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THE ANALYSE OF PRECIPITATION AND TEMPERATURE IN AFYONKARAHISAR (TURKEY) IN RESPECT OF BOX-JENKINS TECHNIQUE

AFYONKARAHİSAR'DA (TÜRKİYE) YAĞIŞ VE SICAKLIĞIN BOX – JENKİNS TEKNİĞİ İLE ANALİZİ

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Abstract

Research area is Afyonkarahisar Province which takes place inland, 800 km from coast. Continental climate characters are seen in area. Afyonkarahisar which takes place in central west part of Aegean region in southwest of Turkey. It is also in crossroads because Afyonkarahisar is in the boundaries of Mediterranean Central Anatolia and Aegean regions. According to climate type models, the climate of research area is sub-humid in respect of de Martonne, it is semi-arid in respect of Erinç, it is generally arid and low degree humid and according to Aydeniz climate classification, it is arid. Box-Jenkins technique (ARIMA) which is a method of analyses and prediction in time series, has been used in the study. According to this method, trend analyses have been made in respect of long annual mean of temperature and precipitation in Afyonkarahisar. According to ARIMA model, the predictions have been produced until the year 2015 and according to Quadratic ve Linear Trend models, predictions have been produced until the year 2025. According to ARIMA model, an increase in precipitation as 14 mm. has been predicted until the year 2015. According to Quadratic Trend model, a decrease in precipitation as 20 mm. has been predicted until the year 2025. And also according to Linear Trend model, an increase in precipitation as 2-3 mm. has been predicted until the year 2025. On the other hand, According to ARIMA model, an increase in temperature as 0,3-0,4 °C has been predicted until the year 2025. According to Quadratic Trend model, an increase in temperature as 1,2 °C. has been predicted until the year 2025 And also according to Linear Trend model, an increase in temperature as 0,5 °C has been predicted until the year 2025. This decrease in temperature correspond to the increases in temperature as 1,4-5,8 °C which are predicted by United Nations between the year 1990-2100.

Key Words: Box-Jenkins Technique, Climatic Change, temperature, precipitation, Afyonkarahisar.

Öz

Çalışma alanı, Türkiye'nin Ege Bölgesinde, Ege Denizi kıyılarından 800 km içeride yer alan Afyonkarahisar ili olup yörede karasal iklim özellikleri görülmektedir. Çalışmaya konu olan Afyonkarahisar, Türkiye'nin güneybatı kesiminde, Ege Bölgesi'nin, İçbatı Anadolu Bölümü'nde, Ege Bölgesi'nin doğuya doğru sokulduğu Akdeniz, İç Anadolu ve Ege bölgelerinin kesiştiği bir konumda yer almaktadır. İklim tipi modellerine göre, çalışma alanının iklimi de Martonne göre, yarınemli, Erinç'e göre yarıkurak, Thorntwaite göre, kurak az nemli ve Aydeniz iklim sınıflandırmasına göre ise kurak iklim sınıfına girmektedir. Çalışmada, zaman serilerinde bir analiz ve tahmin yöntemi olan Box-Jenkins tekniği (ARIMA) kullanılmıştır. Bu yönteme göre, Afyonkarahisar'da sıcaklık ve yağışın uzun yıllık ortalamalarına göre trend analizleri yapılmıştır. ARIMA modeline göre 2015 yıllına kadar, Quadratic ve Linear Trend modellerine göre ise 2025 yılına kadar tahminler üretilmiştir. Yapılan analizlerden ARIMA modeline göre yağışta 2015 yılına kadar 14 mm'lik artış, 2025 yılına kadar Quadratic Trend modeline göre 20 mm'lik azalma, Linear Trend modeline göre ise 2-3 mm'lik artış olacağı tespit edilmiştir. Sıcaklık için yapılan analizlerden ARIMA modeline göre 2025 yılına kadar yaklaşık 0,3-0,4 °C'lik bir artma, Quadratic Trend analizine göre 1,2°C, Linear Trend analizine göre 0,5°C'lik artış olacağı öngörülmüştür. Sıcaklıktaki bu artış Birleşmiş Milletlerin 1990-2100 yılları arasında dünya için öngördüğü 1,4-5,8 °C'lik sıcaklık artışları ile örtüşmektedir.

Anahtar Kelimeler: Box –Jenkins Tekniği, İklim Değişikliği, sıcaklık, yağış, Afyonkarahisar.

1. INTRODUCTION

Important degradations occur in Earth Ecosystem as well as the increase in greenhouse gases, at present. It is predicted that these degradations will continue in future. That humans who cause the degradation in natural balance, lead to the problems whose results can be very negative will be inevitable (Öztürk, 2002).

Burning fossil fuel, deforestation, land use changes and the concentration of greenhouse gases in atmosphere has been increasing sharply since industrial revolution. All these reasons and urbanization increase greenhouse effects and surface temperature of the Earth increases. Warming which started at the surface temperature at the late of 19 th century, has been more clear after 1980's. The temperature surpasses a record in global scale. The last of high temperature records occurred in the year 1998. 1998 had been the warmest year since the year 1860 in terms of either global mean or northern and southern hemisphere means (Türkeş et al, 2000).

According to 3. assessment report of IPCC, global surface mean temperature had increased as 0,6 °C (between 0,4 - 0,8 °C). The results of new climate models of IPCC predict that global surface mean temperature will increase between *1,4-5,8 °C* in the period of 1990-2100 (IPCC).

