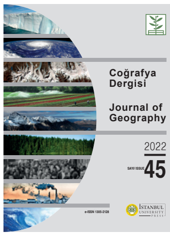

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Periodic Changes of Temperature Extremes at Some Selected Stations in Turkiye (1970-2018)

Türkiye'de Seçilen Bazı Istasyonlarda Sıcaklık Ekstremlerinin Dönemsel Değişimleri, 1970-2018

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ABSTRACT

Understanding the long-term variations of extreme temperature events is important for detecting and understanding the characteristics of climate change. However, it is not clear to what degree urbanization impacts climate change. In the study, station pairs were created by selecting 42 stations that recorded data between 1970-2018 to reflect the climate characteristics seen in Turkey.

The changes of the selected climate indices in these station pairs in the hot (April-September) and cold (October-March) periods were examined by taking into account the observations covering the years 1970-2018. This study utilized the RClimDex program and Mann Kendall trend analysis technique. The RClimDex program was used to generate 27 climate indices. The information derived from the indices not only demonstrates how the mean value changes over time, rather, it; also contains information about how the statistical distribution of the data has changed. In addition, the results provide crucial information about the trends of extremes. In the study, 4 indices related to temperature (Diurnal Temperature Range, Cool Nights, Warm Nights, Minimum of Minimum) were selected and examined. When the changes in the climate indices of the selected stations in the hot and cold periods are examined, it is observed that the change in the hot period is more pronounced than the change in the cold period. According to Mann Kendall trend analysis, most of the trends are statistically significant at the 95% level in all station pairs examined. Results of the trend analysis show that the fastest tendency to increase occur in stations located in the Black Sea, Aegean and Mediterranean coastal zones where the moisture content in the air is higher. This finding points to the positive feedback mechanism created by the increased moisture content in atmosphere through global climate change.

Keywords: Extreme Temperature, Climate Indices, Climate Change, Mann-Kendall, Trend, Turkey

ÖZ

Ekstrem sıcaklık olaylarının uzun süreli değişimlerini anlamak, iklim değişikliğinin tespiti ve özelliklerinin anlaşılması için önemlidir. Bununla birlikte şehirleşmeden ne kadar etkinin geldiği açık değildir. Çalışmada Türkiye'de görülen iklim özelliklerini yansıtacak şekilde 1970-2018 yılları arasında verilere sahip 42 istasyon seçilerek istasyon çiftleri oluşturulmuştur. Bu istasyon çiftlerinde seçilen iklim indislerinin sıcak ve soğuk dönemdeki değişimleri,1970-2018 yılları arasını kapsayan rasatları dikkate alınarak incelenmiştir. Bu inceleme için RClimDex programı ve Mann Kendall trend analizi tekniği kullanılmıştır. RClimDex programı 27 adet iklim indisi üretmektir. İndislerden türetilmiş bilgi yalnızca ortalama değerin zaman içinde nasıl değiştiğini değil; aynı zamanda verinin istatistiksel dağılımının nasıl değiştiği konusunda da bilgi içerir. Ayrıca sonuçlar ekstremlerin trendleri hakkında çok önemli bilgiler sağlamaktadır. Çalışmada sıcaklık ile ilgili olan 4 indis seçilerek incelenmiştir. Seçilen istasyonların iklim indislerinin sıcak ve soğuk dönemdeki değişimleri incelendiğinde sıcak dönemdeki değişimin, soğuk döneme göre değişimin daha belirgin olduğu gözlenmiştir. Mann Kendall trend analizine göre incelenen tüm istasyon çiftlerinde Trendlerin çoğu %95 seviyesinde istatistiksel olarak anlamlıdır. Trend analizinin sonuçları istasyonlarda en hızlı artış eğiliminin havadaki nem içeriğinin daha yüksek olduğu Karadeniz, Ege ve Akdeniz kıyı kuşağında yer alan istasyonlarda gerçekleştiğini göstermektedir. Bu durum küresel iklim değişimi ile birlikte atmosferde artan nem içeriğinin oluşturduğu pozitif geri besleme mekanizmasını düşündürmektedir.

Anahtar kelimeler: Ekstrem Sıcaklık, İklim İndisleri, İklim Değişimi, Mann-Kendall, Trend, Türkiye

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1. INTRODUCTION

Extreme weather events are defined as uncommon weather events. In order to define the measured temperature or precipitation values as exceptional or extreme, functions of various statistical distributions are used as a base and the measured value should be included in the 10th and 90th percentile range according to the normal probability distribution (IPCC, 2007). Extreme weather events directly affect human life and activities. From the 21st century onwards, there has been an increase in the severity of extreme events along with increases in industrialization, urban construction and population growth. The response of each area to the changes that occur due to extreme events will vary based on geographical location. The Mediterranean basin is listed among the areas which will be most affected by this variability according to World Meteorological Organization (WMO) and the Intergovernmental Panel on Climate Change (IPCC) reports (IPCC, 2007; IPCC, 2013; WMO, 2016).

Lack or scarcity of long-term daily meteorological observations in many countries, inability to understand the significance of global warming and lack of studies in regions and countries make it difficult to identify extreme events in a global scale. In recent years, the number of observations all over the world and the increase in studies on this subject has accelerated the obtaining of more objective results (Erlat and Yavaşlı, 2009).

In addition to the general global trend of warming, cities are the areas where climate change is the most prominent (Sarif et al., 2020, Sarif and Gupta, 2019), due to high density of buildings, roads, and industrial areas. The main causes for this differentiated climate are factors such as urban surface materials, geometry and height of buildings, urban temperature sources and air quality (Landsberg, 1981; Marsh, 1991).

Materials with high absorption such as asphalt, stone, concrete and glass that are frequently used on city surfaces absorb and store heat just like a reflector with their dark colors, opaque and rough surfaces (Rousta et al., 2018). This increases the energy retention and storage time of urban surface materials. Low albedo values in cities generate high net radiation and temperature values increase. Urban structures absorb more heat compared to natural environments (Pathak et al., 2020). While solar radiation is dispersed by reflection in open areas, this is reflected in solar radiation through tall buildings in urban areas (Gönençgil, 2011). Absorption increases in direct proportion with dark building materials, and high-rise buildings reduce airflow, thereby preventing, heat loss from horizontal movement and convective mixing (Kum and Kılıç, 2013).

The studies conducted in Europe showed that the number of summer days and heat waves were higher in the last years (IPCC, 2013; Kum and Kılıç, 2013). Another study that examined the temperature extremes in some European stations between 1946 and 1999 pointed to increases in the number of summer days on the continent. This warming trend was statistically significant in 16 of the 42 stations for summer days (Klein and Können, 2003). A study that explored the air temperatures for the period for 1950–1999 in connection with sea water temperatures and atmospheric circulation in the Mediterranean Basin in the summer season presented that the coolest summers were in the mid-1960s and 1970s and the coolest summer for this period was experienced in 1976. The 1950s, 1980s and 1990s were characterized by warmer summer seasons, with the highest values found in 1994 and 1999 (Xoplaki et al., 2003).

A study conducted by Alexander et al., 2006 evaluated the daily temperatures of 200 stations distributed globally from the 1951-2003 period and 16 temperature indices found that the annual numbers of summer days decreased in a narrow area including a large part of India and the eastern part of the U.S, while showing a significant upward trend in northern Canada, western Europe, the Middle East, Australia and the south of Brazil (Alexander et al., 2006).

