Statistical Modelling of Drought Indicators and Evaporation / Transpiration and Their Impact on Determining the Erosion Ability of Winds in Iraq

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Abstract. Geographical studies are concerned with analyzing and interpreting its most important phenomena, especially those related to climate, which in one way or another affect the provision of harsh environmental conditions such as drought, desertification, and others, as well as being one of its prominent manifestations. As these studies are interested in one way or another in determining the mechanism of action in life, as they are interested in determining the various human activities, and in this research, the researchers were interested in adopting (10) Iraqi climatic stations to find and calculate the values of the phenomena referred to from drought, evaporation / transpiration, wind erosion and the strength of wind pressure in Iraq, using an applied quantitative-statistical method to determine the monthly and annual ranges of wind erosion for the period (1986-2018), and by applying the correlation, regression and determination coefficients. As well as cartographic representation using Excel techniques and geographic information systems (GIS).

1. Introduction
The climate of Iraq is described as thermal extremism, fluctuation, rain anomalies, drought and continental, as a result of its distance from water bodies, as the closest water body to it is the Arabian Gulf, which provides its climate with high humidity often, especially in summer and especially in the southern regions, while the greatest impact, especially in winter, is influenced by the Mediterranean Sea.

The general climatic characteristics referred to above vary between Iraq’s stations spatially and temporally - and this variation is reflected in the variation in indicators of drought, evaporation / transpiration and susceptibility to wind erosion, as the degrees of drought differ due to different temperatures, humidity and rainfall amounts, and this in turn affects the variation in the amounts of evaporation and evaporation / transpiration as well. Between these stations and with the variation in wind speed - all of this formed the basis for a clear change in the degrees of climatic susceptibility to wind in breaking up and transporting soil crumbs, which appeared in different regions as well. All of this coincided with the dryness of the soil, especially sandy ones and with the lack of vegetation cover in general in most areas of Iraq, especially in recent times.

The research boundaries are located within the Republic of Iraq, which is bordered by Turkey to the north, Iran to the east, Syria, Jordan and Saudi Arabia to the west, and Kuwait and Saudi Arabia to the south, and extends between latitudes (29 5° – 37 22°) in the north, and longitudes (38˚ 45’ - '48˚ 45’) in the east, Figure (1), as this location far from marine influences contributed to the lack of moisture and rain, in addition to the extreme temperature extremes. The research included the adoption of a
number of Iraqi remote stations distributed in various regions of Iraq. In addition, for the period (1986-2018).

The main research problem revolves around (how do the characteristics of drought, wind erosion and the strength of wind pressure vary as a result of the different characteristics of wind, rain and evaporation / transpiration).

As for the hypothesis, there is a spatial and temporal variation within the boundaries of the wind and water erosion regions in Iraq because of the influence of a number of factors related to temperature, wind and rain, and the resulting variations in the amounts of drought and evaporation of transpiration.

![Figure 1. Locations of climate stations in Iraq [1][2]](image)

2. Materials and Methods

2.1. Basic concepts and climatic measurements

2.1.1. The characteristics of drought in the climate of Iraq

The drought ACSAD organization defines drought as “a temporary and non-cyclical natural phenomenon that may last for years or a decade, in which the rainfall rate is below the median value, and accordingly drought can occur in any region regardless of its climate classification.” Whereas, the Meteorological Organization (WMO) indicated that drought occurs when the total seasonal rainfall is less than or equal to (60%) of the average for more than two consecutive seasons.

Thorn Thwaite identified four main types of drought, which he defined as “the inability of atmospheric moisture or soil moisture to germinate, or where atmospheric moisture and soil moisture are insufficient for the processes necessary for germination.” These include “permanent drought, represented by the desert, as there is no rainy season equal to the amount of water.” It is necessary for germination, and agriculture is only irrigated, and seasonal drought, in which rain falls in one season and is absent in another, and agriculture is carried out in the rainy season. Finally, the invisible drought, in which the moisture (atmospheric or soil moisture) is less than the plant's need. [3]

Drought causes many problems, including increased soil erosion. Thorn Thwaite relied on the equation below (which relied on precipitation r and temperature T) to determine the dryness if the result of the equation is less than 16, the climate is considered dry, as is the case in most areas of Iraq.

\[
\sum 1.65 \left( \frac{r}{T + 12.2} \right)^{10/9}
\]
The results of the above equation depend on the temperature, which Table (1) indicates the spatial and temporal variation in its rates, as the highest temperatures are recorded in the hot summer months, especially in the Nasiriyah station (38.2 °C) in the month of July due to the dry weather and the station’s distance from marine influences, in addition to the perpendicular sunlight in this month, while the temperatures decrease to reach their lowest rates in the winter months, especially the month of Jan, when the lowest temperature was recorded in the Sulaimaniyah station in northern Iraq by about (6.8°C).

