IMPACT OF LAND -USE CHANGES ON THE TEMPERATURE VARIABILITY: A CASE STUDY OF LAHORE

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ABSTRACT: The objective of the present study is to investigate the impact of land-use changes on temperature variability in the study area. Lahore is the second-largest city in Pakistan and is facing tremendous pressure in rapid population growth, socio-economic development, and urbanization that change the pattern of land use. Consequently, the annual dT_{min} temperature is increasing more rapidly as compared to the dT_{max} temperature. Seasonal temperature variation is also highlighted that dT_{min} temperature is increasing more rapidly in the spring season. The regression method was used to figure out the temperature variation. Results of the study revealed that Lahore has witnessed a dramatic growth in the built-up area which had a prominent effect on Land surface temperature as well. The Normalized difference vegetation index (NDVI) is used to calculate built-up area in Lahore from 1972 to2015. In 1972 the total built-up area of Lahore was only 62.88 Square kilometers which increased 557.38 square kilometers in 2015.

Key words: Temperature, Variability, LST, NDVI, minimum, maximum.

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INTRODUCTION

The land use dynamics have been transformed significantly during the past few decades. The natural and human factors both are responsible for this land use transformation (Hassan *et al.,* 2016; Rubia *et al.,* 2016).Rapid population growth, industrial development, urban sprawl, changing climate, and urbanization have been identified as the key factors of land cover dynamics (Hassan *et al.,* 2016; Dutta & Das, 2019; Msofe, et.al, 2019). In the past, in order to address the needs of the rapidly growing global population, the vegetation cover is converted into the agrarian lands. However, the transformation of vegetation cover into the cultivable land was to fulfil the growing population's food requirements and identified another main factor of land use and land cover changes (Nugroho *et al.,* 2018). The transformation in the pattern of land use and land cover changes always took place in urban structure and development, ultimately on the verge of cultivable land, green spaces, and barren land (Dutta *et al.,* 2020).

It is observed that temperature is showing the rising trend all over the world because of changing climate and the developing world countries are more vulnerable for this climate change (United States EPA,2011, Rehman *et al*.,2015).The increase in greenhouse gases such as carbon dioxide, methane is the main reason of climate change. Ultimately, it has been increased the earth's surface temperature(Muhiodin, 2014; Msofe, et.al, 2019).The global warming and urban heat islands are considered the main drivers that have increased the temperature in the urban areas(Masaru *et al*.,2015).

Climate change impact will be more obvious in cities mainly in metropolitans of under developing regions because of substantial population growth. In urban areas ecosystem services are greatly affected due to rapid urbanization, massive population growth and urban sprawl.

Urban expansion is the main driver to climate change. Subsequently the emission of hazardous gases like CFC, CO_2 and greenhouse gases are more in cities than the suburbs (Muhiodin, 2014).

Urbanization has altered the land use and land cover modification and as well as the structure of the atmosphere. The land use modification has changed the micro and mesoclimate of the urban areas as compared to the suburbs (Zhou *et al.,* 2011;Tesfa *et al*,2018). For example, Cities have weaker winds, more temperature and the amount of incoming solar energy received in cities mainly depend on cloud cover, air pollutants and street network orientation. Mega urban structures tend to affect the flow of radiation (Huang *et al.,* 2011). Furthermore, the micro-urban climate is greatly affected due to complex nature and surface structures existed in cities (Huang *et al.,* 2011). Due to rapid population growth and urban development cities tend to have higher temperature because of reduction in surface moisture and less vegetation cover (Sumit *et al*.,2018).The heat emitted from built-up manmade structures and landscapes (observe the sun's energy and then re emits) and heat released from human activities reported high temperaturecompared to its nearby rural areas (Kumar *et al*., 2013).

MATERIAL AND METHODS

Lahore being the provincial capital of Punjab and ranked 2nd largest city of Pakistan enjoys the status of fast-growing metropolis. The latitudinal extension of Lahore is 31°-15' and 31˚-43' north latitudes and 74˚-01' and 74˚-39' east longitude .City is located at an altitude of 213 meters above mean sea level. The total area of Lahore as reported 680 square miles(1094sq.Kms.) and 1772 square kilometers (GOP,2002).The humid subtropical type of climate with extreme summer season is experienced in Lahore.

