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Analysis of Population Growth in the City of Baquba Using Geographic Information Systems and Remote Sensing

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Abstract: ***The population size and geographical distribution vary from one place to another as a result to several natural and human factors. This study focuses on analysing the population growth and geographical distribution in the district of Baquba district for the period 2003-2019. Baquba has witnessed a clear development which causes an increase in its population size, making it the largest urban center in Diyala Province. In this regard, this study intends to shed a light on the population density and the associated geographical distribution throughout the district of Baquba. To carry out this research, spatial analysis and demographic analysis are carried out based on model equation of the population expansion. Furthermore, the Lorenz curve is used to explain the intensity of population density in Baquba district during the studied years.***

Keywords: ***City of Baquba, Population Size, Geographic Information Systems, Lorenz Curve.***

1. INTRODUCTION

Most studies, especially those that deal with planning and development, are thought to revolve around the population as their principal axis. The population's features, growth rates, and distribution are a continually changing factor, therefore understanding them is necessary when establishing economic and social policies. When compared to other concerns and problems, population issues normally take precedence. This is due to its great impact on public life, society and its tight connection to development (Shanahan,e tal., 2015; Van den Bosch and Bird, 2018).

One of the most significant demographic phenomena that has to do with population geography is the study of population distribution. Based on the definition of geography as the study of

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places and their relationships, it has an outstanding value (the science of place). Whereas the distribution of the population reflects the truth of the distribution towards collecting or scattering depending on the features and strong or weak relationships that this place has (Chengalur-Smith and Sidorova, 2003; Soberón, 2010; Lowrey and Kim, 2016).
The variation in the distribution of the population of any city from one place to another and from one year to another, is explained by factors that affected that distribution, and were reflected in the different concentration of the population in its various administrative units. To discover the necessary solutions and create the necessary plans to address these changes and their demands from many angles, the study of demographic changes in the governorate is therefore necessary. In other words, it is necessary to know the characteristics of the population, its growth rates and its distribution, being the constantly changing element.

Due to the disparity in population densities and changes in those densities by growth or decrease throughout the districts of the Diyala governorate, the Baquba district is regarded as a good region to examine population changes that occurred there. Specifically, the district of Baquba has witnessed population changes in terms of the growth of the population size and the change of the population distribution map in the district. This study intends to analyse the spatial distribution of the population in Baquba, and to explain the reasons behind. It has been decided to evaluate the population distribution in the district of Baquba during the period 2003-2019 using statistical methods and modern techniques.

When allocating basic services to the people in a way that is compatible with the population distribution in the Baquba area, decision-makers in planning institutions may use this type of research as a basis for their decisions. In this aspect, figuring out population growth rates and urban policy is crucial to enhancing quality of life on the social, economic, and environmental levels (Holden and Otsuka, 2014; Profiroiu et al., 2020). It is fair to admit that understanding the population variance at the spatial level would aid the future development planning process. It is also considered a substrate that contributes to eliminating a number of other economic and social problems associated with high growth rates, such as poverty and unemployment. Those can represent the superiority of the recent study. To conduct the aim of this study, the following objectives will be utilised:

First: Analysis of the spatial distribution of the population at the level of the administrative units of residential area in the district of Baquba. Accordingly, the extent to which this distribution varied within the study period will be investigated.
Second: Studying the geographical distribution of the population in Baquba District.
Third: Detecting the axes of population spread and their places of concentration.
Fourth: Providing the reasons that led to the current distribution of the population in Baquba district.

Search area limits
The city of Baquba, which serves as the administrative hub of the Diyala Governorate and is made up of twelve residential districts, is where the search's geographic parameters are established. Baquba is situated in the southwest of Diyala. The results of the inventory and