Table 1. Average temperatures °C in Iraq for the period (2018-1986)[4]

| STATION   | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | av   |
|-----------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|
| DUHOK     | 7.6 | 10.1| 13.8| 18.5| 24.4| 30.2| 33.4  | 32.8| 28.1| 22.2| 14.2| 9.5 | 20.4 |
| MOSUL     | 7.3 | 9.3 | 13.3| 18.5| 25.1| 31.2| 34.8  | 34.1| 28.1| 22.1| 13.9| 9   | 20.6 |
| SULAIMANIYA | 6.8 | 8.5 | 13.2| 17.7| 23.8| 30  | 33.5  | 33.4| 28.7| 22.4| 13.8| 9.1 | 20.1 |
| BAGHDAD   | 9.8 | 12.7| 17.4| 23.4| 29.3| 33.3| 35.8  | 35.1| 31.1| 25.1| 16.4| 11.6| 23.4 |
| RUTBA     | 7.8 | 9.9 | 14.2| 19.8| 25  | 29.3| 32    | 31.9| 28.3| 22.3| 14.6| 9.5 | 20.4 |
| HAI       | 11.6| 14.2| 19  | 25.3| 31.7| 36  | 38    | 37.6| 33.5| 27.9| 18.9| 13.4| 25.6 |
| DIWANIYA  | 11.5| 14.2| 19.1| 25.2| 30.9| 34.6| 36.6  | 36.3| 32.8| 26.7| 18.3| 13.3| 25   |
| SAMAWA    | 11.3| 14  | 19  | 25.1| 31.6| 35.3| 37    | 36.8| 33 | 27  | 18.2| 13.4| 25.1 |
| NASIRIYAH | 12  | 15  | 20.2| 25.8| 32.3| 36.2| 38.2  | 37.9| 34.1| 28.2| 19.2| 13.7| 26.1 |
| BASRA     | 12.6| 15.4| 20.1| 26.5| 33.2| 36.9| 38.6  | 38.2| 34.3| 28.7| 19.9| 14.3| 26.6 |

As for the other element on which the drought equation depends, it is rain, which is characterized by its fluctuation, its extremism and its very clear variation between the climatic stations of Iraq, as there was almost no rain in the hot summer months, especially (JUN, JUL, AUG), while the highest amounts were recorded in the month (JAN), especially in the northern stations, as in the Sulamaniyah station, where it recorded (118.9 mm), and the rain decreases as we head south to reach the lowest amounts in the Samawa station with an annual total of (105.9 mm) due to its distance from the effects of the Mediterranean depressions, Table (2). In addition to the factors mentioned in the temperature, which is reflected in the increase in drought levels, especially in the southern regions of Iraq.

Table 2. Amounts of Rainfall mm in Iraq for the period (2018-1986)[4]

| STATION   | JAN   | FEB   | MAR   | APR   | MAY   | JUN   | JULY  | AUG   | SEP   | OCT   | NOV   | DEC   | TOTAL |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| DUHOK     | 110.4 | 93    | 82.7  | 57.1  | 25.2  | 0.6   | 0.3   | 0     | 0.7   | 22.9  | 64.9  | 90.2  | 548   |
| MOSUL     | 60.6  | 56.5  | 54.7  | 38.6  | 15.8  | 1.4   | 0.2   | 0     | 6.4   | 14.7  | 44.2  | 62.5  | 349.8 |
| SULAIMANIYA | 118.9 | 115.7 | 104.5 | 83.8  | 37.2  | 1.4   | 0     | 0     | 1.6   | 35.4  | 92.5  | 121.2 | 712.2 |
| BAGHDAD   | 22   | 17    | 16.5  | 15.4  | 3.1   | 0     | 0     | 0.1   | 0.6   | 23.7  | 18.5  | 123.1 |
| RUTBA     | 12.5 | 21.7  | 14.3  | 10.6  | 6.7   | 0.1   | 0.1   | 0.4   | 15.1  | 15    | 12.2  | 108.8 |
| HAI       | 24.3 | 18.5  | 19.5  | 14.3  | 2.6   | 0     | 0     | 0.5   | 7.7   | 24.6  | 21.2  | 133.2 |
| DIWANIYA  | 21.9 | 13.8  | 12.4  | 15.1  | 3.2   | 0     | 0     | 0.6   | 5.4   | 21    | 15.4  | 108.8 |
| SAMAWA    | 19.7 | 15.1  | 16.4  | 9.8   | 4     | 0     | 0     | 0.2   | 5.7   | 20.7  | 14.3  | 105.9 |
| NASIRIYAH | 21  | 14.6  | 20    | 15.9  | 3.2   | 0     | 0     | 0.8   | 6.8   | 22.4  | 20.3  | 125   |
| BASRA     | 25   | 17.3  | 19.6  | 12.9  | 3.7   | 0     | 0     | 0.3   | 0.8   | 6.1   | 17.9  | 25.7  | 128.5 |