Afyonkarahisar which takes place in central west part of Aegean region in southwest of Turkey. It is also in crossroads because Afyonkarahisar is in the boundaries of Mediterranean Central Anatolia and Aegean regions (Figure 1).

How continental climate which depends on different geographical characters all over the Turkey, will have a trend is important in terms of the solutions for problems caused by Global Warming. That the trends of global warming have been determined is decided in Afyonkarahisar which indicates continental clime characters, for determining local reflections.

Figure 1. The location map of research area.

Afyonkarahisar and its neighbour are affected by frontal activities which emerge from Black sea and East Mediterranean Basin and low degree temperature is common in winter months. Low degree temperature is coherent with continental climate of Central Anatolia in winter term. On the other hand, because of the fact that polar fronts get away toward North, tropical air mass affects the area in summer season. For this reason, precipitation decreases and temperature increases. Annual mean temperature is 11,2 ^{0}C (1975-2008) and annual total precipitation is 418 mm. Precipitation increases in spring but it decreases in summer within the year.

According to climate type models, the climate of research area is sub-humid in respect of de Martonne, it is semi-arid in respect of Erinç, it is generally arid and low degree humid and according to Aydeniz climate classification, it is arid (Erinç, 1969; Ardel, 1969).

Afyonkarahisar is involved in Central Anatolia Continental Climate type as macro climate (Atalay, 2000) so that climate in Afyonkarahisar and its neighbourhood indicate semi-arid and sub-humid. Because of topographical factors, differentiations appear (Yılmaz, 1999).

In this study, Box-Jenkins technique which is a method in statistics in which different techniques and methods are used, in order to predict the changes, trend, oscillation and deviation in climate at present and in the future. So the reflections of climate changes in global scale in Afyonkarahisar, the determining the trends in temperature and precipitation and projections and probabilities toward future have been discussed.

1.1. Research Significance

Precipitation and temperature have been analysed in Afyonkarahisar case which takes place in continental region in this study in order to predict the changes of climate members in the future. For this reason, it is aimed that precipitation and temperature are predicted by using ARIMA models which is an important metot in statistics and seen as a model which is used in mass-production of synthetic. So, probable increases and decreases in the future will have determined and also the trends and amount will have determined by the future. The study is important in terms of being an important reference point of projections which will be made toward future.

1.2. Data and Metod

In this study, according to ARIMA models which is applied to the dynamic processes by using long annual temperature and precipitation belonging to Afyonkarahisar (1975-2008) and Box-Jenkins technique, trend analyses have been made.

A method of analysis and prediction in time series, Box-Jenkins technique depends on discrete, linear and stochastic processes. Autoregressive, autoregressive – moving average and combined autoregressive – moving average are Bob-Jenkins prediction models. While AR (p), MA (q) and a combination of these, ARMA (p, q) are applied to stationary processes, ARIMA (p, d, q) is applied to nonstationary processes (Box and Jenkins, 1970; Box and Jenkins, 1976: Hamzacebi and Kutay, 2004, Bahadır and Saraçlı, 2010; Özdemir and Bahadır, 2010).

AR (p) models are illustrated as;

$$Y_t = \Phi_1 * Y_{t-1} + \Phi_2 * Y_{t-2} + \ldots\ldots\ldots\ldots + \Phi_p * Y_{t-p} + \gamma + a_t$$

In the formula;

$Y_{t-1}, Y_{t-2}, \ldots . Y_{t-p}$ are the previous observation values of the sequence,

$\Phi_1, \Phi_2, \Phi_p \ldots .$ are coefficients for previous observation values,

γ is a constant number

a_t is an error term.

MA (q) models;

$$Y_t = \mu + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots\ldots\ldots - \theta_q a_{t-q}$$

represent in the formula;

error terms; $a_t, a_{t-1}, a_{t-2}, \ldots . a_{t-q}$, and

error term multiples; $\theta_1, \theta_2, \ldots . \theta_q$

μ gives the average of the series belonging the process.

ARMA models are stationary stochastic models and they give the linear function of observation and the error terms

ARMA (p, q) models can generally be stated

$$Y_t = \Phi_1 * Y_{t-1} + \Phi_2 * Y_{t-2} + \ldots\ldots\ldots\ldots + \Phi_p * Y_{t-p} + \gamma + a_t + \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots\ldots\ldots - \theta_q a_{t-q}$$

Under the circumstances when time series are stationary, that is, under the conditions when the variance of the process average and covariance do not differ in accordance with time, ARMA (p, q) or one of the appropriate models of the special form of ARMA (p, q), ARMA (p) or MA (q) can be used. This situation is called nonstationary situation. It is for this reason the nonstationary series are stabilized so that the usage of this type of series makes it possible to achieve more accurate results (Box and Jenkins, 1976).

Making the time series is achieved by subtraction. If time series has a linear trend, the first subtraction series is stationary. If time series has an curvilinear trend, by taking the subtraction of the subtractions, the second subtractions series are stabilized and this situation, ARIMA model is expressed as (p, d, q). At this point d is stabilizing and subtraction parameter (Dobre and Alexandru, 2008).

ARIMA model has four basic phases. In the first phase, general model class is identified. For the choice of general model, the qualifications of theoretical functions are utilised by taking its autocorrelation functions into consideration. In the second phase, a model that is appropriate for the structure of the findings is determined. For this purpose, correlation and autocorrelation functions are utilised. In the phase of model determining, one of the model classes of AR, MA, ARMA, ARIMA is chosen. In the third phase, parameters of temporary model are identified by statistical method and their relevance is stated. And in the final phase, the suitability control of the model is conducted. By establishing an autocorrelation graphic of the lines of the temporary model, autocorrelation is examined (Yaman et al).