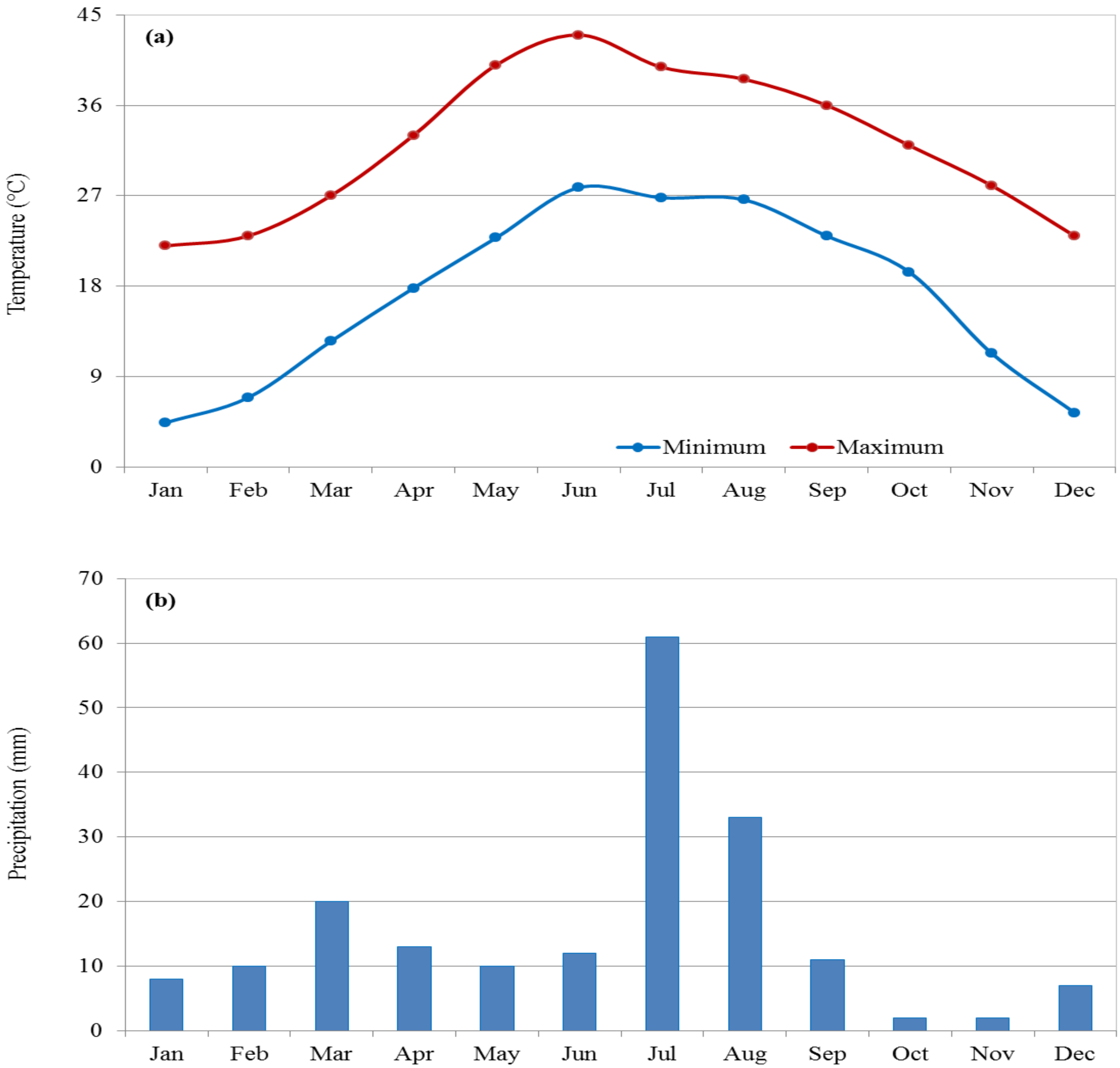


Figure 1: Average monthly minimum and maximum temperature variability and rainfall in Lahore. Source :http://www.weather-and-climate.com Extracted on 9-11-2017.

The temperature data of mean monthly daily minimum and maximum for the Lahore city was used for analysis. The data from the time period of 36 (1980-2015)was collected from Pakistan Meteorological Department (PMD) the regional office located at Jail Road, urban station. In the study, area to evaluate the time series data regression method was used. Temperature and time period were taken as dependent and Independent variables respectively. The minimum (dT_{min}) and dT_{max} temperature variability are figured out by using the Regression Method. The consistency of data was checked and organized by keeping in view the international Season Scheme e.g. for winter it is devised into three-months scheme December, January, and February(DJF), March April, May(MAM for Spring; for summer June, July and August(JJA) and for autumn September, October, and November(SON) were taken. The linear method was used for trend analysis. The Standard Normal Homogeneity Test (SNHT) was run on time series data and no major breakpoint and error were reported during the 36 years' time period. The data was analyzed by using the following equation:

$$y = a + Bx + \varepsilon i$$

$y = c + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + e$ Y is response variable, a intercept of the line, B is slope of the line, X is independent variable and εi random error. To find out the minimum and maximum temperature trends and pattern in Lahore, both seasonal and annual bases "Y" are considered dependent variable i-e Time./ is taken as an independent variable. The Landsat image for the years 1972-2015 were acquired from United states Geological Survey(USGS).