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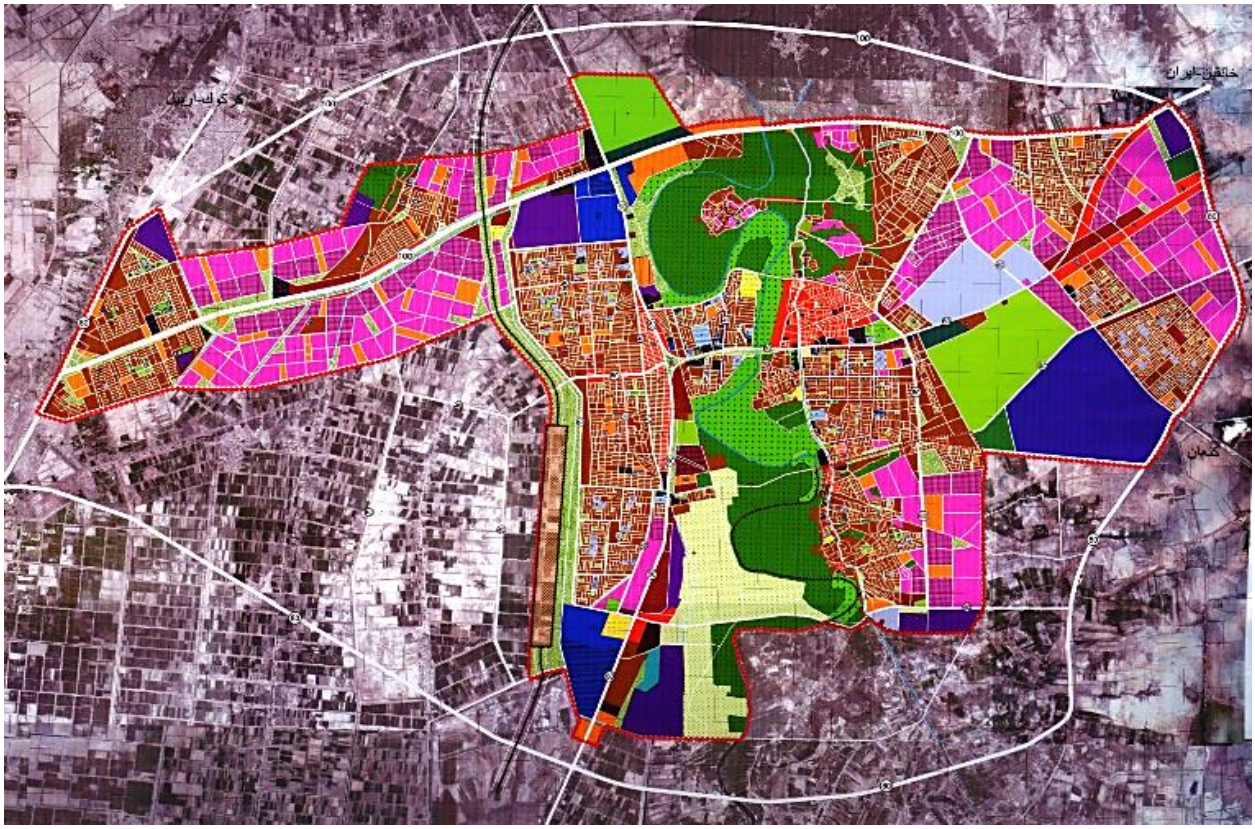
numbering for the year 2019 show that it has 292866 inhabitants. According to the map 1, its astronomical location is between latitudes 33° and 56°35′N and longitudes 44° and 45°56′E, and the search timeframe is between 2003 and 2019. The population of the area was determined using statistical and analytical methods, which led to the analysis of the findings that would help the relevant authorities create future plans for the city of Baquba. In this regard, maps, remote sensing programs, GIS and tables are helped to explain the temporal and spatial change of the population of Baquba.



Map 1. Location of Baquba District in Diyala Governorate

Location

One of the key pillars for identifying the city's inhabitants is the study of the area. Studying a place's geography gives one the chance to evaluate the social, political, and economic relationships that unite its center with its environs (Logan et al., 2007; Goodfellow, 2017).

The district of Baquba has shared borders with the districts of Khalis and Muqdadiya from the north, and with the districts of Muqdadiya and Baladruz from the east, while the district of Al-Mada'in in Baghdad governorate forms its southern borders, and each of the districts of Khalis and Adhamiya is its western borders, and thus it occupies the northeastern borders of Baghdad governorate.

The city of Baquba is situated within the region, or its metropolitan region, within the circle of the contiguous region, buffer zone, which has a radius between 11 and 91 kilometers. It is close to the capital of Iraq, Baghdad. The density of the regional highways that connect to Baquba

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and the earlier passage of significant routes from them, which connect Iraq with Iran and Asia and assisted the city's growth and development, both illustrate the significance of the city's location.

Position

The position gives information about the natural characteristics of the region or area where the city is located, such as the surface, terrain's topography, slope, geological composition, soil, water resources, local climate, and other geographical features like volcanoes and earthquakes (Navalgund et al., 2007). Therefore, there is a direct relationship between the characteristics of the location and the population growth of the city of Baquba. The spatial characteristics are also one of the most important factors affecting the population expansion of the city (Ford, 1999).

