

# Spatial Variation of Rainfall between Nineveh and Basra Governorates due to Terrain Elevation Using Digital Elevation Model–Geographic Information System

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## ABSTRACT

The study discussed the change in the amounts of rainfall falling on two governorates of Iraq, one in the north and the other in the south, differing in topographic elevation. The descriptive analytical approach, drawing inferential maps, and adopting a digital elevation model were used to prove the results. The study aimed to identify the effect of the terrain elevation factor on increasing precipitation. Rainfall and its decrease with the decrease in sea level in the two study areas emerges the importance of using the digital elevation model (DEM) as an analysis tool in building three-dimensional models of terrain phenomena to give a comprehensive survey of the Earth's surface, and this in turn enhances the accuracy of the extracted results as well as demonstrating the capabilities inherent in the geographic information system (GIS) program in dealing with input and analysis. And processing and outputting quantitative and descriptive data. The most important results are that the areas with the highest rainfall, with rain reaching more than 360 mm, correspond to the highest terrain, which reaches a height of 1800 meters above sea level, represented in the areas of the Aqra Mountains Al-Sheikhan Sinjar Makhmour, within Nineveh Governorate. In the second study area, Basra Governorate, we find that the highest elevation areas are located within the desert range of the Western Plateau and Hafr Al-Batin Valley approximately 290 m, and it is a land of lime, gravel, and sand. Thus, the originality of the scientific fact in this study becomes clear to us, which is the decrease in rain values in these areas that Its averages do not exceed 182 mm, as the anomaly in its precipitation system has become clear, as we find low-lying areas exposed to more rain than areas crossed by a high contour line, due to its rocky and limestone formation, which is located within the desert tongue of the Iraqi Western Plateau region, adjacent to both the states of Kuwait and Saudi Arabia. The scientific value comes from the results obtained in showing the importance of the factor of eroding, which has a clear difference in (two governorates) of Mosul, which has a mountainous nature, and the high eroding and surface features in the Basra Governorate, which has low land, and the role of modern technologies in highlighting the effect of this on the difference in rainfall rates in both.

**Keywords:** topography, DEM, equal height lines, rainfall, climate change.

## INTRODUCTION

The digital elevation model (DEM) is the foundation and basis for deducing and extrapolating information related to the topography of the region. As for the concept of the digital elevation model, it expresses sets of data with a digital representation based on the raster system formula. Each cell (pixel) contains a digital value representing the average elevation. The surface of the Earth in the area

of this pixel. This model uses either the geographical coordinate network, that is, the network of longitudes and latitudes, especially with data that changes and separates due to the curvature of the Earth, or the UTM network is used in the case of a shared data set, if the DEM scale is small. It uses geographic coordinates, and if it is large, it can use any type of them. The research aims to clarify the effect of the erosion factor in some areas of Iraq and its reflection in the rates of rain falling in an

area that is affected, such as Nineveh, and another that is relatively flat and low, such as Basra. The research does not represent a means of predicting rain fall, but rather relying on weather data and with the help of satellite visuals to diagnose lines of equal elevation to show the results. It was produced in the form of a geographical map using the information system (GIS) program, and thus it is a new comparative study in Iraq.

Our study was a continuation of what other researchers had begun, including a study (Valipour et al, 2023) to predict rainfall using three artificial intelligence models for one, two, or three days in locations with different climates in the United States of America in 28 locations. The study concluded that the prediction was consistent. Between observed precipitation and expected precipitation, advanced studies have been used in this scope by adopting high-resolution digital models to correct Landsat images in particular to avoid the difficulties of mountainous areas and their differences in heights (Franks and Rengarajan, 2023) and to discover their impact on climate elements, and a study (Alam (et al, 2021), which explained the role of climate change in the variation of rainfall at selected stations in Pakistan using non-parametric techniques, was able to determine climate-induced changes in the direction of precipitation and expected temperatures at three stations using the Mann-Kendall test and the Sen slope, and a study indicated (Abdulkareem, et al, 2020) indicates the possibility of extracting spatial information with less time and effort using the indentation model, as (Ruzinoor, et al, 2012) explains the representation of the terrain in a three-dimensional (3D) form by expressing the third dimension in terms of (X, Y, Z), which helps in the possibility of seeing the true surface of the Earth as it is in nature. The amount of height determines the rainfall. Finally, one of the recent and applied studies dealt with the digital elevation model in obtaining the truth about the impact of the Earth's terrain on various aspects of life, relying on geographic information systems, including A study (Goodchild and Haining 2004) on the quality of applied systems in GIS to provide important information about ground elevation, that is, monitoring the environment and predicting its renewable changes, including rain values.

