CORRELATION COEFFICIENT ANALYSIS BETWEEN $PM_{2.5}$ CONCENTRATIONS AND SOME METEOROLOGICAL PARAMETERS IN IRAQ

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ABSTRACT

This study aimed to investigate of the spatial analyses of the correlation coefficient between Particulate matter $PM_{2.5}$ and meteorological parameters in Iraq Using remote-sensing data and meteorological Parameters datasets for the period 2003–2020. $PM_{2.5}$ is one of the primary air pollutants across the world. Quantifying interactions between meteorological conditions and $PM_{2.5}$ concentrations is essential to understanding the variability of $PM_{2.5}$. The spatial variations of the relationships between the annual average $PM_{2.5}$, the annual average rainfall, temperature wind speed, and pressure were evaluated using the Pearson correlation coefficient model. The results indicated that there were positive correlations between $PM_{2.5}$ concentrations and both temperature and wind, while there was a negative correlation with pressure. As for rainfall, there were positive correlations in some areas and negative in others. The results also showed that the most associated factor with $PM_{2.5}$ is wind. it becomes clear to us that the correlations between fine particles and meteorological factors differ according to the regions, the terrain, the local climate, human and natural differences, and weather changes.

Keyword: air pollution, Iraq, temperature, wind, pressure, rainfall, Remote sensing, GIS, climate change

*** Part of M.Sc. thesis of the 1st author.**

مجلة العلوم الزراعية العراقية- 2024:55(4):1292-1302 ود وآخرون

تحليل معامل الارتباط بين تراكيز $PM_{2.5}$ وبعض العوامل الانوائية في العراق

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المستخلص

هدفت هذه الدراسة إلى التحقيق في التحليلات المكانية لمعامل الارتباط بين $PM_{2.5}$ وبعض العناصر الجوية في العراق باستخدام بيانات الاستشعار عن بعد و بيانات العناصر الانوائية للفترة 2003–2020. الجسيمات ($PM_{2.5}$) هي واحدة من ملوثات الهواء الأساسية في جميع أنحاء العالم. يعد قياس التفاعلات بين ظروف الأرصاد الجوية وتركيزات $PM_{2.5}$ ضروريًا لفهم تباين الجسيمات .تم تقييم الاختلافات المكانية للعلاقات بين متوسط $PM_{2.5}$ السنوي ، والمتوسط السنوي لهطول الأمطار، وسرعة الرياح ودرجة الحرارة ، والضغط باستخدام نموذج معامل ارتباط بيرسون. أشارت النتائج إلى وجود علاقة ارتباط موجبة بين تراكيز $PM_{2.5}$ وكلا من درجة الحرارة والرياح، بينما كان هناك ارتباط سلبي مع الضغط. أما بالنسبة للمطر فقد كانت هناك ارتباطات موجبة في بعض المناطق وسلبية في مناطق أخرى. وأظهرت النتائج أيضًا أن أكثر العوامل ارتباطًا بجسيمات $PM_{2.5}$ هي الرياح. يتضح لنا أن الارتباط بين الجسيمات الدقيقة وعوامل الانواء الجوية يختلف باختلاف المناطق والتضاريس والمناخ المحلي والاختلافات البشرية والطبيعية وتغيرات الطقس.

الكلمات المفتاحية: تلوث الهواء, العراق, درجة الحرارة, الرياح, الضغط, الامطار, الاستشعار عن بعد, نظم المعلومات الجغرافية، التغير المناخي