Normalized Difference vegetation Index (NDVI) and varied techniques were applied to calculate the built-up area.Thermal bands of Thematic Mapper(TM), Enhanced ThematicMapper Plus(ETM+) and Operational Land imager/Thermal Infrared Sensor(OLI/TIRS) were used to extract the land surface temperature in the study area.

Figure (2&3) are highlighting the seasonal and annual variability in dT_{min} and dT_{max} temperature trends in the study area. It is observed from the trend line that in the winter season the dT_{min} the temperature of Lahore was 1.72 and dT_{max} temperature was recorded 1.75.In summer the dT_{min} Temperature in Lahore was 0.88 and dT_{max} temperature was -1.19.In spring and summer season the dT_{min} was recorded 3.40 and 2.63 respectively. While the dT_{max} is recorded -1.40 in Autumn and -1.26 in the spring season. The maximum increase in dT_{max} and dT_{min} is noted in the spring season. The annual temperature variability in Lahore is showing the dT_{min} temperature is increasing more rapidly as compare to $dT_{max.}$ The Annual dT_{min} and maximum temperature are recorded at 2.14 and 0.77 respectively. The maximum increase is recorded in minimum temperature in Lahore during the time period of 1972-2011.

After 1998 the annual dT_{min} temperature is showing a rising trend as it was the era of rapid urban growth and development in Lahore city. The increase dT_{min} in temperature in the study area is rising due to anthropogenic activities and rapid urban growth. The dT_{min} temperature is showing the rising trend across Lahore

Figure 4: illustrate. In contrast (part b) is highlightings the variation in temperature (part a) showing the minimum increase. In contrast (part b) highlights the maximum increase in a built-up area in a square kilometer in the study area for the time period of 1972-2015.The built-up area was taken as an independent variable on the average the response variable that was temperature .Due to urban growth the build-up area the increased in the built-up area was observed 0.007 unit. On the other hand, with the decrease in the independent variable on the average the response variable (temperature) will be decreased by -0.001 units. The figure 5 highlighted the urban expansion and land cover change of Lahore from 1972-2015.The total area of Lahore is 1729 square kilometers. In 1972 the extend of total build up area of Lahore was only 62.82 square kilometers. The built-up area was increased 100.123 square kilometer in 1980.In 2015 the total built up area was calculated 557.387 square Kilometers.

Consequently, within 43 years, Lahore city has witnessed the maximum increase in its built-up area. Overall change in the land cover area of Lahore was calculated 494.507square kilometers. The barren land, open and green spaces, and agricultural land are rapidly transformed into building-up structures because of rural to urban migration, urbanization, rapid growing population, and Socioeconomic development. Indian Punjab is located on the east that limits the expansion of Lahore on eastern side .The rate of expansion is more in North and Southward direction.

Table 1: Correlation of monthly temperature in study area.

		Minimum	Maximum	Mean	Std. Deviation
Jan	Tmax	15.20	21.50	19.2000	1.37032
	Tmin	4.80	10.00	7.2081	1.18119
Feb	Tmax	18.90	26.70	22.2297	1.63823
	Tmin	7.10	14.70	10.1622	1.57116
Mar	Tmax	22.60	31.40	27.1595	2.11430
	Tmin	11.90	19.20	15.1135	1.82348
Apr	Tmax	28.80	38.00	34.1568	2.00867
	Tmin	16.90	24.30	20.5568	1.71861
May	Tmax	33.20	43.10	38.9270	2.20374
	Tmin	21.10	27.80	25.0135	1.80357
Jun	Tmax	35.90	41.70	39.4270	1.66894
	Tmin	25.50	29.60	27.2946	.99497
Jul	Tmax	33.60	39.30	35.6135	1.37460
	Tmin	24.80	28.70	26.9784	.75687
Aug	Tmax	32.40	37.70	34.8216	1.14240
	Tmin	24.20	28.70	26.7297	.90488
Sep	Tmax	32.70	38.50	34.6216	1.16408
	Tmin	22.20	26.70	24.8865	.96008
Oct	Tmax	27.20	34.50	32.5919	1.31580
	Tmin	16.90	22.20	19.3541	1.49770
Nov	Tmax	24.60	29.60	27.5730	.99181
	Tmin	9.90	16.10	13.2081	1.42622
Dec	Tmax	16.50	23.80	21.9946	1.25165
	Tmin	6.00	11.00	8.4054	1.29913

