Climate change and its effect on agriculture water requirement in Iran-Khuzestan plain

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Abstract :

Global climate change is one of important issues interested by water resources experts in recent decades..Regarding global climate change, temperature and precipitation forecasting can have significant role in decision making and optimum use of water resources. Carried studies in Iran, like other regions of world, show increasing pattern in annual temperature. The present study was designed to survey temperature increase in Khuzestan plain that is located in the southwest of Iran and its effect on potential evapotranspiration and water uses in Agriculture. The effect of temperature increase on agriculture water uses in Khuzestan plain was carried out based on analysis of annual temperature time series and theoretical base of evapotranspiration and crop water requirement. Study area includes vast part of Khuzestan province that has 16 meteorological stations in Behbahan, Ahvaz, Dezful and Karkheh regions. Results of analysis of annual temperature time series showed 3.7 centigrade increase in temperature for a 100–year period. Sensitive analysis of water requirement model showed 14, 8, 4 and 2.7 percentage change in potential evapotranspiration per one percent change in temperature, wind speed, sun hours and relative humidity parameters, respectively. Increasing rate of potential evapotranspiration due to temperature increase was 2.04, 2.01, 1.52 and 2.23 (mm/year) in Behbahan, Ahvaz, Dezful and Karkhehregions, respectively. Also, the increasing rate of wheat water requirement due to temperature increase was 723, 508, 339 488 (m^3/ha) in studyregions during the next 50 years.

Keywords: Climate change, Time series, Temperature, Evapotranspiration, Water requirement,

Introduction

Temperature is an important climate parameter which has undeniable effects on hydrological cycle, crop production process and agriculture water uses. In recent years, climate change and occurrence of anomaly rains leads to extreme weather events, floods, and droughts. Several researches in Iran showed significant increase in annual temperature. In the other hand, temperature has significant role in determination of potential evapotranspiration, which is a basic parameter in hydro climatology studies, irrigation and drainage system design processes and water balance and crop water requirements models. Various studies have been carried out in temperature change in Iran and other areas of the world. Rasouli [10] analyzed temperature in Tabriz with time series. He separated elements of time series and showed that temperature in Tabriz has had increasing trend in recent 50 years and the slope of the trend has been 0.0265. He stated that his study can provide a suitable background for analyzing time serried in other stations and identifying their behavior into time. Furthermore, it is a good scope for future forecasting by professionals by understanding of indexes and by using of usual models - such as ARMA[1]- capabilities. Asakereh and Kheradmand [3] used SARIMA approach for pattern modeling of the mean monthly temperature in Jask in over a 104 years period. Simulation of final pattern revealed that the mean monthly temperature time series has positive trend. Increasing trend of annual temperature in Khark had demonstrated by above researches in previous studies. Rahimzadeh *et al*. [9] studied climate changing in Iran with investigating minimum and maximum temperature series by applying statistical models. Kashkoli *et al.* [7] compared Penman-Monteith, FAO modified Blaney Criddle and Thornthwaite methods in determination of potential evapotranspiration in the north of Khuzestan and results showed that the average of daily potential evapotranspiration with Penman-Monteith method is estimated lower than other methods. Jamei [6] estimated monthly and yearly irrigation requirements, hydromodule of agriculture and horticulture crops and hours of pumping in Khuzestan plains. Appling of time series methodology in precipitation and rivers flow regime is also reported. Sudden change in rainfall characteristics such as rainfall amount and the number of rainy days in Amman, Jordan, were studied in a 81 years period by Samadi and Zghoul [11] and results showed a decreasing trend

[1] *Auto-Regressive Moving Average*

in rainfall amount and a shifting trend in rainy days. In their study, decreasing trend of rainfall in Mefrak synoptic station, with the mean annual rainfall of 165 mm, has mentioned 0.5 mm/year. A survey on climate change effect on the amount of low flows in Thames River, England, was carried out by Wilby and Harris [13]. Yurekli and Kurunc [12] used stochastic methods for forecasting daily minimum flow in three hydrometry stations of Cekerek Stream basin for using in drought analysis. They used ARIMA and Thomas-Fiering models.This study was designed to survey temperature increase in Khuzestan plain and its effect on potential evapotranspiration and water uses in Agriculture. Water resources management has many problems and challenges but present study carried out for investigating of the individual effect of climate change induced temperature increase on crop water requirements.