2. ANALYSES AND FINDINGS

Statistical trend analysis of temperature and precipitation was carried out in Afyonkarahisar. SPSS and Minitap programmes were used in the conducted analysis. The analysis of Minitap programme yielding more accurate results was used, and its trends and projections are found in harmony with the variation values anticipated by The United Nations. Shorter-term assessments were also made by using ARIMA Modelling for the purpose of answering the very question whether the variations in the temperature and precipitation values support the reflections of global climate change in Afyonkarahisar.

According to linear trend analysis, average temperature has the tendency of continuously increasing. This increasing tendency also had the inclination to increase in the same rate after 2000 s. As a result of tendency analysis of linear trend analysis, it was found that during a 15 year-period until the year 2015, there will have been a increase by 0,5 ^{o}C in the average temperatures. According to meteorological data, during the period between the year 1975 and 2008 an increase by 0,5 ^{o}C took place. So there will be a 1 ^{o}C increase in temperatures in Afyonkarahisar in a 40 year-period (Figure 2).

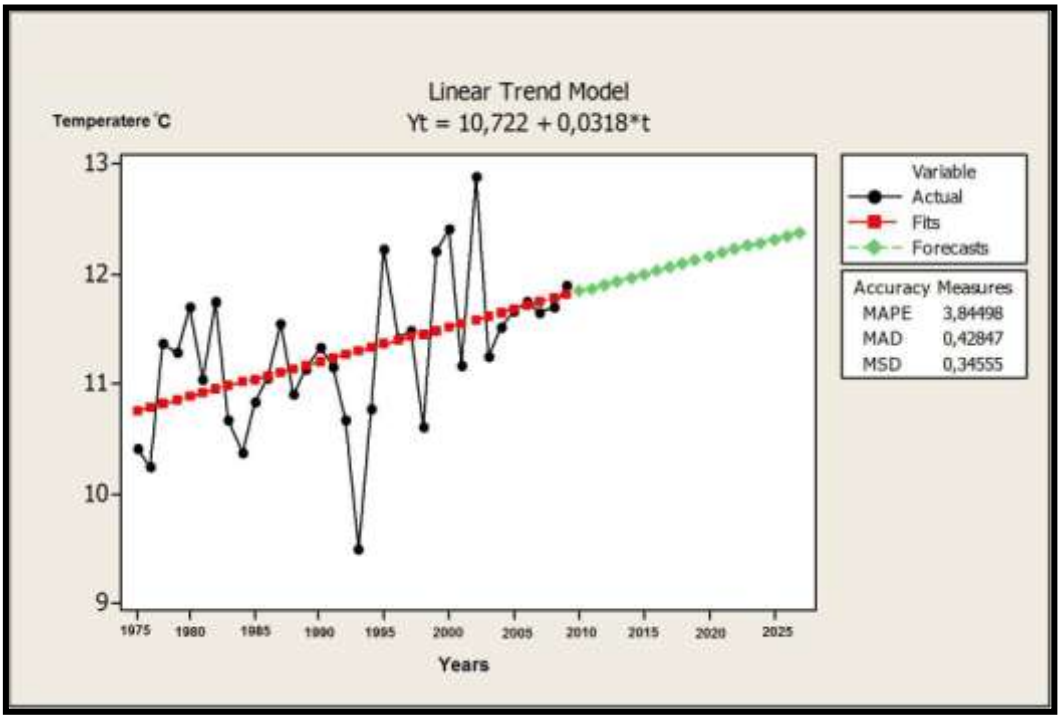

Figure 2. According to the Linear Trend Model, the temperature change tendency in Afyonkarahisar until the year 2025.

According to quadratic trend analysis, it has been found out that annual average temperatures in Afyonkarahisar will increasingly continue. According to meteorological data, from the year 1975 to 2008, a 0,5 ^{o}C increase was seen. According to trend analysis, it was undertood that the 1,4 – 5,8 ^{o}C increase that was calculated globally and with which the anticipation of the United Nations coincided, and it was revealed that tendencies are upward, so the global warming will seriously be observed in Turkey, too. According to quadratic trend analysis, it was estimated that there will be a 1,2 ^{o}C increase in temperatures in Afyonkarahisar until the year 2025. Average amount of these values is a 0,8 ^{o}C increase in the temperature (Figure 3).

