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Determining the Frequency of Dry Years in Najaf Governorate Using the Standard of High Temperature and Rain During the Period 1988 – 2017

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The dry years in Iraq in general, and Najaf governorate in particular, are one of the most important climate problems because the drought phenomenon is one of the most dangerous natural disasters that severely affects natural and human resources. This phenomenon is considered one of the early climate phenomena documented in the history of Iraq. It is a recurring phenomenon, which may last for months or even years. Severe drought may cause enormous damage and losses to the economy if it lasts even for a short period. So, try to imagine the situation in the case of long periods. At this point, the importance of the research is clear, whereas the research problem lies in the following question: How can the dry years and their frequency in Najaf governorate be determined and identified? The research assumes that the frequency of dry years in Najaf governorate can be determined by using several standards and statistical methods, including the standard of high temperature and rainfall in the region. To address this topic, the research included the following: an Introduction, followed by Part One that deals with the characteristics of temperature and rain in Najaf governorate during the period 1988 - 1917, and Part Two, in which the dry years and their frequency in Najaf governorate are identified, using the standard of high temperature and rain. The research has a number of conclusions as well as the list of resources.

Key words: *Drought, Climatic Phenomena, Najaf Governorate, Climate, Economy.*

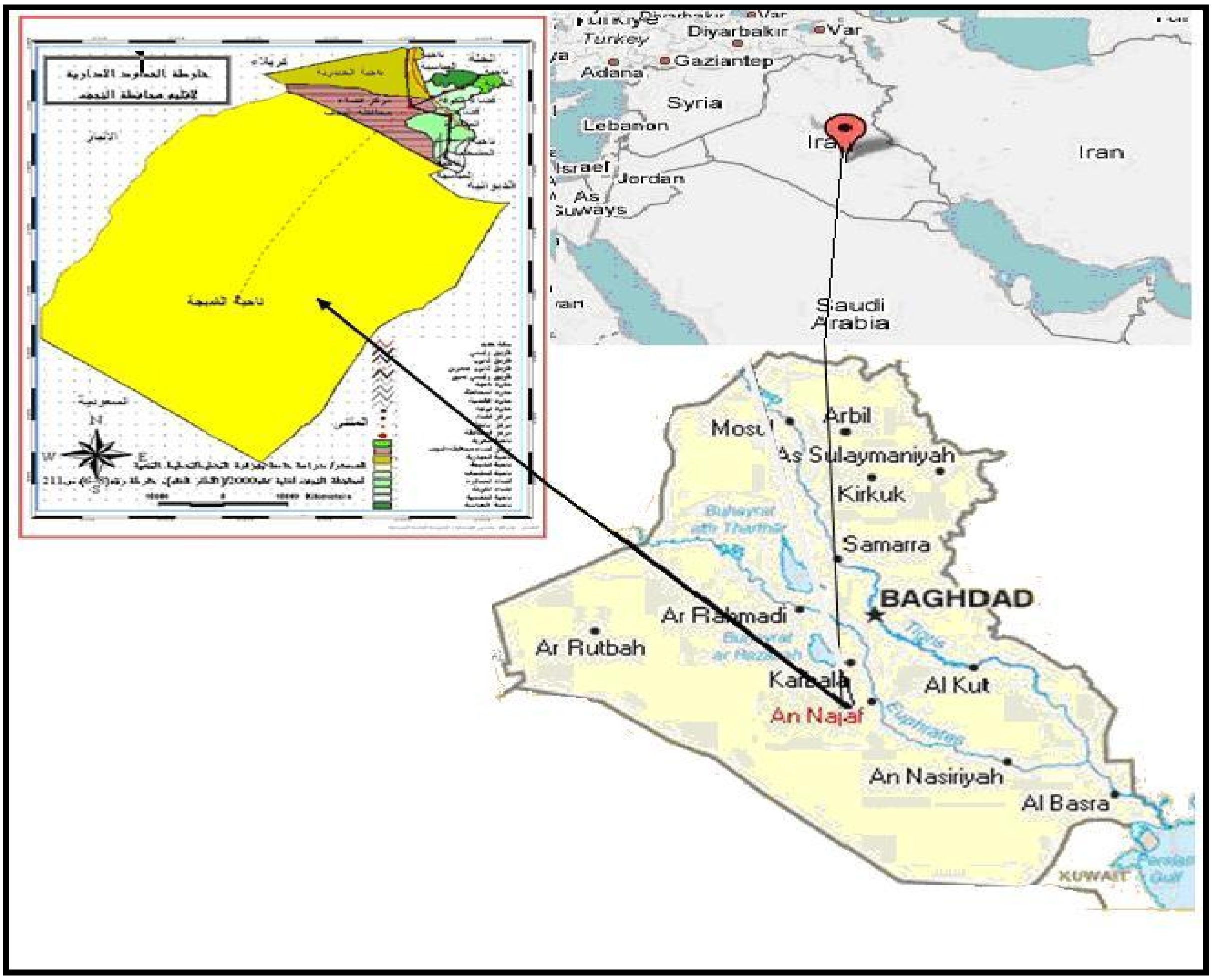
Introduction

Many arid and semi-arid climate countries of the world, including Iraq and the study area, suffer from drought problems. Many factors lead to the emergence of drought phenomenon, including lack of rain, high temperature and evaporation. Najaf governorate is characterised by certain climatic conditions, such as high temperature, evaporation values and shortage of rainfall, which affect the prevalence of drought conditions in general, and its severity in frequent recurring periods (Afrah Ibrahim Shamkhi, 2018).

Numerous studies have confirmed that drought occurs when the rain ceases to fall. So, lack of rain is considered a major indicator of drought. However, the frequency of the problem of drought in certain periods and years suggests that there are several other climatic factors relating to shortage of rainfall, such as high temperature, high wind, and low relative humidity. But temperature is the most important factor, especially the highest temperature (Nasser Waly Fareeh, 2000).

