URBANIZATION EFFECT ON TRENDS OF EXTREME TEMPERATURE INDICES IN ANKARA

Serhat SENSOY (1), Necla TÜRKOĞLU (2), İhsan ÇİÇEK (2), Mesut DEMİRCAN (1), Hüseyin ARABACI (1), Erdoğan BÖLÜK (1)

(1) Turkish State Meteorological Service, Ankara, Turkey Email: ssensoy@mgm.gov.tr
(2) Ankara University, Faculty of Languages, History and Geography, Ankara, Turkey
Emails: nturkoglu@ankara.edu.tr , ihsan.cicek@ankara.edu.tr , mdemircan@mgm.gov.tr , harabaci@mgm.gov.tr , eboluk@mgm.gov.tr

Özet: Ekstrem sıcaklık olaylarının uzun süreli değişimlerini anlamak, iklim değişikliğinin tespiti ve özelliklerinin anlaşılması için önemlidir. Bununla birlikte kentleşmeden ne kadar etkinin geldiği açık değildir. Bu çalışmada kent özelliğine sahip Ankara iklim istasyonu ile kırsal özelliklere sahip Esenboğa istasyonu seçilmiştir. Nüfusu 100 binin altında olan yerler kırsal olarak belirlenmiştir. (Kındap vd., 2012; Hua vd., 2007). 1960-2010 periyodunda günlük veriler kullanılarak iklim indislerini hesaplamak için RClimDex yazılımı kullanılmıştır. Hesaplanan sıcaklıkla ilişkili iklim indislerinin trendlerine bakılarak Ankara kent merkezi için şehirleşme etkisi değerlendirilmiştir. Kentleşme etkisini gösteren en belirleyici indisler minimum sıcaklıklarla ilişkili olan Donlu Günler (FD0), Serin Geceler (TN10p), Sıcak Geceler (TN90p), Soğuk Devre Süresi (CSDI), Tropik Geceler (TR20), Büyüme Sezonu Uzunluğu (GSL) ve Günlük Sıcaklık Aralığı (DTR) indisleridir. Yaz Günü (SU25), Sıcak Günler (TX90p) ve Sıcak Devre Süresi İndisleri (WSDI) ise maksimum sıcaklıkla ilişkili indislerdir ve güneş etkisi nedeniyle şehirleşme etki analizinde belirleyici değillerdir. Sonuçlar kentleşmenin en belirgin etkisinin minimum sıcaklıklar üzerine olduğunu göstermiştir. Minimum sıcaklıktaki artışlar kent içerisinde Tmax-Tmin olarak hesaplanan DTR'yi azaltmakta iken kırsal alanda ise minimum sıcaklığın gece daha fazla düşmesiyle bu aralık artmaktadır. Trendlerin çoğu %95 seviyesinde istatistiksel olarak önemli bulunmuştur. Sonuçlar Ankara'da hızlı nüfus artışı, artan trafik, yeşil alanın azalması, sanayileşme, asfalt-beton gibi sıcaklığı emen yüzeyler ve şehrin jeomorfolojisinin de katkısıyla yaşanan sıcaklık terselmeleri şehirleşme etkisinin artmasına sebep olmaktadır (Çiçek, 2004).
Anahtar Kelimeler: Şehirleşme, iklim değişikliği, indisler, eğim

Abstract: Understanding the long-term change of extreme temperature events is important to the detection and attribution of climate change. However, it's unclear how much effect coming from the urbanization. In this study we selected Ankara climate station which has the city characteristics and Esenboğa station which has rural characteristics If the population less than 100 thousand it's determined as rural area (Kındap et al., 2012; Hua et al, 2007). Daily data has been used and RClimDex software has been run in order to calculate climate indices for the time periods of 1960-2010. Urbanization effects on trends of extreme temperature indices in Ankara have been evaluated. The most decisive climate indices which show urbanization effects have been found as Frost Day (FD0), Cool Night (TN10p), Cold Spell Duration Index (CSDI). Warm Night (TN90p), Tropical Night (TR20) and Growing Season Lengths (GSL) trends are greater in the city than rural. However, Summer Days (SU25), Warm Days (TX90p) and Warm Spell Duration Indices (WSDI) haven't found as decisive for urbanization effect due to sunrise relation. The results show that the most obvious effect of urbanization on climate is on minimum temperatures. These results show stronger urbanization effect in Ankara due to decreasing green areas, increasing concrete and asphalt surfaces, low albedo values, different latent heat flux and heating from traffic and other energy uses. Its geomorphology and accordingly development of inversion effect have additional contribution to the urbanization in Ankara (Çiçek, 2004).
Keywords: Urbanization, climate change, indices, trend

MATERIALS AND METHODS

In this study, we have run RClimDex software to calculate temperature related climate indices for rural station Esenboğa (33.00E, 40.07N) and urban station Kalaba, Ankara (32.53E, 39.57N) for the period from 1960 to 2010. We selected the same data period in order to compare station's outputs for the same climatic period. In order to detect urbanization effect, we computed average trends for every index, relative to the period 1971-2000. Before the index calculation, data quality controlled and their homogeneity tested. We run RClimDex software to calculate indices (Zhang, X., et al., 2005). Software user guide are available from (Url 1). http://etccdi.pacificclimate.org/software.shtml.

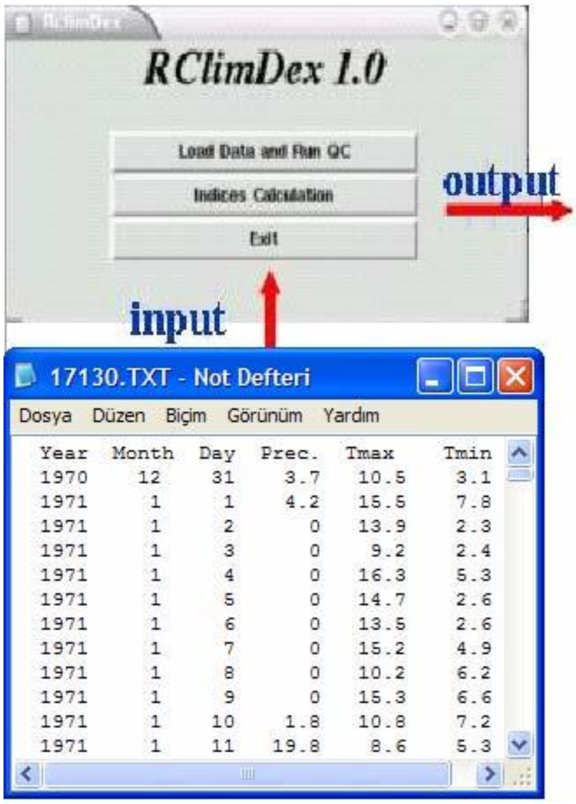


Figure 1. *RClimDex Software and raw data*

After the data had been quality controlled and tested for homogeneity, RClimDex calculates and creates 16 temperature related climate indices (Table 1).

