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Uzaktan Algılama Yağış Verileri Yardımıyla Kuraklık Aşma Olasılığı İndeksi'ni (KAOİ) Kullanarak Konya İli Kuraklık Analizi

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ÖZET

Kuraklık hem çevre hem de insan hayatı için riskler oluşturan, yeri ve süresi konusunda belirsizlikle karakterize edilen iklimsel bir fenomendir. Son analizler, çeşitli matematiksel yöntemler ve teknolojideki ilerlemeler kullanılarak farklı zaman dilimlerinde kuraklıklar üzerinde gerçekleştirilebilir. Bu çalışma, Türkiye'nin Konya İlinde belirlenen 31 gözlem noktası üzerinde bir kuraklık analizi yapmak üzere tasarlanmıştır. Analiz edilen veriler, Mart 2000'den Şubat 2025'e kadar kaydedilen aylık toplam yağış değerlerini içermekte olup, bu veriler PERSIANN sistemi (Yapay Sinir Ağları kullanarak Uzaktan Algılama ile Yağış Tahmini) kaynaklıdır. Belirlenen noktalar için aylık yağış toplamları, Kuraklık Aşma Olasılığı İndeksi (KAOİ) için girdi parametreleri olarak kullanılmıştır. Bulgulara göre, 2006 yılı, özellikle Konya İli genelinde, şiddetli kuraklık koşullarıyla yaşanırken, 2019 yılı ise ıslaklık koşullarıyla karakterize edilmiştir. Islak koşulların daha sık karşılaşıldığı ve bu durumun yüzde 50,17'lik bir sıklık değeriyle belirlendiği gösterilmiştir.

Drought Analysis of Konya Province using Drought Exceedance Probability Index (DEPI) with Remote Sensing Precipitation Data

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ABSTRACT

Drought is a climatic phenomenon that poses risks to both the environment and human life. It is characterised by uncertainty regarding its location and duration. Recent analyses of droughts can be conducted over various timeframes using a range of mathematical methods and advancements in technology. The present study is designed to conduct a drought analysis across 31 specified observational points within Konya Province, Türkiye. The data set under scrutiny encompasses monthly total precipitation values recorded from March 2000 to February 2025, obtained from the PERSIANN system (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks). The monthly precipitation totals from the designated points were then used as input parameters for the Drought Exceedance Probability Index (DEPI). The findings indicate that the year 2006 was marked by severe drought conditions, particularly in the region encompassing Konya Province, while 2019 was characterised by wet conditions. The analysis revealed that wet circumstances were encountered more frequently, with a frequency value of 50.17%.

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INTRODUCTION

Drought is a regular, repeating natural calamity that may intermittently impact human survival efforts. Consequently, comprehending drought features may significantly aid in formulating improved mitigation strategies [1, 2]. Although several drought definitions exist in the literature, a commonly accepted quadruple categorization has emerged. These include climatic, agricultural, hydrological, and socio-economic droughts [3, 4]. Meteorological drought is extensively examined in the literature and seen as a precursor to all other forms of drought.

Reduced normal precipitation during the lowest documented 30-year precipitation series is the only determinant of meteorological drought, which is a weather-only phenomenon. When there isn't enough water in the soil to keep plants from dying and withering, this is called an agricultural drought. Overuse of water and careless farming methods may cause agricultural droughts even when precipitation and water supplies are sufficient. However, even when there is enough precipitation and water in the reservoirs, hydrological drought may still develop if the local population that uses water is large or if there are too many rural activities and irrigation projects [5-8]. When a social or economic function in life is negatively impacted, it is referred to as a socioeconomic drought.

Drought indices are employed to assess the severity, persistence, and dissemination of drought impacts. De Martonne Method [9], Palmer Drought Severity Index [10], Decile Index [11], Aydeniz Method [12], Erinç Method [13], Standardized Precipitation Index [14], Aggregate Drought Index [15], Reconnaissance Drought Index [16, 17], and Streamflow Drought Index [18] are among the measures. In addition to these indices, the development of new drought monitoring indices continues. The Drought Exceedance Probability Index (DEPI), which was devised by [19], is one of the most recent indexes. DEPI is a variant of the ISSP (Indice Standardisé de Sécheresse Pluviométrique) that was created by [20]. DEPI is calculated by summarizing cumulative monthly precipitation anomalies, as is the case with other indices such as the Standardized Precipitation Index (SPI) of [14] and the SPEI [21]. Conversely, the empirical probability of the drought level exceeding the previous month's DEPI score is demonstrated.