In this research, we used the statistical standard that depends on maximum temperature in addition to the standard of rain to identify the dry years and its frequency in Najaf governorate, which lies between longitudes 43º East - 44º East and latitudes (32º 20 North - 30º North in the southwestern part of Iraq, and 161 km away from the capital "Baghdad as per Map 1. Before applying this standard, it is necessary to address the characteristics of these two climatic elements in the region during the study period (Alaa Qahtan Nuri, 2007).

Map 1. Location of Najaf governorate



Source: Alaa Qahtan Nouri, Factors affecting the selection of the proposed Najaf International Airport site, Higher Institute of Urban and Regional Planning, University of Baghdad, Master's thesis (Unpublished), 2007.

Part One

Characteristics of Temperature and Rain in Najaf Governorate during the Period 1988-2017

First: Characteristics of Temperature

Temperature is one of the most important climatic elements that have a great role in the prevalence of drought features in any region, and in showing the effects resulting from its recurrence for months or years.

Generally, the temperature is always high in Najaf governorate due to its geographical location, which makes it exposed to enormous solar radiation that in turn affects the temperature. It is a well-known fact that the annual mean temperature in the governorate was 25.1°C during the period 1990 - 2017. Through Table 1 and Figure 1, we note that there is a monthly variation in its rates, as in April the temperature begins to rise to 24.8°C, and continues to rise reaching its highest recorded values of 37.9 and 37.4°C during July and August respectively. This rise results from the fact that the sunlight during the hot season takes the vertical form while targeting the study area, in addition to the long hours of sunlight, which greatly leads to an increase in the recorded temperature values. During several months and years, this rate exceeds the general rates, leading to the prevalence of drought conditions within the region (Kazem AbdelWahab, 1991).

Temperatures begin to decrease as of September to 32.5°C, and continue to decreasing due to the declination of sun rays during the cold month to score 17.9 and 12.7°C) during November and December respectively, recording its lowest rates during January of 10.8°C.

As for the maximum temperatures recorded in the study region, the annual rate has reached 32.05°C. Based on the same table, it is noted that this rate experienced a spatial variation in its recorded values during the months of the study period. Temperature begins to rise during March to 25°C, then begins to gradually rise to record its highest values during July and August of 45.3°C and 45.1°C, respectively, as a result of the lack of Mediterranean depressions in the region, lack of cloudiness and clear skies, and the vertical sun radiation. All these factors make the region exposed to enormous quantities of solar radiations during the day, which in turn lead to the highest recorded temperatures. In November, it continues to decrease to 24.7°C while recording its lowest rate during January of 16.8°C.