Table 1. *List of temperature related climate indices used in the study*

ID	Indicator name	Definitions	UNITS
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
ID0	Ice days	Annual count when TX(daily maximum)<0ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
FD0	Frost days	Annual count when TN(daily minimum)<0ºC	Days
GSL	Growing season Length	Count of day at least 6 days T>5ºC	Days
TXx	Max Tmax	Monthly max. value of daily maximum temp	ºC
TXn	Min Tmax	Monthly min. value of daily maximum temp	ºC
TNx	Max Tmin	Monthly max. value of daily minimum temp	ºC
TNn	Min Tmin	Monthly min. value of daily minimum temp	ºC
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temp. range	Monthly mean difference between TX and TN	ºC

Kendall's tau based slope estimator has been used to compute the trends since this method doesn't assume a distribution for the residuals and is robust to the effect of outliers in the series (Sensoy, S., et al, 2013).

URBANIZATION- CLIMATE RELATIONSHIP

Large concrete buildings and roads due to their thermal capacity store emit greater heat than the lighter surfaces and vegetation. One of the fundamental components that set a city apart from its rural surroundings is the climate that prevails over urban environments. In urban areas, buildings and paved surfaces have gradually replaced preexisting natural landscapes. As a result, solar energy is absorbed into roads and rooftops, causing the surface temperature of urban structures to become 10-21°C higher than the ambient air temperatures (Taha, 1992).

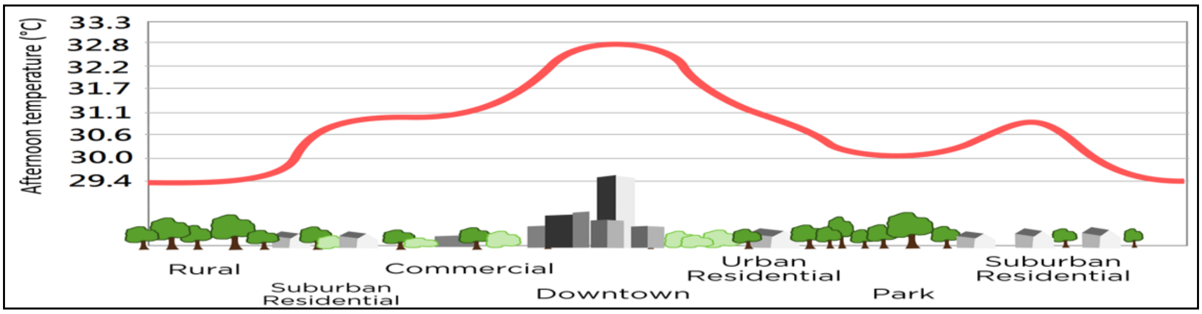


Figure 2. *Urban heat island profile (modified from NOAA, 1999) (Url 2,3)* ***(****Tanrıkulu, 2006)*

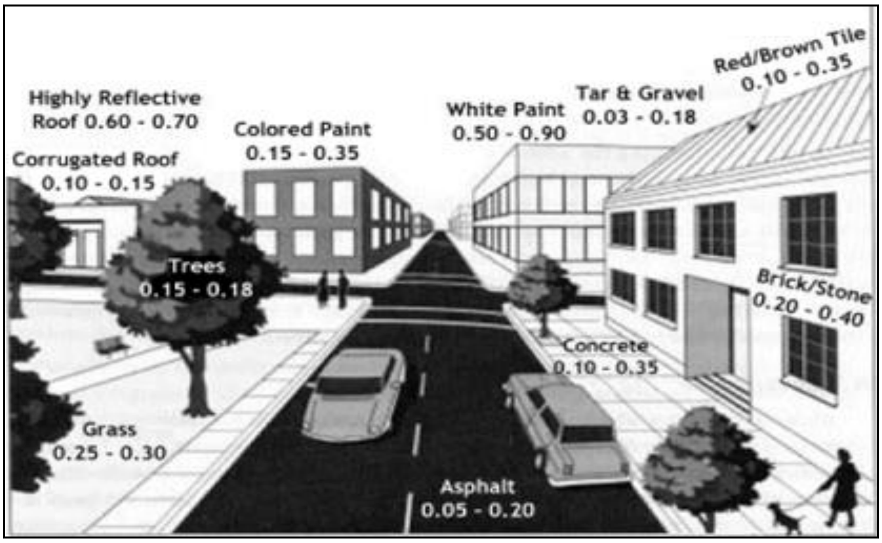


Figure 3. *Various urban environment albedos (NOAA, 1999)*

Figure 3 shows albedo values for various urban surfaces, the albedo is a measure of the amount of solar energy reflected by the surface. Beside the low albedo, different latent heat flux and heating from traffic and other energy uses can raise air temperature in a city by

1 - 3°C. This phenomenon is known as an "urban heat island (Oke, 1982).

GEOGRAPHICAL AND DEMOGRAPHIC INFORMATION OF ANKARA

Study area was selected as rural station Esenboğa (33.00E, 40.07N, elevation 949 m) and urban station Kalaba, Ankara (32.53E, 39.57N, elevation 891 m). Bird's eye view distance between two stations is 23km.

