Safwan A. Mohammed[1*], Riad Qara Fallah[2]
[1] Institution of Land Utilization, Technology and Regional Planning, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, Debrecen, Hungary
[2] Department of Geography, Faculty of Arts and Humanities, Tishreen University, Lattakia, Syria
***Corresponding author:** safwan@agr.unideb.hu

CLIMATE CHANGE INDICATORS IN ALSHEIKH-BADR BASIN (SYRIA)

ABSTRACT. The trends and variability of climate change were studied through analyzing the trend of change in the annual temperature and rainfall averages during the period (1960 – 2016) in Al-Sheikh Badr Region by using Normal Distribution and De-Martonne index. The results showed a (-189 mm) linear decrease in the general trend of the rainfall, associated with a (+0.9° C) increase in the general trend of the temperature between 1960 and 2016. Also, Normal distribution showed that the probability of extreme temperatures events higher than 17.5°C increased from 3.3% during the period 1960-1990 to 24.8% during the period 1991-2016. While the probability of an extreme annual rainfall (more than 1800 mm) decreases from 5.3% to 4.7%, nevertheless, the probability of rainfall events less than 800mm where increased. Furthermore, there is a significant trend of drought in the studied area, where the De-Martonne index reaches (-10.75) through the period (1960-2016).

KEY WORDS: Climate change, Normal Distribution, De-Martonne Index, the Mediterranean Region

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INTRODUCTION

In this era, climate change has been considered as one of the most global phenomena that affected many ecosystems, resulting in floods, droughts, and rainfall changes. Mediterranean area is considered as one of the most affected regions by climate change (Nouaceur and Mursrescu 2016), as well as, Arab region which already suffers from water scarcity and any changes will lead to catastrophic impact in ecosystems and different economic and social activities.

Syria, which located in the Middle East, has affected badly by climate change (Skaf and Mathbout 2010; Giorgi 2006; Toreti et al. 2016) including gradually declining in average rainfall patterns and increasing average of temperature, which leads to more drought conditions (Åkesson and Falk 2015).

Climate change components had not been widely studied in Syria, Jalab et al. (2014) proved that there is a significant increase in the average annual temperature in the three regions (Latakia, Kasaab and Slenfeh) in Syria, during the period of analysis 1978-2011. Similarly, Skaf and Mathbout (2010) emphasize the positive trend in dry days number in Syria by using the Effective Drought Index (EDI) during the period 1968-2008, also, Skaf and Saker (2015) analyzed the precipitation characteristics during the period 1960-2010 in six meteorological stations located in the Syrian coastal region, and proved a significant negative trend in annual precipitation in all stations. In a similar vein, Haleme and Qara Fallah (2015) indicated the presence of a decline in the annual rates of rainfall in some stations in Tartous, during the period 1970 – 2010 by using Gamble's distribution. Interestingly, Alsaleh, et al. (2005) indicate that the surface air temperature in Syrian stations seems to be affected by solar cycle and quasi-biennial oscillation as well as the El-Nino southern oscillation with positive trend of annual and seasonal temperature for all studied locations except Latakia during the period from 1955 to 2000. Conversely, Nouaceur and Mursrescu (2016) analyzed rainfall data from three Mediterranean countries (Algeria, Morocco, and Tunisia) and pointed out of the beginning of a gradual return to wetter conditions in these countries, which considered as the first indicator against IPCC reports.

Therefore, the main objective of this research to analyze the trends of climate change components (rainfall and temperature) in Al-Sheikh Badr Region (Syria) during the years 1960-2016, by using Normal Distribution, and De-Martonne index.

MATERIALS AND METHODS

Study area

The research has been conducted in Tartous governorate, in the north of Syria (35° 57′ 40″ and 36o 15′ 55″ East, and 34° 59′ 55″ and 35° 5′ 39″ North; 536 m; Fig. 1).