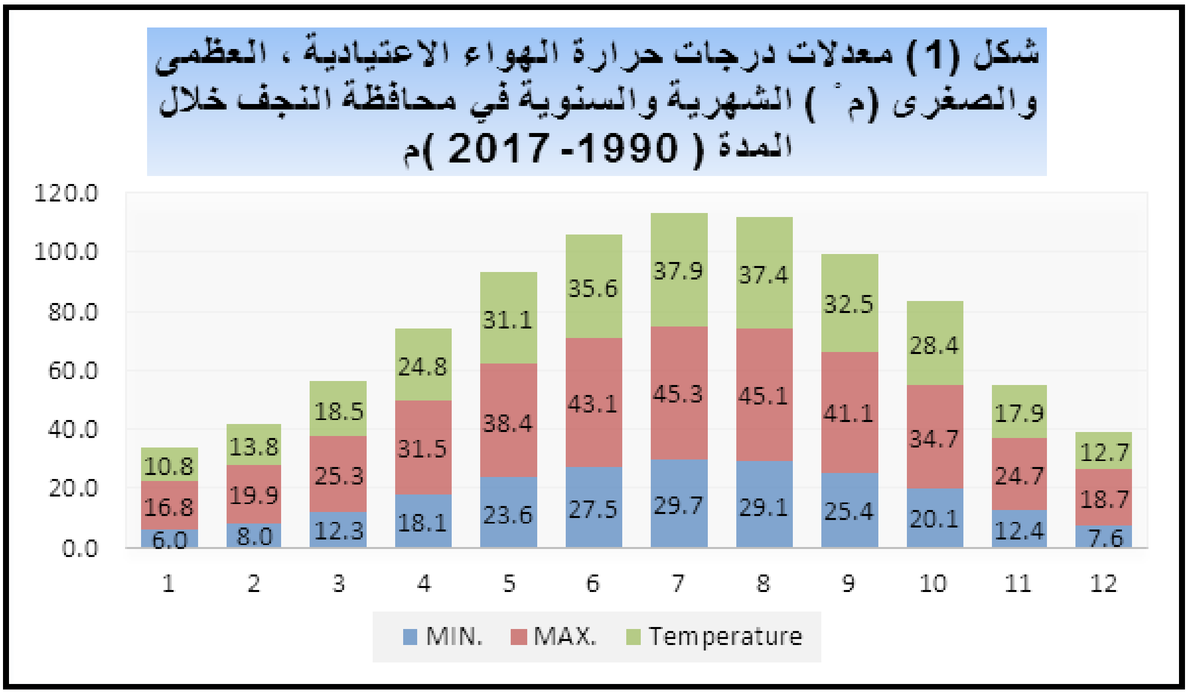
As shown in Table 1 and Figure 1, there is the same above variation in terms of the minimum temperatures recorded in the study area. Temperature recorded its highest rates on July and August of 29.7°C and 29.1°C, respectively, while it recorded its lowest values during December, January and February of 7.6°C, 6°C and 8°C, respectively, at an annual rate of 18.3° C.

Table 1: The monthly and yearly normal-maximum-minimum temperatures (°C) in Najaf governorate during the period 1990 – 2017

Months	Normal temperature	Maximum temperature	Minimum temperature
January	10.8	16.8	6.0
February	13.8	19.9	8.0
March	18.5	25.3	12.3
April	24.8	31.5	18.1
May	31.1	38.4	23.6
June	35.6	43.1	27.5
July	37.9	45.3	29.7
August	37.4	45.1	29.1
September	32.5	41.1	25.4
October	28.4	34.7	20.1
November	17.9	24.7	12.4
December	12.7	18.7	7.6
Annual rate	25.1	32.05	18.3

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological organization and Seismology, Baghdad, unpublished data.