## **MATERIALS AND METHODS**

The research relied on a digital elevation model by identifying a number of sites in the two study areas, making a comparison between them, and extracting them into digital maps using a geographic information systems program, as well as drawing maps of equal elevation for both of them, and then matching them with maps designating rain regions in each region. The use of meteorological data was used. Iraqi and Seismic Monitoring Department, Iraqi Center for Agricultural Meteorology, <https://www.agromet.gov.iq/eng/index.php>, to accurately determine rainfall rates and then conduct scientific analysis of the results and data of digital models with rainfall values according to the Terrain factor in the two study areas.

### **Problem statement**

The scientific method of the study dealt with asking the question, which is considered the main motivation for the research, as the clear definition of the problem means arriving at half the solution, and the main problem revolves around do rainfall values vary spatially due to the terrain elevation factor between Nineveh and Basra governorates using DEM-GIS techniques. A number of secondary problems arise from it, as follows:

1. Do rainfall amounts vary spatially and temporally according to the data of the digital elevation model (DEM) in the two study areas?
2. Does the difference in the factor of erosion affect the variation in the geographical distribution of rainfall according to the contour maps and the map of the rainfed regions in the two study areas?

### **Study hypothesis**

Hypotheses are expectations made to know the connection between causes and effects, and when they are proven to be true, they are a general law that can be referred to in explaining all relevant phenomena. The main hypothesis is modified into (rainfall varies spatially due to the terrain elevation in the Nineveh and Basra governorates, with differences in DEM results, contour lines, and GIS maps accordingly). A number of secondary hypotheses emerge from it, as follows:

1. A spatial and temporal variation appears in the amounts of rainfall falling in the two study

areas, due to the surface topography in each of them and according to what was indicated by the data of the model used in the research.

2. The terrain elevation characteristic affects the variation in the geographic distribution of rainfall in the two study areas by using the outputs of the DEM model, the contour line, and GIS maps.

### The study area boundaries

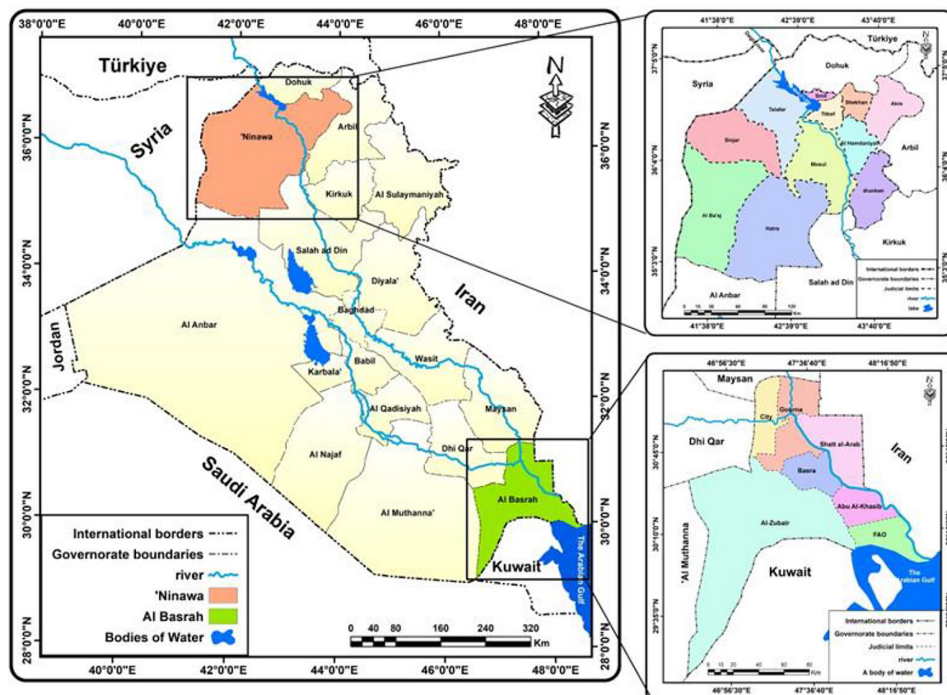
The study area is represented by the governorates of Nineveh and Basra, as Nineveh is located between two latitude circles ( $34^{\circ}55' - 37^{\circ} 3'$ ) to the north, and between two longitudes ( $41^{\circ}25' - 44^{\circ}25'$ ) to the east. Geographically, it is located in the northern and northwestern part of Iraq. It is bordered to the north by Dohuk Governorate, to the east by Erbil and Kirkuk Governorates, to the south by Salah al-Din and Anbar Governorates, and to the west by the Syrian Arab Republic. Its territory also occupies part of the mountainous and undulating regions in Iraq. Basra Governorate is located in the southernmost part of Iraq, and extends between two latitude circles ( $29^{\circ}05' - 31^{\circ}20'$ ) north, and longitudes ( $46^{\circ}40' - 48^{\circ}30'$ ) east, Geographically, it is bordered by the provinces of Maysan and Dhi Qar to the north, the Iraqi-Iranian border to the east, the Iraqi and Kuwaiti borders,

