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Investigation of Turkey's climate periods in terms of precipitation and temperature changes

Taha Demirgül [*1], Cavit Berkay Yılmaz [1], Büşra Nur Zıpır [1], Fatma Sena Kart [1], Muhammet Fatih Pehriz [1], Vahdettin Demir [1], Mehmet Faik Sevimli [1]

[1]*KTO Karatay University, Civil Engineering Department, Konya, Türkiye*
demirgultaha@gmail.com; cavitberkayyilmaz@gmail.com; busranurzpr@gmail.com; senahorzum987@gmail.com; m.f.pehriz@gmail.com; vahdettin.demir@karatay.edu.tr; mehmet.faik.sevimli@karatay.edu.tr

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Abstract

In the current century, the climate crisis and the search for a solution take an essential place on the agenda of the whole world. Depending on the temperature and precipitation factors, natural disasters such as drought and flood negatively affect the living ecosystem and the economy. In this study, precipitation and temperature changes between the old climate period (1981-2010) and the new climate period (1991-2020) of Turkey were examined on the basis of 81 provinces and 25 water basins, and the climate periods of the country were compared. The precipitation and temperature data used in the study are long-term average data obtained from monthly average data. In addition, the variation of temperature and precipitation data according to the location, and separate interpolation maps were created for the old and new periods. When the old (574 mm) and new (573,4 mm) precipitation normals are examined throughout the country, a decrease of 0.6 mm (0.1%) has been detected.

1. Introduction

In the 21st century, the whole world has accepted the reality of the climate crisis and the search for effective solutions has increased. However, industrialization and the human population, which started in the 18th century and increased exponentially every century, accelerated the climate change process by causing mistakes that are very difficult to reverse on a global scale. In this process, despite the warnings of scientists, politicians especially in developed countries ignored these warnings and continued to industrialize rapidly, and by releasing a terrible amount of greenhouse gas into the atmosphere, they caused the deterioration of climate balance, especially temperature and precipitation [1].

Time-dependent changes in temperature and precipitation parameters cause irreversible deterioration in the hydrological balance with events such as drought and flood. Changes in air temperature, melting of glaciers in the poles and inland areas, rising sea levels, and increasing the frequency and intensity of floods, droughts and precipitation are the most important of these indicators [2]. These effects negatively affect the endemic plant and animal diversity and basic production areas (agriculture and livestock) of our country, and therefore the nature and economy, with the irregularities in precipitation and temperature parameters in our country, which experiences many climates at the same time. In this context, it is of great importance to examine the management policies of limited water resources to be implemented in the future and to conduct future analyzes on these parameters.

Drought, which is a natural climatic event that can occur at any time and place, can be defined as water scarcity caused by the decreasing trend of the moisture content of a region. Drought usually occurs slowly and covers a long period. Animals and plants in arid climates are adversely affected by the lack of moisture and the high variability of precipitation. Drought is one of the hardest disasters to detect [3]. A flood, which is the opposite of this situation, is when a stream overflows from its bed for different reasons and damages the surrounding lands, settlements, infrastructure facilities and living things [4].

There are many studies examining precipitation and temperature parameters in our country. When the relevant literature is examined, Partal (2003) analyzed the precipitation data in 96 stations in Turkey, which he examined with Mann-Kendall and Sen's T-test, and found negative trend findings in the Central and Eastern Black Sea Regions in the winter season [5]. Büyükyıldız (2004) conducted a study on precipitation data of 25 stations belonging to the Sakarya Basin, Sen's T-test, Spearman Rho test, Mann-Kendall test, Seasonal Mann-Kendall, Sen's Trend Slope Method, Van Belle and Hughes (using the trend) Homogeneity test and Mann-Kendall Rank Correlation tests, he detected 44 significant trend presences in the 95% confidence interval and reported that this trend presence was positive with 20% and negative with 80% [2]. Özfidaner (2007), as a result of the study he carried out on the monthly and annual precipitation data of 32 stations in Turkey using T-test, Mann-Kendall Rank Correlation test and Regional Mann-Kendall Rank Correlation tests, showed that in the winter season, the negative direction, autumn, spring and in the summer seasons, positive trend findings were found [6]. Ölgen (2010) reported that annual precipitation variability in Turkey decreases regularly from south to north, and that precipitation in large parts of the country, especially in the south and southeast regions, causes significant deviations in summer due to tropical air currents. However, in the north of the Black Sea Region, he concluded that the precipitation caused by the northern air currents reduced the precipitation variability in the region [7]. Demir (2018) examined the precipitation data of 19 stations in the Black Sea region by applying the Run test, Mann-Kendall test, Linear Trend test and Şen Trend tests and determined that there was a positive trend in the East and Central Black Sea regions and a negative trend in the West Black Sea region [8]. Yılmaz (2021), examining the 57-year temperature and precipitation data of the Eastern Black Sea region, determined a positive trend as a result of his study [9].