Figure 1. The monthly and yearly normal-maximum-minimum temperatures (°C) in Najaf governorate during the period 1990 – 2017



Source: Table 1

Second: Characteristics of the Rain

Rainfall and its quantity are one of the most important climatic elements that affect the recurrence and frequency of dry years. In the study area, the rainfall system follows the Mediterranean rain system of western continents (between latitudes 30 ° - 40 ° North), which is affected by the Mediterranean depressions (the primary factor of rainfall in the study area). These depressions hit the study area as of October and cease during May. Moreover, the region is exposed to Sudanese depressions that have an effect on the amounts of the rain, in addition to the region's exposure to the impact of secondary systems (the Arab Gulf and Red Sea systems) that lead to variable amounts of rain. Therefore, most of the rain of the study area is of the typhoon type that accompanies air depressions.

In general, rain quantities in the study area are fluctuating and irregular. It falls only during the cold season because there are several factors affect the region, including geographical location, air masses, air depressions, altitude above sea level, and the continental temperature. Moreover, the falling rain is of typhoon type that comes with air depressions, especially the Mediterranean ones that, after hitting, create a state of climatic instability and rainfall. As for the upward falling rain, it is of rare occurrence (Basil Ihsan Al-Qashtaini, 1998).

In this area, rain is short and its amount greatly keeps decreasing for several months and years in a frequent manner, leading to drought during those months and years (we will discuss this point in the next part). Through Table 2 and Figure 2, we figure out that rain quantity is low, as its annual total rate is 86.43 mm during the period 1990 - 2017. Rain quantity varies during months of rainfall. Rain precipitation starts with small quantities, such of October with 4.3 mm due to the impact of the Mediterranean depressions on the region. Then, those quantities increase significantly during November to 20.3 mm, followed by a decrease during December to 10.5 mm. During January, amounts of rain increase up to 15.03 mm, but in February and March, the rate decreases amounting to 9.09 mm and 9.88 mm respectively.

According to the same Table and Figure, it is noted that the rate of rainfall re-increases during April to 13.77 mm, due to the impact of air depressions hitting the study region and the central and southern regions of Iraq (69 - 77 air depressions during November and May) (Neyran Ali Hussein, 2018), plus the influence of air masses and air fronts witnessed during this period. During May, these quantities decrease to 3.56 mm, and it ceases raining during June, July, August and September due to the study region inability to get to these factors, as a result of the predominant high pressure system that prevents their arrival, directing them towards northern Iraq and the study region.

As shown above, it is evident that there is a great variation in rain precipitation within the study region and that the frequent lack of rain for several months leads to the phenomenon of dry years, which will be discussed later.

Table 2: The monthly and yearly rates of rain (mm) in Najaf governorate during the period 1990 – 2017

Months	January	February	March	April	May	June	July	August	September	October	November	December	Annual rate
Rates	15.03	9.09	9.88	13.77	3.56	0	0	0	0	4.3	20.3	10.5	86.43

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi Meteorological organization and Seismology, Baghdad, unpublished data.

Figure 2. The monthly and yearly rates of rain (mm) in Najaf governorate during the period (1990 – 2017)

Source: Table 2

Part Two

Identifying the Dry Years in Najaf Governorate, Using the Standard of High Temperature and Rain

Drought can be defined as one of the frequent climatic phenomena occurring in arid and semi-arid regions. It will be a grave phenomenon if it continues for consecutive several months or years, as this decreases river water and ground water amounts. This results in dry soil and lack of natural plants, creating the phenomenon of desertification that negatively affects the human beings, agricultural and economic activities and all aspects of life (Ali Hussein El-Shalash, 1988).

In certain regions, drought phenomenon frequently recurs during consecutive years as a result of several interrelated climatic reasons. Mostly, these reasons relate to the atmospheric pressure systems, especially at levels 300 - 500 millibars, and that any change in the levels of these systems or their elements affects the surface systems. Of the most important reasons for the dry years in Iraq in general and Najaf Governorate in particular, there are fragile air systems over the Mediterranean and the lack of frontal air depressions, which are the main source of rain in the eastern Mediterranean region (to which the study area belongs). Furthermore, the lack of recurring Mediterranean depressions causes less frequent depressions that combined together during those years and the frequency of relatively low-humidity Sudanese depressions that do not generate heavy rains over the region and raise temperatures and dust during those years, causing the problem of drought. Thus, the properties of several climatic elements during those years lead to the emergence of drought phenomenon as a clear-cut climatic problem, causing the decrease of rain quantities and high temperature.

