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Research Article

Time Series-Based Annual Rainfall Estimation for Aksaray Province

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Abstract **–** In this study, annual precipitation data in Aksaray province of Turkey were examined by time series analysis for the period 1980-2023 and future precipitation estimates were made. In the study, statistical models such as Auto.ARIMA, Holt-winters and TBATS were used together with deep learning models such as NNTAR, MLP and ELM. The performances of the models were evaluated with MAPE values for various test lengths. While the NNTAR model stood out as the most successful model with the lowest error rate among deep learning methods, Auto.ARIMA and Holt-Winters provided low error rates in certain cases among statistical models. The research provides important findings for the sustainable management of water resources in semi-arid regions such as Aksaray.

Keywords – Time Series Analysis, Aksaray Rainfall Forecast, Deep Learning Models, Climate Change.

I. INTRODUCTION

Data accumulated over time often forms the basis in many scientific and industrial applications. These data, obtained by experiments or observations or data collection systems at fixed intervals, are reduced into a time series. Time series are a series of data analyzed for changes in data depending on time and to estimate future values based on these changes [1]. Time series analysis enables us to comprehend the internal dynamics of data and predict the future pattern by analyzing the pattern, trend, seasonality fluctuation, and irregular movements in data. Time series models allow the predictions of the future based on the historical past of the data. The time series analysis of a city's rainfall data may show the trends of rainfall in the past, and the seasonal and annual changes to estimate how many rains are expected in coming years. Such predictions significantly help in the making of strategic decisions across areas like agriculture, water management, and urban planning. At the same time, time series analyses serve as an effective tool in the forecast of market trends, energy demand projections, assessments of risks related to climate change, and even the monitoring of epidemics in health.

Time series analyses make use of regularity in the data concerning the past to predict possible future behavior. By observing trends and seasonal cycles in past data, prediction of possible future trends is easier. This shall be used as a strategic guide to support correct decision-making processes. These models give an increase in prediction accuracy while minimizing variability, hence giving an institution, business, or scientist a data perspective.

Time series are used for strategic forecasting in many areas. They have critical applications in financial markets for stock and exchange rate forecasting, in economics for inflation and unemployment rate projections, in meteorology for weather and climate change forecasting, in the energy sector for demand planning, and in healthcare for epidemic disease monitoring. Besides, time series analysis also forms a support for decision-making and raises efficiency in commercial areas, such as sales and inventory management in retail, forecasting of traffic density in transportation, and optimization of cargo movement in logistics.

In the recent years, significant changes have been noticed in the precipitation regimes due to the impact of climate change. Precipitation fluctuations have both direct and indirect influences on every constituent of ecosystems; above all, they leave prominent effects on the environment, vegetation, animal populations, and human life [2]. Disruptions in the ecosystem balance threaten animal populations, and even habitats of species, although scanty or excess precipitation may be negative to development processes in plants. It is also of critical importance in terms of direct food security and economic sustainability in areas such as human activities and agriculture.

In this paper, the rainfall data observed in Aksaray Province of Turkey for the period of 1980-2023 were analyzed and future foresights have been made. Estimations by this study help existing literature in view of possible long-term influences on local and regional ecosystems.

II. MATERIALS AND METHOD

In this study, time series, which have a very wide application area [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23][24][25][26], were used. Time series are often preferred in forecasting processes because they allow analysis of data points in order over time. This analysis method helps predict future events by capturing patterns such as trends, seasonality, and serial dependency in past data. Time series provide important information, especially in areas such as financial markets, weather forecasting, and demand forecasting; because data in these areas often change over time, and previous observations are of great benefit in understanding future results.

A. Dataset

The dataset used for Aksaray consists of 44 records. The minimum rainfall, maximum rainfall and average rainfall in the dataset covering the years 1980-2023 are 19.63 mm, 42.69 mm and 29.01 mm, respectively. In Figure 1, annual precipitation amount for Aksaray province between 1980-2023 is given as a time series.

