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Relationship Between Winds with Surface Roughness and Carbon Dioxide Concentrations Over Iraq

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Abstract: The methodology used in the study is based on hourly and monthly rates (wind speed and direction, CO_2, and surface roughness) obtained from the European Center for Numerical Weather Prediction at 30 sites in Iraq in 2020. The results showed that the maximum wind speed was 4 m/s at 12:00 noon, while the prevailing wind direction for all sites in Iraq was towards the northwest (NW) and the minimum wind speed was 2 m/s at 00:00 AM. By analysing the monthly wind speed and direction for some selected stations, it was found that the highest value of (SW), i.e., 64% was recorded at Rutba station, and the lowest value of (SW) at Basra station was 45%, where the prevailing direction was found to be towards the north-northwest (NNW). The spatial analysis concluded that the wind movement is directed from the north and northwest, explaining that the wind reverses its direction from the mountainous heights to flat lands due to the roughness of the surface in the northern regions above the stations of Iraq. Spearman's test was carried out between wind speed and surface roughness, and between carbon dioxide and surface roughness. It was found that the correlation strength is weak, and the relationship is inverse between surface roughness and wind speed. This analysis is considered the best way to choose the best wind power plants.

Key words: Atmospheric dynamics, carbon dioxide, wind speed, surface roughness, Iraq.

Introduction

The wind speed is subject to several changes and as a result of these changes, the surface roughness and wind amplitude parameters change depending on the topographical features of space, time, and altitude (Laban et al., 2019).

It is known that the wind speed is constantly changing, as the wind produces turbulence through which it facilitates the exchange of pollutants and gases such as oxygen and greenhouse gases that enact fixed water bodies and the atmosphere (Ro & Hunt, 2007). Researchers have suggested a relationship linking dust concentration with wind speed, as the results show that dust and aerosol emissions can be predicted depending on wind speed and relative humidity, as both are considered determinants of dust concentration in the atmosphere (Csavina et al., 2014; Dadaser-Celik & Eda, 2014). Previous studies were conducted in which statistical methods were applied to determine the characteristics of daily changes in wind speed and the difference in the features of wind speed, where wind speed close to the surface of the earth was used. The results showed that wind speed plays an important role in the hydrological cycle and air dispersion (Liu et al., 2022). Researchers presented a scientific study showing that the characteristics of wind speed have a significant impact on the operation and stability of energy dynamics. Therefore, appropriate modelling is necessary for the quantitative estimation of the wind probability

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distribution function and for the probabilistic energy system analysis (Alzubaidi et al., 2022). Specialists in the field of atmospheric dynamics presented a proposal to increase the reactive power of wind speed and direct control of the torque of wind turbines to ensure minimum total harmonic distortion regardless of wind speed fluctuations (Tamalouzt et al., 2022). Predicting wind speed is important for the generation and improving the use of wind energy by relying on multivariate inputs with wind speed, as wind speed is a source of alternative energy and also meets the growing needs of wind energy (Sun & Tongdan, 2022). A research team in a joint scientific study converted the observed data for an area to that imposed at a height of 10 meters on open flat terrain in order to evaluate the wind environment, as the results showed that wind speed is essential for calculating design wind loads (Lee et al., 2022). In a scientific study different from previous studies in the Andes Mountains in Ecuador, wind speed prediction systems were used for the purpose of determining suitable locations for wind energy applications using dynamic neural networks aimed at accurate prediction of wind speed in complex terrain (López & Pablo, 2022). A scientific study that explores the effect of wind intensity and environmental stability on the structure of the column and the dispersion of pollution numerically, as large urban areas are often exposed to excessive levels of heat and pollution, which may result in the formation of a column on the scale of urban areas from the release of heat in a stable atmosphere (Abbassi et al., 2022). The performance of the research model and weather forecasting was evaluated through the (WRF) model in order to know the optimal parameters for determining wind speed, this is what was applied in this scientific study to predict wind speed (Souza et al., 2023). Wind speed entered the military and civil field through the use of small manned aircraft, where the researcher concluded that there is an urgent need to predict the weather and wind speed to improve the safety of aircraft operations (Wilson et al., 2022). This study aims to study the effect of winds on surface roughness and carbon dioxide concentration
?? over selected areas in Iraq.