In the literature, there are also many studies on temperature parameters. Türkeş (2000) reported that the warming of the world's surface temperatures, which started in the 1950s, increased every year and broke global temperature records. After the cold year of 1992 in Turkey, temperatures increased to a record level in 1998, and this year was the warmest year between 1850 and 2000, both in the global average and in the temperature averages of the northern and southern hemispheres [10]. Öztürk (2002) reported that according to the scenarios put forward by the United Nations Intergovernmental Panel on Climate Change (IPCC), an average increase of 1 to 3.5 degrees in global temperature is foreseen until 2100. From this, it follows that even under the most optimistic conditions, there will be an increase in temperature of about 0.1 degrees every 10 years. As a result of this; he stated that there will be very different consequences that will result from the rise in sea level, change in temperature and precipitation regimes and reach the dimensions of the disaster. Again, according to Öztürk (2002), semi-arid and arid regions (South East and Central Anatolia regions) and semi-humid (Aegean and Mediterranean regions) regions will be more affected by the increase in temperature [11]. Bahadır (2011) in his study examining the effects of global climate changes in Turkey, stated that there was a decreasing trend in annual and seasonal average temperatures in our country from 1975 to 1992, and an increase in average temperatures began to be observed after 1992 [12]. Dabanlı (2017) investigated the impact of climate change on precipitation and temperatures using SRES A2 and B2 scenarios of Max-Plank Meteorology Institute (EH40PYC) and Hadley Center (HadCM3) models. As a result of the study, it was determined that the land and sea temperatures increased in parallel with each other. Looking at the temperature records in the northern hemisphere, it was seen that the 1990s were the hottest years of the last 1000 years [13]. According to the Climate Change and Agriculture Evaluation Report, there has been a rapid increase in the accumulation of greenhouse gases released into the atmosphere as a result of activities that do not comply with sustainability principles, and this situation has strengthened the natural greenhouse effect and caused an increase in the average surface temperatures of the earth, triggering global warming. As a result of global warming, climate change has manifested itself with varying effects in different areas [14]. According to the climate change model studies conducted according to the Turkey Drought Assessment Report, temperatures are expected to increase by 0.5 to 3.0 °C until 2050 and by 0.5 to 4.0 °C until 2100, according to the optimistic scenario. According to the pessimistic scenario, temperatures are expected to increase by 0.9 to 3.5°C by 2050 and by 0.9 to 6.3°C by 2100 [15]. The basins most sensitive to temperature increase are those in the Eastern Mediterranean and Southeastern Anatolia Regions. In the Climate Assessment (2021), it has been reported that the average temperature of Turkey in 2021 (14.9°C) is 1.4°C higher than the average temperature (13.5°C) between 1981 and 2010 [16]. According to the IPCC 3rd Assessment Report, it is estimated that the annual average temperatures of Turkey will increase by 1 to 3 °C until 2050. Every region in our country will be affected by climate change in different ways) [17].

Scopus is one of the two most comprehensive databases in the world. Vosviewer, on the other hand, is a program that visualizes data obtained from databases such as scopus and web of science with the network

analysis method [18]. For the literature review, the results obtained in the search with the keywords 'precipitation and temperature and change and turkey' in scopus were divided into author (Figure 1a), country (Figure 1b) and keyword (Figure 1c) categories with vosviewer analysis was made.

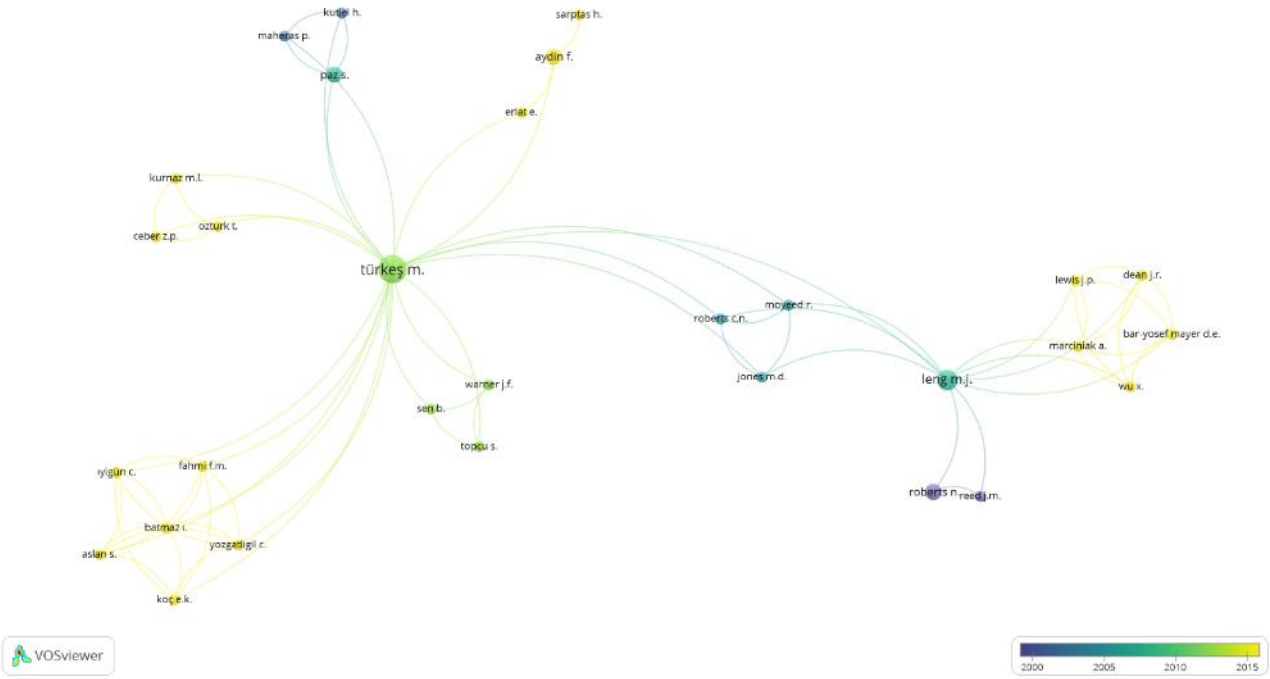

Figure 1a Network map of the authors according to the results from the Scopus Database