*** جزء من رسالة ماجستير للباحث الاول.**

Received:11/5/2022, Accepted:7/8/2022

INTRODUCTION

Numerous research have concentrated on the consequences of air pollution and aerosols on human health, climates, meteorological events, and the environment. $PM_{2.5}$ is particulate matter with an equivalent diameter less than or equal to 2.5µm in aerodynamics(28).The capacity of an airborne particulate to enter the lungs and bloodstream deeply and unfiltered makes it the deadliest type of air pollution. The impacts of $PM_{2.5}$ concentrations in human health can be divided into indirect and direct effects.Indirect effects normally affect a much wider geographic area and are more difficult to control. One of the most dangerous effects is the acidification of fresh water sources. Through oxidation reactions, aerosols such as sulphur and nitrogen oxides are converted into acidic substances such as sulphuric and nitric acid and negatively impact fish population and forest ecosystem health. Major natural aerosol sources include volcano emissions, sea spray, and mineral dust emissions. Anthropogenic sources include emissions from industry and combustion activities. Another significant source of PM pollution comes from traffic. PM sources might be either primary or secondary in origin. Secondarily generated particles in the atmosphere have both natural and anthropogenic origins (27).There is a correlation between $PM_{2.5}$ and meteorological factors where both affect the other that the particle has a considerable impact on regional temperature, precipitation, and extreme events (34),(18). Pollutant emission, transport, dispersion, chemical transformation and deposition can be influenced by meteorological variables such as temperature, humidity, wind characteristics (26). In meteorology Because it directly impacts our life, temperature is considered one of the most crucial meteorological and climatological components,Temperature can be used as a measurement to identify the weather if it is cold or hot (24). The movement of air masses on the surface of the earth is referred to as the wind. These atmospheric air movements are brought on by a pressure difference (pressure gradient) that results from heterogeneity in the atmosphere's heating by the sun. Pressure gradient causes air masses to move, as the atmosphere heats up, it warms the air in it causing it to move upwards hence creating areas of low pressure. The air moves from high-pressure areas in the direction of low pressure areas, that way creating a wind(16). The force that atmospheric air applies to things' surfaces due to its weight is known as atmospheric pressure (27), and One of the most crucial meteorological and climatological elements is precipitation. The amount of water that falls as rain on a surface during precipitation is a factor that should be carefully studied. This measurement is made using a rain gauge and expresses the height of the rainwater (also known as depth) on a horizontal surface Rainwater height is measured in millimeters or centimeters(26). Zahraa and Al-Salihi (33), developed an artificial neural network model to estimate meteorological data and daily PM10 data in Baghdad city. The result provides capability of the generalization of artificial neural network model has a power full performance in pollutants calculations . The relationship between $PM_{2.5}$ and meteorological parameters has been the subject of numerous previous research, including, PU Wei-wei et al (30). Checked on the effect of meteorological factors on PM2.5 in Beijing. The result showed that the transportation of southerly wind aggravated the fine particulate pollution degree of urban, and it is also the primary reason of the pollution in rural area. $PM_{2.5}$ concentration decreased as the northerly wind increased in both urban and rural areas and Hourly precipitation above 1 mm can eliminate $PM_{2.5}$ effetely. B. H. Mahd et al (29). found out the relationship between the daily average of meteorological parameters, and the daily average of air pollutant concentrations in Duhok city, Iraq. The results showed that there is a positive relationship between pollutants and temperature, a negative relationship with pressure, and a positive relationship with wind speed. This paper aims to investigate the spatial analyses of the correlation coefficient between Particulate matter PM2.5 and meteorological parameters which include rainfall, temperature, wind speed, and pressure data using the Pearson correlation coefficient model in Iraq for the period 2003–2020.

MATERIALS AND METHODS

Study area: This study area is Iraq which has an area of 437,065 km^2 (2). Iraq is a country in the Northern Hemisphere, lying between longitudes (38.45°-48.45° E) east of the Greenwich line and latitudes (29.5°-37.5° N) north of the equator. In the northern region of the Arab Homeland, and also in the southwest corner of Asia is surrounded by Saudi Arabia and Kuwait to the south, Turkey to the north, Iran to the east and Syria to the west(5,8.12). The climate of Iraq is strongly influenced in the summer by subtropical high pressure. By contrast, during the winter solstice, as the northern hemisphere is tilted away from the sun, the subtropical high pressure is replaced by periodic low pressure systems that travel from west to east across Iraq bringing winter rains and snow in the mountain regions of the north. One of the most significant features of Iraq is the high extreme of temperature in the one day (i.e. day and night) and between summer and winter seasons. Winter is cold, and the temperature ranged from about 2 °C during night and increases to 16 °C at daytime. Summer is very dry and hot to extremely hot, with mean temperature in shadow reaching more than 43 °C in July and August, and decreasing to 26 °C at night. More features of Iraq climate is drought which occurred because the shortage of precipitation and limited its falling especially in winter and sides of autumn and spring, and the increase of evaporation due to the high quantity of solar radiation falling on the surface causes the increase in the drought (1, 7, 11, 13). Iraq lies in the Mediterranean region where rainfall occurs nearly in three seasons including winter, autumn, and spring, and disappears in summer. The region is often divided into three rainfall zones according to the annual rainfall amounts; northern, middle, and southern. Rainfall in Iraq varies during the year approximately from 50 mm in the southwest to 1000 mm in the northeast The north and northeast of Iraq usually receive higher amounts of rain than the south (9, 15). Winds in Iraq in northern region has low compared to the middle and southern regions and Seasonal wind speeds showed that the summer and spring seasons saw the greatest values, while the autumn and winter seasons saw the lowest (3, 6). Iraq surface is divided into four main parts in terms of terrain forms to the following areas: Mountain Region: Situated primarily in the north and north-eastern regions of Iraq, the mountain region makes up 5% of the country's total land area (4). The height is between 300 and 1000 meters above sea level. The average annual rainfall in this area is around 1000 mm, and the high summits are covered in snow As a source of its water resources, this region of Iraq is regarded as being the most significant, Hills and Plateau Regions: The plateau in this region is between 200 and 1000 meters above sea level in altitude. 15% of Iraq's total land area is in this region. The hilly mountains to the north and the Mesopotamian plain to the south encircle this area (10, 14).

