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ANALYSIS OF LONG-TERM TEMPERATURE DATA USING MANN-KENDALL TREND TEST AND LINEAR REGRESSION METHODS: THE CASE OF THE SOUTHEASTERN ANATOLIA REGION

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Abstract

Nature has been adversely affected by increasing industrialization – especially after the latter half of the last century – when accelerating technological development, unplanned urbanization, incorrect agricultural policies, deforestation, and the excessive and unsuitable use of energy have acted as factors to increase the release of gases into the environment. The global warming effect of greenhouse gases has had a negative impact on the meteorological and hydro-meteorological parameters, such as the temperature and precipitation, which are the main elements of a region's climate. In particular, sudden changes occurring in air temperature lead to major changes in the design of air conditioning systems, energy analysis, and heating- and cooling-load calculations such as degree-day. Various energy-forecasting methods are being developed for air-conditioning systems in buildings, animal shelters and controlled environmental agriculture structures. Accurate and easily accessible climatic data are extremely important in terms of analysing the accuracy and energy efficiency of air conditioning systems. In this study, the trends and changes over a long period of daily maximum, minimum and mean temperature data were analyzed using the Mann-Kendall trend test and linear regression analysis, and comments have been made about nine provinces in the Southeastern Anatolia Region of Turkey. As a result of these analyses, it has been concluded that maximum temperatures of the provinces of Adıyaman, Gaziantep, Mardin, Şanlıurfa, the mean temperatures of the provinces of Adıyaman, Batman, Gaziantep, Kilis, Mardin, Siirt, Şanlıurfa and Şırnak, and the minimum temperatures in the provinces of Gaziantep, Kilis show statistically significant rising trends.

Key words*: climate change, Linear Regression Analysis, Mann-Kendall Trend Test, Southeastern Anatolia Region, temperature.*

INTRODUCTION

Climate parameters that have a variable structure constantly differ in their temporal and spatial aspects. A majority of the Earth exhibits changes within short or long periods due to the nature of its own climate. A short-term climate change shows a difference in an annual measurement of any climate parameter from the long-term mean (Gardner et al., 1996; Karabulut and Cosun, 2009).

Temperature, the main climate factor, has a significant role in the identification of global climate variability. The changes that occur in temperature are important in understanding the general climate structure. Therefore, in recent years, studies on climate change have focused on the trend analyses of the temperature parameter (Kadıoglu, 1997; Turkes et al., 2008; Karabulut and Cosun, 2009).

Human factors are believed to have contributed to climate change from the mid-19th century. They have led to an increasing deterioration of ecological balance, along with rising population and developing technology. Changes associated with natural causes have advanced slowly for many years and the change has now become palpable. The biggest impacts of climate change will occur in countries in the middle and high altitudes. Turkey is among the countries that will be greatly affected by this change due to its geographical location (Karabulut et al., 2008).

The increases identified by Sensoy et al. (2005), that occurred in Turkey's mean, maximum and minimum temperature series –

particularly in the spring and summer after the cold year of 1992 – suggested that temperatures in Turkey are tending to rise, while the number of frost and icy days falls, along with daily temperature range. They indicated that cool nights decrease as hot nights increase, and that both maximum and minimum temperatures are rising. The difference between daily maximum and minimum temperatures diminishes because of global warming in many regions throughout the world (Tecer et al., 2004; Cosun and Karabulut, 2009).

As in other countries, various studies related to climate change that specifically focus on trend analysis are also being carried out in Turkey. These trend analyses carried out on temperature demonstrate the existence of statistically significant increases throughout the country (Partal and Kahya, 2006; Ozkul et al., 2008).

The aim of this study is to examine the trends of the daily maximum, minimum and mean temperature values of the nine provinces located in the Southeastern Anatolia Region – where agricultural activities are concentrated and where the hottest geographical areas in the country are found – by using Linear Regression Analysis (LRA) and the Mann-Kendall Trend Test (MKT).

