THE IMPACT OF URBANIZATION ON MEAN ANNUAL TEMPERATURE OF LAHORE METROPOLITAN AREA, PAKISTAN

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ABSTRACT: This study was aimed at to evaluate the process of urbanization and its possible correlation with mean annual temperature (MAT) in metropolitan area of Lahore for the last fifty years (1962-2012). Some parameters of urbanization were selected i.e. increase in built-up land, number of factories, number of vehicles, and reduction in vegetation cover. In order to analyze degree of correlation among mean annual temperature (MAT) and each parameter, bivariate Pearson correlation analysis was carried out. Results showed slight decrease in mean maximum temperature and considerable increase in mean minimum temperature of Lahore. It leads to linear progression towards decrement in mean annual temperature mainly due to rapid paced urbanization over the past in Lahore metropolitan area. Reduction in vegetation cover and increase in built-up area are identified as major contributors among all selected multifarious human and natural factors. Possible solution to overcome future change in temperature could be afforestation, use of environmental friendly transportation, increase in urban green spaces and mass media campaign to make people realized about the adverse effects of rise in temperature due to anthropogenic activities. The highlighted results in present research study provided guidelines to policy makers, urban planners and city managers of Lahore for better urban planning strategies in years to come.

Keywords: Urbanization, Mean annual Temperature, Land use and land cover, Pearson correlation, Lahore.

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INTRODUCTION

The possible reasons and intensity of temperature changes have widely been studied by research scholars around the world (Heisler, 1986; Grimmond, 2007 and Yilmaz *et al.*, 2009). Cities are more prone to modifying climatic conditions and become warmer as compared to surrounding rural areas (Yilmaz *et al.*, 2009). In southeast China, estimated increase in mean annual temperature of 0.05°C per decade is due to urbanization which is characterized by changes in the percentage of urban population (Zhou*et al.*, 2004). Among possible causes in the process of urbanization, conversion of vegetative land surfaces into concrete and asphalt are found to be more profound (Asaeda *et al.*, 1996; Roth *et al.*, 2002 and Akbari, 2009). Thus, absorption rate of solar heat increased due to Pacca roads (Asaeda *et al.*, 1996 and Doulos *et al.*, 2004).

The Land use and land cover (LULC) are geographical terms usually used interchangeably by the researchers. Land use can be considered as human activities in a defined geographical region. However, all physical features of that land are known as its land cover. The study of the land use and land cover modifications are now regarded as an important analytical tool for making new policies for supervising and monitoring the city management and expansion in both developed and under developed countries. The National Research Council of America has worked on climatic changes which are effected by Land use and land cover (LULC) processes because these are thought to be important climate drivers (Mahmood *et al.*, 2010).

Study Area: This study is an attempt to document temperature changes in the metropolitan area of Lahore, the capital of the Punjab, Pakistan. The Lahore Metropolitan Area (LMA) is located between 31°-15' and 31°-43' north latitudes and 74°-01' and 74°-39' east longitude. The study area is bounded by Sheikhupura district on the north and western side, while on the eastern side with Wagah international border of India and with Kasur district on the south. The Ravi River passes away on the northern flank of Lahore. Since it is the capital of the province of Punjab and is second fast growing metropolis of the country after Karachi. So, adverse effects of urbanization on temperature in Lahore Metropolitan Area are important to be studied. It is under the jurisdiction of Lahore Development Authority (LDA) therefore, consists of most parts of district Lahore, part of district Kasur and Ferozewala Tehsil of district Sheikhupura. It covers an area of 2,306 sq. km, 208 to 213 m above the mean sea level. The study area slopes from north-east to the south-west and is located on the alluvial soil of River Ravi (NESPAK, 2004).