Data source

In this study there are two sources of data, the first monthly data of $PM_{2.5}$ were downloaded from the Copernicus website (Copernicus is the European Union's Earth observation program It offers information services that draw from satellite Earth Observation and in-situ (non-space) data. The European Commission manages the Programme) (https://ads. atmosphere.copernicus.eu).The second source used in this paper were monthly meteorological datasets. meteorological parameters includes temperature, precipitation, wind speed, and pressure gridded data were provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) for the period (2003-2020). The total grids in study area were 210 grids with horizontal coverage global and horizontal resolution 0.75°×0.75°. Figure 1 shows the distribution of the total grids in Iraq for the period 2003–2020.

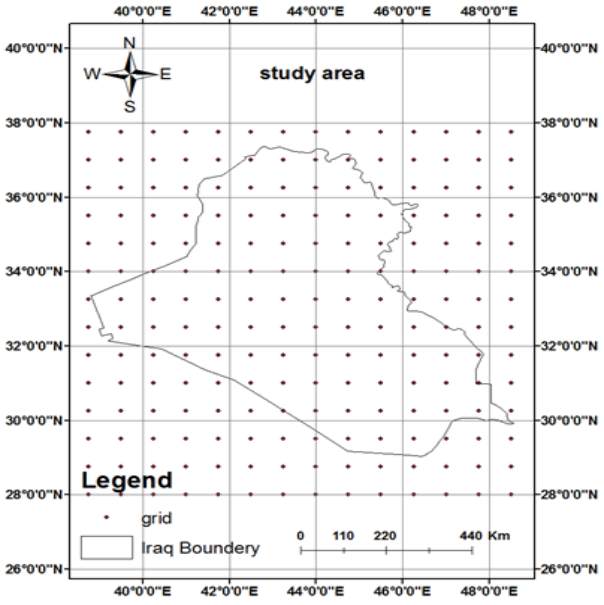


Figure 1. location map of study area, Iraq

Methodology: The correlation coefficient It is a very simple tool, but it is the most used by practitioners. It measures the degree of linear relationship between two variables using equation:

$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

$$= \frac{s_{xy}}{\sqrt{s_{xx}\ s_{yy}}} \quad \text{..... (1)}$$

Where:

$$s_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = n\tilde{s}\,x^2 \quad ,$$

$$s_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2 = n\tilde{s}\,y^2 \quad \text{.....(2)}$$

and

$$s_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = \sum_{i=1}^{n} x_i\ y_i - n\bar{x}\bar{y} \quad \text{..... (3)}$$