Table 2: Correlation of Monthly T_{max} in the study area.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	Correlation	1	.705	.480	.452	.332	.081	.467	.241	.462	.336	.437	.400
	P-value		.000	.003	.005	.044	.634	.004	.151	.004	.042	.007	.014
Feb	Correlation	.705	1	.541	.625	.521	.159	.372	.434	.517	.509	.604	.406
	P-value	.000		.001	.000	.001	.348	.023	.007	.001	.001	.000	.013
Mar	Correlation	.480	.541	1	.623	.414	.251	.447	.266	.301	.558	.545	.386
	P-value	.003	.001		.000	.011	.134	.005	.111	.070	.000	.000	.018
Apr	Correlation	.452	.625	.623	1	.608	.326	.275	.421	.168	.667	.641	.473
	P-value	.005	.000	.000		.000	.049	.099	.009	.320	.000	.000	.003
May	Correlation	.332	.521	.414*	.608	1	.493	.110	.257	.146	.466	.533	.312
	P-value	.044	.001	.011	.000		.002	.518	.124	.388	.004	.001	.060
Jun	Correlation	.081	.159	.251	.326	.493	1	.126	.349	.024	.167	.284	.113
	P-value	.634	.348	.134	.049	.002		.459	.034	.886	.322	.088	.505
Jul	Correlation	.467	.372	.447	.275	.110	.126	1	.310	.394	.449	.456	.620
	P-value	.004	.023	.005	.099	.518	.459		.061	.016	.005	.005	.000
Aug	Correlation	.241	.434	.266	.421	.257	.349	.310	1	.367	.361	.352	.304
	P-value	.151	.007	.111	.009	.124	.034	.061		.025	.028	.033	.068
Sep	Correlation	.462	.517	.301	.168	.146	.024	.394	.367	1	.358	.289	.305
	P-value	.004	.001	.070	.320	.388	.886	.016	.025		.029	.083	.066
Oct	Correlation	.336	.509	.558	.667	.466	.167	.449	.361	.358	1	.728	.487
	P-value	.042	.001	.000	.000	.004	.322	.005	.028	.029		.000	.002
Nov	Correlation	.437	.604	.545	.641	.533	.284	.456	.352	.289	.728	1	.710
	P-value	.007	.000	.000	.000	.001	.088	.005	.033	.083	.000		.000
Dec	Correlation	.400	.406	.386	.473	.312	.113	.620	.304	.305	.487	.710	1
	P-value	.014	.013	.018	.003	.060	.505	.000	.068	.066	.002	.000	

Table 3: Correlation T_{min} of Individual Lahore Seasonal.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	Correlation	1	.132	-.301	-.116	-.087	.454	.350	.181	.257	.029	.200	.047
	P-value		.436	.070	.494	.609	.005	.034	.284	.124	.863	.236	.780
Feb	Correlation	.132	1	.352	.310	.264	-.122	-.071	.197	.108	-.130	.099	-.023
	P-value	.436		.032	.062	.114	.473	.677	.242	.525	.445	.559	.893
Mar	Correlation	-.301	.352	1	.281	.160	-.363	-.155	-.186	-.236	-.208	.146	.010
	P-value	.070	.032		.092	.344	.027	.361	.270	.159	.217	.389	.953
Apr	Correlation	-.116	.310	.281	1	.408	-.070	-.137	.193	-.146	.150	.040	.224
	P-value	.494	.062	.092		.012	.682	.418	.253	.389	.376	.815	.183
May	Correlation	-.087	.264	.160	.408	1	.124	-.479	-.047	-.432	.247	.017	.232
	P-value	.609	.114	.344	.012		.466	.003	.782	.008	.140	.919	.167
Jun	Correlation	.454	-.122	-.363	-.070	.124	1	.092	.336	.235	.419	.147	.243
	P-value	.005	.473	.027	.682	.466		.586	.042	.161	.010	.387	.147
Jul	Correlation	.350	-.071	-.155	-.137	-.479	.092	1	.176	.458	.001	.180	.054
	P-value	.034	.677	.361	.418	.003	.586		.296	.004	.994	.288	.749
Aug	Correlation	.181	.197	-.186	.193	-.047	.336	.176	1	.398	.396	.219	.380
	P-value	.284	.242	.270	.253	.782	.042	.296		.015	.015	.193	.020
Sep	Correlation	.257	.108	-.236	-.146	-.432	.235	.458	.398	1	.056	.071	.068
	P-value	.124	.525	.159	.389	.008	.161	.004	.015		.743	.678	.689
Oct	Correlation	.029	-.130	-.208	.150	.247	.419	.001	.396	.056	1	.474	.711
	P-value	.863	.445	.217	.376	.140	.010	.994	.015	.743		.003	.000
Nov	Correlation	.200	.099	.146	.040	.017	.147	.180	.219	.071	.474	1	.550
	P-value	.236	.559	.389	.815	.919	.387	.288	.193	.678	.003		.000
Dec	Correlation	.047	-.023	.010	.224	.232	.243	.054	.380	.068	.711	.550	1
	P-value	.780	.893	.953	.183	.167	.147	.749	.020	.689	.000	.000	

