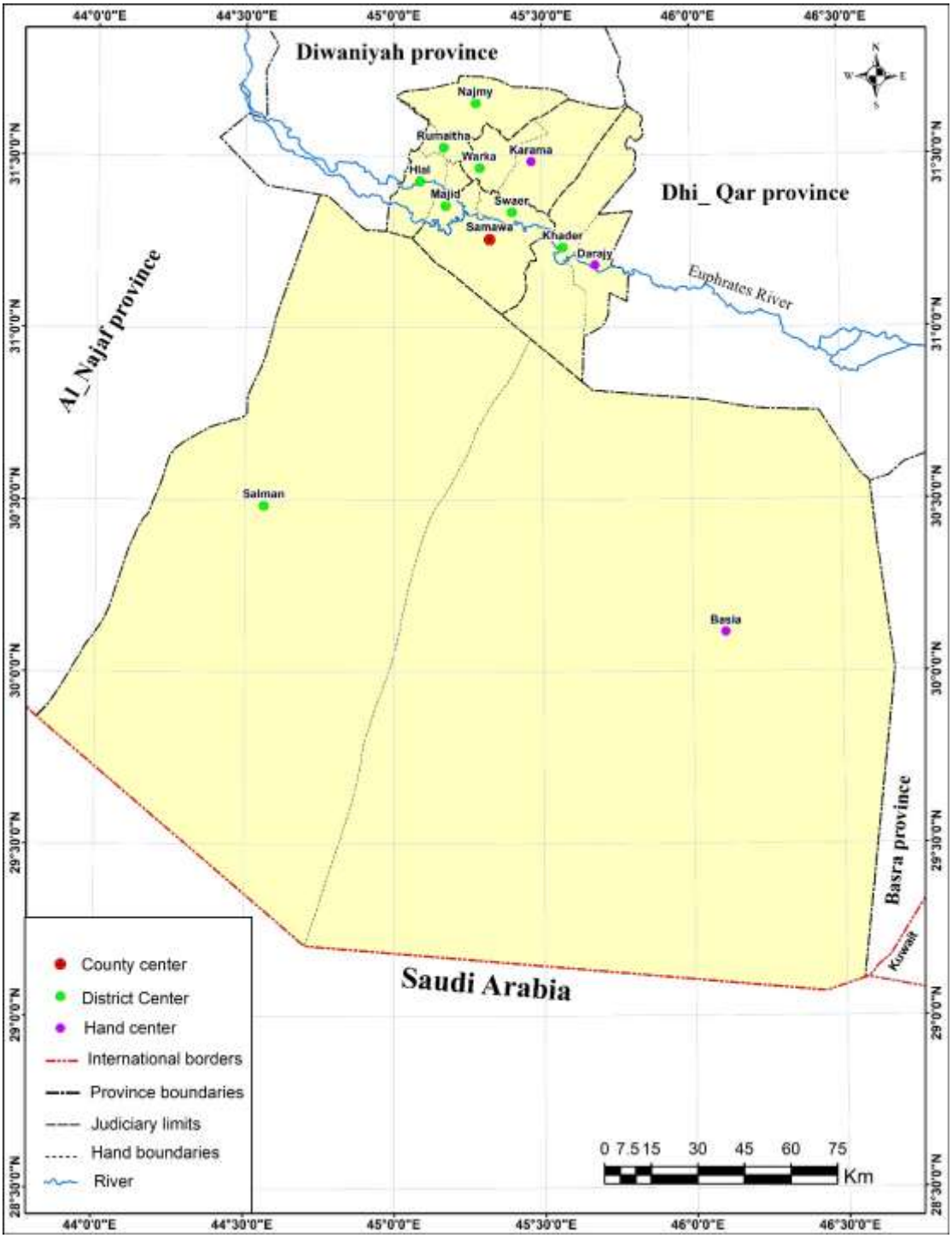

Figure1: Map Al-Muthanna Administrative Units 2020

8 Variation of disease prevalence in the province:

Talking about Covid-19 prevalence in Al-Muthanna 2020 according to the administrative units, (Table1) and (Figure. 2) show the great variation in the volume and intensity of the disease cases reported and provided by the records of the administrative units of hospitals in Al-Muthanna province, and from the Vital & Health Statistics Section in the Public Health Directorate. The variation of Covid-19 cases prevalence among the regional centers and the sub-district administrative units are as follows: In Al-Salman district, the outbreak rates reached the primacy (277.9) per 10.000 people. In addition, in Uruk district, it reached (51.3) per 10.000 people. In Al-Samawah, Rumaitha, Khudhir, and the sub-district Busayyah, it reached more than two-thirds of Covid-19 prevalence (80.6, 160.5, and 162.8) in a row, per 10.000 people. This is due to what these centers have of medical services, with regard to Al-Salman district. The high

ISSN NO: 2770-0003
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prevalence is due to the failure in presenting the essential services, in particular the medical ones, as there is no general hospital nor specialized one that could present medical aid in Al-Salman nor in Busayyah. This is what makes local people go where they think that there is a good medical services in closer regions, Al-Samawah and Khudhir.

Table 1: Covid-19 prevalence 2020 in Al-Muthanna in terms of the administrative units

Administrative Unit	Cases[22]	Cases/10000
Al-Samawah	5150	162.8
Rumaitha	2075	160.5
Khudhir	949	80.6
Uruk	540	51.3
Al-Salman	324	277.9

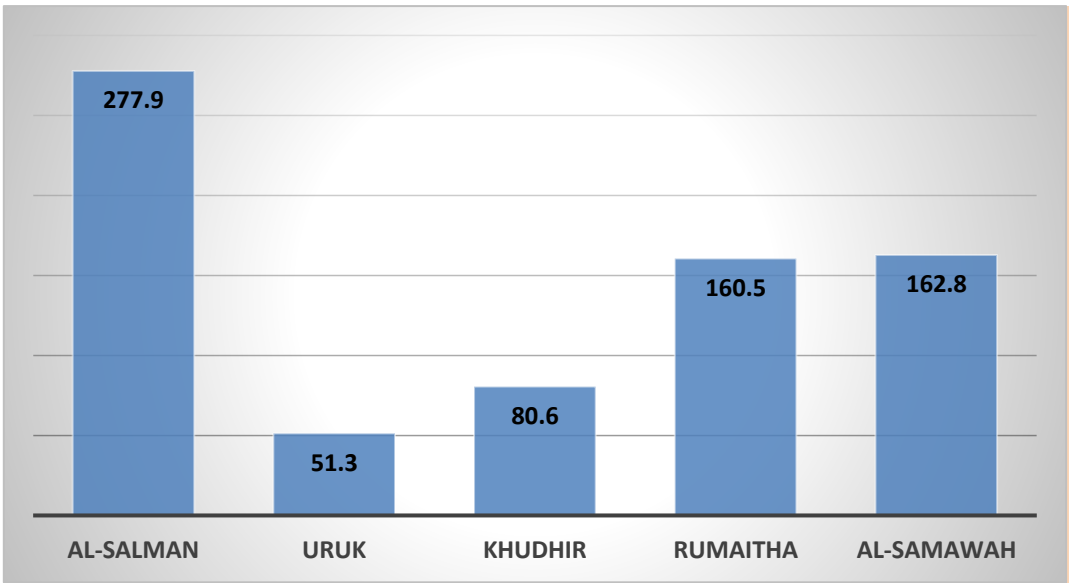

Figure 2: rates of Covid-19 in Al-Muthanna in terms of the administrative units 2020

Source: Table (1) data.

