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Aylık Yağış ve Bağıl Nemdeki Eğilimlerin Değerlendirilmesi: Konya'da İklim Değişikliği Referansı İçin Kapsamlı Bir Analiz

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ÖZET

Konya ili ekilebilir arazi bakımından yüksek bir orana sahip olduğu için ve Konya ilinde yağışın mevsimsel değişkenlik göstermesinden dolayı bu çalışmada Konya ili için bağıl nem ve yağış trend analizi araştırılmıştır. Türkiye Devlet Meteoroloji Dairesi, 1929'dan 2020'ye kadar 91 yıllık dönemi kapsayan bağıl nem ve yağış miktarına ilişkin istatistikler sağlanmıştır. Yağışın ve bağıl nemin içinde bulunduğu meteorolojik verilerin trend analizinin incelenmesi için Mann Kendall Testi ve Sen'in Trend Eğim Metodu kullanılmıştır. Yapılan analizler sonucunda yağış verileri için Kendall'ın tau değerlerinin Ocak'tan Aralık ayına kadar −0,087 ile 0,121 arasında değiştiği ve değerlerin çoğunluğunun sıfıra yakın olduğu belirlenmiştir Çoğu p değeri 0,05'ten büyük olarak hesaplanmıştır ve Sen'in eğimi değerlerinin aylık yağış için-0,087 ila 0,121 arasında değiştiği belirlenmiştir. Sonuçlara bağlı olarak Kendall'ın tau ve Sen' in eğimi değerleri sıfıra yakın ve p değerleri yüksektir; bu durum aylık ortalama yağış eğilimlerinde istatistiksel anlamlılık eksikliğine işaret etmektedir. Bağıl nem verileri için Kendall'ın tau değer aralığı-0,007 ila -0,248 olarak hesaplanmıştır ve p değerleri birkaç ayda (Ocak, Haziran, Aralık) 0,05'ten az olarak bulunmuştur. Sen'in eğimi değerleri ise 0,076 ila 0,000 aralığında değiştiği saptanmıştır. Sen'in eğimi ve Mann-Kendall testi, istatistik açısından üç ay boyunca (Ocak, Haziran ve Aralık) bağıl nemin azalma yönünde önemli bir eğilim olduğunu, ancak ortalama bağıl nem için diğer aylarda bu eğilimin olmadığını göstermektedir. İklim değişikliği tahmin edilirken, Konya'nın bağıl nem ve yağış oranlarında önemli farklılıklar öngörmeyen senaryo ve iklim modellerinin yol gösterici olabileceği söylenebilir.

Assessing Trends in Monthly Precipitation and Relative Humidity: An Analysis for Climate Change Reference in Konya

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ABSTRACT

Due to the high proportion of arable land in the province of Konya and the seasonal variability in rainfall in this region, this study investigates the trend analysis of relative humidity and precipitation for the province of Konya. The Turkish State Meteorological Service provided the statistics on relative humidity and the amount of precipitation covering a 91-year span from 1929 to 2020. Mann Kendall Test and Sen's Trend Slope Method were used at 95% confidence level to investigate the trend analysis of meteorological data of relative humidity and precipitation. In the lights of analysis, the values range from −0.087 to 0.121 for the months of January through December, with the majority of values being near 0 for Kendall's tau, most p-values are larger than 0.05, and the values for Sen's slope range from −0.087 to 0.121 for the monthly precipitation. Depending on the results, the values for Kendall's tau and Sen's slope are close to zero, and the p-values are high, indicating a lack of statistical significance in the trends for the average monthly precipitation. The range of values is −0.007 to −0.248 for Kendall's tau, p-values are less than 0.05 in a few months (January, June, December), and 0.076 to 0.000 is the range of values Sen's slope for average relative humidity. Sen's slope and the Mann-Kendall test indicate that there is a significant tendency toward a decreasing relative humidity for three months (January, June, and December) in terms of statistics but not for the other months for average relative humidity. It was suggested that when predicting climate change, scenarios and climate models that do not predict significant differences in Konya's relative humidity and precipitation could be considered as a guide.