and the Arabian Gulf to the south, and Muthanna Governorate to the west (Al-Kinani and Ajeel, 2021), Figure 1, and its territory occupies part of the Iraqi alluvial plain and the Western Plateau regions Desert.

## ANALYSIS AND RESULTS

### Analysis and simulation of the digital elevation model in Nineveh Governorate

The topography of an area refers to the shape of the Earth's surface, which is described by its elevation, slope, and aspect, among other features, Topographic conditions determine the energy flows that transport water and energy from higher to lower elevations, such as how much solar energy will be received or how much rain will affect the area. During the calculation of the digital elevation model, which is an indicator of the Earth's topography on a large scale (Bora, et al., 2021). The terrain greatly affects the estimation of the value of weather and climate elements for any region in the world, as the surface of Nineveh Governorate is characterized by variation in its topographical characteristics from one region to another, as its surrounding by highlands and high



**Figure 1.** Administrative map of Iraq, including the governorates of Nineveh and Basra. Source: Republic of Iraq, Ministry of Water Resources, Directorate of Public Survey, Map Production Department, Administrative Map of Iraq, Basra and Nineveh, at a scale of 1,000,000:1, Baghdad, 2023

mountain ranges has influenced the determination of the direction and paths of the winds and air depressions. The Tigris River also penetrates the governorate in a zigzag manner from Northwest to southeast, dividing it into two parts, an eastern section that is characterized by being higher because it extends within the high mountainous region, and a western section, the greater part of which extends in the undulating region (Nafea, 2022). Figure 2 shows the distribution of ground elevations in Nineveh based on the analysis of the digital elevation model. The highest elevation areas (mountainous areas) are found using the DEM program in the northern, northeastern, and northwestern parts of the governorate, which are dark brown in color, as their elevation ranges between (895–1879 meters above sea level, which is the most abundant in rain for the administrative units in the governorate. It includes the regions of Akre, Al-Sheikhan, Sinjar, and an area to the southwest of the governorate called Dokan, where Mount Makhmur is located. As for the very low-lying areas, they are represented by the first category, in which rainfall values vary between The few or none of them, whose height ranges between 101–269 meters, represent areas of parts of the Mosul district, the Hatra area, and Al-Baaj.

The rains begin with a seasonal rainfall system at the beginning of the autumn months. This is due to the advancement of the Mediterranean depressions, which are the basis of rain in Iraq and in the two study areas. They increase as the depressions progress towards the winter season due to the increase in the number of depressions coming from the Mediterranean Sea, and then begin to decline in the spring season due to the lack and ineffectiveness of the depressions. The season ends in May due to the retreat of the polar front and its rise to a latitude of (50-60) north (Al-Rawi, 1990), leading to the advance of the Indian monsoon depression, which dominates the study area during the summer months

Nineveh Governorate is characterized by the diversity of surface shapes. Map 3 represents lines of equal elevations that indicate the importance of the factor of erosion and height above sea level, which controls climate elements. The most important highlands in Aqra district represent Jabal Aqra, which reaches a height of approximately 1447 meters, and Jabal Khayri. Its height is 1470 meters, and the height of Mount Sheikhan is 1100 meters, and the heights of Mount Sinjar are about 1500 meters high above sea level (Al-Jabouri, 2005).