MATERIALS AND METHODS

This temporal study was conducted to record and assess year-wise temperature changes in response to urbanization with statistical and Geographic information system (GIS) techniques. Four available satellite images for different years including 1973, 1992, 2003 and 2011, were used for analysis purpose. These images were pre-processed by layer stacking of bands. 1,2,3 and 4 of Multispectral scanner system (MSS) and 4, 3, 2 bands of Thematic Mapper (TM) and enhanced thematic mapper plus (ETM+) to analyze Land use (LU) changes by using Earth resource data analysis system imagine (ERDAS) 9.3 and ArcMap 9.3. Using stacked images for further processing, study area was clipped with the help of geo referenced image and supervised classification was applied to identify different land use classes i.e. vegetation cover, built-up area, water, bare soil. The acquired results laid down the source for deriving statistics of land use changes over selected time period. Subsequently, overall findings of causes which were contributing in temperature trend change because of urbanization were identified. On the other hand, secondary data was collected for analyzing the temporal trend of temperature from 1962 to 2012 from Pakistan Metrological Department. Other data sets including few urbanization indicators i.e. number of vehicles, number of factories etc., were acquired from 1962-2012 in order to find out the possible correlation between these indicators from different sources including, Excise and Taxation department Lahore and Punjab Bureau of Statistics as driven variables for temperature. The methodology was adopted in order to observe the significant changes in temperature trend with respect to passage of time and to find out possible causes behind it, the Pearson correlation test was applied using SPSS for statistical analysis. Later both results from prior mentioned data sets were correlated and interpreted simultaneously to identify the degree of impact of each land use features on mean annual temperature (MAT).

RESULTS AND DISCUSSION

Population Growth: Population growth was considered to be a major cause for a range of environmental problems as reported by (Adger *et al.,* 2003). According to the currently available statistics on human population and area /land size, population density for the population growth of Lahore wasrecorded and was estimated to be from 1.16 million to 10.36 million during 1951 to 2012 respectively. This alarming growth rate increased the population density from 70 to 499 persons/km^2. However, 73% of the total population of Lahore Metropolitan Area was urban in nature while remaining wasrural (GOP, 2012). Below scatter plot of the variables MAT and LMArepresented data points along a line flowing from the bottom left to the upper right, with the indication of presence of some significant positive correlation with value of .813. This was also reported in 4th intergovernmental panel on climate change (IPCC) assessment report in 2007 that growth of population gave rise to human activities which were main contributors in global warming (Solomon *et al*, 2007).
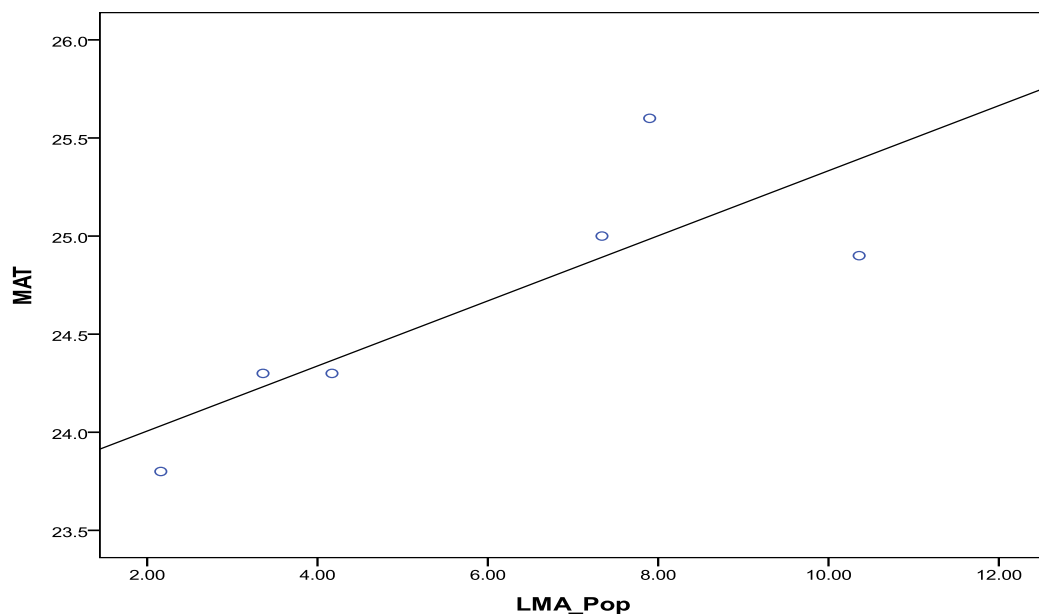

Fig. 1. Scatter diagram showing Correlation between MAT and Population Explosion at LMA

Urbanization and Land use changes: After 1980, temperature impact of land cover change was observed extensively at LMA (Shirazi, 2012; Bhalli and Ghaffar, 2015). Similarly, impact of urbanization and land use changeswere investigated through satellite imageries with the supervised classification for Lahore metropolitan areas in this study. It was classified into built-up area, vegetation; water bodies and bare soil, extracted from images as shown in fig. 2. It clearly showed that the land use of study area changedsignificantly during the last 50 years.