Specialists of this field have used several standards to identify and set the dry years in various studies on climate, including:

- The dry year equation, which uses the amount of rain precipitation and its standard deviations.
- Standard Precipitation Index (SPI.)

The coefficient of drought according to the presumption of Kovda, that is based on rain precipitation and evaporation / transpiration is calculated according to the Penman formula (Abdullah Qassem, 1981).

In this research, we will apply the standard of temperature and rain precipitation to identify the dry years and its frequency in the study area. This standard counts on the monthly and annual maximum temperatures only and the monthly and annual rainfall rates, as follows:

$Dr = (T^6 – R^6)$

In order to apply this equation: Firstly, identify the years needed to be studied, then adopt the following steps to obtain the variables, as follows:

1- Adjust the monthly means of the maximum temperature, using the following formula:

$Temperature^{6}/T^{6} = (T - T^{-})/\ SD$

whereas:
T^{6}: the adjusted temperature for every month of the year.
T: the monthly mean of maximum temperatures for every month of the year.
T^{-}: the monthly mean of maximum temperatures for every month of all years.
SD: The standard deviation of the monthly mean of maximum temperatures for all years.

2- Adjust the monthly means of the amount of rain using equations and symbols, similar to the formula of adjusting the monthly means of the maximum temperatures, as follows:

$Rain^{6}\ /R^{6} = (R - R^{-})/\ SD$

After extracting the mean for each year out of the adjusted means of the maximum temperatures and the amounts of rain, in order to capture the value of T^{6} and R^{6}, the above-mentioned equation of drought standard is applied to all the set years to reach the desired results (Ali Mukhlif, 2019).

According to this method, the dry year can be identified as the year in which the coefficient value exceeds (**zero**), that is, its value is positive **(+),** while the value of humid year is negative (**-**).

After applying the equation in step no. 1 "Adjusting the monthly means of maximum temperatures", the data shown in Table 3 weas obtained.

Table 3: The monthly means of maximum temperatures in Najaf governorate during the period 1990 – 2017

Month / year	January	February	March	April	May	June	July	August	September	October	November	December	Rate
1990	-1.27	-1.25	-0.40	-0.75	-0.44	-1.08	-0.50	-2.25	-0.77	-0.45	1.40	0.72	-0.59
1991	-1.27	-1.25	-0.40	-0.75	-0.44	0.15	-0.50	-1.55	-1.23	-1.07	0.82	-0.68	-0.68
1992	-1.79	-2.18	-2.46	-1.48	-2.13	-2.06	-2.30	-1.03	-1.15	-0.37	-1.13	-1.46	-1.63
1993	-1.33	-1.43	-0.87	-1.81	-2.33	-1.79	-0.91	-0.74	-0.69	-0.21	-1.42	0.67	-1.07
1994	0.87	0.14	-0.05	0.98	-0.12	-1.35	-1.54	-1.44	-0.62	-0.33	-1.02	-1.81	-0.52
1995	0.29	-0.21	-0.27	-0.81	0.14	-0.55	-1.88	-0.79	-1.23	-0.64	-0.62	-0.64	-0.60
1996	0.06	-0.10	-1.17	-0.88	1.12	-0.82	0.88	-0.15	-1.08	-0.53	-0.10	1.20	-0.13
1997	0.35	-1.31	-1.73	-0.95	0.40	0.42	-1.26	-2.08	-1.15	-0.72	-0.85	-0.59	-0.79
1998	-1.27	-0.85	-1.47	0.65	-0.05	1.22	0.33	0.66	-0.16	0.02	2.09	1.28	0.20