The plains that extend on both sides of the Tigris River occupy large areas, the most

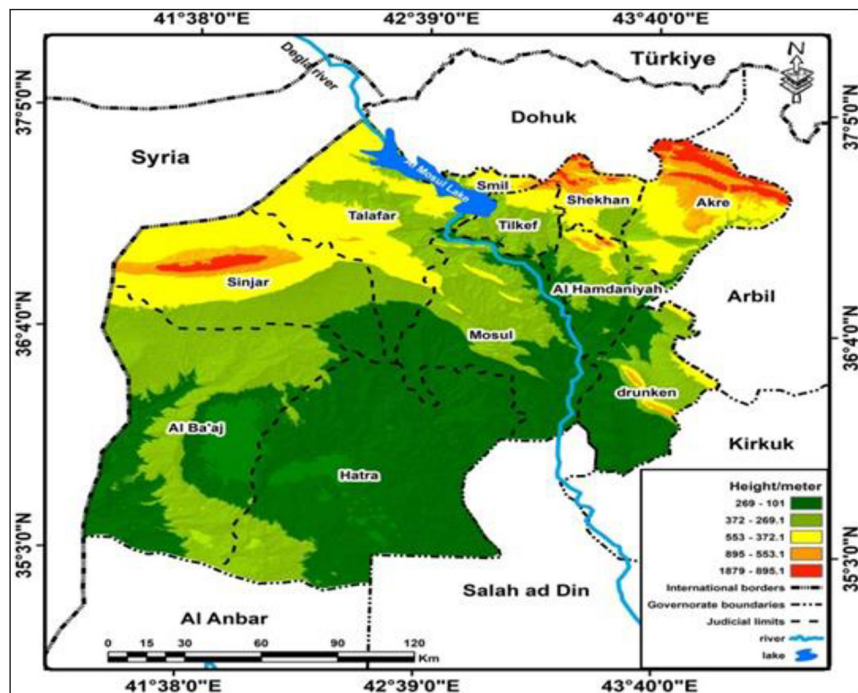


Figure 2. Digital elevation model in Nineveh Governorate, Source: Relying on the digital elevation model with a discriminant resolution of (30×30), and the outputs of the Arc Map 10.8

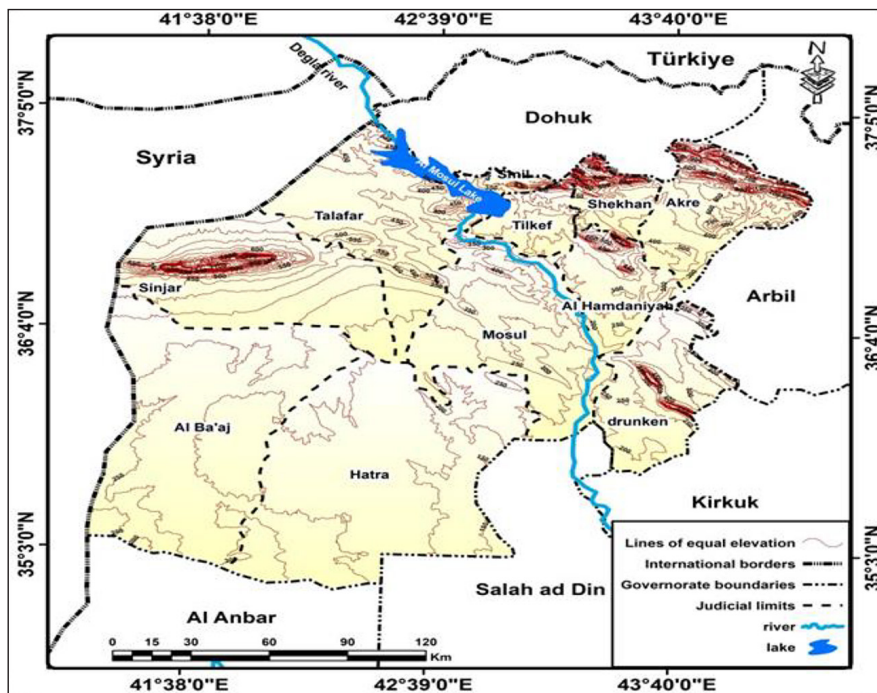
important of which are the eastern plains, whose heights range between (200–500 meters) and the western plains, which occupy the largest percentage of the area of Nineveh Governorate, with an area of 30,140 km<sup>2</sup>, larger than the eastern plains. It is divided into two parts, the first is the northern Jazira Plain and the second is the southern Jazira Plain. (Al-Yasiri, 2003), Figure 4 showed that the results of the digital elevation model maps agree with the maps of equal rainfall lines in the study area, that the northern region has mountainous terrain due to the values of the contour lines being close to each other, and the low-altitude and flat terrain begins as we head south from digital elevation model (Figure 3).