The correlation coefficient is independent of the units of measurement the limits of r are −1 ≤ R ≤ 1. If r is close to zero, then it indicates that the variables are independent or the relationship is not linear. Note that if the relationship between X and Y is nonlinear, then the degree of linear relationship may be low and r is then close to zero even if the variables are clearly not independent. The signs of r thus determine the direction of the association (22). The spatial distribution of the annual parameters and correlation coefficient maps were carried out using a Geographic Information System (GIS) which is a computer-based information system that provides tools for the collection, integration, management, analysis, modeling, and presentation of data referred to in the accurate graphical representation of objects in space (20). Many GIS software packages are available, graphic interface, the ability to handle different types of geographic objects, and a set of powerful tools and extensions (33). There are many different approaches to classification of the spatial interpolation procedures, like point interpolation and region interpolation, global and local, and exact and approximate interpolation. Numerous systems exist for both interpolations of local and global, the example for the global systems are the trend surface analysis and Fourier series, and an example for local technologies are proximal, Kriging, B-splines technique and Inverse Distance Weighting (IDW): is an interpolation technique in which interpersonal estimates are based on values from nearby locations that are only weighted by distance from the interpolation site(34). Except for the basic assumption that the proximal points in the interpolation site must be more relevant than the far-off points, IDW makes no assumptions about spatial relationships. This method uses a linearly weighted set of sample points to determine cell values. The opposing distance determines the weight. Based on their distance from the output point, IDW allows the user to control the importance of known points on the defined values(21). IDW relies primarily on two assumptions: the first is that the anonymous value of a point is affected by the proximity control points more than the remote points. The degree of impact (weight) of the points corresponds to each other directly with the inverse distance between the points raised to the force (34). Inverse Distance Weighting needs to have some parameters of the trigger, such as the parameters of the search neighborhood, the exponential factor, and the homogenization factor. It is particularly suitable for limited data sets, where other installation techniques may be affected by errors. This technique is very flexible and allows the evaluation of the data set with the direction or contrast of information in the research area. The inverse distance interpolation is defined by the following equation(19).

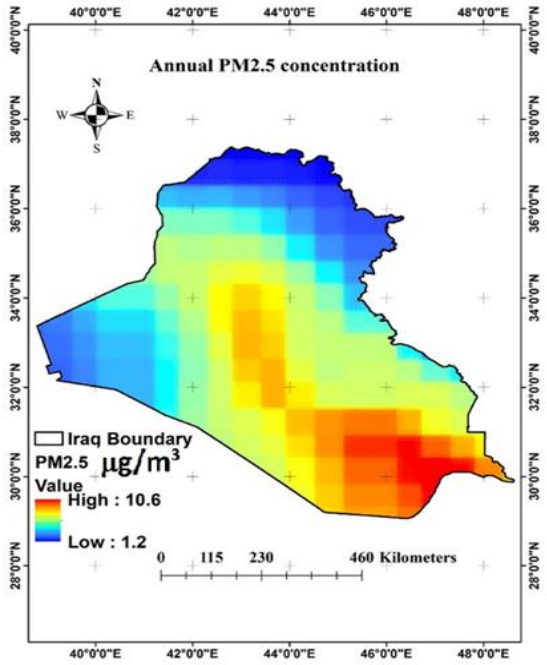
$$Z = \frac{\sum_{i=1}^{k} w_{ij} z_i}{\sum_{i=1}^{k} w_{ij}} \quad \text{.....(4)}$$

Where: Z: is the point to be estimated, Zi : the

observed value at control point i (i=1,…,k), Wi : the weighting function that determines the relative importance of each individual control point Zi in the interpolation procedure, k: the total number of the points that are used in the interpolation (19). This weighting relationship affects the giving of data points close to the interpolation point relatively large weights, while the effect is small on distant points (31).

RESULTS AND DISCUSSION

Figures 2,3,4,5,6 shows the maps of the $PM_{2.5}$ concentrations and meteorological parameters in Iraq. From Figure 2, it can be seen that shows the highest concentrations of $PM_{2.5}$ in the southern regions were 10.6 µg/m3 and are higher than the permissible exposure limit, where the permissible exposure limit for these particles is 10 µg/m3 for one year.



Figuer 2. The annual average of PM2.5 concentrations

The reason is due to the high concentrations in this area due to population activities, a large number of cars, oil refineries and other human reasons, and it can be due to natural causes Like drought and lack of rainfall. The lowest values for $PM_{2.5}$ concentrations were in the northern regions, where they recorded 1.2 µg/m3.======Figure 3. shows the annual average of pressure at the surface . It can seen noted that the lowest pressure value recorded in the northern regions is 738 hpa. The reason is due to the fact that the pressure decreases with height above the surface of the earth the altitude in the northern regions ranges between 1000-3000 meters above sea level, so it is higher compared to the rest of the regions of Iraq. While we note that the highest pressure values are recorded in the central and southeastern regions of Iraq, where it recorded 1010 hpa, and they are areas of high pressure due to their slope.

