IMPACT OF URBANIZATION ON MEAN TEMPERATURE ANOMALIES AND CLIMATE INDICES IN TURKEY

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Abstract:
Understanding the long-term change of temperature events is important to the detection and attribution of climate change. However, it's unclear how much effect coming from the urbanization. According to the law issued in 2012, the city with population 750,000 and more was called as metropolis. If the population is less than 100 thousand it's determined as rural area. In this study we tried to eliminate urbanization effects on temperature anomalies by removing 30 metropolitan cities from the anomaly assessment. Also we have been calculated temperature indices for Ankara and Istanbul city centers and their rural areas in order to determine their trend differences. 1971-2016 annual temperature data of the 99 rural stations were used for temperature anomaly analysis. Extraction of metropolises from analysis caused to reduce the long term mean temperature from 13.5 to 13.1°C based on 1981-2010 but did not cause any change in positive temperature trend. Still positive temperature anomalies have been found since 1998. Frost Days (FD0), Cool Nights (TN10p), Cold Spell Duration Index (CSDI). Warm Nights (TN90p), Tropical Nights (TR20) and Growing Season Lengths (GSL) trends are greater in the Ankara and Istanbul city than their rural. We have clearly noticed that the minimum temperatures have great increasing trends in the city centers. But in both analyzes, it was observed that the positive temperature trends in Turkey were affected by global climate drivers, rather than the urbanizations.

***Keywords*:** Urbanization, temperature anomaly, impact, indices

INTRODUCTION

There were many studies on effect of urbanization on climate (Çiçek, 2004, Hua et al., 2007, Kindap et al., 2012, Oke, 1982), Taha., 1992, Tanrıkulu., 2006, Sensoy et al., 2015, Demircan et al., 2017 and Georgescu et al., 2012). But this is new study on impact of urbanization on mean temperature anomalies. In Turkey we have been used 130 stations data to detect mean temperature anomaly including metropolitan. We wanted to eliminate impact of urbanization on this analysis. We extracted 30 metropolitan data in mean temperature analysis and we do same analysis with 99 rural station data. Also we have been calculated temperature indices for Ankara and Istanbul city centres and their rural areas (Table 1). Extraction of metropolises from analysis decreased the long term mean temperature from 13.5 to 13.1°C but did not cause any change in increasing trend (Fig 1). FD0 and TN10p have more declining trends in the Ankara and Istanbul city centre than their rural while TN90p and TR20 have increasing it. As the rural population declines, the urban population is increasing rapidly (Fig. 1).

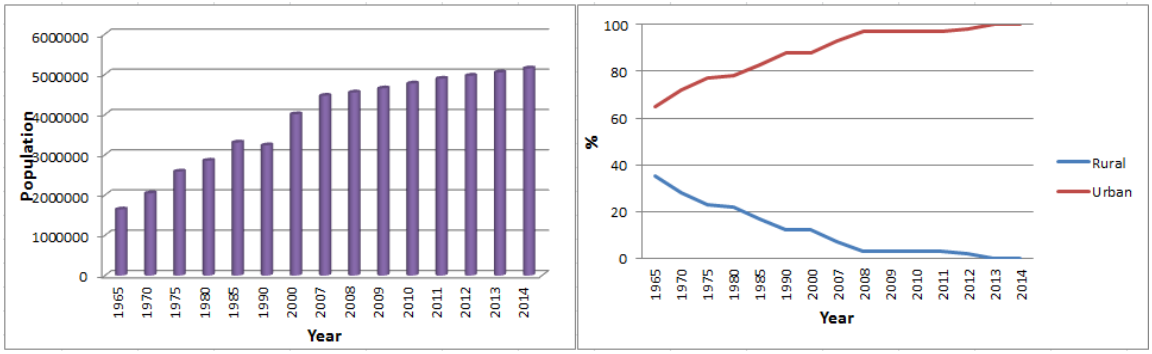

Figure 1. *Ankara population (left), Ankara rural and urban population ratio (right) (TUİK)*

