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# Spatial Analysis of Relative Humidity and Its Effect on Baghdad City for The Years 2008, 2013 and 2018

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**Abstract**

Urbanization phenomenon did expand rapidly in Baghdad-Iraq due to security improvement and the human desire for daily services availability, where reducing the agricultural lands "Greenlands" negatively affected the climate rate. The relationship between urban expansion and relative humidity was studied from 2008 to 2018 using remote sensing data (satellite images of Landsat 5 and Landsat 8) and relative humidity rate data obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF). Data were processed and analyzed using ArcGIS v: 10.2. Results showed changes in human activities (land use (LU)) and urban areas, where increasing urbanization declines vegetation and turbulence climate. The study provides a significant correlation between increasing urbanization and relative humidity rate. Thus, the unintended use of the land may affect the local climate.

**Keywords:** Relative humidity, Normalized Difference Index (NDI), Remote Sensing, (ECMWF) Data, Classification Techniques.

# التحليل المكاني لتأثير الرطوبة النسبية على مدينة بغداد للسنوات 2008، 2013 و 2018

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**الخلاصة**

توسعت ظاهرة التحضر بسرعة في بغداد - العراق نتيجة التحسن الأمني والرغبة البشرية في توافر الخدمات اليومية ، حيث أثر تقليص الأراضي الزراعية "الاراضي الخضراء" سلباً على معدل المناخ. دراست العلاقة بين التوسع الحضري والرطوبة النسبية من عام 2008 إلى عام 2018 باستخدام بيانات الاستشعار عن بعد (صورة الأقمار الصناعية لاندسات 5 ولاندسات 8) وبيانات معدل الرطوبة النسبية التي تم الحصول عليها من المركز الأوروبي للتنبؤات الجوية متوسطة المدى (ECMWF). عولجت البيانات وتحليلها باستخدام برنامج ArcGIS v: 10.2. أظهرت النتائج تغيرات في الأنشطة البشرية (استخدام الأراضي (LU)) والمناطق الحضرية، حيث ادى التوسع الحضري المتزايد إلى انخفاض الغطاء النباتي واضطراب المناخ. اظهرت الدراسة علاقة ارتباط ذات دلالة إحصائية معنوية بين زيادة التحضر ومعدل الرطوبة النسبية. وبالتالي، قد يؤثر الاستخدام غير المقصود للأرض على حالة المناخ المحلي.

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## Introduction

Urban growth is considered one of the generalities common human causes of a decrease in agricultural land causes deterioration of natural vegetation [1], where agricultural land converted to urban regions in a short time and making a notable consequence on the local environment [2]. Proper consideration and decision-making to monitor land-use change are required for controlling climate variability [3].

According to global studies, researchers ought to epitomize different results regarding rapid urbanization and its effect on humidity rates [4]. These results should be obtained from international information sources that are considered one of the applications of physics for urban districts within the continuous spectrum of spatial and temporal fields [5]. It is necessary to possess an active spatial technique employed to monitor Land use and Land cover (LULC) change to avoid future risks [6]. A wide variety of recent studies performed under diverse strategies in collecting information regarding land use employing remote sensing and geographic information system (GIS) procedures has established its effectiveness in obtaining accurate data during any period for spatial assessment of LULC [7]. Remote sensing images can evaluate and detect variation in land use /land cover [8] and [9]. Throughout the previous studies, scientists have discovered atmospheric climate variation caused by rapid urban expansion, where the urban environment is influenced by different factors, such as "natural conditions" like the balance of surface power, the water cycle, also, the result of human activities like air pollution and modification in the shape of the land [10]. A study conducted about urban climate showed that the model urban climate included rising air temperature, pollution, cloudiness, foggy days, reduced relative humidity, increased insolation, and rain rates. Therefore, the negative consequences of urban climate effects might be unhealthy for humans [11] and [12]. The urban area has been subjected to the stresses caused by Urban Heat Island UHI elect; thus, relative humidity is lower in some seasons where urban land acquired higher temperatures than their surrounding agricultural areas.

This is mainly due to replacing vegetation cover with human activities like commercial and industrial factories, generators, etc., where much solar radiation is absorbed by greenhouse gases, including different heat capacity and surface radiate properties [13]. This results in higher temperatures that pose a significant threat to human health; it is essential to monitor this change as urban land surfaces are constantly spatially complex, and significant variations can occur in relative humidity [14]. In addition, current research has demonstrated that the spatial configuration of land use classifications at a city scale is essential, so remote sensing techniques have been used to monitor land covers [15] and [16].

The work aims to study the effect of climatic factor "relative humidity" on Baghdad city through an urban change over five years.

## 2. Methodology

### 2.1. Study Area Location

The study area is located within a latitude of (33.452°N to 33.184°N), and longitude of (44.189°E to 44.576°E); the Universal Transverse Mercator (UTM) projection within Zone 38 North, and the World Geodetic System (WGS-1984) datum were applied to the images. The upper-left corner is (379698.33 3743512.5 m), and the lower-right corner is (495320.1 3631887.92 m), with a resolution of 30 m [17]. Baghdad has a population of about 7,216,040, distributed over an area of approximately 204.2 $km^2$, as shown in Figure 1.