Early warning systems and precise drought analysis are very vital to reduce the effects of droughts given their broad ramifications. By supplying real-time and historical rainfall data, advances in satellite-based precipitation data—including the PERSIANN system—have tremendously enhanced drought monitoring. Ensuring water security, agricultural production, and environmental sustainability in a climate becoming more erratic depends on an awareness of the origins, impacts, and mitigating techniques of droughts. Affecting ecosystems, water supplies, and agriculture all around, drought is among the most terrible natural calamities. Understanding and tracking drought conditions depend on accurate precipitation records. Extremely high-resolution, satellite-based precipitation estimations produced by the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) technology are priceless for drought study. PERSIANN advances early warning systems, drought monitoring, and water management and disaster preparation decision-making by providing continuous, worldwide precipitation data.

One of Turkey's biggest provinces in area, Konya Province is crucial for agricultural output. Still, its geographical position and climate make it prone to drought. Thus, in Konya, drought analysis and management are quite important. The objective of the study is to periodically analyze the drought from January to December using the DEPI devised by [19] to monitor the drought by utilizing the monthly precipitation totals of 31 study points that have been designated and located in Konya Province, Turkey. The Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) system was employed to acquire precipitation data, which was determined by the location of the meteorological stations of the Turkish State Meteorological Service. In terms of agricultural output, Konya province is rather important and often runs the danger of drought. Important actions to reduce the harmful effects of drought are included in the studies carried out and the developed management strategies. In this regard, the battle against drought in the area depends much on the sustainable use of water resources, the adoption of drought-resistant farming methods, and efficient monitoring systems.

MATERIALS AND METHODS

With regard to land area, Konya is among Türkiye's biggest provinces; it also has strategic significance for agricultural output. But its position in the Central Anatolia Region results in semi-arid climatic traits and inadequate water supplies (see Figure 1). The University of California, Irvine's Center for Hydrometeorology and Remote Sensing (CHRS) created the satellite-based precipitation estimate tool known as PERSIANN. In order to predict precipitation worldwide, it processes satellite infrared (IR) and passive microwave (PMW) data using machine learning methods, particularly artificial neural networks (ANNs). The current operational PERSIANN (Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks) system employs neural network function classification and approximation methods to estimate the precipitation rate for each 0.25° x 0.25° (approximately 625 km²) pixel derived from infrared brightness temperature images obtained from geostationary satellites.

The PERSIANN system initially relied on fixed infrared images and was subsequently enhanced to incorporate both infrared and daytime visible images. This study employed the PERSIANN algorithm to generate global precipitation data using geostationary long-wave infrared images. The precipitation product encompasses the global range from 50°S to 50°N. Model parameters are routinely updated utilizing precipitation forecasts obtained from low-orbit satellites [24]. In this study, PERSIANN data was used to determine a drought situation for the entire Konya Province. However, instead of providing separate graphs for the 31 points, the areas of the districts and the amounts of precipitation were multiplied and averaged. In this way, a single precipitation value and graphs were obtained. Information that is more in-depth on this system may be obtained from [25-32].

Figure 1
Map of Konya Province and its Districts [22].

The districts within Konya Province and their coordinates are shown in Table 1.

Table 1
Observational points and coordinates.