9 The Qualitative Composition of the Infected People:

This means that the infected people are classified into males and females. Diseases can infect both sexes without exception and in various degrees that are different depending on the disease pattern in the province. (Figure. 3) shows relative infection differences between males and females. The statistics revealed the truth that males are infected more than females as the recorded cases of males reached 4469 64% rate of the overall infections[3] , whereas female cases reached 2469 35.9% . This difference in infection is because males contact with the pathogens more than others. The anatomical structure of males and the functional competencies that may affect the degrees of resistance and immunity, and because of movements and mingle among males more than females as it is the nature of Al-Muthanna community which tends to restrict women`s behavior and participation in work[12].

Table 2: The Qualitative Composition of Covid-19 infected people in Al-Muthana for 2020

Male	%	Female]	%
4469	64	2469	35.9

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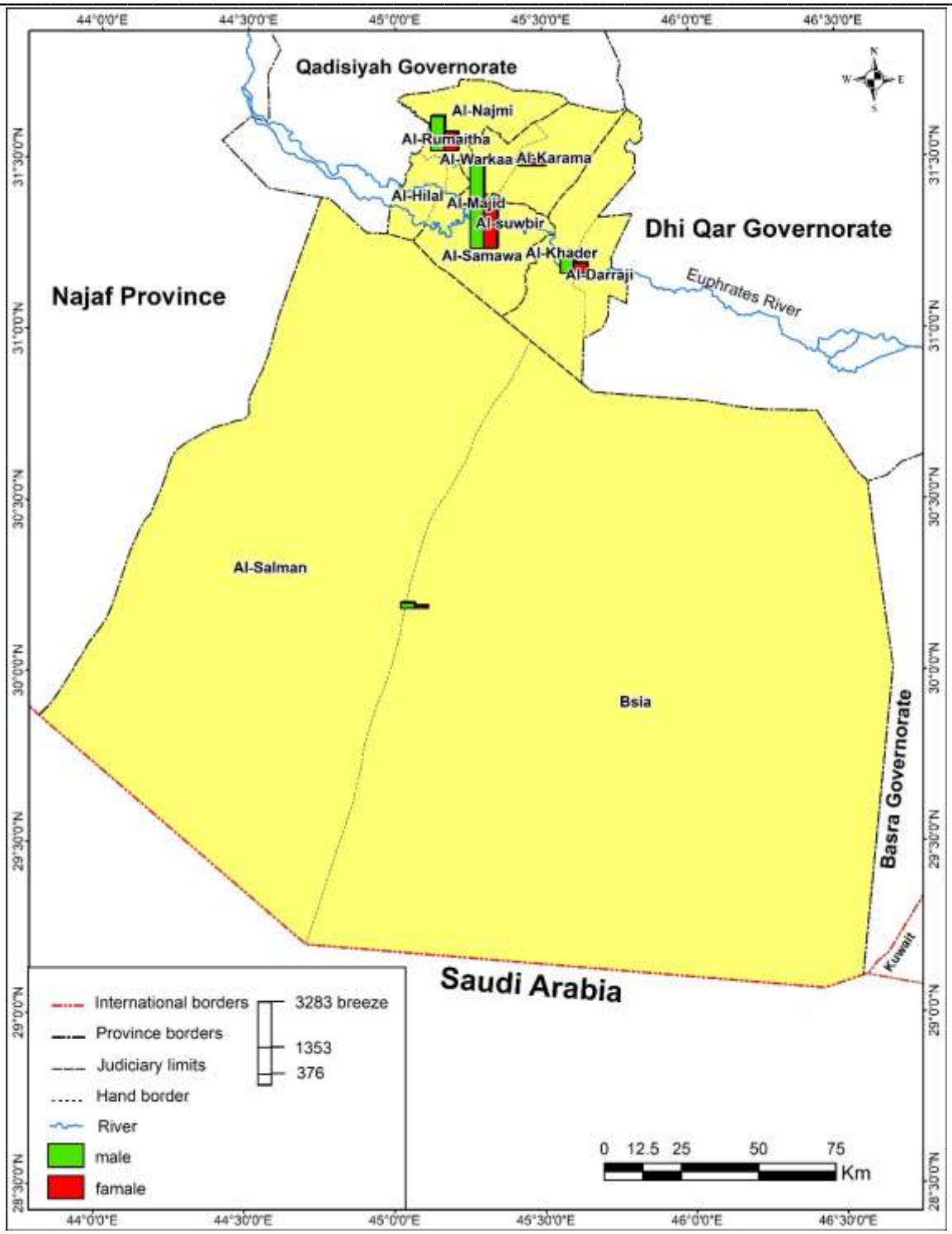

Figure 3: Map The Qualitative Composition of Covid-19 infected people in Al-Muthana for 2020
(Source: Adopted from Arc GIS10.6 and the data of Table 2)

10 Age Structure:

Age structure of infected people refers to the process of distributing them according to their ages. (Figure. 4) and (Table 3) show that the numbers of Covid-19 cases among the age group (22-40) are the highest comparing to the rest, as this age group reached 5465 cases which represent 60.4% and came first in the number of cases . This is due to the idea they have about being immune, but this is unconfirmed truth. Besides that, the tough economic environment where they live so they have to break curfew and keep working. On the other hand, the age group (45-64) came second with 2210 cases representing 24.4%, as they are living with chronic illnesses so they are more vulnerable to be infected than others. The age group (65) came third having (575) cases with 6.3% because they are of weak immune systems and low oxygen levels.

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The (15-19) age group was in the fourth place with (403) cases 4.4% and the other age group (10-14) reached 204 cases, which compose 2.2% of the overall infections. So, this one got the fifth place since they have a healthy respiratory system and they normally do not suffer from any illness in their bodies before. The 6th group is (5-9) age group which recorded (109) cases, rating 1.3% of the overall cases. Children of (1-4) ages reached 54, 0.5% in the 7th place because they have healthy immune systems with increasing white blood cells. The last rank is the group age (infants) recorded 18 cases rating 0.2%.