Khuzestan province has an area of 63633.6 Km^2 and it's located in the southwest of Iran (47 °40' to 50° 33' longitude and 29° 57' to 33° latitude). This study covers extensive area of Khuzestan province includes four regions of Behbahan (Behbahan, Hendijan, Shadegan and Ramhormoz), Ahvaz, Dezful and Hamidieh (Karkheh). Meteorological data of synoptic stations and evaporation stations were used. Behbahan region include Evaporation stations of Idnak, Behbahan, Pagachi Ramhormoz, Buzi Shadegan and Dehmolla. Ahvaz region include Evaporation stations of Gotvand, Shushtar,Arab Asad and Ahwaz synoptic station. Dezful region includes Evaporation stations of Dez dam, Dezful dam, Safi-Abad synoptic station and Safi-Abad climatology station. Evaporation stations of Karkheh district include Payei-Pol, Abdolkhan and Hamidieh. Fig 1 shows studied meteorological stations of Khuzestan province.

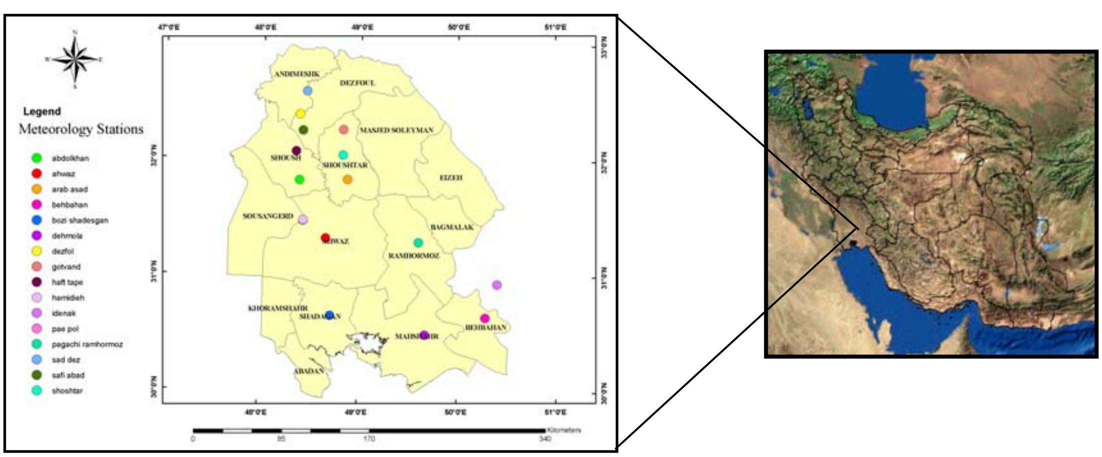

Fig.1. Studied meteorological stations in Khuzestan province.

Materials and methods

Methodology : Phenomena analysis with statistical models can help us in better understanding, descripting, controlling and forecasting of processes. The objective of these processes study is obtaining more knowledge about them, modeling their random mechanism and predicting their future state. In this study, primarily analysis of time series method was used for identifying time series components and their effects on potential evapotranspiration and agriculture uses. At first, graphic indexes of time series such as raw data index, smoothed, moving average and variability for analyzing temperature time series. Also, main components of time series such as trend, cyclical, seasonal and irregular were computed. Annual fluctuations in temperature were adjusted by consequent averaging of data series and smoothed index was determined. Also, moving average index was determined by consequent grouping averaging. In order to precise analysis of temperature data, main components of time series such as trend, cyclical, seasonal and irregular were intended and these components were separated with multiple mathematical model. For this purpose, trend component was computed with minimum square method and then cyclical component was determined. Annual temperature data usually have not seasonal effects and so when trend and cyclical components were computed, irregular component can be determine easily.

The increasing trend of temperature time series was clearly obvious. In order to explain the existence situation of time series trend, two non-parametric and parametric tests, Man-Kendall and linear regression, were used. Man-Kendall is a free distribution test applied to prove existence of trend in time series data. This method replaces values of time series data $(x_1, x_2, x_3, \ldots\ldots, x_n)$ instead to rating values $(R_1, R_2, R_3, \ldots\ldots, R_n)$. The statistical parameter of this test, S statistics, expresses as follows [8]:

[1]

$$s = \sum_{i=1}^{n=1} \left[\sum_{j=i+1}^{n} \mathrm{sgn}(R_j - R_i) \right]$$

$$\begin{cases} \mathrm{sgn}(x) = 1 \quad for \quad x > 0 \end{cases}$$

where: $\operatorname{sgn}(x) = 0 \quad for \quad x = 0$ [2]

$\operatorname{sgn}(x) = -1 \quad for \quad x < 0$

If the null hypothesis, H0, is true, then S is calculated by normal distribution with mean zero and variance $\sigma = n(n-1)(2n+5)/18$. Z statistics are also estimated as follows:

$$z = |s| / \sigma^{0.5} \qquad [3]$$

The positive values of S statistics indicate increasing trend in time series and conversely.