No	Observational Point Name	Coordinates (Latitude and Longitude)
1	Akşehir	38.368833, 31.429667
2	Ahırlı	37.240278, 32.114722
3	Akören	37.451725, 32.380321
4	Altınekin	38.298889, 32.879167
5	Beyşehir	37.677667, 31.746333
6	Bozkır	37.183333, 32.246111
7	Cihanbeyli	38.650578, 32.921860
8	Çeltik	39.023921, 31.803972
9	Çumra	37.565833, 32.790000
10	Derbent	38.016389, 32.017222
11	Derebucak	37.391944, 31.514444
12	Doğanhisar	38.136944, 31.676389
13	Emirgazi	37.892500, 33.841111
14	Ereğli	37.525500, 34.048500
15	Güneysınır	37.267972, 32.720792
16	Hadim	36.988552, 32.456480
17	Halkapınar/İvriz	37.441389, 34.151944
18	Hüyük	37.962500, 31.596800
19	Ilgın	38.276333, 31.894000
20	Kadınhanı	38.230900, 32.217300
21	Karapınar	37.715300, 33.525600
22	Karatay	37.860556, 32.583889
23	Kulu	39.078833, 33.065667
24	Meram	37.868678, 32.471331
25	Sarayönü	38.262000, 32.387500
26	Selçuklu	37.983700, 32.574000
27	Seydişehir	37.449600, 31.853800
28	Taşkent	36.909293, 32.497615
29	Tuzlukçu	38.467222, 31.652500
30	Yalıhüyük	37.292222, 32.112222
31	Yunak	38.820500, 31.725833

Drought Exceedance Probability Index (DEPI)

The DEPI calculation is performed in a series of sequential stages. Initially, the precipitation anomalies (AP) for each month in the series are determined using the following expression:

$$AP_i = P_i - P_{MEDi} \quad (1)$$

$\boldsymbol{P_i}$= Precipitation of the month i;

P_{MEDi}= Median precipitation of the month i for the study period

Figure 2 illustrate an example of the calculation of these monthly anomalies.

The index employed the median to identify surpluses and deficits, as it is deemed more suitable than the average for highly variable meteorological regimes [20]. Cumulative precipitation anomalies are identified starting from the first month of the series. Upon the identification of a negative anomaly, a dry sequence commences, followed by the resumption of accumulation in that specific month. Subsequent to this restart, the monthly increment of anomalies continues. Following the accumulation period, the dry run concludes once the cumulative anomalies revert to a positive state. During this wet run, anomalies continued to accumulate until a new negative precipitation anomaly was identified. A new dry sequence commences at that point, estimated using the same method. The methodology involves the continuous accumulation of surpluses, facilitating accurate prioritization of anomalies and halting processes in the presence of negative anomalies. Therefore, the assessment of this second step

