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(RESEARCH ARTICLE)

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Temporal-spatial monitoring of population growth with RS-GIS technology at Wasit province of Iraq

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Abstract

In this study, the growth rate of the population in a spatial-temporal manner has been modeled and explored by relying on the data from remote sensing and using the analytical functions of the geographic information system in Wasit province of Iraq during the period from 2000 to 2020. WorldPop layers were used to prepare population maps and forecast it in 2025 with the help of artificial neural networks. The predictive model was highly accurate (R 2 = 0.98). The next step was to measure the relationship between the rate of population growth and the changes in water areas and the primary production of vegetation with the help of time series of satellite data, which showed the distribution of the population. It is denser in the central, northwestern and southeastern areas of Wasit province. Low density populations have higher frequency. While from 2015 onwards, the frequency of some population classes with higher density increased compared to lower densities. In general, the trend of changes in the average population in the study area has been completely linear. But the maximum annual population density changes were upward and nonlinear. Changes in the area of deciles representing denser areas have increased and the area of deciles representing less densely populated areas has faced a decrease. The results and findings of this study showed that NPP changes were less predictable compared to population density changes because it is a complex function of climatic and human factors. In the estimated population density map in 2025, dense population cores have been formed in the northeastern areas of Wasit province in the vicinity of the border areas with Iran.

Keywords: Population density map; Wasit province; Population growth rate; RS-GIS

1 Introduction

Knowing the size and distribution of human population is necessary to understand and respond to many environmental, economic, political and social challenges (Wang and Wu, 2010). Among the important aspects that can be mentioned in relation to population changes and centralization: a- Unwanted consequences and side effects that remain over time, such as the destruction of natural resources and forest lands, pastures and agricultural lands, b- Using Targeted and optimal human resources are active in the path of comprehensive and sustainable development based on mutual planning and management of human and natural resources. The main objectives of this study: Investigating the rate of population growth in Wasit province and measuring the correlation between the rate of population growth and changes in natural resources such as water areas and vegetation. In 1900, only 13% of the world's population lived in cities, this proportion reached 49% and 29% in 1950 and 2005, respectively. According to the UN population forecast, this amount will reach 60% by 2030. In other words, out of the 8 billion world population in 2030, about 4.9 billion people will live in cities (United Nations, 2006).

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2 Material and methods

Wasit province is in the eastern border of Iraq with 44.5 to 56.5 degrees east longitude and 31.9 to 33.4 degrees north latitude. Wasit province shares a border with Baghdad province, the capital of Iraq, from the northeast with Diyala province, from the east with Iran, from the southeast with Maysan province, from the south with Dhi Qar province, and from the west with Babol and Al-Qadisiyah (Diwaniyah) provinces. Wasit was called Wasit because it is in the middle of Kufa, Basra and Ahvaz, and it was one of the three big cities of Iraq before Baghdad was built. According to the last census of Iraq in 1997, the population of Wasit Province was reported to be 687,354 people, but currently, based on the statistics announced by the Iraqi Ministry of Commerce (coupons issued in the province), the current population of Wasit Province is estimated at 1,141,000 people. Remote sensing techniques along with images taken from satellites with modern methods of statistical analysis are the materials of this study that have led us to reach the correct result.

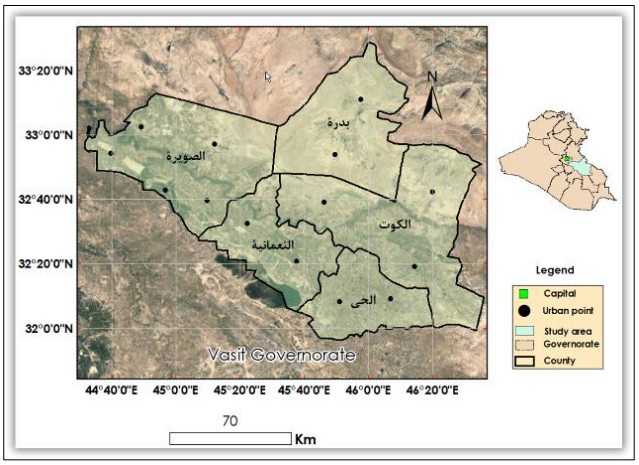

Figure 1 Geographical location of the study area

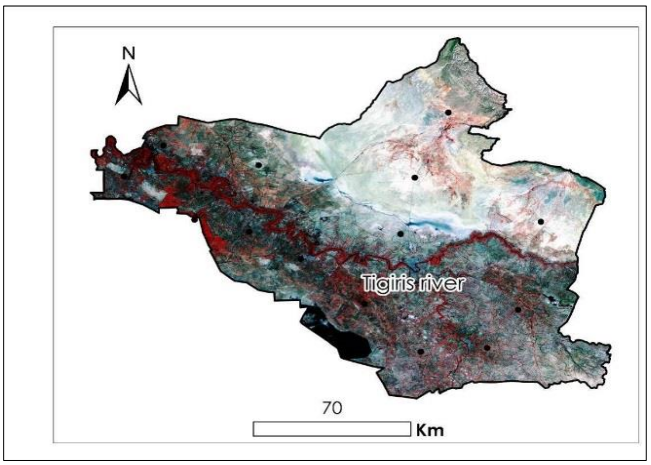

Figure 2 False colour satellite image of Wasit province, obtained by combining bands 5, 4 and 3 of Landsat 8 satellite