Table 3: Age Structure of Covid-19 infected people 2020 in Al-Muthanna governorate[22]

Less than a year	1-4 year	5-9 year	10-14 year	15-19 year	20-44 year	45-64 year	Over 65 year	Total
18	54	109	204	403	5465	2210	575	9038
0.2%	0.5%	1.3%	2.2%	4.4%	60.4%	24.4%	6.3%	

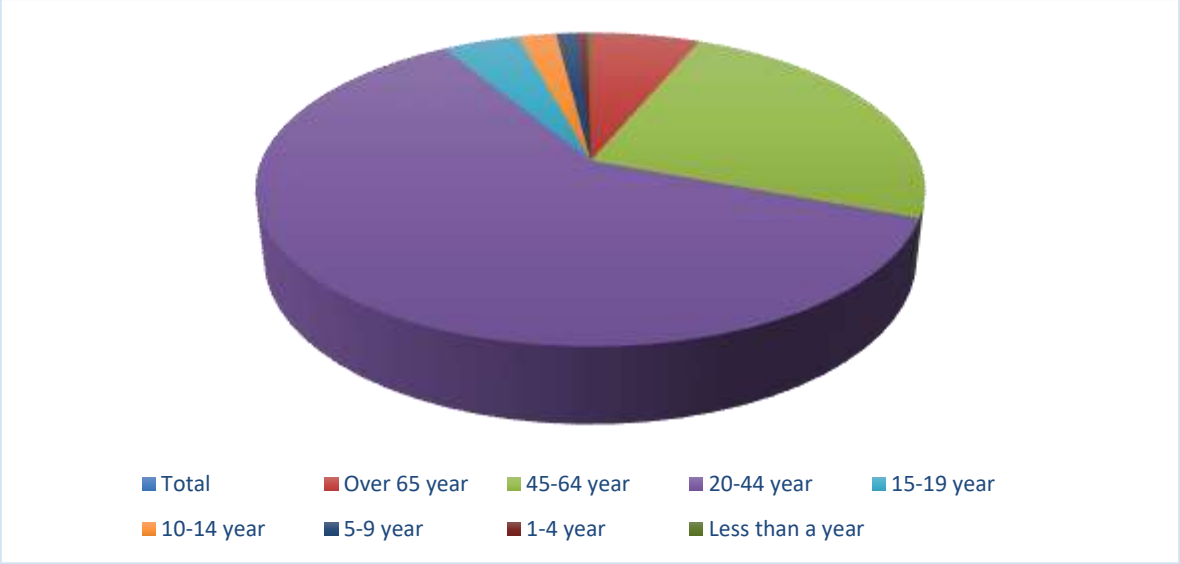

Figure 4: Age Structure of Covid-19 infected people 2020 in Al-Muthanna Governorate

Source: Table (3)

11 Geographic information system analysis (GIS):

The methods and tools of spatial Analysis in GIS are used, particularly the functions of measuring the geographical distribution, including the phenomenon average measure or Central Feature, Average Nearest Neighbor, Directional Distribution, and Standard Distance.

11.1 Spatial Distribution of Covid-19

(Table 4) and (Figure. 5) show that the Covid-19 cases in Al-Muthanna (2020) were distributed to twelve administrative units. The overall spatial distribution of Covid-19 in terms of administrative units indicates that the center of Al-Samawah was in the top among the rest of units with (56.9%), whereas (Uruk and Al-Salman) had the least rate (3.5%, 5.9%) respectively.

Table 4: relative Spatial Distribution of Covid-19 in Al-Muthanna (2020) in terms of administrative units.

Administrative Unit	2020	%
Al-Samawah	5150	56.9
Rumaitha	2075	22.9
Khudhir	949	10.5
Uruk	540	5.9
Al-Salman	324	3.5
Total	9038	100

Source: Adopted from the data of Table (1)

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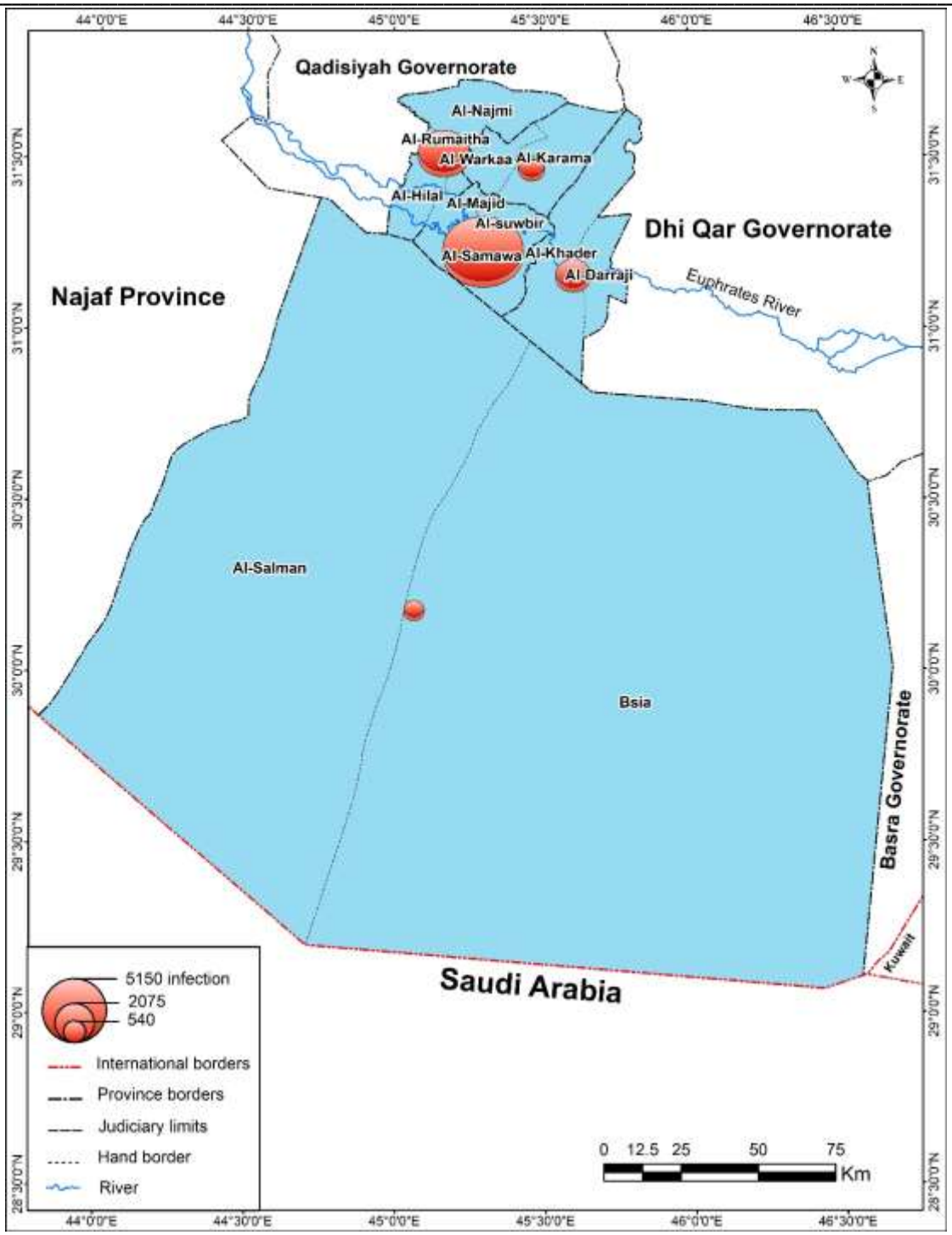

Figure 5: **Map Spatial Distribution of Covid-19 in Al-Muthanna (2020)** (Source : the data of Table 4) using Arc GIS10.6)

11.2 Central Feature: this tool identifies the feature or the located place which is the nearest to the distribution center of the feature individuals in progress. The central feature refers to a specific value lies in the mid of cases distribution. It is the virtual or ideal position to the central point of Covid-19 cases [20].