1999	0.87	0.95	0.12	0.52	0.66	-0.02	-0.64	0.02	-0.85	0.14	-0.04	-0.11	0.13
2000	-0.40	-0.73	-0.40	1.18	0.01	-0.55	1.37	0.55	-0.54	-1.23	-0.96	-0.37	-0.17
2001	0.06	0.14	0.76	-0.15	-0.77	-0.91	-0.08	0.72	0.61	-0.02	-0.33	0.24	0.02
2002	0.52	0.66	0.51	-1.28	-0.64	-0.82	0.12	-1.03	-0.23	0.29	0.13	-1.11	-0.24
2003	0.52	0.66	0.51	-1.28	-0.64	0.15	-0.50	0.66	-0.31	0.21	-0.33	-1.07	-0.12
2004	0.46	0.48	1.41	-0.22	-0.25	0.51	0.82	0.66	1.30	0.84	-0.44	-0.77	0.40
2005	0.23	-0.39	0.16	1.11	0.08	0.15	0.88	0.31	0.07	-0.14	-0.27	1.72	0.33
2006	0.35	0.48	0.89	0.52	1.12	2.19	-0.15	1.13	0.53	0.06	-0.39	-1.33	0.45
2007	-0.69	0.54	-0.01	-0.95	2.55	1.13	0.54	0.60	1.61	0.80	1.51	0.32	0.66
2008	0.64	1.64	0.16	-0.48	0.14	1.04	-0.57	0.25	-0.69	0.29	0.02	1.24	0.31
2009	0.64	1.64	0.16	-0.48	0.14	1.04	-0.57	0.25	-0.69	0.29	0.02	1.24	0.31
2010	2.89	1.88	1.41	0.32	0.60	1.57	1.02	0.72	1.15	0.68	2.09	1.28	1.30
2011	-0.23	-0.39	-0.14	-0.15	-0.51	-0.20	0.05	0.02	-0.08	-0.92	-1.71	-0.20	-0.37
2012	0.35	-0.73	-0.83	1.18	0.40	0.77	0.88	0.02	0.46	0.21	0.65	0.37	0.31
2013	0.69	1.30	0.76	0.58	-1.68	-0.64	-0.29	-0.15	-0.31	-0.84	-0.50	-0.64	-0.14
2014	-0.12	0.31	0.42	0.98	0.53	-0.29	-0.15	0.66	0.07	-0.49	-0.44	1.02	0.21
2015	0.87	0.83	0.33	0.32	0.99	0.15	1.23	0.84	2.07	0.49	-0.62	-0.59	0.58
2016	0.29	1.30	0.46	1.38	0.34	0.86	0.95	1.42	0.00	4.28	0.48	-0.68	0.92
2017	0.00	-0.50	-0.01	0.18	0.66	0.51	1.65	1.36	2.30	0.06	0.99	1.59	0.73

Source: Prepared by the researcher, using Iraqi Meteorological organisation and Seismology data and applying the equation Temperature^6 /T^6= (T– T$^-$)/ SD)

After applying the equation of adjusting the monthly means of rain in step no. 2, the data shown in Table 4 was obtained.

Table 4: The monthly adjusted means of rain precipitation in Najaf governorate during the period 1990 – 2017