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INTRODUCTION

Relative humidity (RH) is the percentage that represents the level of moisture in the air relative to its maximum capacity at a given temperature [1]. Relative humidity plays a significant role in various aspects such as human well-being, hydrological research, agriculture, and irrigation management [2-3]. Unusually high or low levels of relative humidity can have detrimental effects on human health, including the increased risk of illnesses such as colds, flu, nosebleeds, asthma attacks, and allergies [4-6]. Additionally, elevated relative humidity can contribute to increased precipitation, which may have adverse consequences for the economy [4-6]. Prediction of humidity is also becoming crucial because of the factors mentioned above [7].

The balanced and sustainable use of national and international water resources required for irrigation, energy production, and industrial and domestic activities is increasingly being impacted by factors such as changing demographics, migrations, non-planned urbanization, land and water usage, and other external factors [8-9]. On the other hand, rainfall, climate, agricultural production, and the utilization of water resources, among other factors, are perhaps the most important components of the complex hydrological cycle that affects our daily lives. Therefore, rainfall directly influences the understanding of climate change [10]. The changes observed in precipitation provide information about climate change, therefore, in studies related to detecting climate-related changes, the determination of the trend analysis of precipitation is frequently encountered [11-14]. Mann-Kendall, linear regression, variability of precipitation, and coefficient of variation methods were applied to the precipitation data of Kahramanmaraş province for trend analysis by Karabulut and Cosun, and it was stated that there is no significant increasing or decreasing trend in annual precipitation in terms of statistics [15]. Dalkılıç (2019) conducted a trend analysis on 31 years (1978-2018) of precipitation data from meteorological stations placed in the city centers of Erzincan, Gümüşhane, and Bayburt. The analysis utilized the Şen trend test, Spearman Rho, Mann-Kendall, and Seasonal Mann-Kendall tests. The study identified an increasing trend in certain months during the winter season and a decreasing trend in some months during the summer season [16]. Using monthly total precipitation data from 19 precipitation monitoring stations in the Black Sea Region of Turkey that were recorded between 1960 and 2015, trends of monthly, annual, and seasonal precipitation data were identified by Demir and the findings indicated that whereas total precipitation rises at stations in the Central and Eastern Black Sea regions, it falls at stations in the Western Black Sea region [17]. Demir also investigate that the trend analysis of water-level changes in lakes and sinkholes in Konya region at 95% of the confidence interval using meteorological parameters [18]. According to the result, the study was concluded as accurately estimating how long-term precipitation affects sinkhole and lake water levels is complicated [18]. Yağbasan et al. used in their study the Mann-Kendall, Modified Mann-Kendall, Sen Trend, and Linear Trend at confidence levels of 90%, 95%, and 99% to explore trend analysis of average monthly pan evaporation, air temperature, precipitation, humidity, wind speed, cloud cover, and sunshine duration for the lakes Eymir and Mogan which are classified as shallow lakes [19]. The findings indicated that at all confidence levels, there was an increasing trend in both lake levels for three methodologies (Mann-Kendall, Sen Trend, and Linear trend) [19].

Konya, with 12.2% of Turkey's total arable land, is categorized as a second-grade drought region in the country, experiencing considerable variation in annual precipitation throughout the different seasons [16]. Therefore, this study aimed to conduct trend analysis of relative humidity and precipitation, which will aid in formulating prospective climate scenarios, for Konya at 95% of confidence level.

MATERIALS AND METHODS

Study Area and Data

Konya, the largest province in Turkey, is located at an elevation of approximately 1,006 meters and covers an area of 41,001 km^2. It lies roughly between 36.70° and 39.25°N latitude and 31.25° and 34.43° E longitude. Three urban districts—Karatay, Selçuklu, and Meram—with a combined population of over 1,390,000 make up its center region (Figure 1). According to Asaad et al. (2022) [20], Konya is classified as a second-grade drought region in Turkey, and its yearly precipitation varies with the seasons.

