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A Statistical Analysis of the Geographical and Climatic Variables Influencing the Continentality Degree in Al-Anbar Governorate

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Abstract:
Continental phenomenon is an essential feature of the climate of the study area, which is characterized by high annual thermal range between (24-25) ° C, low rainfall (58-200) mm per-year and high evaporation values in the summer due to reaching maximum temperatures more than (45) ° C, all this was reflected in the dryness of the region and the dominion of the phenomenon of desertification and thus the destruction of ecosystems and disruption in their balance.
The research aims to show the impact of geographical and climatic factors in the variability of the pattern of geographical distribution of the bituminous degree. The research adopted statistical testing in revealing the most important of those factors affecting this distribution of the six stations, and the results were as the following:
1-All stations recorded a single climatic description, dominated by the very dry continental region according to the Borisov equation, between (72) degrees for Al-Qaim station, located in the far northwest of the governorate, and (76.2) degrees at Al-Nukhaib station located in the south of the governorate.
2- The results of the statistical test showed that the most variable and influencing factors in the phenomenon are relative humidity, wind speed, latitude and the number of clear days with high interpretation coefficients and of significant significance affecting the phenomenon amounted to (81%), (80%), (73%) and (71%) respectively, and with a high correlation strength of (90%), (89%), (85%), and (84%) respectively.
Keywords: Continental phenomenon, Borisov equation, western desert plateau, Anbar Governorate.

Introduction

Continentality is a climatic characteristic typical of the interior regions of continents, particularly concentrated within the latitudinal range of 18° to 20° north of the equator. Continental climate predominates in the Northern Hemisphere, especially in areas far from large water bodies such as expansive lakes, seas, and oceans. This climate is marked by a wide diurnal temperature range, with hot summers where maximum temperatures exceed 45°C, and cold or relatively cold winters where minimum temperatures fall below 8°C, sometimes even below freezing. The diurnal and annual temperature range is influenced by the region’s astronomical and geographical location as well as its topography (1).

The study area’s distance from major water bodies results in low and irregular atmospheric humidity and precipitation levels. Additionally, the influence of cyclonic weather systems and moist air masses is weak due to the area's considerable distance—approximately 521 kilometers—from the Mediterranean Sea, with the city of Al-Qa’im being the nearest and most affected city in Al-Anbar Governorate by Mediterranean depressions. This influence diminishes progressively as one move eastward and southeastward across the governorate. Meanwhile, the effect of the Euphrates River and the Haditha Dam Lake remain limited to the adjacent and surrounding areas. Consequently, the study area and its six meteorological stations are characterized by a distinctly continental climate, as illustrated in Table (1) and Maps (1) and (2).

Research Problem:

Do geographical and climatic factors influence the spatial distribution pattern of continentality in the western desert plateau of Al-Anbar Governorate?

Research Hypothesis

Various geographical and climatic factors affect the spatial distribution pattern of continentality in Al-Anbar Governorate.

Research Objective

This study aims to identify the impact of geographical and climatic factors on the spatial variation of continentality and to determine the most influential factors shaping this distribution pattern in Al-Anbar Governorate.

1 **Table 1.** Astronomical location of the selected stations in Anbar Governorate and their height above sea level.

No.	Station Name	Station Code	Longitude (E	Latitude (N	Elevation (m)
1	**Ramadi**	**645**	**43.18°**	**33.3°**	**48**
2	**Haditha**	**634**	**42.48°**	**34.1°**	**108**
3	**Ana**	**629**	**41.57°**	**34.3°**	**138**
4	**Al-Qa'im**	**627**	**41.41°**	**34.2°**	**177**
5	**Rutba**	**642**	**40.17°**	**33.9°**	**630**
6	**Nukhayb**	**658**	**42.15°**	**31.9°**	**305**

Source: Ministry of Transport and Communications, General Authority of Meteorology and Seismology, Climate Department, unpublished data.

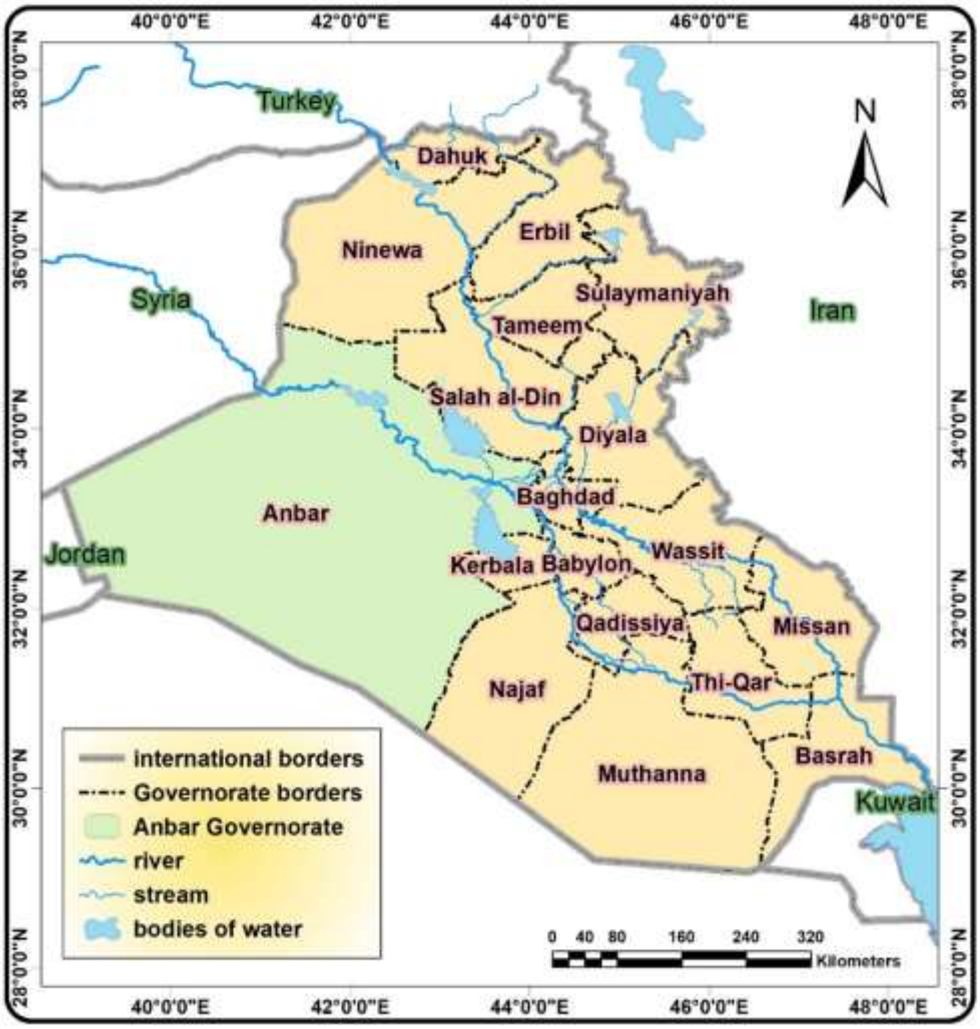
Table 4: Factors Influencing the Geographical Distribution of Continentality in the Western Desert Plateau of Al-Anbar Governorate for the Period (1998–2020)