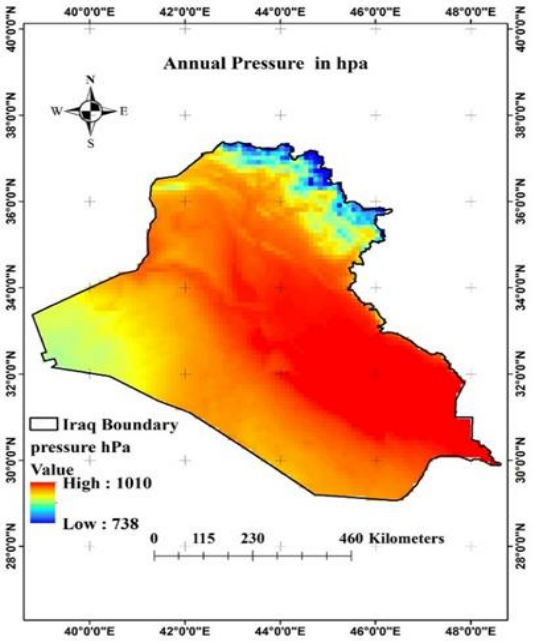
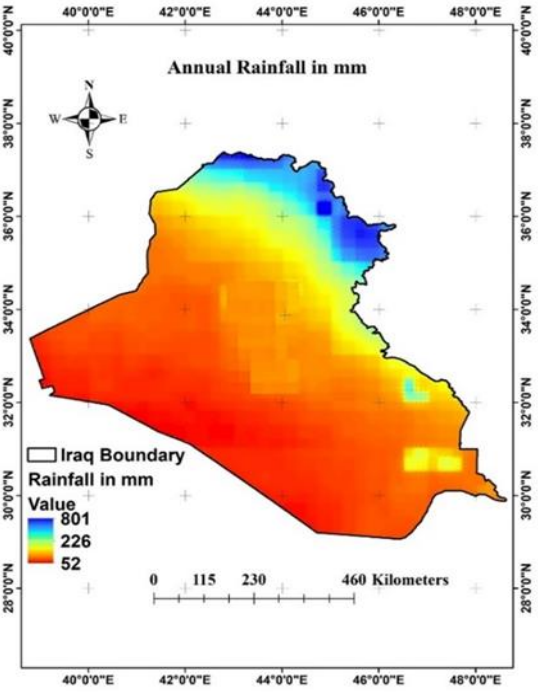


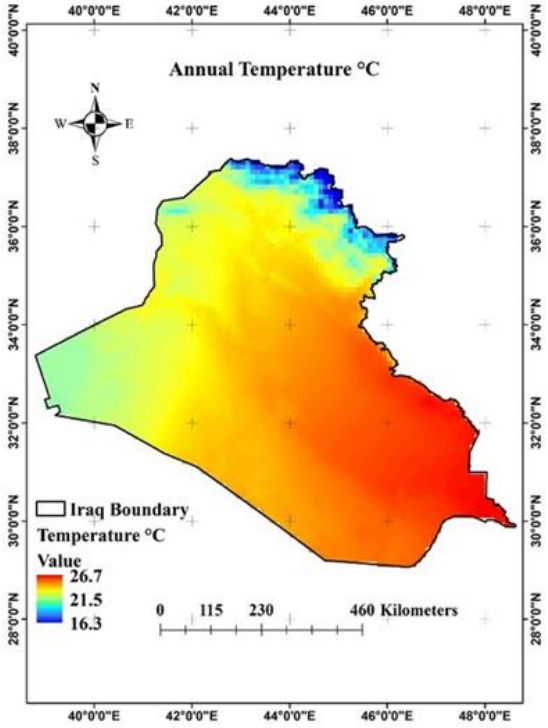
Figure 3. The annual average of pressure

It can be note the highest values of rain recorded in the northern regions were 801 mm As for the central regions, the average rainfall was 226 mm, while the lowest values for the average rainfall were in the western and southwestern regions, see Figure 4.



Figuer 4. The annual average of Rainfall

Figure 5. shows the annual averages of temperatures. The temperatures can be divided into three distinct regions. The lowest temperature is in the northern parts of Iraq, which covers about 8% of the study area, its value was 16.3°C, the central region, which occupies about 69%, with temperatures of 21.5°C, and the southern region, which records the highest average temperature of 26.7°C, and covers about 23%.