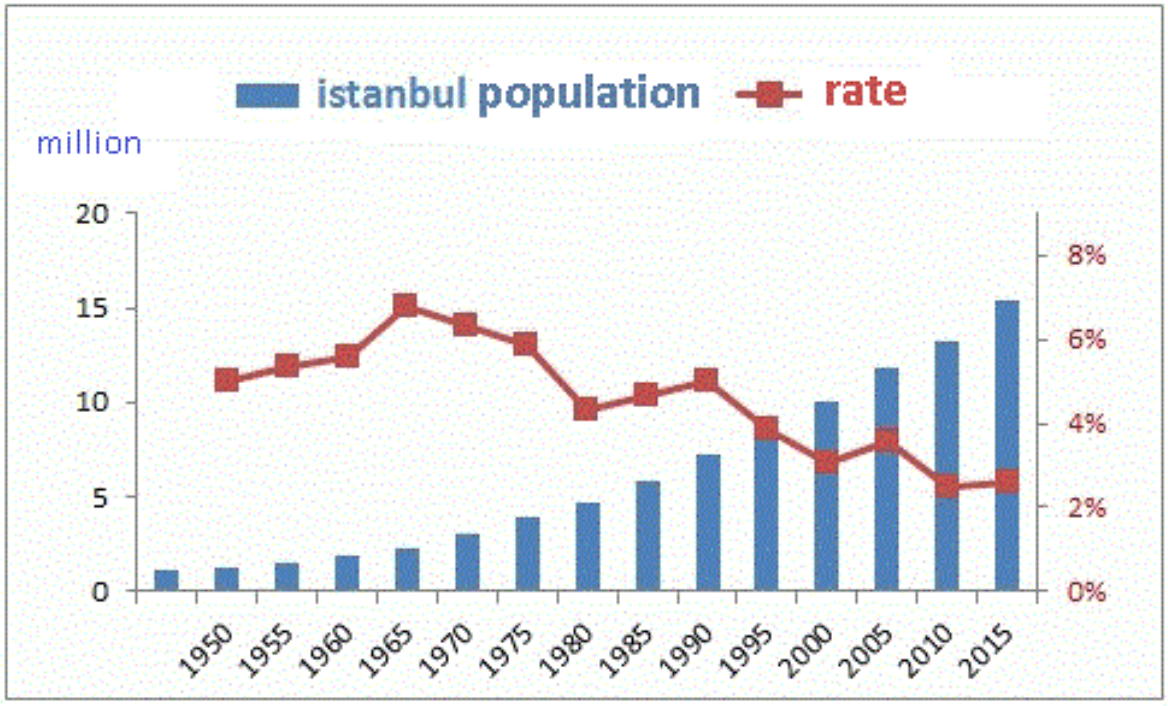

Figure 2. *Istanbul population and rate of increase (TUİK)*

Although population increase rate has been decreased, Istanbul population reached 14,804,116 by 2016 census. 18,55% of Turkey population live in Istanbul.

DATA AND METHODS

Annual mean temperature belong to 130 stations from 1971 to 2016 has been used for anomaly detection. Climatic normal has been calculated from 1981-2010 base periods. After this analysis 30 metropolitan cities (population greater than 750,000) and Afyonkarahisar (714,523) have been extracted from the database. Mean temperature and anomalies have been recalculated again (Table 2.).

RClimdex software has been used to produce climate indices. Ankara and Göztepe stations have been selected to represent urban areas and Esenboğa and Şile have been selected to represent rural. 1961-2010 daily maximum and minimum temperature and precipitation data of these four stations have been used in order to calculate climate related temperature indices. All the indices were calculated *(Table 1)*, but only four of them (FD0, TN10p, TN90p and TR20) were shown due to limited places. Software user guide are available at: http://etccdi.pacificclimate.org/software.shtml.

APPLICATION AND RESULTS

Annual mean temperature anomalies have been calculated including major cities (130 stations, Fig. 1a) and without major cities (99 stations, Fig. 1b) based on 1981 to 2010 period.

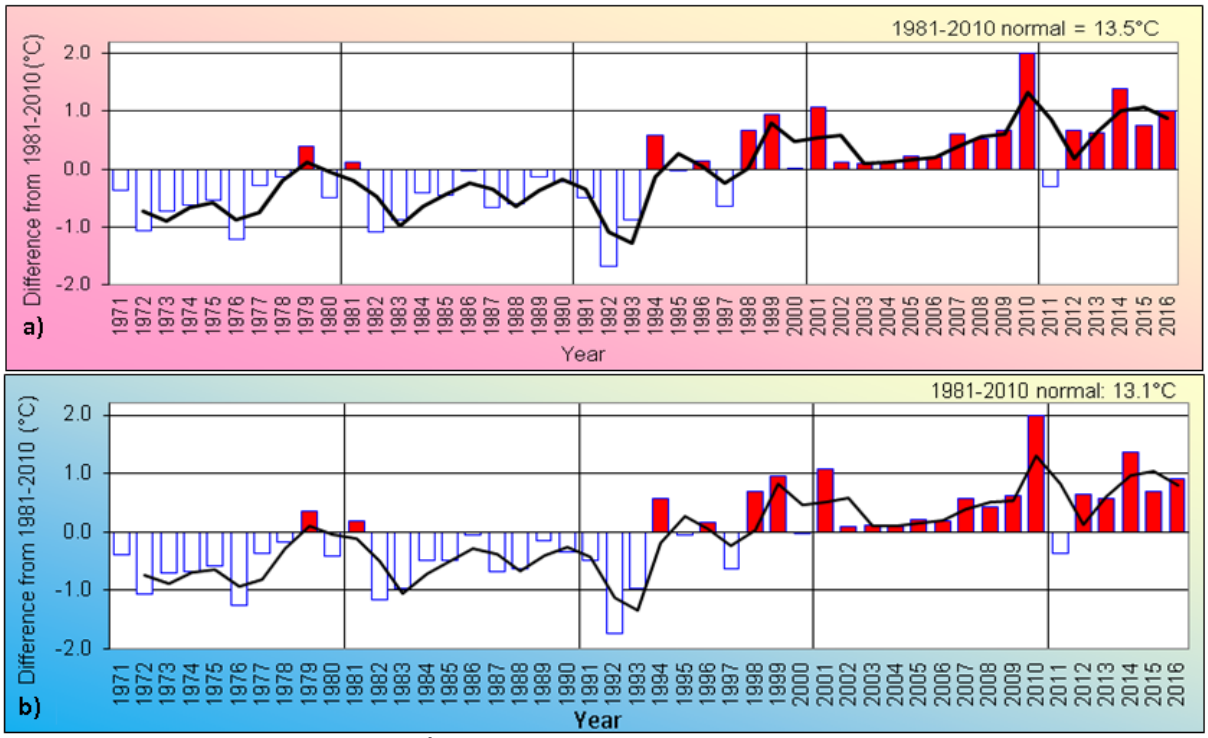

Figure 3. *Mean Temperature anomalies of Turkey with (a) and without major cities (b) (Coşkun et al, 2017)*