N0	Climatic station	Continental Degree Y	latitude X1	Height(m) X2	Distance from water bodies (km) X3	Annual average solar radiation values (cal/cm2/day) X4	Average annual angle of incidence of solar radiation (degrees) X5	Average annual actual day length (hours) X6	Average annual temperature (°C) X7	Annual temperature range (°C) X8	Annual wind speed (m/s) X9	Total annual evapotranspiration (mm) X10	Annual average relative humidity (%) X11	Cloudiness amount (day) X12	Annual total number of clear days (days) X13	Total annual rainfall (mm) X14
1	Ramadi	72.7	˚33.3	48	805	507	˚56.95	8.9	22.4	24.2	3.1	2186	44	18	103	103
2	Haditha	73	˚34.1	108	661	387	˚56.11	8.8	20.8	24.8	3.4	2057	46	20	197	141
3	Ana	73	˚34.3	138	575	393	˚55.86	8.7	20.7	25	3.3	2061	45	22.3	192	156
4	Al-Qa'im	72	˚34.2	177	521	409	˚55.95	8.9	20.3	24.6	2.8	1972	47.4	21	193	201
5	Rutba	73.3	˚33.9	630	517	492	˚57.21	9.1	20	24.1	3.4	1925	40	17.3	203	117
6	Nukhayb	76.2	˚31.9	305	747	420	˚57.88	9.2	22.4	24.3	3.8	2219	36	16	213	58

Source: Prepared by the researchers based on:

1. Ministry of Transport and Communications, General Authority for Meteorology and Seismology, Climate Department, unpublished data.

Tables (1) and (3).



Map1. Location of the study area in Iraq.

Source: Republic of Iraq, Ministry of Water Resources, General Directorate of Survey, Map of Iraq and Anbar 2019, scale 1:1000,000 and Arc GIS 10.4 outputs.

1.4 Statistical Test Results of the Effective Variables in the Spatial Distribution Pattern of Continentality in Al-Anbar Governorate

Statistical analysis methods constitute one of the important sources in the field of geographical knowledge, which geographers rely on for analyzing research across its various branches. These methods hold special significance in addressing research problems, thereby advancing planning and development programs. Accordingly, the researchers employed several statistical tools to process the influential variables affecting continentality degree, including the simple correlation coefficient, coefficient of determination (explanation), and multiple linear regression. The results of the impact of these variables are presented in Table (5) as follows:

These variables differ in the nature of their relationships and the strength of their influence on the phenomenon. Some factors exhibit a positive correlation, contributing to an increase in the continentality degree, while others show a negative correlation, reducing it. Based on the data in Appendix (1) and Table (5), the influential factors on the spatial distribution pattern of continentality are as follows:

- **Latitude (North):** This is a significant factor affecting the spatial distribution pattern of the continentality index in the study area. It explains approximately 0.733 of the total spatial variance of the phenomenon. The correlation of this factor is very good and positive, reaching about 85%. The linear regression results indicate that an increase of one unit in latitude results in a decrease in the continentality index by 1.343 units. Therefore, this factor has a strong and statistically significant effect on the studied phenomenon (Figure 1).
- **Elevation above Sea Level:** This factor also shows a strong influence on the phenomenon under study, explaining about 0.404 of the total spatial variance of the continentality index. A weak positive correlation of about 30% exists between elevation and continentality. The regression equation reveals that an increase of one unit in elevation leads to an increase in the continentality index by 0.497 units. However, this factor does not have a statistically significant impact on the phenomenon (Figure 2).
- **Distance from Water Bodies:** This factor has a limited effect on the studied phenomenon due to the geographical distance between the study area and the nearest water bodies, primarily the Mediterranean Sea—unlike the neighboring countries that are directly adjacent to it. This variable explains approximately 0.188 of the total geographical distribution of the continentality index. It shows a weak positive correlation with the phenomenon, reaching 43%. An increase of one unit in this variable leads to a very slight increase in the continentality index by about 0.005. Therefore, this factor does not demonstrate a statistically significant impact on the studied phenomenon (Figure 3).
- **Annual Average of Solar Radiation Values:** This factor has a limited impact, accounting for 0.005 of the total variation in the continentality index. It has a weak positive correlation of 60% with the phenomenon. However, an increase of one unit in solar radiation results in a very slight decrease in the continentality index by about 0.001. Thus, this factor lacks statistical significance in affecting the phenomenon (Figure 4).