Figuer 5. The annual average of temperature

Figure 6. shows the annual average of wind, indicating that, in comparison to the center and southern regions, the northern regions record lower wind speeds In the northern regions, the wind speed is recorded at 4.48 m/s and begins to increase. In the central regions, it reaches 5.48 m/s. The highest wind speed is recorded in the southern and southeastern regions at 6.64 m/s.

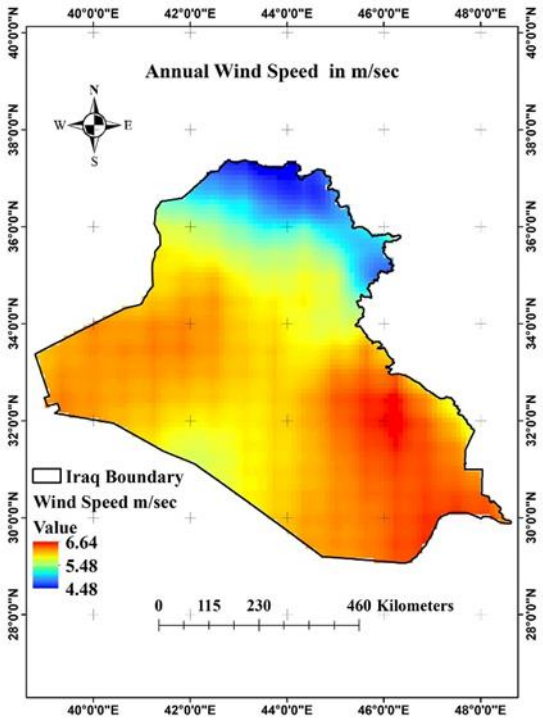


Figure 6 . The annual average of wind speed

The Pearson correlation coefficient between $PM_{2.5}$ concentration and temperature, rainfall, wind speed, and pressure for each gride have been calculated for the period in the study area. also, the result of the correlation coefficient between $PM_{2.5}$ and temperature was shown in Figure 7. It can be seen that the is a positive relationship between temperature and $PM_{2.5}$ we note that the values of the correlation coefficient differ in the northern regions in the central and southern regions. The reason is due to the difference in temperature because Temperatures can be divided into two or three distinct zones, with the south of the country having higher temperatures and the north having lower temperatures, where the annual spatial temperature trends are decreasing from the south to north (2).

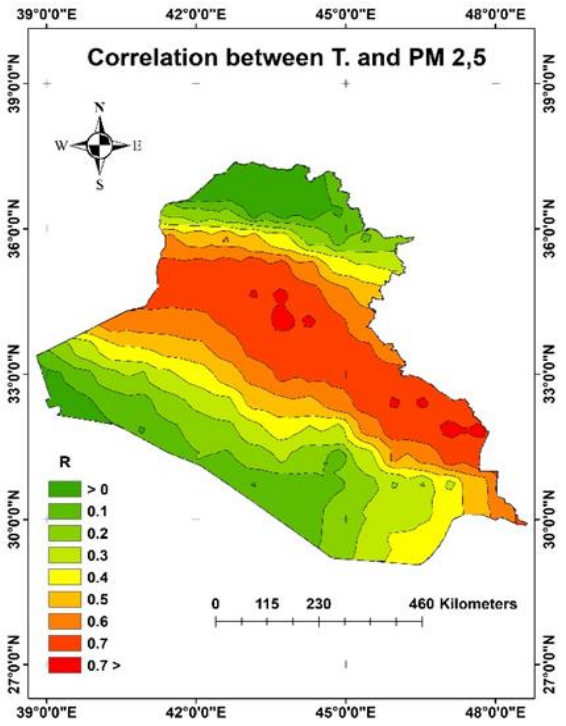


Figure 7. The correlation coefficient between $PM_{2.5}$ and temperature

In addition, the temperature is associated with latitude and longitude and are linked with the height of the sun and the strength of solar radiation and topography the higher the temperature is possible to enhance the formation of aerosols and increase the concentrations of $PM_{2.5}$. In the northern regions, there is a weak correlation, because the northern regions have lower concentrations of PM compared to other regions, where the northern part is surrounded by mountains. Green plants may help purify the air Less human activity and the low population density in the northern suburbs were factors in the decrease in concentrations and there is a weak correlation. Also in the southern and southwestern regions, where the correlation values range (0-4) While there is a strong correlation in the central regions, where the correlation values reach 0.7 and are greater than 0.7 . The results are in agreement with some studies are in the study influence of meteorological parameters on air quality (29) the results were a positive correlation of pollutants with temperature and their concentrations increase slightly with increasing temperature which is in good agreement with the results of other researchers (23,25).