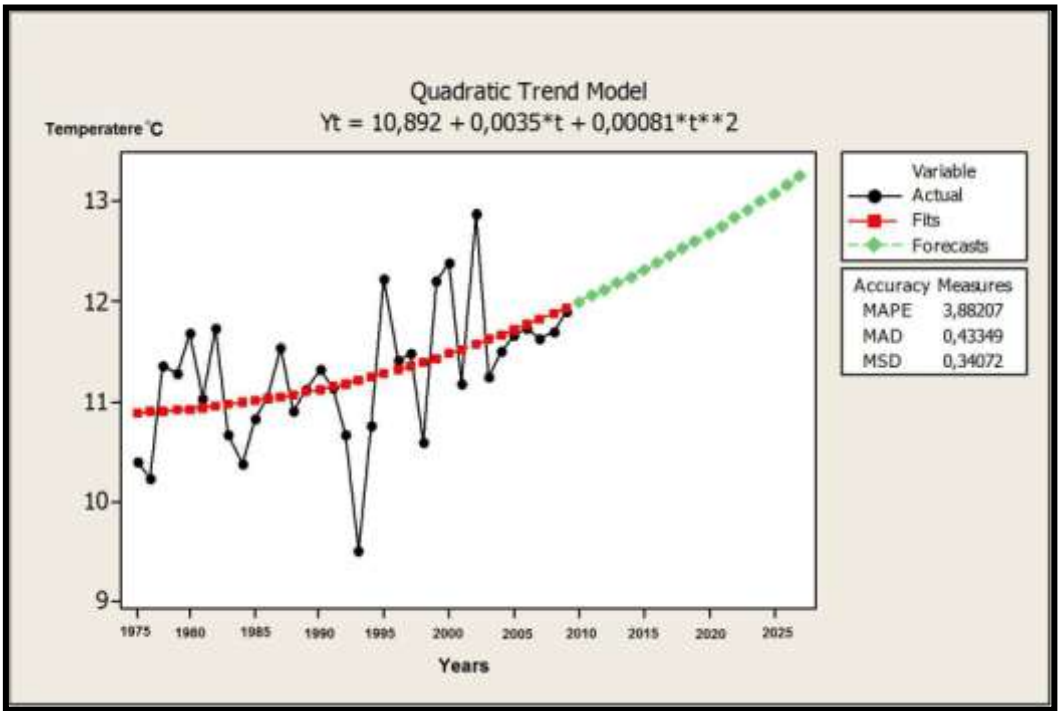

Figure 3. The temperature change tendency in Afyonkarahisar until the year 2025 according to Quadratic Trend model.

In the tendencies in trend analysis made for precipitation, a downward tendency in precipitation is compatible with the anticipation of United Nations about the decline in precipitation around the world. According to Linear Trend analysis, until the year 2025, there won't be a dramatic change in the amount of precipitation in Afyonkarahisar, on the contrary, it has been concluded that will be an increase by 2-3 mm in precipitation. However, according to meteorological measurements, it has been observed that there is an downward tendency from the year 1975 until 2008, and it has been also seen that within a nearly 33 year-period, there was a few (5 mm) mm decrease. Especially after the year 2000, there have been some fluctuations in the amount of precipitation. But, although there are significant changes in the total average precipitation amounts, these ups and downs are compensating for each other while moving from one year to another.

According to Quadratic Trend analysis, it was anticipated that in the year 2025 there would be a decline by 20 mm by displaying a decline in precipitation amount. The decline will reach the year 2025 gradually (Figure 4). It has been determined that there won't be a sharp decline and there will be a decline by a few mm from one year to another. The fact that the tendency of precipitation is generally downward reflects the effects of global warming in the territory. When the downward tendency is considered along with the upward tendency in temperature, it is understood that the becoming arid tendency across our country will also be observed locally in Afyonkarahisar. The anticipation of the United Nations about the results of global warming values has shown that while the predictions vary, it is very challenging that the expected effect will be at global extent, and as long as the atmospheric conditions remains at this level, its reflections will be gradual.

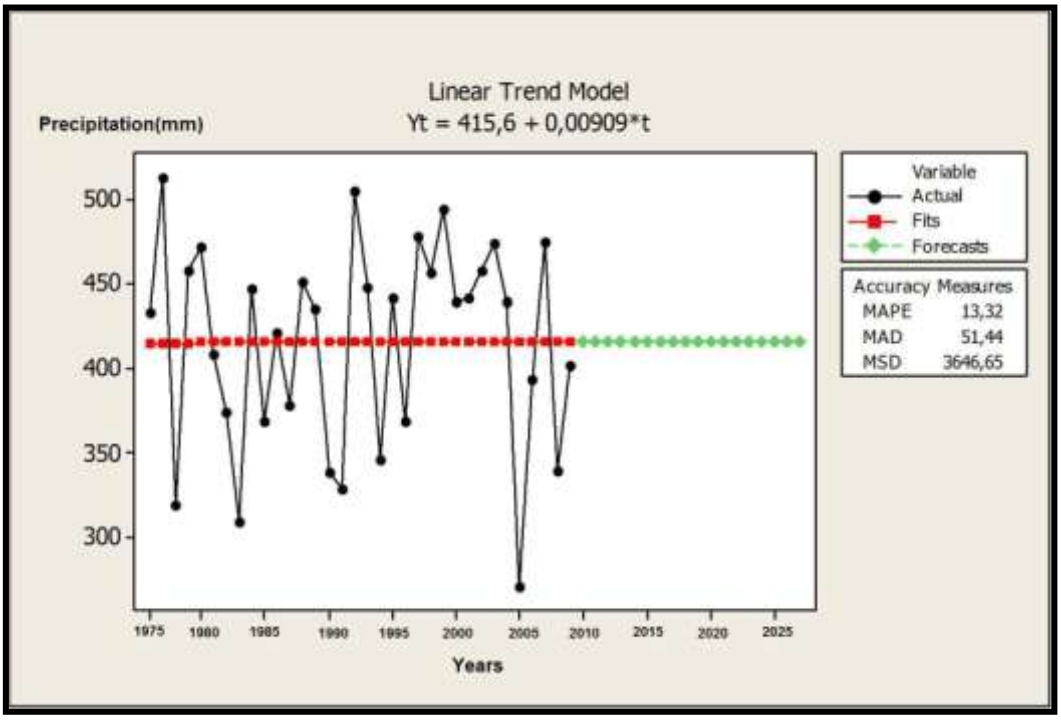

Figure 4. Precipitation variation tendency in Afyonkarahisar until the year 2025 according to Linear Trend Model.