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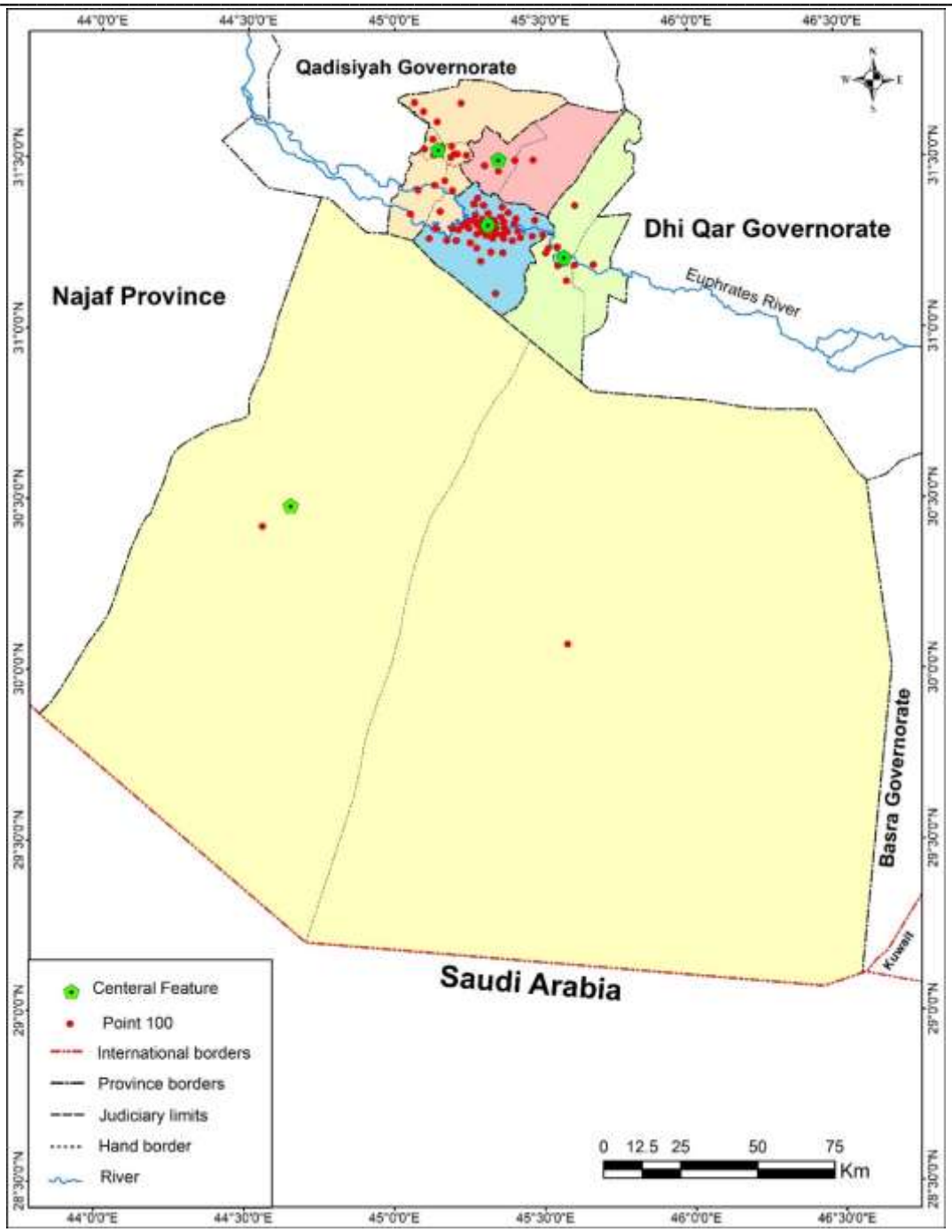

Figure 6: **MapThe central feature of Covid-19 cases in 2020 in Al-Muthanna according to the administrative units (**Source : the data of Table (5) using Arc GIS10.6)

11.3 Mean Center:

It is a basic demand to know the mean center in analyzing plenty of spatial distribution. Mean center helps in knowing the comparison between the actual center and ideal one. Through it, we can recognize the mean position to be the distribution center ,expressed as Center of concentration [5]. It is known as center of disease concentration and the purpose of it, in most studies, is to know the average for the points. It is the location which represents the central position among the points where the total points away from it should be less than any other location on the map . Since using this scale is to represent the spatial concentration center, different iterative values should be provided from another place according to the numeric value of the number of phenomenon in a particular place. By that, each point will carry its actual weigh for the weighted spatial mass center[15]. By applying this scale, as in (Figure. 7)., it is shown that the spatial mean center is in the upper mid part. This means in the northern part of Al-Muthanna specifically in a central position of Al-Samawah that represents the main attraction point of the population i.e. the point where

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people are evenly distributed in all of the governorate directions. In addition, it has institutions and medical stations which are lacked in other units, and it represents the heart of the spatial distribution. The virtual or optimal locations of the central point of covid-19 cases in each administrative unit of Al-Muthanna : in Rumaitha, the central geographical point lies within 28.89 km to the concentration or mean point on its northwest. For Al-Khudhir, it lies on its southwest within 25.88km. In Uruk, it lies on its northwest within 22.24km. The central point of Al-Salman lies on its southwest within 113.21km away from the mean point.

Concerning the representation of Covid-19 cases recorded as points in Al-Muthanna, it would be difficult to represent all the cases recorded in the province on map. It is necessary to choose quantitative mean to the cases with points. The number of points which represents the feature and its meaning should be known[11]. The number of corona cases recorded in Al-Samawah reached (51.5) cases. Rumaitha has reached (20.7) cases. The quantitative mean has been chosen to the point that each point represents (100 cases) . So, instead of drawing (5150)points for Al-Samawah, there will be (5150÷100=51.5 points) which means the actual distribution is divided by (100) least value, as shown in table (5) and (Figure. 7,8).

Table 5: Quantitative mean of Covid-19 cases represented by points in Al-Muthanna according to the administrative units 2020

Administrative Units	2020	
Samawah	5150	51.5
Rumaitha	2075	20.7
Khudhir	949	9.5
Uruk	540	5.4
Al-Salman	324	3.2
Total	9038	90.4
Points Number	Each point represents 5 cases	Each point represents 100 cases