Extraction of metropolises from anomaly detection decreased the long term mean temperature from 13.5 to 13.1°C based on 1981-2010 normal, but did not cause any change in increasing trend. There are increasing trends in Turkey temperature since 1988 except 2011. It is observed that the positive temperature anomalies in Turkey are not only the effects of urbanization but also the effects of global climate drivers.

Table 1 *Kendall's tau based slope estimate in temperature related climate indices in Ankara and İstanbul*

Indice	Esenboğa, Ankara	Kalaba, Ankara	Şile, İstanbul	Göztepe, İstanbul
CSDI	-0.013	-0.077	0.011	-0.045
FD0	0.177	-0.120	0.204 *	-0.086
GSL	0.081	0.334	-0.134	0.028
ID0	-0.030	-0.020	-0.004	-0.009
TR20	0.028 *	0.206 *	0.114	0.462 *
TN10p	-0.025	-0.113 *	0.075	-0.102 *
TN90p	0.093	0.209 *	-0.057	0.129 *
TNx	0.037 *	0.048 *	0.035 *	0.037 *
TNn	0.105 *	0.088 *	0.043	0.071 *
SU25	0.368 *	0.190	0.692 *	0.837 *
TX10p	-0.015	-0.005	-0.011	-0.036
TX90p	0.124 *	0.069	0.115 *	0.124 *
TXx	0.039 *	0.026	0.069 *	0.018
TXn	0.081 *	0.051 *	0.027	0.021

WSDI	0.247 *	0.133	0.019	0.108
DTR	0.009	-0.013 *	0.019 *	0.003

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

Table 2. *Populations of Metropolises greater than 750.000 (TUIK,2016)*

Metropolis	Total Population	Male population	Female Population	Population%
İstanbul	14,804,116	7,424,390	7,379,726	% 18,55
Ankara	5,346,518	2,653,431	2,693,087	% 6,70
İzmir	4,223,545	2,104,632	2,118,913	% 5,29
Bursa	2,901,396	1,454,059	1,447,337	% 3,64
Antalya	2,328,555	1,174,936	1,153,619	% 2,92
Adana	2,201,670	1,101,340	1,100,330	% 2,76
Konya	2,161,303	1,073,631	1,087,672	% 2,71
Gaziantep	1,974,244	998,926	975,318	% 2,47
Şanlıurfa	1,940,627	976,938	963,689	% 2,43
Kocaeli	1,830,772	927,157	903,615	% 2,29
Mersin	1,773,852	885,583	888,269	% 2,22
Diyarbakır	1,673,119	844,011	829,108	% 2,10
Hatay	1,555,165	780,854	774,311	% 1,95
Manisa	1,396,945	701,094	695,851	% 1,75
Kayseri	1,358,980	681,269	677,711	% 1,70
Samsun	1,295,927	640,699	655,228	% 1,62
Balıkesir	1,196,176	596,896	599,280	% 1,50
Kahramanmaraş	1,112,634	565,816	546,818	% 1,39
Van	1,100,190	561,592	538,598	% 1,38
Aydın	1,068,260	533,004	535,256	% 1,34
Denizli	1,005,687	500,398	505,289	% 1,26
Sakarya	976,948	490,935	486,013	% 1,22
Tekirdağ	972,875	499,819	473,056	% 1,22
Muğla	923,773	470,404	453,369	% 1,16
Eskişehir	844,842	421,580	423,262	% 1,06
Mardin	796,237	400,475	395,762	% 1,00
Malatya	781,305	389,572	391,733	% 0,98
Trabzon	779,379	385,009	394,370	% 0,98
Erzurum	762,021	381,138	380,883	% 0,95
Ordu	750,588	376,243	374,345	% 0,94
Afyonkarahisar *	**714,523**	354,458	360,065	% 0,90

* Afyonkarahisar is not a metropolis but it's candidate to become

Comparison of temperature related climate indices in the city and rural conditions

The most decisive climate indices which show urbanization effects are related with minimum temperature which are CSDI, FD0, GSL, ID0, TR20, TN10p, TN90p,TNx, TNn. However, SU25, TX10p, TX90p, TXx, TXn, WSDI are related with maximum temperature and haven't found decisive for urbanization effect due to include sun radiation in daytime. DTR is decreasing in the city centers due to increasing minimum temperature.