City topography

Diyala River is the most important geomorphological phenomenon within the location of the city of Baquba, located on its two sides. As a result of the flatness of the surface, river bends and turns. In general, the gradient of the land starts from the two edges of the Diyala River and Saria Stream and then decreases away from them and at a height ranging between 20 m to 22 m above the sea level, except for a small area that represents the nucleus of the old city located on both sides of the Saria stream at a height of 11 m above the sea level. The reason for the gradual rise in this way is due to the large number of river sediments that lead to the rise of the two edges of the river from the surrounding lands.

When observing the axes of urban growth in the city, the topography of the site had no influence in determining its directions. However, it was important to analyse the effect of human factors in some directions. Due to its position or strong agricultural production as well as the existence of other determinants of special uses (the camp) from the eastern side, the city is surrounded by orchards in significant portions at high prices. Due to the lack of natural or human determinants on the western side, urbanization and population growth there occurred more quickly than on other sides, especially in the direction of the arterial route that connects the city to Baghdad via its old and new lines.

The climate

Due to its direct impact on human organic processes as well as its indirect effects, which are reflected in the quality of soil and the growth of natural and agricultural plants, climate is one of the natural factors that affects the geographical distribution of the population and the variation in their density (Burton, 2000, Dodman, 2009; Richards et al., 2019). In light of the various climate factors, we shall emphasize the factors that affect population distribution most significantly, namely temperature and rainfall. The pace of temperature change varies between the summer and winter seasons since the temperature in the Baquba district is often defined by its rise in the summer and its low or (moderate) level in the winter.

The Baghdad and Khalis areas were considered in this research as they are closer to the study area with a considerable difference in their climate.

According to Table 1, the average high temperature during the warmest summer months is 41.6 ºC in Baghdad and Khalis while the average low temperatures are 25.5 ºC and 25.8 ºC in

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Baghdad and Khalis, respectively. Furthermore, the average high temperatures during the coldest winter months in Baghdad and Khalis are 19.1 ºC and 18.85 ºC, respectively. However, the average low temperatures during the coldest winter months in Baghdad and Khalis are 7.6 ºC and 7.35 ºC, respectively. Table 1 also shows the average rain in Baghada and Khalis with annual rates of 11.0 mm/s and 11.64 mm/s, respectively.
The rainfall in the district of Baquba has characterized by continental and seasonal, as it reaches its peak in the months of January and December, and they are absent in the summer. Thus, it can be stated that the fluctuation of rainfall is clear.

Table 1. Monthly and annual averages of temperature and rain in Baghdad and Khalis for the period 2003-2019

Month	High and low temperatures ºC		Rain mm/s	
	Baghdad	Khalis	Baghdad	Khalis
January	16.1/5.5	16.1/5	22.86	25.4
February	18.8/7.2	18.3/7.2	22.86	22.86
March	23.8/11.1	23.3/11.1	20.32	22.86
April	30.5/16.6	30/16.6	15.24	15.24
May	36.6/22.2	36.6/22.2	5.08	5.08
June	41.6/25.5	41.6/25.5	0	0
July	44.4/27.7	44.4/28.3	0	0
August	43.8/26.6	43.8/27.2	0	0
September	40/23.3	40/23.3	0	0
October	32.7/17.7	32.7/18.3	7.62	7.62
November	23.8/11.1	23.3/11.1	17.78	20.32
December	17.7/6.6	17.7/6.1	20.32	20.32
Annual rate			11.00	11.64

Source: Ministry of Transport and Communications, General Authority for Meteorology, Climate Division. 2019

Soil
There are various different types of soil in the Baquba district, including the coarse-textured, low-saline soil found along dams and riverbanks. Geographically speaking, these soils can be found in the Al-Aabara, Baquba, Center, Buhrz (Eshnuna), and Bani Saad districts. River shoulders soils are the second category. They are also known as high river banks soils. Both Baquba (the center) and the Bani Saad district, as well as the Al-Aabara district, have these soils dispersed along confined stretches of the Diyala River channel. The third type of soil in the study area is the basin soil. This type of soil is the most prevalent throughout the study area due to its low relative height to sea level.
Regarding the basin soils, they are found in the lowest portions of the study area's lands and remain uncultivated due to their high saline content. These soils are located in areas with little population of Baquba's center, in the southern and central portions of the Canaan district, and on the southern edges of the Khan Bani Saad district.