Model (DEM), as Nineveh is located at the rain line 300–400 mm, where the maximum (highest) total rainfall is concentrated in the fourth category, whose values fall between 337.6–363 mm, and occupies the northern parts of the area specified for the study. Within the units, Akre, Al-Shaykhan, Talkif, Al-Hamdaniya, Dokan, Mosul, and Sinjar, where the mountain highlands are mostly concentrated according to the data of the DEM model, the rain line includes the third category, which ranked highest The second, whose total rainfall ranges between 312–337 mm to include parts of Mosul and the Jazira Plateau, and begins to decrease and decrease in

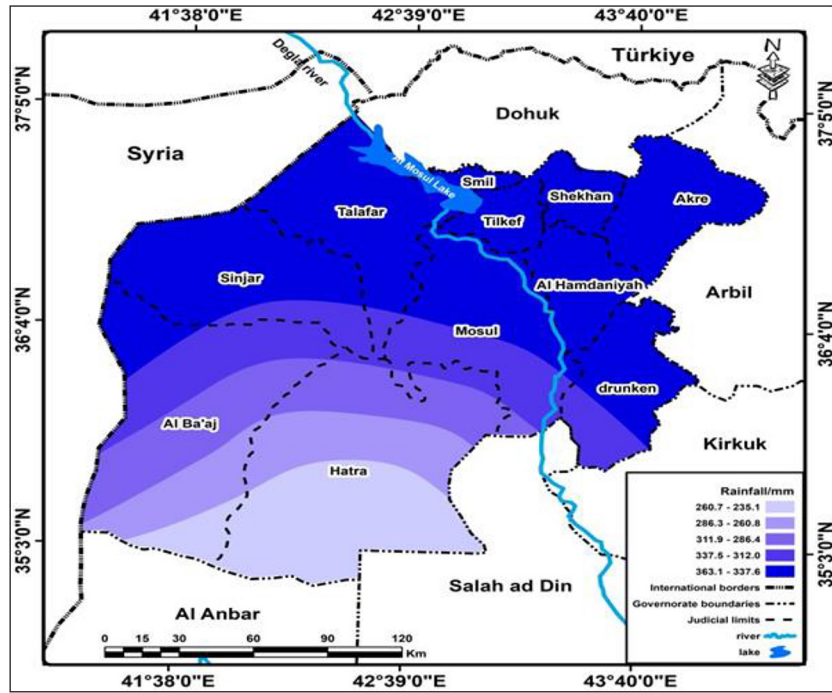
values as we head south of the study area, reaching between 235–260 mm in the urban area. In general, Nineveh Governorate is characterized by high rates of rainfall (Figure 4). It is due to the clarity of the factor of consolidation, firstly, and its location in relation to latitude circles, secondly, and its contact with cold air, the depth of the grooves, and the activation of deepening air depressions, in addition to the governorate's convexity and height, which helped increase the amounts of rain, either by raising the winds to the upper levels of condensation, or by delaying the speed of the air depressions, which increases From the length of time during which rain falls (Al-Dazii, 2010). Coherent climatology has become an indispensable element in climate modeling under current and future climate scenarios (Kriticos, et al, 2012), especially changing global precipitation amounts.