Comparison of Cold Spell Duration Indices (CSDI) Trends

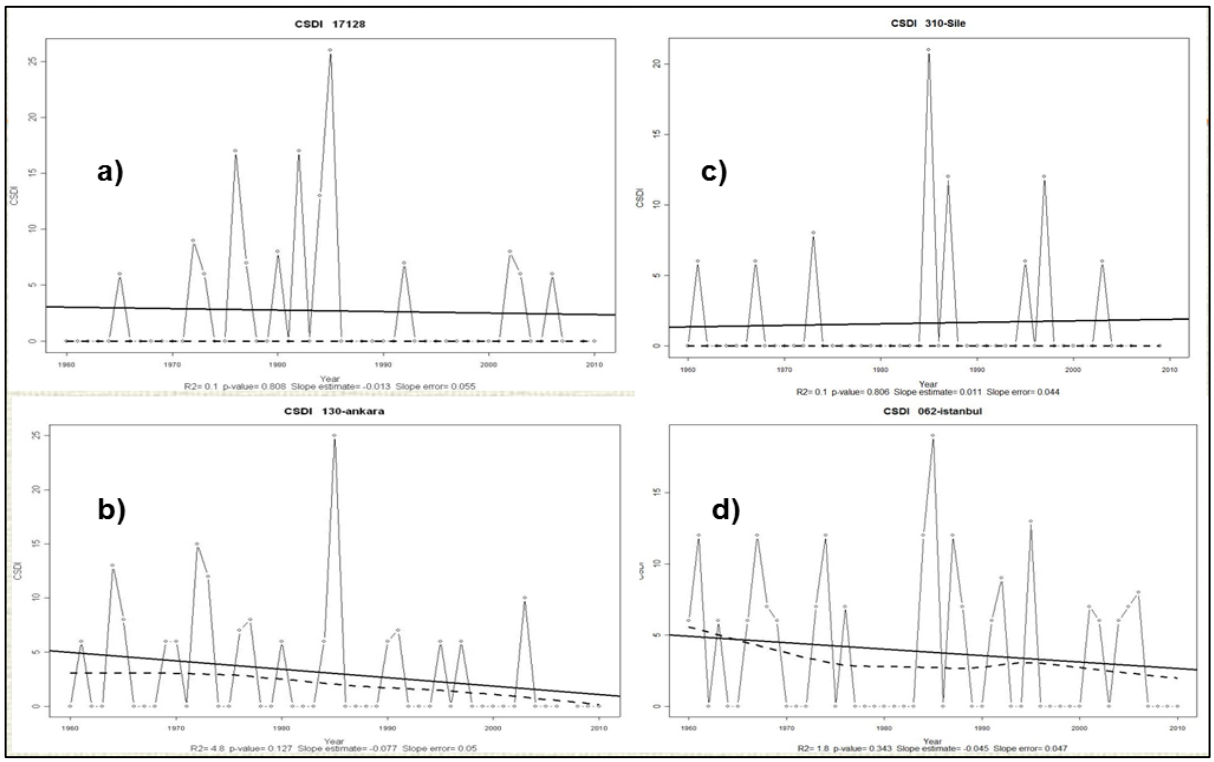

Figure4*. Cold Spell Duration indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Cold Spell Duration Indices has more decreasing trends in the city centers (Figure 4).