Year / Month	January	February	March	April	May	June	July	August	September	October	November	December	Rate
1990	-0.54	0.94	-0.67	-0.69	-0.75	0.0	0.0	0.0	0.0	-0.51	-0.80	-0.98	-0.33
1991	-0.78	0.32	0.25	-0.69	-0.75	0.0	0.0	0.0	0.0	0.27	-0.65	0.16	-0.16
1992	-1.02	-0.30	1.16	0.07	-0.50	0.0	0.0	0.0	0.0	-0.51	0.86	1.45	0.10
1993	1.73	1.51	-0.96	4.31	0.76	0.0	0.0	0.0	0.0	-0.30	-0.39	-0.79	0.49
1994	1.05	-0.59	-0.11	-0.46	-0.62	0.0	0.0	0.0	0.0	1.73	1.66	1.18	0.32
1995	-1.09	0.83	-0.04	0.63	-0.69	0.0	0.0	0.0	0.0	-0.51	-0.56	-0.47	-0.16
1996	2.20	0.55	1.79	-0.43	-0.07	0.0	0.0	0.0	0.0	-0.51	-0.77	-0.68	0.17
1997	-0.20	-0.88	0.20	-0.47	-0.62	0.0	0.0	0.0	0.0	3.39	1.33	1.54	0.36
1998	1.54	0.98	2.66	-0.69	-0.75	0.0	0.0	0.0	0.0	-0.51	-0.80	-0.99	0.12
1999	0.37	-0.14	-0.60	-0.69	-0.75	0.0	0.0	0.0	0.0	-0.51	-0.57	0.15	-0.23
2000	-0.44	-0.78	-0.98	-0.61	-0.75	0.0	0.0	0.0	0.0	0.13	0.22	-0.05	-0.27
2001	-0.26	0.08	-0.57	0.74	-0.45	0.0	0.0	0.0	0.0	-0.46	-0.72	0.83	-0.07
2002	-0.88	-0.48	0.02	0.60	0.10	0.0	0.0	0.0	0.0	-0.46	-0.59	0.18	-0.13
2003	-0.97	-0.95	-0.97	0.07	0.44	0.0	0.0	0.0	0.0	-0.51	0.20	0.93	-0.15
2004	0.86	-0.83	-0.90	-0.45	0.79	0.0	0.0	0.0	0.0	-0.51	-0.36	-0.83	-0.19
2005	1.12	0.06	0.41	0.00	-0.71	0.0	0.0	0.0	0.0	-0.51	-0.54	-0.80	-0.08
2006	0.92	3.58	-1.02	1.34	1.66	0.0	0.0	0.0	0.0	-0.18	0.27	3.16	0.81
2007	-0.23	-0.70	-1.02	-0.23	-0.75	0.0	0.0	0.0	0.0	-0.51	-0.80	0.22	-0.34
2008	0.40	-0.85	-0.96	-0.68	-0.32	0.0	0.0	0.0	0.0	2.90	-0.78	-0.09	-0.03
2009	-1.32	-0.34	1.16	0.24	-0.71	0.0	0.0	0.0	0.0	0.37	-0.60	-0.52	-0.14
2010	-1.09	0.60	-0.36	0.05	1.08	0.0	0.0	0.0	0.0	-0.51	-0.80	-0.88	-0.16
2011	0.60	1.12	-0.48	0.53	-0.41	0.0	0.0	0.0	0.0	-0.47	-0.80	1.07	0.10
2012	-1.31	-0.54	-0.70	-0.68	-0.39	0.0	0.0	0.0	0.0	-0.22	-0.18	-0.98	-0.42
2013	1.11	-0.62	-0.70	-0.68	3.52	0.0	0.0	0.0	0.0	-0.28	3.29	-0.82	0.40
2014	-0.90	-0.68	1.92	0.01	-0.75	0.0	0.0	0.0	0.0	-0.17	-0.17	-0.24	-0.08
2015	-0.37	-0.61	0.17	-0.45	0.79	0.0	0.0	0.0	0.0	-0.22	0.98	-0.68	-0.03
2016	-0.05	-0.64	0.46	-0.38	1.19	0.0	0.0	0.0	0.0	-0.22	1.37	-0.58	0.10
2017	-0.44	-0.64	0.85	-0.27	0.41	0.0	0.0	0.0	0.0	-0.20	0.73	-0.50	-0.01

Source: Prepared by the researcher, using Iraqi Meteorological organisation and Seismology data and applying the equation Rain^6 /R^6= (R – R$^-$)/ SD).

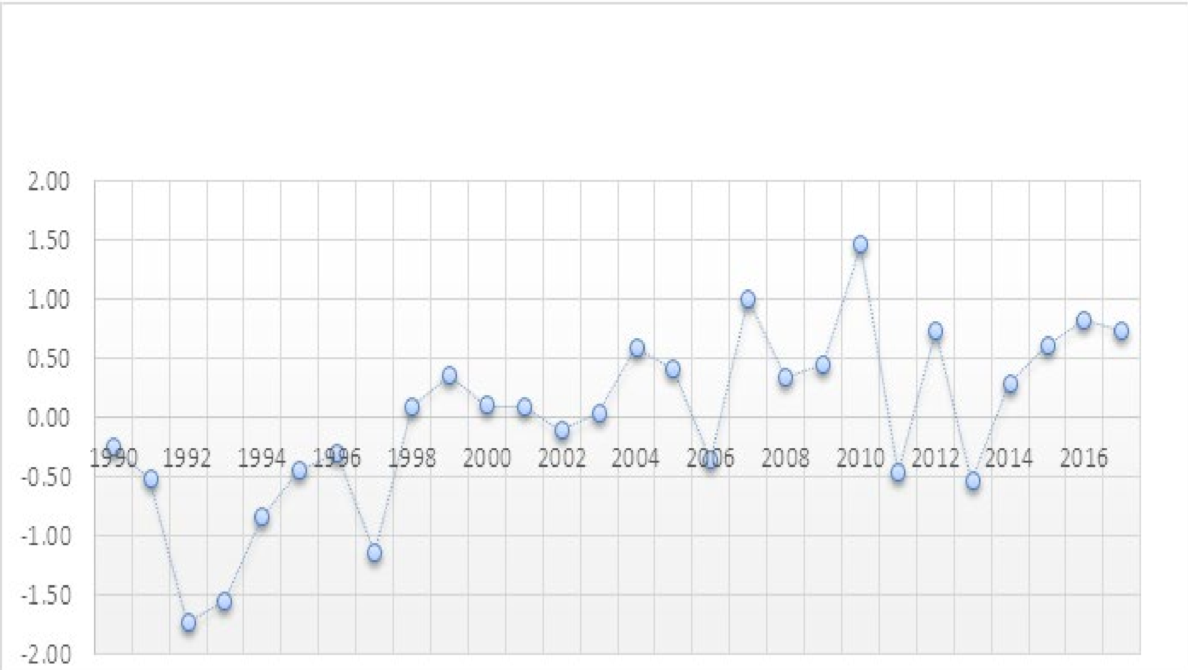
After extracting the mean for each year out of the adjusted means of the maximum temperatures and rainfall in order to capture the value of T^6 and R^6, and applying the equation of drought standard, the dry years in Najaf governorate during the period 1990 - 2017 have been determined (Table 5 / Figure 3).