Table 5: Results of Multiple and Simple Correlations of Factors Affecting Continentality Degree in the Western Desert Plateau of Al-Anbar Governorate

NO	Factor (independent variable)	Symbol	Coefficient of explanation (determination) R2	Correlation coefficient and its nature (±)	Regression value
1	latitude	X1	0.733	0.85	- 1.343
2	Height above sea level (m)	X2	0.407	0.30	0.002
3	Distance from water bodies (km)	X3	0.188	0.43	0.005
4	Annual average solar radiation values (cal/cm2/day)	X4	0.005	0.06	- 0.002
5	Average annual angle of	X5	0.624	0.79	1.413

	incidence of solar radiation (degrees)				
6	Average annual actual day length (hours	X6	0.487	0.69	5.462
7	Average annual temperature (°C)	X7	0.309	0.55	0.774
8	Annual temperature range (°C)	X8	0.084	0.29	- 1.203
9	Annual wind speed (m/s)	X9	0.807	0.89	3.911
10	Total annual evapotranspiration (mm)	X10	0.349	0.59	0.007
11	Annual average relative humidity (%)	X11	0.817	0.90	- 0.308
12	Cloudiness amount (day)	X12	0.475	0.68	- 0.419
13	Annual total number of clear days (days)	X13	0.710	0.84	0.156
14	Total annual rainfall (mm)	X14	0.691	0.83	- 0.025

Source: Based on Appendix (1).

- **Annual Average of Solar Incidence Angle:** This factor demonstrates a strong influence on the studied phenomenon, explaining about 0.624 of the total spatial distribution of continentality. It has a strong positive correlation of approximately 79%. An increase of one unit in this factor leads to a rise in the continentality index by approximately 1.412 (Figure 5).
- **Annual Average of Actual Day Length:** This factor also shows a strong effect on the studied phenomenon, accounting for about 0.487 of the total distribution. The correlation is positive and strong, reaching around 69%. An increase of one unit in this variable results in a significant increase in the continentality index by approximately 5.461 (Figure 6).
- **Annual Average Temperature:** This variable has a notable impact on the spatial distribution of the studied phenomenon, explaining about 0.309 of its variation. It demonstrates a clear positive correlation with the continentality index, reaching around 55%. An increase of one unit in this factor results in an increase of approximately 5.773 in the continentality index (Figure 7).
- **Annual Thermal Range:** This factor has a limited effect on the spatial distribution of the continentality index, explaining approximately 5.087 of the variance. It shows a weak positive correlation with the phenomenon at about 29%. However, an increase of one unit in this factor leads to a decrease in the continentality index by approximately 1.203 (Figure 8).
- **Annual Average Wind Speed:** This variable is among the most significant and essential factors, as it strongly affects the spatial distribution pattern of the continentality index in the governorate. It accounts for approximately 5.807 of the total variance. The correlation is very strong and positive, reaching 89%. The results of the linear regression equation indicate that an increase of one unit in average annual wind speed results in an increase in the continentality index by approximately 3.910. This factor has a statistically significant impact on the studied phenomenon (Figure 9).

- **Annual Total Evapotranspiration:** This factor has a limited explanatory power, accounting for approximately 0.0349, as its influence on the phenomenon is indirect. The continentality index is more directly affected by astronomical location or other dominant climatic variables such as increased wind speed and temperature during summer. This variable shows a moderate positive correlation of about 59%. The regression equation indicates that an increase of one unit in this factor leads to a slight increase in the continentality index by approximately 0.007 (Figure 10).
- **Annual Average Relative Humidity:** This is one of the most influential factors affecting continentality in the study area. It explains approximately 0.817 of the total spatial distribution of the phenomenon. The correlation is very strong and negative, reaching about 90%. An increase of one unit in relative humidity leads to a decrease in the continentality index by approximately 0.308. Therefore, this variable is considered both strong and statistically significant in its effect on the studied phenomenon (Figure 11).
- **Cloud Cover Amount:** This factor demonstrated another strong effect on the studied phenomenon, explaining approximately 5.475 of the total variances. It shows a moderately strong positive correlation of about 68%. An increase of one unit in cloud cover results in a decrease in the continentality index by approximately 0.418 (Figure 12).
- **Annual Total of Clear Days:** This factor showed a strong influence on the phenomenon under study, explaining about 0.710 of the total spatial variability in the continentality index. It has a strong positive correlation with the phenomenon, reaching around 84%. An increase of one unit in this factor results in an increase of approximately 0.156 in the continentality index. Additionally, this factor has a statistically significant impact on the index (Figure 13).
- **Annual Total Rainfall Amount:** Rainfall is one of the key factors in the spatial variation of the phenomenon, as it contributes to lowering the continentality index in the study area. It accounts for approximately 5.691 of the total spatial variances. It shows a strong positive correlation with the phenomenon, estimated at about 83%. The linear regression results indicate that an increase of one unit in rainfall results in a decrease in the continentality index by approximately 0.024. This factor is also statistically significant in its influence on the studied phenomenon (Figure 14).