Table 4:Seasonal temperature variability in the study area.

		Minimum	Maximum	Mean	Std. Deviation
Winter	Tmax	19.20	22.90	21.1378	.86710
	Tmin	6.30	11.00	8.5784	1.11608
Spring	Tmax	29.60	36.20	33.4108	1.51635
	Tmin	17.00	23.40	20.2270	1.48748
Summer	Tmax	34.90	39.10	36.6216	.95310
	Tmin	25.20	28.10	27.0081	.63917
Autumn	Tmax	28.90	33.90	31.5946	.79790
	Tmin	17.40	21.00	19.1514	1.06292

Table 5. Seasonal T_{min} in the study area.

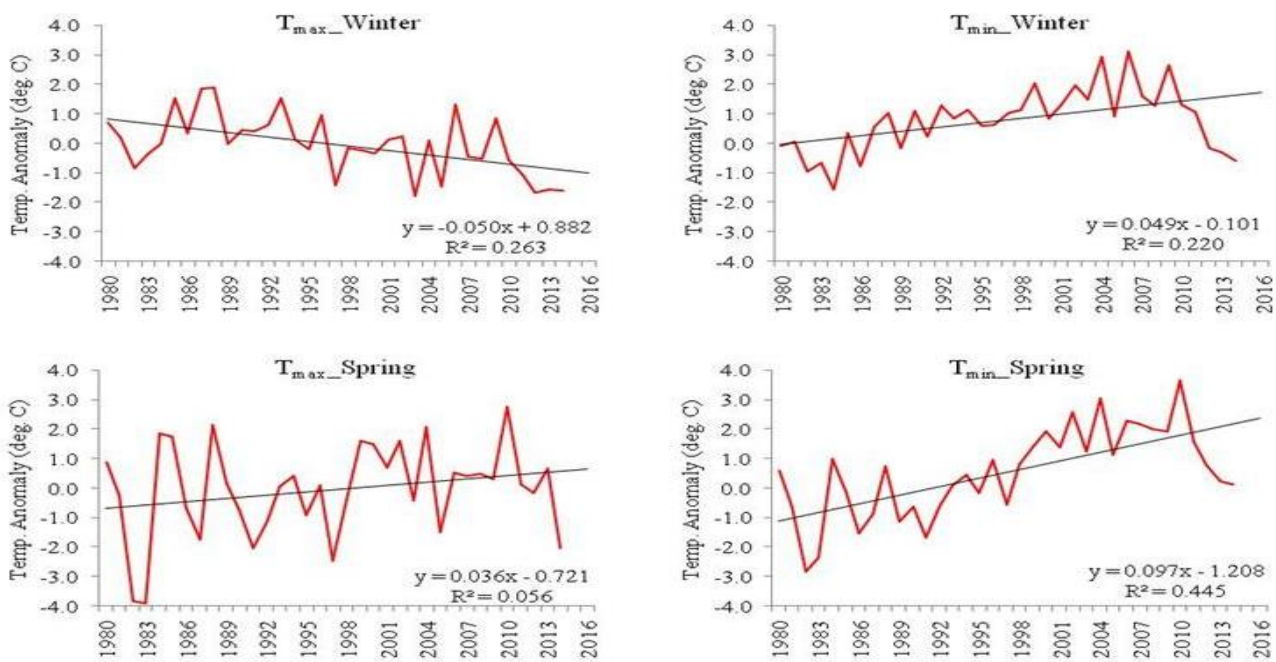
		Winter	Spring	Summer	Autumn
Winter	Correlation	1	.677	.502	.744
	P-value		.000	.002	.000
Spring	Correlation	.677	1	.537	.695
	P-value	.000		.001	.000
Summer	Correlation	.502	.537	1	.526
	P-value	.002	.001		.001
Autumn	Correlation	.744	.695	.526	1
	P-value	.000	.000	.001	

Table : 6 Seasonal T_{max} in the study area.