Figure (2) indicates that Iraq appeared in 3 rainy regions, the most rainy section occupied the least area and included the stations of Dohuk and Sulaymaniyah in the north, while the least rainy region occupied the rest of the northern section, while the least rainy regions occupied the largest part of the area of Iraq and included the central and southern sections with rain not exceeding (260mm) maximum.
2.1.2. Characteristics of evapotranspiration in Iraq

The method of "Najib Kharoufa" was adopted to calculate the amount of evaporation / transpiration in the stations of the study area to show the quantities of water losses by conducting a linear correlation between temperature and day length on the one hand, and the amount of possible evaporation / transpiration on the other hand, and assuming a linear variation in the number of hours of solar brightness and a linear variation in the degree of the heat. [6]

\[
\text{ETO} = C \cdot P \cdot T_c^{1.30}
\]

ETO = Possible evaporation/transpiration (mm)
P = the percentage of the number of hours of monthly sunshine to their annual number.
Tc = Average Air Temperature
C = coefficient of local correction from the climatic data for the months (June, July, August).
C = 0.22 (1+ n/N) (0.90+W/100) (1-0.5Rh) (0.97+ E/10.000).

2.1.3. Characteristics of wind erosion and its pressure strength in Iraq

Erosion means the removal of the upper part of the soil due to natural or human factors. [7]. It is a mechanical displacement of ground materials that can be moved from their places to other areas. Erosion is caused by a variety of factors such as water flow, wind, ice and waves [8].

That is, it represents a mechanical displacement of the crumbling materials resulting from weathering and deposition in other places. [9] Wind erosion is the process of lifting dry and loose particles capable of erosion from the surface layer of the soil by the kinetic energy of the wind [10]. Wind erosion is the process of lifting dry and loose particles capable of erosion from the surface layer of the soil by the kinetic energy of the wind [11].

There are two types of erosion, aquatic and aerobic. Winds play a fundamental and prominent role in the formation of some geomorphological phenomena in the desert and coastal regions through two main processes [11]:

Scatter: It is the removal of soil particles from their place and their transfer to another place. It is also called wind sweep, and geomorphology is also known as winnowing. It is also expressed as Scatter sand. The transport process takes place in three ways: (surface crawl, jump, suspended Load) [12].

Refinement represents the effects resulting from the impact of materials carried or transported by wind on the surfaces of rock.
The effect of erosion and its activity is related to a number of geographical factors, including the characteristics of the climate, as temperatures work to dry the soil, dismantle it and prepare it for the forces of erosion. The wind speed and its characteristics also have a major role in the drying of the soil, the transfer of fragments and soil erosion, and moisture and rain have a positive role in stabilizing the soil and reducing its dryness and thus less exposure to the processes of erosion and erosion. In addition to the activity of sand dunes moving by wind, rain also contributes to the transport process, and sand grains begin to move when the wind speed reaches (12-20 km/h). The amount of sand transported at a wind speed of (34 km/h) is (10 times) the amount of sand transported at a wind speed of (24 km/h). [13] Sand grains are transported by wind in three ways (hanging, jumping and crawling).