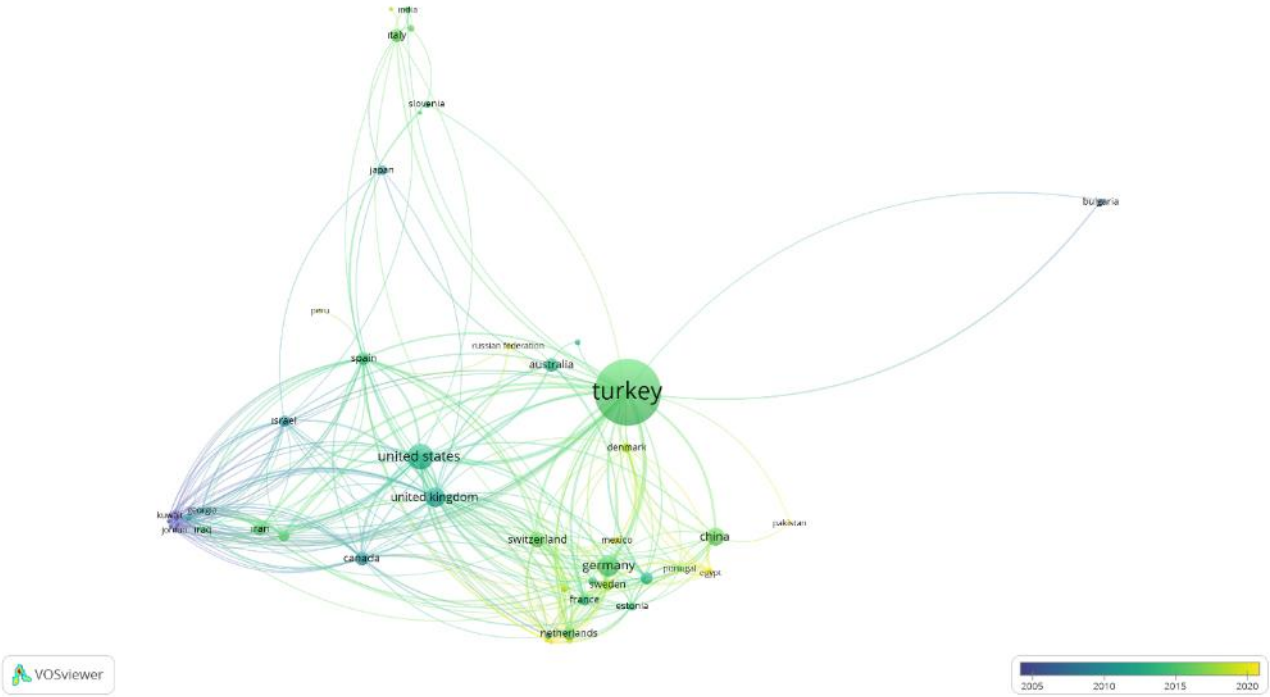

Figure 1b Network map of countries according to the results obtained from the Scopus database

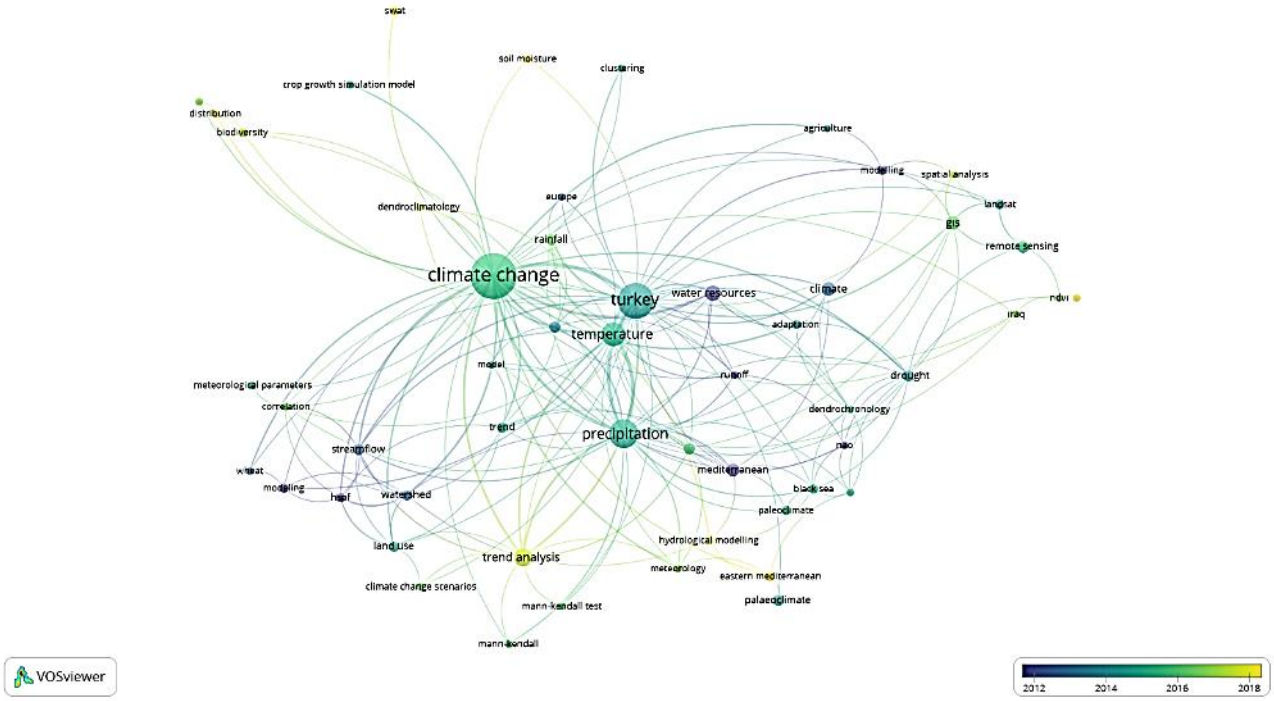

Figure 1c Network map of the keywords used according to the results obtained from the Scopus database

As can be seen in Figure 1a, the authors working in the field of precipitation and temperature change in turkey and the years of study started to increase after 2010 and intensified in recent years.