Figure 1. *Konya's districts and location in Turkiye [21].*

Table 1 provides the characteristics of precipitation and relative humidity and the time series plot is shown in Figure 2.

Table 1. *Statistical attributes of precipitation and relative humidity for Konya*

	Min.	Max.	Mean	Std. Dev.
Precipitation (mm)	0.00	144.10	28.30	24.57
Relative humidity (%)	25.00	86.00	59.59	14.10

Trend Analysis

A trend is the gradual increase or decrease in the value of any chosen parameter over time. The tests that are both parametric and non-parametric are run to find the trend. The analysis of hydro-meteorological time series, where the data is frequently incomplete and not normally distributed, frequently makes use of non-parametric tests. Because non-parametric tests become independent of the dataset's statistical distribution, they have an advantage over parametric tests [22]. In this study, the tests applied to determine trend analysis are explained below.

Trend analysis is a tool used to identify changes over time and predict possible future trends. Therefore, trend analysis of long-term precipitation data can contribute to planning, management and decision-making processes in various sectors. "Sen's Trend Slope," a time series analysis method, is used to determine the trend of a variable over time. This method is based on the Sen's

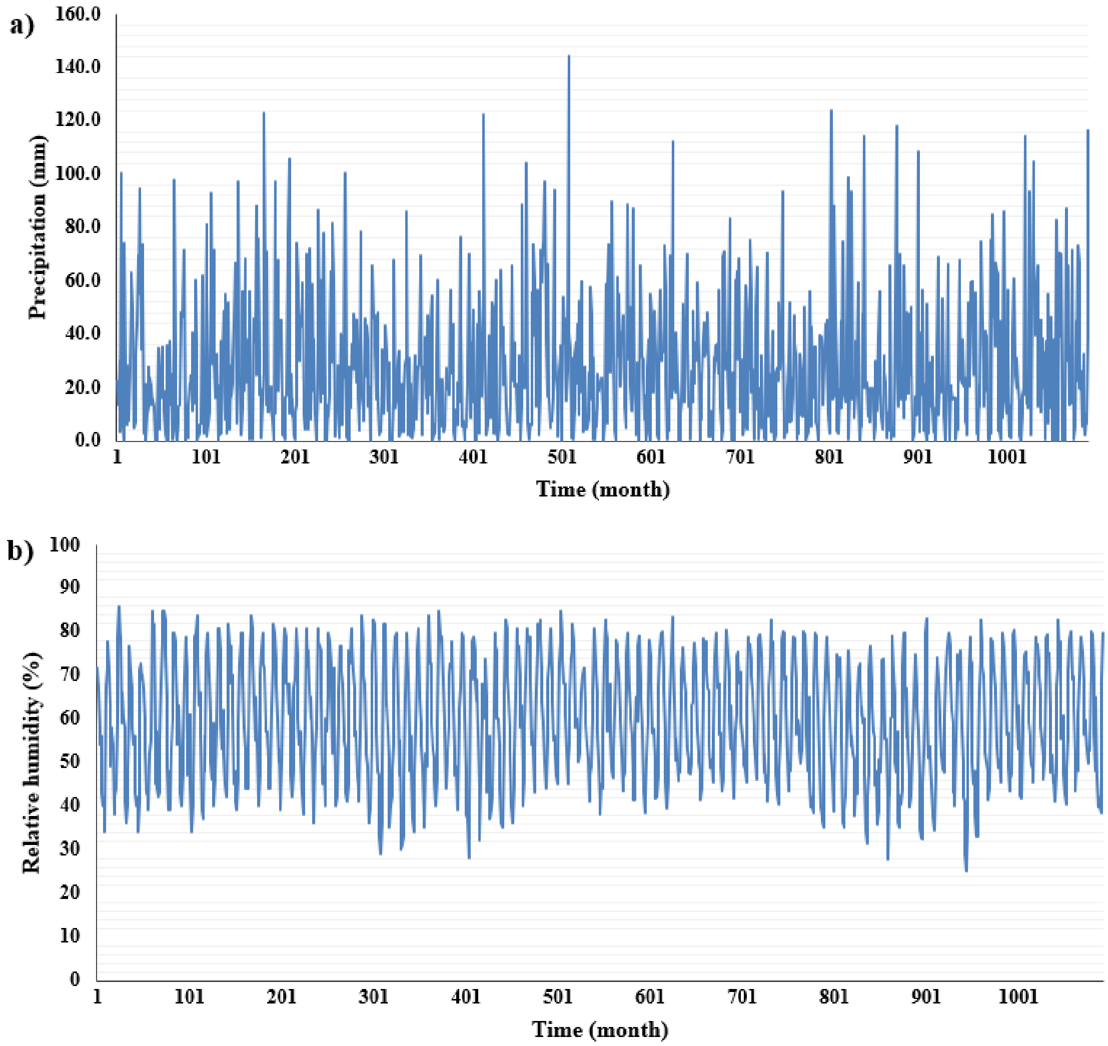

Figure 2. *Time series plot of a) the monthly precipitation data and b) the relative humidity data*

Tendency Test, a non-parametric test like the Mann-Kendall test. Sen's Trend Slope uses median values to determine the trend between sequential observations in the data set.

The Sen's Trend Slope method is widely used in a variety of applications, especially for determining trends in time, and in fields such as hydrology, meteorology, and environmental sciences. The long-term dataset of monthly precipitation data accumulated over 90 years is an important resource for assessing various climate trends and changes. Analyzing this data set can provide many advantages.

Mann-Kendall Test

One non-parametric test is the Mann-Kendall test. The observations $x_1,..., x_n$, which are random variables with a similar distribution and are independent of time, are arranged over time, in accordance with the null hypothesis (H_0). The alternative hypothesis (H_1) states that the distribution of values for x_k and x_j in the series is not similar for all ($k, j \leq n$) with $k \neq j$, suggesting the existence of a linear trend in the series. Equations (1) and (2) are used to calculate the statistic for the Mann-Kendall test [23].

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \tag{1}$$