Data and Methodology

Study Area

Iraq was chosen for this study, which lies within geographic coordinates between latitudes north of the equator (29.5-37.5°N) and northern hemisphere latitudes (39.45-48.45°E) (Yehia et al., 2023). Iraq has a dry subtropical continental climate, with hot and dry summers and cold winters, with high temperatures and little rain in the central and southern regions (Al-Taai et al., 2021). In this study, monthly and hourly data were used, including (WS) and (WD), as well as (SR) and CO_2 obtained from the European center (ECMWF, 2020).

Data

The various processes occurring in the atmosphere must be understood by analysing them, collecting data, identifying variables occurring in the upper atmosphere and the surface layer, and comparing them with other studies. Wind speed and direction were compared to surface roughness at 30 sites in a selected area over Iraq divided according to surface roughness affecting wind speed near the Earth's surface. The data were processed using the MATLAB program, which converts the data files from text to numbers, which is easily handled in graphical and statistical operations, obtained from the European Center for Medium-Range (ECMWF) (Yang et al., 2022) for the period from 1/1/2020 to 31/12/2020. The data indicate hourly wind speed and direction at two heights (10 m and 40 m), and surface roughness data were also collected (Abbood et al., 2021).

Method

Calculate the coefficient of friction u^*, which is the turbulent velocity generated by the wind speed under the action of an external force. The result of the change is either in the horizontal or vertical direction, denoted by (Wever, 2012):

$$u^* = u' = w' \tag{1}$$

u' and w' are the turbulent velocities in the horizontal and vertical directions, respectively. u^* can be calculated using the wind profile equation (Ehrmann et al., 2017):

$$\ln(z) = k/u^* u(z) + \ln z_0 \tag{2}$$

Among them, $u(z)$ on the x-axis and $\ln(z)$ on the y-axis have a linear relationship, so the formula of the straight line ($y = a\ b\ x$) can be similar to formula (2) under neutral conditions. So, we can identify you *, using the slope value as shown (Özkan & Onur, 2022):

$$u^* = k/\text{slope} \tag{3}$$

where k is the constant and its value $k = (0.4)$.

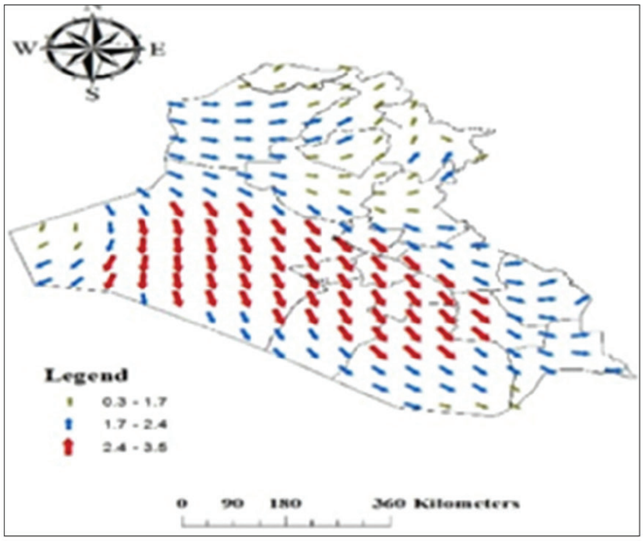
In the same way, the roughness length can be determined using the following equation (Zhang et al., 2021):

$$Z_0 = \text{Exp}\ (a) \quad (4)$$

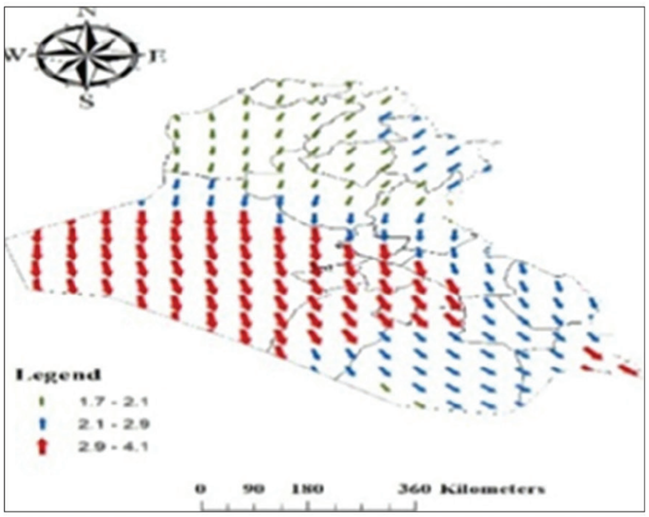
where (a) is the intercept in Z-axis.