MATERIALS AND METHODS

The Southeastern Anatolia Region (SAR), which includes Turkey's important reservoirs in terms of water resource potential: the valleys of the Euphrates and Tigris rivers, was selected in the study. There are nine provinces in the region, and the long-term daily maximum, mean and minimum temperature values were obtained from the General Directorate of Meteorology of these provinces. The LRA and MKT techniques utilized in this study are simple and commonly used methods.

Linear Regression Analysis (LRA)

Linear regression analysis is a non-parametric test that determines the relationship between two or more dependent and independent variables that have a causal link. This test analyses whether a linear relationship and trend exists between variables with a 95% confidence interval (Haan, 1977; Hamdi et al., 2009; Singh et al., 2015). The Linear regression equation is shown in equation 1:

$$Y = a + bX \tag{1}$$

Here, Y indicates a dependent variable, X indicates an independent variable, and a and b indicate a constant values. The significance of the linear regression test is tested with a 95% confidence interval using α (significance levels such as 5%, 1%) and Student t-test (Haan, 1977; Sneyers, 1990; Bulut et. al., 2006).

Mann-Kendall Trend Test (MKT)

The MKT is very commonly used because it is not affected by deficient and erroneous measurement in a data series such as hydro-meteorological data. It is non-parametric and facilitates trend determination. The MKT statistic (u(t)) is calculated. Equations 2 and 3 below are used to calculate the MKT statistic:

$$t = \sum_{i=1}^{n} n_i \tag{2}$$

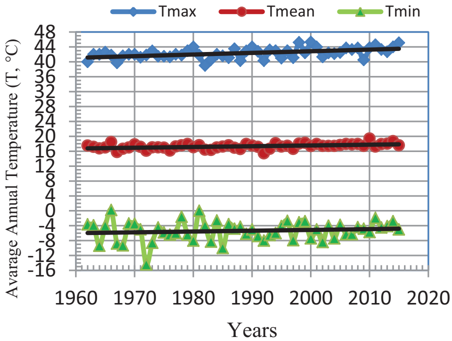
$$u(t) = \frac{(t - E(t))}{\sqrt{\mathrm{var}(t)}} \tag{3}$$

The u(t) value, calculated as a result of the test, is directly compared with the table value (t_{Critic}) of the 95% confidence interval ($t_{\alpha/2,(n-2)}$) in the Student-t distribution, and the existence of a trend in the variables is identified (Mann, 1945; Kendall, 1975; Sneyers, 1990; Partal and Kahya, 2006; Safari, 2012; Ahmed et al., 2014; Soydan et al., 2015).

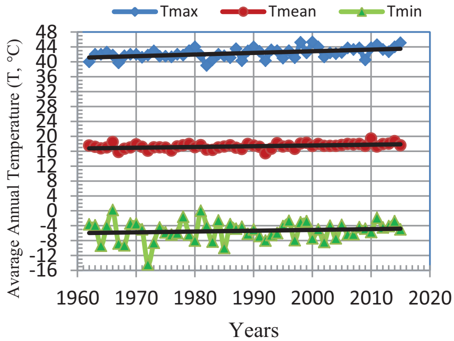
RESULTS AND DISCUSSIONS

Long-term daily maximum, mean and minimum temperature values of the nine provinces are illustrated in Figure 1, by years, to examine the potential climatic changes in the study field.