$$sgn(x_j - x_k) = \begin{cases} +1 & (x_j - x_k) > 0 \\ 0 & (x_j - x_k) = 0 \\ -1 & (x_j - x_k) < 0 \end{cases} \quad (2)$$

The variance of the test statistic S, is calculated (as the number of observations n_i approaches infinity, with t_i representing the duration of a specific tie in month i, the distribution of S_i becomes normal) as shown below [24].

$$Var\ (S) = \frac{n_i(n_i-1)(2n_i+5)-\sum_{t_i} t_i(t_i-1)(2t_i+5)}{18} \quad (3)$$

The following equation is used to calculate the critical (z) value, which is then compared to the standard normal variable (z) [24,25].

$$z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \quad (4)$$

The rejection of the null hypothesis H_0 occurs if the significance level α is not such that $|z| \leq z_{\alpha/2}$. An increasing trend is present if the computed value of S is positive; a decreasing trend is suggested if it is negative [25]. Hypothesis tests are used to determine whether a trend is present or not. The alternative hypothesis (H_a), which is the hypothesis where H_0 is rejected and indicates the presence of a trend, is the hypothesis where the null hypothesis (H_0) shows the absence of a trend. The rejection region, also known as the crucial region, is the area where H_0 is rejected [17] Either the one-tailed or the two-tailed (two-sided) H_a hypothesis is investigated. The probability of covering a parameter is the confidence level of its interval estimate, and it is represented by the notation "1-α," where α is the significance level. A confidence interval is the interval for a parameter that is calculated using the confidence level. The 90%, 95%, and 99% confidence levels are the most often utilized ones [17]. The 95% confidence level was employed in this study.

Kendal' tau

Kendall proposed the concept of tau, a nonparametric rank correlation coefficient, in 1938. Tau is symbolized by the Greek letter τ. [26]. Similar to other correlation measures such as Pearson r, τ is mathematically constrained within the range of −1 to +1, and its numerical value signifies the level of agreement between two ordinal variables. τ serves as a rank correlation measure that shows how much two factors align a set of people or data points in a comparable order. When the $\tau_{(X,Y)}$ value is +1.00, it means that there is perfect agreement between the variables X and Y, meaning that every data point is ranked the same in both variables and is ordered in exactly the same way [26]. When $\tau_{(X,Y)} = -1.00$, it means that two variables have completely different orders for a given collection of data points. Under this situation, a single data point is ranked first in one variable, ranked last in another, and so on [26]. There is no association between the two variables' rank order when τ(x, y) = 0.00.