### Analysis and simulation of the digital elevation model in Basra Governorate

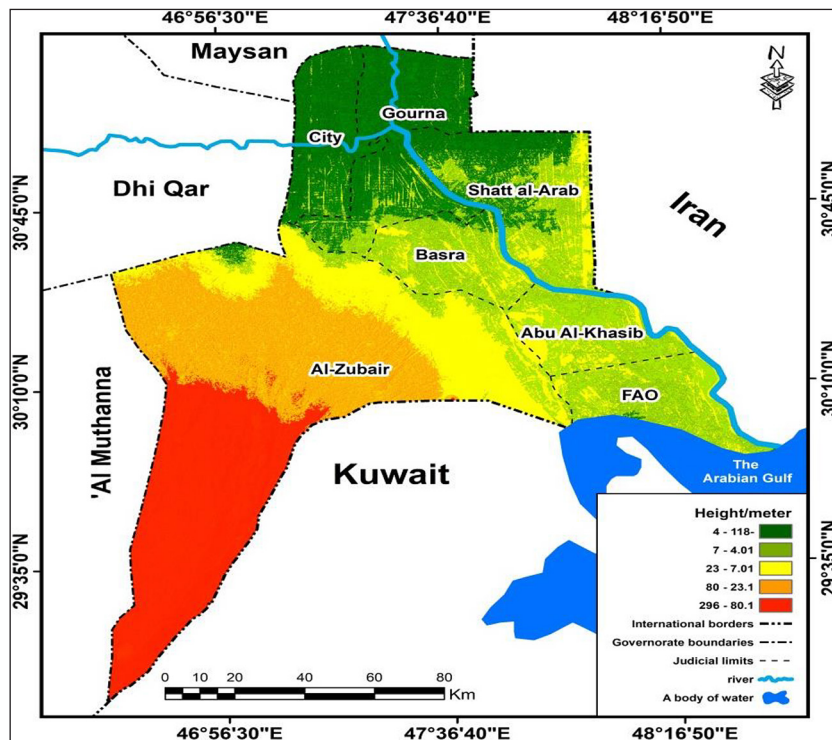
The surface of the earth rises significantly in Basra Governorate at a place called Al-Haswa, which has sandy, rocky soil, located about 6 kilometers east of Al-Zubair, Figure 5, and 16 kilometers west of the Shatt Al-Arab (which is the location of ancient Basra), bringing the



**Figure 3.** Lines of equal elevations in Nineveh Governorate, Source: Relying on the digital elevation model with a discriminant resolution of (30×30), and the outputs of the Arc Map 10.8



**Figure 4.** Rainfall regions in Nineveh Governorate; Source: Republic of Iraq, Ministry of Transport, General Directorate of Meteorology and Seismic Monitoring, unpublished data, 2023 and GIS program outputs



**Figure 5.** Digital elevation model of Basra Governorate; Source: relying on the digital elevation model with a discriminant resolution of (30×30), and the outputs of the Arc Map 10.8

elevation to 200 m and the area of Al-Haswa extends to Al-Zubair, reaching an altitude of approximately 30 m in the city of Al-Zubair itself, where the air becomes drier that the

traveler from Basra to Al-Zubair feels as soon as he reaches the location of Al-Haswa, and the rise continues southwest until it reaches 498 meters in Mount Hump on 33 km south of

Al-Zubair (Wali, 1988). The elevation of the ground surface in Basra ranges between 5–4.5 m above sea level, and the slope of the surface is gradual and slow from north to south at a degree of 1/18000 m<sup>2</sup> (Hamdan, 2013). Digital elevation model data indicated that the areas with the lowest elevations (low-lying areas) are in the first category, which ranges between 4–118 m in each of the areas of the city, Qurna, and parts of the Shatt al-Arab region, and the second, third, and fourth categories in the map are limited to the elevation. Average, reaching the highest elevation in its lands in the fifth category, between 80.1–296 meters, which includes Al-Zubair district and the southern parts of it, which are confined between Al-Muthanna Governorate and the State of Kuwait in the form of a rectangle extending between them, going deep into the Western Plateau desert region, Figure 6 shows lines of contour that shows the elevations shown in Figure 5 is the product of the DEM model used in the study, as the line of elevation 15 m passes through each of the areas of Al-Faw, Abu Al-Khasib, and the center of Basra, while the line of equal elevation 50 m passes through Al-Zubair district, reaching the highest elevation of the contour

line 256 m or more to the far south of Basra, which results in a variation in rain rates.