Comparison of Frost Day (FD0) Trends

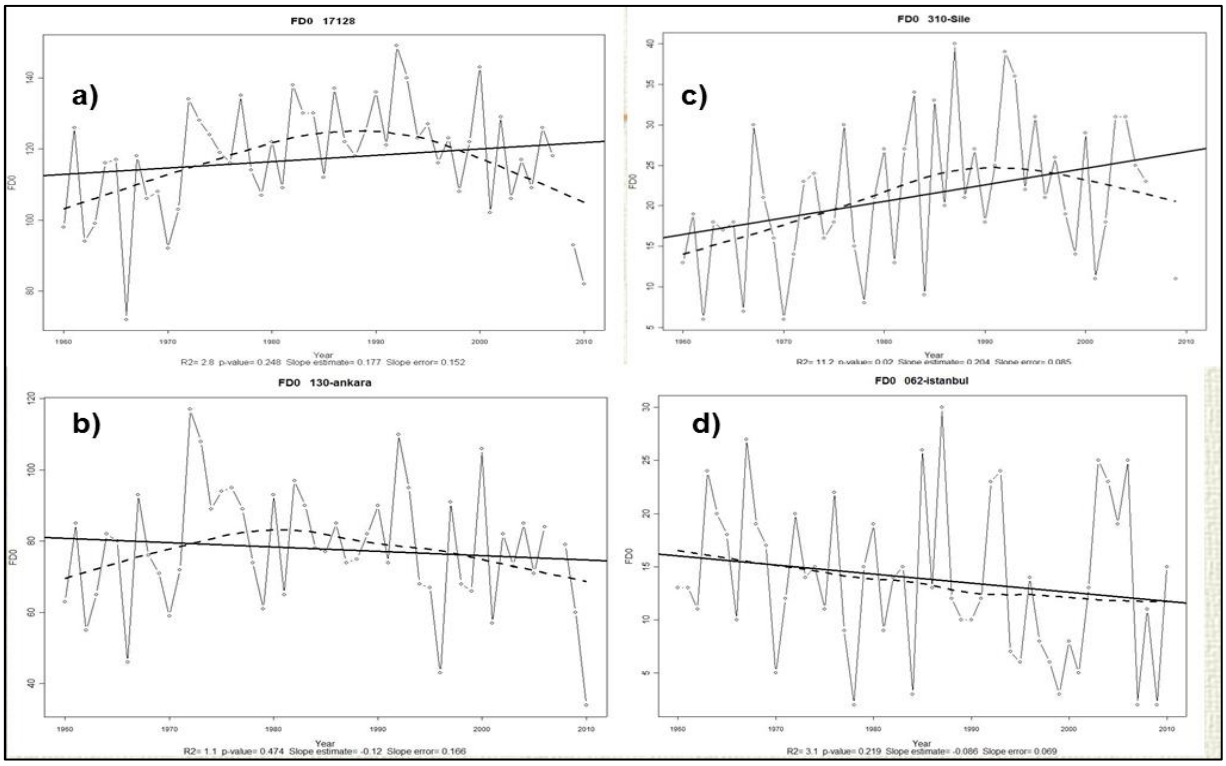

Figure5. *Frost Day Indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Frost Days has more decreasing trends in the city centers.

Comparison of Tropical Nights (TR20) Trends

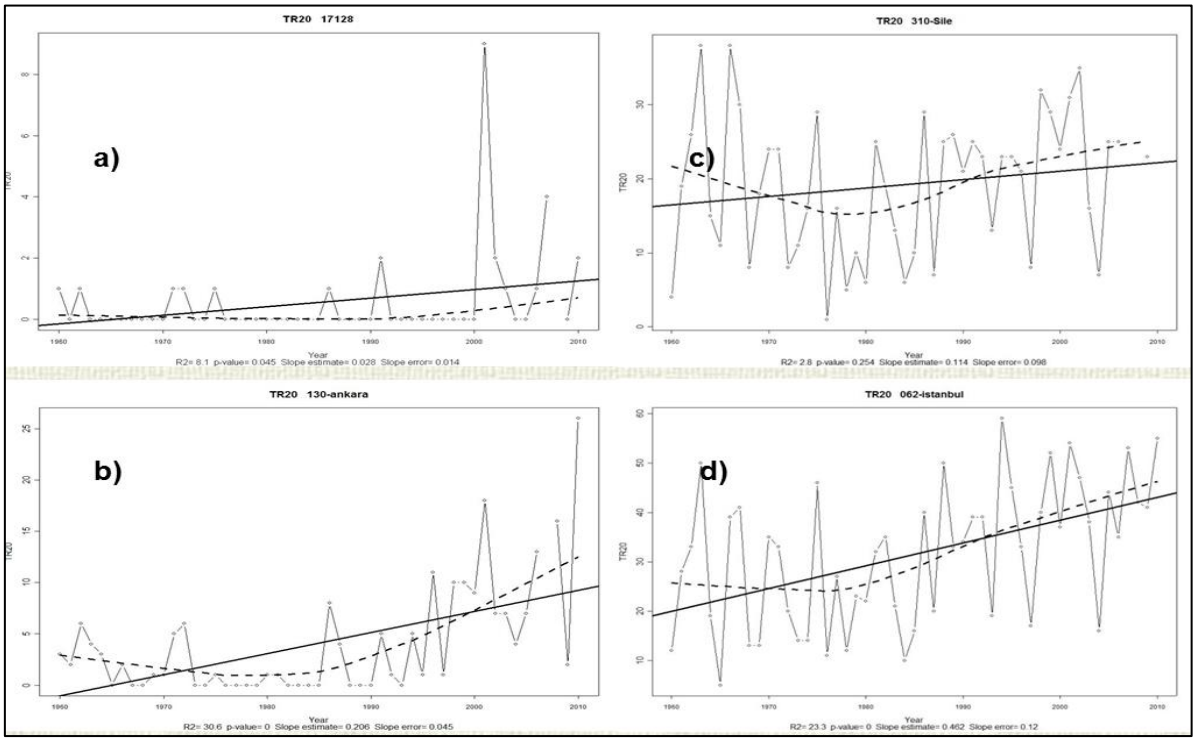

Figure6. *Tropical Nights indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Tropical Nights has more increasing trends in the city centers