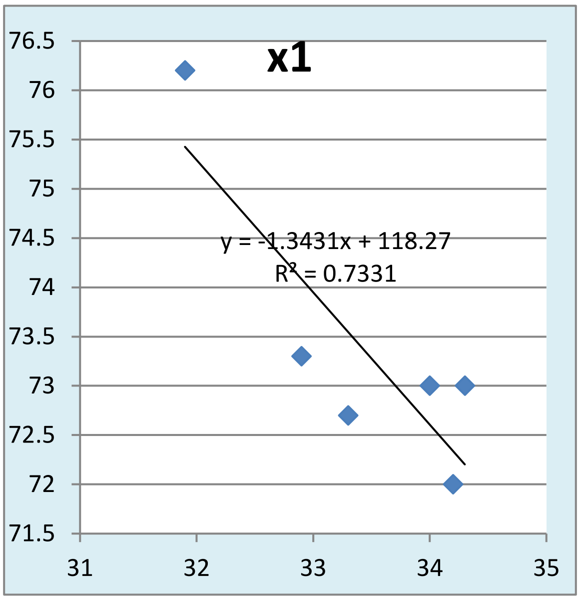


Figure (1) The relationship between continentality and latitude

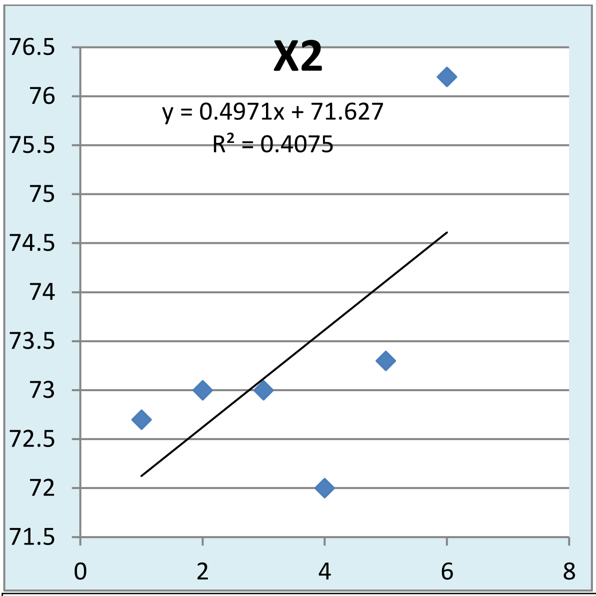


Figure (2) The relationship between the degree of continentality and the height above sea level

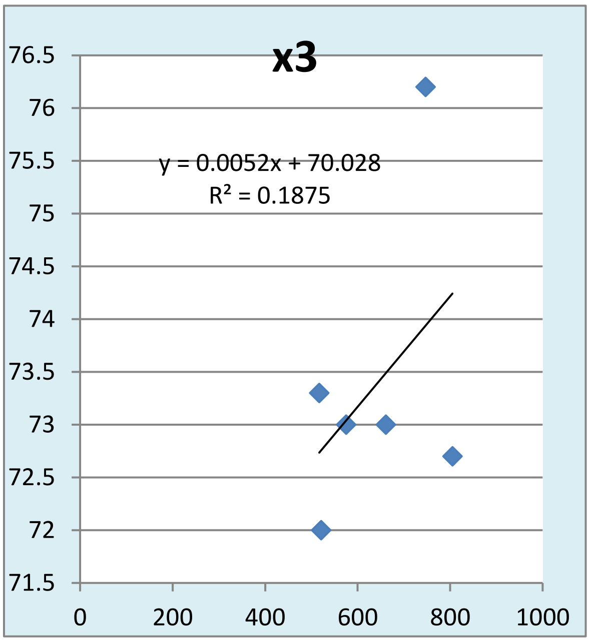


Figure (3) The relationship between the degree of continentality and the distance from water bodies

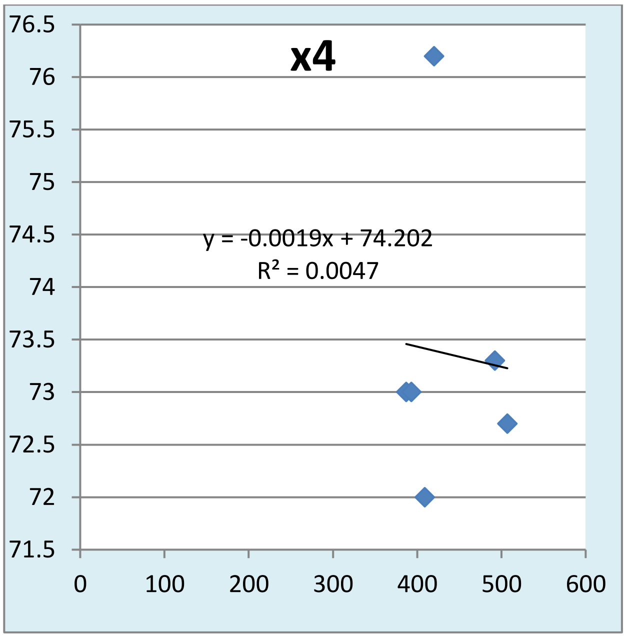


Figure (4) The relationship between the degree of continentality and the annual average of solar radiation

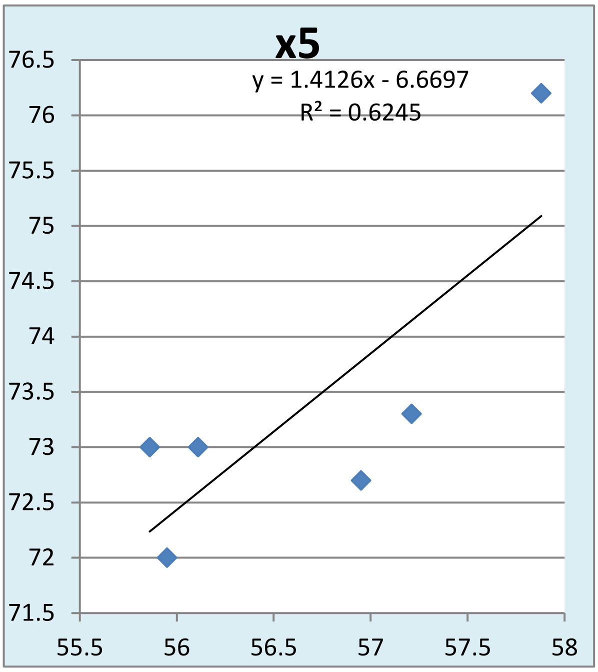


Figure (5) The relationship between the degree of continentality and the annual average angle of incidence of sunlight

