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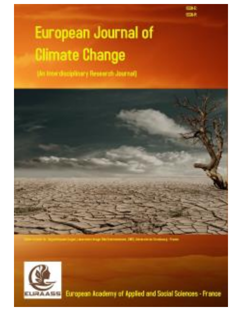


Research Article

# Monitoring and analysis of urban heat Island of Lahore city in Pakistan during winter season

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**Abstract**

The phenomenon of Urban Heat Island (UHI) is a result of various factors ranging from increase in urban built-up land to human activities and affected the climate in urban areas. Therefore, the main objectives of the current study are to monitor the temperature variations and assess UHI in Lahore city. In order to measure the UHI, the meteorological data was collected by installing Digital Weather Station WS-1080, at two selected sites, one at Mozang (urban site) and other at Sangra (rural site) from January 15 to 18, 2015 (4 days) in winter season. The results of the study reveal that notable variations of temperature were recorded between Mozang and Sangra. The mean day-time temperature (23.9°C) was higher at Sangra than Mozang (22.8°C). Whereas temperature at night-time was higher at Mozang and lower at Sangra. The R2 value of 0.0041 also demonstrates positive relationship between UHI and dew point at Mozang. The speed and direction of wind also influences the intensity of UHI. During the observational days, the range of UHI was 4.3°C to 6.2°C. Hence, the difference between the minimum and maximum temperature was almost 2°C and it highlighted that the UHI was enhancing. Lastly, few suggestions were proposed to mitigate the issue of UHI.

**Keywords:**

Urban Heat Island, Urbanization, Lahore, Climate Change.



## 1. Introduction

Urban Heat Island (UHI) is a phenomenon in which temperature of atmosphere and surface is higher in urban areas than the surrounding rural areas. This phenomenon is mostly pragmatic in cities irrespective of their size and location (Connors et al., 2013). The UHI is mostly caused due to the adaptation of earth surfaces by urban development. Moreover, an increase in built-up land and anthropogenic activities are also responsible for UHI (Yang et al., 2016). It is created an unintentional climatic modification due to urbanization that changes the temperature with the growth of cities and may also affect the temperature trends by accumulation of short-wave radiation (Voogt, 2004; Solecki et al., 2005; Brandsma and Wolters, 2012). Ratio of urbanized versus green places for every entity spot, atmospheric surroundings (e.g., humidity, wind, temperature) and social and economic actions verify the development of the UHI

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(Huang et al., 2011). With the increase of urbanization, the land area which is covered with trees, shrubs and vegetated area is transferred into residential, pavement, and industrial area. Besides, the dry permeable area is transferred into impermeable area, resulting in formulation of an “island” which is warmer than the surrounding area, known as urban heat land (Lillesand et al., 2014). Particularly earth surface distinctiveness is mostly represented by land-use and land-cover (LULC) and as its change, its impact inflicted on land surface temperature (LST) and air temperature. Therefore, the link between the LST and LULC has been the centre of attention of many studies on the UHI (Buyantuyev and Wu, 2010: Pal and Ziaul, 2017). The other familiar causes of UHI in an urban centre are large buildings with thermal mugs, and heat emissions, pollution and consumption of energy in a city, lack of green areas, pressure of low albedo material, pressure of low speed wind and loss of long wave radiation on night in low rate (O’ Malley et al., 2014).

The effect of UHI is different in different locations of a city. It is greater to the densest (central) part of the city having maximum temperature. The effect of UHI is classified into two major classes such as people and micro-climates. UHI is playing a foremost impact on the micro-climate, it alternates the local climate such as wind pattern, humidity, frequency of floods and storms and local ecosystems. Moreover, it also contributes in increase of global warming by adding greenhouse gasses into the atmosphere through consumption of energy, extra use of air conditions, and heat emissions releasing from the local environment (O’ Malley et al., 2014). UHI is the joint reaction of several elements. These elements can be classified into controllable and uncontrollable factors and subdivided into short-term effect variables like air speed, cloud cover and cyclic effect, variables such as solar radiations and manmade heat resources (Rizwan et al., 2008). UHI is also caused greater transmission of dengue, in high temperature, low vegetated, and more polluted areas i.e. the findings of a case study of Sao-Paulo (Brazil) has summarized that 7,415 cases (93.1%) of dengue recorded to 28°C temperature. Among these 72.3% cases were in low vegetated cover areas and 3.2% cases in high vegetated cover areas (Araujo et al., 2015).