Results

Figure 1 shows the highest value of the wind speed is 4.1 m/sec in the northwest direction at 12:00 in the evening, while the lowest value was 0.3m/sec at 00:00 in the morning. This is because the wind speed gradually increases to the maximum at the beginning of noon, and then begins to gradually decrease until it reaches the limit before sunrise. As for the direction of the winds, it is more regular and less volatile during the day and at night.



(a) 00:00 am



(b) 12:00 pm

Figure 1: The hourly mean wind speed and direction for 2020. (a) 00:00 am. (b) 12:00 pm.

Figure 2 shows the wind rose diagram for the Mosul station. Preliminary results for wind speeds peaked in May, reaching speeds between 4.5 and 5 m/s. In other words, the direction of the wind is blowing from high in the mountains to the flat ground. It is noteworthy

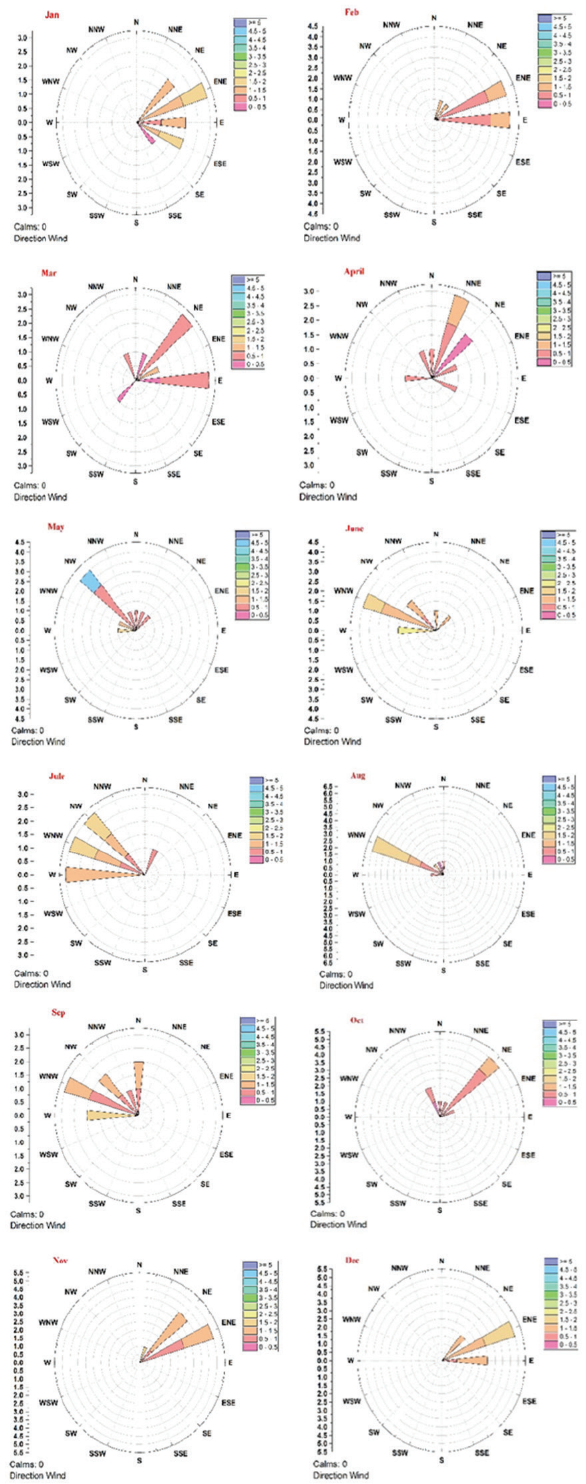


Figure 2: Monthly average (Jan. to Dec.) for wind direction and speed over Mosul station in 2020.

that the lowest recorded wind speeds were recorded in March, with values ranging from 0.5 to 1 m/s, and the wind moved from the center of high pressure to the center of low pressure, and during its blows, it is exposed to several factors that affect its speed and direction. Moreover the winds are strong and strong if the difference or slope is severe, and the opposite occurs in the case that the pressure difference is small.

Figure 3 shows the maximum wind speed observed at Baghdad Station in summer (May, June, July, and August). The wind speed in the northwest direction is 5 m/sec, and the minimum wind speed in each month is 0.5 m/sec (December and January) in the north direction of Baghdad station, the reason is the geographical nature of Baghdad. The earth's surface and its roughness affect the wind movement directly, as the friction of the air with the earth's surface reduces its speed. Therefore, the lower layer of the atmosphere that is directly adjacent to the earth's surface is a completely stagnant layer.