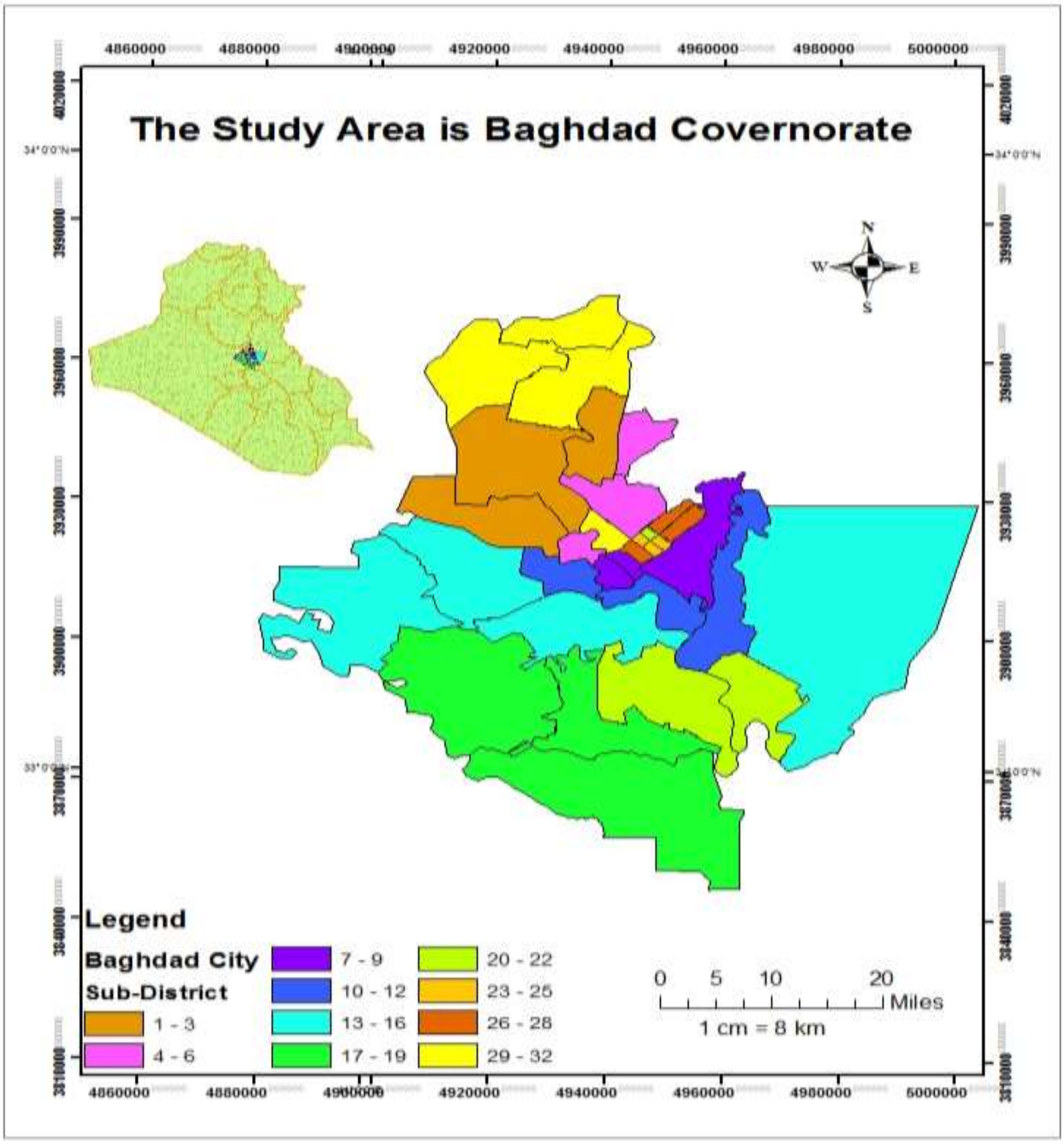



**Figure 1-**The study area represents the governorate of Baghdad, the official capital of Iraq.

**Data Acquisitionhdadd**

The satellite images from Landsat 5 and 8 during the years 2008, 2013, and 2018 were downloaded from the official website for the United States Geological Survey (Uutilized to achieve the research purposes. Satellite images were processed to produce maps of land cover for the study area using ArcGIS V: 10.2 software. The Meteorological data for the relative humidity factor were downloaded from the European Center for Medium-Range Weather Forecasts website (ECMWF) [18] and [19], As shown in Table 1 and Figure 2.

**Table 1-**Relative humidity rates in March for 2008, 2013, and 2018 with their coordinate system points.

| | NO | Coordinate System | | | | Relative Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Longitude (λ) | Latitude (ϕ) | x-axis (UTM) | y-axis (UTM) | 2008 | 2013 | 2018 |
| Average total Relative Humidity (%) | 1 | 44.2 | 33.075 | 425329.73 | 3659886.11 | 73.09 | 72.82 | 79.73 |
| | 2 | 44.95 | 33.45 | 495353.16 | 3701177.02 | 71.92 | 71.55 | 79.29 |
| | 3 | 44.45 | 33.825 | 449104.57 | 3742888.69 | 72.04 | 72.53 | 79.17 |
| | 4 | 43.7 | 33.075 | 378658.12 | 3660352.94 | 72.41 | 71.36 | 79.43 |
| | 5 | 43.7 | 33.7 | 379523.52 | 3729651.91 | 72.89 | 71.34 | 80.13 |
| | 6 | 43.7 | 32.825 | 378316 | 3632635.2 | 72.86 | 70.99 | 82.62 |
| | 7 | 44.45 | 33.2 | 448737.3 | 3673594.16 | 72.14 | 71.53 | 81.33 |
| | 8 | 44.45 | 32.95 | 448592.1 | 3645878.28 | 72.17 | 71.25 | 79.14 |
| | 9 | 43.7 | 33.45 | 379175.63 | 3701931.53 | 74.25 | 71.61 | 80.33 |
| | 10 | 43.7 | 33.575 | 379349.29 | 3715791.59 | 71.80 | 73.02 | 79.32 |
| | 11 | 44.7 | 33.7 | 472198.68 | 3728933.88 | 71.88 | 72.23 | 80.94 |
| | 12 | 44.95 | 33.575 | 495359.83 | 3715035.68 | 73.85 | 71.75 | 79.35 |
| | 13 | 44.7 | 33.45 | 472118.42 | 3701216.14 | 71.75 | 71.04 | 82.18 |
| | 14 | 44.7 | 32.825 | 471920.1 | 3631926.66 | 74.86 | 71.35 | 79.21 |
| | 15 | 43.95 | 33.325 | 402272.47 | 3687809.52 | 72.22 | 70.93 | 79.38 |
| | …… | …… | …… | …… | …… | …… | | …… |
| | 40 | 44.95 | 33.7 | 495366.53 | 3728894.62 | 71.83 | 71.72 | 79.22 |
| | 41 | 43.7 | 33.2 | 378830.05 | 3674212.2 | 74.20 | 71.61 | 79.96 |
| | 42 | 44.45 | 33.075 | 448664.58 | 3659736.08 | 73.72 | 71.42 | 80.02 |
| | 43 | 43.7 | 32.95 | 378486.77 | 3646493.94 | 75.84 | 71.46 | 80.13 |
| | 44 | 44.45 | 33.325 | 448810.27 | 3687452.51 | 72.85 | 73.02 | 82.17 |
| | 45 | 43.95 | 33.7 | 402693.22 | 3729388.24 | 73.52 | 71.93 | 80.62 |
| | 46 | 44.7 | 33.825 | 472239.01 | 3742793.17 | 72.37 | 71.24 | 80.77 |
| | 47 | 43.95 | 33.075 | 401994.3 | 3660091.73 | 72.64 | 71.05 | 79.55 |
| | 48 | 44.7 | 32.95 | 471959.49 | 3645784 | 72.43 | 71.62 | 80.60 |
| | 49 | 43.95 | 33.45 | 402412.26 | 3701668.82 | 75.07 | 71.15 | 80.04 |
| | 50 | 43.95 | 32.825 | 401718 | 3632375.01 | 72.69 | 72.19 | 79.60 |
| | 51 | 44.7 | 33.2 | 472038.69 | 3673499.51 | 72.14 | 71.66 | 81.32 |
| | 52 | 44.7 | 33.575 | 472158.49 | 3715074.87 | 73.05 | 71.12 | 79.07 |
| | 53 | 44.95 | 32.825 | 495320.1 | 3631887.92 | 72.02 | 72.72 | 79.64 |
| | 54 | 44.2 | 33.325 | 425541.65 | 3687603.12 | 72.44 | 72.42 | 79.70 |