In general, the data used in this research fall into four general categories:

- Population density products
- Climatic and altitude layers
- Vegetation time series and Net Primary Production (NPP)
- Satellite images

The first category includes the time series of population data of the world project known as WorldPop, which were received in the form of spatial layers during the period from 2000 to 2020 and were prepared and processed first (Gaughan et al., 2013).

The second category of monthly average information layers of climatology elements including precipitation and air temperature, in the study area from 2000 to the end of 2020. Also, the 30-meter digital elevation model layer or DEM of the study area extracted from ASTER images, in order to display elevation changes and extract The slope map of Wasit province was received and used.

The third category includes time series of Normalized Differential Vegetation Index (NDVI) and NPP products, which are among the products extracted from MODIS images. NDVI time series were received and prepared with spatial and temporal resolutions of 250 meters and 8 days, respectively. While NPP time series with spatial resolution of 250 meters and annual time resolution were used. These layers were studied in relation to demographic changes.

The fourth category includes satellite images and products. Satellite images were mainly used as a background to display other information layers, while satellite products that included time series of NDVI layers and annual volumes of water surface layers obtained from Landsat images were related to the population growth rate of the study area. Were examined.

In addition to the aforementioned data set, data such as Google Earth map service, political, administrative layers and paper maps were used in some data pre-processing processes. Atmospherically corrected Landsat 8 satellite image and 30-meter DEM obtained from Aster images were received and pre-processed for visual display and in other words to be used as background image for the study area.

3 Literature Review

Kodjeo (2007) the process of changes in land cover and land use can be related to population data through population data at the national, district, sector and city levels. Behta (2009) remote sensing data and geographic information system analyzes have a high potential for analyzing urban environment development patterns. In a study, general population estimation methods were categorized into two categories: spatial interpolation and statistical methods. In conclusion, based on that, they estimated the population of residential units. Khai et al. (2015) used LIDAR data to extract residential buildings and then estimate population in non-homogeneous areas. Leo and Herold (2018) investigated the estimation and interpolation of the population of urban areas with the help of remote sensing. They introduced different population estimation methods based on remote sensing data including traditional and modern methods. They acknowledged that population estimation methods based on remote sensing are divided into three general, semi-partial and partial categories.

In a study in 2018, Al-Kaabi (2018) analyzed the spatial distribution of land uses using available maps and data and using GIS tools. Hammad (2019) concluded by using RS-GIS techniques that the changes in urban land use and especially the growth of the road network have been the most important factors driving the physical growth of the study area during the last three decades. Das and Angedi (2021) estimated land use and land cover classes from multi-temporal Landsat images. They concluded that there is a positive correlation between built-up areas and population, which indicates the effect of population pressure for further growth and development of built-up areas. Warde (2020) in a study of the growth of urban limits and areas around the city of Met Salsil in Egypt: considered agricultural land to be the most important obstacle to urban growth and predicted the growth of urban areas in the future based on past historical data.

Hashemi (2017) prepared a population density distribution map of Iran at the city level based on the population and housing census statistics of 2018. The results of his research can be useful in the long-term planning of the country to prepare for earthquakes. Hamim et al. (2020) studied the urban growth of Najaf Ashraf city based on urban land use criteria and considering the vision and effective solutions during a ten-year period by drawing the future time horizon. The most important finding of their study was that in 2017, a large gap was observed between residential and non-residential land, which could help the future growth and expansion of the urban limits of the study area.

4 Results

NDVI and NPP time series: The time series of NDVI layers were obtained from two sources: MODIS products and Landsat images. Each of these datasets had their own limitations and advantages. The images of different generations of Landsat satellites have a rich archive of images (nearly 50 years) that can be used to extract NDVI; Their spatial accuracy is 30 meters from Landsat 5 onwards, however, due to the failure of the scan line corrector (SLC) in Landsat 7 satellite, the continuous coverage of the images in the period from 2000 to 2010 has been problematic. Another data source for preparing the time series of NDVI layers was the NDVI products extracted from Aqua and Terra satellite images.