Nastos and Matzarakis, 2008 identified a negative trend in the number of tropical days in Greece between 1955 and 1976 and a positive trend between 1976 and 2000. The stations with the highest positive trend are also the cities with strong heat islands due to Greece's urban development. Kioutsioukis et al., 2009 stated that there was a significant increase in the number of summer days in 7 out of 19 stations in Greece and that the warming tendency became especially evident in the summer months.

The study conducted by Amani-Benia et al., 2018 investigated the effect of green areas in city centers on temperature by focusing on Urban Heat Islands (UHI). As a result, urban green spaces were seen as a factor that mitigates UHI with a cooling effect.

Mostafa et al., (2019) observed that the frequencies of hot days (TX90P) and nights (TN90P) clearly increased in the Egypt region between 1980-2017, whereas cold days (TX10P) and nights (TN10P) decreased. As a result of the study, it was observed that night temperatures increased faster than daytime temperatures.

Studies conducted in Turkey on the changes and trends of minimum and maximum temperatures and daily temperature differences showed an overall downward trend for decrease in maximum temperature ranges up to 1992 (except spring), but after this date, maximum temperatures as well as mean and minimum temperature ranges increased especially in the spring and summer seasons (Türkeş et al., 2002).

The highest temperature increases are observed at average minimum values in cities. Heat islands described by daytime maximum temperature analysis are weaker and discontinuous. On the contrary, heat islands formed at night are more powerful and flat, especially if they are developed under anti-cyclone conditions. This is due to the fact that the energy stored by the city surfaces during the day is released at night, the turbulence is weaker to the turbulence during the day and regional variations in local change in cloud covers are less effective. In other words, temperature differences between urban and rural areas tend to decrease during the day while they increase at night time (Çiçek, 2005).

Temperature typically increases in areas with denser construction towards city centers. Despite the irregularity of thermal changes, the descending and rising trends of city temperature is significant. Large cities are capable of creating their own thermal environment. The effect of heat due to urbanization is more effective up to 600-800 m (Ezber et al., 2007).

The number of summer days is increasing in all stations according to observations conducted in 100 stations in Turkey in the period from 1971-2004. According to Mann-Kendall test results, a significant trend of 5% increase was determined especially in the majority of the stations on the Black Sea coast (Şensoy et al. 2008).

Population is increasing rapidly both in Turkey and globally. This is accompained by Parallel rapid migration towards cities. Cities are growing spatially and due to the increase in asphalt surfaces, increase in buildings, decrease in albedo and use of vehicles, urbanization can cause additional heat in the city because the energy gained during the daytime in cities is maintained at night. Temperatures higher in urban areas compared to rural areas. This is termed Urban Heat Island (UHI). This study aimed to reveal whether the determined extreme temperature indices presented more variability in urban areas compared to rural areas while exploring the changes in the hot (April-September) and cold (October-March) periods for 1970-2018.

2. MATERIALS and METHODS

Data obtained from 42 stations were used (**Fig. 1**) for the study. The daily maximum and minimum temperature data for these 42 stations were obtained from the Turkish State Meteorological Service. 42 selected stations were divided into pairs as stations located in their province and district, and station pairs were formed. The designated stations used in the study were selected from every region of Turkey based on the following criteria: stations having complete data for the years 1970-2018, stations with no change of location for the determined period,

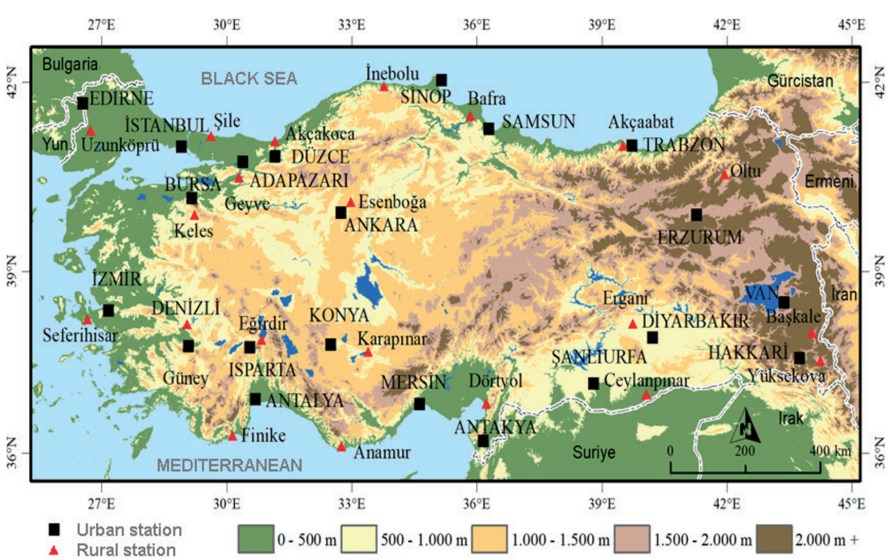

Figure 1: Geographical distribution of weather stations used in research

Table 1: Weather Stations Used In Research and Their Geographical Characteristics

Urban	Rural	Latitude (N)	Longitude (E)	Elevation	Urban	Rural	Latitude	Longitude	Elevation(m)
Ankara	Esenboğa	38° 26′ 38° 12′	32° 53′ 40° 07′	891-949	Isparta	Eğirdir	37° 45′ 37° 52′	30° 33′ 30° 50′	997-920
İzmir	Seferihisar	37° 47′ 38° 09′	27° 10′ 26° 50′	29-22	Adapazarı	Geyve	40° 47′ 40° 31′	30° 25′ 30° 18′	30-100
Denizli	Güney	36° 53′ 36° 18′	29° 05′ 29° 04′	425-806	Hakkari	Yüksekova	37° 34′ 37° 34′	43° 16′ 44° 17′	1728-1900
Antalya	Finike	40° 50′ 41° 05′	30° 42′ 30° 09′	42-2	Konya	Karapınar	37° 58′ 37° 43′	32° 33′ 33° 33′	1031-1004
Düzce	Akçakoca	41° 00′ 41° 01′	31° 10′ 41° 05′	146-10	Erzurum	Oltu	39° 55′ 40° 33′	41° 16′ 41° 59′	1758-1322
Trabzon	Akçaabat	38° 28′ 38° 03′	39° 43′ 39° 34′	30-3	Bursa	Keles	40° 14′ 39° 55″	29°00′ 29° 04′	100-1063
Van	Başkale	37° 08′ 36° 51′	43° 21′ 44° 01′	1671-2400	Mersin	Anamur	36° 48′ 36° 05′	34° 38′ 32° 50′	3-4
Şanlıurfa	Ceylanpınar	37° 54′ 38° 17	38° 46′ 40° 03′	549-398	Sinop	İnebolu	42° 01′ 41° 59′	35° 10′ 33° 47′	32-64
Diyarbakır	Ergani	41° 40′ 41° 16	40° 14′ 39° 46′	677-1000	İstanbul	Şile	40° 43′ 41° 11′	29° 13′ 29° 37′	32-83
Edirne	Uzunköprü	36° 12′ 36° 51′	26° 34′ 24° 41′	51-52	Samsun	Bafra	41° 17′ 41° 35′	36° 18′ 35° 56′	4-20
Antakya	Dörtyol		36° 10′ 36° 13′	100-28					

stations with suitable and specific characteristics for urban-rural settlements (Hua vd., 2007). The hot period was defined as April-September and October-March was defined as the period.