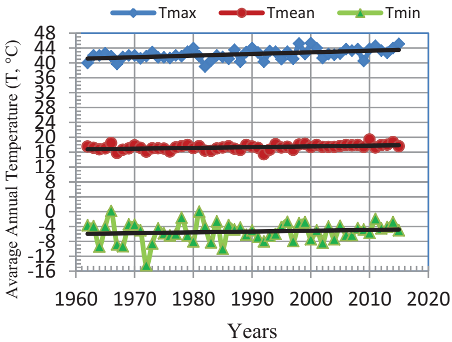
Adıyaman



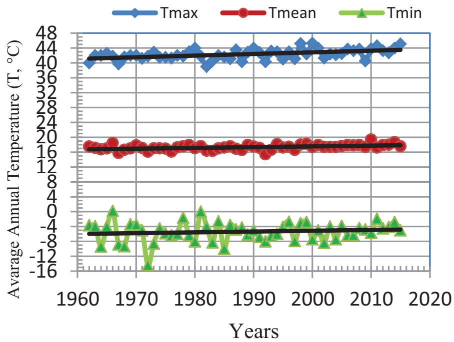
Batman



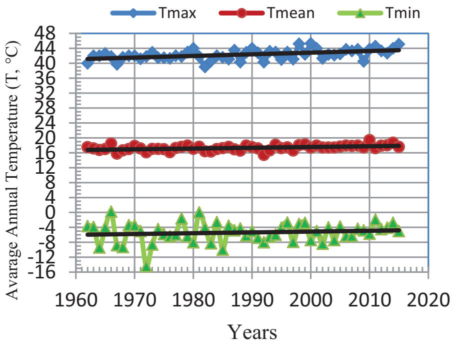
Diyarbakır



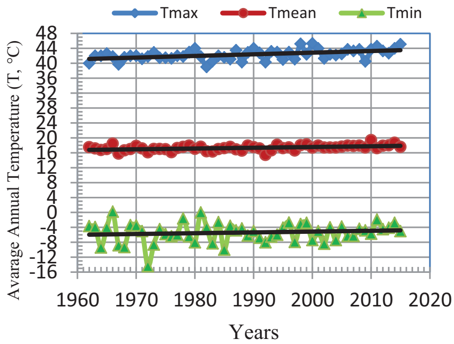
Gaziantep



Kilis



Mardin



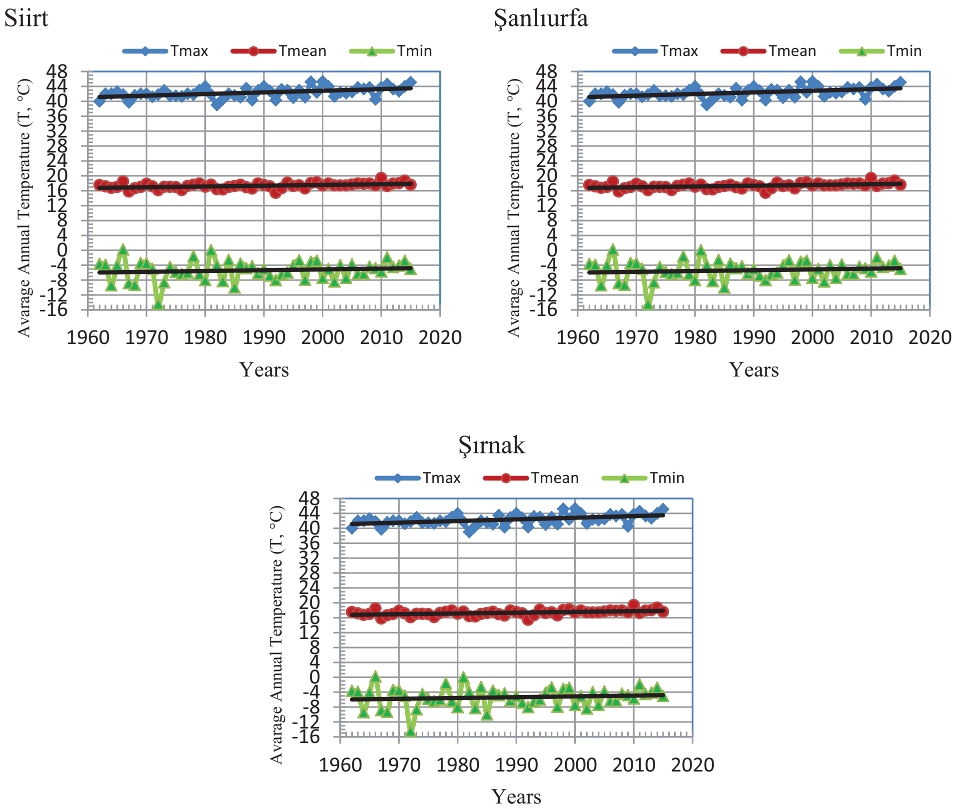


Figure 1. Visual changes in long-term daily maximum (T_{max}), mean (T_{mean}) and minimum (T_{min}) temperature values

Figure 1 indicates that the trends of the temperature series generally agree with one another. Depending on the potential climatic changes in the region, significant rising trends have occurred in the regional provinces of Adıyaman for maximum and mean; in Gaziantep for maximum, mean and minimum; in Mardin for maximum and mean temperatures; in Şanlıurfa for maximum and mean temperatures; in Kilis for mean and minimum temperatures, and in Batman, Siirt and Şırnak for mean temperatures.

These results agree with the predictions made by Turkes et al. (2002) with the 1975–2005 annual and seasonal maximum, mean and minimum temperature increases. The geographical position of the region supports the rising trend along with long-term temperatures. In another study that examined temperature and precipitation values through trend analysis (Bahadir, 2011), the southern part of Turkey was said to be particularly sensitive to climatic changes. It indicates that the rising trend in temperature will continue and be occasionally severe in the future in the provinces of the Southeastern Anatolia project field. Therefore, our findings are compatible with these predictions.