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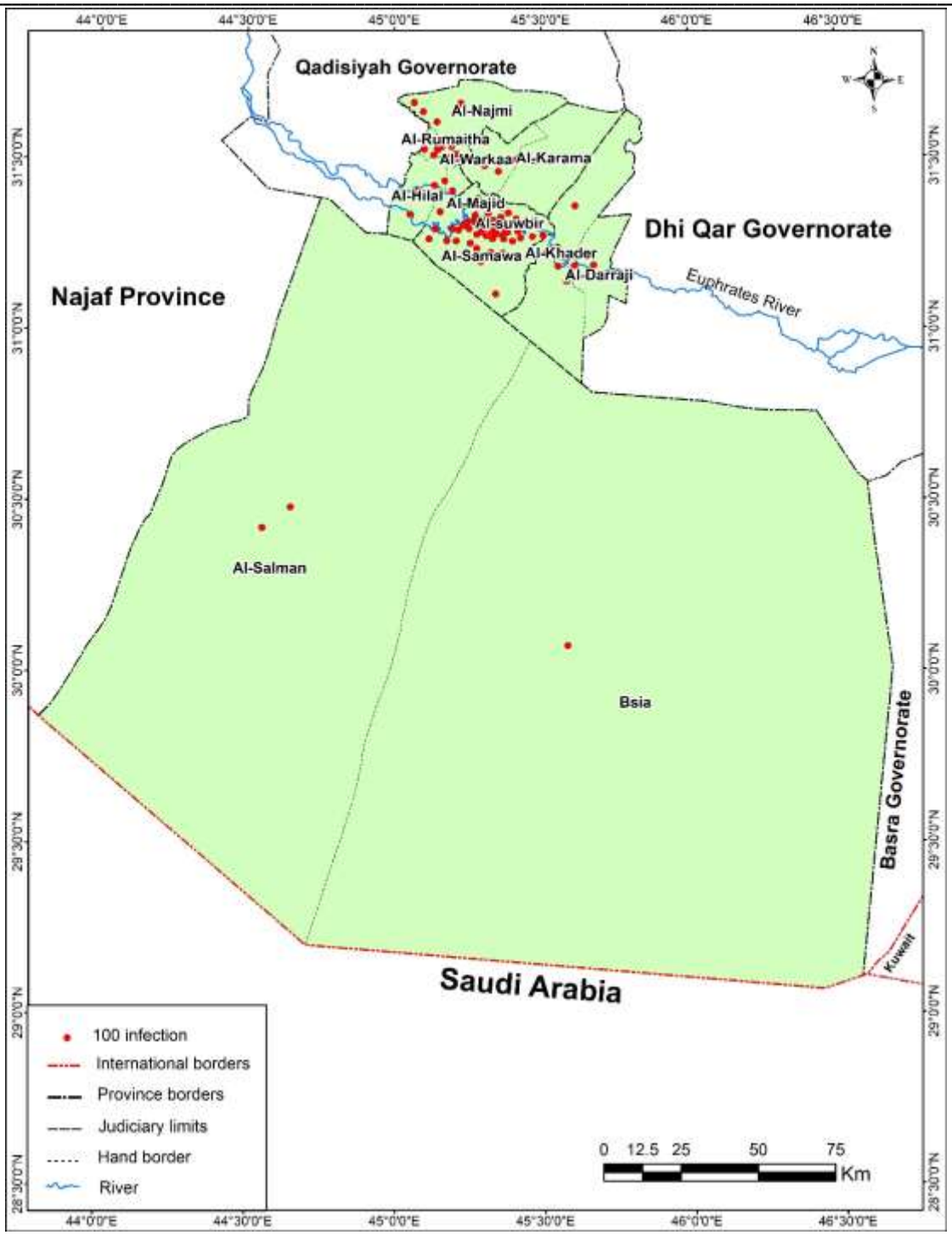

Figure 7: **Map the actual distribution of Covid-19 cases 2020 in Al-Muthanna province according to the administrative units (**Source : the data of Table 5) using Arc GIS10.6)

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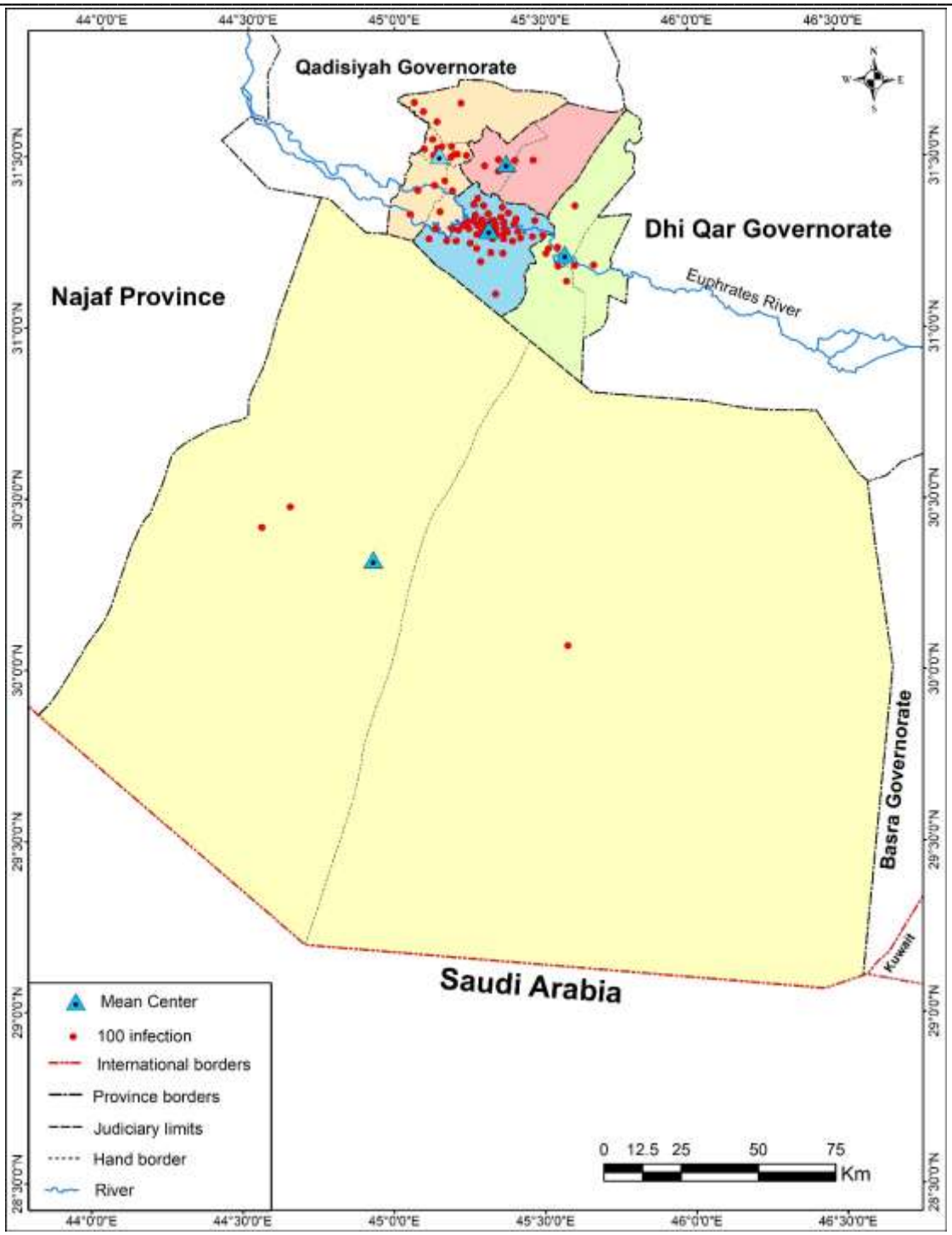

Figure 8: **Map mean center location (spatial potential center) of Covid-19 cases 2020 in Al-Muthanna governorate according to the administrative units** (Source : the data of Table 5) using Arc GIS10.6)