In studies carried out by Vitousek *et al.*, (1997) and Matson *et al.*,(1997) revealed the environmental impact of land use throughout the world, ranging from changes in atmospheric composition to the extensive modification of Earth's ecosystems. Mas *et al.,* (2004) found that LULC caused by anthropogenic activities which increased Mean annual temperature. Alteration and transfer of natural land was also observed largely due to conversion of agricultural field, over-cutting and unplanned cutting of trees. Sajjad *et al.,* (2009) has also been witnessed that temperature increase was profoundly affected by urbanization.
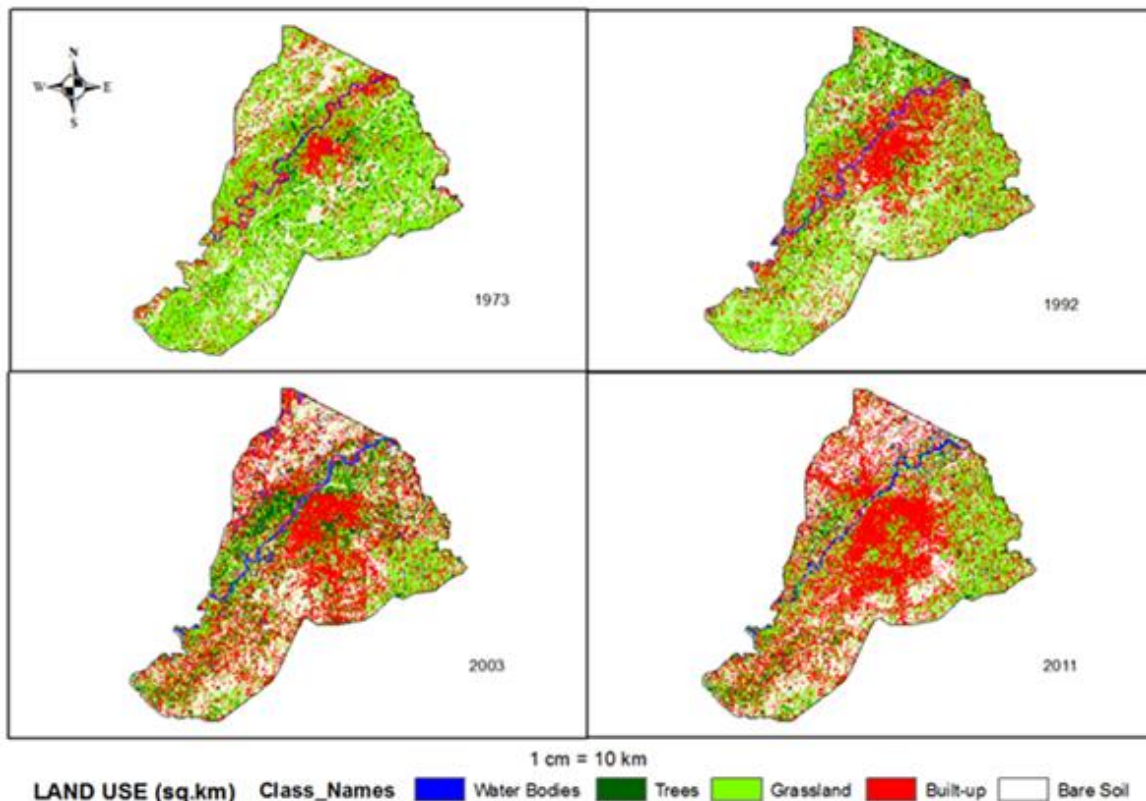

Fig.2. Showing Land use Changes in Lahore Metropolitan Area from 1973 to2011

The calculation of the area was made in square kilometers with decadal intervals as follows:

Increase in built up area: It was observed that the urban development along with variation in its morphology brought changes in the land use and land cover, both at global and regional scales. Land use and land cover changes portrayed the development pattern of the city in terms of the height with sky scrapers, extension on land with the reduction of agricultural land and density of buildings with construction. Urban development was actually transformation of vegetated area to impervious surface i.e. asphalt and concrete made roads that could be clearly observed in land use classification of the study area. With the derived area statistics of built-up, following results were obtained for finding out the magnitude of change in mean annual temperature (MAT) with urbanization. The R^2 value was 0.94, showing a highly positive correlation between MAT and urban development. It also indicated that there was a strong relationship between urbanization and MAT at 95%significant level while P-value was not greater than 0.05. The results of the present study were in line with findings of Jamei *et al.,* (2015) who found similar results in Malacca, Malaysia by analyzing its two areas including old and new city which showed more built-up area in old city which was warmer than the new city area.

Table 1. Land use Changes of Lahore Metropolitan Area

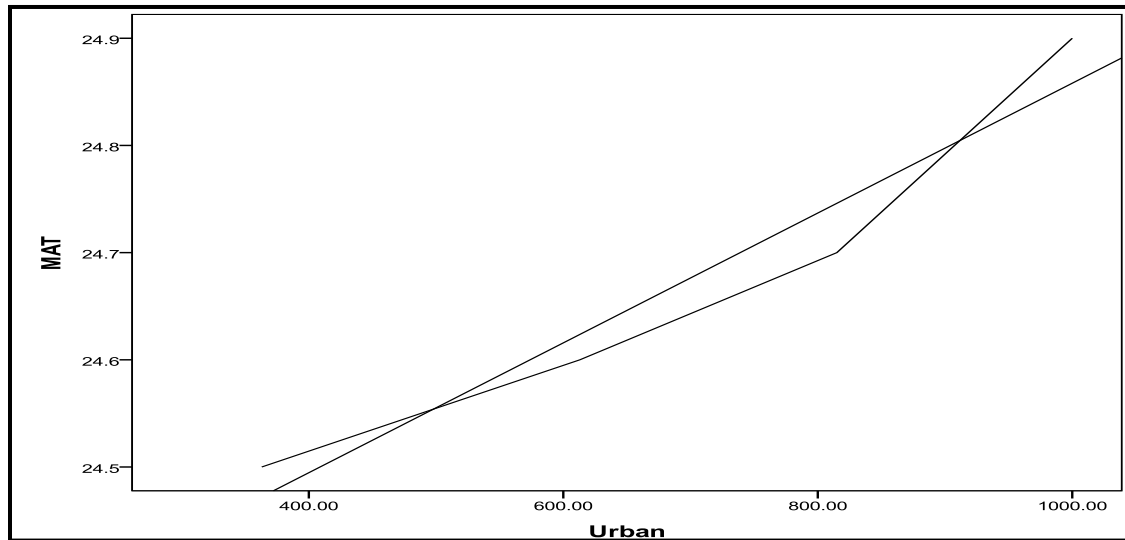| Land use	Area in Square kilometers			
	Landsat			
	MSS 23rd Mar, 1973	TM 15th Oct, 1992	ETM 31st May, 2003	ETM 03rd June , 2011
Built-up Area	363	613	815	895
Trees (Vegetation)	895	144	277	480
Grassland (Vegetation)	1181	937	444	401
Bare soil	572	559	590	510
Water bodies	28	57	91	24

Fig. 3. Showing Correlation between Urbanization and MAT

Number of Registered vehicles: According to the Lahore Motor Vehicle Registering Authority statistics, 238,790 vehicles were registered in 2007, while 290,919 vehicles were registered in 2011, which showed 18 percent increase for the year under report. This could be predicted from the above data that about 343,000 more vehicles could be estimated to be registered during the four years coming in 2015. The results of present study showed a correlation value of .487, indicating positive correlation between numbers of vehicles registered per years and MAT at 95% significant level.In a study conducted by Yilmaz *et al.*, (2009) reported that increased number of vehicles, along with other factors in Erzurum, Turkey had no significant effect on mean temperatures of the city but affected maximum temperature remarkably. The possible reason could be that Erzurum city may not have so thickly populated area as compared to Lahore.