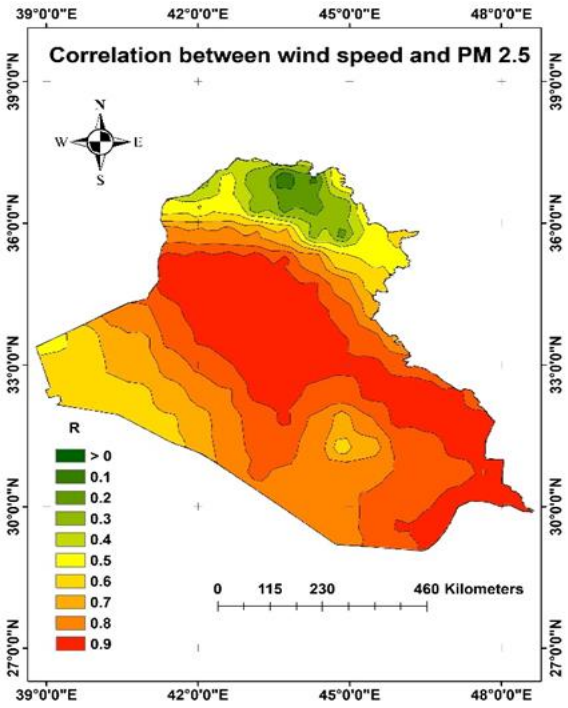


Figure 8. The correlation coefficient between PM2.5 and wind speed

Figure 8. showed the correlation coefficient between $PM_{2.5}$ and wind speed in the study area. the relationship is a positive correlation in all study areas.it can be seen that in the center and southeast have a very strong correlation (0.9), but in the northern region, there is a weak correlation, while in the southwest and west there is a good-very good correlation (0.5-0.8). The reason for this can be due to the fact that the Prevailing wind direction over Iraq is Northwesterly, Northwest wind is of great importance because it eases the high summer heat in the region, As well as the dryness of these winds to come from the drylands within the Syrian plateaus also contributed to making Iraq characterized by drought, It is also the windiest type escort of a dust storm in addition to Compared to the center and southern sections, the winds were weaker in the northern region .Through the study that showed the effect of meteorological parameters on air quality(29). Wind speed had an effect on pollutant concentrations and also on the correlation between pollutants and The variations of wind speed are positively correlated with pollutant concentrations Also, these results are in good agreement with the results of other researchers (17,23). Figure 9. shows the correlation coefficient between $PM_{2.5}$ and rainfall.