UHI is studied by various researchers at various times in various locations by looking its impact on energy consumptions in buildings, its effect to increase the urban temperature and cause to increase the demand of electricity for cooling (Kolokotsa and Gobakis,. 2014). During a study conducted in Padua city (Italy), the data of air temperature, humidity and global solar radiation was acquired from period of 2010 and 2011 and were measured from different angles across the city from city to sub-urban and rural areas. The results show the increase of up to 6°C UHI in city as compared to the sub-urban and rural areas (Busato et al., 2014). In New York, a study found the difference of temperature 2°C between the vegetated and non-vegetated area of the city (Hafner and Kidder., 1999). Similarly, in Singapore the difference of 4°C is found between urban and rural areas (Wong and Yu., 2005). The greater contributor of UHI is the residential area followed by an industrial area (Li et al., 2011).

UHI mitigation are classified into two major classes, first by planting the trees and vegtation by providing the shade in an urban area and second by making the urban surface into white roofs, and concrete material by absorbing solar radiation like two walls of houses may reduce the temperatures from 11°C to 25°C, Vines on the wall reduce the temperature 20°C and trees in the parking area reduces the temperature 25°C to its surrouding and sub-urban area (Cleare, 2006; Doick and Hutchings, 2013). A study was conducted to mitigate the urban heat island through a global climatic model by using white roofs, the results shows that all the urban areas have decreased 33% temperature. Urban diurrnal temperature is reduced 0.6°C and daily minimum temperature is reduced 0.3°C, such a difference in temperature is due to absorbtion of solar radiation. Therefore, the use of white roofs is beneficial for the reduction of UHI (Voogt, 2004). A study is conducted in California (USA) with over 250 participants are participated for shade trees planted in the outdoor of houses. An average of 3 trees were planted from the distance of 10 feet (3m) from the houses, results were interesting that energy use is reduced approximately 2% that were used for heating and the energy that is used for cooling saved 1% energy (Solecki et al., 2005). Vegetation and water are the two ways by which UHI is mitigated. Therefore, in Phoneix city, two third of municipality water is to use for the maintenance of shrubs, trees, vegetation, pool evaporation and grass (Larson et al., 2013).

The issue of UHI in Pakistan is also accelerating, causing serious environmental and health concerns in bigger urban centres viz. Karachi, Lahore, Islamabad, Rawalpindi, Gujranwala, Multan and others. A recent study conducted in Lahore reported that just in a decade from 2000 to 2011 the temperature is raised 0.73% in the entire city, due to the relationship of UHI and LULC (Shah and Ghouri, 2015). Minimum temperature is increasing in Lahore as compared to maximum temperature particularly in spring season (Sajjad et al., 2015a). Similarly, a study conducted in twin cities Islamabad and Rawalpindi reveals the increase of UHI from 0.193±0.0440°C during summer and 0.349±0.0300°C during winter seasons (Memon, 2014). Hence, keeping in view the literature, the objectives of the current study are to monitor the temperature variations and to assess the Urban Heat Island in Lahore city.

## 2. Materials and Methods

Lahore is the 2nd largest urban centre of Pakistan having a population of 11,126,285 (PBS, 2017). Geographically, it is located between 31°15' to 31°43' North latitude and 74°10' to 74°39' East longitude. Lahore district is adjacent to district Kasur and Sheikhupura (Sajjad et al., 2009). The district has a hot semi-arid steppe type of climate. The alarming growth rate in urban population has boosted up the population congestion, environmental pollution, commuting problems and improper provision of civic services to the citizens.

The selection of the study sites from where the data derived is an important work in any study. Therefore, two sites were selected to install the weather station. A village named Sangra located in west of Lahore as a rural site and Mozang as an urban site were selected after survey of these areas. Mozang is often known as the heart of Lahore as it is a congested area and has many government and semi-government offices, shops, small industries and the houses of employees. Traffic is also at its peak that produce many harmful pollutants causing many diseases, sometimes may lead to death. Energy consumption is also greater in Mozang as compare to the rural site Sangra.