The linear regression test is a parametric test used for data with normal distribution. It illustrates linear relationship between time (x) and variable (y). Regression slope (b) and intercept (a) are calculated by the following equations:

$$b = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}) / \sum_{i=1}^{n} (x_i - \bar{x})^2 \quad , \quad a = \bar{y} - b\bar{x} \qquad [4]$$

S statistics is calculated as $s = b / \sigma$, where:

$$\sigma = \left((12 \sum_{i=1}^{n} (y_i - a - bx_i)) / (n(n-2)(n^2 - 1)) \right)^{0.5} \qquad [5]$$

S statistics follows T-test distribution under the null hypothesis with freedom degree of (n-2).Normal distribution of data and independent errors (deviation from trend) are linear regression assumptions, the same as normal distribution with mean zero. After revealing the existence of trend in the time series, its quantitative value was calculated by minimum square method of time series.

Effect of temperature increase on agricultural water uses in the Khuzestan plain based on potential evapotranspiration and crop water requirement [2] was performed by Cropwat software [5].

Results and Discussion :

Annual temperature time series analysis **:** For recognizing the temperature behavior of Ahvaz synoptic station, annual mean temperature changes (raw data index) are shown in fig. 2.

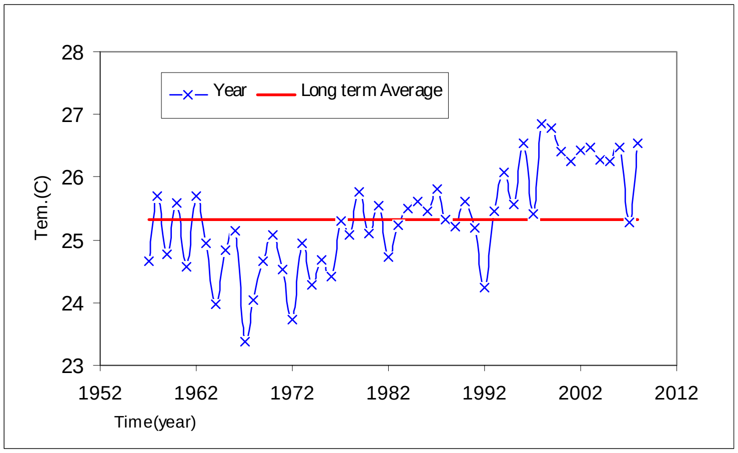

Fig. 2 Annual mean temperature changes in Ahvaz (raw data index).

This figure demonstrates the average annual temperature of 25.3 and its changes ranged between 23.4 and 26.9 centigrade.Fig. 2 clearly shows trend component in annual temperature time series, but it’s not reliable.Discussion about the existence of trend should be proved or be rejected by respective tests. To determine the existence of trend in the annual temperature time series, two non-parametric and parametric tests Men -Kendall and linear regression were used.Statistical analysis results are presented in Table 1. The results indicate an increasing trend in time series and this trend is significant in statistical level of 1 percent ($\alpha = .01$)

Table 1- Statistical analysis to prove or reject the trend component in time series of temperature

Statistics and critical values	Test statistics	$\alpha = 0.1$	$\alpha = 0.05$	$\alpha = 0.01$	Result
Men-Kendal test	5.145	1.645	1.96	2.576	S (0.01)
Linear regression	6.617	1.68	2.01	2.68	S (0.01)

Annual fluctuations in temperature was adjusted (in fact, Smoot index was determined) by consequent averaging from observed data series (Fig.3). Moving average index was calculated by repeated averages of observed data groups. This index is one of the various indexes used in preliminary analysis of time series and known as the variability index that shows the pattern of annual variation. Fig.4 shows moving average index in a 5 years period.

In this research, in order to accurate analysis of temperature observations, main components of temperature time series such as cyclic, seasonal and irregular were considered, and components were separated using a multiple mathematical model. For this purpose, the trend component was calculated by minimum square method and then the cyclic component series of observed data were determined. On the other hand, Annual temperature data usually have not seasonal effects and so when trend and cyclical components were computed, irregular component can be determine easily. Result of these calculations is presented in figures 5 and 6.