As well as the effect of soil properties such as its composition and content of organic, as well as its texture and specific density, and finally its moisture content. As well as the nature of the transported materials (size, shape, mineral composition, hardness, density and impact angle). The characteristics and nature of the surface, represented by surface roughness and topographical phenomena, have a significant impact on increasing its effectiveness. The effectiveness of erosion and its effects are also increased by wrong human activities, including:

Excessive and overgrazing and the movement of animals, which lead to the uprooting of plants, leaving the soil exposed to erosion and disintegration. Excessive logging and removal of vegetation cover by shepherds lead to the demise of much of the vegetation cover, which contributes to exposing the soil to erosion. This is accompanied by a lack of cultivation of pastoral and other crops, as in recent times.

The activity of the movement of civil and military means of transportation in the vegetated areas destroys large areas of pastures and forests, and this is what is happening in many of Iraq's pastures.

There are wrong or untimely agricultural methods, such as expanding the plowing of marginal lands, despite the insufficient rains and the wrong plowing method, as well as the wastefulness followed in agriculture, as the land is plowed and left for up to a full year, especially in the parts of the study area within the desert plateau, which contributes to the disintegration of the soil and prepare them for transportation and in order to find the effect of the wind and its strength, it is necessary to analyze its speed as shown in Table (3), as the wind speed in Iraq varies spatially and temporally, and in general its rates decrease as we head from the north (5.1 km/h) as in the MOSUL station reaches its highest speed in the south as in the station Basra (14.5 km/h),[13] and generally includes the highest rates of wind speed in the hot months, which affect the increase in erosion degrees when the soil is dry and the weather is very hot.

Table 3. averages of wind speeds km/h in Iraq for the period (1986-2018) [4]

| STATION     | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | av  |
|-------------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|
| DUHOK       | 6.1 | 6.5 | 6.1 | 6.1 | 7.6 | 6.1 | 5.4  | 5.8 | 6.1 | 6.1 | 5.4 | 5.0 | 6.0 |
| MOSUL       | 4.3 | 5.0 | 5.3 | 6.1 | 6.8 | 6.5 | 6.1  | 5.4 | 4.3 | 3.6 | 2.9 | 4.0 | 5.1 |
| SULAIMANIYA | 5.4 | 7.2 | 8.6 | 9.7 | 9.0 | 9.4 | 7.6  | 6.8 | 7.6 | 6.8 | 5.8 | 4.3 | 7.4 |
| BAGHDAD     | 9.4 | 10.4| 11.9| 11.5| 11.9| 14.0| 14.8 | 12.6| 10.4| 9.7 | 9.4 | 9.4 | 11.3|
| RUTBA       | 7.2 | 9.0 | 10.1| 9.7 | 9.4 | 9.4 | 11.2 | 8.3 | 6.5 | 6.1 | 5.4 | 5.8 | 8.2 |
| HAI         | 10.8| 13.0| 13.0| 13.3| 13.7| 18.0| 17.6 | 15.8| 14.0| 11.9| 11.2| 10.4| 13.6|
| DIWANIYA    | 7.2 | 8.3 | 9.4 | 9.7 | 8.6 | 10.1| 10.1 | 7.9 | 6.5 | 6.1 | 6.1 | 6.5 | 8.0 |
| SAMAWA      | 9.7 | 11.5| 13.0| 13.3| 13.7| 15.5| 14.4 | 13.0| 11.2| 10.1| 9.0 | 9.4 | 12.0|
| NASIRIYA    | 10.8| 12.2| 13.7| 14.4| 14.8| 18.4| 18.4 | 15.8| 13.7| 10.8| 10.1| 10.1| 13.6|
| BASRA       | 12.2| 13.7| 14.8| 14.8| 15.1| 19.8| 19.1 | 16.2| 14.0| 11.2| 11.5| 11.2| 14.5|

To find the strength of the wind pressure, the equation below was used: [14]

Wind force (kg/m²) = 0.006 × wind speed squared (km/h).
The force of wind pressure applied to the dry of the soil surface is more than the force of the earth’s gravity. Those particles begin to separate from the surface of the soil and then move by wind energy, causing wind erosion when the wind speed exceeds the initial speed required for the movement of the erosive particles. As the various particles of the surface layer of the soil move in size (1 mm and less), the particles whose diameter is less than (0.1 mm) are related to a height of about (1 km), and the particles whose diameters range between (0.1-0.5 mm) move by leaping, while the larger particles move by crawling on the surface of the earth, due to its large size and weight. The minutes that move in the way of jumping are of great importance in being a strong mechanical work, and that the percentage of minutes that move in this way ranges between (50-70%) affecting the process of wind erosion\(^1\). Accordingly, the minutes that move in the manner of jumping have an important and influential role in helping the rest of the other minutes in the movement, as they move the large minutes to crawl or raise the very small minutes in the air. That is, there is a double force that moves loose and portable soil, thus increasing the effectiveness of the wind in the emergence of the wind erosion process\(^{15}\).