Climate indices are indicators that are produced from raw data and demonstrate changes in climate. Twenty-seven core climate indices were identified by the Expert Team on Climate Change Detection and Indices (ET-CCDI) assembled by the World Meteorological Organization (WMO). RClimDex software was used to calculate the indices in the study. Sixteen of these climate indices are related to extreme temperature. RClimDex software based on the R-Statistics package, was developed by Xuebin Zhang and Feng Yang on behalf of Expert Team to calculate these 27 indices by entering the daily maximum and minimum temperatures and precipitation amounts. The RHtest package is also available to test the homogeneity of data sets. In addition, quality control can be performed in the data series with the help of RClimDex without any calculation.

Homogeneity procedures were applied to data sets during indices calculations. Data homogeneity, homogeneous climatic time series change, is defined as data resulting only from climatic change (Aguilar et al., 2003). RHtest program was used for data homogeneity. This analysis is based on the linear trend applied to the whole time series and the two-phase regression model (Xiaolan 2003).

The data were arranged in the format of the program for each station and quality control was performed. In order to control the quality of the data and to detect possible quality problems, the software plots a plurality of graphs of the daily data and marks the statistical data outside the Xort ± 4 standard deviation data (Outlier). These data are written to the quality control file, errors are corrected or the missing value code is entered instead. The quality control procedures in the software are as follows:

- If the precipitation value is (-), it is considered as a missing value (-99.9)
- If Tmax <Tmin, both pieces of data are considered as missing values (-99.9)
- If the data is outside Xort ± 4St. deviation, it is considered problematic.

After the quality control stage, RClimDex software was run with data from 1970-2018 to produce climate indices. With the help of RClimDex climate indices outputs a time series was created with the differences between the urban-rural station pairs and index values. The Mann-Kendall test was used to analyze the trends of this different time series.

Various tests are used to determine whether there is a change in the trend of a temporal data series and if there is a change, whether this change leads to a significant increase or decrease. The Mann Kendall test was chosen as the most appropriate test since the temperature indices studied in this research could present extreme values. The non-parametric Mann-Kendall test is frequently used to test the statistical significance of the

Table 2: Indices Used In Research and Their Definitions (WMO)

Index	Name of Index	Definition
DTR	Diurnal Temperature Range	Difference between TX and TN (Tmax- Tmin)
TN10p	Cool Nights	Percentage of days when TN<10th percentile
TN90p	Warm Nights	Percentage of days when TN>90th percentile
TNn	Min of Tmin	Monthly minimum value of daily minimum temperatures

increase or decrease in the time series. In this method, the rank of data is more important than data size. It is useful because it allows missing data and it is not necessary to comply with a certain distribution at hand (Kalaycı and Kahya, 1998). In addition, the test eliminates the effect of serial correlation, is easy to implement and is based on ranks. As with all correlation methods, the Mann-Kendall test is a method independent of the distribution used to find the relationship between two variables (Sneyers, 1990). Positive values of the test statistic (u (t)) indicate an upward trend over time, while negative values (u (t) <0) indicate a downward trend. When u(t) reaches critical values corresponding to the level of significance, the reliability level of the trend is significant. Graphically, u(t), the progressive series, and u ′(t), calculated as reversed series, approach each other at the place where the change begins and then move away from each other and express their significance at the place where the trend starts. If there is no trend in the series, u(t) and u ′(t) approach each other many times and oscillate closely.

The reversed Mann-Kendall test statistics u ′(t) are also calculated in a similar manner. This time, the data is numbered from beginning to end (i′). The values of u(t) over ± 1.96 determine the 95% confidence interval (Sneyers 1990).

By taking into consideration the increasing temperatures within the scope of climate change and the studies mentioned in the introductory section of this study, the changes in the tendency of warm nights and cool nights indices were selected based on the relationship between urbanization and the increase in minimum temperatures. In addition, the monthly minimum value of daily minimum temperatures and diurnal temperature range indices were selected to observe extreme temperature changes (**Tables 1-2**). Frost days, ice days, cool days and warm days were not selected because they were related to maximum temperature and would not have been impacted by urbanization. Growing season length was not selected because it was regarded as an agricultural index.

3. RESULTS and DISCUSSION

3.1. Temperature Indices

3.1.1. Diurnal temperature range (DTR)

The DTR is obtained from the differences of daily maximum and minimum temperatures. As the minimum temperature increases in cities are greater than the maximum temperature, they generally show significant decreasing trends in DTR. In rural areas, generally, significant increase trends are observed since maximum temperature increases are more global. While there is not much increase in cold period DTR data in Ergani, the increase in hot period DTR data is higher. Changes in Erzurum, Ergani, Diyarbakır and Başkale stations are related to continentality (**Fig. 2-5, Table 3, 4**).

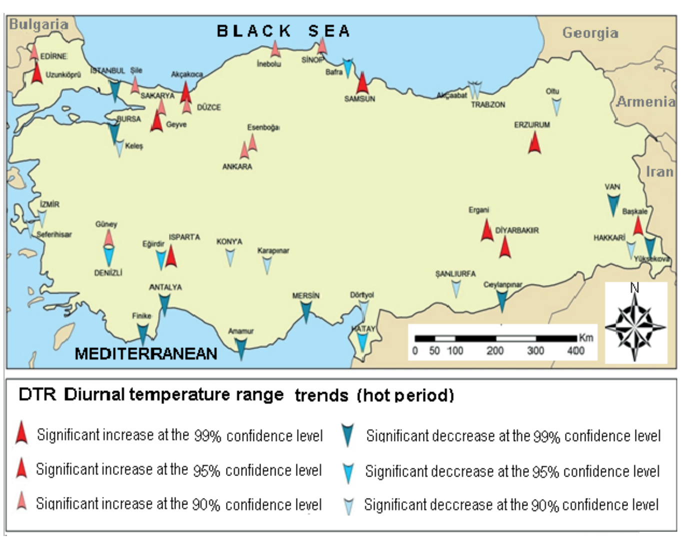

Figure 2: Diurnal temperature range trends (hot period)

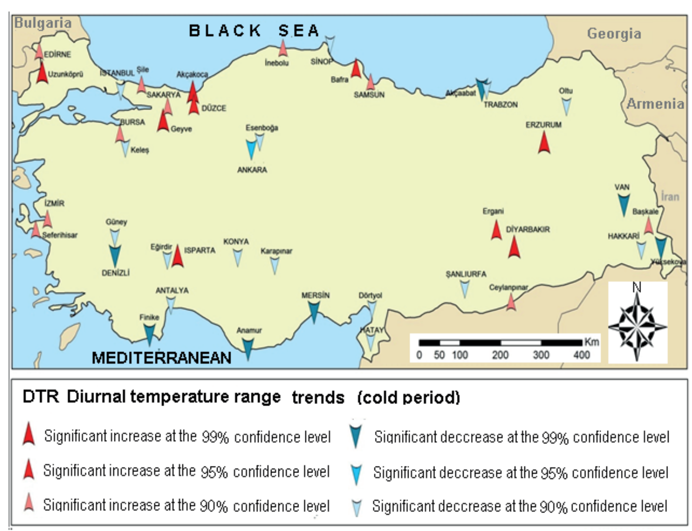

Figure 3: Diurnal temperature range trends (cold period)