In Figure 1b, it is seen that the country working the most on this issue is Turkey, and these studies have increased after 2015. It is seen that the countries that have been working on these issues in recent years are Egypt, Pakistan and the Russian federation.

As can be seen in Figure 1c, it was seen that the most common and written keywords were Turkey, climate change, precipitation and temperature.

In this study, the monthly average temperature and precipitation data of the old normal (1981-2010) and the new normal (1991-2020) of Turkey, the changes in the province, water basins and Turkey-wide were visualized by using IDW interpolation method and the results were interpreted.

2. Material and Method

2.1. Study Area

Turkey (26°-45° E, 36°-42° N) is a country surrounded by seas on three sides [19]. Turkey is located both in the temperate and subtropical zones due to its location. While the coasts of Turkey are suitable for a temperate zone climate due to the effect of the seas, continental climate characteristics are observed since the sea effects are not observed in the inner parts of the country. Therefore, different climates are seen in Turkey: Mediterranean climate, Marmara (transitional climate) climate, Continental climate and the Black Sea climate. Considering today's climatic conditions, the effects of global climate change in Turkey are manifested as a decrease in water resources, drought, heatwaves, an increase in floods and a reduction in agricultural productivity [20]. In middle belt countries like Turkey, there are two different periods during the year: rainy winter and dry summer periods. Turkey receives 35% of its annual total precipitation during the winter months. This is followed by the spring and autumn seasons, and this rate drops to 11% in the summer months. All of the Eastern Mediterranean and Central Anatolia and some parts of the Southeastern Anatolia Region are considered arid, and some areas are considered very arid and desert [3].

Flood, which is one of the dangerous situations seen in Turkey, is seen in the Black Sea region, which receives the most precipitation [21]. In the Marmara, Aegean and Mediterranean regions, floods occur due to the geomorphological features of these regions. In the Mediterranean region, precipitation events in the spring season cause floods [22]. The risk of flood disasters in the Eastern Anatolia, Central Anatolia and Southeastern Anatolia regions of the country is at the lowest level compared to other regions [23]. Even if precipitation is high in these regions, the geological forms of the regions prevent flooding.

Turkey is among the countries in the risk group in terms of the possible effects of global climate change. As a result of the effects of climate change, drought in some regions and floods in others is very likely. The study area has been determined as 81 provinces of Turkey, 25 water basins and the country in general.

Figure 2a The study area and locations of stations

Figure 2b The study area and locations of water basins

2.2. Material

Long-term monthly average temperature (°C) and precipitation (mm) data were obtained from the report of the General Directorate of Meteorology on "Temperature and Precipitation Normals for the period of 1991-2020" and dated 25.11.2021. The temperatures of the water basins were obtained by taking the average of the temperatures of the stations in the basin. The table containing the statistical information of the old and new normals all the provinces is given below (Table 1).

Table 1. Descriptive statistical information on old and new precipitation and temperature normal for provinces

	Precipitation (mm) (1981-2010)	Precipitation (mm) (1991-2020)	Temperature (°C) (1981-2010)	Temperature (°C) (1991-2020)
Mean	618,97	619,08	13,09	13,55
Maximum	1407,5	1602,2	19,5	20,2
Minimum	352,3	349,2	3,6	4,3
Standard Error	18.58	21.11	0,37	0,36
Standard Deviation	167.30	190.07	3,29	3,28
Kurtosis	5.08	7.78	0,40	0,43
Skewness	1.53	1.95	-0,42	-0,44

In Table 1, the average of the precipitation normals for the provinces increased from 618.97 mm to 619.08 mm. Temperature normals increased from 13.09°C to 13.55°C. The highest temperature increased from 19.5 °C to 20.2 °C, while the lowest temperature increased from 3.6 °C to 4.3 °C.

2.3. Method

2.3.1 Inverse Distance Weighting (IDW) Method

The Inverse Distance Weighting (IDW) is an interpolation method used to create data from the data that cannot be sampled by the exemplary points, wherein the creation of these data depends on the interpositional distance and formula applied by considering relations with various points [24].

$$f(x,y)=\sum_{i=1}^{n} w_i f_i \tag{1}$$

$$w_i=\frac{h_i^{-p}}{\sum_{j=1}^{n} h_i^{-p}} \tag{2}$$

Here;
f_i; represents the known height value,
w_i; represents the weights and the sum of their values must Equation 1,
p; is taken as a power parameter and denoted by exponent,
h_i; represents the spatial distance between the sample points and the interpolation points [25-26].

3. Application

Determination of precipitation and temperature normals and analysis of changes are of great importance for Turkey, which is very sensitive to drought and flood hazard [27]. These analyzes play a key role in the studies to be carried out in terms of water management. In this study, the data of precipitation and temperature normals of 81 provinces were visualized using the IDW interpolation method.

IDW interpolation maps of old and new precipitation normals are shown in Figures 3, 4, 7, 8 and temperature normal are shown in Figures 5, 6, 9, 10.