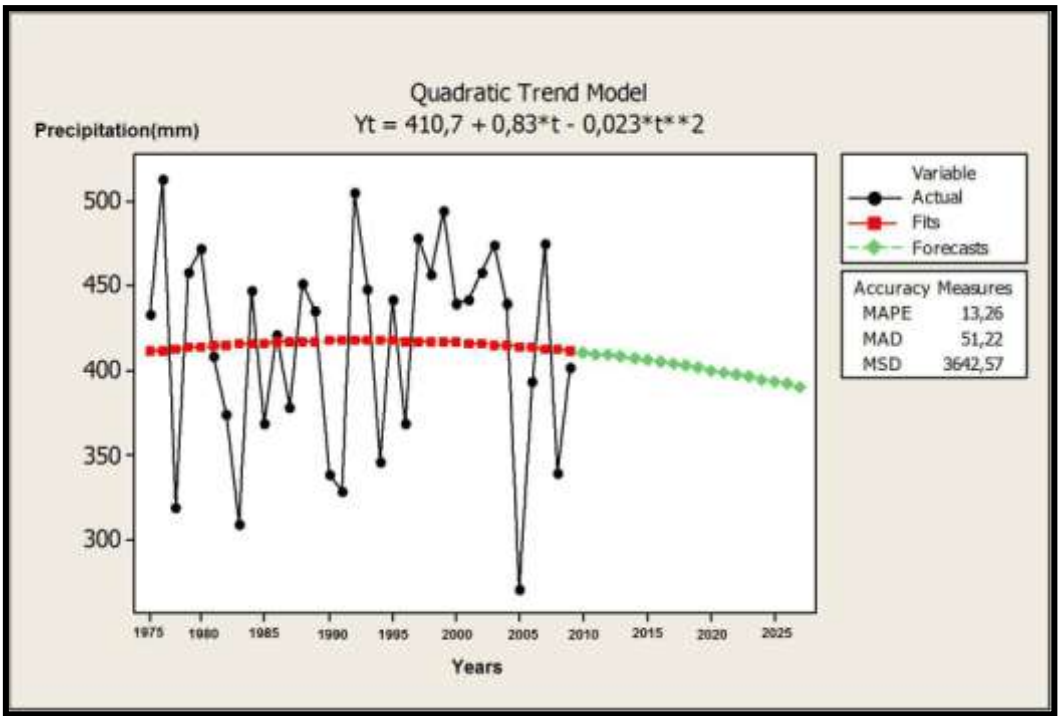

Figure 5. Precipitation variation analysis in Afyonkarahisar until the year 2025 according to Quadratic Trend Model.

Schedule 1. Tendency results of Quadratic and Linear Trend analysis.

Years	Linear-Precipitation	Quadratic-Precipitation	Linear-Temperature	Quadratic-Temperature
2009	415,95	411,02	11,84	12,01
2010	415,96	410,18	11,87	12,07
2011	415,97	409,29	11,90	12,13
2012	415,98	408,36	11,93	12,19
2013	415,99	407,39	11,96	12,26
2014	416,00	406,36	11,99	12,33
2015	416,01	405,29	12,03	12,40
2016	416,01	404,17	12,06	12,47
2017	416,02	403,00	12,09	12,54
2018	416,03	401,79	12,12	12,61
2019	416,04	400,53	12,15	12,69
2020	416,05	399,22	12,19	12,76
2021	416,06	397,87	12,22	12,84
2022	416,07	396,47	12,25	12,92
2023	416,08	395,02	12,28	13,01
2024	416,09	393,53	12,31	13,09
2025	416,10	391,99	12,34	13,17
2026	416,11	390,40	12,38	13,26

The fact that more than one variation is used in the analysis which is conducted according to ARIMA method so that the prediction of nonstationary variations of chronic series yields more reliable results is considered. ARIMA technique depends on the identification of the autoregressive moving average form of the stationary time series. For this purpose especially the time series is rendered stationary (by taking the first logarithmic subtraction) and one of the efficient ARIMA models, whose general formula is given below, is studied (Box and Jenkins, 1976).

$$yt = b0 + b1yt\text{-}1 + b2\ yt\text{-}2 + ... + yt\text{-}p + a1ut\text{-}1 + a2ut\text{-}2 + ... + ut\text{-}q + vt \quad (4)$$

In this formula, p represents the autoregressive part, q represents delay time of moving average part, and d represents the subtraction degree.

If the time series includes discrete, linear and stochastic process, it is called Box-Jenkins or ARIMA model. Mentioned models are also known as linear filtering models. Autoregressive (AR), moving average (MA), combination of AR and MA, autoregressive moving average, are the most common linear stationary Box-Jenkins models. Models which are applied to stabilized models that were once nonstationary, as a result of subtraction process are called Autoregressive Integrated Moving Average (ARIMA). ARIMA model is also known as Ben-Jenkins Technique. In box-Jenkins models the purpose is the identification of the linear models which is suitable for the time series and which contains the least parameters (Yaman et al, 2001).

The autoregressive correlation function (ACF) (Figure 7) which was formed from average precipitation series belonging to annual series (Figure 6) and partial autoregressive correlation function diagrams (Figure 8), it has been observed that the model is supposed to have moving average (Figures 6-7 and 8).