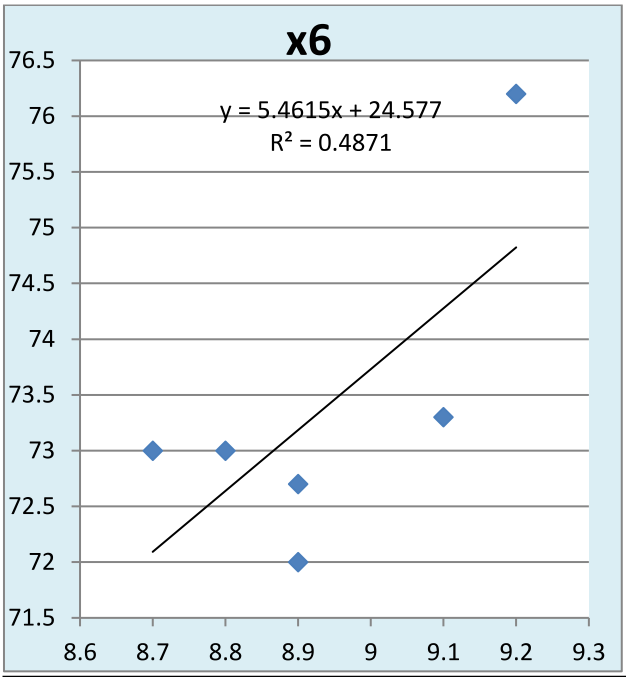
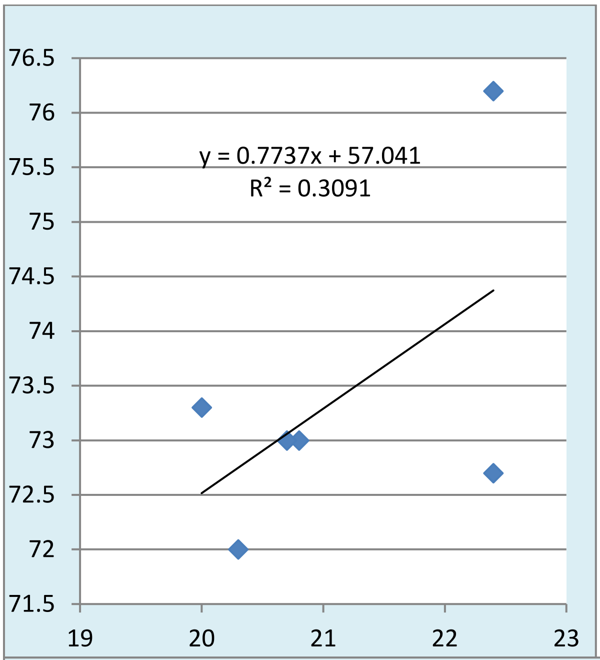


Figure (6) The relationship between the degree of continentality and the annual average of actual day length



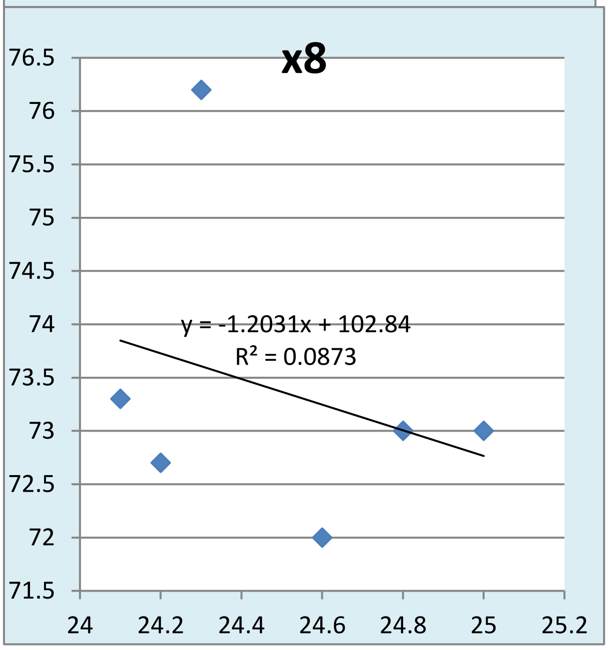


Figure (7) The relationship between the degree of continentality and the annual average temperature

Figure (8) The relationship between the degree of continentality and the annual temperature range

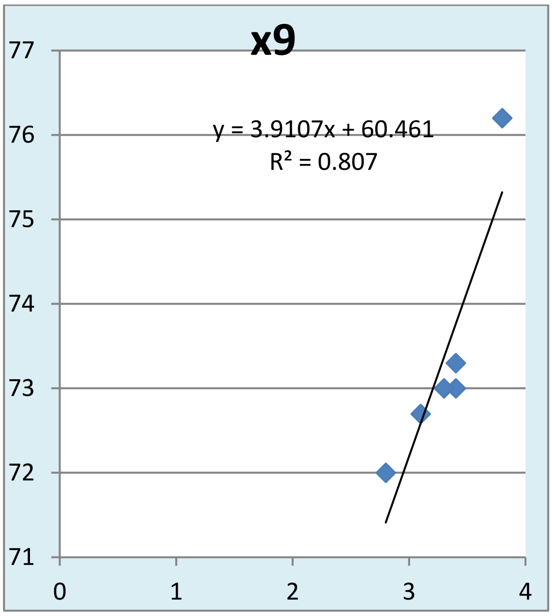


Figure (9) The relationship between the degree of continentality and the annual average wind speed

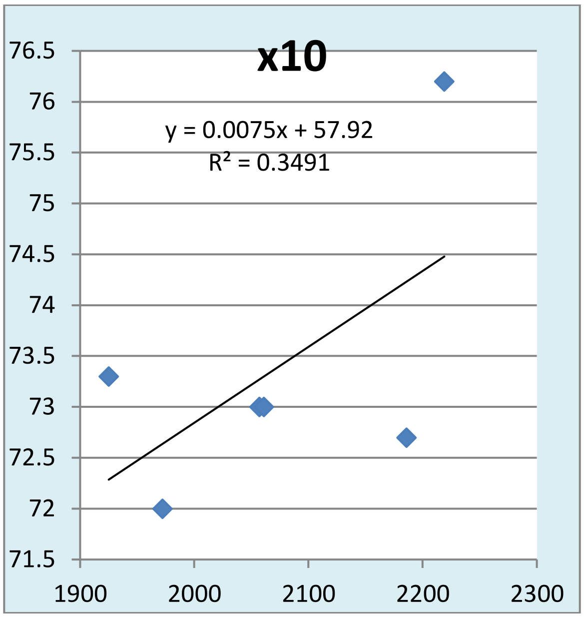


Figure (10) The relationship between the degree of continentality and the annual total of evaporation-transpiration