When Fig. 3 and Fig. 4 are examined, it is seen that the highest precipitation normal and the highest increase were in Rize with a difference of 194.7 mm and a percentage of 13.83% new normal- old normal/old normal for example ((1602.2mm-1407.5mm)/1407.5mm). On a provincial basis, the highest decrease was seen in Erzurum with a difference of 75.3 mm and a percentage of 12.84%. Since the precipitation heights in the central part of the country are well below 573.4 mm, which is considered the precipitation normal, these regions are under the threat of drought. Rize station, on the other hand, continues to be the riskiest station that can be flooded by exceeding the old precipitation height.

When Figure 5 and Figure 6 are examined, it is seen that there is an increase in temperature in all provinces except Bitlis. The highest increase on a provincial basis was seen in Ardahan with a difference of 0.7 °C and an increase of 19.44% ((4.3°C-3,6°C)/3.6°C). The only province with a temperature decrease was Bitlis with a difference of 0.2 °C and a decrease of 2.08%. The desert climate coming from Syria is effective in the stations adjacent to Syria. In the stations on the Mediterranean coast, the temperatures are above the country average

due to the Mediterranean climate. Northeast stations, on the other hand, are the stations where the lowest temperatures of the country are seen due to both terrestrial and high altitudes.

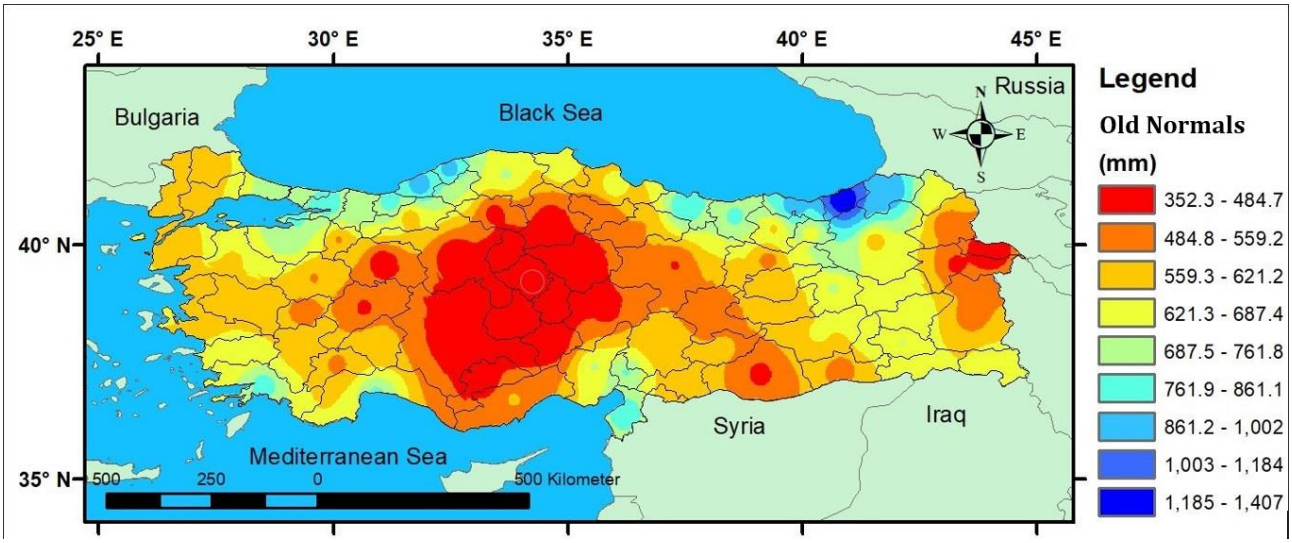

Figure 3. Old Precipitation Normals (1981-2010)

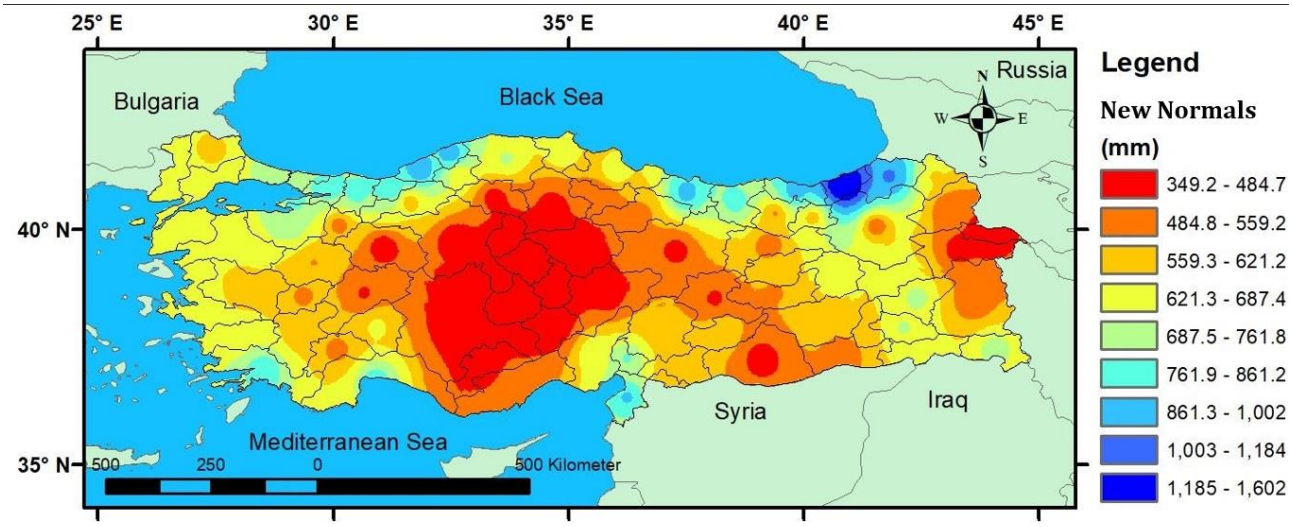

Figure 4. New Precipitation Normals (1991-2020)