Figure 4 shows that the wind speed at Rutba station reaches a maximum of 6 m/s in July, and we note that in November the wind speed drops to 0.5 m/s, indicating that the cause of the high velocity average wind speed during the summer is the result of a convective thermal predominance related to the intensity of global warming, as well as a deepening seasonal temperature difference.

Figure 5 shows the wind speed at Basrathe maximum wind speed in May, June, and July blowing from the northwest to the south is over 5m/s, and the minimum wind speed was 0.6 m/s. The main reason for changes in wind speed and direction is the effect of surface temperature on air turbulence and instability. The rise in temperature makes the air near the earth's surface lighter, which pushes it upward to be replaced by less hot air coming from the layers of the atmosphere above it. Therefore, probably a layer of turbulent air can form above the earth's surface during the day, where the hot air rises to the top and the air descends. In addition, downdrafts come from high wind speeds, so they transmit a large amount of power to areas where the wind is strong, weakening the wind reach. At night, the Earth's surface temperature decreases, and the air near the Earth's surface will become secure.

Figure 6 shows 75% of the carbon dioxide concentrations covering the central and southern regions represented by the Baghdad and Basra stations, and the reason is the establishment of large number of factories and laboratories that produce fossils. The factories emit high amounts of carbon dioxide during the day due to the continuous operation of machinery and mechanical equipment, but at 00:00 in the morning there is a decrease in carbon dioxide concentrations because the wind speed is very low.

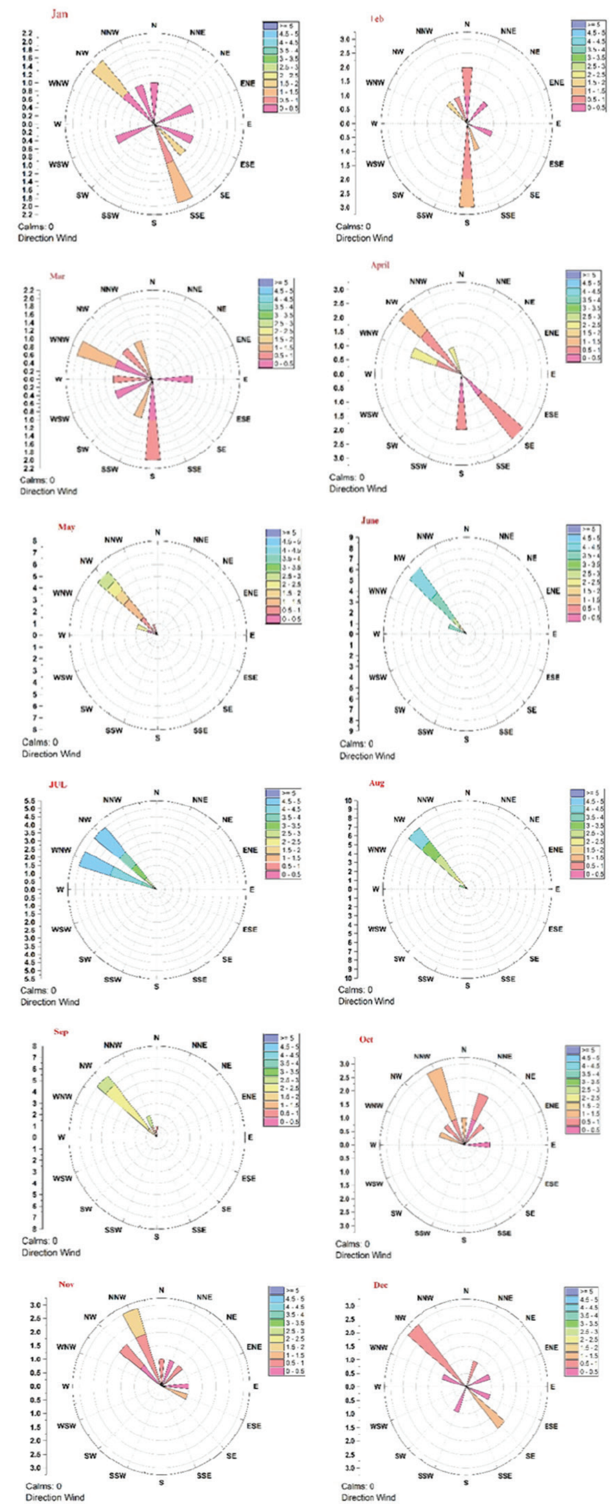


Figure 3: Monthly average (Jan. to Dec.) for wind direction and speed over Baghdad Station in 2020.