		Winter	Spring	Summer	Autumn
Winter	Correlation	1	.238	.397	.451
	P-value		.156	.015	.005
Spring	Correlation	.238	1	-.274	-.107
	P-value	.156		.100	.530
Summer	Correlation	.397	-.274	1	.592
	P-value	.015	.100		.000
Autumn	Correlation	.451	-.107	.592	1
	P-value	.005	.530	.000	

Table 7 : Annual minimum and maximum temperature in the study area.

	Minimum	Maximum	Mean	Std. Deviation
Tmax	28.60	31.90	30.6946	.63637
Tmin	17.00	20.30	18.7459	.92904



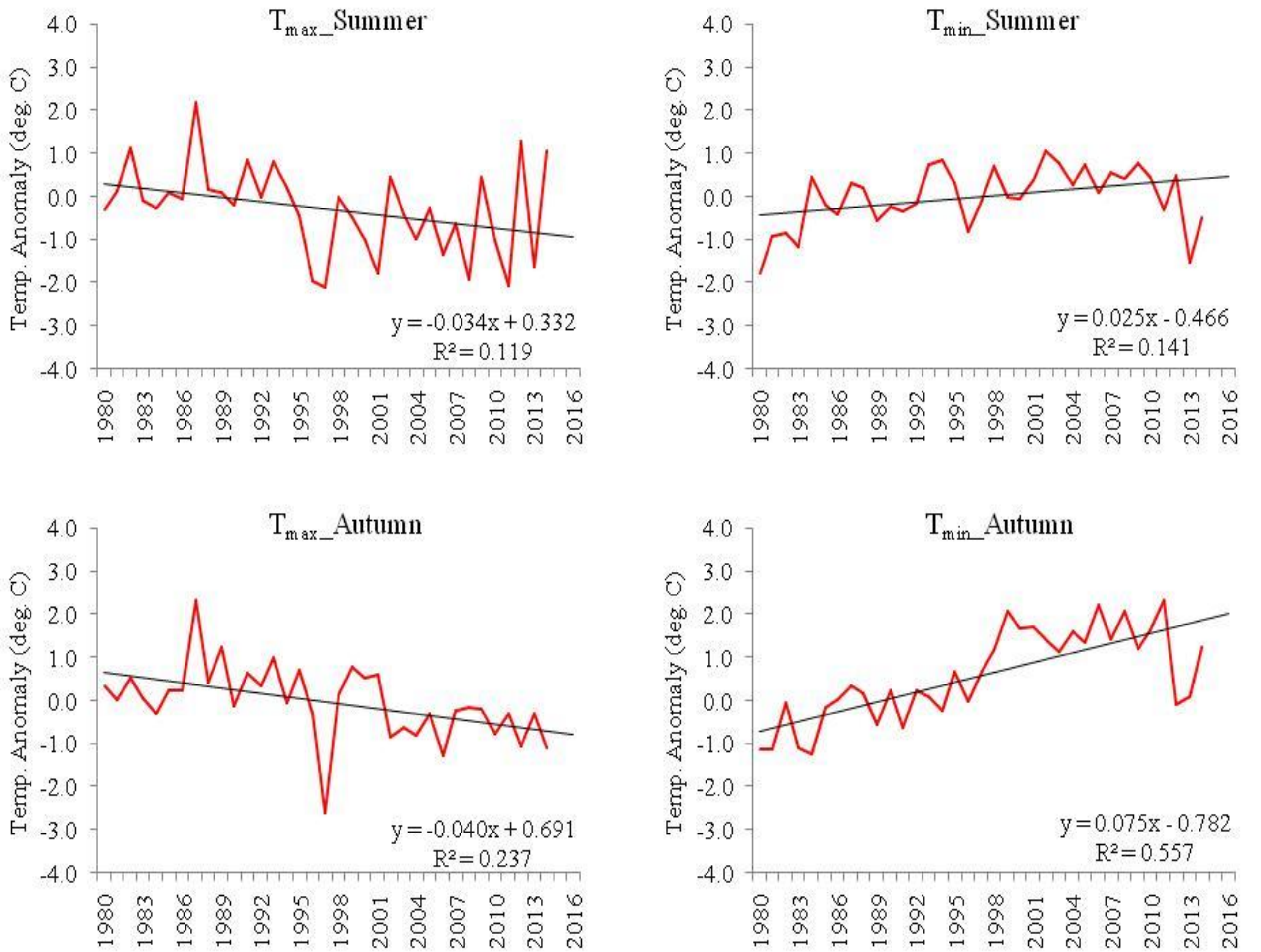


Figure 2: Seasonal Temperature trends in the study area 1980 to 2015 dT_{min} is showing on right while dT_{max} temperature is given on left.