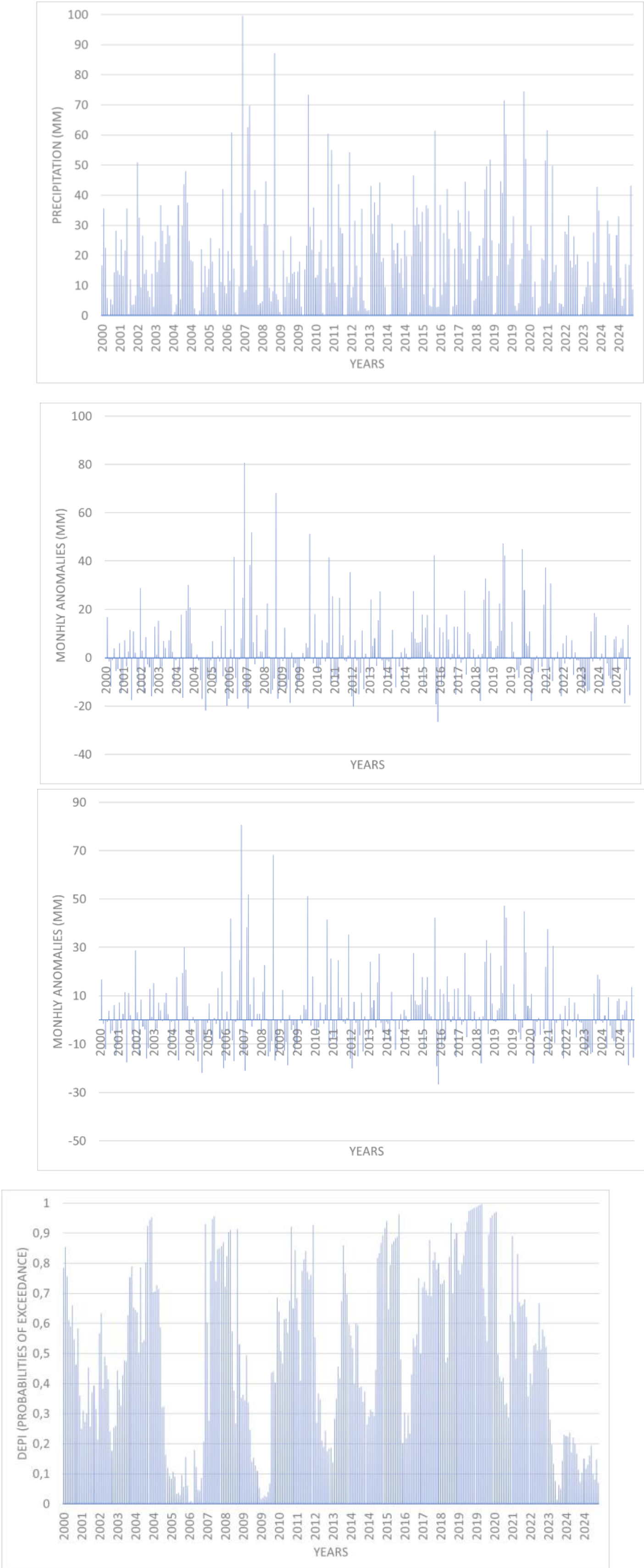

Figure 2
Process of implementing the Drought Exceedance Probability Index (DEPI) in the precipitation series of Konya, 2000-2025.

corresponds with the expression:

$$APAc_1 = AP_1,$$

$$APAc_i = \sum_{j=r}^{i} AP_i \quad i > 1 \tag{2}$$

where $APAc_i$ = precipitation cumulative anomaly of the month i; r = the value marking the start of the dry run and follows the expression:

$r = max\{k{:}\, 1 \le k \le i, AP_k < 0, APAc_{k-1} \ge 0\}$, k: parameter from 1 to i to determine which month the drought started

It is essential to note that if $AP_i < 0$ and $APAc_{i-1} \ge 0$, then r=i, leading to $APAc_i$=AP_i, which indicates the commencement of a new dry series. In summary, the third step involves sorting the series of cumulative precipitation anomalies identified in the previous stage in ascending order, from the months with the most significant negative cumulative anomalies, or deficits, to those with the most substantial positive anomalies, or surpluses. Adhering to the aforementioned steps is necessary to derive the empirical probabilities of exceedance corresponding to each month of the series. Following the sorting process, the formulation of DEPI necessitates the calculation of the probability of exceeding the detected event on a monthly basis, employing the plotting positions method established by [23]:

$$Pexced_{APAci} = DEPI_i = M_{APAci}/(n+1) \tag{3}$$

where; $Pexced_{APAci}$ =empirical probability of exceedance of the month i, namely, the DEPI of the month i;
M_{APAci}= position of the precipitation cumulative anomaly of the month i in the sorted series, from lowest to highest cumulative anomaly or largest observed deficit,

n= total number of months in the series.

Therefore, the DEPI for a specific month represents the probability of exceedance associated with its cumulative rainfall anomaly, as determined by the aforementioned methodology. The probability values encompass an estimate of the hazard, with DEPI values below 0.5 indicating a significant accumulation of anomalies that are unlikely to be exceeded. Droughts are intensifying as they near zero levels. The index's significance and its advancements over similar indices lie in its ability to restart the measurement of cumulative anomalies whenever a new dry month ($AP_i < 0$) occurs during a surplus period (with $APAc_{i-1} \ge 0$). This ensures accurate identification of dry runs of varying lengths from a single index calculation. Table 2 presents the DEPI drought classification values.

Table 2
DEPI drought classifications according to DEPI values [19].