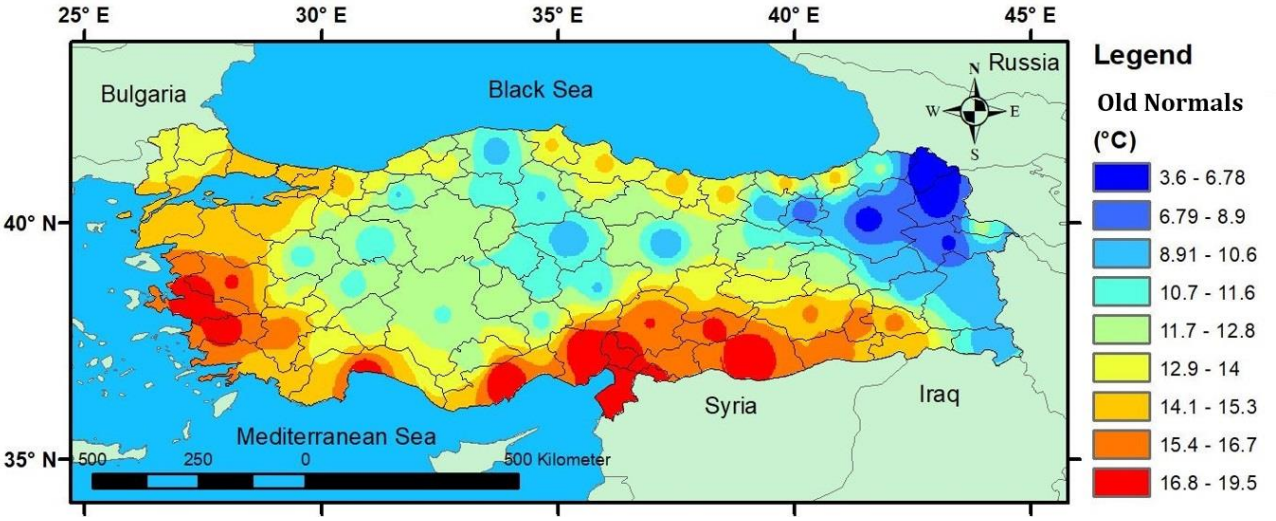

Figure 5. Old Temperature Normals (1981-2010)

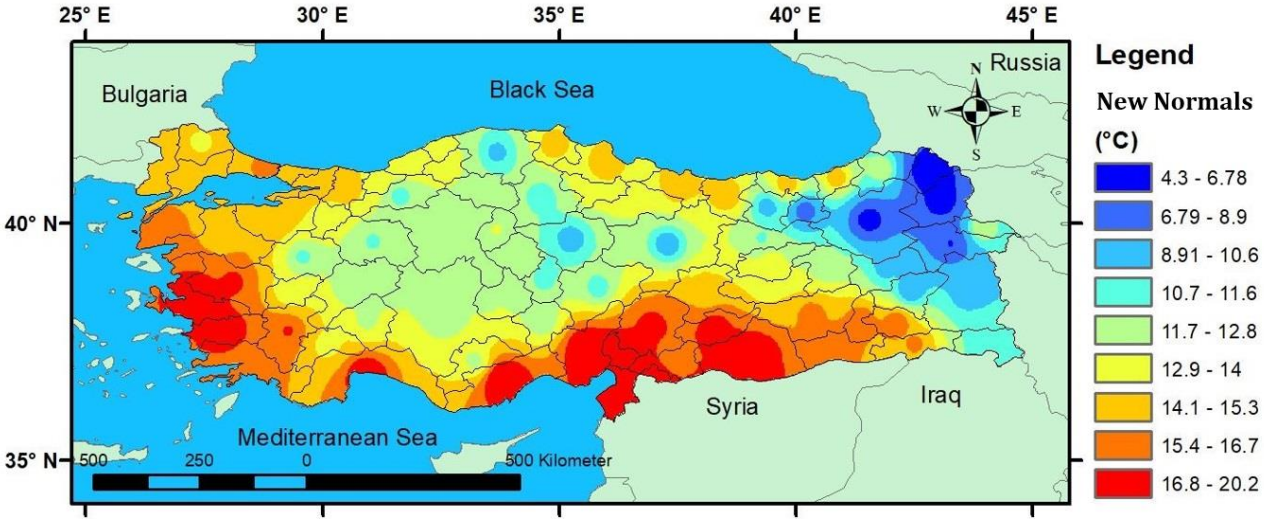

Figure 6. New Temperature Normals (1991-2020)