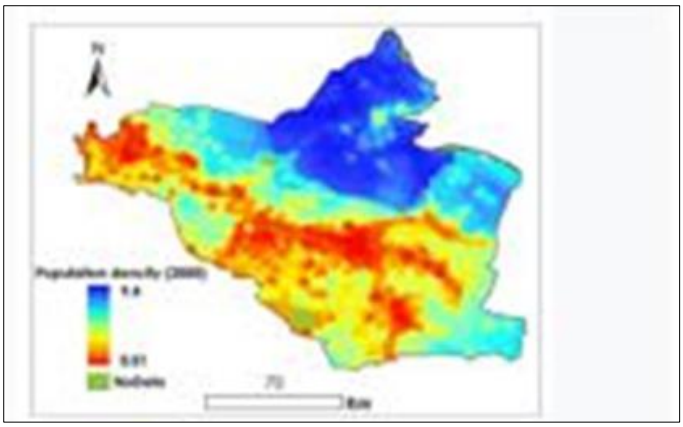

Figure 3 Population density map in 2000

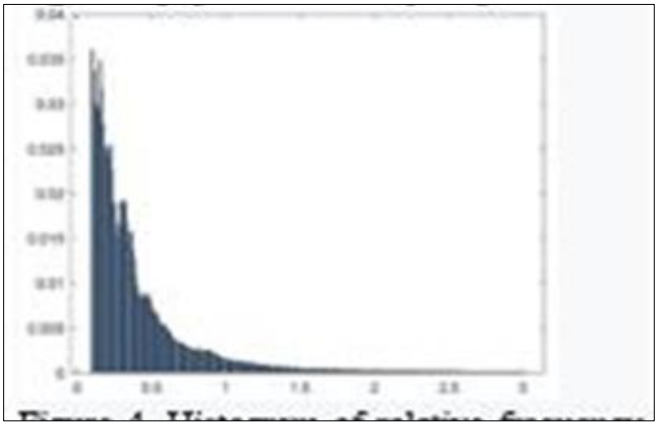

Figure 4 Histogram of relative frequwncy of population density in 2000

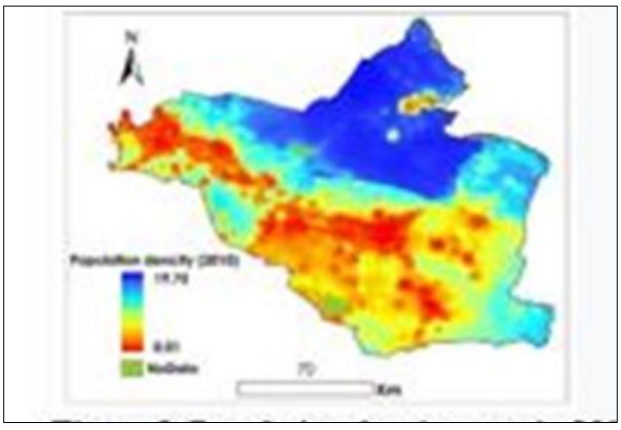

Figure 5 Population density map in 2010

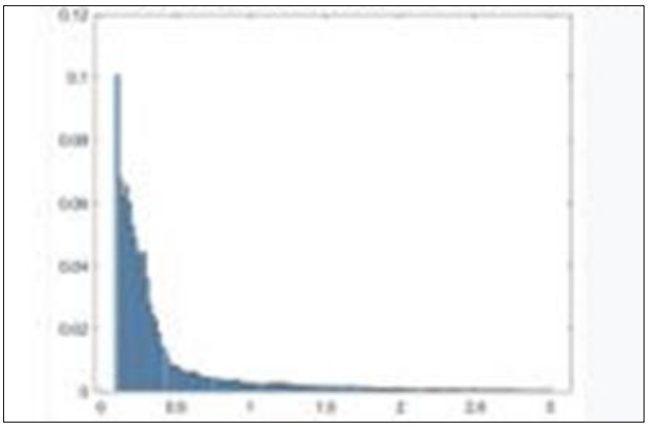

Figure 6 Relative frequency Histogram of population density in 2010

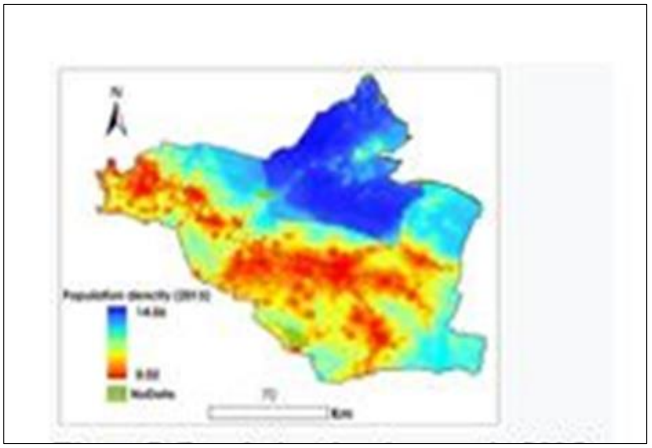

Figure 7 Population density map in 2015

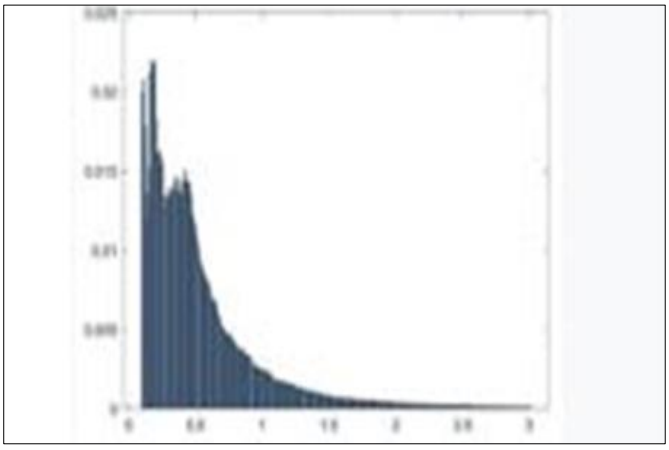

Figure 8 Histogram of relative frequwncy of population density in 2015

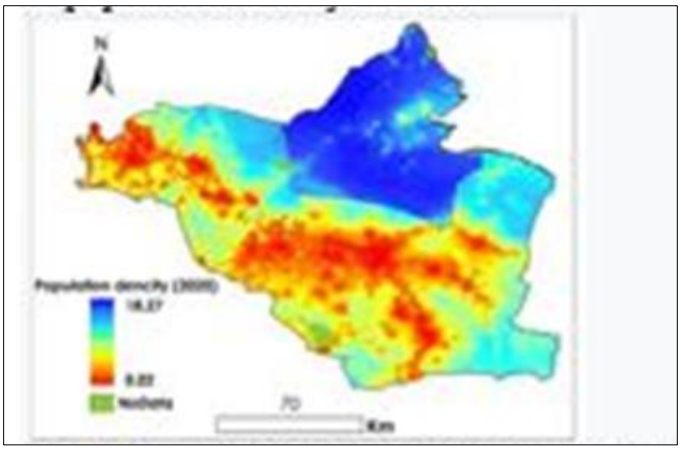

Figure 9 Population density map in 2020

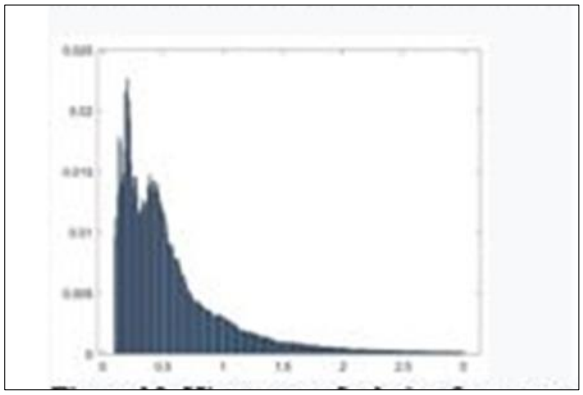

Figure 10 Histogram of relative frequwncy of population density in 2020

In general, the population distribution is denser in the urban centers located in the center, northwest and southeast of the study area, examining the trend of changes in the frequency of population density shows that low population densities show higher frequencies, and in general, the trend of changes in all The frequencies are uniform until 2015. From 2015 onwards, some higher population densities show a higher frequency than lower densities, and this causes the abundance graphs from this period onwards to have several peaks and to deviate from the uniform state of previous years.