Figure 4. *Geographic Location of rural station (Esenboğa) and urban station (Kalaba, Ankara)*

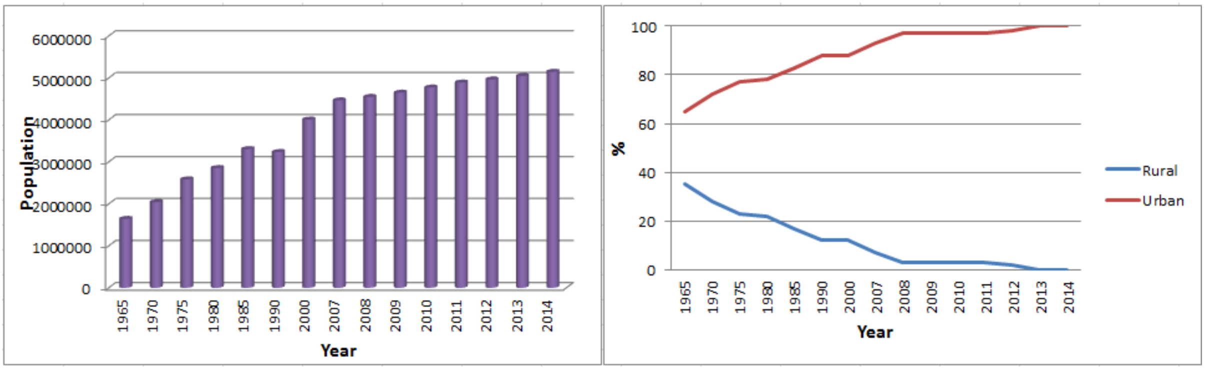


Figure 5. *Ankara population (left), Ankara rural and urban population ratio (right) (TUİK),(Url 5)*

Ankara population was 1.644.302 in 1965 but its population increased more than 3 times since 1965 (5.146.307 in 2014). From 1970 to 2007 there are great changes in the population. This shows that beside the normal population growth rate, there are great amount of migrant population to Ankara. As a result Ankara urban environment under the stress of increased and migrant population, enhanced energy consumption of the growing population, increased traffic load and industrial activity, deforestation and release of waste product into the atmosphere and hydrosphere. Ankara rural population ratio has decreased from 35% to 0 while urbanization ratio increased from 65% to 100%.

ANKARA CLIMATIC CONDITIONS

According to Thornthwaite climate classification, Ankara has been found semi dry in southern part, semi dry-less humid in northwestern part and semi humid in northern Nallıhan. Because of the continental climate condition, there are big differences between day and night temperature and winter and summer temperature. According to Trewartha climate classification, universal thermal scale, winter is cold (1.3°C), summer is warm (22°C) (Url 4).

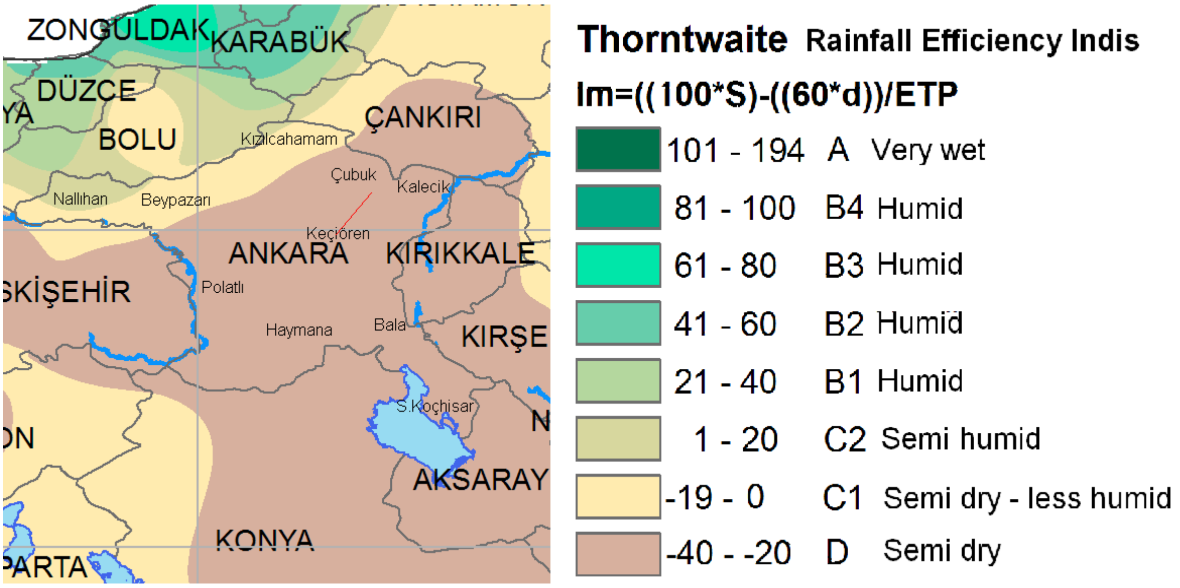


Figure 6. *Ankara climate classification via Thornthwaite method (Sensoy, S., 2006)*

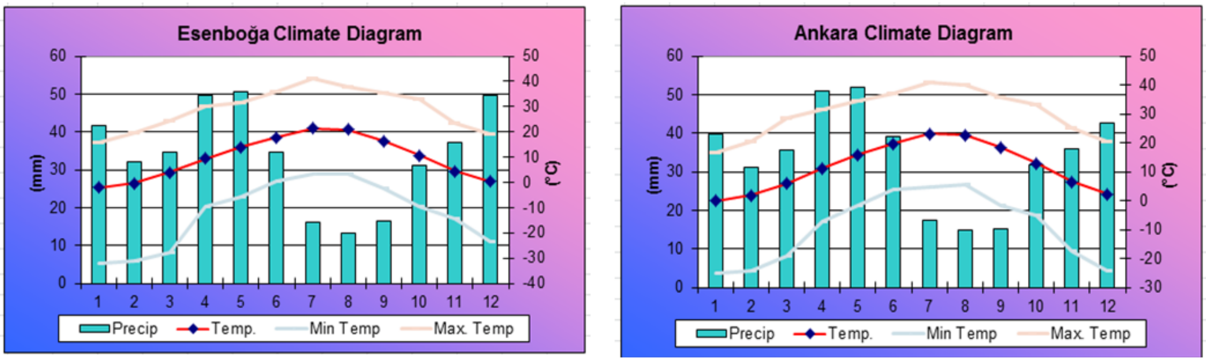


Figure 7. *Climate diagram for Esenboğa (left) and Climate diagram for Kalaba, Ankara (right)*

Esenboğa and Ankara usually receive rainfall in all months but July, August and September precipitation are less. Mean annual precipitation total is 406 mm in both stations. Minimum temperature are -32.2°C and -24.9°C, maximum temperature are 41.2°C and 41.0°C and mean temperature is 9.7°C and 11.6°C respectively.