Table 3: Diurnal Temperature Range (DTR-Urban) Mann Kendall Test Results

Results of Mann-Kendall Trend Analysis

Stations	First	Last	n	Test Z	Significance	Stations	First	Last	n	Test Z	Significance
	Year						Year				
Ankara	1970	2018	43	-1.98	**	İstanbul	1970	2018	43	0.75	
Antalya	1970	2018	43	-1.42		İzmir	1970	2018	43	1.43	
Bursa	1970	2018	43	1.32		Konya	1970	2018	43	-1.49	
Denizli	1970	2018	43	-2.35	**	Mersin	1970	2018	43	-3.13	***
Diyarbakır	1970	2018	43	2.95	***	Adapazarı	1970	2018	43	0.77	
Düzce	1970	2018	43	2.03	**	Samsun	1970	2018	43	2.24	**
Edirne	1970	2018	43	1.27		Sinop	1970	2018	43	0.25	
Erzurum	1970	2018	43	4.84	***	Trabzon	1970	2018	43	0.14	
Hakkâri	1970	2018	43	-1.27		Urfa	1970	2018	43	-1.08	
Hatay	1970	2018	43	-1.09		Van	1970	2018	43	-3.86	***
Isparta	1970	2018	43	-0.58							

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval), 2.58 + *** (Within 99% confidence interval)

Table 4: Diurnal Temperature Range (DTR-Rural) Mann Kendall Test Results

Results of Mann-Kendall Trend Analysis

Stations	First	Last	n	Test Z	Significance	Stations	First	Last	n	Test Z	Significance
	Year						Year				
Esenboğa	1970	2018	43	1.50	**	Şile	1970	2018	43	1.61	
Finike	1970	2018	43	-6.53		Seferihisar	1970	2018	43	-1.58	
Keles	1970	2018	43	0.16		Karapınar	1970	2018	43	0.31	
Güney	1970	2018	43	0.50	**	Anamur	1970	2018	43	-6.02	***
Ergani	1970	2018	43	6.32	***	Geyve	1970	2018	43	3.80	***
Akçakoca	1970	2018	43	4.79	**	Bafra	1970	2018	43	-1.76	*
Uzunköprü	1970	2018	43	4.54		İnebolu	1970	2018	43	1.35	
Oltu	1970	2018	43	-1.25	***	Akçaabat	1970	2018	43	-0.34	
Yüksekova	1970	2018	43	-4.32		Ceylanpınar	1970	2018	43	-3.23	***
Dörtyol	1970	2018	43	-0.63		Başkale	1970	2018	43	2.77	***
Eğirdir	1970	2018	43	4.40							

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

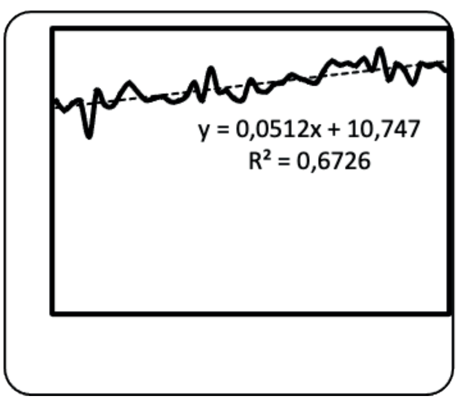

Figure 4: Ergani diurnal temperature range (DTR) linear trend graphic

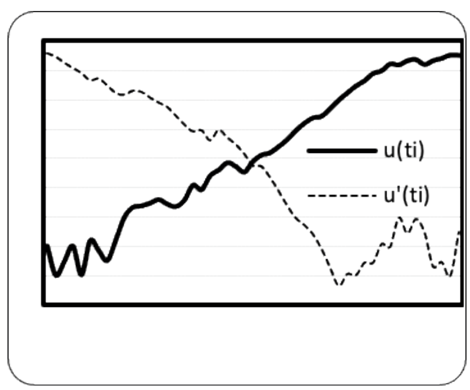

Figure 5: Ergani diurnal temperature range (DTR) Mann Kendall Test graphic

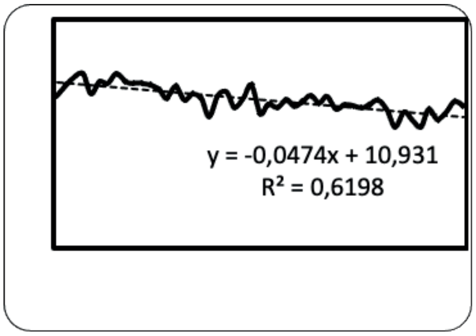

Figure 6: Finike diurnal temperature range (DTR) linear trend graphic

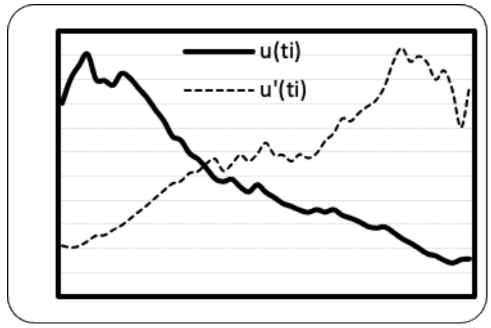

Figure 7: Finike diurnal temperature range (DTR) Mann Kendall Test graphic

3.1.2. Cool nights index (TN10p)

The cool night index is the number of nights in which percentage of days when TN<10th percentile. There is a significant decrease in cool nights in the hot period in the Ankara, Esenboga, Yuksekova, Bafra, Antalya, Finike, Hatay, Dortyol, Bursa, Isparta, Sinop, Denizli, Istanbul, Sile, Ergani, Izmir, Seferihisar, Duzce, Konya, Karapinar, Urfa, Ceylanpinar, Edirne, Mersin, Anamur, Van, and Adapazarı stations, whereas a significant increase in cool nights was observed in the Eğirdir and Erzurum stations (**Fig. 8-13, Tables 5-6**).

In most stations, there is a significant decrease in the number of cool nights. This decrease is more prominent in urban stations

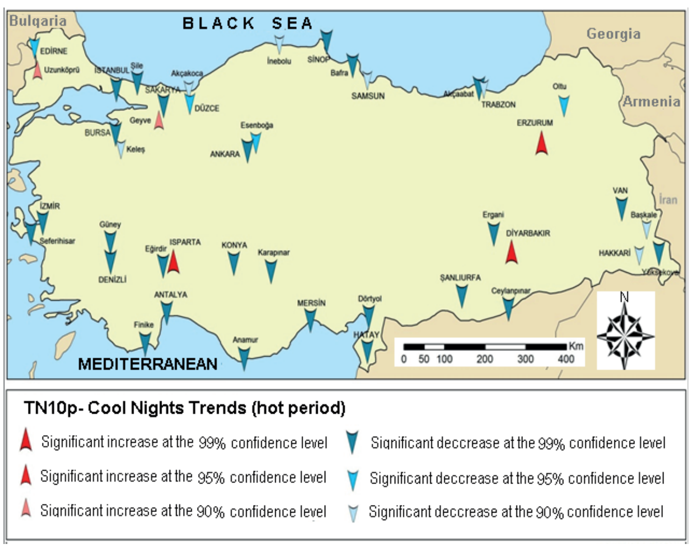

Figure 8: Cool nights trend (hot period)