Increase in number of factories: Like, Hua *et al.,* (2008) observed that temperature increase in rapidly developing industrial areas of china from 1961 to 2000, results for Lahore metropolitan area were also having a positive correlation value of 0.455 between number of

factories and MAT increase at 95% significant level while P-value was less than 0.05.

Reductions in vegetative cover: The vegetation cover of the LMA was almost dwindled due to unplanned and over cutting. The Natural land has been replaced mainly by built-up areas in the last 50 years (Sajjad *et al.,* 2009). Results showed a highly negative correlation between reduction in vegetation cover and MAT at a significance level of 95% as given by alpha value (Zia, 2013).

Changes in Mean Annual Temperature (MAT) of Lahore: In the present study, the mean annual temperature (MAT) showed an increasing trend i.e. 23.8 °C to 25.6 °C from 1962-2012, which was similar to the findings of Turkes and Sumer (2004) who found significant warming trends from 1929 to 1999 in most parts of the country. Moreover, results of Lahore metropolitan area also revealed that during the year 2002, 2004, and 2009 were warmest years having a temperature of 25.6 °C during the last fifty years whereas year of 1983 was recorded to be lowest in the selected time period. Warmest years were typically observed during last decade. The trend line indicated almost linear progression with increment of the Mean annual temperature (Fig. 8).
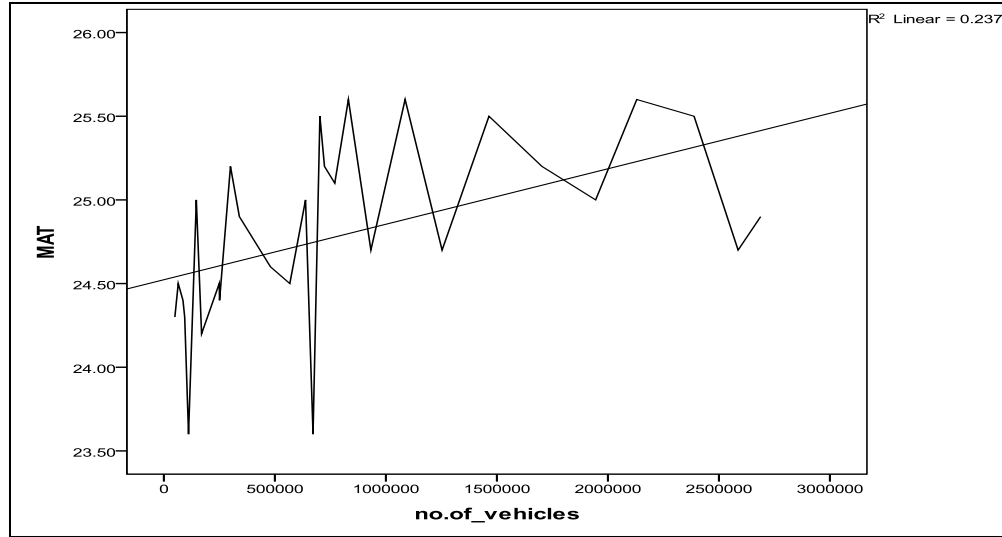
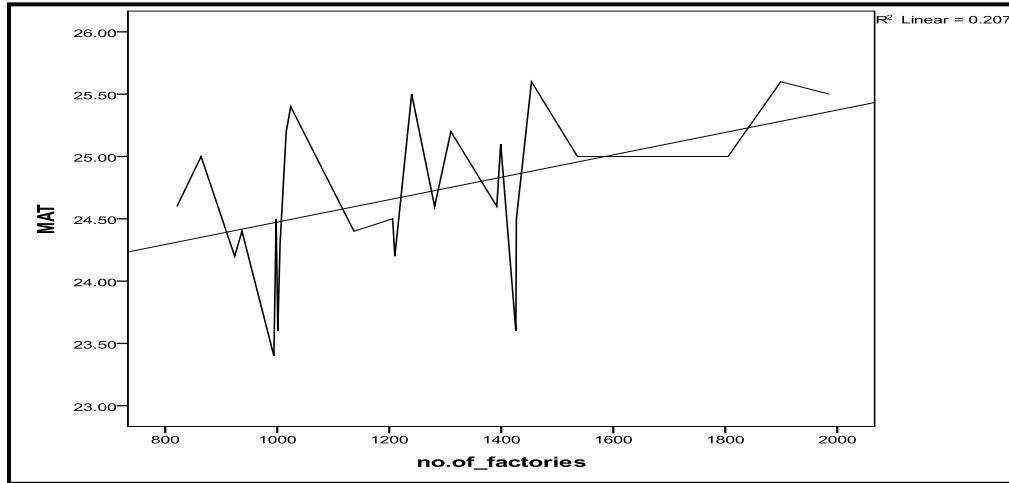**Fig.4: Showing correlation between increase of vehicles and MAT**