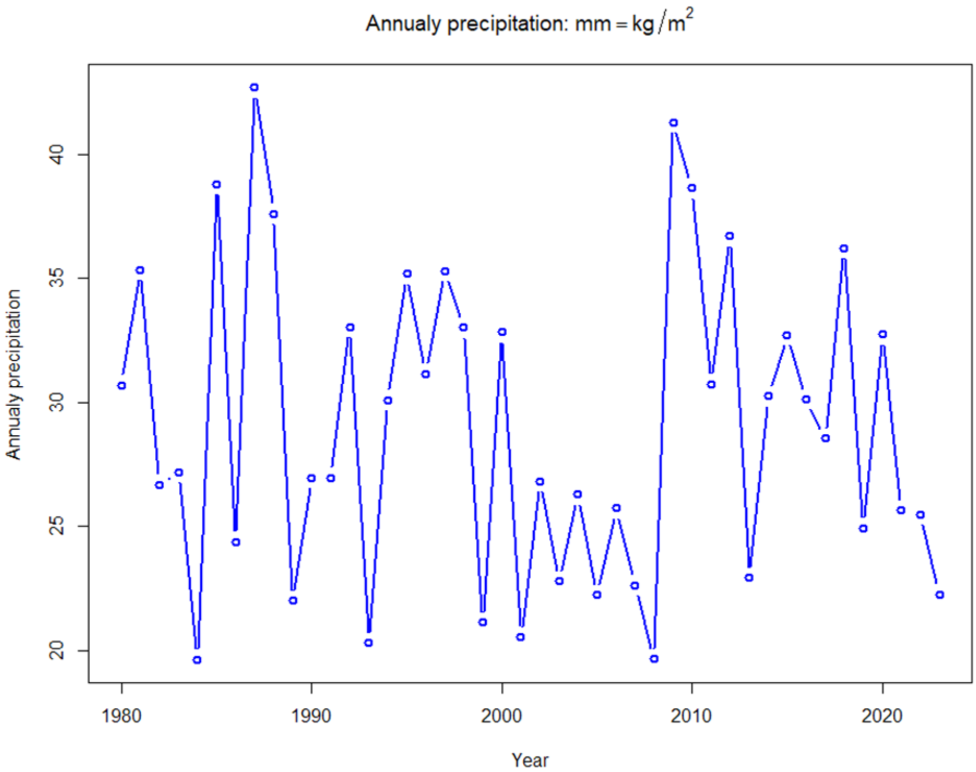

Fig. 1. Annual precipitation amounts for Aksaray province of Turkey between 1980-2023.

Figure 1 shows the annual precipitation amounts for Aksaray province of Turkey between 1980-2023. In general, it is seen that the precipitation amount has fluctuated over the years. The significant fluctuations in the graph show that precipitation reached high levels in some years (for example, in 1987, 1990, 2011) and decreased in some years (for example, in 1984, 1996, and 2014). This fluctuation shows how seasonal and climatic variables affect precipitation amounts.

When we look at the right side of the graph, i.e. recent years, a general downward trend in precipitation amounts is observed. This decline is a striking indicator in terms of the sustainability of water resources in semi-arid regions such as Aksaray. Factors such as global climate change and drought may be a reason for this decreasing trend. Decreasing precipitation can have negative effects on agriculture and water resource management, so it is important to make forward-looking estimates and develop sustainable water management policies.

III. RESULTS

In the first analysis of time series were performed in the R-Studio environment using R-based deep learning models such as Neural Network Time Series Forecasts (NNTAR), Multilayer Perceptron (MLP) and Extreme Learning Machine (ELM). The best results were obtained by using different lengths of training/test data. Test data lengths were taken as 36%, 41%, 48% and 50%, respectively, while test MAPE values are given in Table 1. The graphs of the model predictions are given in Figure 2.

Table 1. MAPE values of the analyses performed depending on four different test lengths for the annual rainfall dataset of Aksaray province

Model	**Test length 16 (36%)**	**Test length 18 (41%)**	**Test length 21 (48%)**	**Test length 22 (50%)**
	MAPE (%)	**MAPE (%)**	**MAPE (%)**	**MAPE (%)**
NNTAR	17.76	**17.43**	17.44	17.84
MLP	18.24	**17.94**	19.37	18.73
ELM	18.53	**17.75**	19.07	18.81

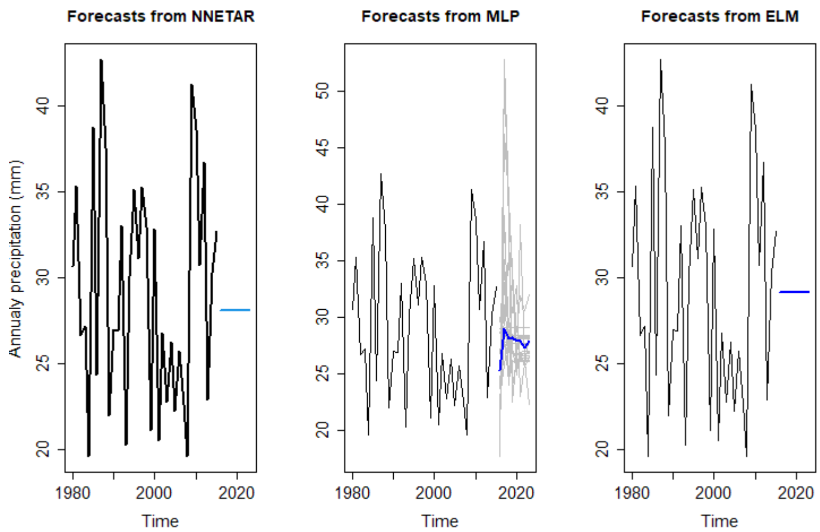

Fig.2. Prediction graphs of the models when the dataset is divided into 18% testing and 82% training.