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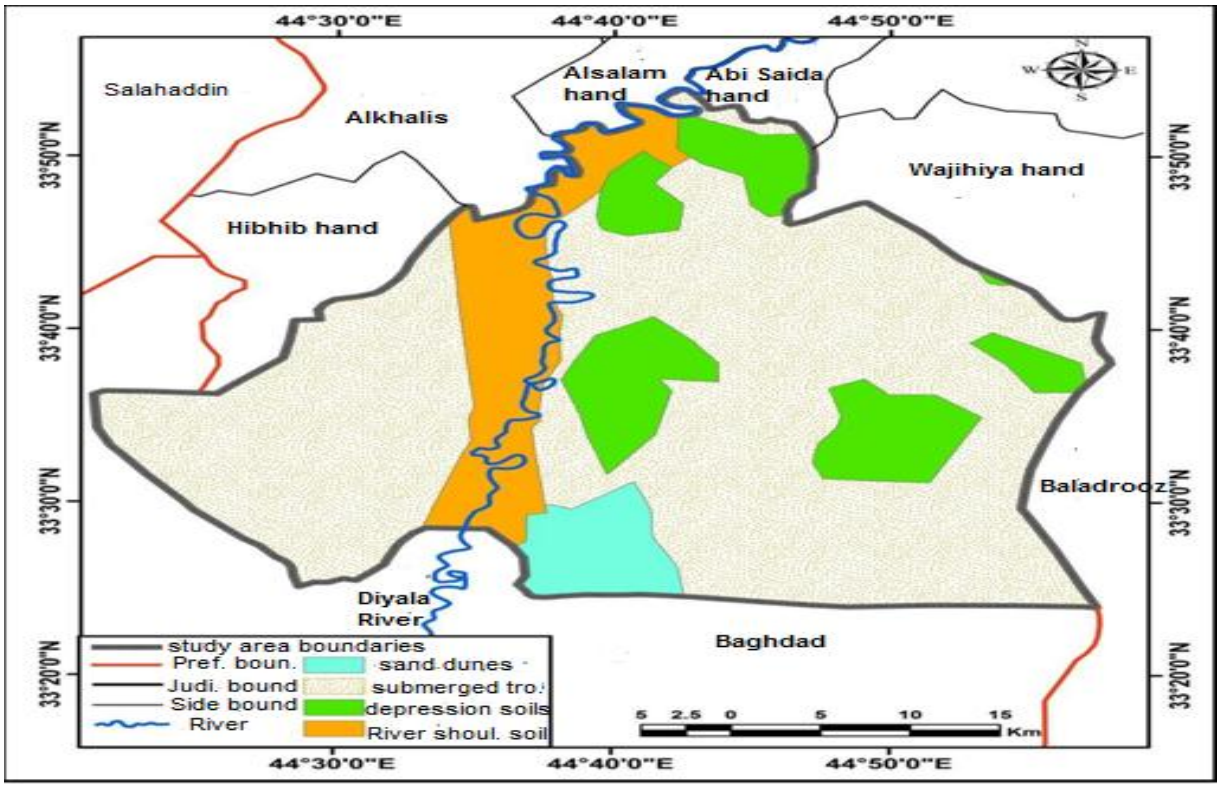
The last type of soil is sand dunes. This type of soil is considered to be of little prevalence in the study area, as its presence is confined to the far south of Baquba district, specifically in the south of Buhraz district, as shown in Map 2.



Map 2. Distribution of soil types in Baquba District (Buringh, 1960)

Information sources and modelling side

Remote sensing

The term "remote sensing" refers to a technology technique for learning about an object's properties without coming into contact with it (Aggarwal, 2004; Patra, 2010, Campbell and Wynne, 2011; Ma et al., 2019). Due to its continuous updating, high accuracy, and vast monitoring areas—which are carried out by satellites, planes, balloons, and other means around-the-clock—as well as the accuracy of its data, which can reach (10) meters in the French satellite and (2) meters in the Russian satellites—its data is of great importance to the GIS.

The remote sensing means are as follows;

A- Digital satellite images that are stored on magnetic tapes or discs and arrive at the main station. Large numbers of these photographs can be identified as having been captured on high-sensitivity photographic film.

B- Aerial images: These images are characterized by accuracy, as they can improve the accuracy of images of satellites if they are linked, but the monitoring area is relatively small.

C- Digital camera images: Compared to satellite images, cameras record images that are acquired in digital form, much like in photographs of satellites. It is one of the modern

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methods that may be employed from a close distance for the objectives of scientific research. The high cost of these cameras, however, still places some restrictions on this strategy.

D- Data from the Global Positioning System (GPS) is a cutting-edge technique for precisely determining locations and their height above sea level. It is connected to a sophisticated system that is one of many satellites launched for this purpose.

After performing a large number of operations on these images in order to interpret, correct, process, and upload them in different ways, we can obtain specialized maps bearing classifications that serve the study's objective from all of these remote sensing methods. The resulting set of maps constitute a significant and wide-ranging base in the GIS.