RESULTS

Table 2. *Trends in temperature related climate indices in Esenboğa and Ankara*

			Kendall's tau based slope estimate	
Indice	**Start Year**	**End Year**	**Esenboğa**	**Kalaba, Ankara**
SU25	1960	2010	0.368 *	0.190
ID0	1960	2010	-0.030	-0.020
TR20	1960	2010	0.028 *	0.206 *
FD0	1960	2010	0.177	-0.120
GSL	1960	2010	0.081	0.334
TXx	1960	2010	0.039 *	0.026
TXn	1960	2010	0.081 *	0.051 *
TNx	1960	2010	0.037 *	0.048 *
TNn	1960	2010	0.105 *	0.088 *
TX10p	1960	2010	-0.015	-0.005
TX90p	1960	2010	0.124 *	0.069
TN10p	1960	2010	-0.025	-0.113 *
TN90p	1960	2010	0.093	0.209 *
WSDI	1960	2010	0.247 *	0.133
CSDI	1960	2010	-0.013	-0.077
DTR	1960	2010	0.009	-0.013 *

(*) Trends are statistically significant at 95% level (p value < 0.0.5)

Urbanization effects on trends of extreme temperature indices in Ankara have been evaluated. The most decisive climate indices which show urbanization effects have been found as Frost Day (FD0) which has decreasing trend in Ankara as -0.12days(10yr)$^{-1}$ while increasing in Esenboğa as 0.177days(10yr)$^{-1}$, Cool Night (TN10p) -0.113days(10yr)$^{-1}$, and -0.025days(10yr)$^{-1}$, Warm Night (TN90p) 0.209days(10yr)$^{-1}$, 0.093days(10yr)$^{-1}$ Cold Spell Duration Index (CSDI) -0.077days(10yr)$^{-1}$, -0.013days(10yr)$^{-1}$, Tropical Night (TR20) 0.206days(10yr)$^{-1}$, 0.028days(10yr)$^{-1}$, Growing Season Lengths (GSL) 0.334days(10yr)$^{-1}$, 0.081days(10yr)$^{-1}$ respectively. However, Summer Days (SU25), Warm Days (TX90p) and Warm Spell Duration Indices (WSDI) are related with maximum temperature and haven't found as decisive for urbanization effect due to sunrise relation.

The results show that the most obvious effect of urbanization on climate is on minimum temperature. This causes decrease in Diurnal Temperature Range (DTR=Tmax-Tmin) in Ankara as -0.013ºC$(10yr)^{-1}$ while increasing in rural station Esenboğa as 0.009ºC$(10yr)^{-1}$. Most of these trends found statistically significant at 95% level. These results show stronger urbanization effect in Ankara.

COMPARISON OF TRENDS IN TROPICAL NIGHTS (TR20)