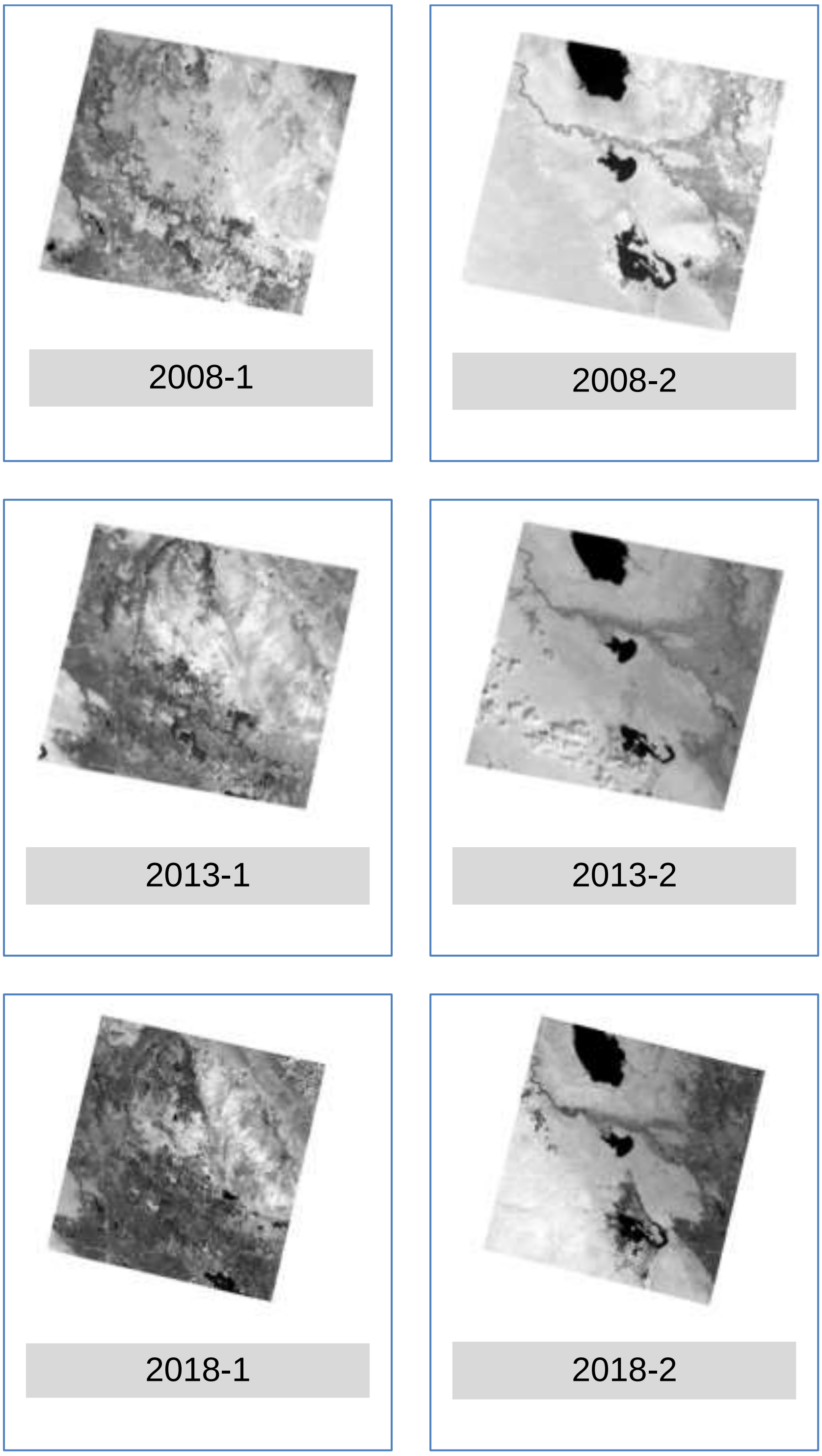



**Figure 2-** The raw satellite images were subjected to noise removal (clouds and dust).

**Classification Technology**

The classification is defined as sorting pixels with a similar spectral signature for all the features in the study area through satellite imagery sensing; the features include Land Cover (LC) or human activities or Land Use (LU) that form the main areas in the study area. The purpose is to calculate areas and the extent to which climatic factors such as relativity humidity and temperature [20]. The classification is based on pixels sensed by the satellites Landsat-5 and Landsat-8 (TM, or OLI), where the pixels vary in contrast to their color spectrum; they are always scattered because the features overlap them in some areas. The classification process includes two ways, supervised and unsupervised, as shown in Figures 3 and 4.