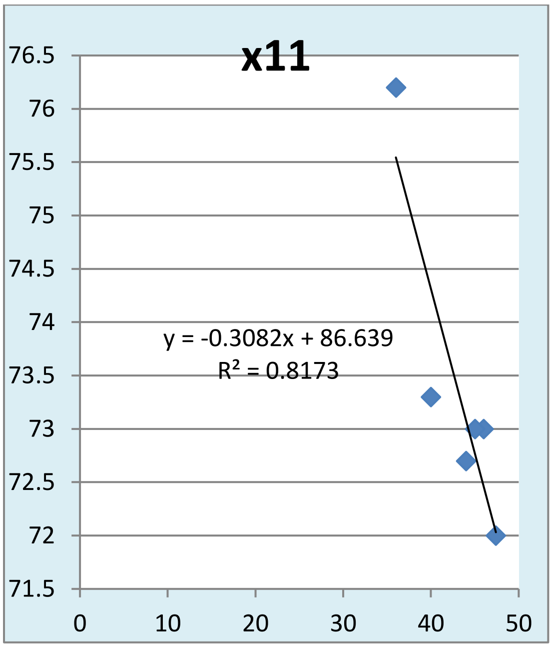


Figure (11) The relationship between the degree of continentality and the annual average of relative humidity

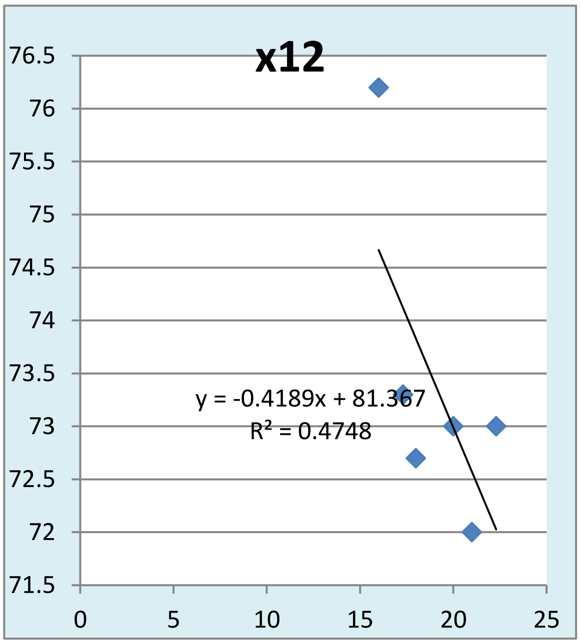
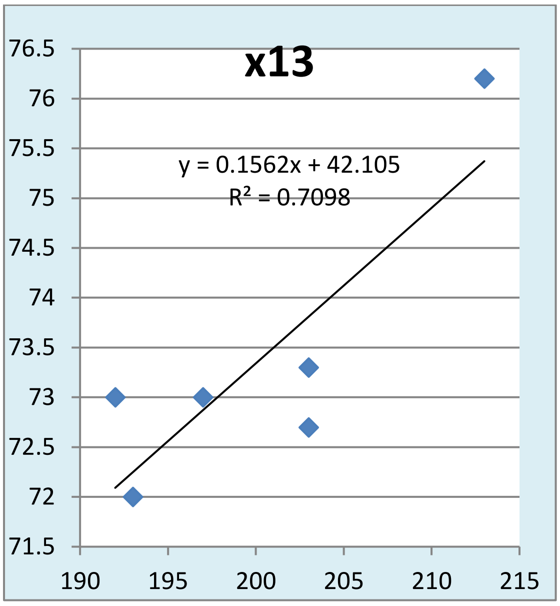


Figure (12) The relationship between the degree of continentality and the amount of cloudiness (day)



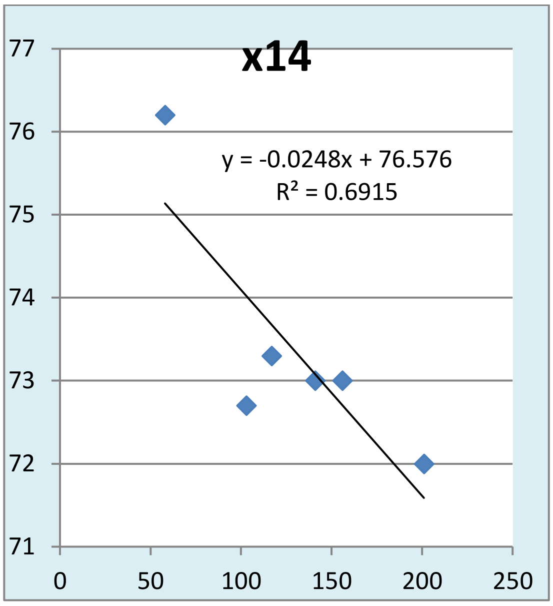


Figure (13) The relationship between the degree of continentality and the annual total number of clear days (day)

Figure (14) The relationship between the degree of continentality and the total annual rainfall amount.

1-5 Conclusions

1. The seven climatic stations in Al-Anbar Governorate collectively represent a single climatic classification of *high continentality* according to the Borisov equation, with slight variations among individual station values. Al-Nukhayb station recorded the highest continentality value at approximately 76.2, while Al-Qa'im station registered the lowest at around 72.

2. The general trend of continentality aligns with the spatial distribution of temperature values across the study area. The continentality values exhibit an increasing gradient from the north and northwest toward the south and southeast.

3. The results of the statistical analysis of the impact of independent variables on the studied phenomenon revealed that the most influential factors were relative humidity, wind speed, latitude, and number of clear days. These variables showed high explanatory power and statistically significant effects on the phenomenon, with determination coefficients of approximately 81%, 80%, 73%, and 70%, respectively, and strong correlation coefficients of about 90%, 89%, 85%, and 84%, respectively.