Comparison of Cool Nights (TN10p) Trends

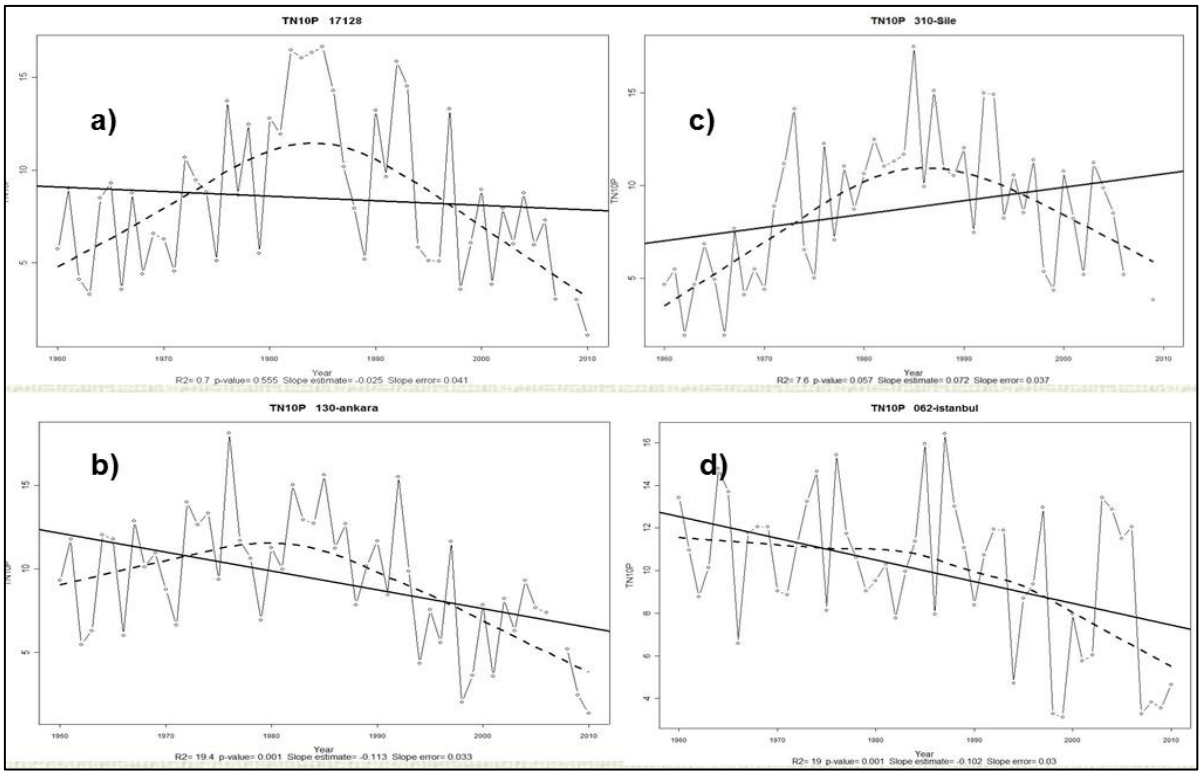

Figure7. *Cool Nights indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Cool Nights has more decreasing trends in the city centers.

Comparison of Warm Nights (TN90p) Trends

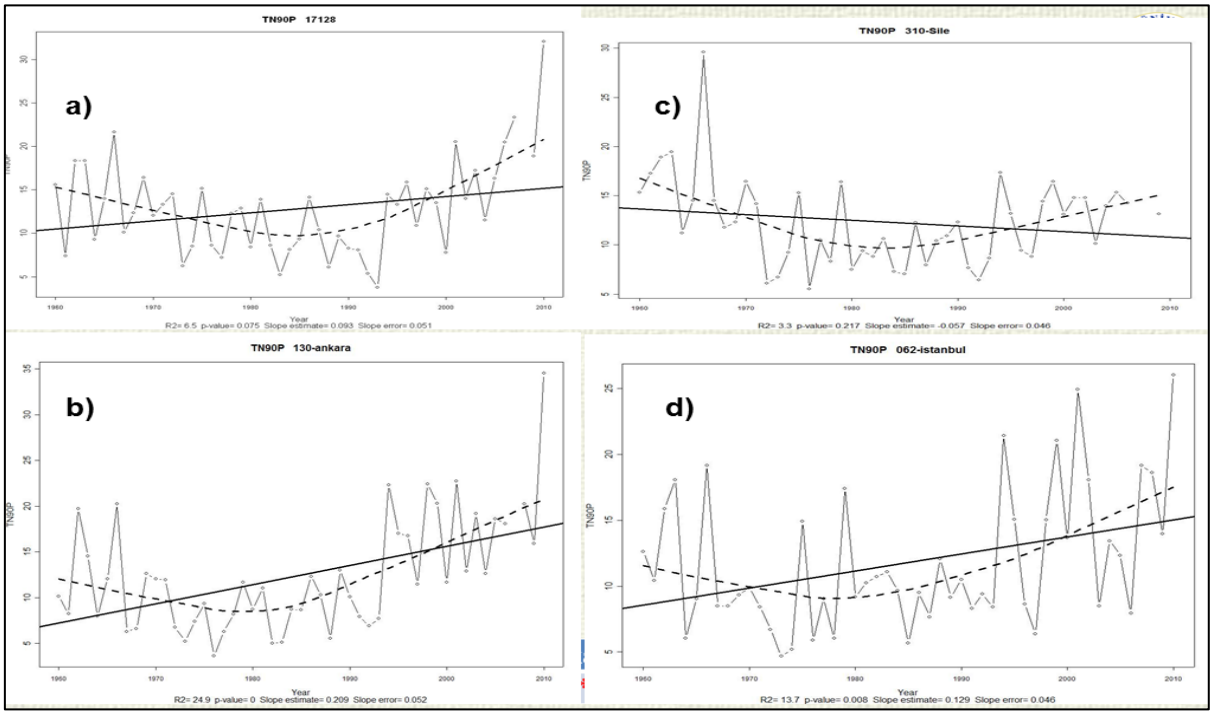

Figure8. *Warm Night Indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Warm Nights has more increasing trends in the city centers.