In both classification methods, the least two adjacent values or above and these similar pixels were arranged in the form of contiguous (zone, region, or clusters). In the supervised method, the process concluded with the means of testing samples from the study area in which the most critical existing or selected features are selected and of the most significant value (Maximum likelihood classification), while in the unsupervised classification, automatically by summing of the selected features that depend on iso cluster classification technology [21] and [22], as shown in Figure 5.

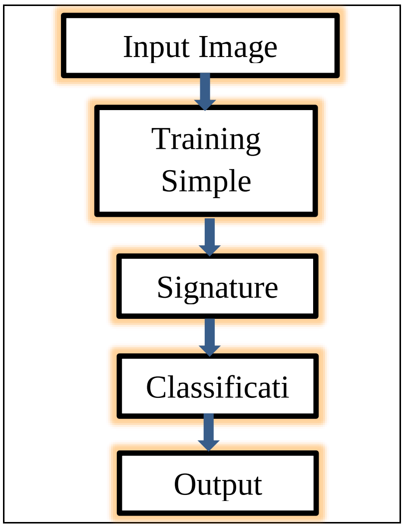



**Figure 3**-Diagram of the supervised classification method, [23].

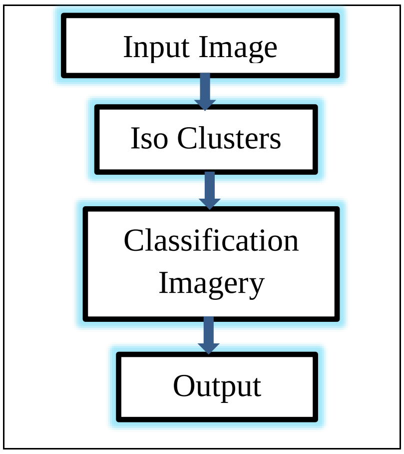



**Figure 4-**Diagram of the unsupervised classification method, [23].

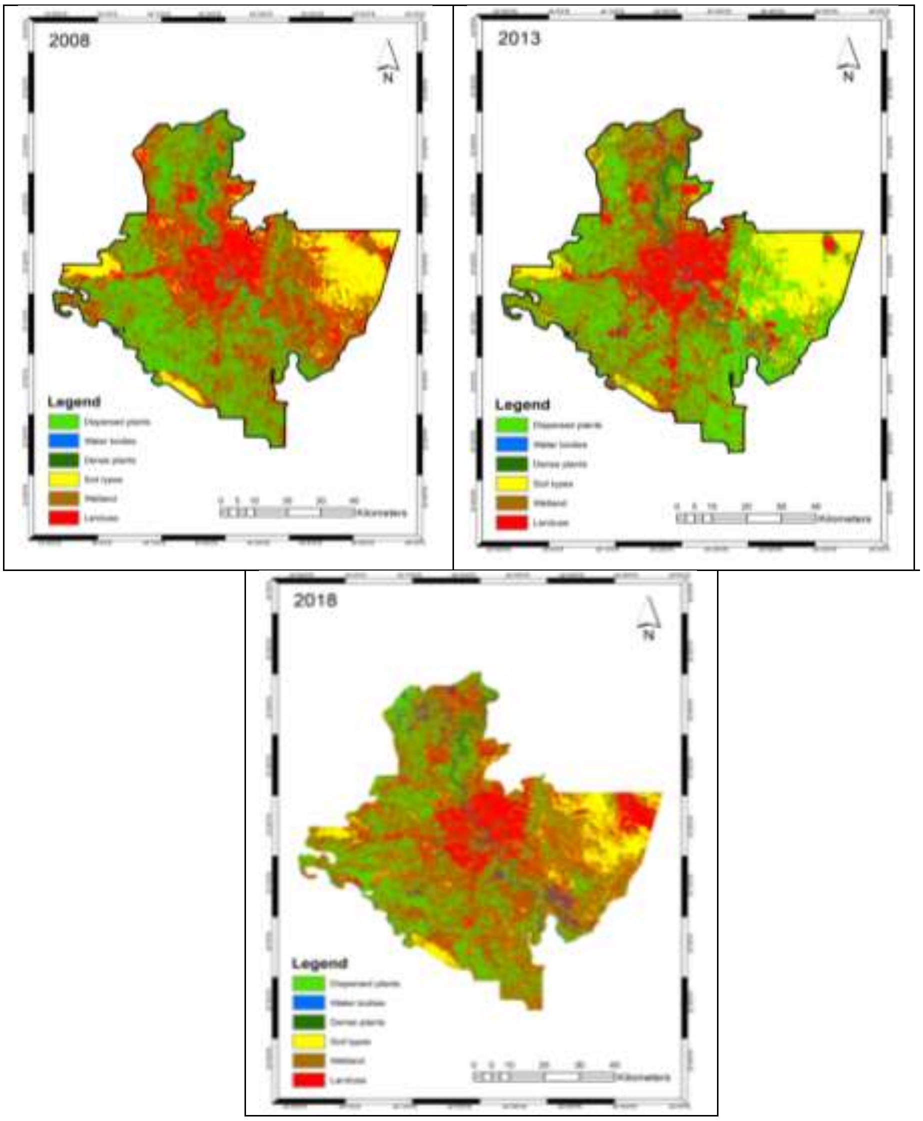



**Figure 5-**The Supervised and Unsupervised classification for the study area, for the period 2008, 2013 and 2018, [23].

The urbanization feature was chosen as a criterion for the effect of relative humidity by calculating the areas-difference and the results of extended-green areas. The abnormal increases in temperature and its effect on human activities and the imbalance in the maintenance of life were observed. Urbanization feature increased significantly from 2008-to-2018; it increased by approximately 2% of its original size from 2008 to 2018, Table 2 and Figure 6. Due to migration from the countryside to the city to obtain daily services for humans [24], increased urbanization can affect local climate change and, therefore, affects the relative humidity rate due to reduced vegetation cover and increased temperature [25].