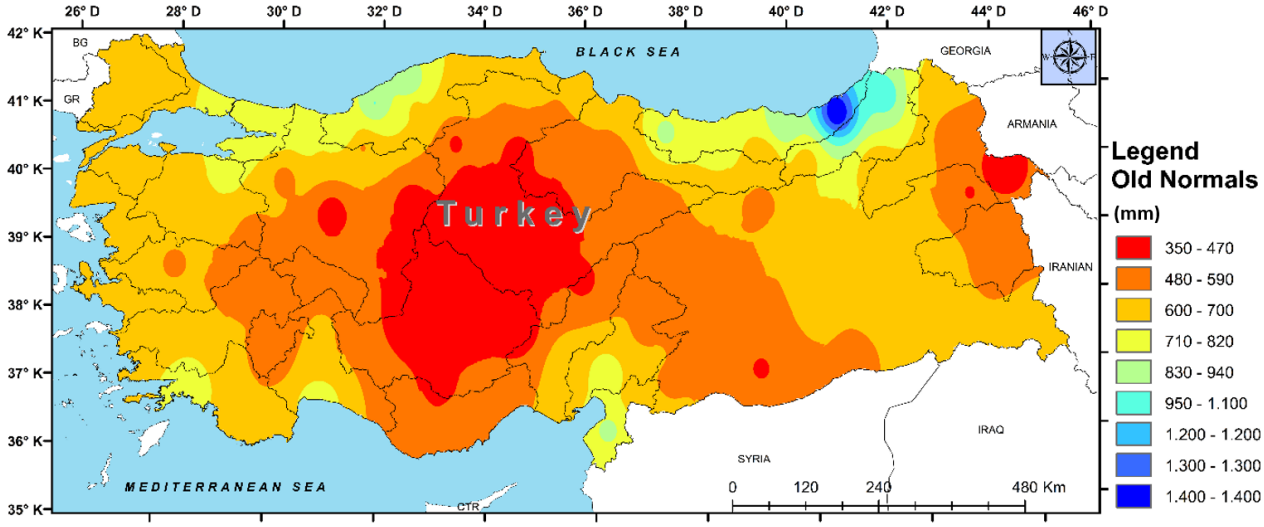

Figure 7. Old Precipitation Normals (1981-2010)

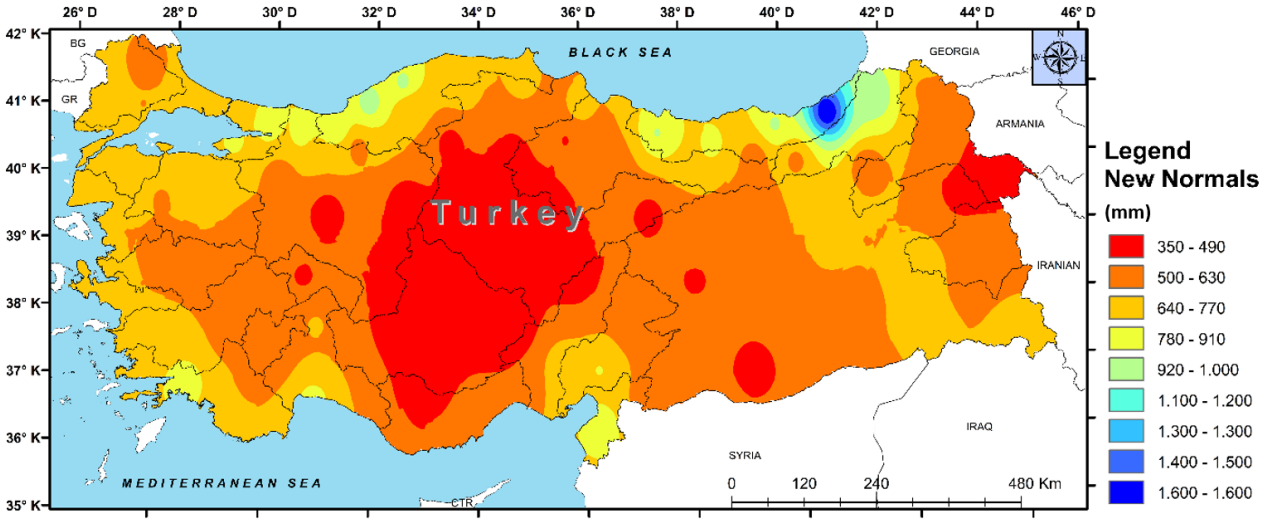

Figure 8. New Precipitation Normals (1991-2020)

Looking at Figure 7 and Figure 8 it has been determined that the water basin with the highest precipitation increase compared to the old normal is the Eastern Black Sea Basin with a difference of 52.1 mm and 5.50% ((999.9 mm-947.8 mm)/947.8 mm). It has been determined that the water basin with the highest decrease in

precipitation is the Çoruh Basin with a difference of 54.6 mm (709.2 mm-763.8 mm). In terms of percentage, it was determined that there was a decrease of 8.12% ((479.7 mm-522.1 mm)/522.1 mm) in the Van Lake Basin. It has been understood that the only water basin whose precipitation height never changes compared to the old normal is the Sakarya Basin with 472.8 mm.