DEPI values (probabilities of exceedance)	Drought severity level	% months of a series within the interval	Return period (years)
DEPI≥0.5	Wet conditions	50	2
0.5>DEPI≥0.16	Mild drought	34	6
0.16>DEPI≥0.07	Moderate drought	9	15
0.07>DEPI≥0.02	Severe drought	5	20
DEPI<0.02	Extreme drought	2	50

RESULTS AND DISCUSSION

Figure 3 displays a graph that illustrates the quantity of precipitation that falls in the province of Konya. The graph is broken down by year and month. When looking at these graphs that were created using PERSIANN data, it can be seen that the Konya Province in the Central Anatolia area saw the least amount of rainfall in the month of August, while the maximum amount of rainfall was recorded in the month of October. There was the least amount of rainfall that was recorded in the month of January, particularly in the years 2002, 2006, 2008, 2023, and 2024. 2008, 2016, 2021, and 2023 were the years that had the least amount of rainfall during the month of February overall. In the month of March in 2012, there was hardly any precipitation. When it comes to rainfall, it is possible to say that the year 2009 had the least amount of precipitation in April, while the years 2002, 2008, and 2020 had the least amount of precipitation in May. 2001 and 2006 were the years that had the least amount of rainfall recorded in June. From the beginning of July to the end of the month, there was hardly any precipitation at all. Rainfall did not occur in the month of August in the years 2005, 2010, 2011, and 2013. Neither the year 2004 nor the year 2013 had any rainfall during the month of September. In 2004, 2016, and 2024, there was no rainfall reported during the month of October. Again, there was no precipitation throughout the months of November and December in 2015.