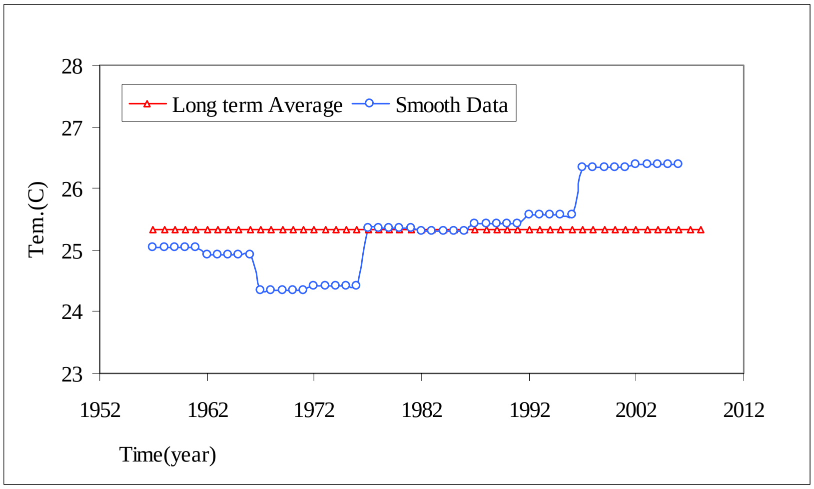

Fig.3. Smooth index of mean annual temperature in Ahvaz

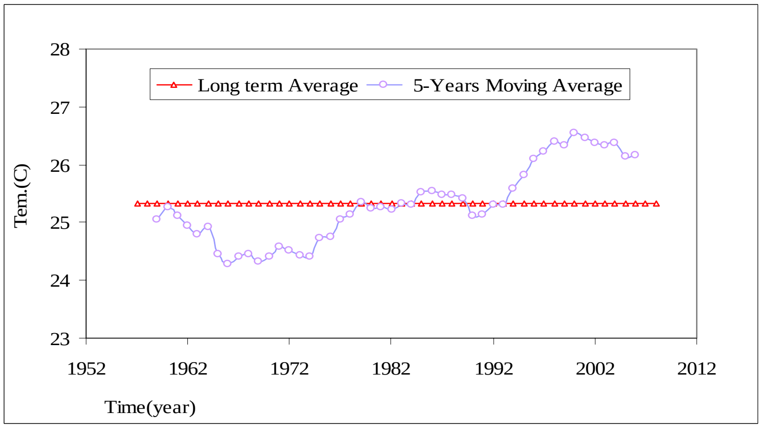

Fig.4. 5-years moving average index of mean annual temperature in Ahvaz

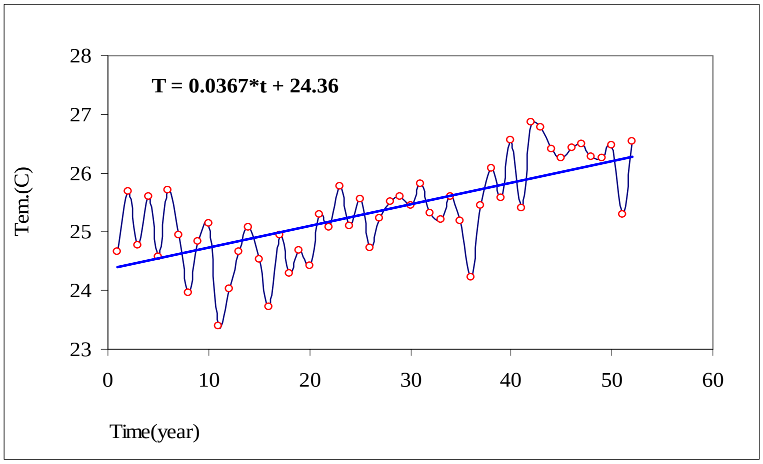

Fig.5. Trend of mean annual temperature changes in Ahvaz

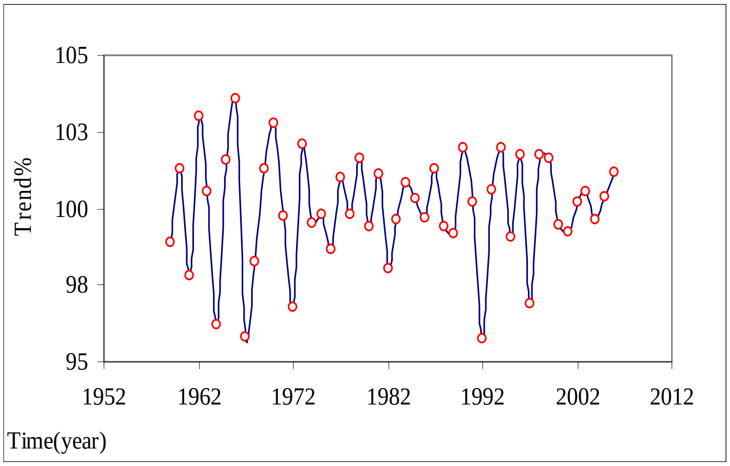

Fig.6. Percentage changes of irregular component for mean annual temperature in Ahvaz