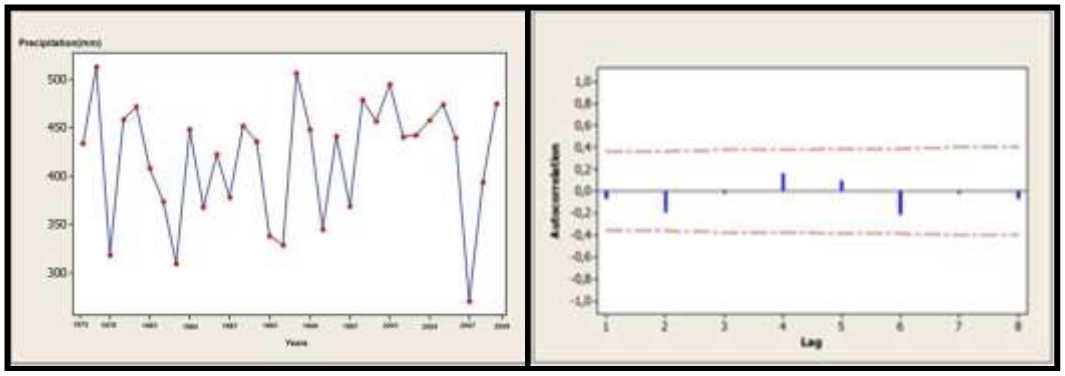

Figure 6. Precipitation distribution in years

Figure 7. Precipitation autocorrelation.

It has been observed that for ARIMA model, which is used for identification of the significance of variation tendency in precipitation, error margin is low, and that they didn't exceed the lower and upper security limits and it is the appropriate model (Figure 7-8). As a result of all these accuracy analysis, trend analysis is began to be used. Through Quadratic trend analysis, which was carried out in accordance with ARIMA model, it was estimated that there will be a 14 mm increase in the amount of precipitation in Afyonkarahisar by the year 2015. According to the long annual analysis of the general tendency of the series, decreases in the amount of precipitation and according to the short annual anticipating an upward tendency have been detected.

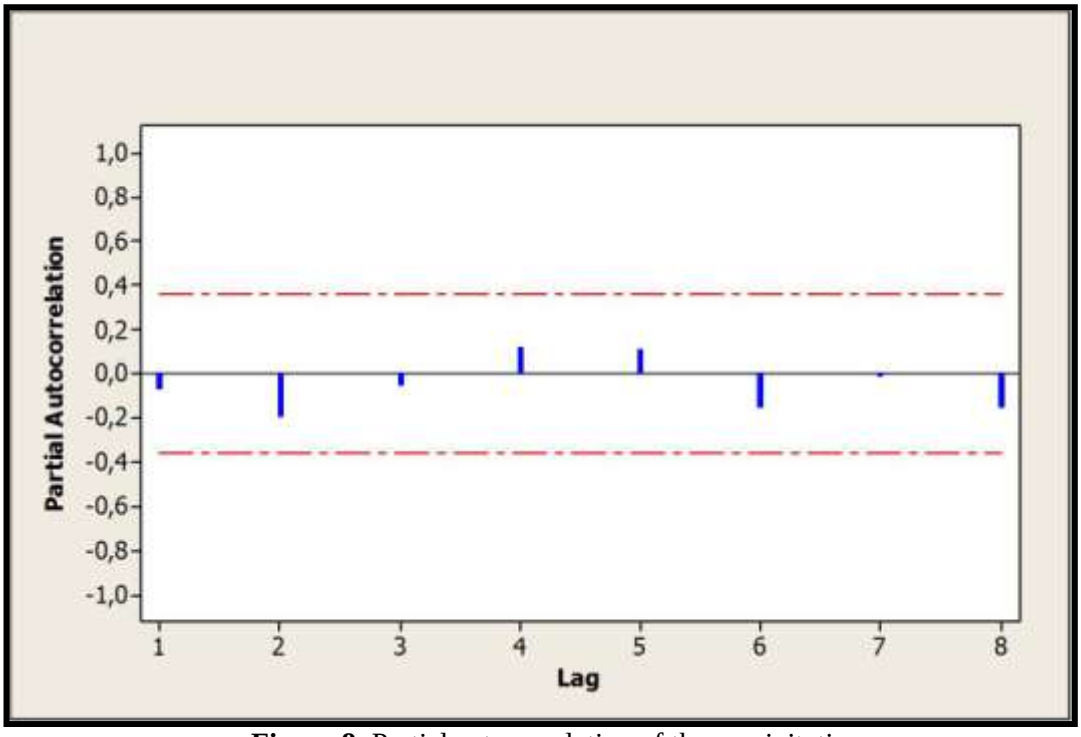

Figure 8. Partial autocorrelation of the precipitation.