Climatic Erosion means the ability of climatic elements to form conditions that lead to dryness and disintegration of soil surface particles, which facilitates the process of transporting them by wind. It is extracted based on the formula of the International Food and Agriculture Organization F.A.O in 1979\(^2\) and its formula as follows\(^{16}\):

\[
C = \frac{12 \times V^3}{100 (PET - P/PET)} \times n
\]

\begin{align*}
C &= \text{Annual climatic susceptibility to wind erosion} \\
V &= \text{wind speed (m/s)} \\
PET &= \text{monthly rate of evapotranspiration/potential transpiration (mm)} \\
P &= \text{amount of rain (mm)} \\
n &= \text{number of days in the month}
\end{align*}

2.2. The results of the applications of drought, evaporation / transpiration and the strength of wind erosion

2.2.1. The values of drought coefficients in Iraq

Table (4) indicates that most of Iraq's climate falls within the dry regions, except for the northern sections, which came within the semi-humid regions. The hot summer is the driest month in Iraq.

Table 4. values of the drought coefficient in Iraq according to Thorn Thwaite equation for the period (1986-2018)\(^{17}\)

| STATION  | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | tot | Status |
|----------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-------|
| DUHOK    | 11.1| 8.1 | 6   | 3.3 | 1.1 | 0   | 0    | 0   | 0   | 4.5 | 8   | 43.2| semi wet |
| MOSUL    | 5.8 | 4.8 | 3.9 | 2.1 | 0.6 | 0   | 0    | 0   | 0.6 | 3   | 5.5 | 26.4| semi dry |
| SULAIMANIYA | 12.7| 11.2| 7.9 | 5.2 | 1.7 | 0   | 0    | 0   | 0.7 | 1.7 | 6.8 | 11.4| 58.6| semi wet |
| BAGHDAD  | 1.7 | 1.1 | 0.9 | 0.7 | 0.1 | 0   | 0    | 0   | 0   | 0.2 | 1.3 | 1.2 | 7.2 | dry |
| RUTBA    | 1.6 | 1.6 | 0.8 | 0.5 | 0.2 | 0   | 0    | 0   | 0.7 | 0.9 | 9.9 | 6.6 | dry |
| HAI      | 1.7 | 1.1 | 1   | 0.6 | 0.1 | 0   | 0    | 0   | 0.3 | 1.3 | 1.3 | 7.3 | dry |
| DIWANIYA | 1.5 | 0.8 | 0.6 | 0.6 | 0.1 | 0   | 0    | 0   | 0.2 | 1.1 | 0.9 | 5.8 | dry |
| SAMAWA   | 1.4 | 0.9 | 0.8 | 0.4 | 0.1 | 0   | 0    | 0   | 0.2 | 1.1 | 0.9 | 5.7 | dry |
| NASIRIYA | 1.4 | 0.8 | 1   | 0.6 | 0.1 | 0   | 0    | 0   | 0.2 | 1.1 | 1.3 | 6.6 | dry |
| BASRA    | 1.7 | 1   | 0.9 | 0.5 | 0.1 | 0   | 0    | 0   | 0.2 | 0.9 | 1.6 | 6.8 | dry |

Figure (3) shows that Iraq included 3 different regions of drought - the drier regions occupied the largest part of the area and included all the central and southern sections, followed by the
less arid region and occupied the northern section - except for the stations of Dohuk and Sulaymaniya, which came within the third least arid region and with a range (2-23°).

Figure 3. Drought factor in Iraq [18]

2.2.2. Values of evapotranspiration in Iraq stations

Evaporation/transpiration values increase with the increase in solar brightness and temperatures with the lack of moisture and rain. Table (5) indicates that the highest values of evaporation were recorded in the hot, dry summer months, as the highest rates were recorded in the Basra station (435.6 mm) in July, while they decline significantly in the northern sections, the lowest rates were recorded in the month of JAN (28.2mm) in the Sulaimaniya station. FIGER (4).