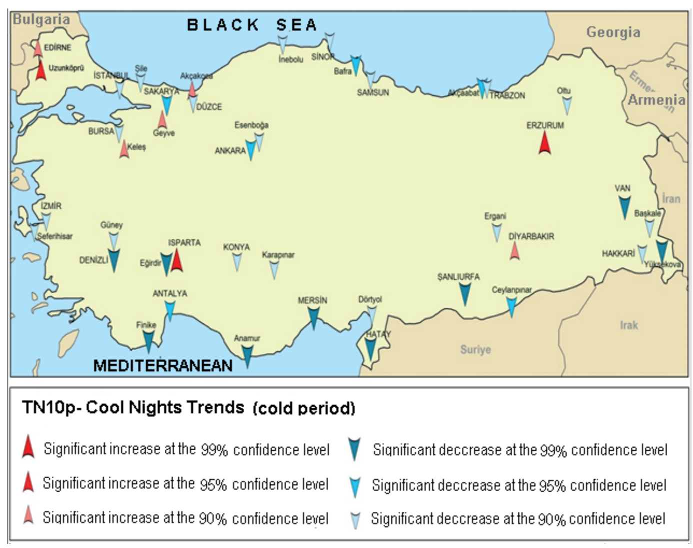

Figure 9: Cool nights trends (cold period)

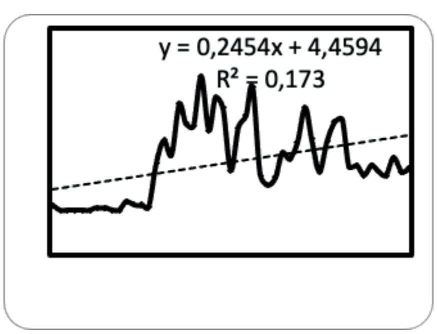

Figure 10: Eğirdir cool nights (TN10p) linear trend graphic

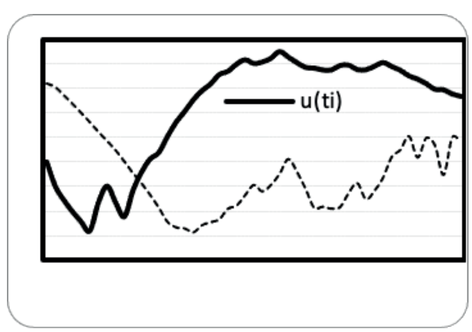

Figure 11: Eğirdir cool nights (TN10p) Mann Kendall Test graphic

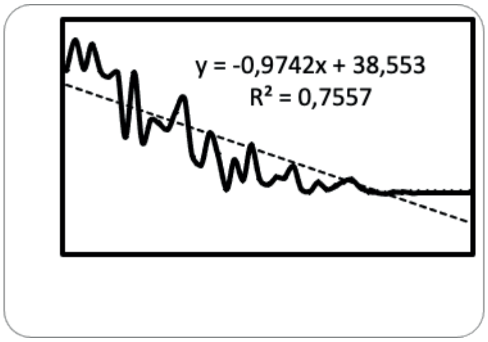

Figure 12: Mersin cool nights (TN10p) linear trend graphic

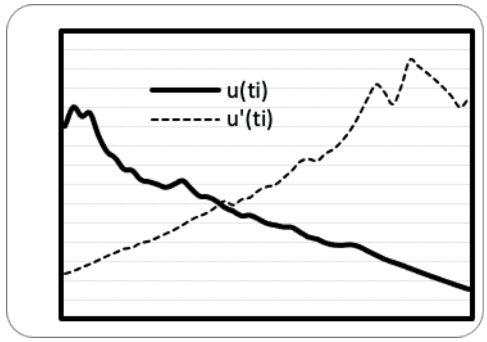

Figure 13: Mersin cool nights (TN10p) Mann Kendall Test graphic

Table 5: Cool Nights (TN10p-Urban) Mann Kendall Test Results (Hot Period)

Results of Mann-Kendall Trend Analysis											
Stations	First Year	Last Year	n	Test Z	Significance	Stations	First Year	Last Year	n	Test Z	Significance
Ankara	1970	2018	43	-3.82	***	İstanbul	1970	2018	43	-4.77	***
Antalya	1970	2018	43	-3.55	***	İzmir	1970	2018	43	-3.60	***
Bursa	1970	2018	43	-4.29	***	Konya	1970	2018	43	-2.67	***
Denizli	1970	2018	43	-6.16	***	Mersin	1970	2018	43	-7.40	***
Diyarbakır	1970	2018	43	3.16	***	Adapazarı	1970	2018	43	-4.20	***
Düzce	1970	2018	43	-2.10	**	Samsun	1970	2018	43	-1.50	
Edirne	1970	2018	43	-1.98	**	Sinop	1970	2018	43	-2.63	***
Erzurum	1970	2018	43	3.11	***	Trabzon	1970	2018	43	-1.78	*
Hakkâri	1970	2018	43	-1.57		Urfa	1970	2018	43	-5.20	***
Hatay	1970	2018	43	-4.21	***	Van	1970	2018	43	-5.09	***
Isparta	1970	2018	43	-4.54	***						

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

Table 6: Cool Nights (TN10p-Rural) Mann Kendall Test Results (Hot Period)

Results of Mann-Kendall Trend Analysis											
Stations	First Year	Last Year	n	Test Z	Significance	Stations	First Year	Last Year	n	Test Z	Significance
Esenboğa	1970	2018	43	-2.42	**	Şile	1970	2018	43	-3.02	***
Finike	1970	2018	43	-6.65	***	Seferihisar	1970	2018	43	-5.17	***
Keles	1970	2018	43	-1.84	*	Krapınar	1970	2018	43	-2.87	***
Güney	1970	2018	43	-2.55	**	Anamur	1970	2018	43	-5.57	***
Ergani	1970	2018	43	-2.85	***	Geyve	1970	2018	43	0.39	
Akçakoca	1970	2018	43	-0.83		Bafra	1970	2018	43	-3.87	***
Uzunköprü	1970	2018	43	0.66		İnebolu	1970	2018	43	-1.63	
Oltu	1970	2018	43	-1.87	*	Akçaabat	1970	2018	43	-2.68	***
Yüksekova	1970	2018	43	-5.58	***	Ceylanpınar	1970	2018	43	-4.69	***
Dörtyol	1970	2018	43	-3.71	***	Başkale	1970	2018	43	-0.65	
Eğirdir	1970	2018	43	3.76	***						

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

compared to rural stations. The ongoing increase in temperatures at nights in urban stations has reduced the number of cool nights. Urbanization creates changes in what would usually substances because of the increase in asphalt surfaces, the formation of additional heat sources and the increase in the use of vehicles. As a result, changes in temperature trends are observed. The number of cool nights decreases in urban areas due to the higher minimum temperatures at night in urban areas which are hotter during the day compared to rural areas.