Sen's Trend Slope Method

This non-parametric method can be applied when there is a linear trend for the unit change over time (actual slope). It can handle missing data and is not impacted by extreme values or data errors [25, 27]. The following formula determines the N Q_i parameters at times j and k, which are sorted from smallest to largest and represented as x_j and x_k (when j > k) [23].

$$N = n(n-1)/2 \quad (5)$$

$$Q_i = \frac{(x_j - x_k)}{j-k} \quad (i = 1, \dots, N) \quad (6)$$

Sen's slope estimator, a useful statistic for estimating the linear trend slope parameter, is the median of these N Q_i values [23]. The following seventh equation is utilized when the number N is odd, and the following eighth equation is utilized when the number N is even to determine the unit change in the pertinent observations over time.

$$Q_{median} = Q_{(N+1)/2} \quad (7)$$

$$Q_{median} = \frac{|Q_{N/2} + Q_{(N+2)/2})|}{2} \quad (8)$$

Using Sen's non-parametric method, the obtained Q_{median} value is evaluated using a two-sided test within a 100(1-α) % confidence interval, and the true slope is determined [25-27].

RESULTS AND DISCUSSION

The trend analysis results of Konya's average monthly total precipitation data are given in Table 2. For ordinal data, Kendall's tau is a correlation measure. It shows the average monthly total precipitation data's trend's strength and direction. A strong increasing trend is indicated by values near 1, a strong declining trend is shown by values close to −1, and no significant trend is indicated by values close to 0. As indicated in Table 1, the values for January through December vary from −0.087 to 0.121, with the majority of values being near 0. Because Kendall's tau values are close to zero, these values are indicating weak or no significant monotonic trend. The null hypothesis that there is no trend in the data is tested by the p-value linked to Kendall's tau. Table 1 also shows that the majority of the p-values are high (greater than 0.05), indicating that there is not enough evidence to reject the null hypothesis of no trend for each month. Fiaz Hussain et al. conducted analysis of precipitation data using methods such as Innovative Trend Pivot Analysis Method and Trend Polygon Star Concept for Soan River Basin in Pakistan [28]. The findings indicated that there were increasing and decreasing trends in different time periods [28]. The findings are supported by the comparison with the results of a similar study in the Soan River Basin, and the p-values associated with Kendall's tau confirm the lack of evidence to reject the null hypothesis of no trend for each month.

Table 2. *Trend Analysis Results of Average Monthly Total Precipitation Data*

Series\Test	Kendall's tau	p-value	Sen's slope
January	0,020	0,777	0,032
February	−0,087	0,220	−0,087
March	−0,030	0,671	−0,026
April	0,027	0,703	0,032
May	−0,017	0,813	−0,025
June	0,001	0,989	0,000
July	−0,047	0,534	−0,008
August	0,121	0,141	0,013
September	0,023	0,756	0,006
October	0,077	0,280	0,104
November	0,075	0,297	0,094
December	0,029	0,691	0,049

Sen's slope, which provides an indication of the trend's magnitude, is the median of all slopes between paired data points. The average monthly precipitation data has values ranging from −0.087 to

0.121, most of which show quite minor trends (Table 2) and these values suggest that if a trend exists, it is not particularly steep. Sen's innovative and trend analysis for analysis was employed for Duzce, Zonguldak, Bartin, Kastamonu, and Sinop provinces in Turkey using data of sea surface temperatures,wind directions and wind speeds by Ceyhunlu et al. [29]. The results indicated that a rise in high wind speeds (15–25 m/s), an upward trend in medium wind directions (120˚-160˚), and an increase in sea surface temperature at elevated levels (15–27 °C) were noted using Sen's Innovative Method. Conversely, a decrease in daily analyses of wind speed was observed through trend analysis methods such as Mann–Kendall and Spearman Rho [29]. This suggests that different trend analysis methods may yield contrasting results, emphasizing the importance of choosing an appropriate method for the specific characteristics of the data under investigation.