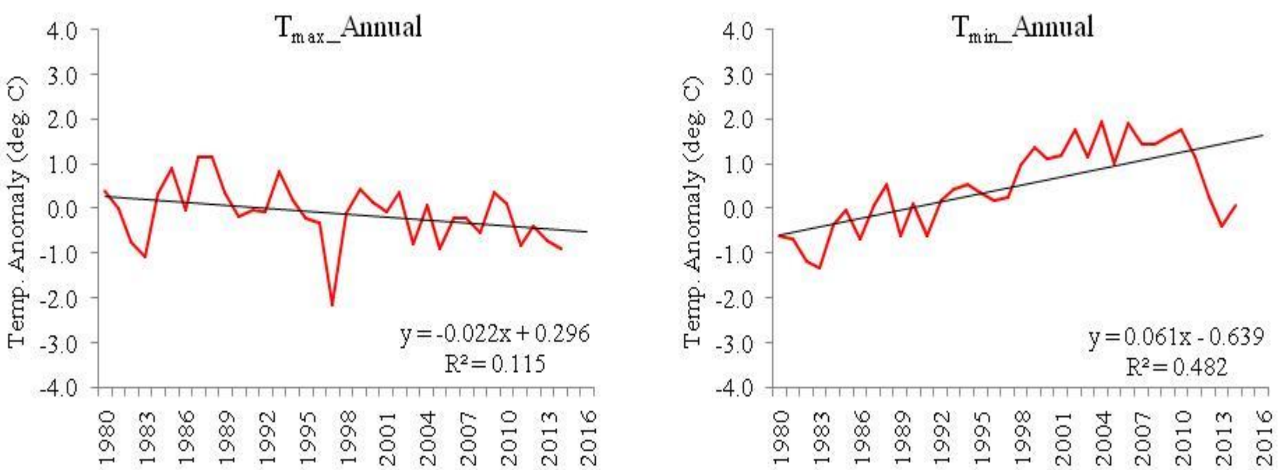


Figure 3: Annual temperature trend (minimum and maximum)in study area for 1980-2015.

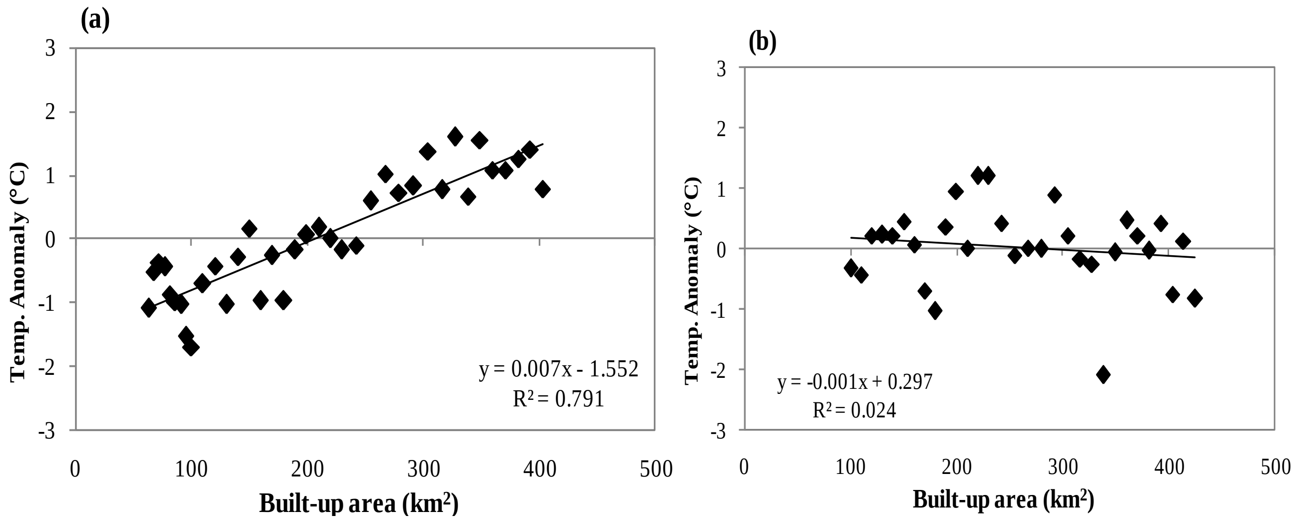


Figure 4: Built up area in the study area.