Specialized maps

The system's database is populated with the topographic maps, land uses, vegetation coverage, residential areas, and political and administrative borders through direct numbering, and the measurements and projections are then united into a single scale and projection system. The geographic information system offers excellent facilities in this area, starting with the entry's precision and fluidity and continuing with the ability to convert between various scales and projections that are widely used. The system can also turn many of the numbered maps created by other computer systems into databases, giving it access to all of the data that is currently available.

Modelling equations of population expansion

First, the population size for a hypothetical year can be estimated using vital statistics and immigration records. This requires the collection of the following data;

- The size of population during the last year,
- The number of deaths for the same period.
- The volume of inward emigrants for the same period.
- The volume of immigrants abroad for the same period

After collecting these data, the following equation is used

$$Population\ size\ (for\ a\ specific\ year) = (births\ size + population\ size\ for\ the\ previous\ year - deaths) + (internal\ migrants - migrants\ abroad \quad (1)$$

It is useful to extract the natural increase rate due to its relationship to the population fertility rate and the population mortality rate. This in turn would identify the impact of migration on obtaining high or low growth rates, positive or negative. The natural increase rate for any society is represented in Eq. 2

$$Natural\ increase\ rate = Crude\ birth\ rate - Crude\ death\ rate \quad (2)$$

The crude birth rate and crude death rate are calculated using the following equations

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$$Crude\ birth\ rate\ = \frac{Birth\ size\ in\ a\ given\ year}{Population\ in\ the\ middle\ of\ the\ year}\ x\ 100$$
$$Crude\ death\ rate\ = \frac{\text{Amount of deaths in a given year}}{\text{Population in the middle of the year}}\ x\ 100 \quad (3)$$

Second, the annual increase percentage (the percentage of change) can be estimated using census data. This percentage measures the ability to calculate the population change that occurs in population growth (increase or decrease), due to the natural and spatial movements. The annual increase percentage (r) is calculated using the following equation.

$$r = (\left(\frac{P_1}{P_0}\right)^{\frac{1}{n}} - 1) \quad (4)$$

P_1 and P_0 are the post census and previous census, respectively. n is the number of years between the two plurals.

Spatial analysis

GIS has provided many tools and functions in the field of data analysis and networks. Data Analysis can be identified as the collecting spatial data of sites and comparing the visuals in a different time period. A number of satellite images of the city of Baquba were taken for different years between 2003 and 2019 and the change in urban expansion was noticeable due to the erosion of green areas and the random fragmentation of housing within the neighborhoods residential, high-density and commercial. Maps 3 – 5 are the satellite images of population growth of the city of Baquba and its suburbs for 2003 and 2019 after conducting a spatial analysis in the Arc Map GIS program from the drawing operations to determine the areas of lower density, higher density and medium density.

Map 3. Distribution of the population with the lowest density by regions of Baquba between 2003 and 2019 by GIS

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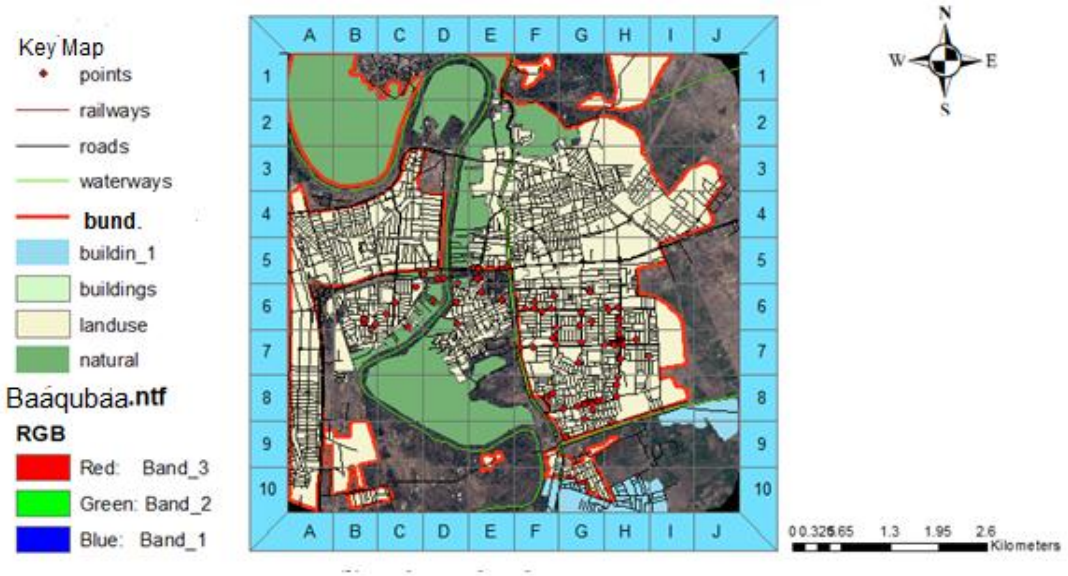
Map 4. Distribution of the middle-density population by regions of Baquba between 2003 and 2019 by GIS