3.1.3. Warm nights index (TN90p)

The warm nights index shows the number of days above the 90% percentile of the daily minimum temperature data series, aligned from large to small. It is obvious that the increase in the urban stations in warm nights is higher than the rural stations in almost all rural-urban stations. This shows that urbanization is compatible with the increase in the number of warm nights.

Significant increases are seen in most of the stations on warm nights during the hot and cold periods. The only significant decrease occurs in Isparta, Erzurum and Diyarbakır stations (**Fig. 14-19, Tables 7-8**). The tables show increases observed every 10 years in station pairs on warm nights during the cold period. Accordingly, almost all stations have significant increases in terms of warm nights. Again, the tables show that the increase in urban stations is higher than rural stations. The increase rates in the cold period are less compared to the hot period. At nights, loss of energy in urban stations is less compared to rural stations since daytime heating in urban stations is higher than the heating

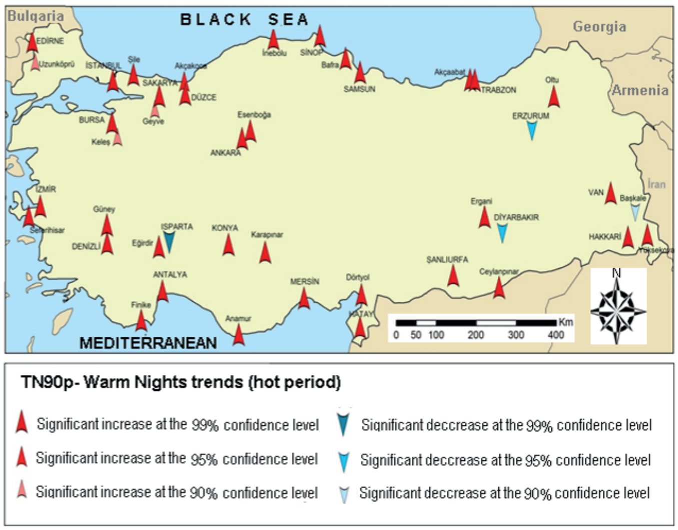

Figure 14: Warm nights trend (hot period)

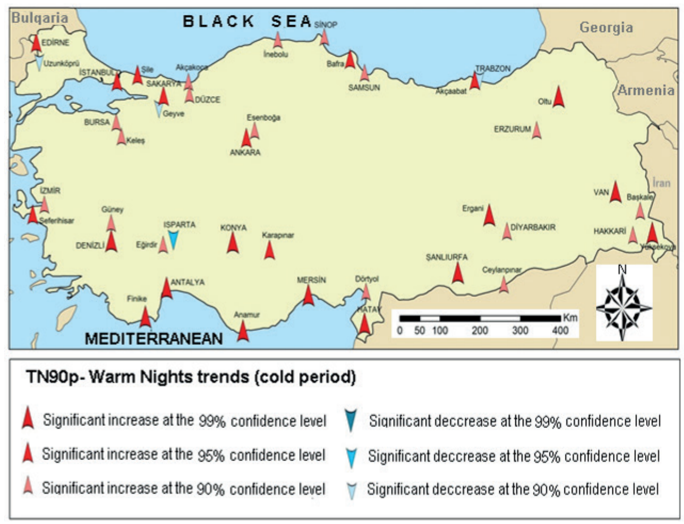

Figure 15: Warm nights trend (cold period)

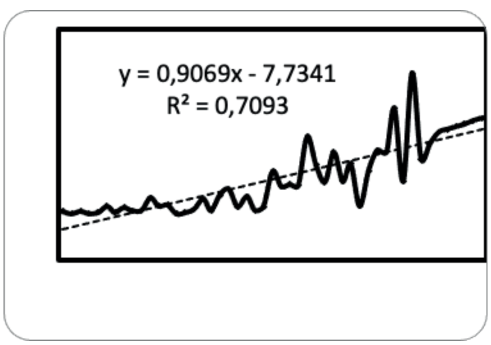

Figure 16: Mersin warm nights (TN90p) linear trend graphic

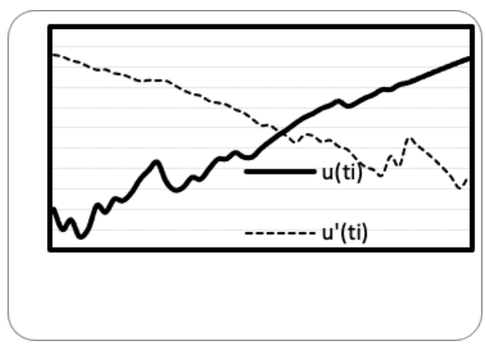

Figure 17: Mersin warm nights (TN90p) Mann Kendall Test graphic

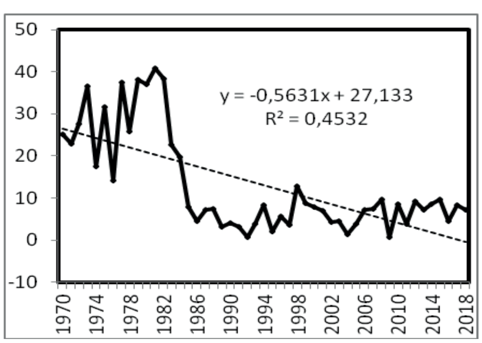

Figure 18: Eğirdir warm nights (TN90p) linear trend graphic

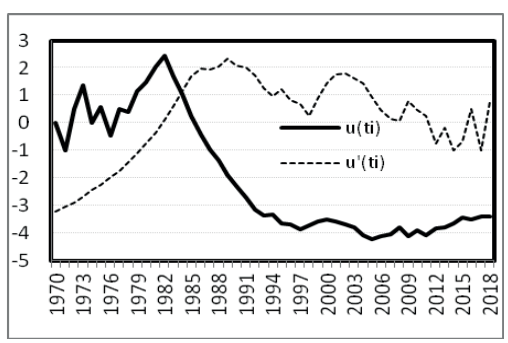

Figure 19: Eğirdir warm nights (TN90p) Mann Kendall Test graphic

Table 7: Warm Nights (TN90p -Urban) Mann Kendall Test Results (Hot Period)

Results of Mann-Kendall Trend Analysis											
Stations	First (Year)	Last (Year)	n	Test Z	Significance	Stations	First (Year)	Last (Year)	n	Test Z	Significance
Ankara	1970	2018	43	2.33	**	İstanbul	1970	2018	43	2.05	**
Antalya	1970	2018	43	2.64	***	İzmir	1970	2018	43	1.76	*
Bursa	1970	2018	43	0.15		Konya	1970	2018	43	2.79	***
Denizli	1970	2018	43	2.87	***	Mersin	1970	2018	43	5.21	***
Diyarbakır	1970	2018	43	0.29		Adapazarı	1970	2018	43	2.47	**
Düzce	1970	2018	43	0.70		Samsun	1970	2018	43	1.23	
Edirne	1970	2018	43	2.37	**	Sinop	1970	2018	43	1.54	
Erzurum	1970	2018	43	-0.60		Trabzon	1970	2018	43	-0.02	
Hakkâri	1970	2018	43	0.95		Urfa	1970	2018	43	3.80	***
Hatay	1970	2018	43	2.87	***	Van	1970	2018	43	3.87	***
Isparta	1970	2018	43	1.03							