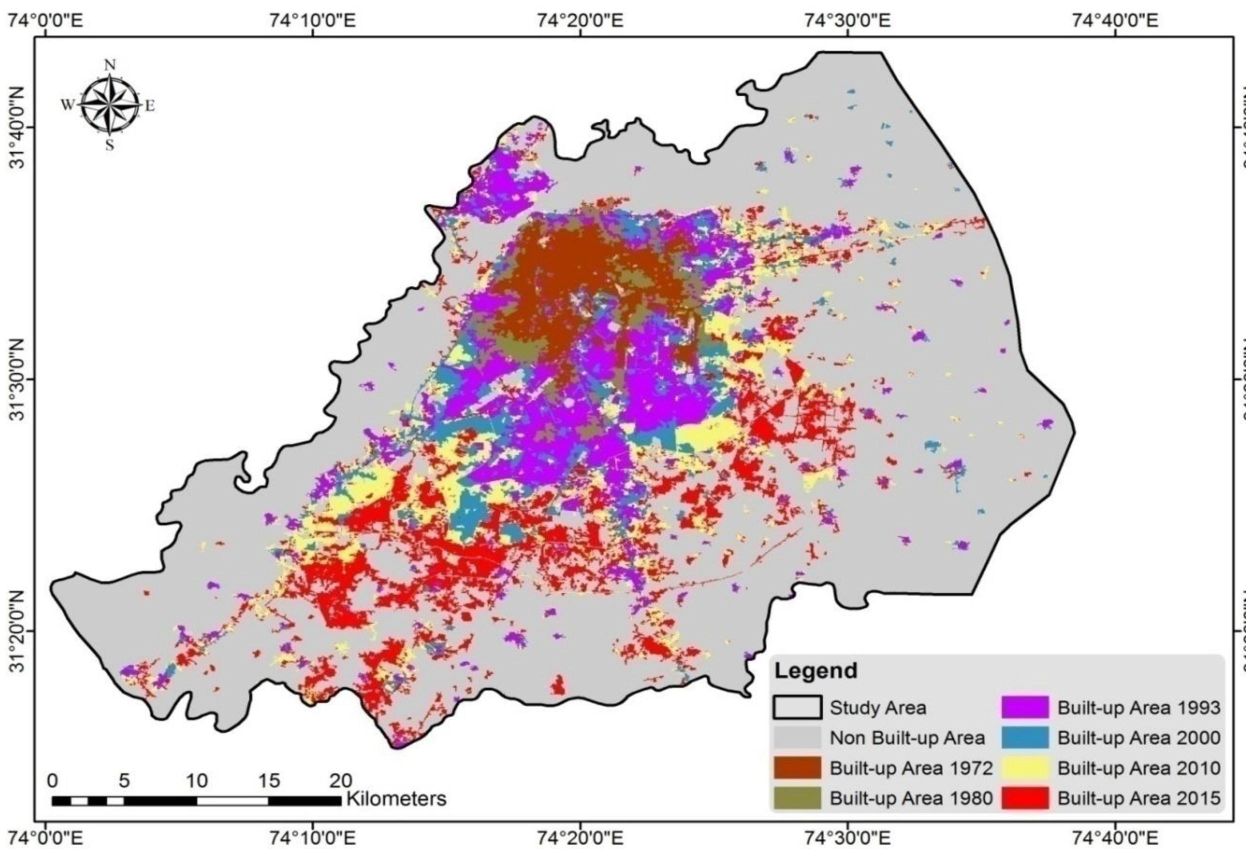


Figure 5 : Urban expansion in Lahore from 1972-2015

Conclusions: A comprehensive study was conducted to determine the impact of land cover changes on temperature variability in Lahore, which is the 2nd largest city and has experienced unprecedented urban and economic growth during past decades. The results indicated that the land cover map of Lahore has been changed significantly. The dT_{min} is showing a significant increase during the study period due to anthropogenic activities and rapidly growing population and urbanization the natural land surface is converted into built-up structures. The overall increase in the built-up area has been calculated 494.507 square kilometers. Moreover, among all the factors the alteration of vegetation cover and open spaces to build up infrastructure had a more obvious impact on temperature increase in the study area.

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