In order to demonstrate the statistical significance of the trends in long-term annual daily maximum, mean and minimum temperature values of the provinces in the study area, a linear regression analysis was carried out in a first phase, and an MKT was conducted in a second phase. The linear analysis equations and features of the provinces, by years, are illustrated in Tables 1, 2, and 3.

Table 1. Linear regression analysis features of long-term daily maximum temperatures

Weather Station	Regresion Coefficient (b)	Correlation Coefficient (r)	t value	t_{critic}	p value	Trend No	Trend Inceases	Trend Decreases
Adıyaman	0.0440	**0.494**	**+ 4.100**	±2,0036	**0.000**		**X**	
Batman	- 0.0161	0.170	- 1.260	±2,0054	0.212	X		
Diyarbakır	- 0.0043	0.055	- 0.400	±2,0054	0.689	X		
Gaziantep	0.0264	**0.302**	**+ 2.330**	±2,0054	**0.024**		**X**	
Kilis	0.0132	0.045	+ 1.050	±2,0054	0.296	X		
Mardin	0.0280	**0.371**	**+ 2.940**	±2,0054	**0.005**		**X**	
Siirt	0.0017	0.010	+ 0.140	±2,0054	0.887	X		
Şanlıurfa	0.0219	**0.084**	**+ 2.020**	±2,0054	**0.049**		**X**	
Şırnak	0.0209	0.195	+ 1.330	±2,0162	0.189	X		

Table 2. Linear regression analysis features of long-term daily mean temperatures

Weather Station	Regresion Coefficient (b)	Correlation Coefficient (r)	t value	t_{critic}	p value	Trend No	Trend Increases	Trend Decreases
Adıyaman	0.0205	**0.451**	**+ 3.640**	±2,0036	**0.001**		**X**	
Batman	0.0291	**0.503**	**+ 4.270**	±2,0054	**0.000**		**X**	
Diyarbakır	- 0.00332	0.071	- 0.510	±2,0054	0.615	X		
Gaziantep	0.0299	**0.552**	**+ 4.870**	±2,0054	**0.000**		**X**	
Kilis	0.0201	**0.474**	**+ 3.960**	±2,0054	**0.000**		**X**	
Mardin	0.0275	**0.552**	**+ 4.500**	±2,0054	**0.000**		**X**	
Siirt	0.0211	**0.391**	**+ 3.120**	±2,0054	**0.003**		**X**	
Şanlıurfa	0.0235	**0.491**	**+ 4.140**	±2,0054	**0.000**		**X**	
Şırnak	0.0380	**0.608**	**+ 5.080**	±2,0162	**0.000**		**X**	