As shown in Table 3, the values range from −0.248 to −0.007, indicating a general decreasing trend in relative humidity for most months and several months have p-values less than 0.05 (January, June, December). The negative Kendall's tau values for the months of January, June, and December are linked to significant p-values (less than 0.05), suggesting a statistically significant decreasing trend in relative humidity throughout these months.

Table 3. *Trend Analysis Results of Average Relative Humidity Data*

Series\Test	Kendall's tau	p-value	Sen's slope
January	−0,170	0,029	−0,047
February	−0,145	0,062	−0,055
March	−0,086	0,271	−0,041
April	−0,007	0,929	0,000
May	−0,083	0,282	−0,029
June	−0,182	0,019	−0,076
July	−0,033	0,675	−0,006
August	0,075	0,338	0,029
September	−0,056	0,471	−0,027
October	−0,008	0,924	0,000
November	−0,111	0,149	−0,045
December	−0,248	0,001	−0,048

Sen's slope values are generally low (Table 3), suggesting a gradual or weak decreasing trend in relative humidity. Achite et al. [30] investigated the precipitation data from six stations in Algeria's Wadi Ouahrane basin, spanning the years 1972 to 2018, and analyzed for precipitation changes using the innovative trend risk analysis (ITRA), innovative trend pivot analysis (ITPAM), and trend polygon star (TPS) visualization methodologies. According to the study, the ITRA graphs indicated the direction of precipitation trends and assign a risk class to each trend. Discrepancies in polygons from ITPAM graphs revealed seasonal variations and trends in precipitation across different sites. TPS maps illustrated monthly precipitation variations, emphasizing transitions between dry and wet seasons. In the ITRA results, lower and medium precipitation regimes exhibited less trend, while imbalances are observed in high precipitation regimes. IPTAM method application indicated an overall increasing trend in precipitation [30]. According to the IPTAM approach, the study by Achite et al. [30] on precipitation data in Algeria's Wadi Ouahrane basin suggests an overall increasing trend in precipitation. It also provides insights into seasonal fluctuations, risk assessment, and precipitation trends utilizing cutting-edge analysis methodologies.

CONCLUSION

Trend analysis of precipitation and relative humidity could be an indicator of climate change, be used to predict potential floods, droughts, or other natural disasters in certain regions, significantly affect agricultural productivity. Konya has 12.2% of Turkey's total arable land and contains population of over 1,390,000. Therefore, it is crucial to determine the trend analysis of precipitation and relative humidity for Konya.

In conclusion, the trend analysis results for the average monthly total precipitation data in Konya reveal varied patterns across different months. While some months exhibit positive trends, indicating an increasing pattern, others show negative trends, suggesting a decreasing pattern. However, it's important to note that many of these trends are not statistically significant, as evidenced by the p-values exceeding conventional significance levels.

Similarly, the trend analysis of average relative humidity data presents a mixed picture. Several months demonstrate negative trends, suggesting a decline in relative humidity, while a few months show positive trends, indicating an increase. Again, the statistical significance of these trends varies, with some being significant and others not.

Overall, the results highlight the complexity and variability in precipitation and relative humidity patterns in Konya. It is crucial to consider these findings cautiously and explore additional factors that may contribute to the observed trends. Future research and monitoring efforts should aim to provide a more comprehensive understanding of the climate dynamics in Konya, helping to inform climate resilience strategies and water resource management in the region. According to this study, scenarios and climate models that do not forecast appreciable variations in Konya's precipitation and relative humidity could be used as references when anticipating climate change.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest

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Conceptualization, K.E. and Ş.E.; Methology, K.E. and Ş.E.; Writing - Original Draft, K.E.; Writing - Review & Editing, K.E.

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