Table 5. values of evapotranspiration/mm in the Iraq for the period (2018-1986) [19]

| STATION    | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | AV  |
|------------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|
| DuHok      | 30.4| 62.4| 79  | 122.9| 185.4| 258.5| 299.8| 275.3| 199.5| 137.8| 67.7| 39.4| 146.5|
| Mosul      | 30.7| 79.6| 129.7| 202.8| 284.2| 332.6| 304.9| 210.8| 144.8| 69.9 | 39  | 157.3|
| Sulaimaniya| 28.2| 44.9| 78.9| 122.1| 193.5| 268.2| 315.2| 295.9| 216.8| 148  | 69.7| 40.1| 151.8|
| Baghdad    | 48.5| 66.1| 120.1| 184.9| 273.4| 321.9| 360.2| 332.7| 254.8| 183  | 94  | 59.2| 191.6|
| Rutba      | 35  | 66.5| 89.6| 144.5| 216.2| 264.8| 302.5| 285.2| 218.9| 152.4| 78.4| 44.4| 156.5|
| Hai        | 64.5| 81.2| 142.5| 215.2| 318.5| 374.7| 409.2| 383.2| 296.5| 222.1| 120 | 76.2| 225.3|
| Diwaniya   | 63.7| 81.2| 143.4| 213.9| 308.2| 355.9| 389.7| 366  | 288.5| 209.8| 115.2| 75.4| 217.6|
| Samawa     | 61.5| 80  | 141.8| 212.9| 312.8| 361.3| 392.3| 371.3| 290.7| 212.2| 115.2| 76.7| 219.1|
| Nasiriyah  | 71.5| 92.3| 162.8| 232.6| 342.2| 395.5| 431.8| 406.9| 319.7| 238.4| 129.9| 83.1| 242.2|
| Basra      | 76.6| 96  | 161.4| 240.8| 352.7| 403  | 435.6| 409.6| 322.3| 244.9| 136.8| 88.6| 247.4|

Figure 4. Evapotranspiration Regions in Iraq for the period (2018-1986) [20]
2.2.3. The strength of the wind pressure in Iraq

This pressure force depends on the wind speed, as the highest-pressure force was recorded in the months and the stations that recorded the highest wind speed, especially in the hot months and the further we head south. It was recorded at the Mosul station in the month of DEC at (0.09 km/m²), Table (6).

### Table 6. Wind pressure strength kg/m² in Iraq for period (2018-1986) [21]

| STATION | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | Av  |
|---------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|
| DUHOK   | 0.22| 0.25| 0.22| 0.22| 0.34| 0.22| 0.17| 0.20| 0.22| 0.17| 0.15| 0.22|     |
| MOSUL   | 0.11| 0.15| 0.20| 0.22| 0.28| 0.25| 0.22| 0.17| 0.11| 0.08| 0.05| 0.09| 0.16|
| SULAIMANIYA | 0.17| 0.31| 0.45| 0.57| 0.57| 0.93| 0.34| 0.28| 0.34| 0.28| 0.20| 0.11| 0.34|
| BAGHDAD | 0.53| 0.65| 0.85| 0.80| 0.85| 1.18| 1.31| 0.95| 0.65| 0.57| 0.53| 0.78|     |
| RUTBA   | 0.31| 0.49| 0.61| 0.57| 0.53| 0.53| 0.75| 0.41| 0.25| 0.22| 0.17| 0.20| 0.42|
| HAI     | 0.70| 1.04| 1.01| 1.06| 1.12| 1.94| 1.87| 1.51| 1.18| 0.85| 0.75| 0.65| 1.14|
| DIWANIYA| 0.31| 0.41| 0.53| 0.57| 0.45| 0.61| 0.61| 0.38| 0.25| 0.22| 0.22| 0.25| 0.40|
| SAMAWA  | 0.57| 0.80| 1.01| 1.06| 1.12| 1.44| 1.24| 1.01| 0.75| 0.61| 0.49| 0.53| 0.88|
| NASIRIYA| 0.70| 0.90| 1.12| 1.12| 1.24| 1.31| 2.02| 2.02| 1.51| 1.12| 0.70| 0.61| 0.61| 1.16|
| BASRA   | 0.90| 1.12| 1.31| 1.31| 1.37| 3.25| 2.18| 1.57| 1.18| 0.75| 0.80| 0.75| 1.30|

2.2.4. Values of climatic susceptibility to wind erosion in Iraq

The high permeability of the soil of most areas of the study area and its inability to retain water and the increase in the rate of evaporation led to its drying and thus increasing its susceptibility to severe wind erosion. It appeared that the highest values of erosion ability appear in the hot months with high evaporation and severe drought, as the month of June constituted (20.1%) of erosion in Iraq and the lowest was in the month of DEC, at (2.64%). The erosion regions can be identified as follows: Table (7) and Fig (5).