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

Table 8: Warm Nights (TN90p -Rural) Mann Kendall Test Results

Results of Mann-Kendall Trend Analysis											
Stations	First (Year)	Last (Year)	n	Test Z	Significance	Stations	First (Year)	Last (Year)	n	Test Z	Significance
Esenboğa	1970	2018	43	1.44		Şile	1970	2018	43	2.50	**
Finike	1970	2018	43	5.57	***	Seferihisar	1970	2018	43	2.54	**
Keles	1970	2018	43	0.57		Karapınar	1970	2018	43	2.34	**
Güney	1970	2018	43	1.75	*	Anamur	1970	2018	43	4.47	***
Ergani	1970	2018	43	2.63	***	Geyve	1970	2018	43	1.20	
Akçakoca	1970	2018	43	0.69		Bafra	1970	2018	43	2.25	**
Uzunköprü	1970	2018	43	-0.26		İnebolu	1970	2018	43	1.00	
Oltu	1970	2018	43	3.55	***	Akçaabat	1970	2018	43	2.36	**
Yüksekova	1970	2018	43	4.04	***	Ceylanpınar	1970	2018	43	1.75	*
Dörtyol	1970	2018	43	1.87	*	Başkale	1970	2018	43	1.42	
Eğirdir	1970	2018	43	-2.39	**						

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

observed in rural areas and as well as effect of factors such as urbanization, population increase, proximity of industrial facilities to city centers, increase in asphalt surfaces, formation of additional heat sources and increased use of vehicles. For this reason, the number of warm nights increased more in urban centers compared to rural stations.

3.1.4. Monthly minimum value of daily minimum temperature indice (TNn)

It represents the smallest value in the series of minimum daily temperatures. There was a decrease in the Güney, Isparta, Erzurum and Diyarbakır stations and an increase in other stations in general in the hot period. In the cold period the stations showing decreasing trends are Edirne, Uzunköprü, Geyve, Isparta, Karapınar, Diyarbakır and Erzurum, which are all continental stations (**Fig. 20-23, Tables 9-10**). The monthly minimum values of daily minimum temperatures were observed to increase in most stations.

The urbanization effect is most evident at minimum temperatures. Due to the fact that the energy accumulated during the daytime in city centers can be maintened at night., the monthly minimum value of minimum temperatures are higher in urban areas compared to rural areas. In all the stations on the map, there was an increase in the minimum temperatures as a result of the general warming trend in the world, but this rate was higher in urban stations than in rural stations.

Global mean temperatures in the world are increasing. There is a similar increase in annual mean temperatures in Turkey as well. However, due to urbanization effect and local climatic conditions, the impact on living things has become more pronounced. The population is increasing rapidly both in Turkey and globally, which is accompained by rapid migration towards cities. Cities are growing spatially while their populations increase. Urbanization causes changes in the natural fabric due to the increase in asphalt surfaces, the formation of additional heat sources and the increase in the use of vehicles.

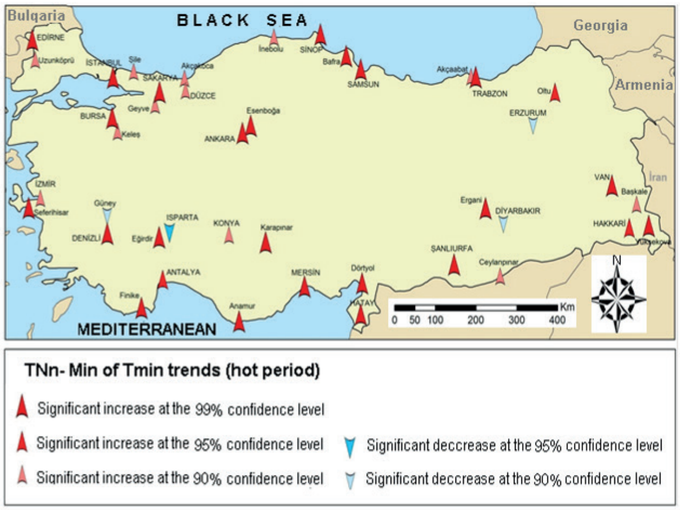

Figure 20: Minimum of daily minimum temperature (TNn) (hot period)

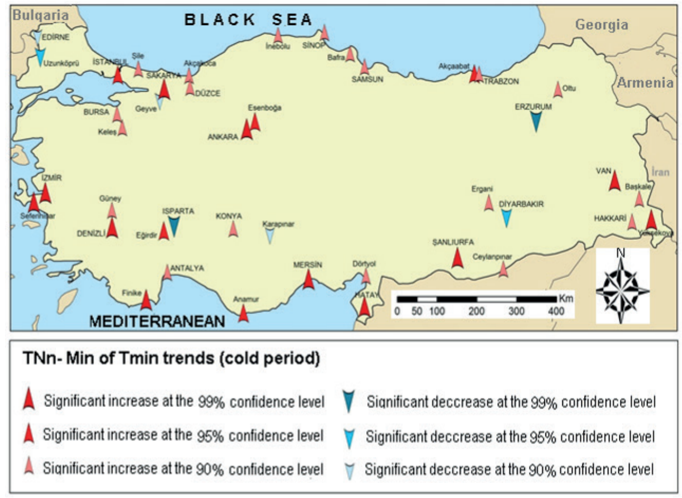

Figure 21: Minimum of daily minimum temperature (TNn) (cold period)

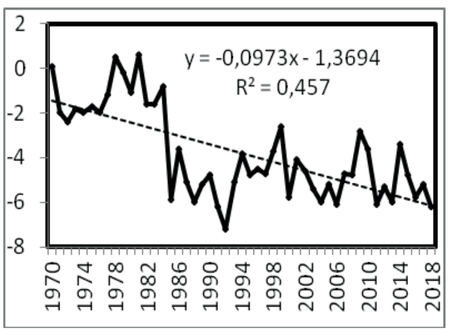

Figure 22: Eğirdir minimum of daily minimum temperature (TNn) linear trend graphic

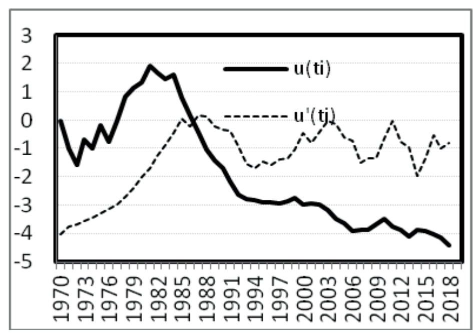

Figure 23: Eğirdir minimum of daily minimum temperature (TNn) Mann Kendall Test graphic

In Europe, the greatest increase in mean temperatures was detected between 0.5 and 1.0 °C per decade in winter and spring. It was observed that the long-term temperature changes varied regionally depending on the season. It was identified that warming was faster in the spring in southwest Europe, the southeast, and its central parts compared to winter since the 1960s (de Luis et al., 2014; Dumitrescu et al., 2015; El Kenawy et al., 2012; Serquet et al., 2011); While it was concluded that summer warming was the increasing trend in southeast Europe, it was identified that autumn and winter had near-zero or slightly declining trends (Brázdil, 2009; Feidas et al., 2004; Klein Tank et al., 2005; Mamara et al., 2016).

This study examined the change of extreme temperature indices in urban and rural areas based on the urban/rural centers in Turkey in addition to the overall global warming trend in the world.