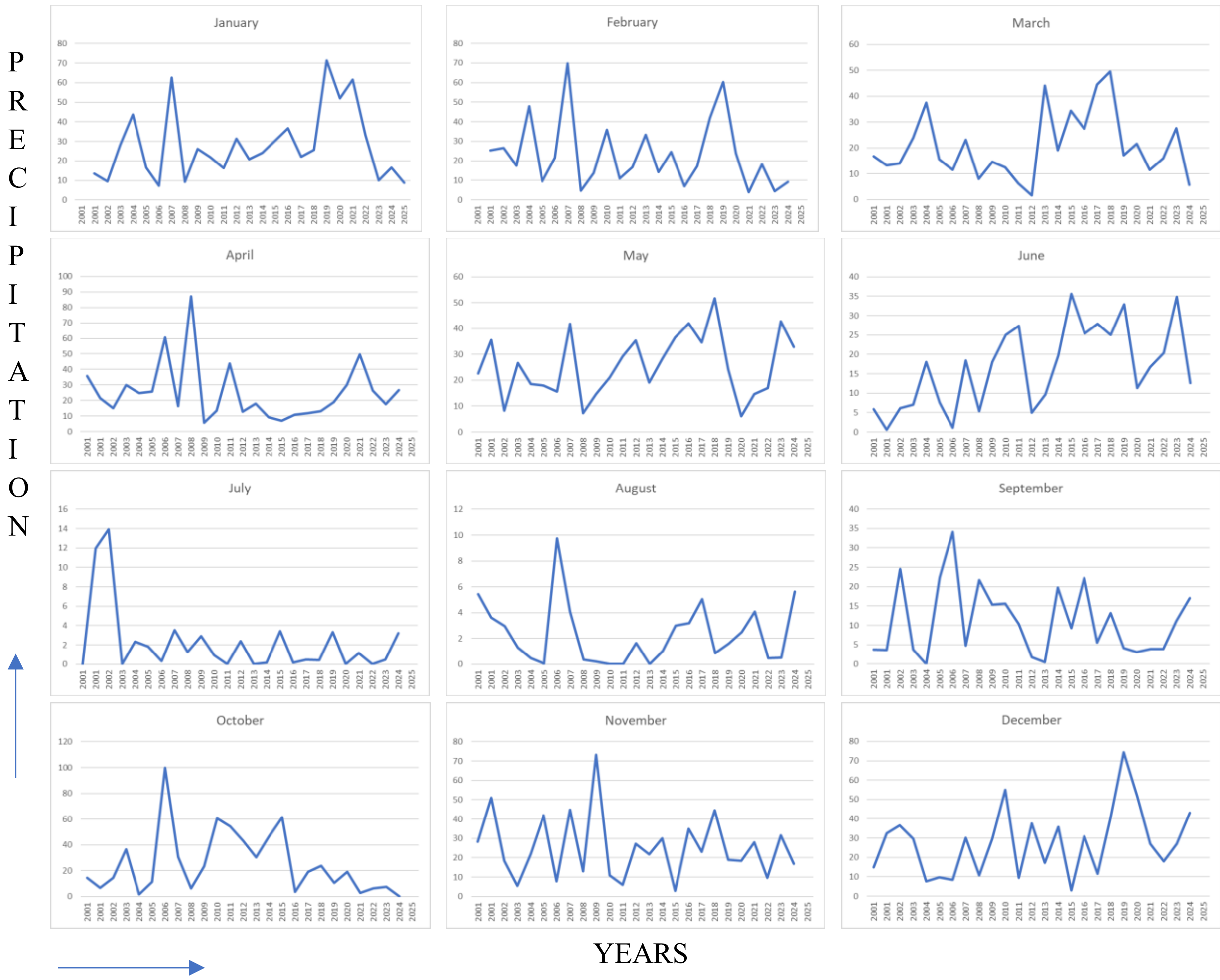

Figure 3

Yearly Variation of Monthly Precipitation Values in Konya Province as a Whole.

The monthly DEPI values were graphed for durations of time when data was available. The yearly change in DEPI values is broken down by month and shown in Figure 4. On the graphs, a zero line represents a DEPI value of 0.5, which symbolizes the border between dry and wet circumstances. This value shows that the conditions are dry. One might make the assertion that the severity of the drought is proportional to the degree to which the DEPI values are closer to zero. The years that had a DEPI that was more than 0.5 were considered to be rainy years.

When one examines the graphs shown in Figure 5, it is evident that the DEPI values have changed in the direction of drought, particularly after the year 2020. The DEPI values indicate that severe drought conditions existed in January of 2006, but extreme wet conditions were reported in the year 2020. In the month of February, circumstances of severe drought were reported in the years 2006 and 2023, and conditions of wetness were observed in the years 2004, 2007, 2015, 2019, and 2020. In March of 2006, circumstances of severe drought were seen, however in 2018, 2019, and 2020, situations of excessive wetness were reported. The month of April was characterized by the presence of significant drought in the years 2005, 2009, and 2023, while extreme wet conditions were seen in the years 2004 and 2019. In the month of May in 2009, there was a severe drought that was seen, however in 2019 there were circumstances that were excessively moist. There were three years in which June was characterized by great drought: 2005, 2006, and 2009. In 2019, however, June was characterized by unusually wet circumstances. Both July and August were characterized by the same drought and wet conditions as were recorded in June. When September rolled around in 2009, situations that were severe dry prevailed, but in 2015, conditions that were very wet were the norm. In 2005 and 2009, October was one of the months that had catastrophic drought conditions, much like many other months. Extreme drought conditions were encountered throughout the months of November and December in the year 2005. If we wish to make a general observation, we may make a specific observation based on the DEPI graphs by month, which is that the DEPI values were dominated by severe drought circumstances in the year 2006, and that wet conditions were encountered in the year 2019.