11.4 Average Nearest Neighbor

This model is used as one of the statistic tests to determine the spatial distribution patterns of the geographical phenomena, through using a mathematical method based on measuring the distance between each point and the nearest neighbor point. In other words, the analysis of the real or actual distance which separates the centers distributed on the map on points shape, and their rate to the rate of the excepted points separating the points in random distribution pattern[1] . The aim is to get an evidence to determine the geographical distribution pattern of Covid-19 cases in population's pattern whether it is (Clustered, Random, and Uniformed). Detecting the geographical distribution pattern of the endemic can help us recognize the effective variations in forming this pattern. The patterns that are shown by this test vary among the clustered pattern of (0-0, 67) value, convergent pattered (0, 68 – 0, 99), dispersed pattern (1-1, 99), and uniformed

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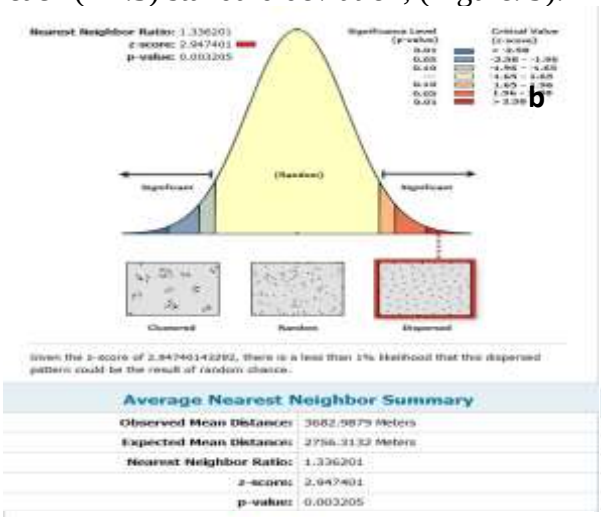
pattern (2-2, 5). If the calculated average was less than the expected one for such number of locations in the same geographical area (Random Distribution). The pattern of the endemic would be clustered. Whereas if the calculated distance was larger than the expected distance of a potential random distribution. The geographical distribution for locations or places of disease or population would be dispersed. So, the nearest neighbor can be expressed by calculating the ratio between the calculated distances divided by the expected one. If nearest neighbor is less than (1) Integer, the geographical distribution of Covid-19 is clustered, while if it is more than (1) Integer , the distribution is dispersed[6] .

Using nearest neighbor technology, we concluded that Covid-19 distribution pattern in Al-Muthanna is dispersed or geometrically irregular (Near to randomness) and does not submit to a specific system with less than 95% significance level in all administrative units of the governorate. This means that there is less than 1% possibility that this distribution is coincidence. This is because some residential neighborhoods are highly populated, and others are of wide areas.

It has been shown that the nearest neighbor ratio of the distribution resulted from the division of calculated distance average between the disease phenomenon locations and the expected distance for this type of disease number on the area of the same land recorded value (1.2) in Al-Samawa and Z value was (3.6) standard deviation which is more than (1) integer. This means that its distribution is dispersed. Moreover, in Rumaitha, the distribution is dispersed as well. It reached (1.3) value and Z was (2.9) standard deviation. Al-Khudhir is with dispersed distribution pattern with value reached (1.6) and Z was (3.9) standard deviation. As for Uruk the dispersed pattern is dominant with (2.8) and Z was (7.8) standard deviation. In Al-Salman, the average of nearest neighbor was the result of the calculated average divided by the expected average of Covid-19 which is (4.4), that means the dispersed pattern is dominant where Z value increao reach (11.5) standard deviation, (Figure. 9).

a



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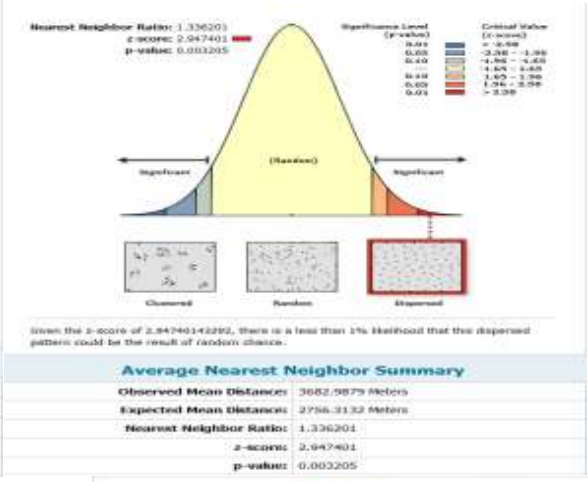

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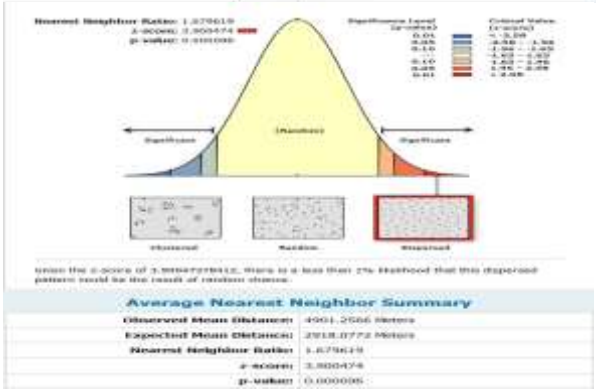

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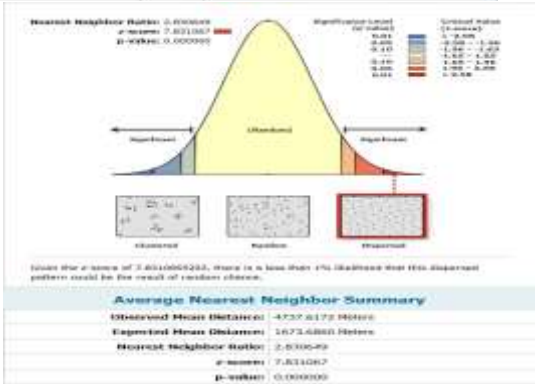

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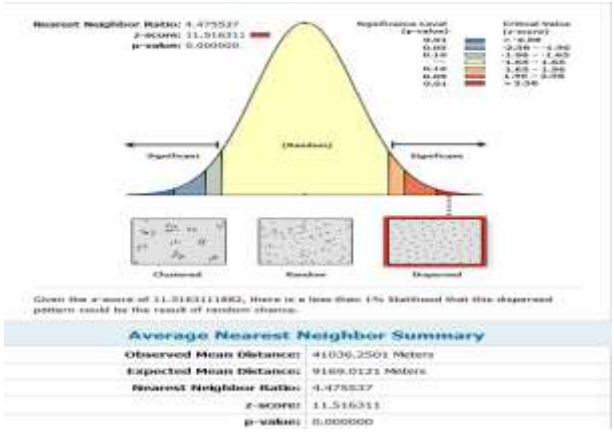