**Table 2-**Extraction of urbanization areas from the classification process, used as a measure of the climatic factor (relative humidity).

| **year** | **Area km²** | **Area %** |
|---|---|---|
| **2008** | 1278 | 24.5 % |
| **2013** | 1361 | 26.1 % |
| **2018** | 1481 | 28.4 % |

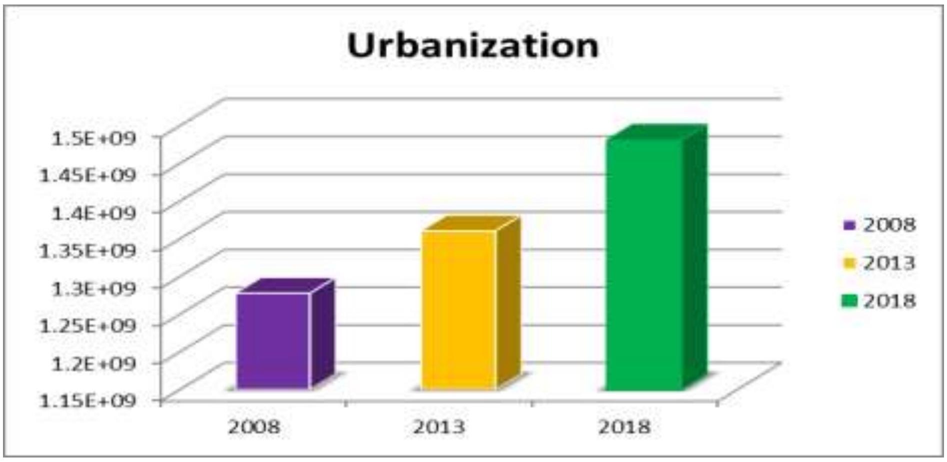


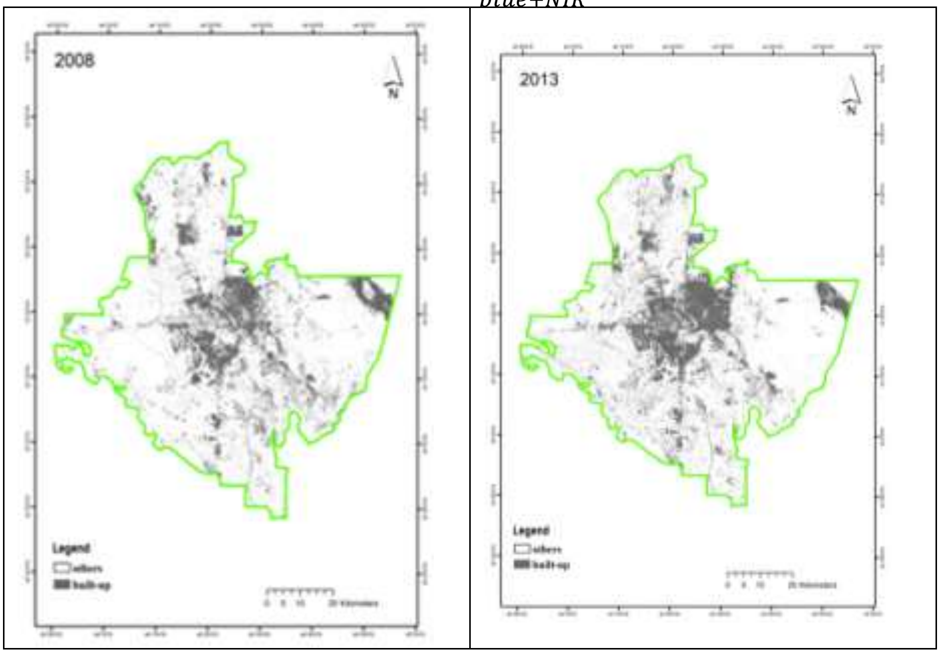

**Figure 6-**The graph shows a constant increase in the urbanization area during 2008, 2013, and 2018.

**Normalized Difference Index (NDI)**

The process of extracting urban areas (Land Use) from the study area may not give accurate results to know the effect of relative humidity on human activities in a scientific way, where the search for a feature is so clear to see this effect [26] and [27].

Therefore, the NDI was used to extract the built-up areas in the study area from Landsat 5 and 8 images [28], where we observe that it gives more accurate results than other indexes as shown in the equation, Figures 7 and 8 and, see table 3 [29].

$$NDI = \frac{blue-NIR}{blue+NIR} \quad \text{………, (1)}$$



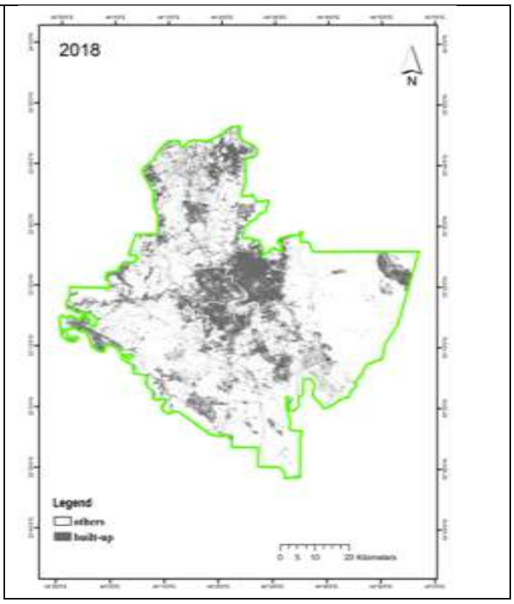



**Figure 7-**Extracted NDI regions from satellite images.

**Table 3-**The calculated areas from occupied NDI build-up in the study area.

| Year | Area km² | Area % |
|---|---|---|
| **2008** | 946 | 18.1 % |
| **2013** | 1088 | 20.8 % |
| **2018** | 1271 | 24.3 % |