### Table 7. values of annual climatic susceptibility to wind erosion in Iraq - period (2018-1986) [22]

| STATION | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| DUHOK   | -4  | -0.81| -0.07| 0.79| 2.48| 1.47| 1.05| 1.27| 1.47| 1.27| 0.04| -1.1 | 3.85  |
| MOSUL   | -0.52| 0.64| 0.44| 1.04| 1.96| 1.74| 1.52| 1.05| 0.52| 0.28| 0.96| -0.25| 7.82  |
| SULAIMANIYA | -3.37| -3.6 | -1.53| 1.85| 3.91| 5.25| 2.87| 2.13| 1.62| -0.4 | -1.08| 10.53|      |
| BAGHDAD | 2.98| 5.16| 9.61| 9.01| 11.01| 17.8| 21.37| 13.29| 7.31| 5.87| 3.94| 3.75| 111.11|
| RUTBA   | 1.29| 2.37| 5.72| 5.47| 5.28| 5.27| 9.23| 3.77| 1.75| 1.57| 0.82| 0.92| 43.27 |
| HAI     | 5.22| 10.27| 12.48| 14.19| 16.87| 37.5| 36.47| 26.41| 17.77| 10.75| 10.75| 5.46| 206.48|
| DIWANIYA| 1.63| 2.86| 4.98| 5.49| 4.24| 6.59| 6.81| 3.33| 1.75| 1.48| 1.21| 1.44| 41.78 |
| SAMAWA  | 4.15| 7.58| 12.79| 14.3| 16.79| 23.85| 19.84| 14.46| 8.93| 6.62| 3.85| 4.43| 137.79|

1. Slight wind erosion areas

It appeared in three regions of Iraq and forms the northern sections (Dohuk, Mosul, Sulaymaniyah), as it recorded the lowest rates of erosion, not exceeding (11°) due to the low rates of drought, evaporation / transpiration, wind speed and strength of pressure in those areas compared with the rest of Iraq regions.

2. Medium wind erosion areas

This region appeared in the Al-Rutba station and the western sections of Iraq are formed as a stone area stronger than the factors of wind erosion in pressure and transport at a rate of (43.57) and Al-Diwaniyah station in the south (41.78).

3. Severe wind erosion areas

The erosion areas within this region were occupied in the Baghdad stations at (111.11 degrees) and Samawa (137.79 degrees).

4. Very severe wind erosion areas

This region occupied the southern regions of Iraq, which are areas where the values of drought and evaporation intensify with increasing temperatures and decreasing rain, as well as an increase in wind
speed, as in the Basra station at a rate of (248.29), followed by Nasiriya (211) and then the HAI (200.48).

Figure 5. Regions of wind Erosion in Iraq (2018-1986)

3. Results and Discussion

3.1. Statistical modeling of the relationship between drought indicators and wind erosion in Iraq

3.1.1. The effect of rain on the susceptibility to wind erosion

Table (8) indicates that there are degrees of correlation of varying strength, but they are generally strong and inverse, which means that the increase in rain leads to a decrease in the degrees of wind erosion, as the highest correlation (-0.83) was witnessed in Dohuk station, being one of the heaviest rainy stations with correlation rate of (69%) , while the weakest was in Al-Diwaniyah station (-0.46) with an effect rate of (21%) because it is a hot, dry station with little rain.