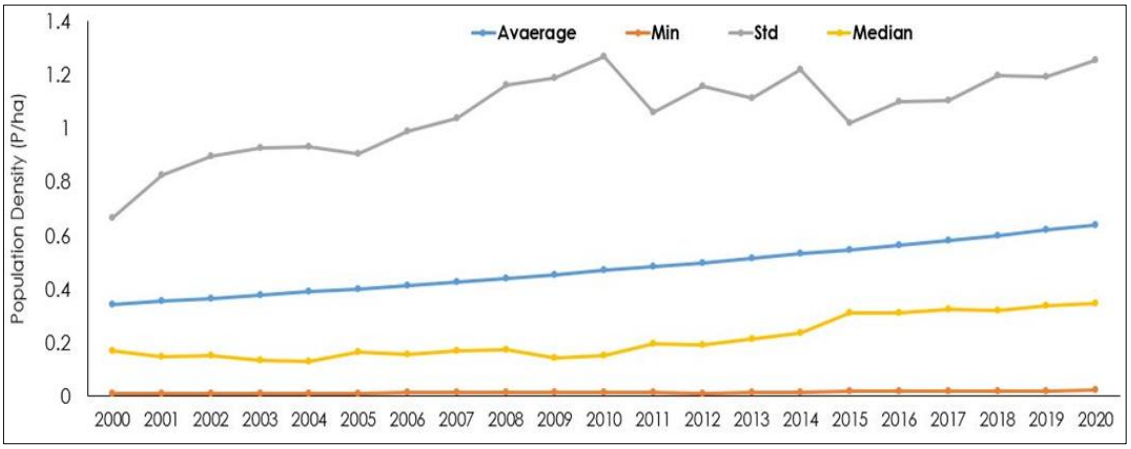

Figure 11 Statistical characteristics of population density in the period from 2000 to 2020 in Wasit province

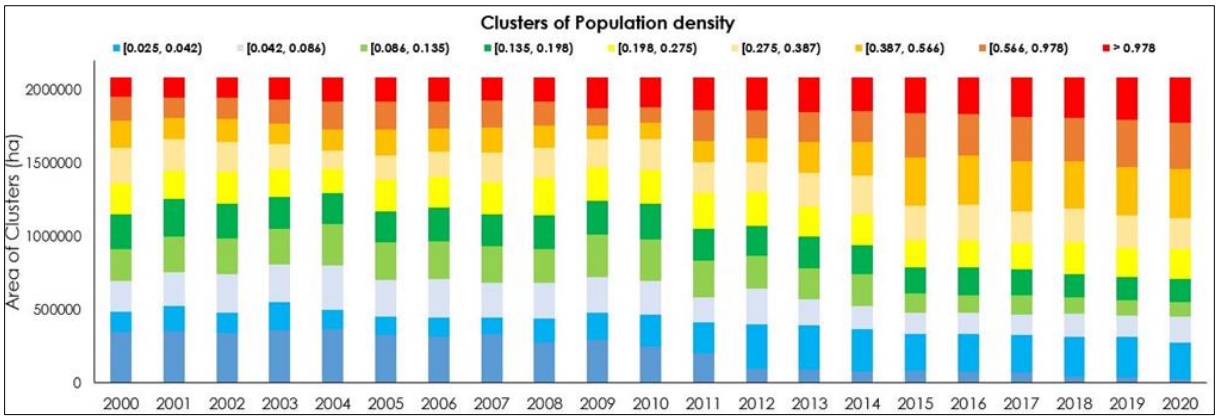

Figure 12 Changes in the area of population density deciles in the period from 2000 to 2020 in Wasit province

Important points related to population density changes in this 20-year period in Wasit province were noticed:

- The area of the 10th decile of population density, which shows dense population areas in Wasit province, has faced a significant increase.
- The area of the first decile of population density, which shows the areas with low population density in Wasit province, has been associated with a decrease in the studied two-decade time period.
- In general, the area of deciles representing denser areas has increased and the area of deciles representing less densely populated areas has decreased.

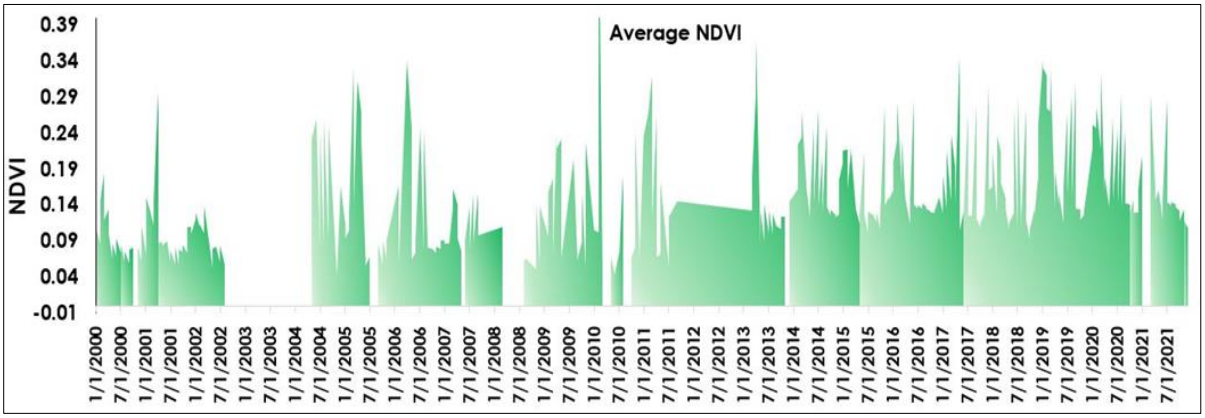

Figure 13 Average NDVI changes from Landsat time series in the period from 2000 to 2020 in Wasit Province