Map 5. Distribution of the population with the highest density by regions of Baquba between 2003 and 2019 by GIS

Demographic analysis

Based on the model equations of the population expansion (described in section 8.3), Table 2 shows the change in the population distribution and detect the pattern of population distribution in Baquba. Table 2 also shows the fluctuation in the annual growth rate of the population of the neighborhoods of Baquba district. It can be stated that the population of Almuealimin' neighborhood has increased from 18,978 in 2003 to 27,728 in 2019. This increase is attributed to the increase in the proportion of expatriates working in agriculture in particular. Also, this increase can be attributed to the impact of the Diyala University that attracts residents from the province and from outside Baquba to move around as well as expatriates to work in the

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Almuealimin neighborhood, which causes the population growth. The same incline trend of population growth was also concluded in other tested areas of Hittin, Al-Sawamra, Shafta, Altahrir Alawlaa, Altahrir Althaania, Baquba Aljadida, Mafraq and Yarmouk. On the other hand, the population sizes of Altakia Alawlaa and Altakia Althaania have decreased from 7,413 and 123,438 in 2003 to 5,198 and 15,025 in 2019, respectively. Alsaray has also witnessed the same decline of population size where it decreases from 5,221 in 2003 to 4,636 in 2019. This is due to the migration of residents to other neighborhoods, especially the Baquba Aljadida neighborhood to take advantage of living close to the Diyala University.

In the context of population size, Table 2 shows the highest population gathering reached in 2003 in the center of Baquba in the Altakya Althaania, where the center appears crowded or overcrowded with points. However, the number of population has decreased as people move away from the center in 2019. Map 3 introduces the same fact as the high population density away from the center.

The clear imbalance of population size in the Altakia Althaania area from 2003 to 2019 (Table 2 and Map 6) would introduce the intensity of people to migrate from the centre and live in specific areas around the agricultural line. The Altakia Althaania area characterises by the deterioration of health services, shortage of doctors of many specialties, especially pediatricians and obstetricians, besides the increased of water and air pollution due to its proximity of brick production factories and poultry factory. These are the main sources of the hazardous waste dump, which in turn affects the vegetation cover in the region.

Almuealimin neighborhood has got the second highest population density after the altakia althuania compared to the rest of the residential neighborhoods in 2003. This is due to the high number of immigrants from other governorates and regions within the governorate to work and study at Diyala University, in addition to the availability of services and ease of transportation, where the University of Diyala contributed to revitalizing the commercial movement, and positively affected the increase of projects, which worked to revitalize the economic movement in the region in general. The large urban expansion has led to the residents' desire to settle in the Almuealimin neighborhood due to the services it provides.

The Hittin neighborhood showed a noticeable increase in population density from 2003 to 2019, and this can be seen by comparing the dotted of map 3 for the specified years, which is due to its being an agricultural area, and the focus of attention for job seekers from the region and expatriate workers to work in agriculture. In addition, the presence of agricultural products companies aids to attract the movement of people towards the Hittin.

Al-Saray neighborhood showed a decrease in population density in 2019 compared to 2003, and this may be due to the region's lack of many services, especially the paved road network to facilitate the residents' access to their lands. This district has witnessed an external migration towards other residential neighborhoods, especially Baquba Al-Jadida and Almuealimin.

Yarmouk district showed a high population density for 2019 compared to 2003. This can be ascribed to the availability of large areas of agricultural land, and the dependence of its inhabitants primarily on agricultural activity. Expatriates from outside the governorate had a significant impact on the demographics of Baquba district and its high densities, as the number of registered expatriate workers reached 12,678 in 2019.