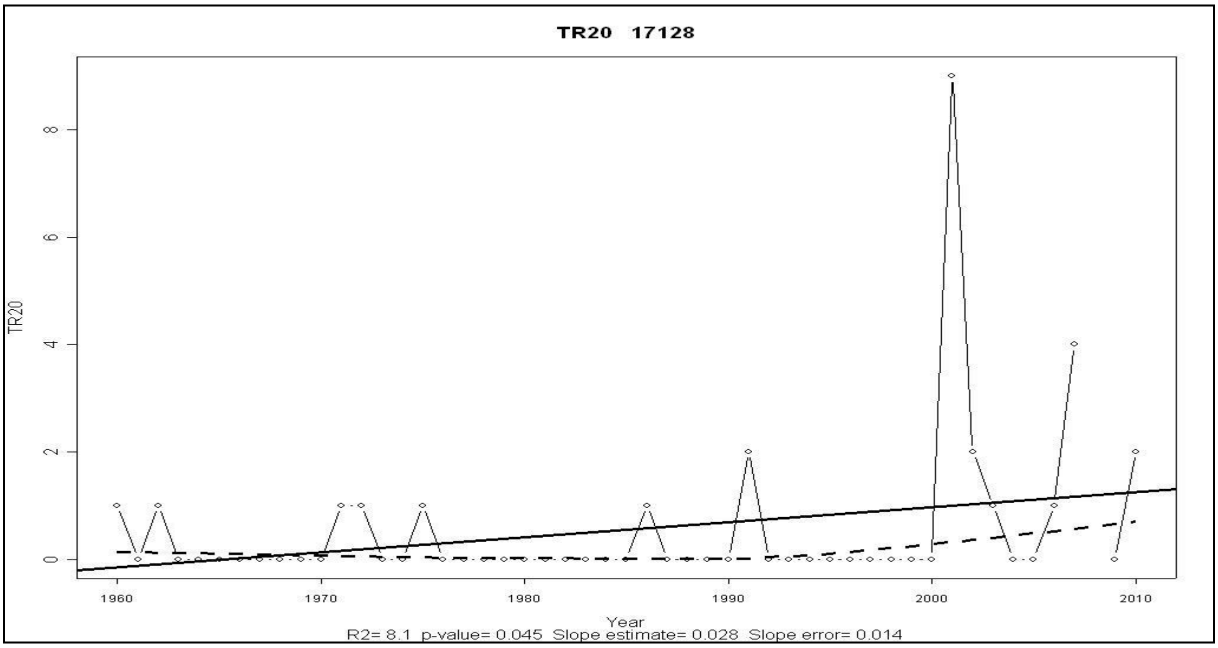


Figure 8*. Trend in Tropical night in Esenboğa*

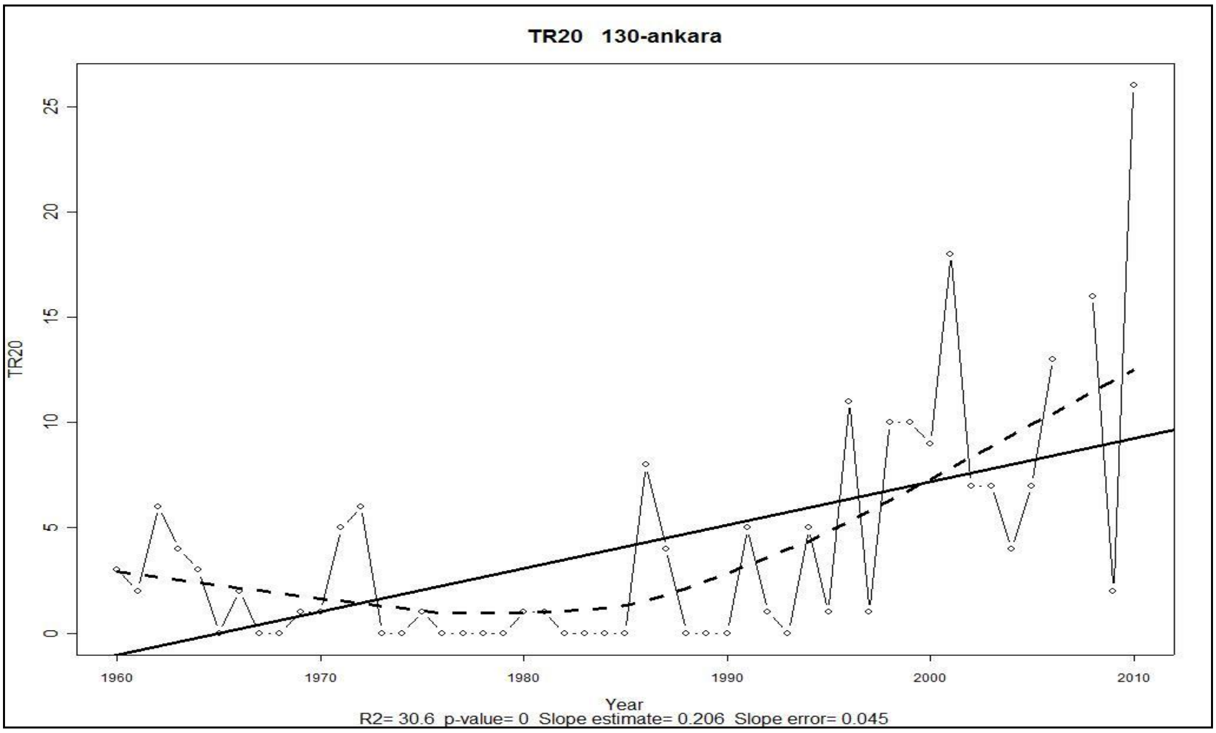


Figure 9. *Trend in Tropical night in Kalaba, Ankara*

A tropical night is Tmin > 20°C and have increasing trend in Esenboğa and Ankara as 2.8 and 20.6 days/100 years respectively. But urban trend 7 times stronger than rural. This shows that the urban cause a clear increase over the minimum temperature due to heated surface release temperature more slowly than rural in the night. Both trends are statistically significant at 95% level due to p value is less than 0.05.

COMPARISON OF TRENDS IN FROST DAYS (FD0)