Fig.5. Showing Correlation between Increase of Factories and MAT
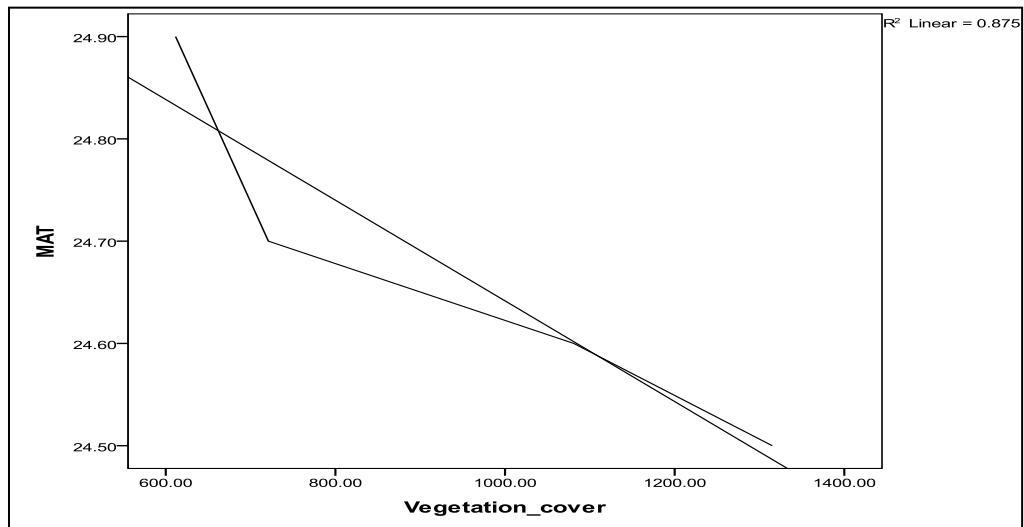

Fig. 6. Showing Correlation between Reduction in Vegetation Cover and MAT

Table 2. Degree of Correlation by Different Drivers behind the TemperatureTrend Changes in the Lahore Metropolitan area.