a. Al-Samawa

b. Rumaitha

c. Al-Khudhir

d. Uruk

e. Al-Salman

e

Figure 9: **Average Nearest Neighbor**

11.5 Distance Standard

Several Scales are used to study the distribution around center. Distance standard is one of these scales which is one of the dispersion scales and mostly used for measuring the distribution of infections around its middle center as it is the corresponding in the spatial statistics of the standard deviation to distribute the variable readings around its average[21]. Through applying the distance standard analysis on the the administrative units in Al—Muthanna using (Arc GIS10.6). From (Figure. 10) and (Table 6), it was shown that there were some administrative units with extensive Covid-19 cases and others with uncertain distributed cases. So, the center of concentration was determined which represent the mean center to distribute the infected cases (Optimal Center). Through applying Arc GIS10.6 technology, they were represented graphically on the map by drawing a distance standard circle to each administrative unit with its subordinate centroid. The results show that the spatial distribution of Covid-19 in the administrative units, Al-Samawah, Uruk , Al-Khudhir, and Rumaitha, tends to be excessive around their centroid. The radius of circle, which represent the standard distance for each, has reached (8965.10 m, 5595.72m, 7865.46m, and 11058.02m) radius respectively around the center of concentration, except Al-Salman where the spatial distribution of the infection tends to dispersion with (48863.29m). This is due to the nature of the area of Al-Salman which is wide, desert and with low population density. As can be seen, the spatial distribution pattern in most of Al-Muthanna administrative units is centered around the central point of concentration i.e. the direction of the covid-19 cases headed from the southeast to the northwest along the side of Euphrates river and as a result of (urbanization) the geographical extend of the governorate in the northwest.

Table 6: Standard Distance & Circle Standard Distance of Covid19 distribution 2020 in Al-Muthanna governorate

Administrative Unit	Cases	Standard Distance
Al-Samawah	5150	8965.10
Rumaitha	2075	11058.02
Khudhir	949	7865.46
Uruk	540	5595.72
Al-Salman	324	48863.29

ISSN NO: 2770-0003
Date of Publication: 04-08-2022

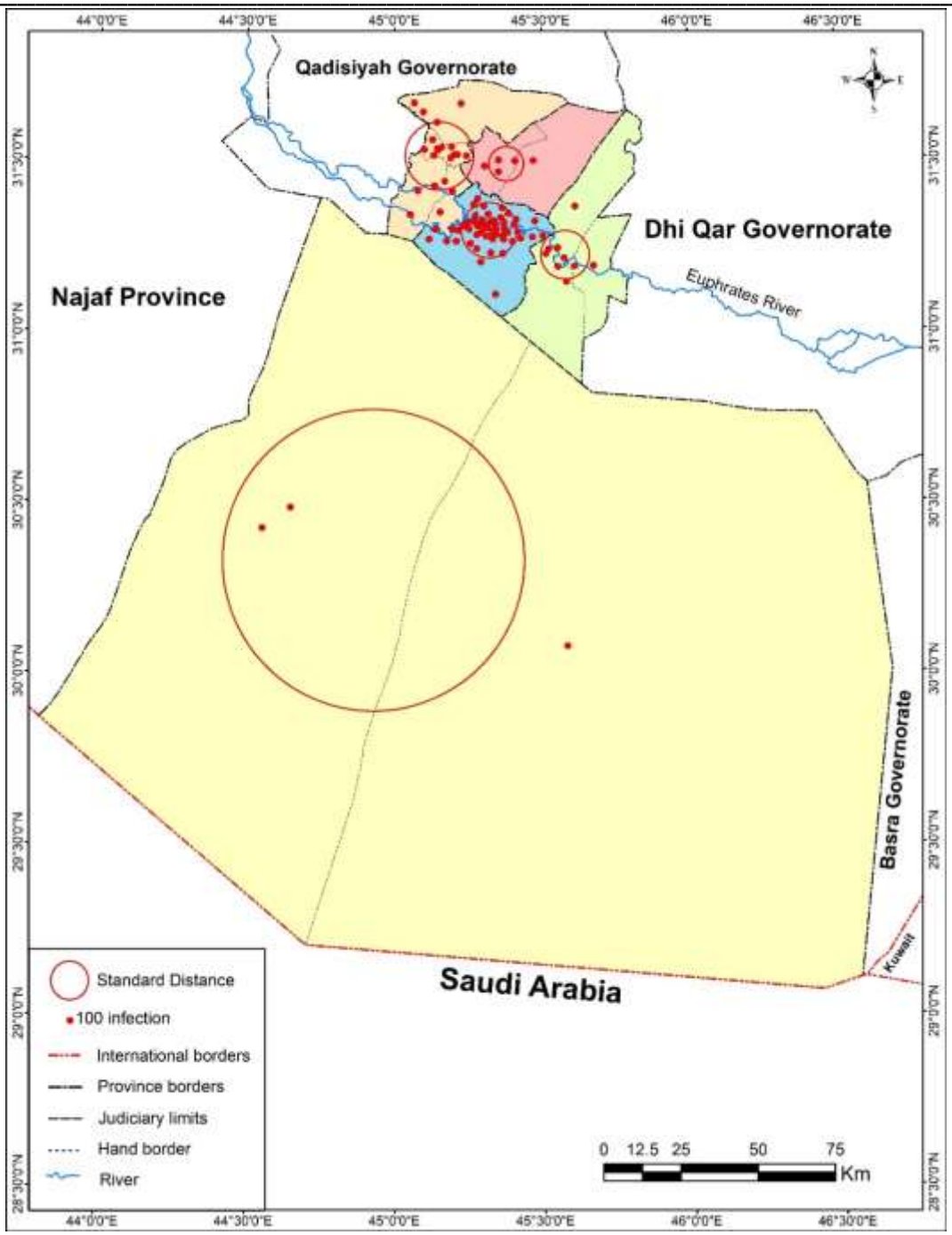

Figure: 10 Map Standard Distance Covid19 cases 2020 in Al-Muthanna governorate in terms of Administrative Units (Source : the data of Table 6) using Arc GIS10.6**)**

11.6 The distributional Direction

The distributional direction is one of the spatial properties. It is the corner unit which represents the size of the gap that appears when two action lines meet, or when a line splits into several directions. The direction is a relative measure. The standard deviation and distribution direction are used to determine the geographical representation area (Covid-19 cases) and recognize how far they spread to the geographical directions (North, South, East, West) in Al-Muthanna. Most of time ,the geographical phenomena distributions do not equal in their spread directions, but take different directions and the general direction corner is measured around its mean center[18] .

(Figure. 11) shows the actual distributional direction (Standard deviation) of Covid-19 distribution pattern in Al-Muthanna in terms of the administrative units. It takes an ovular shape and moves from southeast to northwest in (Al-Samawah, Al-Rumaitha, Al-Khudhir) through the value of the angle rotation calculated of the active spreading. It goes clockwise reaching (89.72392, 3.5073, and 178.19102)

ISSN NO: 2770-0003
Date of Publication: 04-08-2022

respectively along Euphrates river side, except Al-Salman where the direction of the infection cases was from southwest to northeast which goes counterclockwise. This is what the counted angle confirms (113.548239) and it is in the direction of Al-Samawah, Al-Khudhir. Uruk had a different direction that moved from North to West in (81.482523°). As it can be seen, we conclude that the direction of the infection distribution in the administrative units is linked to the population and urban sprawl Urbanization which have been experienced by the administrative units of Al-Muthanna in the stated directions.