Most importantly, Table 2 presents the annual growth rate for the selected areas. Altahrir Alawlaa has the highest annual growth rate of 17.94 people and 14.75 people in 2003 and 2019,

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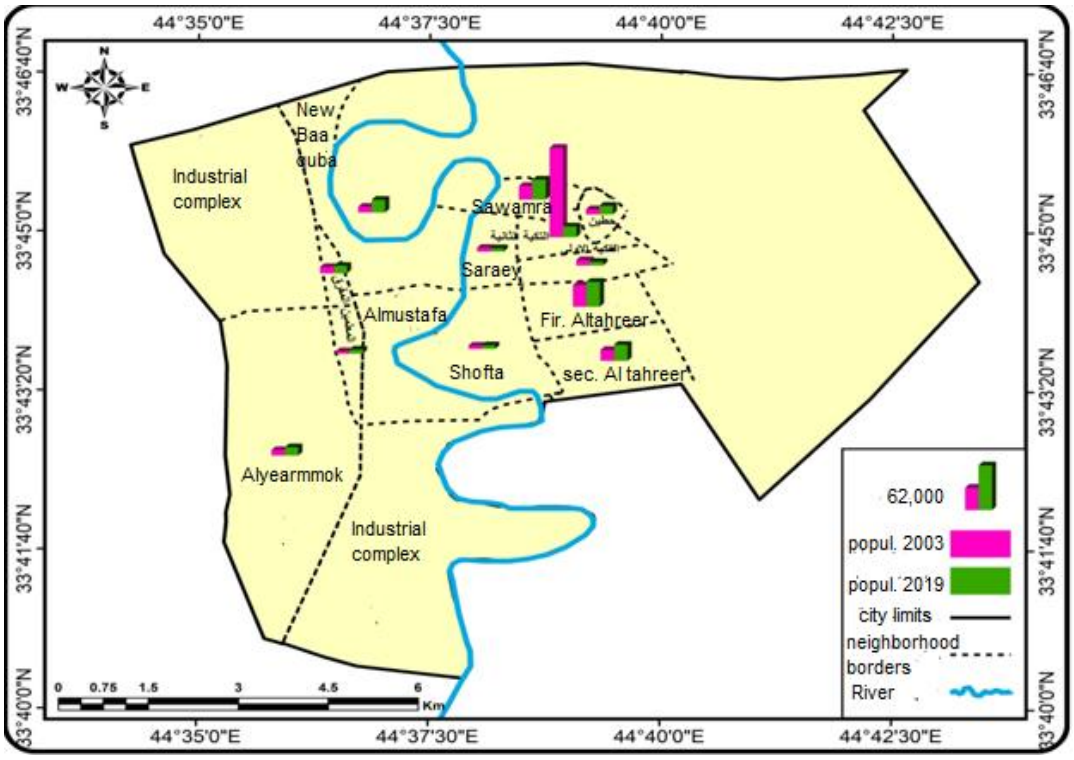
respectively. However, the population growth rate was almost equal around 4.5 people in the residential neighborhoods of Altakia Alawlaa, Hittin, Baquba Aljadida, Mafraq, and Yarmouk. The other neighborhoods of Alsaray, Swamarah, and Shafta have has the lowest population growth rate of 2.6 people.

Table 2. Population of the neighborhoods and of the city of Baquba for the years 2003-and 2019

No.	Residential Neighborhood	2003 Census	Annual growth rate	Residential Neighborhood	2019 Census	Annual growth rate
1	Altakia Alawlaa	7,413	4.38	Altakia Alawlaa	5,198	2.32
2	Altakia Althaania	123,438	7.38	Altakia Althaania	15,025	6.23
3	Alsaray	5,221	2.57	Alsaray	4,636	2.98
4	Hittin	7,289	4.31	Hittin	12,178	4.98
5	Swamarah	3,369	2.91	Swamarah	5,748	2.56
6	Shafta	4,498	2.67	Shafta	5,088	2.28
7	Altahrir Alawlaa	29,932	17.94	Altahrir Alawlaa	34,521	14.75
8	Altahrir Althaania	15,268	8.45	Altahrir Althaania	22,471	9.48
9	Baquba Aljadida	8,017	4.73	Baquba Aljadida	17,684	7.39
10	Mafraq	8,896	4.72	Mafraq	10,554	4.47
11	Almuealimin	18,978	10.63	Almuealimin	27,728	11.78
12	Yarmouk	7,564	4.85	Yarmouk	11,529	4.70



Map 6. Population distribution of Baquba district

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Lorenz curve

The Lorenz curve was used to explain the population density in Baquba district during the years 2003 and 2019, and to reveal the extent of the balance between the population ratio and area in each district. In other words, the Lorenz curve is to measure the inequality between the population ratio and area (Cromley, 2019). The inequity increases as the curve gets farther from the bisector.

Fig. 1 depicts the Lorenz curve for population distribution (horizontal axis) and its relationship to area (vertical axis) in the study region by calculating the difference between the ideal theoretical distribution and the actual distribution of the population over the area. Furthermore, the line of equality (45º) is represented in Fig. 1. It should be emphasized that there is a difference between the population's ideal distribution and its actual distribution. It is clear from the Lorenz curve that approximately 49% of the population is concentrated on more than 28% of the total area of the governorate. Also, 94% of the population is concentrated in an area that does not exceed 70%. These percentages are relevant to the years 2003 and 2019.