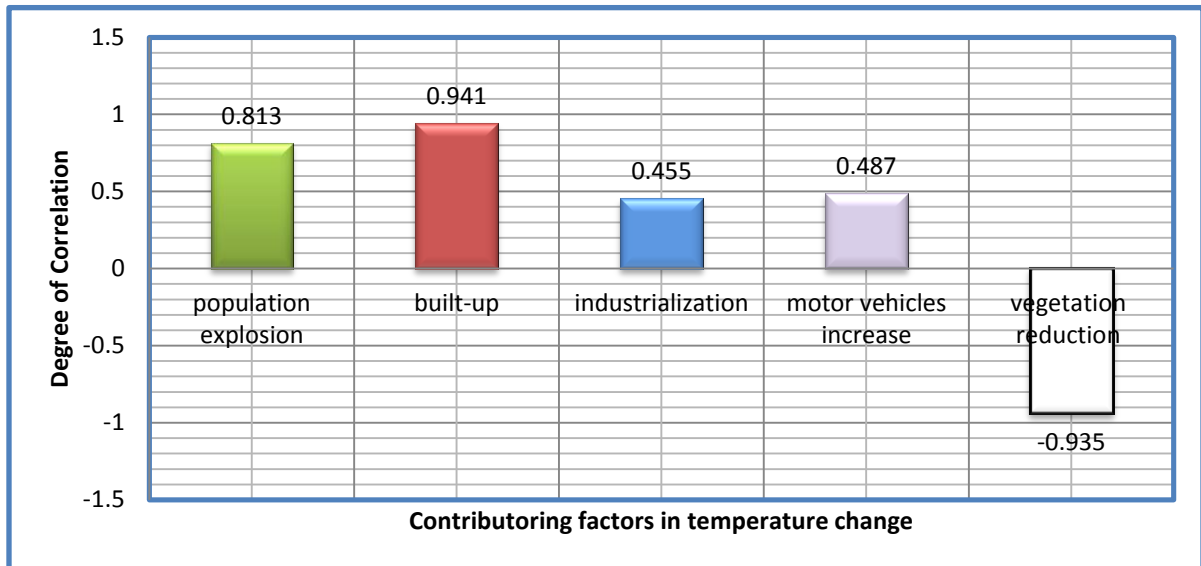| Contributing factors	Degree of Correlation	Type of correlation
Population Explosion	0.813	Positive
Land use change	0.941	Positive
Industrialization	0.455	Positive
Motor vehicles increase	0.487	Positive
Vegetation reduction	0.935	Negative

Fig.7. Comparison Chart showing all Contributing factors in temperature change
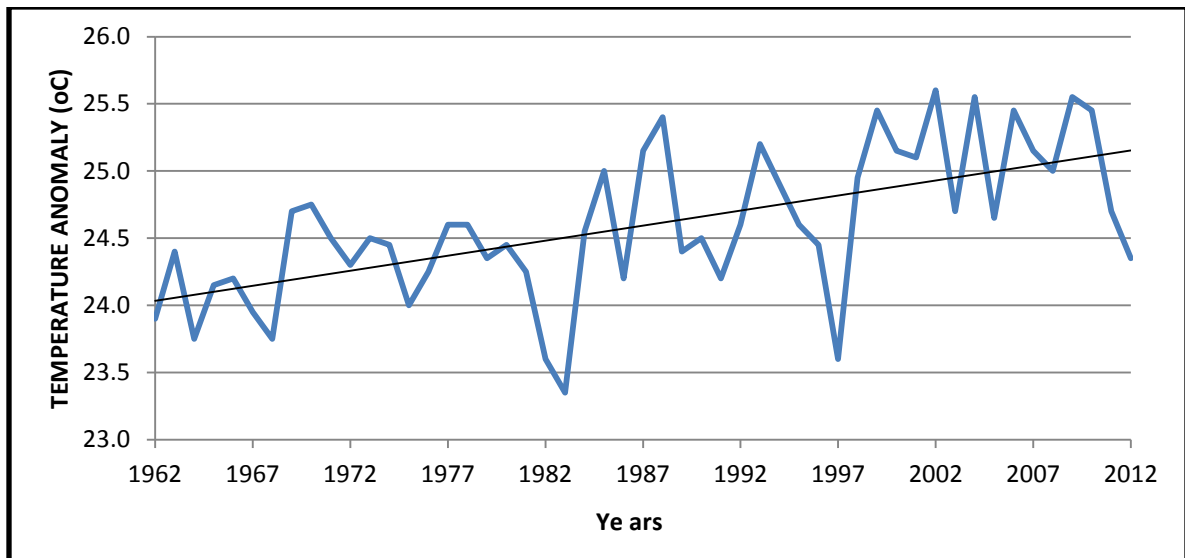

Fig.8. Mean Annual Temperature Trendof Lahore from1962-2012.

Conclusion: It was concluded from the present studies that a significant rise in temperature in LMA during the last 50 years was due to fast paced urbanization. However, among all factors increased built up areas and reduction in vegetation had a profound effect on temperature increase. Moreover, it is also thought to be major contributor in increase of green house gases and has lead to the formation of smog, which appears as a dense layer of clouds of suspended particulates over LMA. This is mainly because of increased greenhouse

effect situation which is responsible to a gradual rise in Lahore's minimum temperature. This phenomenon in turn also affects on the mean maximum temperature also which is decreasing with the passage of time.

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