The rainfall in the governorate according to the factor of elevation (intensification) to demonstrate the map of rainfall regions Figure 7 has the highest rainfall categories recorded in it. The northern region of Basra represents the highest amount of rain with an amount ranging from 171–182 mm, which is a small part of the surface of the governorate, while it was The third and fourth regions have medium rainfall intensity in the center of the governorate, while the region with the least rainfall is concentrated in the southern parts with a rainfall total ranging between 123–135 mm in the Desert Plateau region and the Wadi Al-Batin region.

The climatic scientific fact is evident in that the highest areas are the ones with the highest rainfall values, and this is what applied to the first study area, Nineveh Governorate. However, the second study area, which is represented by Basra Governorate, shows the geomorphological and climatic fact that states that the highest areas are at the contour line 150 m and more is the lowest rainfall because it falls within the desert range of the Western Plateau along the

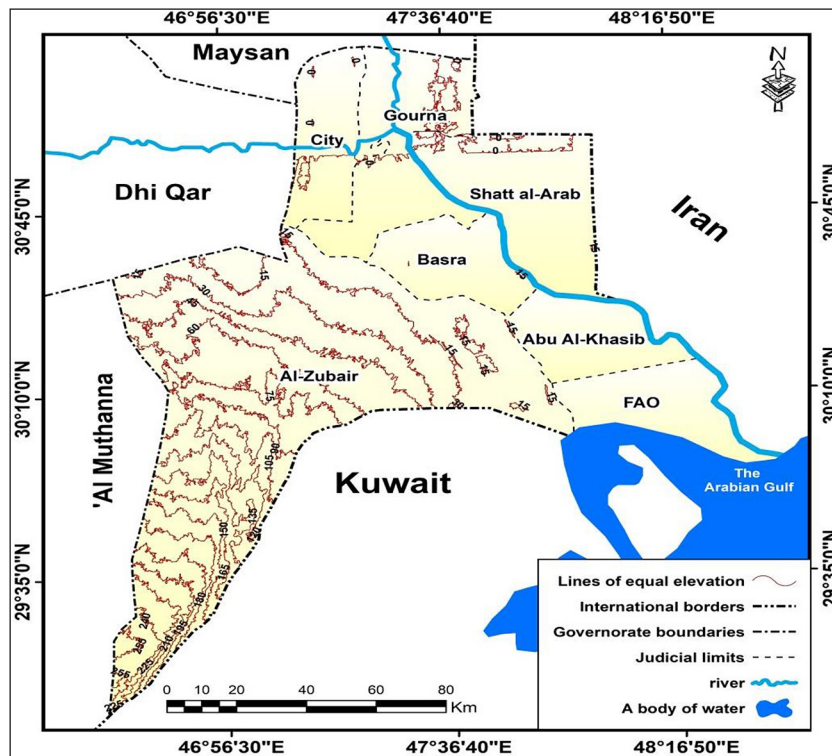
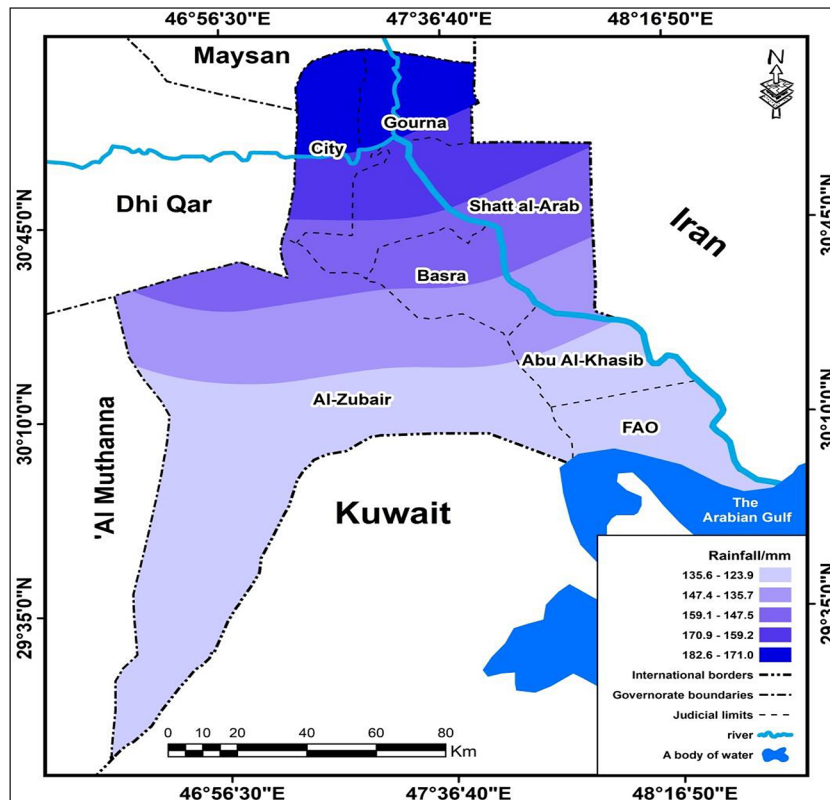