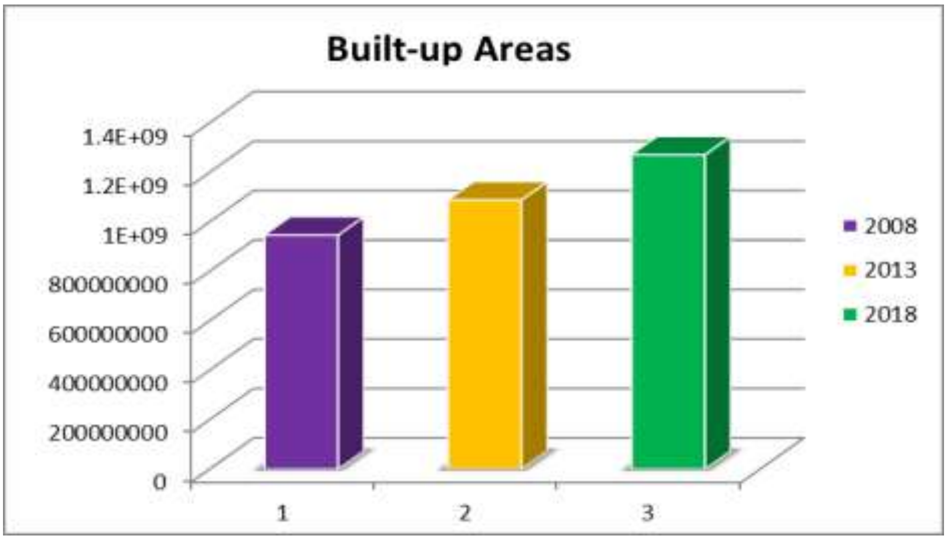



**Figure 8-**The magnitude of the increase in the architectural expansion of the study area during 2008, 2013, and 2018.

**Relative humidity**

The relative humidity is the amount of air's water vapor at a given temperature relative to the maximum amount the air can carry at the same temperature, expressed in percentage. The relative humidity is directly affected by temperature [30]. Atmospheric humidity is one of the main "drivers" of the climate because of the tremendous energy gained or released when water is transformed from one state to another [31]; figure 9 shows the spatial distribution of

relative humidity, temperature, and evaporation during March for the years of 2008, 2013 and 2018; the highest value was 80.18% in 2018 as shown in Table 4.
The relative humidity is either calculated mathematically or measured by devices. The following equation is usually used to calculate the percentage of water vapor in the air the :
Relative humidity = actual water vapor pressure/water vapor pressure at saturation * 100 [32].
Or;

$$\phi = \frac{p_{H_2O}}{p^*_{H_2O}} \qquad \text{.........., (2)}$$

Where;
, $\phi$, relativity humidity,
$p_{H2O}$, partial pressure of water vapor,
$p^*_{H2O}$, the equilibrium vapor pressure of water.
If the humidity reaches 100%, dense fog will be formed, but if the humidity is less than 30%, the air will be almost dry, making people thirsty. The ratio of 60% -70% during the day, with a temperature of 38°, makes you feel that the temperature is higher than it is in reality, and a person sweats to the point that if he spends a long time under that condition, he becomes dehydrated, and he must be transferred to the hospital. The appropriate relative humidity for Iraq is 45%.

**Table 4-**The monthly averages of March for climatic factors (relative humidity, precipitation, evaporation, and total precipitation ) for the years 2008, 2013, and 2018.

| Year \ Month | Relative Humidity (%) gm/ m$^3$ | Temperature (C °) | Evaporation (mm) | Total precipitation (mm) |
|---|---|---|---|---|
| **March-2008** | 72.953 | 24.31 | 0.107 | 0.027 |
| **March-2013** | 71.507 | 23.214 | 0.199 | 0.017 |
| **March-2018** | 80.182 | 23.306 | 0.273 | 0.419 |

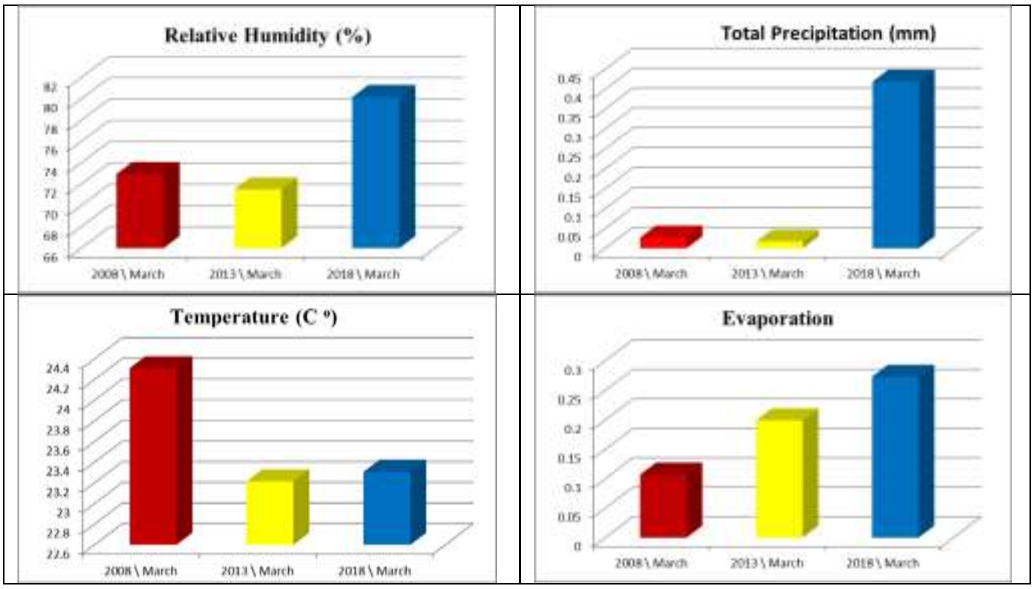



**Figure 9-**The relationship between relative humidity, total precipitation, temperature, and evaporation during March for 2008, 2013, and 2018.

## 2.6. Interpolation Methods

**Inverse Distance Weight (IDW)**

In this research, the spatial variation (Relative humidity) was extracted by following the IDW method. The inverse distance weighted technique is an easy and successful interpolation method that supports the idea that the values of the variables at a point that could be predicted are symmetric to the values of thereabout appointed points [33]. This Technique indicates that every station has a local impact on the rest of the nearby stations that reduce with distance by using an influencing parameter, as shown in Figure 10.