Figure 7 shows the spatial analysis of surface roughness for the whole year (2020). Through GIS

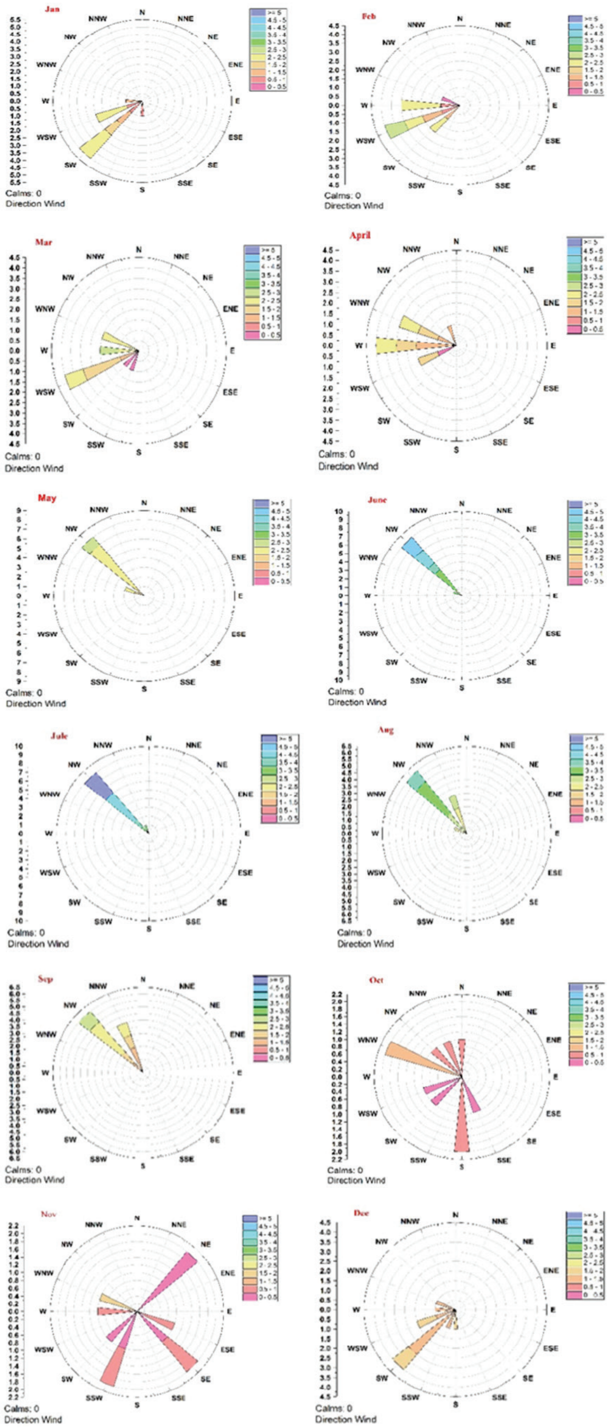


Figure 4: The monthly average (Jan. to Dec.) wind rose over the Rutba Station for the year 2020.