The entire study area, which located in the coastal region, belongs to the Mediterranean humid or subtropical types of climate, with gradually increasing amount of rainfall, and temperature from the west to the east and decreasing from the higher to the lower slopes of the coastal mountains and from north to south (PAP/RAC 1990). January is the coldest month in the study area, while the hottest month is August. The mean of monthly temperature values increases continuously after January to reach their maximum limit during August, the mean of monthly temperatures varies from 4 to 6° C in January, and from 20 to 22° C in July. The average maximum 31 temperature in the coastal area ranges from 15 to 17° C in January to 28 to 29° C in July. While rainfall distribution and reliability are mainly affected by the seasonal routes of the Atlantic cyclones passing eastwards along the Mediterranean. The rainfall season usually begins in September over the coastal area, and hits the maximum in December through January. The average annual rainfall is 1242.86 mm (COLD 2004). The total area of Sheikh Bader is around 20279 hectares (202.79 km^2). The cultivable area is about 13,250 ha, the main agricultural land use are olive, grapes, green housing, apple, wheat and tobacco. The natural land cover consists mainly of different species such as *Quercus L., Arbutus L., Pinus L., Pistacia L., Rhus cariaria, Prunus L., Ceratonia Siliqua L., Laurus Nobilis., Platanus L. Meanwhile, the main types of shrubs are Spartium junceum L., Micromeria rupestris, Thymus capitatus, Artemisia herba Alba, Myrtus Communis L., Poterium Spinosum L., Inula Viscosa, Calycotome Link, Sorghum halepense, Horolum vulgare, Cynodon dactylon, Juniperus oxycedrus* (Ministry of Agriculture 2015).

The land uses can be classified into 5 classes: natural vegetation cover, agricultural lands, bare land, water bodies and urban areas (COLD 2004). The district of Sheikh Bader comprises 77 villages and 10 extension units spread over those villages. Agriculture is the backbone of the area economy.

Data analysis

To achieve the research goals, climatic data were obtained during the period (1960-2016) from the Directorate of Meteorology - Tartous province. The linear trends of the mean variables (rainfall and temperature) were determined, while the numerical values of the changes in the annual rainfall and temperature were calculated by using Simple Linear Regression by SPSS.

Fig. 1. Location of the study area

After that, Normal distribution was used to analyze the probable density values for the high and low extreme events to determine the impact of it in two ways:

$$f(X)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\bar{x}}{\sigma}\right)^2} \qquad (1)$$

Where: $\bar{X}$ is the Average of the event, X is the amount of event, σ is the standard deviation.

For that, mean and standard deviation for the period (1960-2000) were compared to the period (2000-2016) to determine the change in precipitation and temperature within the study area.

The probable density of the variables (temperature and rainfall) for the first period 1960-2000 was calculated on the basis of a value less than 10% of the probability of their occurrence, so that distributed to 5% higher marginal values to the right of the curve, and 5% minimum marginal values on the left of the curve, then the results were compared to the second period 2000-2016, and the differences were calculated.

At the end, The De Martonne aridity index (De Martonne 1926; Croitoru et al. 2013) was calculated as one of the most important indicators to identify dry/humid conditions of different region (Zarghami et al. 2011), which is given by the following equation:

$$IA=\frac{P}{T+10} \qquad (2)$$

For monthly index:

$$Ia=\frac{P_m}{t_m+10}\cdot 12 \qquad (3)$$

Where: P and T are the annual amount of precipitation and mean annual surface temperature in millimeter and in degree Celsius, respectively.

RESULTS AND DISCUSSION

Temperature Changes (1960-2016)

The general trend of temperature was (+ 0.9)°C linear increase during the period 1960-2016 at the study area, as illustrate in Fig. 2, where it showes a gradual increase since 1970 and a clear higher increase of air temperatures since 2000. These result come along with Lionello et al. (2014) research, where they pointed out the rapidly rising of temperatures in the Mediterranean region through the last decades; which leads to significant upward temperature trends since the 1970s (Lelieveld et al. 2016; Zarenistanak et al. 2014). Additionally, Dubrovsky et al. (2014) analyzed the future climate conditions for the Mediterranean region where the results have shown an increase in temperature in all seasons for all parts of the Mediterranean area.

Rainfall Changes (1960-2016)

The general trend of rainfall was (-189) mm linear decrease during the period 1960-2016 at the study area, as shown in Fig. 3. It is also noted that the period between 1990 and 2000 recorded a significant decrease in rainfall pattern with a minimum value of 591.9 mm.

Deitch et al. (2017) pointed out the downward trends in annual precipitation in the the Mediterranean basin. In addition, De Luis et al. (2009) have proved that there is a decrease in the seasonal and annual precipitation at the Mediterranean Iberian Peninsula (IP) through 1950-2000.

Further, Philandras et al. (2011) emphasis the negative trends of the annual precipitation totals exist in the majority of Mediterranean regions, during the period 1901–2009, which create drier conditions (Kutiel et al., 1996; Turkes, 1998), However, this trend will be expected to continue till 2050 resulting decrease of up to 20% in total annual rainfall (Gonçalves et al., 2014).