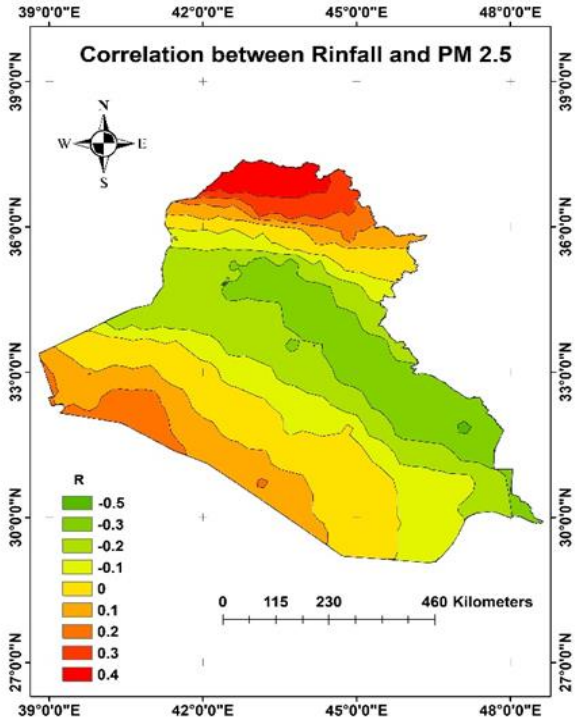


Figure 9. The correlation coefficient between $PM_{2.5}$ and rainfall

The relationship is a positive and negative correlation in the study area. Rainfall plays a role in reducing the amounts of pollutants in the air through the precipitation process, so it is an important factor in maintaining the composition of the atmosphere It is the main method for removing pollutants. It can be seen that there are some regions there are very weak positive correlations and good inverse correlations. In most regions of Iraq, the inverse correlations prevail in the central region. There is a good inverse correlation of -0.5, that is when the amount of rain is high, pollutants are deposited and their concentrations decrease, and vice versa. As for the western regions, there is no correlation While in the northern regions we notice a very weak direct correlation (0.2-0.4) the northern regions receive greater amounts of rain than other regions and also have lower pollutant concentrations compared to the rest of the regions. Figure 10. shows the correlation coefficient between $PM_{2.5}$ and pressure. The relationship is a negative correlation in all study of Iraq. we notice that there is a negative correlation between pressure and $PM_{2.5}$ concentrations, that is, in areas of high pressure, pollutant concentrations decrease. In the northern region, there is a low-pressure area and low $PM_{2.5}$ concentrations as well. Also it can be note that there is no correlation, but in the central regions, the correlation ranges from (-0.5 to -0.8).

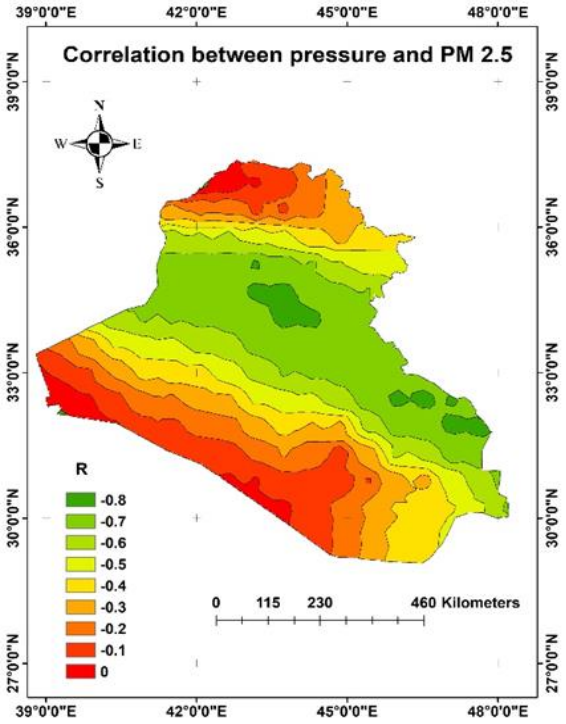


Figure 10. The correlation coefficient between $PM_{2.5}$ and pressure

This means that there is a strong inverse correlation at -0.8 in the central regions. In a study of the influence of weather factors on air quality (29), Its results were in agreement with our results, as it was found that there is an inverse relationship between the concentration of pollutants and pressure, and this result is also consistent with some of the results(32,10).

CONCLUSION

The following main conclusions are attained:

1. The $PM_{2.5}$ have a positve and stable correlation with the temperature parameter, as the higher the temperature, the aerosol formation could be enhanced and PM concentrations increased The highest values of the correlation coefficient were recorded in the central region of iraq, where it was 0.7 and greater than 0.7, while in the northern regions there was no correlation. It have been noticed that the values of the correlation coefficient differ from one region to another, the reason is due to the difference in temperature

2. The relationship between wind and $PM_{2.5}$ is also a positive relationship, and wind is one of the main factors affecting pollutants. The results indicate that wind is the most closely related factor with pollutants we note that

there are strong correlations in most regions, with highest value of the correlation was 0.9, recorded in the central regions, while there was no correlation in the northern regions.

3. The relationship between PM and rainfall, indicate that there are positive and negative correlations in study area. The reason is due to the different amounts of precipitation geographically, seasonally and temporally .In the northern region, weak positive correlations were recorded (0.2-0.4) As for the central regions, there is an inverse relationship, and the highest value of the inverse correlation was recorded -0.5, while the value of correlation was zero in the western region.

4. The relationship between pressure and pollutant concentrations, were negative relationship, the northern region had no correlation. meaning there is no correlation. The correlation values ranged in the central regions from -0.5 to -0.8, where the highest value -0.8 was recorded in the central region.

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