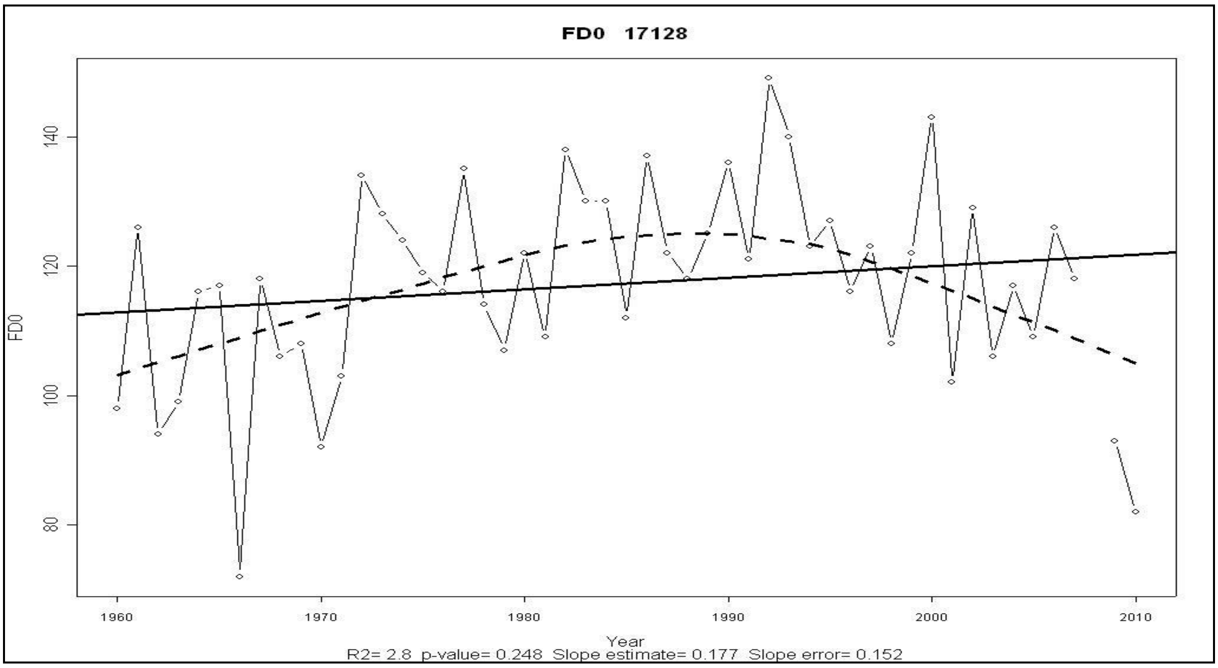


Figure 10. *Trend in frost day in Esenboğa*

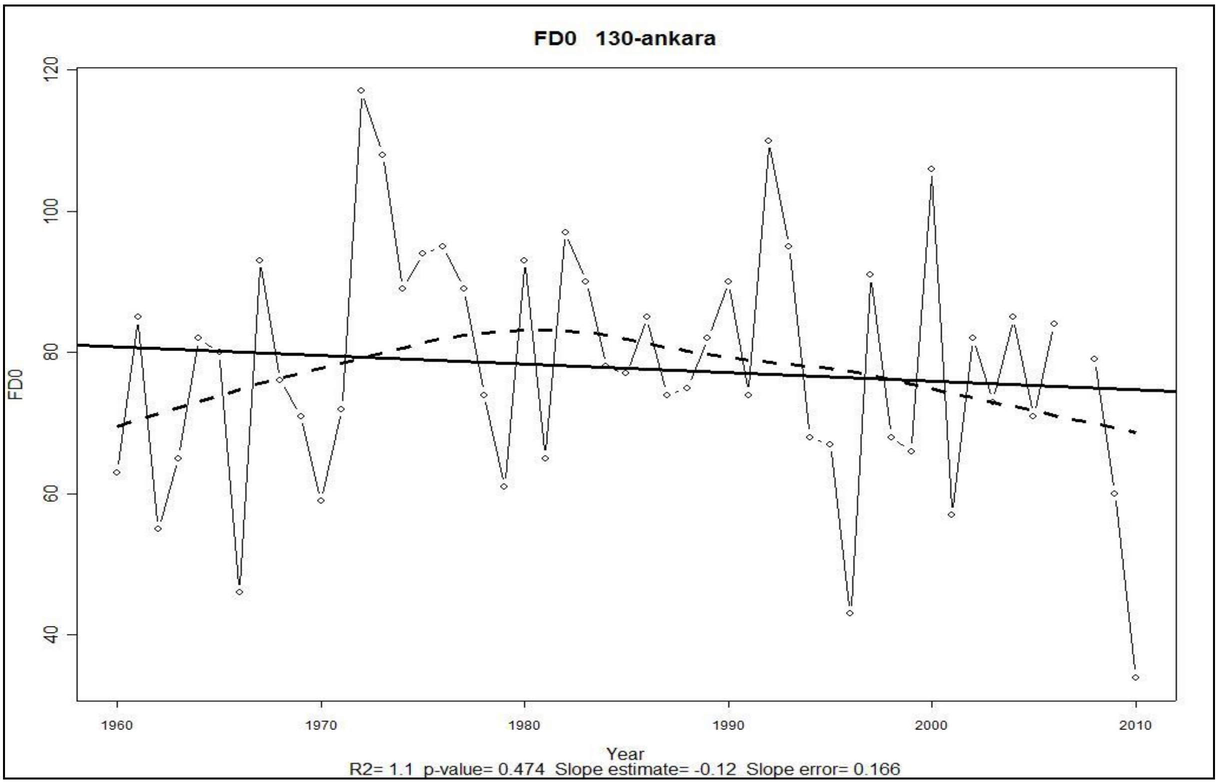


Figure 11. *Trend in frost day in Kalaba, Ankara*

Frost days is the day which Tmin < 0°C and have increasing trend in Esenboğa as 17.7 days but decreasing trend as 12 days/100 years in Ankara. This shows that the urban cause a clear increase over the minimum temperature and this cause decreasing trend in frost days in the city.

COMPARISON OF TRENDS IN COOL NIGHTS (TN10P)