Probable density of the high extreme annual temperature (1960-2016)

Analyzing the mean annual temperature in the study area as shown in Fig. 4 indicates that the probability values of temperature generally increased. In addition, the probability of extreme temperatures is higher than +17.5ºC increased from +3.3% during the period 1960-1990 to +24.8% during the period 1991-2016 (red curve), with a total estimated probability of increase +21.5%, which is an indicator of warming in the study area.

On contrary, a large decrease in the probability of extreme temperatures less than 16.3ºC, can be noted, with the general decrease of the probability from 26.6%

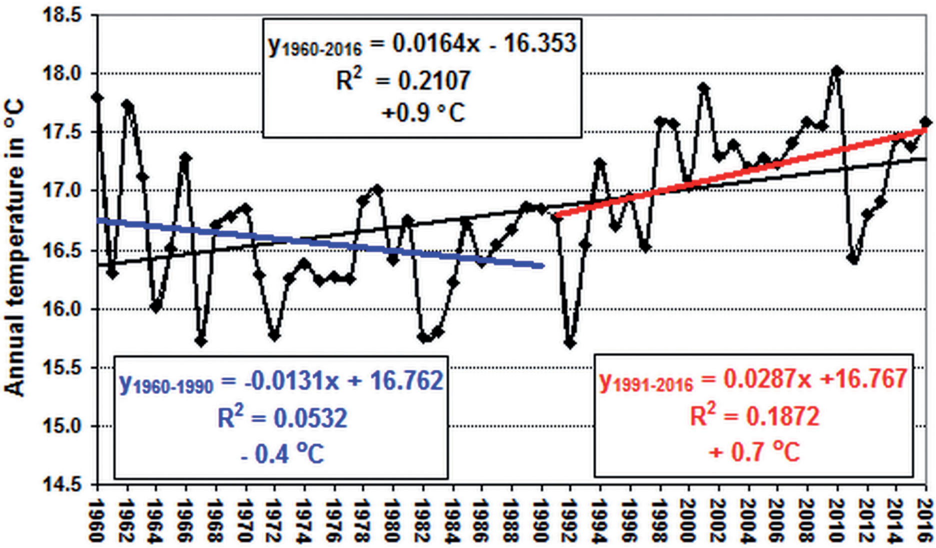

Fig. 2. Trends of annual temperature during the (1960-2016)

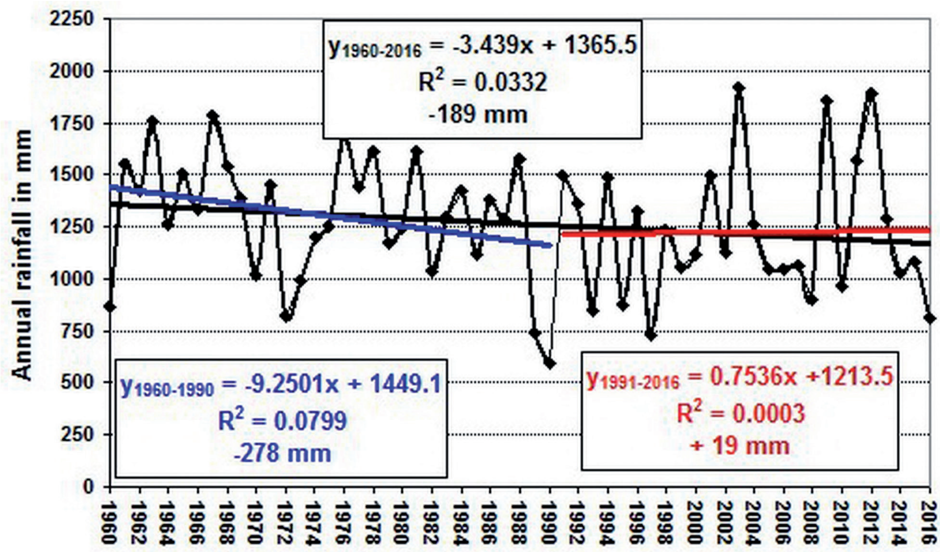

Fig. 3. Trends of annual rainfall amounts during the (1960-2016)