Finally, the results indicated that time series in annual and seasonal scale have significant fluctuations and changes over time. The temperature increasing rate in the region was 3.67 ° C in a 100-year period. Percentage changes of temperature trend component, percentage of cyclic component and Percentage of irregular component was calculated between “95.7 and 103.6”, “98.0 and 103.1” and “95.7 and 104.2”, respectively. 5-years moving average index of temperature shows the changes of mean annual temperature between 24.3° and 26.5 ° C.

Before discussing about the effects of climate change, the relationship between monthly temperature and relative humidity in the study area was extracted and presented in Fig. 7.

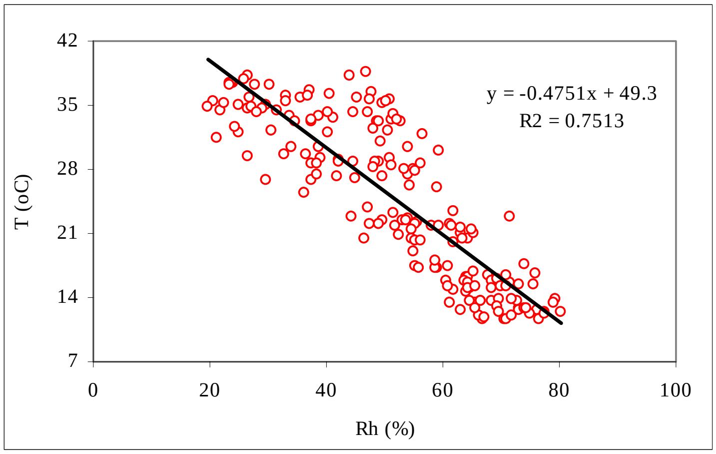

Fig.7. the relationship between monthly temperature and relative humidity in the study area

The results of the climate change effects :

A) Sensitivity analysis of evapotranspiration model : Effects of input parameters on the evapotranspiration estimation model (Cropwat Software) results were evaluated by sensitivity analysis technique. In this study, the mean maximum temperature, the mean minimum temperature, relative humidity, wind speed and sunshine hours as independent parameters and the potential evapotranspiration as a dependent parameter were determined and a sensitivity analysis was performed. Sensitivity analysis, by changing the input parameters, showed that temperature is the highest sensitive parameter and wind speed, sunshine hours and relative humidity are the other sensitive parameters, respectively. Change rate of potential evapotranspiration per one percent change of temperature, wind speed, sunshine hours and relative humidity was 0.71%, 0.42%, 0.21% and 0.13%, respectively.

B) The increase rate of potential evapotranspiration : For determining the increase rate of potential evapotranspiration, the effect of slight increase in temperature on potential evapotranspiration was estimated and then the increase rate of potential evapotranspiration was calculated. This analysis showed that the increasing rate of potential evapotranspiration due to temperature rise in Behbehan, Ahvaz, Dezful and Karkheh was 2.04, 2.01, 1.52 and 2.23 mm, respectively. So, the overall increase of potential evapotranspiration in the Khuzestan plain was estimated about 2 mm per year.

C) The increase rate of crop water requirements : To calculate the water requirements for each plain, national reported cropping patterns data were used (Alizadeh,2007 & Anonymous,1999). Then, total irrigation requirements (cubic meters per hectare per month) considering the allocated area and water requirement of each crop were determined.However, the results of this analysis showed that increasing rate of the water requirements for wheat due to temperature rise in Behbehan, Ahvaz, Dezful and Karkheh will be 723, 508, 339 and 488 (m^3/ha) respectively in the next 50 years. In addition, the increase rate of water requirements due to temperature rise will have reached about 1748, 817, 695 and 1067 (m^3/h), respectively in the study areas, by the next 50 years. This rate in areas with dominant cultures of sugarcane, orchards and palm trees will have reached about 2000, 2600 and 1200 (m^3/h), respectively in study areas, by the next 50 years.

Conclusions

In this study, existence of trend in the annual temperature series was proved using two non-parametric and parametric tests (Men-Kendall and linear regression). The trend was increasing (positive) and its value in the study area region was 3.67° C in a 100-years period. Sensitivity analysis results of water requirement model indicated that potential evapotranspiration increases with increase of temperature, wind speed and sunshine hours. So, the temperature rise in the study area will led to increase of potential evapotranspiration and crop water requirements.

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