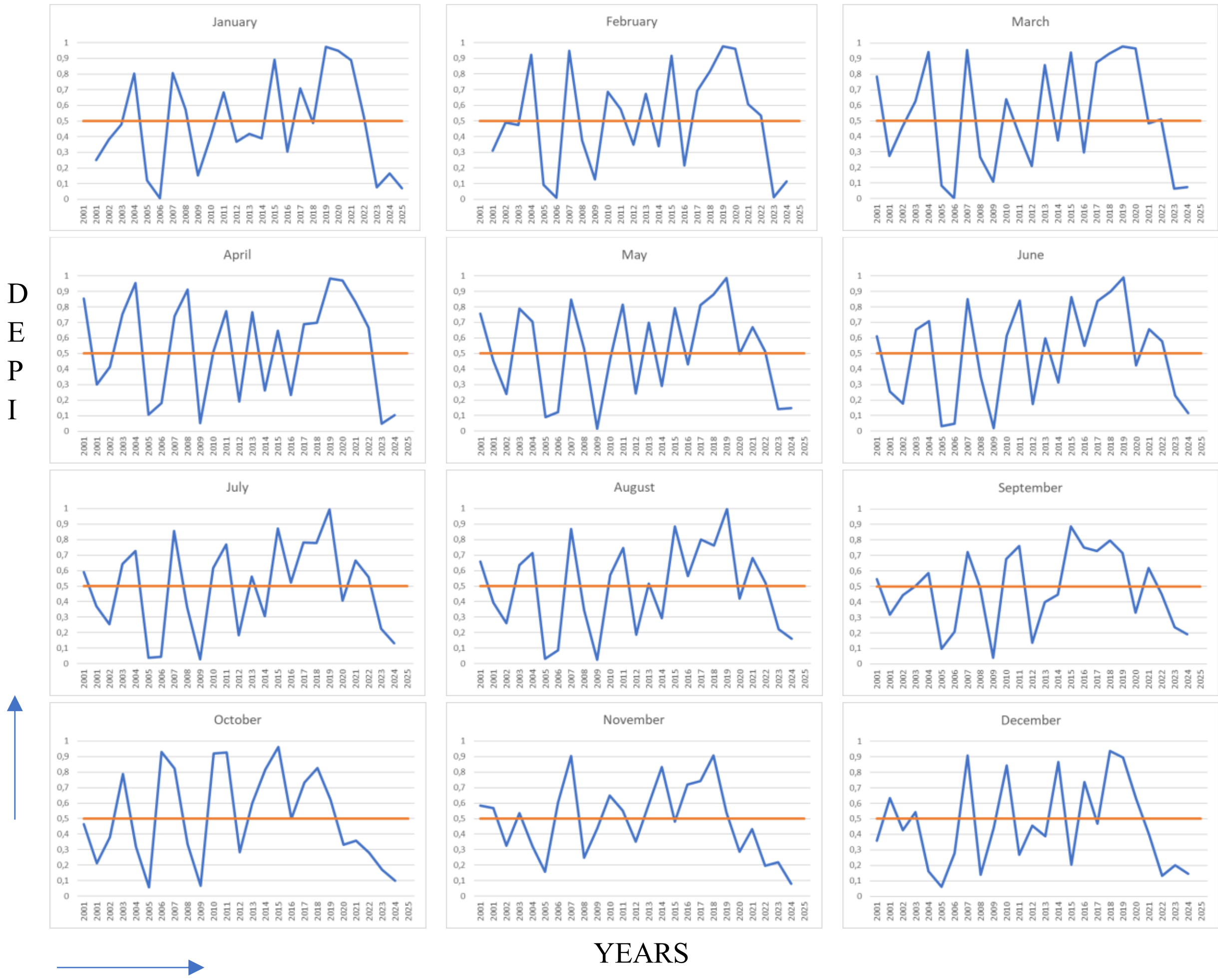

Figure 4

Yearly Variation of Monthly DEPI Values in Konya Province as a Whole.

According to the data shown in Table 3, it is possible to assert that the general territory of Konya was subjected to wet circumstances at a rate of 50.17 percent. On the other hand, circumstances of a

Table 3
Drought frequency values of Konya according to Drought Thresholds.

		Frequency (%)
DEPI≥0.5	Wet conditions	50.17
0.5>DEPI>0.16	Mild drought	34.11
0.16>DEPI>0.07	Moderate drought	9.03
0.07>DEPI≥0.02	Severe drought	5.02
DEPI<0.02	Extreme drought	1.67

moderate drought exist at a rate of 34.11%. At a rate of 1.67 percent, circumstances of very severe drought have persisted.

A relative humidity and precipitation trend analysis was carried out by [33] for the city of Konya Province as part of their research. The analysis conducted revealed that the Kendall's tau values for precipitation data varied from -0.087 to 0.121 from January to December, with the majority of the values being relatively near to zero. This was the conclusion reached as a consequence of the analysis. It was found that the majority of the p-values were larger than 0.05, and it was also found that the values of Sen's slope for monthly precipitation varied from -0.087 to 0.121. According to the findings, the values of Kendall's tau and Sen's slope are very near to zero, and the p-values are large; this implies that there is no statistical significance in the patterns of the monthly average rainfall.