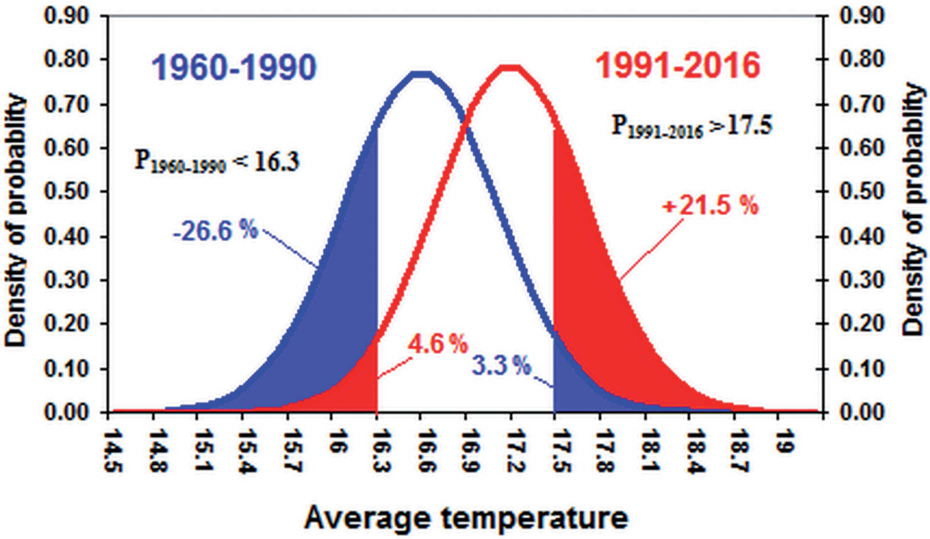

Fig. 4. Average annual mean temperature changes during the period (1991-2016) compared with the period 1960-1990 by using Normal distribution

(blue curve) to 4.6% (red curve). Thus, the probability of extreme temperatures less than 16.3ºC is down by 22%.

Probable density of the high extreme annual Rainfall (1960-2016)

By using Gamble's distribution, the probable values of the rainfall changes during (1991- 2016) compared with (1960-1990) were studied as shown in Fig. 5; which demonstrates an increase in the average rainfall ((less than 800 mm)) from 4.6% during the period 1960-1990 to 10.1% during the period 1990 – 2016 (red line). Moreover, the probability of an extreme annual rainfall (more than 1800 mm) deceased by 0.6%.

De-Martonne aridity index changes (1960-2016)

The De-Martonne aridity index represents the relationship between the temperature and precipitation, which is very important in the arid/humid climate classification.

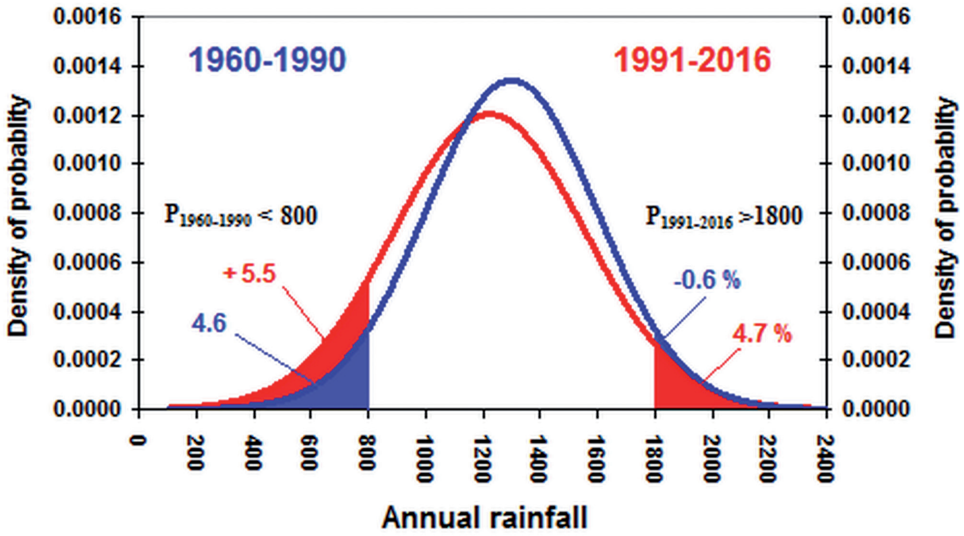

Fig. 5. Average annual rainfall changes during the period (1991-2016) compared with the period 1960-1990 by using Normal distribution

The analysis showed that there was a significant decrease of De-Martonne index by 10.175 during the study period as can be seen in Fig. 6; due to the decrease in the annual rainfall and the increase in the annual average temperature which lead to drought through time (Tanarhte et al. 2012). This was also observed by Mathbout et al. (2018) who reported a significant increase in drought indicators all over Syria through the period 1961-2012, similarly, identify major periods of drought in the Levant from 1998 till 2012. However, statistically, there is no significant change in the period 1960-2000 compared to 2001-2006 as shown in Table 1. And because of the rapid increase in temperature with the variable disturbance of rainfall patterns, many climate models predicted increasing the drought in the Middle East and in Syria (Breisinger et al. 2011).