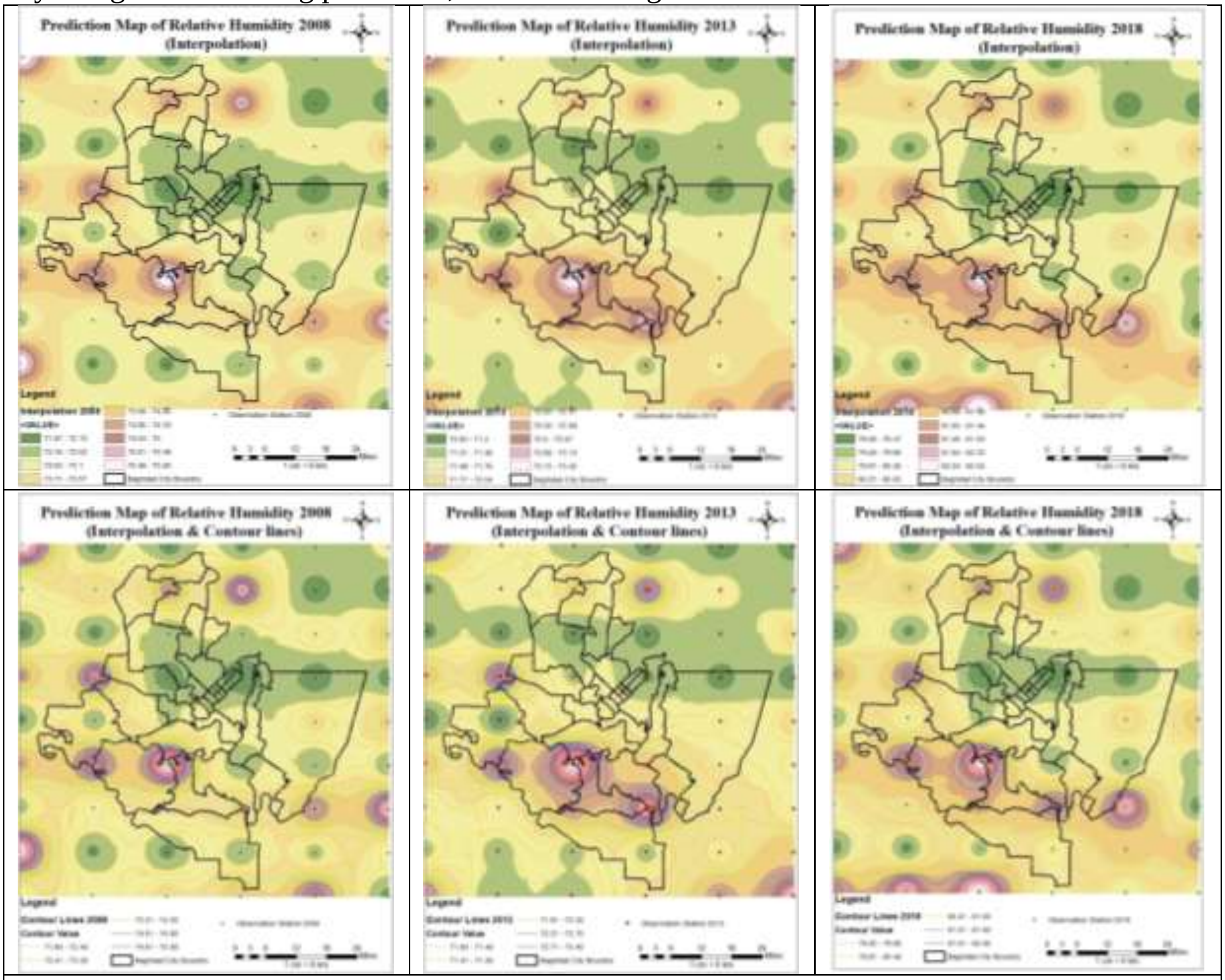



**Figure 10**-The predictive map of relative humidity for the years 2008, 2013, and 2018 using the process of IDW and contour lines.

**Contour lines Method.**

They are imaginary lines that follow the color gamut of area density (relative humidity concentration) and represent the boundaries of each gradient; the values of moisture concentrations are shown in Figure 11 [34], and they are arranged to ascend or descend on the manner of the interpolation technique [35]. The period can be determined experimentally according to the number of absolute values of relative humidity [36], as shown in Figure.11.