Comparison of Summer Days (SU25) Trends

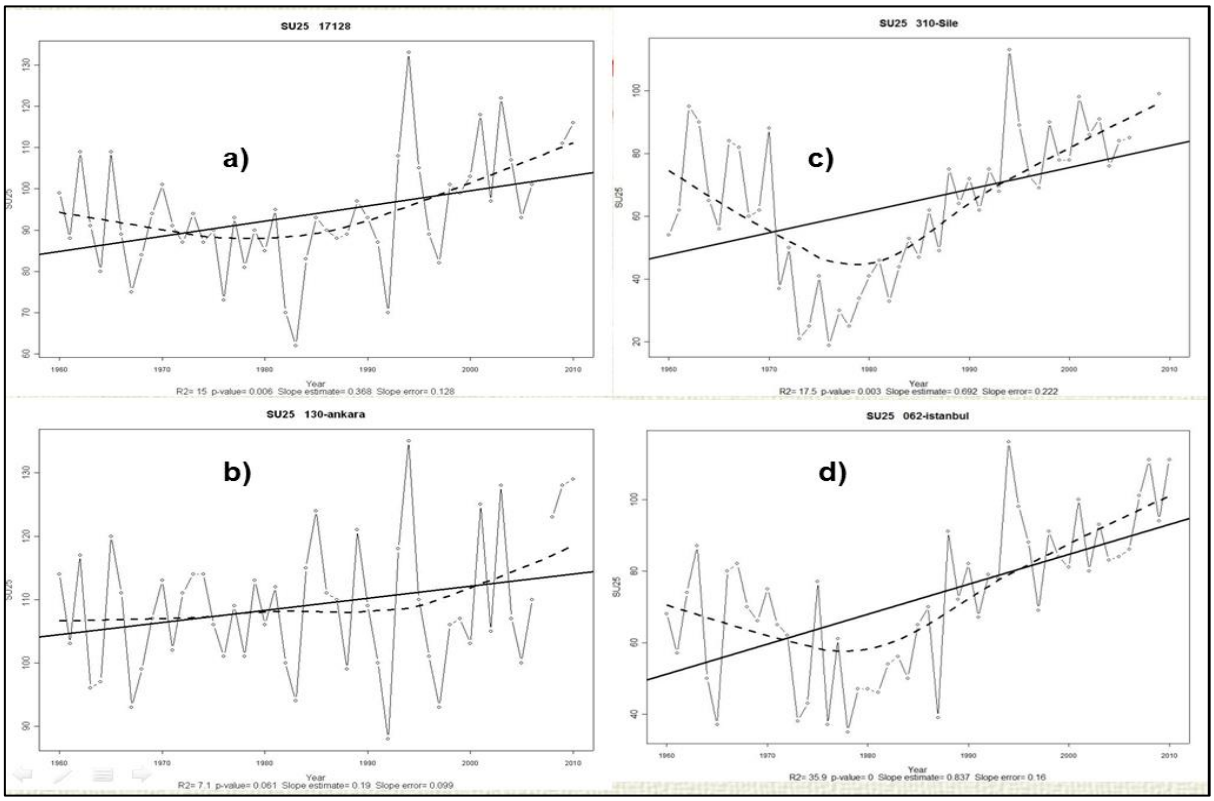

Figure9. *Summer Days Indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Summer Days has increasing trends both in the city centers and rural areas.

Comparison of Warm Spell Duration Indices (WSDI) Trends

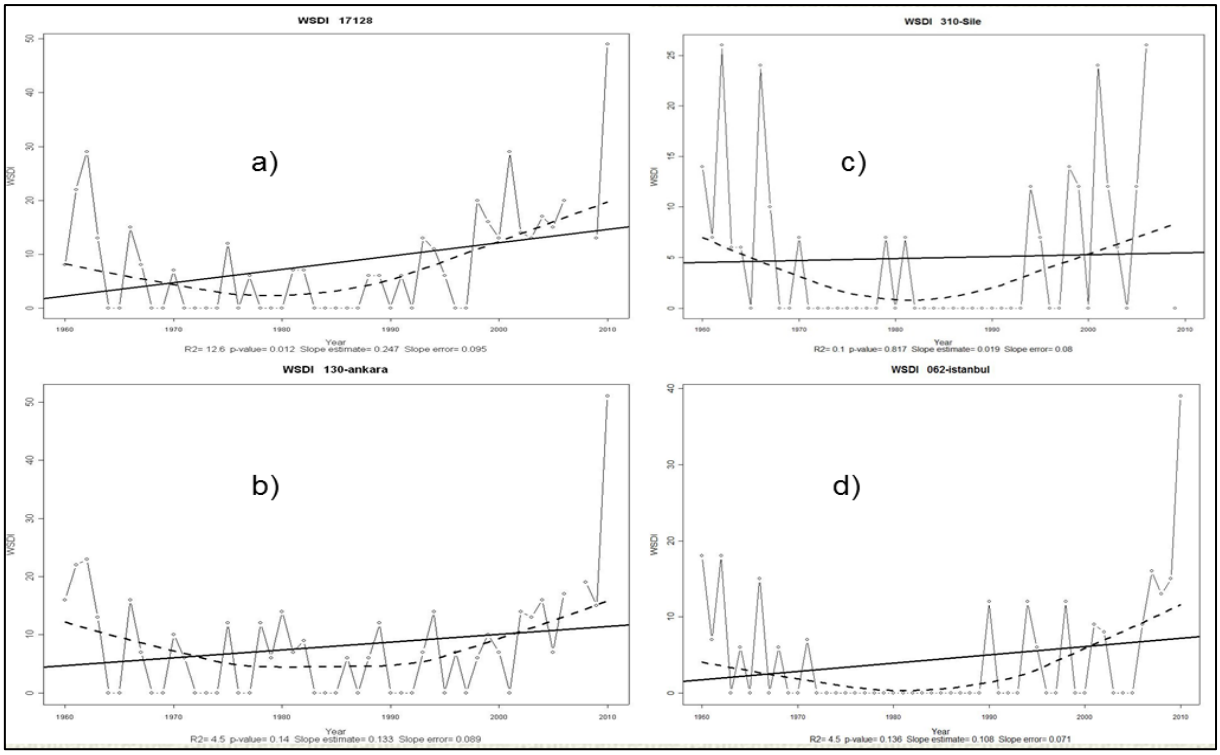

Figure10. *Warm Spell Duration Indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