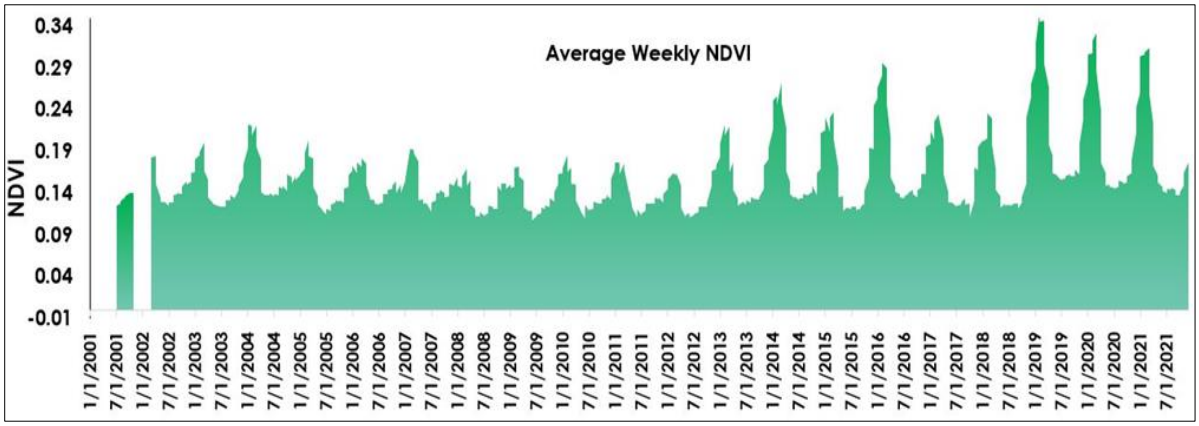

Figure 14 Average NDVI changes from MODIS time series in the period from 2000 to 2020 in Wasit Province

5 Discussion and analysis of results

In many regions of the Middle East and countries such as Iraq, exploitable water resources have always been the limiting factor for the development of areas and population centers. Here, the relationship between these two changes during the two-decade period studied for Wasit province is investigated.

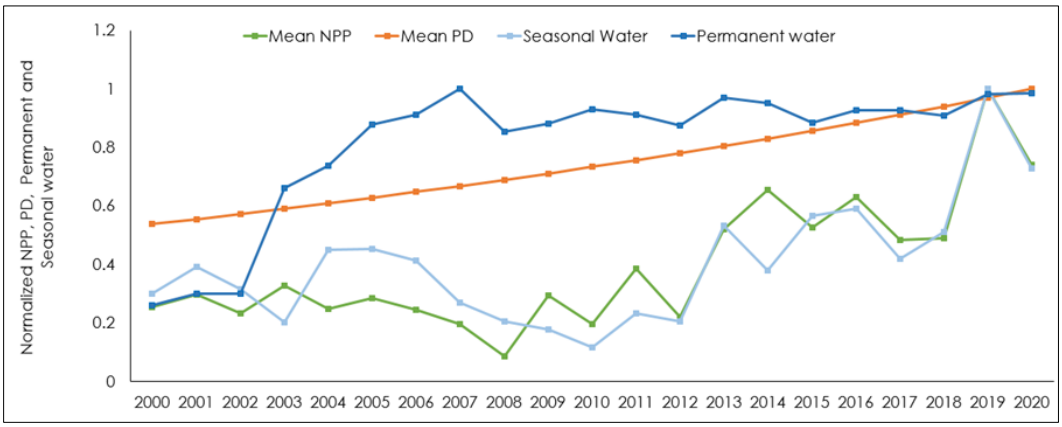

Figure 15 Changes in the normalized average values of surface, permanent water areas, population density and NPP in the period from 2000 to 2020 in Wasit province

The trend of changes in NPP values is better shown as a 2nd degree function with a coefficient of determination (R2) of 0.72. While the trend of demographic changes is completely linear and estimated with R2 0.99. In any case, although the trend of both variables is upward, the NPP changes are less predictable because it is a complex function of climatic and human factors.