4. Some other factors, such as solar radiation and elevation above sea level, showed minimal impact and lacked statistical significance, explaining only about 0.05% and 0.095% of the variance, respectively. The remaining variables had a moderate influence on the phenomenon, with levels of effect falling between the previously mentioned extremes.

1.6 Suggestions and Recommendations

1. Develop strategic planning programs to mitigate the effects of continentality by combating desertification and drought. This includes promoting economic development in desert areas through agricultural expansion, particularly the establishment of cattle and calf farms, along with related agro-industrial facilities such as leather processing and the production of meat and dairy products.

2. Rehabilitate more than sixteen desert oasis projects distributed across various parts of the western plateau in Al-Anbar Governorate.

3. Reclaim desertified areas at the outskirts of certain villages and rural zones by protecting the soil from water erosion during the rainy season and from severe wind erosion through afforestation campaigns along roads and around settlements. This also includes planting drought-resistant vegetation.

4. Establish greenbelts using tall, dense, drought-tolerant tree species to reduce the effects of dust storms, prevent desert expansion, and stabilize sand dunes, particularly in two directions:
   - First: Along Iraq's borders with Syria, Jordan, and Saudi Arabia.
   - Second: Around cities and villages, ensuring dense vertical plantation against the prevailing northwesterly winds, and perpendicular to the westerly winds, which represent the most frequent wind directions in the governorate.

- ➢ Implement rainwater harvesting technologies and construct dams in wadis and seasonal streambeds, in addition to establishing grazing lands at the front and sides of these dams to ensure food sufficiency and reduce overgrazing issues.

- ➢ Benefit from successful regional and global practices in combating desertification, and maintain active cooperation with the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), which includes Iraq, Syria, Jordan, and Saudi Arabia. Collaborative efforts should focus on addressing harsh climatic conditions such as drought, wind erosion, and desert expansion—factors contributing to increased levels of continentality.

- ➢ Expand the network of meteorological and agricultural monitoring stations in the study area and surrounding regions to track weather fluctuations and sand dune movements. Additionally, engage in serious collaboration with regional monitoring stations in neighboring countries to track annual severe climatic phenomena.

- ➢ Utilize Geographic Information Systems (GIS), remote sensing, and satellite imagery to achieve the following:
  - o Produce maps showing the spatial distribution of natural vegetation.
  - o Monitor ongoing increases in desertified areas and their geographic expansion.
  - o Protect the environment from degradation by tracking changes in vegetation cover, overgrazing, and the misuse of surface and groundwater resources.

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Appendix (1)

Results of the relationships and influence between the dependent and independent variables - Anbar regions

variable	Constant value	Regression value	Correlation coefficient	Determination coefficient	F test	Influence
X1	**118.272**	**-1.343**	**0.856**	**0.733**	**10.990**	**There is a moral effect**
X2	**72.882**	**0.002**	**0.308**	**0.095**	**0.419**	**No significant effect**
X3	**70.028**	**0.005**	**0.433**	**0.188**	**0.923**	**No significant effect**
X4	**74.202**	**-0.002**	**0.068**	**0.005**	**0.019**	**No significant effect**
X5	**-6.670**	**1.413**	**0.790**	**0.624**	**6.652**	**No significant effect**
X6	**24.577**	**5.462**	**0.698**	**0.487**	**3.800**	**No significant effect**
X7	**57.041**	**0.774**	**0.556**	**0.309**	**1.790**	**No significant effect**
X8	**102.843**	**-1.203**	**0.295**	**0.087**	**0.383**	**No significant**

						effect
X9	60.461	3.911	0.898	0.807	16.720	There is a moral effect
X10	57.920	0.007	0.591	0.349	2.145	No significant effect
X11	86.639	-0.308	0.904	0.817	17.892	There is a moral effect
X12	81.367	-0.419	0.689	0.475	3.616	No significant effect
X13	42.105	0.156	0.842	0.710	9.782	There is a moral effect
X14	76.576	-0.025	0.832	0.691	8.964	There is a moral effect

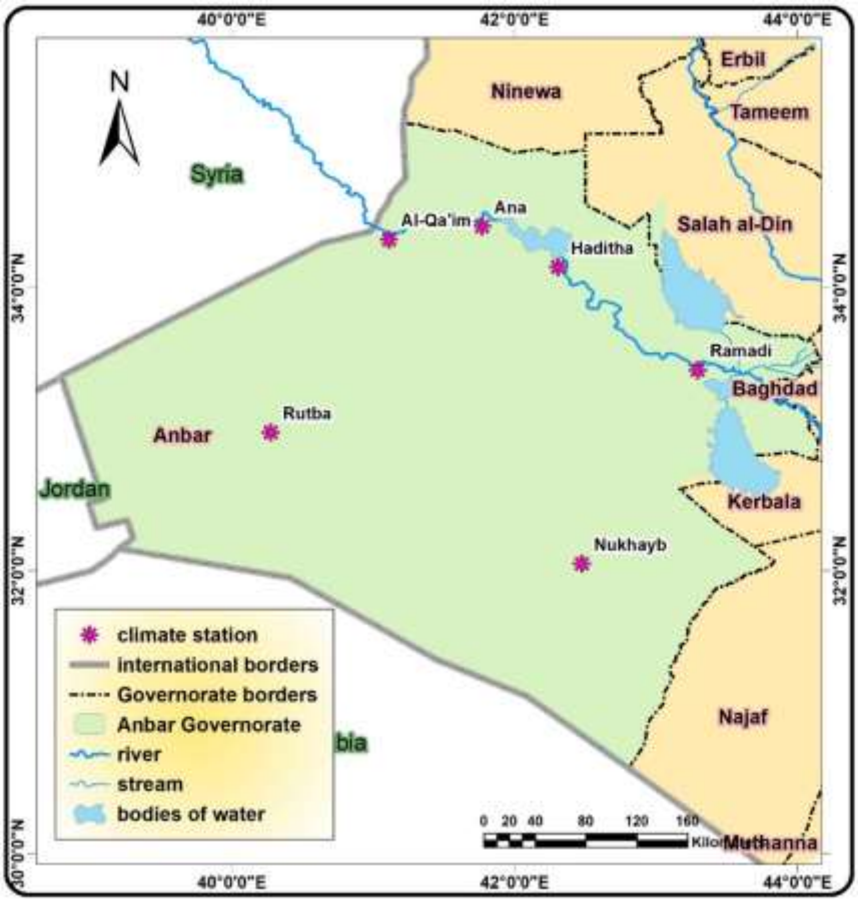
Appendix (2)