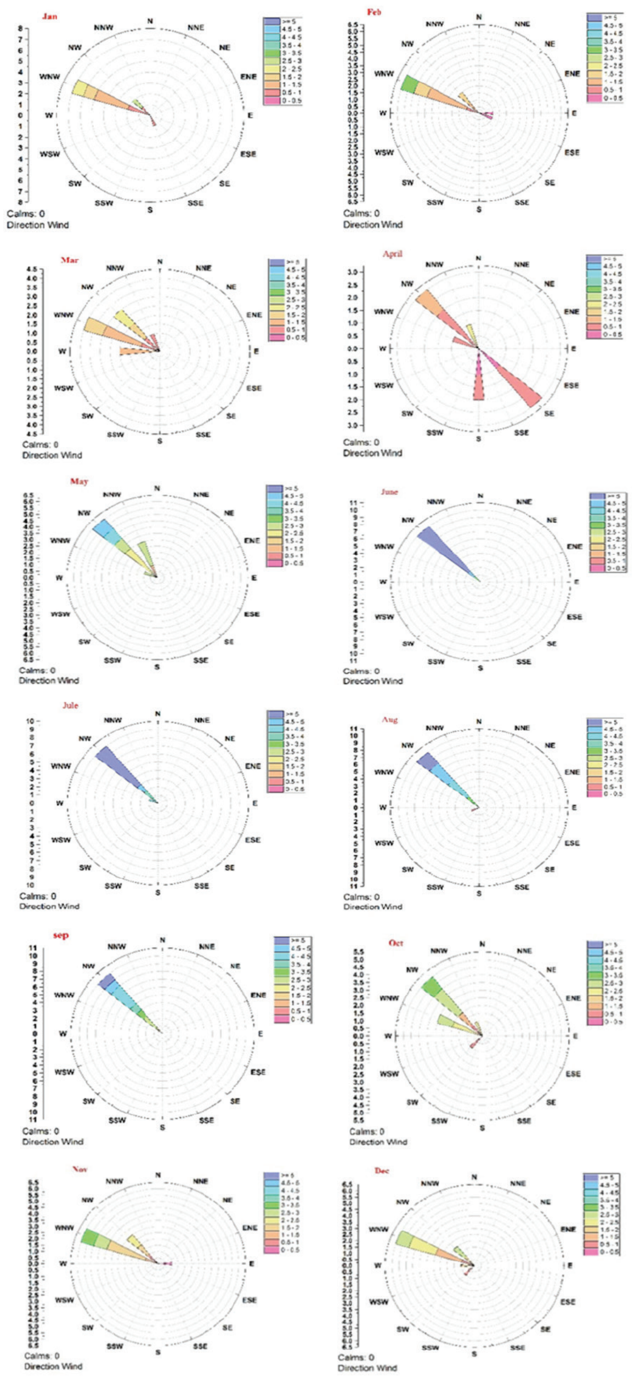
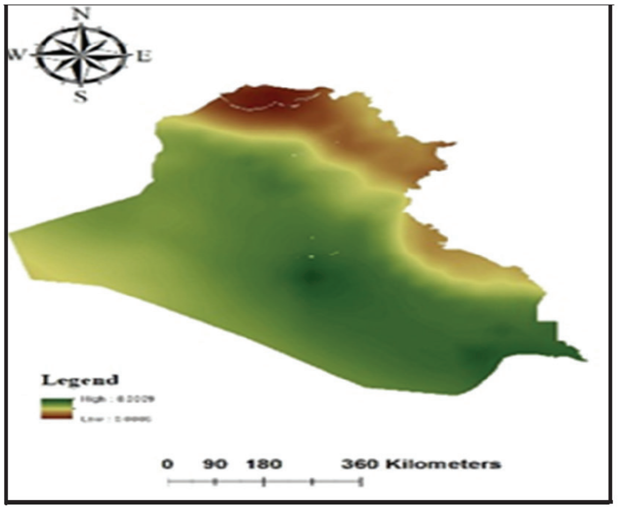
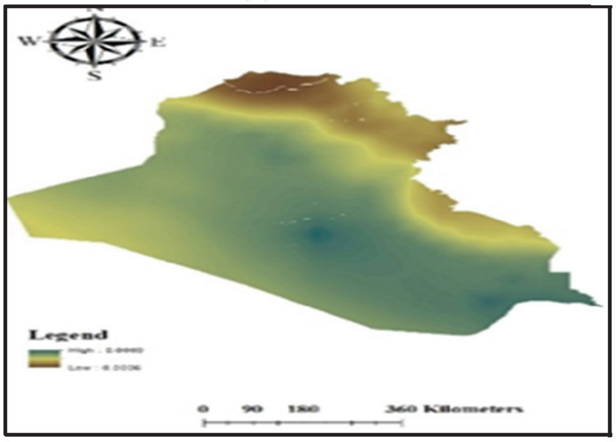


Figure 5: Monthly average (Jan. to Dec.) for wind direction and speed over Basra station in 2020.

analysis, it was found that Iraq can be divided into four regions with different roughness, where the surface roughness ranges from 1 to 66.8 and affects the wind speed, we noticed the region with the least roughness in the first category. The wind speed is the highest, which is what we noticed at Rutba station, followed by the second category, rough areas formed by the Mosul station, and finally, the fourth category, rugged mountain heights, such as the Erbil station, correspondingly, wind speeds vary according to the surface roughness and climatic properties of the study area.



(a)00:00 AM



(b)12:00 PM

Figure 6: Spatial analysis of carbon dioxide over Iraq for the year 2020.