In the study, a significant increase of 99% was observed in 34 stations during hot periods in the warm nights. In the cold season, there was a significant increase of 99% in 21 stations while an increase of 90% were observed in 17 stations during warm nights.

Significant decreases of 99% were detected at 27 stations in the 42 city-rural stations that were investigated in the cool nights during the hot period. There was a significant decrease of 99% and 95% at 15 stations in the cool nights during the cold period and an decrease of 90% at 17 stations. The obtained results show the minimum temperatures and accordingly the number of tropical nights have increased in Turkey since mid-80s. This shows results that are similar to Erlat and Türkeş's, 2017 study. Significant increases of 99% and 95% were observed in the monthly minimum value of minimum temperatures of the hot period in the examined stations, and increases at the level of 90% were observed in 11

Table 9: Minimum of Daily Minimum Temperature (Tnn -Urban) Mann Kendall Test Results

Results of Mann-Kendall Trend Analysis											
Stations	First Year	Last Year	n	Test Z	Significance	Stations	First Year	Last Year	n	Test Z	Significance
Ankara	1970	2018	43	3.74	***	İstanbul	1970	2018	43	3.69	***
Antalya	1970	2018	43	3.62	***	İzmir	1970	2018	43	4.06	***
Bursa	1970	2018	43	3.52	***	Konya	1970	2018	43	2.43	**
Denizli	1970	2018	43	5.24	***	Mersin	1970	2018	43	6.68	***
Diyarbakır	1970	2018	43	-3.04	***	Adapazarı	1970	2018	43	4.24	***
Düzce	1970	2018	43	1.58		Samsun	1970	2018	43	1.62	
Edirne	1970	2018	43	2.79	***	Sinop	1970	2018	43	2.84	***
Erzurum	1970	2018	43	-3.70	***	Trabzon	1970	2018	43	2.27	**
Hakkâri	1970	2018	43	0.75		Urfa	1970	2018	43	3.16	***
Hatay	1970	2018	43	4.13	***	Van	1970	2018	43	3.34	***
Isparta	1970	2018	43	4.69	***						

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

Table 10: Minimum of Daily Minimum Temperature (Tnn -Rural) Mann Kendall Test Results

Results of Mann-Kendall Trend Analysis											
Stations	First Year	Last Year	n	Test Z	Significance	Stations	First Year	Last Year	n	Test Z	Significance
Esenboğa	1970	2018	43	1.97	**	Şile	1970	2018	43	0.78	
Finike	1970	2018	43	6.41	***	Seferihisar	1970	2018	43	4.58	***
Keles	1970	2018	43	0.71		Karapınar	1970	2018	43	2.97	***
Güney	1970	2018	43	1.90	*	Anamur	1970	2018	43	6.27	***
Ergani	1970	2018	43	2.33	**	Geyve	1970	2018	43	-1.47	
Akçakoca	1970	2018	43	0.43		Bafra	1970	2018	43	3.67	***
Uzunköprü	1970	2018	43	-1.32		İnebolu	1970	2018	43	1.67	*
Oltu	1970	2018	43	0.91		Akçaabat	1970	2018	43	1.94	*
Yüksekova	1970	2018	43	3.60	***	Ceylanpınar	1970	2018	43	2.38	**
Dörtyol	1970	2018	43	2.57	**	Başkale	1970	2018	43	0.34	
Eğirdir	1970	2018	43	-3.64	***						

1.645-1.96 * (Within 90% confidence interval),1.96-2.58 ** (Within 95% confidence interval),2.58 + *** (Within 99% confidence interval)

stations. While significant increases of 99% and 95% were observed at the monthly minimum value of minimum temperatures in 16 stations, increases were observed at the level of 90% in 18 stations in cold period. Another indicator of the warming trend is the Diurnal Temperature Range (DTR) obtained from the difference of maximum and minimum temperatures. Since the minimum temperature increases in cities are greater than the maximum temperature increases, DTR generally exhibits significant decreasing trends. On the other hand, significant increasing trends are generally observed in rural areas, in the maximum temperature. There was a significant decrease of 99% and 95% DTR difference in the hot period in 23 stations, and an increase of 90% in 9 stations. Cold period DTR difference decreased significantly at the level of 99% and 95% in 23 stations, while increases at 90% level were observed in 10 stations.

4. CONCLUSIONS

The indices that best show the difference between urban and rural are DTR, TN10p, TN90p and TNn, which are associated with minimum temperature. Therefore, in this study, the trend results of these 4 indices for the period 1970-2018 were examined. Climate indices are indicators that are produced from raw data and show changes in climate. In other words, indices take a snapshot of the data (Xiaolan, 2003). For this reason, indices and descriptive statistics were used to reveal the difference between urban and rural.

Trends in DTR: When the hot period is examined, there are generally significant tendencies of decrease in the Diurnal Temperature Range as the minimum temperature increases in the cities are higher than the maximum temperature increases. In rural areas, significant increases are generally observed in DTR since maximum temperature increases are higher than minimum temperature increases. When the cold period is analyzed, significant increase trends are observed as well. Continentality also has a large effect on increasing trends in DTR.

Trends in TN10p: Significant decreases were observed in cool nights in all stations during the hot period. When the cold period was examined, it was found that there was a decrease in cool nights. Although this decrease was not as significant as the decrease in the hot season, the decrease in the number of cool nights in urban stations was higher than in rural stations.

Trends in TN90p: The number of warm nights, in general, shows significant increases in all stations in the hot season. When the cold period is examined, it was observed that there was a significant increase in most of the stations on warm nights. There was an increase in the number of warm nights in urban-rural stations. The increase in the number of warm nights in urban stations was higher than in rural stations. The energy accumulated in the cities during the day is slowly given back to the city by long wave radiation at night. This is an indication of Urban Heat Island (UHI) which is why cities are warmer than rural areas at night.

Trends in TNn: When the hot period was considered, it was generally found that even the monthly minimum value of daily minimum temperatures increased in most of the stations, and when the cold period was examined, it was generally found that even the minimum value of daily minimum temperatures increased in most of the stations. Urbanization causes the highest increase in minimum value of minimum temperatures. Since city areas retain heat gained during the daytime at night, they form an Urban Heat Island (UHI), which leads to an increase in minimum temperatures.

The results of the trend analysis show that while there is more increase in terms of minimum temperatures in cities, the maximum temperature increase is more evident in rural stations where urban canyon effect is not observed. The decrease in differences between station pairs indicates that the diurnal temperature range decreases more rapidly in urban stations. The most rapid increase in TN10p and TN90p tendency occurs in the stations located in the Black Sea, Aegean and Mediterranean coastal zones where the moisture content in the air is higher. This suggests that increased moisture content in the atmosphere as a result of global climate change is due to positive feedback from humidity.

While temperature increases were observed in all stations due to climate change, it was found that the additional effect of Urban Heat Island (UHI) generated higher temperature increases in cities. It was observed that minimum temperature increases were higher in cities while maximum temperature increases were higher in rural areas.

Temperature rises are experienced around the world with varying degrees of intensity caused by local variations created by mankind. Turkey is no exception, as its cahenges vary from region to region. It is natural that changes observed in extreme temperature indices vary across Turkey, which has high climate variations due to factors such as a large surface area, geographical formations, elevation, terrestrial and nautical geographical conditions.

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