Warm Spell has increasing trends both in the city centers and rural areas.

Comparison of Day Temperature Range (DTR) Trends

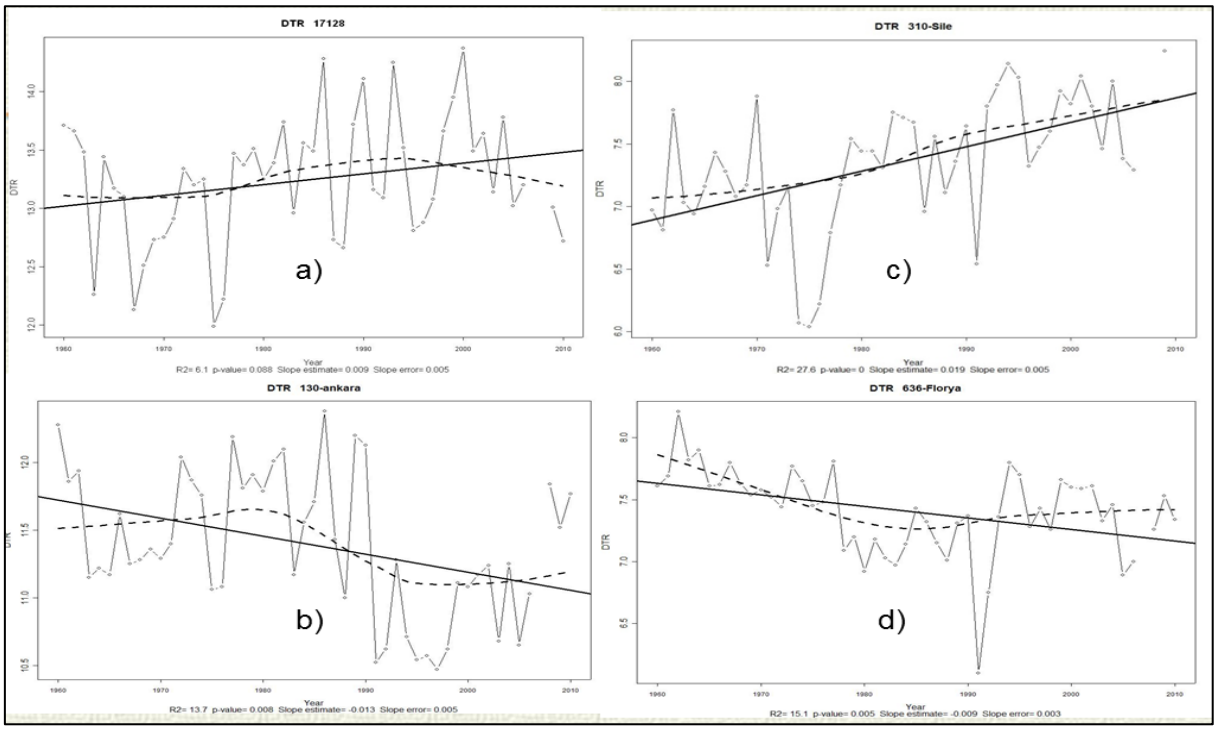

Figure11 *Day temperature range Indices of Esenboğa (a), Ankara (b), Şile(c), Istanbul (d) (Sensoy et al, 2013)*

DTR has increasing trend in the rural area while decreasing in the city centers.

CONCLUSIONS AND RECOMMENDATIONS

In this study we tried to investigate urbanization effects on temperature anomaly and trends of extreme temperature indices in Ankara and İstanbul.

Extraction of major cities from anomaly detection caused a decrease in long term mean temperature from 13.5 to 13.1°C. But again there are still increasing trends in Turkey temperature since 1988 except 2011. It is observed that the positive temperature anomalies in Turkey are not only the effects of urbanization but also the effects of global climatic drivers. Urbanization alone could increase local temperatures (Georgescu et al, 2012).

The most decisive climate indices which show urbanization effects are related with minimum temperature. FD0 and TN10p have more declining trends in the Ankara and Istanbul city center than their rural while TN90p and TR20 have increasing it. However, Summer Days (SU25), Warm Days (TX90p) and Warm Spell Duration Indices (WSDI) are related with maximum temperature and haven't found decisive for urbanization effect due to include sun radiation in daytime.

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) especially in continental station like Ankara. Most of these trends found statistically significant at 95% level. These results show stronger urbanization effect in Ankara and İstanbul city center. Due to the increasing greenhouse gases, temperatures in Turkey are increasing in line with the world.

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