Figure 6. Lines of equal elevations in Basra Governorate; source: relying on the digital elevation model with a discriminant resolution of 30×30, and the outputs of the Arc Map 10.8



**Figure 7.** Rainfall regions in Basra Governorate; source: Republic of Iraq, Ministry of Transport, General Directorate of Meteorology and Seismic Monitoring, unpublished data, 2023 and GIS program outputs

borders of Kuwait and the Kingdom of Saudi Arabia, represented by the Umm Qasr and Safwan districts and the sloping dry valleys, the most important of which is Wadi Al-Batin. Most of the region consists of undulating sandy or rocky desert, where the surface gradually rises from the sea level area in East to an altitude of (300) meters above sea level in the southwestern part (Al-Rubaie, 1985).

## DISCUSSION

Observed from the map of the rainfall regions that rainfall values decrease in Al-Faw district and some areas overlooking the Arabian Gulf, as these regions witness a significant increase in humidity values. Relative to the relative rise in temperature rates, which prevents the process of condensation and rain formation, so the rain is little, not exceeding 135 mm. As for the Northern Region, despite its low contour line, its location is within the alluvial plain and its rain characteristics are affected by the surrounding stations and the neighborhood.

In addition to the fact that the low alluvial plain is a passage area for rainy weather depressions, whether the Mediterranean depression or the Sudanese depression, which makes the most rugged region (Nineveh Governorate) the highest and most abundant in total monthly and annual rainfall. These depressions also reach it stronger and more intense by virtue of their astronomical location compared to Basra Governorate. Which are reached by those depressions that are less severe in their characteristics by virtue of their location and the distance between them and the entry area of the depression, in addition to their being the lowest elevation and flattest in surface appearance compared to Nineveh Governorate. Thus, we achieved the main goal of the study, which is the extent of the influence of the edification factor on rainfall values, based on the results digital elevation model, due to the increasing sophistication of environmental models, there is a continuing need for highly accurate, globally available digital models. (Pham, et al, 2018). To detect fluctuations in rain rates due to differences in ground elevation.



## CONCLUSIONS

The study demonstrated the success of using the digital elevation model, which is one of the applications of geographic information systems, which provides a three-dimensional view of the terrain, in addition to its reliance on satellite images, the global signature system, and digital maps, which provides high accuracy for the results obtained from it in Subject of study.

The factor of indentation varies in the two regions chosen for study according to their regional location in Iraq, depending on the geomorphological features of the surface in each of them. Nineveh Governorate is a mountainous region that is indented according to the characteristics of its geological formation, while Basra Governorate is flat to low land in its north and begins to rise towards the south, where depth The rocky terrain of the desert range within its territory, which gave a clear discrepancy in the data of the DEM model and the contour elevation design, as well as the variation of the rain-fed regions in each of them, respectively.

The factor of erosion in the two regions chosen for study varies according to their regional location in Iraq, based on the geomorphological features of the surface in each of them. Nineveh Governorate is a mountainous region that is rugged according to the characteristics of its geological formation, with a maximum elevation of (1879) metres, and Basra Governorate is characterized by the presence of flat to low land in North of it, it begins to rise towards the south. Its maximum height is (296) metres, where the rocky depth of the desert range is within its territory, which gave a clear discrepancy in the data of the DEM model and the contour elevation design, as well as the discrepancy in the rain-fed regions in each of them, respectively.

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