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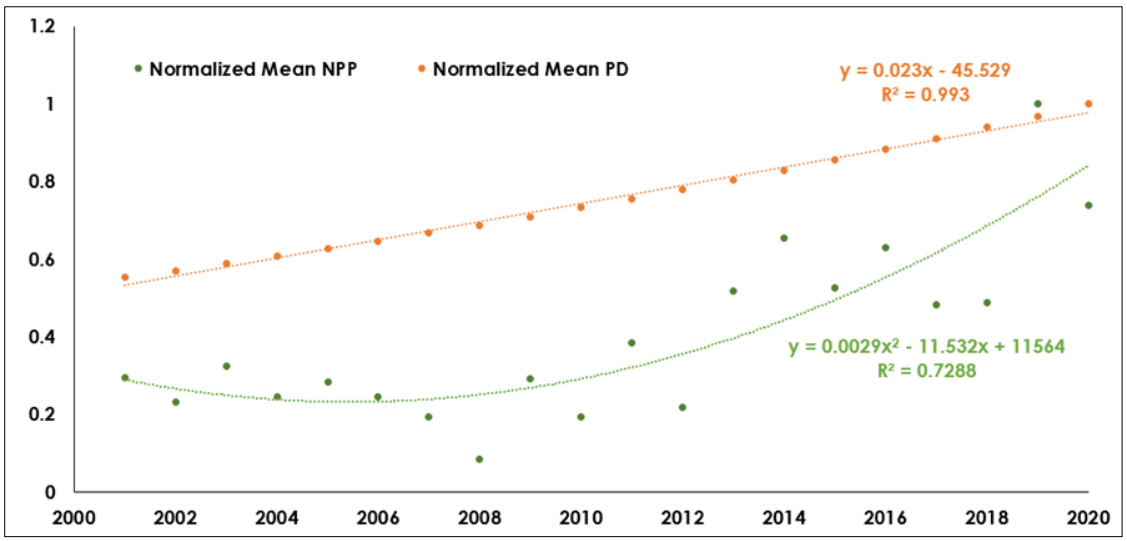

Figure 16 Changes in population density and average NPP values

Figure 16 shows the trend of average changes in population density and area of permanent water areas during the period from 2000 to 2020 in Wasit province of Iraq. As shown in the figure. The trend of changes in permanent water is better shown as a linear function with R2 0.48, and in general, the trend of changes in the area of permanent water has been observed and estimated to be positive and upward since 2002.

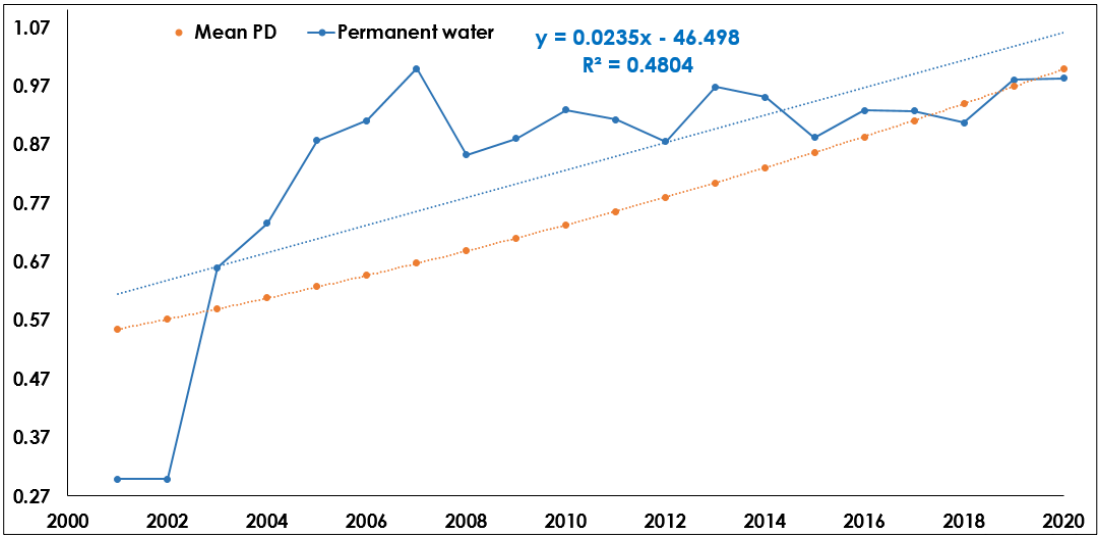

Figure 17 Changes in population density and area of permanent water areas

Finally, Figure 17 also shows the average changes in population density and levels of seasonal water areas during the period from 2000 to 2020 in Wasit province. As can be seen from the figure, the trend of seasonal water changes has shown itself as a 1st degree regression relationship with a coefficient of determination of 0.73. The equation obtained from the fitted line between the points of surface water areas shows that although its changes are strong and positive, its upward slope is not proportional to population changes.