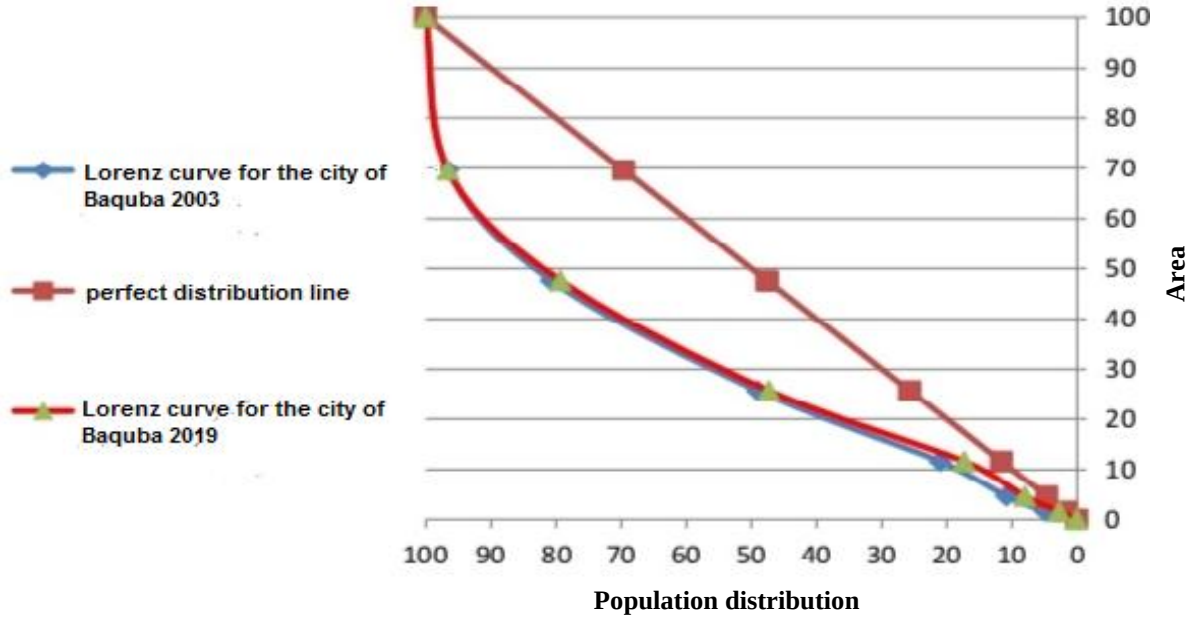

Fig. 1. Lorenz curve for the population distribution of Baquba district for the years 2003 and 2019

The results above would raise a number of issue and therefore, the following recommendations are stated below;

- Ensuring the equitable distribution of institutions and services across the governor's territories, preventing the concentration of services in remote areas. This might help redistribute the population throughout the governor's domains and prevent individuals from traveling across the governorate to places where services are concentrated.
- It is crucial to pay more attention to places where there is a concentration of people, particularly in the Baquba Al-Jadida district, where the population density increased since

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the last census. Due to the heavy traffic in this area, it is important to pave all interior roads and create a system to collect rainwater.

2. CONCLUSIONS

This study aimed to analyse the population density and related geographic distribution in the Baquba district over the years 2003 to 2019 while outlining the primary causes. Based on a model equation for population growth, spatial analysis and demographic analysis were conducted. The intensity of the population density was also explained using the Lorenz curve. The results indicated a clear discrepancy in the population of different sectors at the governorate of Diyala from 2013 to 2019. Specifically, a number of these sectors close to the centre were noticed a decrease from 2013 to 2019 compared to other sectors away from the center which elaborated a clear increase. The data analysis of GIS maps ascertained this fact as the people intend to migrate from the centre and live in specific areas around the agricultural line. Statistically, it has been ascertained that the population size of Baquba district has increased from 8,017 people in 2003 to 17,684 people in 2019. Likewise, the Al-Mealimin district has the second place where the population size increase from 18,978 people in 2003 to 27,728 people in 2019. On the other hand, the population size of Altakia Althaania district has decreased from 123,438 people in 2003 to 15,025 people in 2019.
The Lorenz curve method showed that the concentration of the population based on their densities in the Baquba district is unequal. For the years 2003 and 2019, it was concluded that more than 28% of the governorate's total territory is occupied by more than 49% of the people. Furthermore, 94% of people live in a region where the population density does not rise above 70%.

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