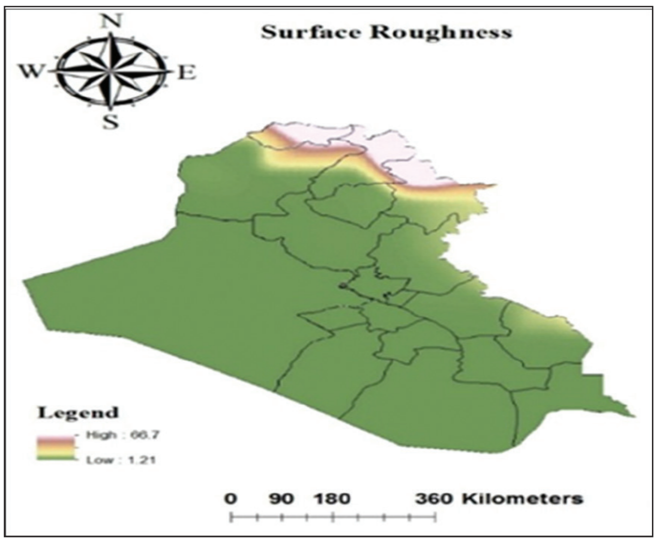


Figure 7: Spatial analysis of surface roughness in Iraq in 2020.

Figure 8 and Table 1 show that due to the lack of topographical factors, the frequency of northwesterly winds in the southern and western stations increased compared with that in the northern and eastern stations, and this area became an air corridor between the northwesterly pressure system centered on the diameter. In summer, the speed of northwesterly winds has increased due to warmer temperatures and localised low pressures that increase air movement this season and the dominance of the ocean.

Table 1: Popular trends in optimal siting for wind farms

Station	*Percentage*	*Prevailing direction of WS*
Mosul	29%	North northwest (NNW)
Baghdad	50%	Northwest (NW)
Rutba	29%	North northwest (NNW)
Basra	45%	Northwest (NW)

Figure 9 and Table 2 show that there is a strong correlation between wind speed and CO_2, as the relationship between them is positive, and the correlation coefficient is 0.9, while the slope is 0.001, and the relationship between them is linear. As for the relationship between wind speed and surface roughness, the strength of the correlation is very weak, since they were found to have an R-value of 0.02, and a value of 0.7 for the slope, and the relationship between the two is inversely nonlinear. The higher the surface roughness, the lower the wind speed. The relationship between surface roughness and carbon dioxide is an inverse relationship and the strength of the correlation is very weak.

Table 2: Correlation strength between WS, CO_2 and SR in Spearman's test

Standards	*R*	*Correlation*	*P*	*Relationship*
WS & CO_2	0.85	V. High Positive	0.0001	liner
WS & SR	0.02	Low positive	0.6826	No-liner
CO_2 & SR	0.04	Low positive	0.0001	liner

Conclusions

Since the study area is located in the Iraqi sedimentary plain, the terrain is simple, the surface is flat, and the wind speed is relatively fast in the southern and central areas. The prevailing winds for all study stations are northwest (NW) by 50%. The highest wind speed