y	Correlations	
-.856-*	Pearson Correlation	x1
.030	Sig. (2-tailed)	
6	N	
.308	Pearson Correlation	x2
.553	Sig. (2-tailed)	
6	N	
.433	Pearson Correlation	x3
.391	Sig. (2-tailed)	
6	N	
-.068	Pearson Correlation	x4
.898	Sig. (2-tailed)	
6	N	
.790	Pearson Correlation	x5
.061	Sig. (2-tailed)	
6	N	
.698	Pearson Correlation	x6
.123	Sig. (2-tailed)	

6	N	
.556	Pearson Correlation	x7
.252	Sig. (2-tailed)	
6	N	
-.295	Pearson Correlation	x8
.570	Sig. (2-tailed)	
6	N	
.898*	Pearson Correlation	x9
.015	Sig. (2-tailed)	
6	N	
.591	Pearson Correlation	x10
.217	Sig. (2-tailed)	
6	N	
-.904-*	Pearson Correlation	x11
.013	Sig. (2-tailed)	
6	N	
-.689	Pearson Correlation	x12
.130	Sig. (2-tailed)	
6	N	
.842*	Pearson Correlation	x13
.035	Sig. (2-tailed)	
6	N	
-.832-*	Pearson Correlation	x14
.040	Sig. (2-tailed)	
6	N	

** The correlation is significant at the 0.01 level.

* The correlation is significant at the 0.05 level.



Map2. Climate stations in the study area.

Source: Based on the Anbar administrative map, Table (2), and Arc.map.10.4 program.

1.2 The Spatial Distribution Pattern of Continentality in the Western Desert Plateau of Al-Anbar Governorate

There are several equations used to measure the degree of continentality, including those proposed by Johnson, Khromov, Gorczynski, Debrach, and Borisov. The present study adopts Borisov's equation to calculate the continentality index as a percentage. The mathematical formula is as follows (2) .

K=(AL)×100K = \left(\frac{A}{L}\right) \times 100

Where:

K = Continentality Index

A = Annual thermal range (°C)

L = Latitude of the station

Table (2) illustrates the classification levels of the continentality index for any station. If the index is less than 30%, the climate is considered maritime. The index continues to increase until it exceeds 80%, at which point the climate is classified as *extremely continental* (3) .

2 **Table 2:** Description of Climatic Conditions According to the Continentality Index

No	Climatic Description	Value
1	Marine Climate	Less than 30%
2	Transitional Climate	31-40
3	Continental Climate	41-50
4	Extreme Continental Climate	51-80
5	Very Extreme Continental Climate	more than 80%

S. H. Al-Jubouri, *Applied Climatology*, 1st ed. Baghdad: University of Baghdad, 2014, p. 72.

The results of the continentality values, calculated according to the applied equation and presented in Table (3), indicate that the climatic condition of all the study stations can be characterized as *highly continental*.

Table 3: Continentality Values and Climatic Condition Descriptions for Stations in the Western Desert Plateau of Iraq

No	Station Name	Latitude (N)	Average temperature for January	Average temperature of July	Annual temperature range	Continental degree	Climatic description
1	**Ramadi**	**33.3°**	**9.4**	**33.6**	**24.2**	**72.7**	Very continental
2	**Haditha**	**34.1°**	**7.9**	**32.7**	**24.8**	**73**	Very continental
3	**Ana**	**34.3°**	**7.9**	**32.9**	**25**	**73**	Very continental
4	**Al-Qa'im**	**34.2°**	**7.6**	**32.5**	**24.6**	**72**	Very continental
5	**Rutba**	**33.9°**	**7.5**	**31.6**	**24.1**	**73.3**	Very continental
6	**Nukhayb**	**31.9°**	**7.9**	**33.8**	**24.3**	**76.2**	Very continental

Ministry of Transport and Communications, General Authority for Meteorology and Seismology, Climate Department, unpublished data, compiled by the researchers.

1.3 Geographical and Climatic Factors Influencing the Spatial Distribution Pattern of Continentality in Al-Anbar Governorate

Table (4) indicates that several factors influence the spatial distribution pattern of continentality. Astronomical location determines the angle of solar radiation incidence and its effect, which is notably high in the study stations, ranging between 70° and 81° during the summer. This increases the number of actual sunshine hours and thermal output. Additionally, the study area is characterized by the dominance of high atmospheric pressure throughout most of the year, which negatively impacts the availability of atmospheric moisture and consequently leads to higher continentality values (4).

Furthermore, the distance from water bodies and the weak influence of such features determine the general climatic character—whether maritime or continental (5) .The negative role of wind factor is also evident in arid and semi-arid regions, where its effect intensifies due to the sandy, loose soils and the vast openness of the generally flat surface in the study area (6) .

The dominance of northwesterly winds in the study area exposes it to dust phenomena, as these winds originate from dry desert lands in the Levantine plateaus or western Iraq, carrying significant amounts of dust, especially during the hot season (7).

There is a correlative relationship whereby wind activity contributes to increasing temperatures, enhancing evaporation rates, and reducing atmospheric humidity in summer. This intensifies wind erosion processes in the study area due to the increased wind pressure on the loose, fragile soil components, resulting in their displacement to other locations (8). All of this had a negative impact on the vegetation cover, leading to a decrease in its density and increased deterioration, as it is directly related to rain and inversely related to drought (9).