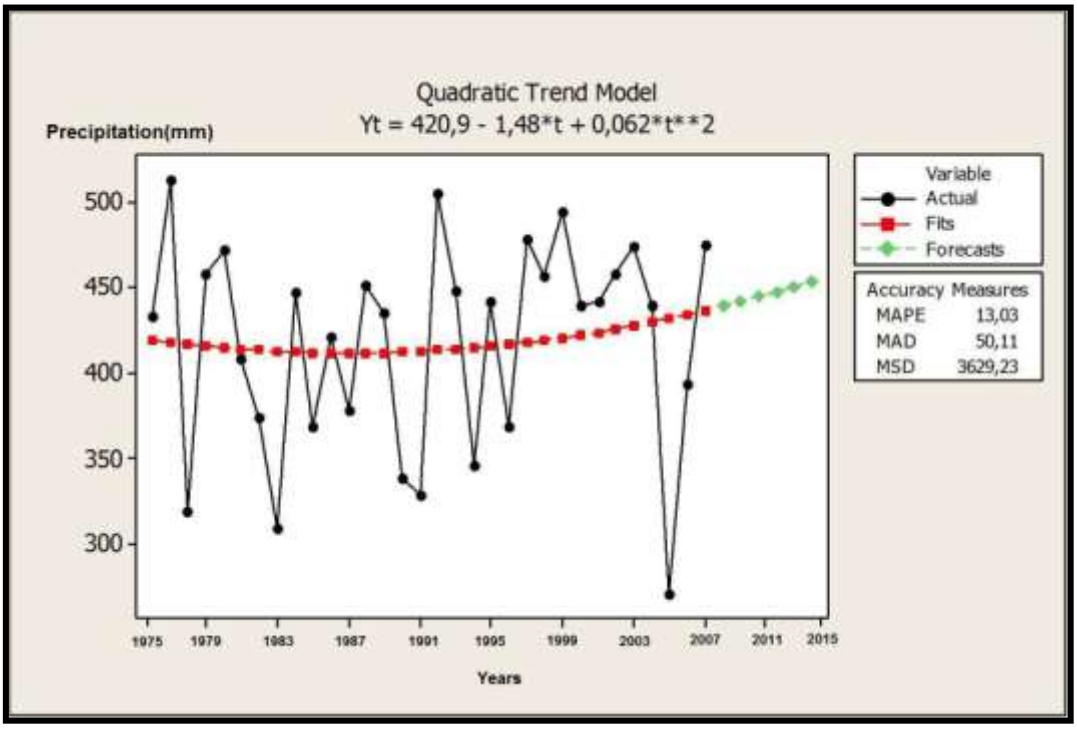

Figure 9. Precipitation of Quadratic Trend analysis according to ARIMA model.

ARIMA Model, which is applied for temperature, by stabilizing the data, accuracy and relevance analysis have been conducted. It has been observed that according to the conducted analysis the annual variations of temperature series (Figure 10) and its tendency course are supposed to have autoregressive correlation function (ACF) (Figure 11) and from the partial autoregressive correlation function (PACF) diagrams the model should have moving average (Figures 10-11 and 12). As the result of data analysis, it has been understood that in both correlation series it didn't exceed upper and lower security limits and it had reliability.

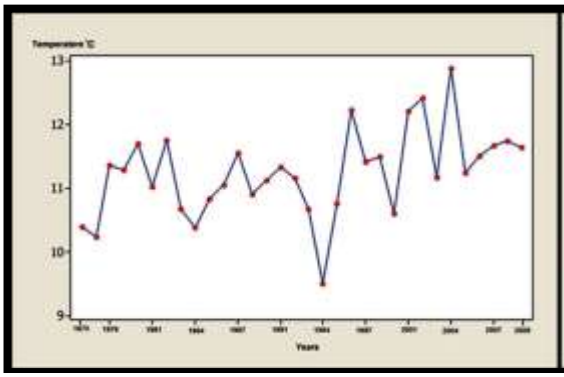

Figure 10. Temperature tendency.

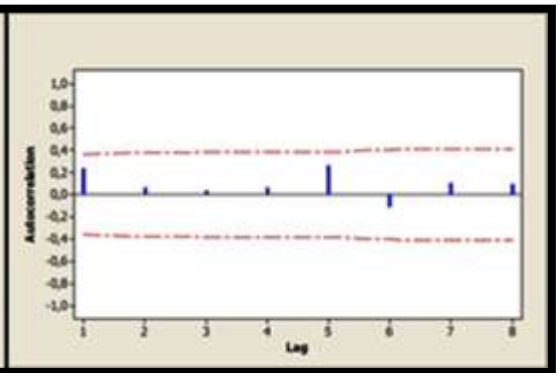

Figure 11. Autocorrelation of temperature.