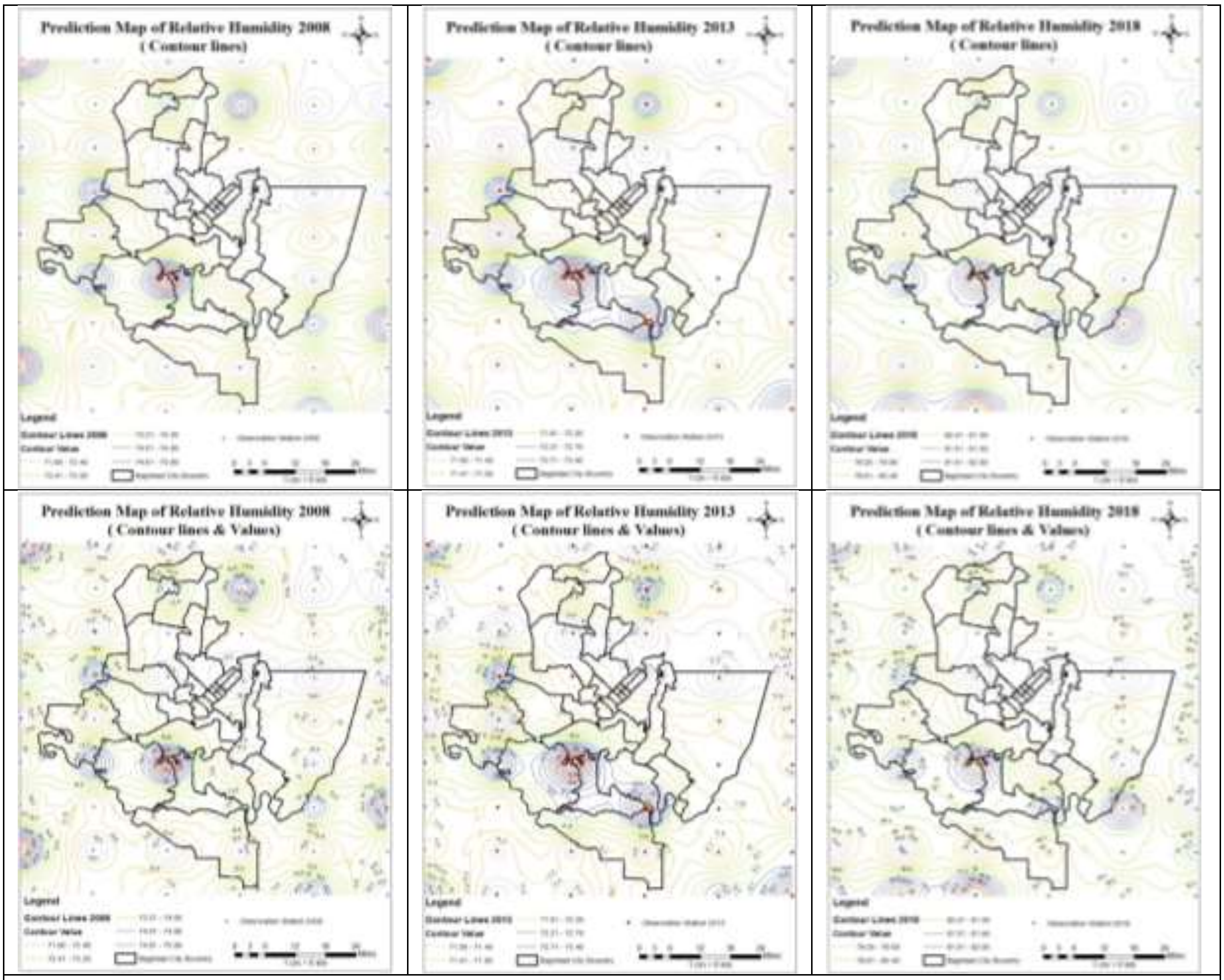



**Figure 11-** Contour lines map with the values, which show the relative humidity concentrations and the boundaries of the areas.

## Results

The relative humidity affected Baghdad province from 2008 to 2018, depending on the temperature changes due to the urban expansion of Baghdad, the continuous encroachment on the vegetation cover, and the expansion of slums. As indicated in table 5 and Figure 12, the difference in 2018 was due to the amount of rain that fell in March, it recorded an average of 0.419 compared to the year 2013, where it was 0.017, and the year 2008 was 0.027, as shown in Figure 9 and Table 4.

The relative humidity is proportional smoothly to temperatures, and as in the previous table and figure also, there is a slight reduction in temperature for the year 2018, and the amount measured as a monthly average of 23.306 C compared with the years 2008 and 2013, which were 24.31 and 23.214 respectively. A large-unprecedented amount of rain compared with other years led to a decline in the temperature, and this does not mean that there is no effect of relative humidity on Baghdad according to the different human activities, including the reduction of the agricultural area.

**Table 5-**Relative humidity rates and urban area.

| Year | Relative Humidity (%) | Urban Area km$^2$ |
|---|---|---|
| **2008** | 72.953 | 1277.9505 |
| **2013** | 71.508 | 1360.7127 |
| **2018** | 80.182 | 1481.0121 |

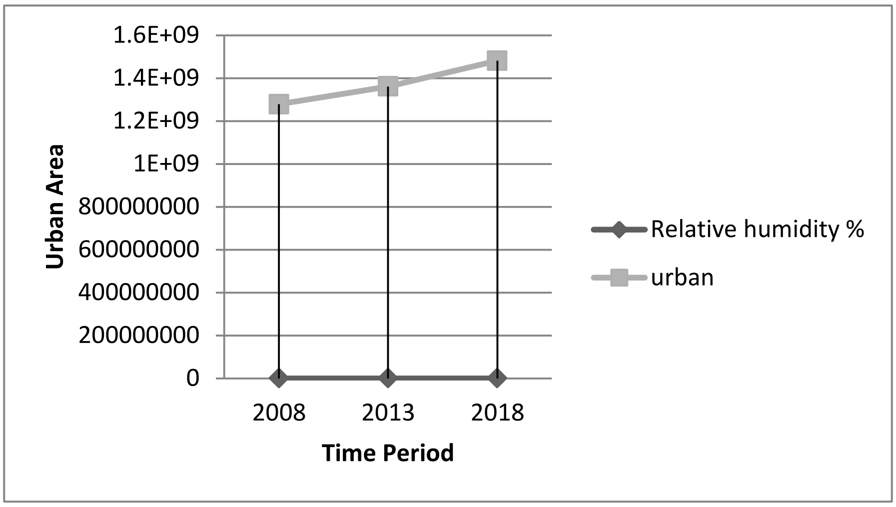



**Figure 12-**The relationship between relative humidity and urbanization.

## 4. Conclusion

The effect of relative humidity on the Baghdad governorate was studied, and March was chosen to see the effect of air humidity clearly, as March in Iraq is considered a month of rain and relatively different temperatures depending on the rainfall; the amount of rain increased noticeably quantity over the years 2008 and 2013.

Conclude from the data used, climatic factors such as relative humidity and temperatures that the expansion of human activities, especially urban ones, have contributed to rising temperatures up to 24.31, 23.214, and 23.306 for the years 2008, 2013, and 2018, respectively. As for the anomalies that appeared for the year 2018 due to the significant rainfall. 0.419 mm was significantly larger than the amounts in 2008 and 2013 were 0.017 mm and 0.027 mm, respectively.

The difference in 2018 is due to the significant rainfall of 0.419 mm, significantly larger than the rainfall in 2008 and 2013, 0.017 mm and 0.027 mm, respectively. The urban areas' expansion was noticed significantly, which were 1277.95, 1360.71, and 1,481.01 $km^2$, and concluded that humidity was significantly affected during 2008 and 2013 and was different during 2018 due to the unpredicted rainfall, which led to an increase in relative humidity. In order to control and understand that predictive maps were produced, the Interpolation technique (IDW) was used to manage the study area in the future. Contour maps, which are the clearest, to mitigate the Baghdad governorate atmosphere to help conduct various activities and monitor the difference that leads to the drought that causes a significant increase in temperature and creates many problems, such as fires. Also, control and reduce informal areas by encouraging vertical construction to control the increase of Baghdad's population.

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