The decrease in precipitation caused by the severe drought of 2006 mostly affected agriculture and resulted in irrigation water shortages for farmers. The little rainfall has led to reduced water supplies, increasing reliance on groundwater for agricultural needs. Drought imposes both direct and indirect effects on urban and ecological systems. The early consequences of drought primarily involve physical and material losses. The losses encompass a decrease in agricultural production, an intensification of fire hazards, a fall in water levels, an uptick in mortality rates among fauna, and damage to the habitats of wildlife and aquatic species. The humid conditions of 2019 were beneficial for agricultural productivity, especially for farmers in Konya Province. The increase in reservoir water levels has favorably impacted both ecological and urban environments.

The parameters of temperature and humidity in the weather have an impact on a variety of areas, including living circumstances, agricultural practices, and transportation [34, 35]. There are a number of factors that influence drought, including temperature and humidity. Additionally, these investigations that were carried out in the province of Konya overlap with one another.

According to the findings of a research [36], in Central Anatolia (which includes Konya Province), air pollution is a major environmental issue that impacts lives and the environment and contributes to global climate change. Air pollution causes are being studied as their global consequences spread. As the global population grows, so does energy demand. Due to population expansion and industrial requirements, air pollution is rising daily, harming all life.

CONCLUSION

Unlike rapid natural catastrophes like hurricanes or earthquakes, droughts start slowly over time and could endure months or even years. From dry deserts to temperate agricultural zones, they are found in many different climatic zones and have strong effects that could cause crop failures, food shortages, economic losses, and environmental damage. Konya is recognized as Turkey's wheat granary and is a region where water-dependent agricultural products, including sugar beet, corn, and sunflower, are cultivated. The Konya Province fulfills a significant portion of its water requirements through subterranean sources. Excessive groundwater extraction is resulting in a rapid decline of water levels in the Konya Province. The ongoing drought is diminishing the renewal capacity of water resources, leading to anticipated larger water crises in the future.

In this study, a drought analysis covering the general area of Konya Province has been conducted. In recent years, the precipitation parameter obtained through satellite-based remote sensing, which has gained popularity, has been used. This method has been preferred because accessing these data is both practical and easy. Moreover, since the accuracy rate is better than terrestrial measurements, it is believed to provide more precise results in drought analysis. The DEPI method applied has not been used as comprehensively for Konya Province before. In this regard, it is believed that this study will contribute to the literature. An examination of drought was carried out by using PERSIANN data via the use of precipitation data spanning from March 2000 to January 2025. In accordance with the findings, dry times are followed by wet periods, and these wet periods are again succeeded by dry ones. In general, the province of Konya is characterized by moist circumstances; nevertheless, in 2006, conditions that were considered to be very dry were seen.

Conscious water use, sustainable agricultural practices, and government-supported water management projects are essential in addressing drought. Failure to implement necessary measures may pose significant threats to the region's agricultural production and water resources in the future. In the province of Konya, it is anticipated that this study will contribute to drought research and provide new perspectives on the topic.

Ethical Statement

This study is an original research article designed and developed by the authors.

Ethics Committee Approval

This study does not require any ethics committee approval.

Author Contributions

Research Design (CRediT 1) F.K. (%50) – E.T. (%50)
Data Collection (CRediT 2) F.K. (%50) – E.T. (%50)
Research- Data Analysis – Validation (CRediT 3-4-6-11) D.Y. F.K. (%50) – E.T. (%50)
Writing the Article (CRediT 12-13) D.Y. F.K. (%50) – E.T. (%50)
Revision and Improvement of the Text (CRediT 14) F.K. (%50) – E.T. (%50)

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Conflict of Interest

The authors declare no conflicts of interest for this study.

Sustainable Development Goals (SDG)

Sustainable Development Goals: 13 (Climate Action)

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