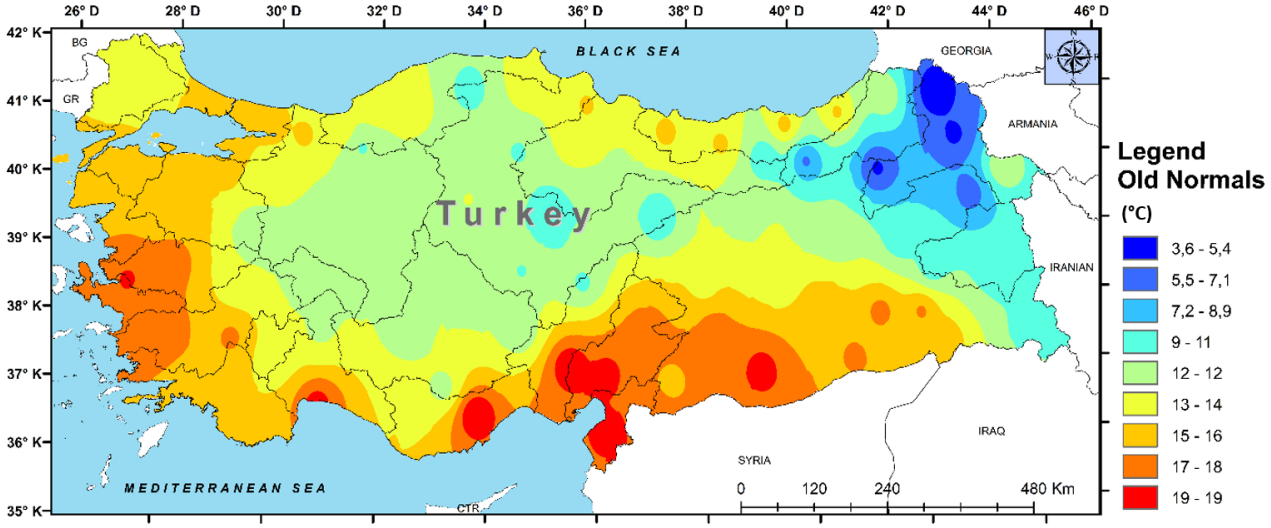

Figure 9. Old (1981-2010) Temperature Normals

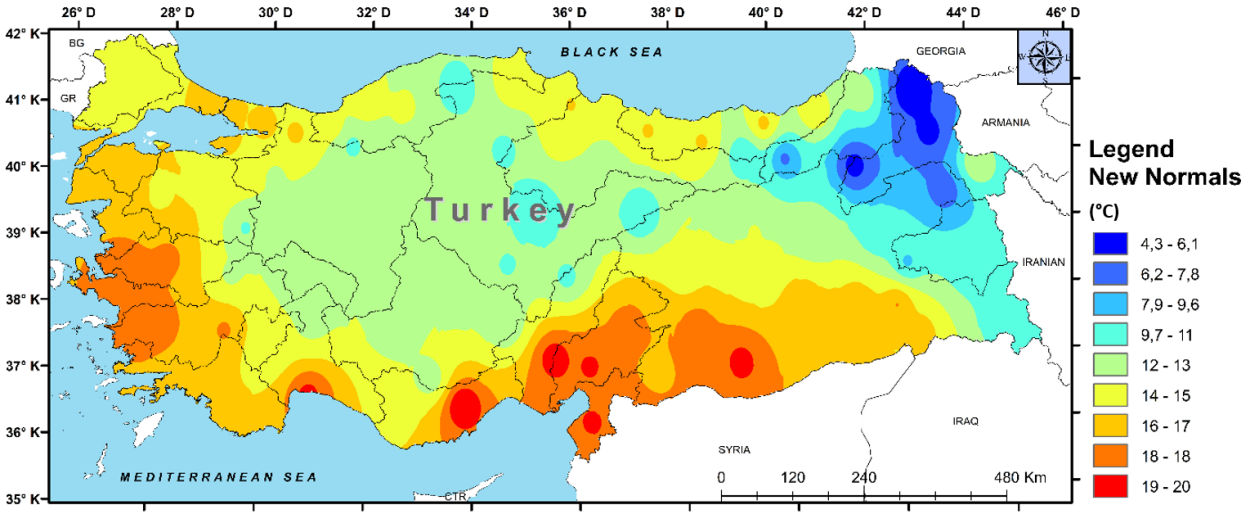

Figure 10. New (1991-2020) Temperature Normals

As can be seen in Figure 9 and Figure 10 it was determined that there was an increase in temperature in all water basins. The highest increase compared to the old normal was detected in the Eastern Mediterranean Basin with a difference of 0.7 °C (20.2 °C -19.5 °C). When the results were analyzed according to the percentage change, it was determined that there was an increase of 7.34% ((6.95 °C-6.48 °C)/6.48 °C) in the Aras Basin.

4. Conclusion and Discussion

The changes in precipitation and temperature of Turkey between the new climatic period (1991-2020) and the old climatic period (1981-2010) were analyzed by mapping with the IDW interpolation method. As a result of the examination, it was determined that the precipitation normal throughout the country decreased (from 574 mm to 573.4 mm) by 0.6 mm (0.1%).

It was observed that annual temperature normals tend to increase (from 13.09°C to 13.55°C) by 0.46°C equal (3.51%) change in all regions of our country.

Considering the average rainfall height of 25 water basins, an increase of 1.19 mm (0.2%) was detected compared to the old normal. However, the fact that the temperature increase has increased by 0.44 °C (3.19%) to the old normal and the precipitation height has not increased sufficiently indicates that it is necessary to be prepared for the fact that there may be a serious drought danger in the next climatic period. Although it is seen that the precipitation heights throughout the country are higher than 573.4 mm, which is accepted as the precipitation normal, there is a serious drought threat, especially in the interior of the country, which is

landlocked and has a continental climate. It is seen that the precipitation heights of the Kızılırmak (460.3 mm-449.4 mm), Sakarya (472.8 mm- 472.8 mm) and Akarçay (478 mm- 480.6 mm) Basins, especially in the Konya Kapali (404.8 mm-394.8 mm), are far below the precipitation normal. In light of all these data, decision-makers should make the necessary arrangements.

In the literature, it is stated that a 30-year period is sufficient to comment on the climate situation by examining the precipitation and temperature parameters of a region [28]. However, examining longer periods allows us to make clearer comments.

In this study, Turkey's climate interpretation was made by examining 30 years of precipitation and temperature data of the General Directorate of Meteorology for Turkey.

Acknowledgement

The visualizations in Figures 1a, 1b and 1c were created using Vosviewer software, and the other figures were created using ArcMap software.

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Author contributions

Taha Demirgül: Conceptualization, Methodology, **Cavit Berkay Yılmaz** Software **Büşra Nur Zıpır:** Data curation, **Fatma Sena Kart:** Writing-Original draft preparation, **Muhammet Fatih Pehriz:** Software, Validation. **Vahdettin Demir:** Visualization, Investigation, **Mehmet Faik Sevimli:** Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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