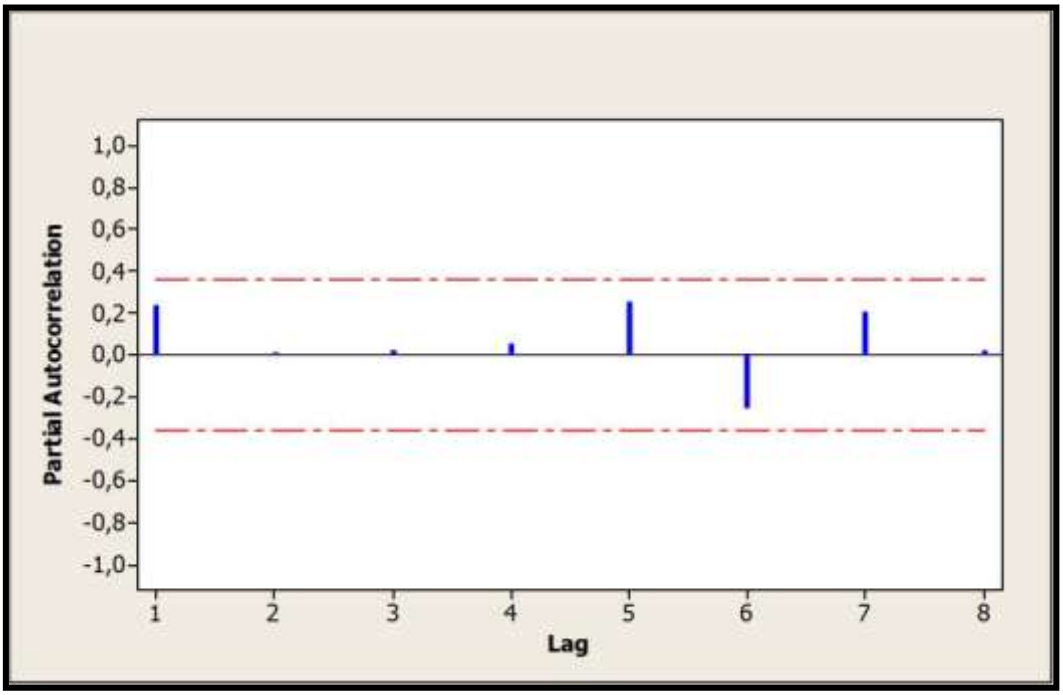

Figure 12. Partial autocorrelation of temperature.

Growth Curve model, which has a higher accuracy rate than the shorter ARIMA prediction models for temperature, has been preferred. According to the model in question, an upward tendency in temperature in Afyonkarahisar until the year 2015 has been detected, and the amount has been predicted as 0,3 – 0,4 ^{o}C (Figure 13). So, that the tendency until the year 2015 will be upward according to ARIMA model and that the amount anticipated until the year 2015 by Quadratic and Linear trend models coincide with each other (Photo, 1-2). The trend analysis conducted according to the temperature tendency has shown that the effects of global warming in Afyonkarahisar coincide with the values around the world.

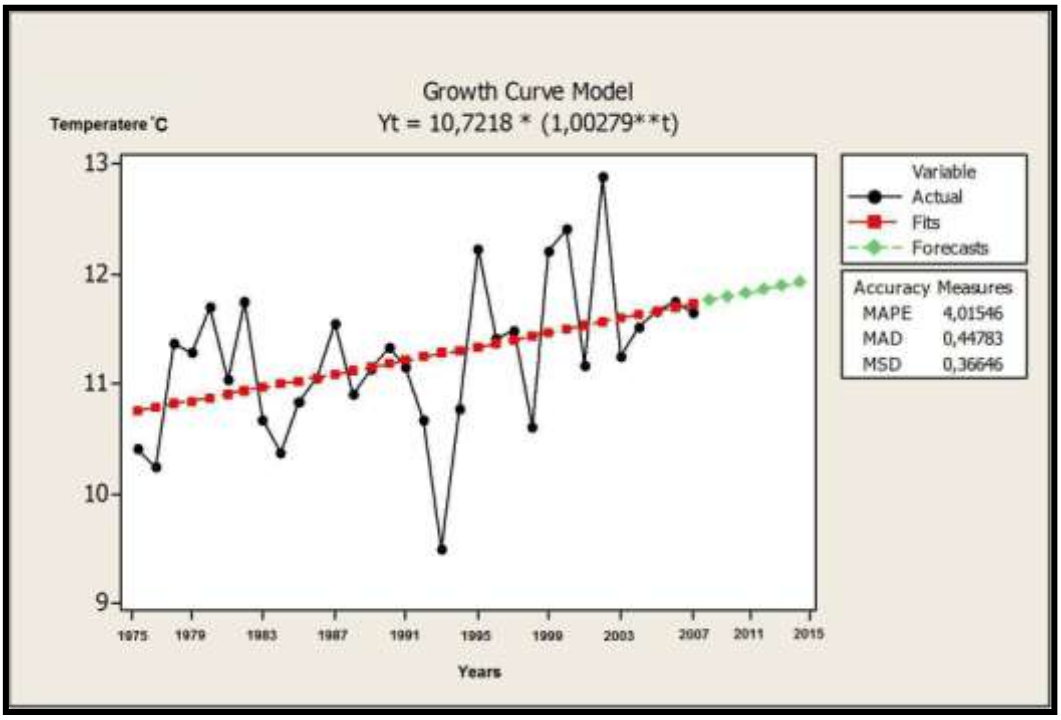

Figure 13. Temperature tendency according to Growth Curve model.

Photo 1. Afyonkarahisar in winter landscapes (2010).

Photo 2. Afyonkarahisar the effects of drought.

3. RESULT

In this study, precipitation and temperature analysis were conducted in accordance with ARIMA (Box-Jenkins Technique), which is used for identifying anticipations and tendencies about future in statistics in Afyonkarahisar.

As the result of analysis conducted for precipitation, it has been determined that there will be an increase (14) in precipitation until the year 2015 according to ARIMA model, on the other hand, there will be a 20 mm decline in precipitation according to Quadratic Trend analysis, which is used in long annual tendency prediction. And according to Linear Trend model, it has been estimated that there won't be a significant variation in precipitation until the year 2025 and there will be a nearly 2-3 mm increase.

As the result of analysis conducted for temperature, it has been anticipated that until the year 2015, as well as 2025, there will be an increase. According to one of ARIMA model, Growth Curve, there will be an increase by 0,3 – 0,4 ^{o}C until the year 2015. According to Quadratic Trend model, which is used for longer annual predictions, the increase will be by 1.2 ^{o}C, and according to Linear Trend model it will be by 0,5 ^{o}C. These values coincide with the increase by 1,4 – 5,8 ^{o}C which anticipated by the United Nations for the world between the years 1990 – 2100, and the fact that the tendencies are upward position shows that the global warming will also be observed at alarming levels in Turkey.

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