Table 8. Statistical relationships between rainfall and wind erosion in Iraq

| STATION   | correlation | Regression | R^2 % | The type and strength of the relationship |
|-----------|-------------|------------|-------|----------------------------------------|
| DUHOK     | -0.83       | -0.03      | 69    | Very strong morale                      |
| MOSUL     | -0.74       | -0.02      | 55    | strong moral opposite                   |
| SULAIMANIYA | -0.87      | -0.05      | 76    | Very strong morale                      |
| BAGHDAD   | -0.75       | -0.46      | 56    | strong moral opposite                   |
| RUTBA     | -0.48       | -0.17      | 23    | Low morale                              |
| HAI       | -0.82       | -0.89      | 68    | Very strong morale                      |
| DIWANIYA  | -0.46       | -0.11      | 21    | Low morale                              |
| SAMAWA    | -0.71       | -0.57      | 50    | strong moral opposite                   |
| NASIRIYA  | -0.77       | -1.02      | 59    | strong moral opposite                   |
| BASRA     | -0.71       | -1.01      | 51    | strong moral opposite                   |

3.1.2. The Effect of Rain on the Strength of Wind Pressure

Table (9) indicates that the effect of rain is also reversed, meaning that the increase in rain works in decreasing the strength of wind pressure, which is a logical relationship as it works in stabilizing the soil, increasing its moisture and reducing the influence of wind on it. (87.4%), while the Dohuk station recorded the weakest relations with a rate of (0.7%).

Table 9. Statistical relationships between rainfall and Wind pressure strength in Iraq

| STATION   | correlation | Regression | R^2 % | The type and strength of the relationship |
|-----------|-------------|------------|-------|----------------------------------------|
| DUHOK     | -0.08       | -0.0001    | 0.7   | Low morale                              |
| MOSUL     | -0.40       | -0.001     | 13.7  | Low morale                              |
Table 10. Statistical relationships between evapotranspiration and Wind erosion in Iraq

| STATION    | Correlation | Regression | R² % | The type and strength of the relationship |
|------------|-------------|------------|------|-----------------------------------------|
| DUHOK      | 0.72        | 0.01       | 51   | strong morale                            |
| MOSUL      | 0.82        | 0.01       | 67   | A very strong morale                     |
| SULAIMANIYA| 0.84        | 0.02       | 71   | A very strong morale                     |
| BAGHDAD    | 0.88        | 0.04       | 77   | A very strong morale                     |
| RUTBA      | 0.62        | 0.02       | 39   | moderately significant                   |
| HAI        | 0.9         | 0.08       | 81   | A very strong morale                     |
| DIWANIYA   | 0.61        | 0.01       | 38   | moderately significant                   |
| SAMAWA     | 0.82        | 0.04       | 68   | A very strong morale                     |
| NASIRIYA   | 0.88        | 0.08       | 78   | A very strong morale                     |
| BASRA      | 0.83        | 0.09       | 69   | A very strong morale                     |

3.1.3. Effect of Evaporation/Transpiration on the Susceptibility of Wind Erosion

Table (10) shows that all relationships are direct, meaning that the increase in evaporation / transpiration increases the susceptibility to wind erosion, and this is logical, as evaporation works in drying, disintegrating and preparing the soil for erosion. The station has an increase in evaporation rates with increasing erosion. As for the lowest in Al-Rutba station, with a correlation of (0.62) and an effect rate of (39%).

Table 11. Statistical relationships between evapotranspiration and wind pressure strength in Iraq

| STATION    | Correlation | Regression | R² % | The type and strength of the relationship |
|------------|-------------|------------|------|-----------------------------------------|
| DUHOK      | 0.06        | 0.0001     | 0.4  | Low morale                               |
| MOSUL      | 0.60        | 0.0004     | 30.3 | Moderately significant                   |
| SULAIMANIYA| 0.40        | 0.0006     | 16.2 | Low morale                               |
| BAGHDAD    | 0.82        | 0.0019     | 67.7 | A very strong morale                     |
| RUTBA      | 0.45        | 0.0008     | 20.0 | Low morale                               |
| HAI        | 0.87        | 0.0029     | 76.3 | A very strong morale                     |
| DIWANIYA   | 0.50        | 0.0006     | 23.8 | Moderately significant                   |
| SAMAWA     | 0.76        | 0.0019     | 57.5 | strong morale                            |
| NASIRIYA   | 0.86        | 0.0032     | 74.3 | A very strong morale                     |
| BASRA      | 0.99        | 0.0900     | 98.5 | A very strong morale                     |
4. Conclusion
The values of drought, evaporation / transpiration, strength of wind pressure, and susceptibility to erosion winds in Iraq vary spatially and temporally due to a large discrepancy between the characteristics of Iraq’s climate, especially with regard to variations in temperature rates, wind speed and rainfall amounts.

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