Table 5: The dry years in Najaf governorate during the period 1990 - 2017, according to the standard of high temperature and rainfall

Dry year	Standard	Year	Dry year	Standard	Year	Dry year	Standard	Year
Dry	0.45	2009	Dry	0.10	2000	Humid	-0.25	1990
Dry	1.46	2010	Dry	0.09	2001	Humid	-0.52	1991
Humid	-0.47	2011	Humid	-0.11	2002	Humid	-1.73	1992
Dry	0.73	2012	Dry	0.03	2003	Humid	-1.56	1993
Humid	-0.54	2013	Dry	0.59	2004	Humid	-0.84	1994
Dry	0.29	2014	Dry	0.41	2005	Humid	-0.44	1995
Dry	0.61	2015	Humid	-0.36	2006	Humid	-0.30	1996
Dry	0.83	2016	Dry	1.00	2007	Humid	-1.15	1997
Dry	0.74	2017	Dry	0.34	2008	Dry	0.08	1998
						Dry	0.36	1999

Source: Prepared by the researcher, based on Table 3 and 4.

Figure 3. Dry years in Najaf during the period 1990 - 2017 according to the standard of high temperatures and amounts of rain



Source: Table 5.

According to Table 5 and Figure 3, there is a temporal variation of the drought years in Najaf governorate during the period 1990 - 2017. It is evident that years of 1998, 1999, 2000, 2001, 2003, 2004, 2005, 2007, 2008, 2009, 2010, 2012, 2014, 2015, 2016, 2017 are dry years. It also clear that this variation in distribution is due to the irregular recurring cycles of temperature and rain, as is the case of relying on the rain element only or temperature element only (Ali Ahmed, 1995). There is a rotation in the years in which drought phenomenon recurs due to the impact of the recorded maximum temperature, which in turn, highlights the properties of drought as a major problem that affects all kinds of water resources and consequently, the human beings and their various activities.

Conclusions:

According to the Above Discussion, We Can Conclude the Following

1- The study area is characterised by high temperatures, especially the maximum temperature, and a shortage of rain. However, the severity of characteristics of both elements will intensify during certain months and years.
2- Because of its affiliation to the arid regions, Najaf governorate witnesses frequent recurring droughts that last for several months or years.
3- Several factors cause the emergence of drought phenomenon, most notably, high temperature and shortage of rainfall in the study area, due to its geographical location, which makes it subject to the effect of several climatic factors.
4- It is possible to identify the frequent dry years within the governorate by using statistical methods that show the effect of several climatic elements on the recurrence of drought phenomenon, including the standard of maximum temperature only, in addition to the standard of rainfall used in this research.
5- As for the dry years, which are identified according to the standard of the influence of high temperatures plus the amount of rain, it is noted that they had no specific time recurrence in the study area due to the variable effect of these two elements.

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