Table 3. Linear regression analysis features of long-term daily minimum temperatures

Weather Station	Regresion Coefficient (b)	Correlation Coefficient (r)	t value	t_{critic}	p value	Trend No	Trend Increases	Trend Decreases
Adıyaman	0.0218	0.130	+ 0.960	±2,0036	0.344	X		
Batman	0.0006	0.010	+ 0.010	±2,0054	0.991	X		
Diyarbakır	- 0.0402	0.130	- 0.980	±2,0054	0.332	X		
Gaziantep	0.0932	**0.470**	**+ 3.910**	±2,0054	**0.000**		**X**	
Kilis	0.0704	**0.422**	**+ 3.420**	±2,0054	**0.001**		**X**	
Mardin	0.0180	0.105	+ 0.780	±2,0054	0.441	X		
Siirt	0.0305	0.141	+ 1.050	±2,0054	0.300	X		
Şanlıurfa	0.0297	0.217	+ 1.640	±2,0054	0.107	X		
Şırnak	0.0242	0.126	+ 0.850	±2,0162	0.402	X		

In Tables 1, 2 and 3, the statistical significance of the trend equations calculated for each province was analysed with correlation coefficient (r), a Student-t test and 5% probability (p) values.

The statistical significance of these trends has been determined to vary between + 4.100 and + 2.020 at daily maximum temperatures (Table 1), between + 5.080 and + 3.120 at daily mean temperatures (Table 2) and between + 3.910 and + 3.420 at daily minimum temperatures (Table 3). Moreover, in the long-term mean temperature changes of the provinces, it has been determined to vary between + 0.0440 and + 0.0219 at maximum temperatures, between + 0.0380 and + 0.0211 at mean temperatures and between + 0.0932 and + 0.0704 at minimum temperatures. The values given were listed to illustrate the important provincial trends. The values of the other non-trend provinces were not taken into account.

As a result of these analyses, it has been concluded that maximum temperatures of the provinces of Adıyaman, Gaziantep, Mardin, Şanlıurfa, the mean temperatures of the provinces of Adıyaman, Batman, Gaziantep, Kilis, Mardin, Siirt, Şanlıurfa and Şırnak, and the minimum temperatures in the provinces of Gaziantep, Kilis show statistically significant rising trends.

Moreover, in terms of the long-term annual average temperature-change values (linear regression analysis) of the regional provinces, the daily maximum temperatures were determined to vary between $+0.0219^oC$ $56^{-1}years^{-1}$ (for Şanlıurfa) and $+0.0440^o C$ $54^{-1}years^{-1}$ (for Adıyaman); the daily mean temperatures varied between $+0.0201\ ^oC/56$ years (for Kilis) and $+0.0380^oC$ $46^{-1}years^{-1}$ (for Şırnak) and daily minimum temperatures varied between $+0.0704^oC$ $56^{-1}years^{-1}$ (for Kilis) and $+0.0932^oC$ $56^{-1}years^{-1}$ (for Gaziantep).

Mann-Kendall Trend Test (MKT)

The changes in the long-term daily maximum, mean and minimum temperature values of the nine provinces in the study were analysed using the Mann-Kendall Trend Test. The result is illustrated in Tables 4, 5 and 6.