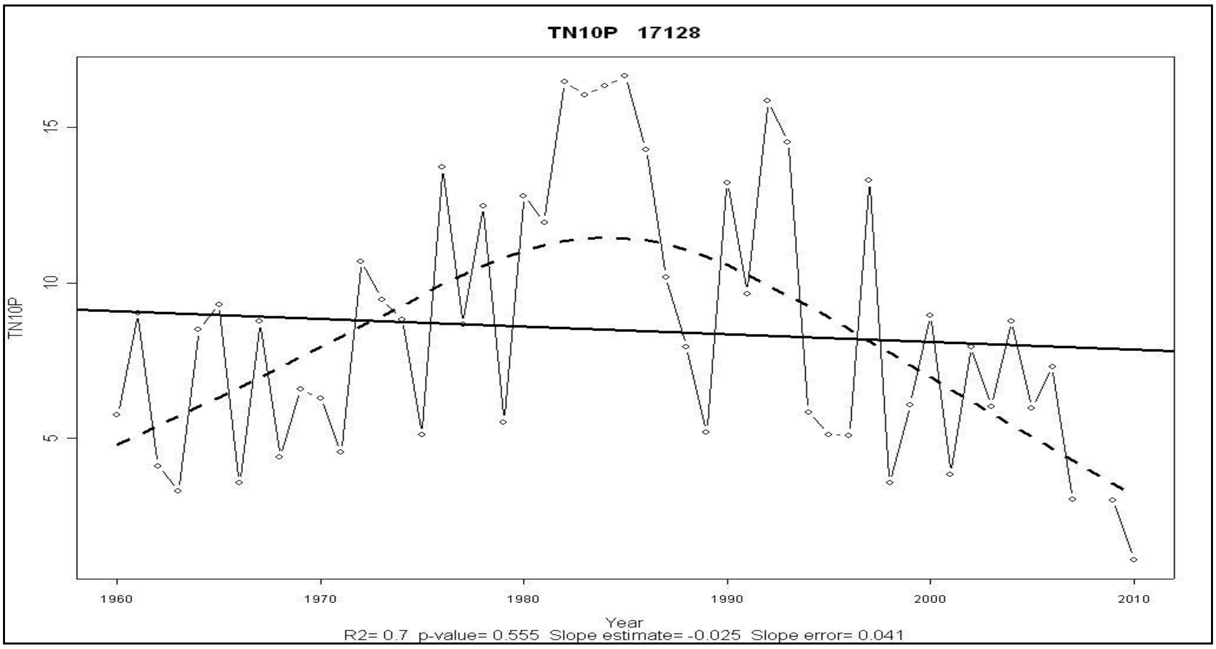


Figure12. *Trend in cool nights in Esenboğa*

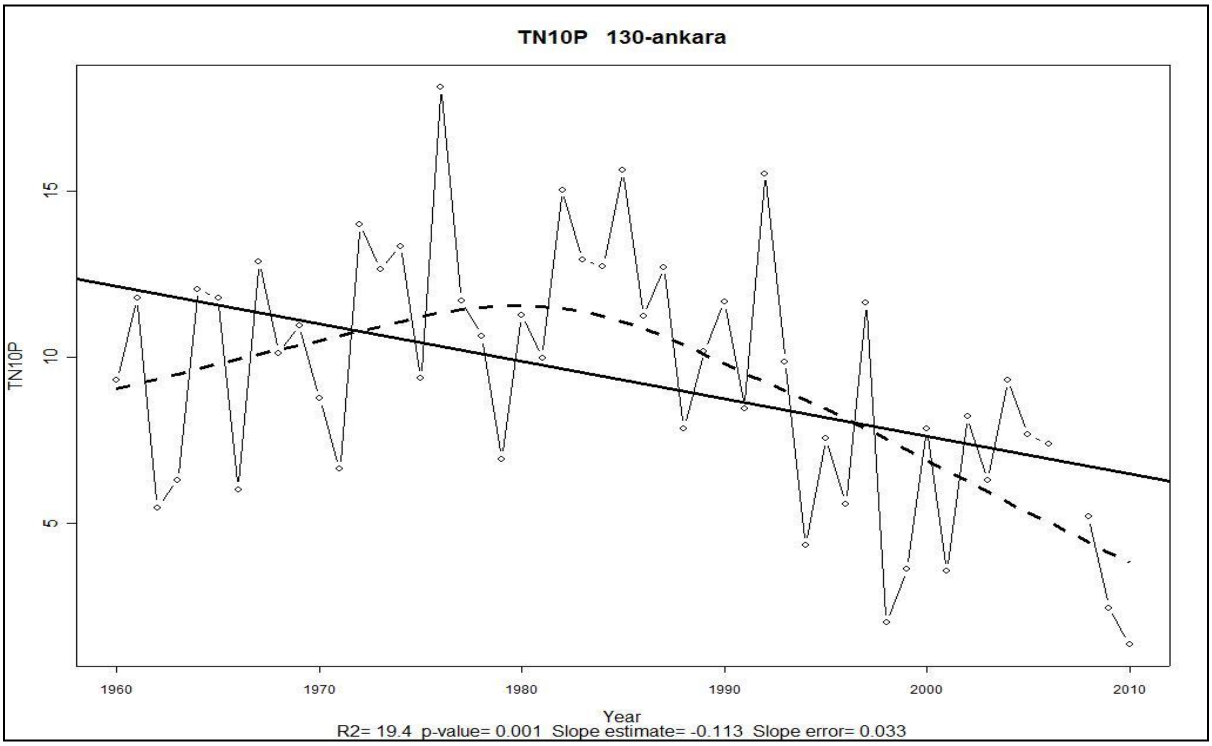


Figure 13. *Trend in cool nights in Kalaba, Ankara*

Cool nights (TN10p) is Tmin < 10th percentile and have decreasing trend in Esenboğa and Ankara as 1.7 and 4.8 days/100 years respectively. This shows that the cool night is rapidly decreasing in urban areas than rural due to increased minimum temperature. Ankara trend is 4.5 times stronger and significant at 95% level of confidence.

COMPARISON OF TRENDS IN DIURNAL TEMPERATURE RANGE (DTR)