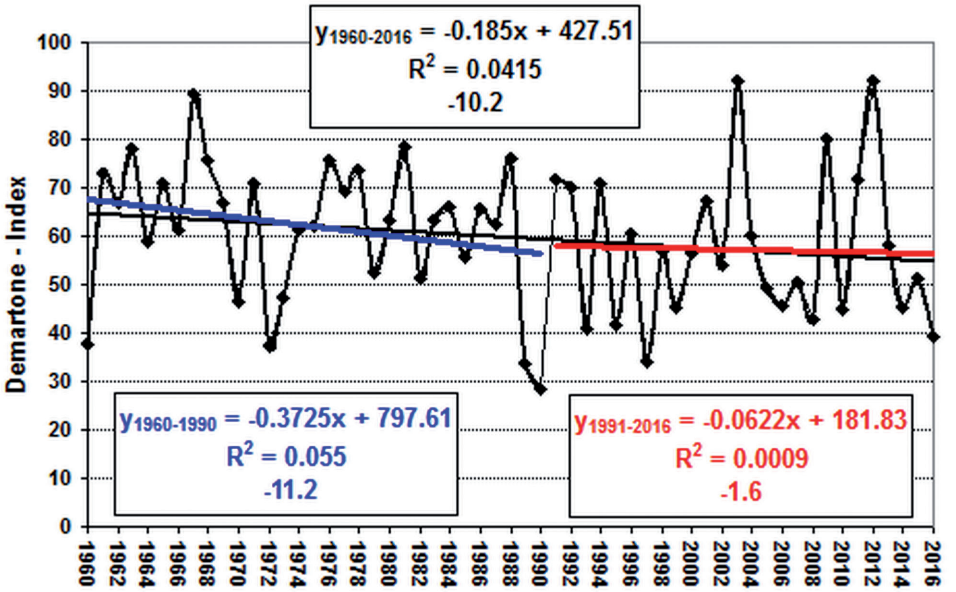

Fig. 6. De-Martonne aridity index changes during the period (1960-2016)

Table 1. The slope in the regression line of temperature, rainfall and De-Martonne aridity index, and the statistical significance of the slope of the regression line

Element	Temperature in °C	Rainfall in mm	De-Martonne Index
Annual change	0.016 +	3.439 -	0.185 -
Trend 1960-2016	0.9 +	189-	10.2-
Sig > 95 %	+	+	+
Average 1960-1990	16.6	1301.1	61.7
Average 1991-2016	17.2	1223.7	57.3
Difference	0.6+	-77.4	-4.4
Sig > 95 %	+	-	-

**Note: The differences among the averages (+) > 95% statistically significant (0) ≤ 95% is not statistically significant*

Generally, climate change become a global issue where the Earth's surface temperature has been increasing from the past century. Many factors such as increased emission of greenhouses gasses, as a result of industrial activities and intensive agriculture are significantly contributed in temperature changes. Also, land use changes which is a direct effect of urbanization that casing urban heat island (UHI) played an important role in climate change (Jorgenson et al. 2019; Comarazamy et al. 2013)

However, there were many indicators of climate change in the Mediterranean region especially in the Middle East (IPCC 2007a; Abu Sada et al. 2015; Zytoon and Shehadeh 2015). Alam and Sharif (2013) conclude that the responsibility of changing in climate in the Middle-East is the global warming which is a result of human interference in the ecosystems (Kousari et al. 2010). Evans (2009) suggested a decrease in storm track activity over the Eastern Mediterranean which is responsible for low rainfall. Similarly, Philandras et al. (2011) suggested that drought conditions and low rainfall in the Mediterranean region are mainly due to positive atmospheric circulation, which lead to move of western winds towards northern Europe causing increased rainfall and temperatures there, while it leads to drier and cooler anomalies in the Mediterranean region (Feidas et al. 2007; Kelley et al. 2015).

CONCLUSIONS

This study aims to analyze some parameters of climate change in Al-Sheikh Badr basin (Syria) during the period (1960-2016). The indicators showed a decrease in rainfall, an increase in temperature and a gradual decrease of De-Martonne aridity index, which will badly affect the ecosystems and different human activities.

For policymakers in Syria, it is important to consider the current and future changes in climatic conditions in order to take steps towards more sustainable natural resource management and water-use efficiency and productivity in agriculture. Furthermore, accelerated steps should be taken towards drought monitoring and early warning systems. Additionally, an assessment should be taken seriously for socio-economic impacts of climate change and their outcomes on different sectors and marginal environments, which should lead to national plans for adaptation to climate change in a multidisciplinary and integrated approach.

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