In the second analysis, using statistically based models, the MAPE percentages of the Auto.ARIMA, Holt-Winters and TBATS models are given comparatively in Table 2 for four different test lengths. Graphs of statistically based model predictions are given in Figure 3.

Table 2. MAPE values of statistically based model analyses performed depending on four different test lengths for the annual precipitation data set of Aksaray province

Model	**Test length 16 (36%)**	**Test length 18 (41%)**	**Test length 21 (48%)**	**Test length 22 (50%)**
	MAPE (%)	**MAPE (%)**	**MAPE (%)**	**MAPE (%)**
Auto.ARIMA	17.51	17.79	19.13	18.87
Holt-Winters	23.43	19.79	17.36	16.94
TBATS	17.70	18.32	19.53	19.19

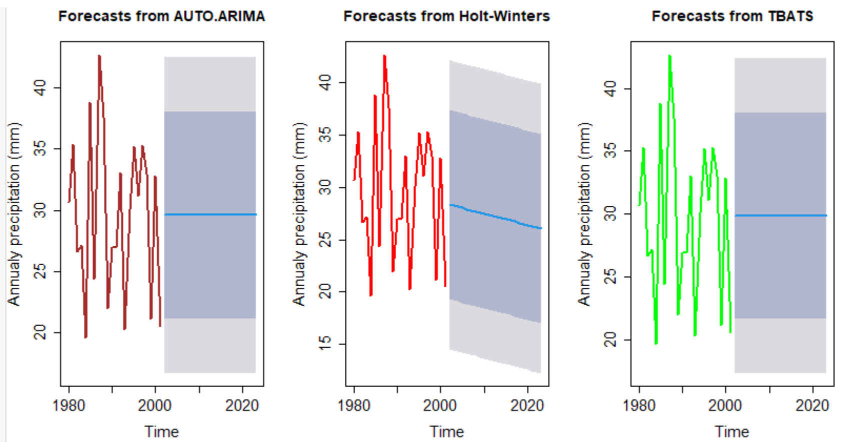

Fig.3. Prediction graphs of the models when the dataset is divided into 50% testing and 50% training.

IV. DISCUSSION

In the first analysis, using deep learning models, the MAPE percentages of the NNTAR, MLP and ELM models are given comparatively in Table 1 for four different test lengths. Test lengths are determined as 16 (36%), 18 (41%), 21 (48%) and 22 (50%), respectively. NNTAR model achieved the most successful results by offering the lowest MAPE percentage in all four test lengths. In particular, MAPE metric value reached the lowest MAPE value with 17.43% when test length was 18. MAPE values of MLP model are 18.24% in test length 16, 17.94% in 18, 19.37% in 21 and 18.73% in 22 and it has higher error compared to NNTAR model. MAPE values of ELM model are similarly relatively high and the lowest error rate is observed with 17.75% in test length 18. According to these results, the NNTAR model is more consistent and has a lower error rate at each test length compared to the other two models, and it is seen to be more successful especially at shorter test lengths.

Table 2 compares the MAPE values of the statistical analyses performed with the Auto.ARIMA, Holt-Winters and TBATS models at four different test lengths. The Auto.ARIMA model generally performed better with lower error rates, especially notable with MAPE values of 17.51% and 18.87% at 36% and 50% test rates, respectively. The Holt-Winters model showed the lowest error rate (16.94%) at 50% test rate, suggesting that the model performed better on larger test sets. Although the error rates of the TBATS model are slightly higher than the other models, it is seen that it provides a generally stable performance. These results emphasize that each model may show performance differences according to different data structures and test rates.

Figure 3 shows the prediction graph of statistical models based on 50% test and 50% training ratio. The blue lines in the graph represent the mean values of the model predictions, the dark shaded areas represent the 80% prediction interval, and the light shaded areas represent the 95% prediction interval. This visual shows the uncertainty level of the predictions and the ability of the models to predict future annual precipitation. The graphs show that the model predictions are generally consistent with the dataset, but the wide prediction intervals should be taken into account, especially in terms of prediction reliability.

V. CONCLUSION

This study has made a significant contribution to the assessment of regional effects of climate change by estimating how precipitation amounts in Aksaray province have changed over time and their future trends. Comparison of deep learning and statistically based models revealed the varying performances of different methods according to data structure and test rates. The obtained results can support strategic decision-making processes in areas such as water resources management, agriculture and urban planning. It was also emphasized that such analyses can help develop long-term policies to combat climate change.

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