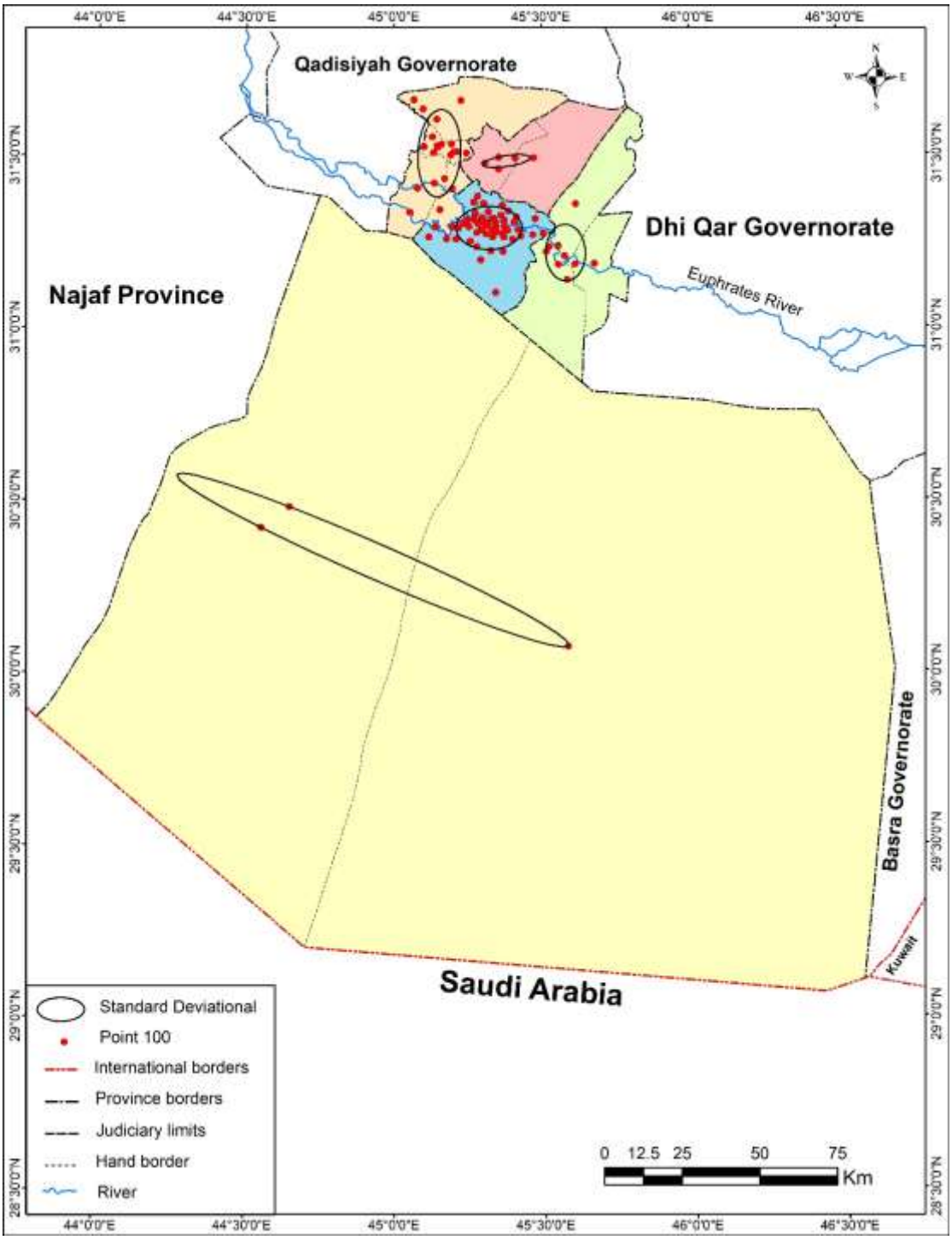

Figure: 11 Map Covid-19 positive cases 2020 in Al-Muthanna according to the administrative units (Source : the data of Table (5) using Arc GIS10.6)

12 Conclusion:

1. The prevalence of Covid-19 in Al-Muthanna population reached the highest in Al-Salman (277.9) per 10.000, while in Uruk ,it reached (51.3) as the lowest.

ISSN NO: 2770-0003
Date of Publication: 04-08-2022

2. The study proved that there is a spatial disparity in terms of the numerical and relative distribution of Covid-19 cases in the districts and sub-district centers. It was clear that district center Al-Samawah was in the top of the administrative units with (56.9%) rate, whereas the least rate is the one of district centers of Uruk & Al-Salman which reached (5.9, 3.5 %) respectively.
3. Corona virus hit all the age groups in the governorate with variable proportions and this is due to the age composition. It has been recognized that Covid-19 cases of age group (20-44) is the highest one in comparison with other age groups. This one reached the top by 5465 cases and 60.4%. Whereas the least is the one of (less than a year) which recorded 18 cases which is 0.2%. The statistics detected that male's cases are more than female cases. Males reported cases reached 4469, which is 64% of the overall cases, while females reported cases reached 2469, which is 35.9% of the overall cases.
4- The mean Center concentration of all administrative units in the upper part or the northern part of the governorate approaching to the river sides, specifically in a central location in Al-Samawah, which represents the main attraction point to all distributions. This means that the population concentration lies there and that is why the prevalence of Covid-19 cases increases.
5. Through using Average Nearest Neighbor technology, it was concluded that the distribution pattern of Covid-19, in Al-Muthanna, is dispersed and geometrically unorganized (close to be random).
6. By applying the standard distance scale, the outcomes showed that the spatial distribution of Covid-19 cases in the administrative units Al-Samawah, Uruk, D.C Khudhir, Rumaitha tends to be concentrated around its mean center. The radius of a circle representing the standard distance for each of them reached (8965.10 m, 5595.72 m, 7865.46m, 11058.02m) respectively around the central point of attraction, except Al-Salman where the spatial distribution tends to dispersed with a radius reached (48863.29m).
7. After using the directional distribution or spread tool represented by an ovular shape, the actual direction of Covid-19 cases in Al-Muthanna according to the administrative units appears to take an ovular shape. It moves from southeast to northwest in all of Al-Samawah, Rumaitha, Khudhir through the value of the calculated angle rotation for the active spread direction which is clockwise reaching (89.72392, 3.5073, 178.19102) respectively and parallel to Euphrates stream, except Al-Salman where the direction of the infected cases was from southwest to northeast which goes counterclockwise. This is confirmed by the calculated angle (113.548239).
8. The capabilities of GIS are shown through applying the methodology of Covid-19 spatial analysis in Al-Muthanna according to the administrative units by using spatial analysis tools.

Recommendations

From the results of the study, the following recommendations can be set:

1. Adopting geographic information systems (GIS) technology in studying and analyzing the geographical distribution of geographical phenomena in general, and the distribution of diseases in particular.

Acknowledgement

We would like to express our thanks and gratitude to the health institutions in the Iraqi Ministry of Health for their kindness and in a great way in seeing the data without which the study would not have been successful.

Declaration

Declaration Conflict of interest The authors declare no conflicts of interest

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