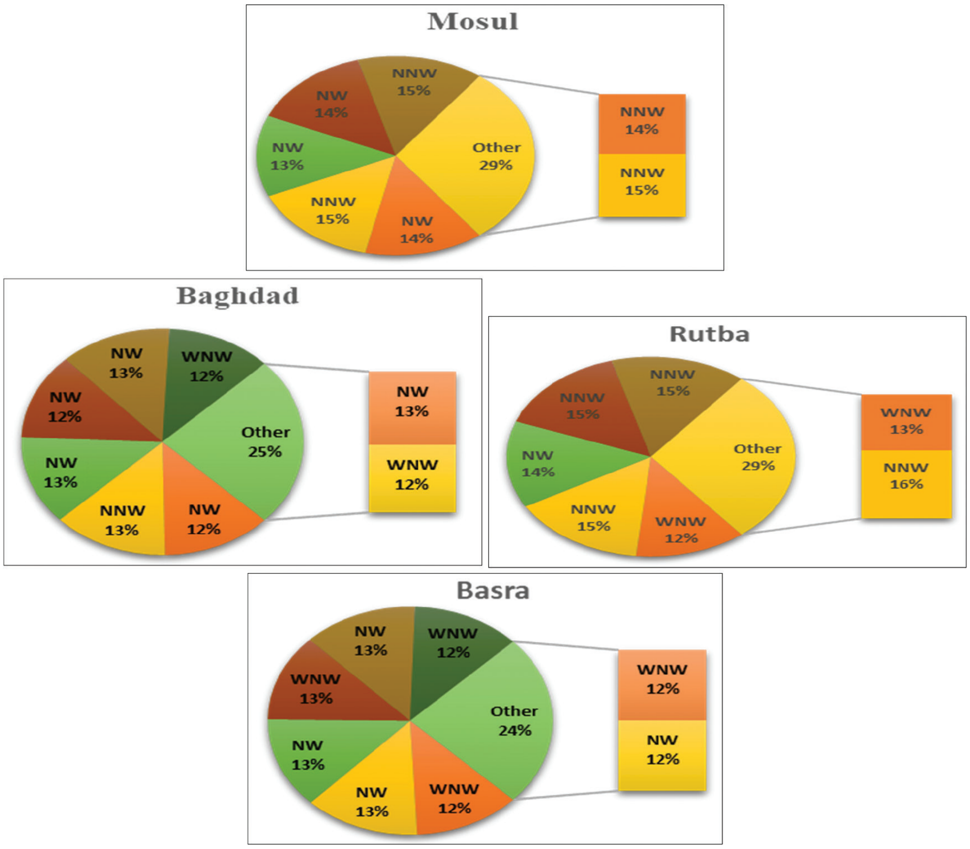


Figure 8: Percentage of the prevailing trend for four selected stations in Iraq.

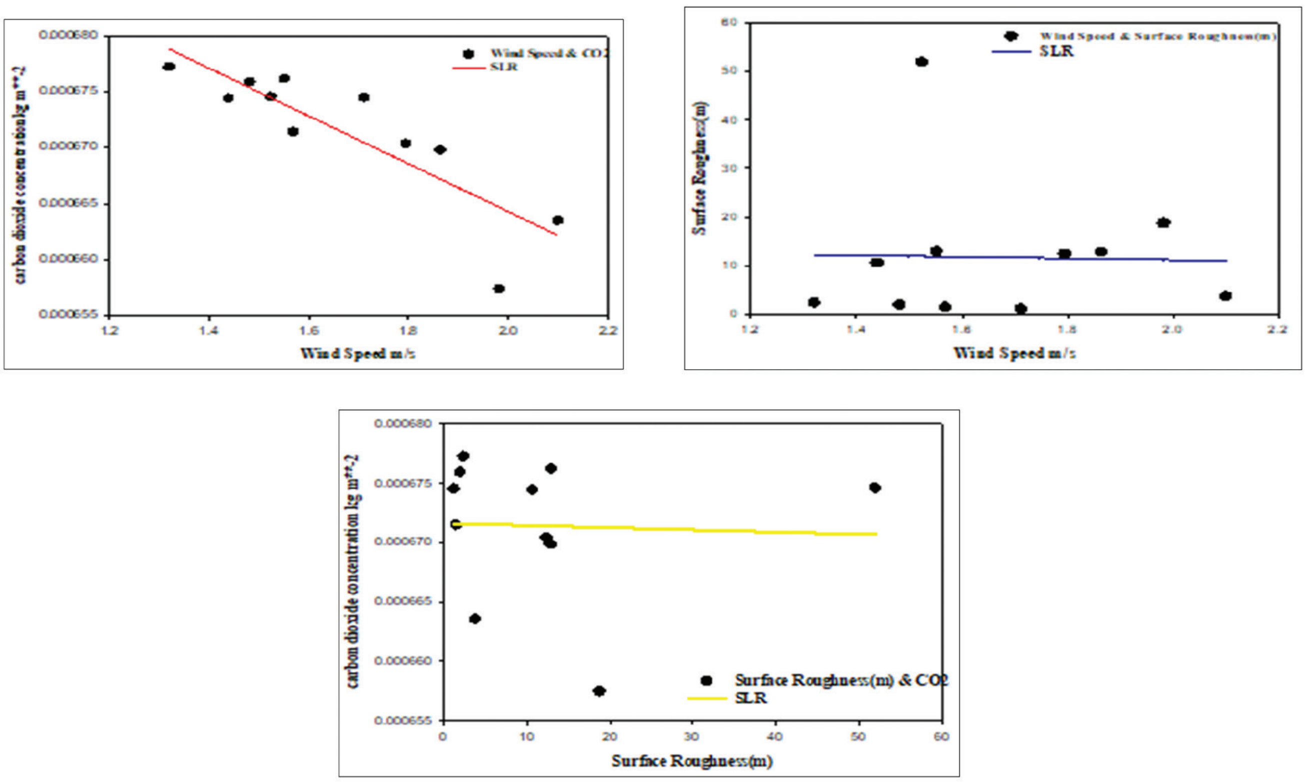


Figure 9: Relationship between wind speed, carbon dioxide rate, and surface roughness in 2020.

appears in summer (June, July, August), and the lowest wind speed appears in winter (November, December). There is a strong and positive correlation between wind speed and CO_2. The correlation between wind speed and surface roughness is weak and inversely proportional.

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