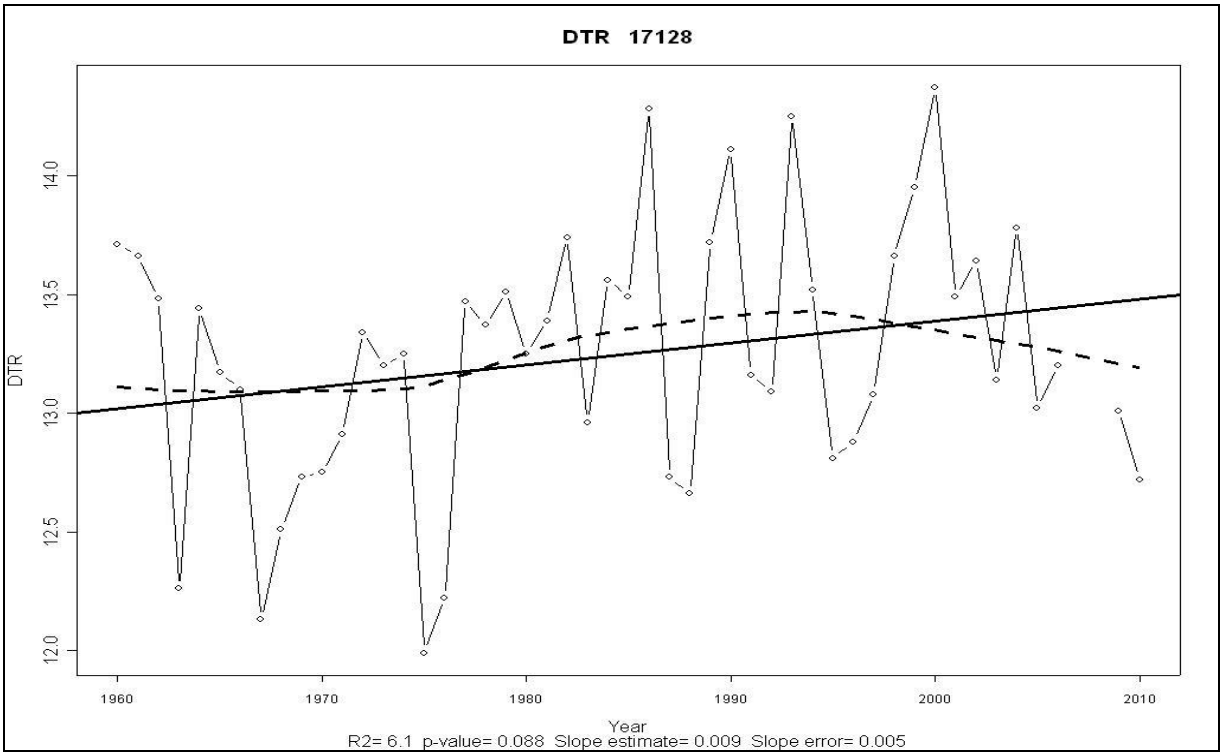


Figure 16. *Trend in diurnal temperature range in Esenboğa*

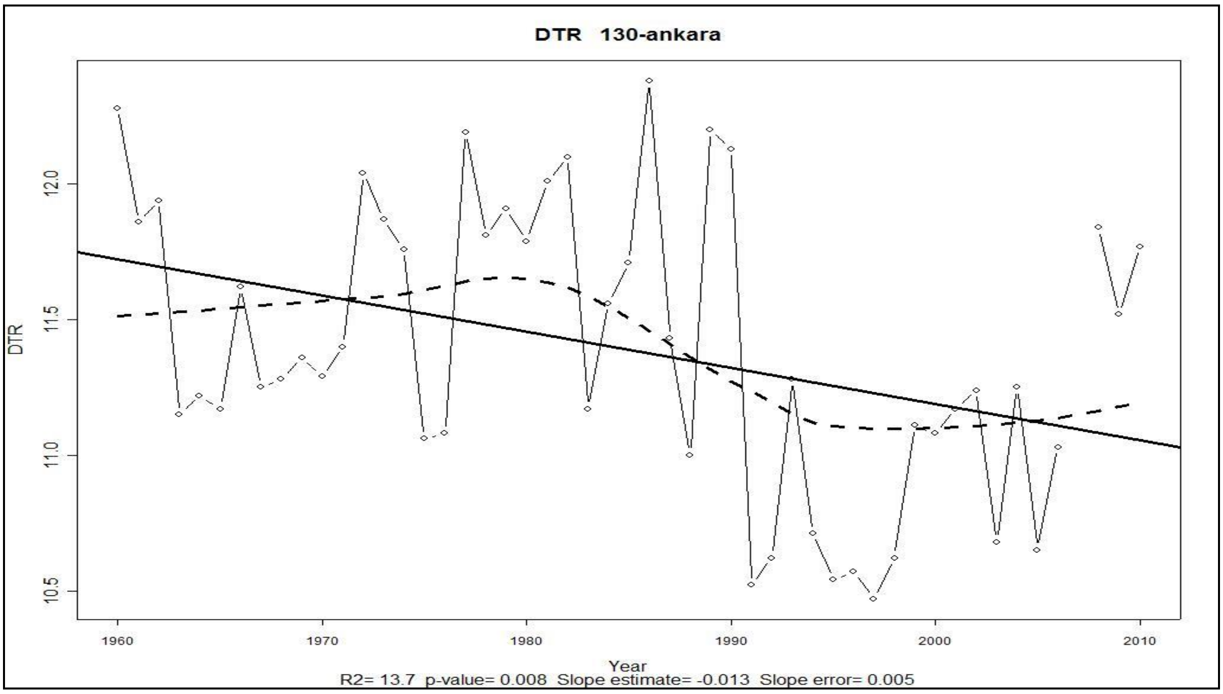
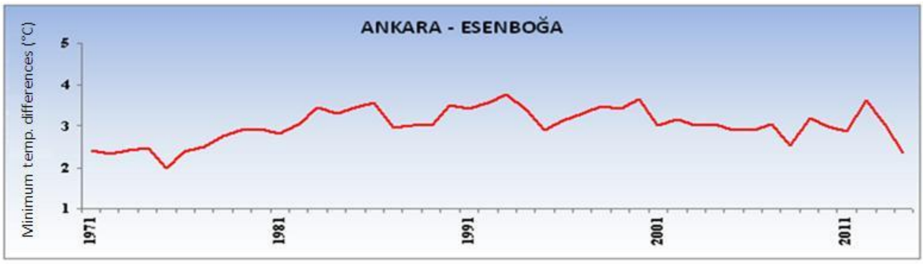


Figure 17. *Trend in diurnal temperature range in Kalaba, Ankara*

Diurnal temperature ranges is Tmax - Tmin. and have increasing trend in Esenboğa as 0.9°C but decreased trend as 1.3°C/100 years in Ankara. This shows that Ankara city center cause a clear increase over the minimum temperature and this cause decreasing trend in DTR. Ankara trend is statistically significant at 95% level of confidence.



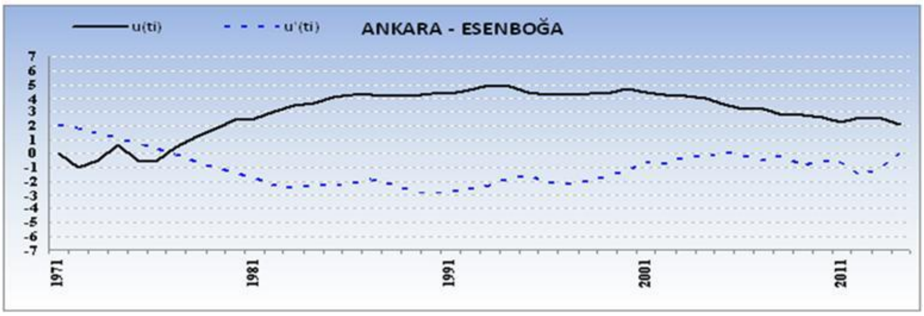


Figure 18. *Minimum temperature differences (upper) and its Mann-Kendall Test (lower)*

Urban-rural minimum temperature differences are small in the beginning of the period but have been increased since 1980. Mann Kendall trend statistics of the minimum temperature differences series has been found u(t)=2.08 and this is significant at 95% level.

CONCLUSION

With more than 5 million populations, Ankara is the rapidly growing city in Turkey and became a 2nd mega city after the Istanbul. In this study, urbanization effects on trends of extreme temperature indices in Ankara have been evaluated. The most decisive climate indices which show urbanization effects are related with minimum temperature. Frost Day (FD0) has decreasing trend in Ankara while increasing in Esenboğa. Cool Night (TN10p) has decreasing trends and it's 4 times stronger in the city than rural. Warm Night has increasing trends and it's two times stronger in the city than rural. Cold Spell Duration Indices (CSDI) has decreasing trends and it's 6 times stronger in the city than rural. Tropical Night (TR20) has increasing trends and it's 7 times stronger in the city than rural. Growing Season Lengths (GSL) has increasing trends and it's 4 times stronger in the city than rural. As seen in the results, there is clear increasing trend in minimum temperature in Ankara. This cause decrease in Diurnal Temperature Range (DTR=Tmax-Tmin) in Ankara while increasing in rural station Esenboğa. However, Summer Days (SU25), Warm Days (TX90p) and Warm Spell Duration Indices (WSDI) are related with maximum temperature and haven't found as decisive for urbanization effect due to sunrise relation. These results show that there is stronger urbanization effect in Ankara due to increasing population, decreasing green areas, increasing concrete and asphalt surfaces, low albedo values, different latent heat flux and heating from traffic and other energy uses. Its geomorphology and accordingly development of inversion effect have additional contribution to the urbanization in Ankara (Çiçek, 2004). According to results, there is clear urbanization effect on trends of minimum temperature indices in Ankara. Most of these trends found statistically significant at 95% level (Table 2). More stations should be operated in order to detect urbanization effect (Alan et. al., 2011).

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