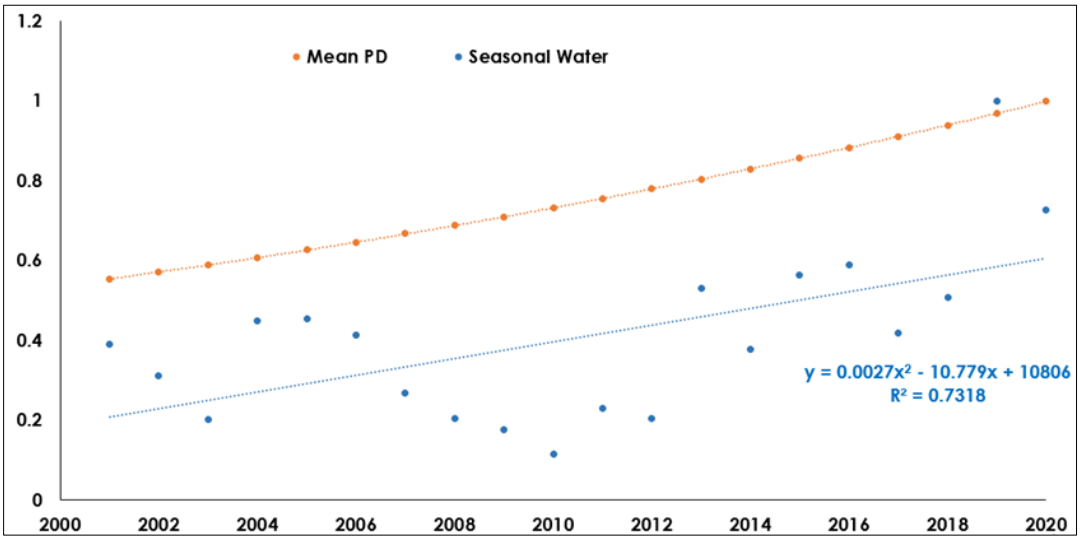

Figure 18 Changes in population density and area of seasonal water areas

Population forecasting: At the end of this section, the forecasting of the population density map for 2025 is discussed based on the population data of the past twenty years and by applying the artificial neural network method.

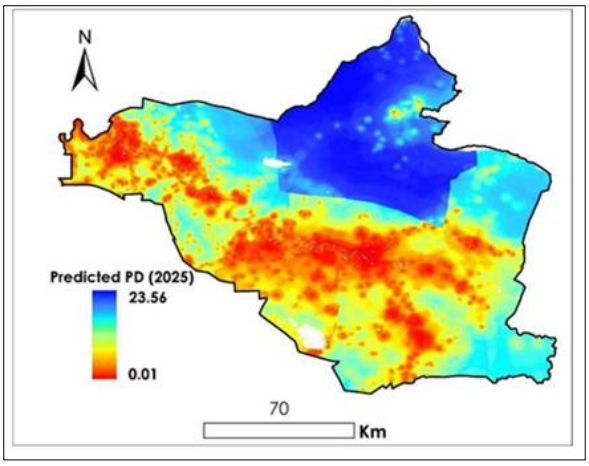

Figure 19 The predicted map of population density in 2025 in Wasit province based on the past trend of population changes and by applying the method of artificial neural networks

The main results and findings of this study are mentioned:

- Population distribution is denser in urban centers located in the center, northwest and southeast of Wasit province.
- Low population densities have shown higher frequencies.
- In general, the trend of population density changes has been uniform until 2015. From 2015 onwards, the frequency of some population classes with higher density increased compared to lower densities; Therefore, many histograms from this period onward have several peaks and are out of the uniform state of previous years.
- The distribution of population changes and its density in Wasit province is different and unique, while the trend of its average changes in the study area is completely linear and has shown an increasing trend with a uniform slope.
- Changes in the maximum annual population density have been generally upward, however, they have not followed a homogeneous and linear trend.
- Changes in the area of deciles representing denser areas have increased and the area of deciles representing less densely populated areas has faced a decrease.
- The change trend of NPP values was shown as a 2nd degree function. While the trend of demographic changes was estimated to be completely linear. NPP changes were less predictable compared to population density changes because it is a complex function of climatic and human factors.
- The process of permanent water changes was better shown as a linear function. The changes in the area of permanent waters did not have a constant trend, however, since 2002, a positive and upward trend has been observed and estimated.
- The trend of seasonal water changes was estimated as a 1st degree regression relationship with R2 of 0.73. On the other hand, the equation obtained from the fitted line between the points of the area of seasonal water areas showed that although its changes were strong and positive, but its upward slope was not estimated according to population changes.
- Forecasting the population density map for 2025 was made possible by using its changes in the last twenty years and with the help of artificial neural networks. The predictive model was highly accurate and its accuracy measurement showed that R2 between the predicted and reference density values was more than 0.98. In the estimated population density map in 2025, the maximum values have shown a significant increase compared to previous years. In addition, dense population nuclei have been formed in the northeastern areas of Wasit province in the vicinity of the border areas with Iran.

6 Conclusion

The result of this research showed that: low population densities have shown higher frequencies. The distribution of population changes and its density in the study area is unique and its average changes were completely linear and had an increasing trend with a uniform slope. While the trend of changes in NPP values was shown as a 2nd degree function.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflicts of interest are declared by the authors.

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