Table 4. MKT results of long-term daily maximum temperatures

Weather Station	Monitoring Period (n)	MKT Value ($u(t)$)	t_{critic}	Trend No	Trend Inceases	Trend Decreases
Adıyaman	54	**+ 3.812**	±2,0036		**X**	
Batman	56	- 0.452	±2,0054	X		
Diyarbakır	56	+ 0.028	±2,0054	X		
Gaziantep	56	**+ 2.474**	±2,0054		**X**	
Kilis	56	+ 0.905	±2,0054	X		
Mardin	56	**+ 2.940**	±2,0054		**X**	
Siirt	56	+ 0.283	±2,0054	X		
Şanlıurfa	56	**+ 2.587**	±2,0054		**X**	
Şırnak	46	+ 1.278	±2,0162	X		

Table 5. MKT results of long-term daily mean temperatures

Weather Station	Monitoring Period (n)	MKT Value ($u(t)$)	t_{critic}	Trend No	Trend Increases	Trend Decreases
Adıyaman	54	**+ 2.678**	±2,0036		**X**	
Batman	56	**+ 4.000**	±2,0054		**X**	
Diyarbakır	56	**- 0.608**	±2,0054	X		
Gaziantep	56	**+ 4.396**	±2,0054		**X**	
Kilis	56	**+ 3.732**	±2,0054		**X**	
Mardin	56	**+ 4.226**	±2,0054		**X**	
Siirt	56	**+ 3.449**	±2,0054		**X**	
Şanlıurfa	56	**+ 3.944**	±2,0054		**X**	
Şırnak	46	**+ 4.232**	±2,0162		**X**	

Table 6. MKT results of long-term daily minimum temperatures

Weather Station	Monitoring Period (n)	MKT Value ($u(t)$)	t_{critic}	Trend No	Trend Increases	Trend Decreases
Adıyaman	54	+ 0.828	±2,0036	X		
Batman	56	+ 1.060	±2,0054	X		
Diyarbakır	56	- 0.862	±2,0054	X		
Gaziantep	56	**+ 3.718**	±2,0054		**X**	
Kilis	56	**+ 3.152**	±2,0054		**X**	
Mardin	56	+ 1.484	±2,0054	X		
Siirt	56	+ 1.060	±2,0054	X		
Şanlıurfa	56	**+ 2.149**	±2,0054		**X**	
Şırnak	46	+ 1.240	±2,0162	X		

The MKT values calculated in Tables 4, 5 and 6 were analyzed against a 5% ($p<0.05$) significance level.

According to the MKT u(t) results statistically significant rising trends have occurred, respectively (see Tables 4, 5 and 6) in the provinces of Adıyaman (+3.812) Mardin, Şanlıurfa and Gaziantep (+2.474) where they vary between +3.812 and +2.474 in maximum temperature, in Şırnak (+4.232), Gaziantep, Mardin, Batman, Şanlıurfa, Kilis, Siirt and Adıyaman (+2.678) where they vary between +4.232 and +2.678 in mean temperatures, and in Gaziantep (+3.718) and Şanlıurfa (+2.149) where they vary between +3.718 and +2.149 in minimum temperatures. The values given were listed to illustrate the important provincial trends. The values of the other non-trend provinces were not taken into account.

CONCLUSIONS

The trend values calculated for long-term daily maximum, mean and minimum temperature values of every meteorology station in the region were analyzed with a 5% ($p<0.05$) level of significance using bidirectional t distribution. It has been determined that there is a statistically significant trend in the long-term maximum temperatures, mean temperatures and minimum temperatures of the provinces in the study area. The geographical location of the Southeastern Anatolia Region, internal migration, unplanned urbanization, deforestation, erroneous agriculture policies and industrialization are believed to be associated with these trends. The province most severely affected by the climatic change in the region is Gaziantep (changes at maximum, mean and minimum temperatures). The change in Gaziantep was found to be +2.64 ^{o}C 56^{-1}years^{-1} for maximum temperatures, +2.99 ^{o}C 56^{-1}years^{-1} for mean temperatures and +9.32 ^{o}C 56^{-1}years^{-1} for minimum temperatures.

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