In order to obtain temperature and meteorological data to monitor the temperature variations and UHI, the Weather Station (WS) 1080 (Digital Data Receiver) is used by keeping in nearby places i.e. garage, open space with a specific range. It has the capacity to receive the data within the transmission range of up to 100 meters (330 feet). The relevant instrument (WS 1080) is much more reliable to collect the data, not only for this study but also for meteorological studies of various types and applications. The major data measuring instruments in the weather station were Wind wane, Anemometer, Rain gauge, Hygrometer and Thermometer. For this purpose, two ground-based weather stations were installed about 1.5 meters above surface of the earth (as an international standard to install a weather station) one at rural site (Sangra) and another at urban site (Mozang). The data was measured with a resolution of 30 minutes of interval. The approximate distance between the urban and rural station was measured as 13 km. After obtaining the data the analysis of the data was performed for different time periods and based on: monitoring period and night-time and day-time periods (Figure 1).

It is known fact that the intensity of urban and rural temperature difference can alters on daily (or diurnal) and seasonal basis (Soltani and Sharifi, 2017). Therefore, the meteorological data were collected on diurnal basis from 15-01-2015 mid night to 18-01-2015 till mid night (96 hours or 04 days) with an interval of 30 minutes. The study period was in winter season and the selection of this short period was because of the calm winds and clear sky during this which helps to study the temperature variations and UHI without biases of external climatic factors i.e. hazy or cloudy weather, very strong winds etc. Finally, the data was coded and analysed in SPSS 17 by applying descriptive statistics and correlation and MS Excel used for preparing graphs.

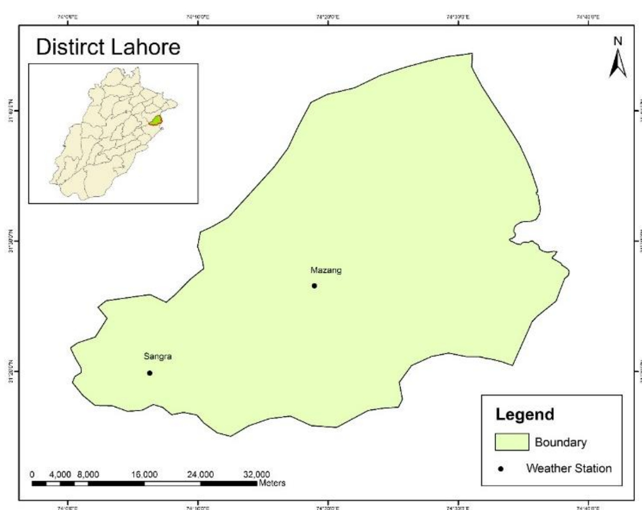


Figure 1: Location Map of Lahore and the Study Sites.

## 3. Results and Discussion

Table 1 elaborate and Figure 3 and 4 visualize the variations of the minimum and maximum temperature of the data collected from urban and rural study sites to find out the temperature variations and subsequently the UHI of the study area. A recent study also found that surface UHI is highly associated with the landuse of the surface (Azevedo et al., 2016). The difference in maximum temperature at rural and urban site was almost equal with the difference of 1°C. On the other hand, there was great difference in minimum temperature of rural and urban sites. The lowest range of temperature during the study period at rural site was 6.7°C to 4.8°C and highest range of temperature at rural station was 22°C to 23.9°C. The lowest range of temperature at urban station was 8.8°C to 10.8°C and the highest range of temperature was 22.5°C to 23°C. This shows the temperature difference between the rural and urban site. This difference is also highlighted due to the surface variability as the rural site has much land under vegetal cover, therefore, trees that absorb heat greatly during day time, emit it in the form of moisture at night time (Figure 3). A previous study also concluded that trees and shrubs in greens paces lessen the mean maximum daily surface temperatures in the summer by 5.7°C as compared to non-woody vegetation, but inclined to maintain slightly higher temperatures in winter (Edmondson et al., 2016). Whereas, on the other hand, the urban site of Mozang lacks of green patches and vegetation as it is congested and populous area, occupied mostly by concreted structures, buildings, roads and epic traffic (Figure 2). A previous study in Egypt found that the mean temperature of UHI in urban areas of Al-Arbin and Al-Suez districts was 7.5°C higher than the mean temperature of the District (Ahmed, 2018).


Figure 2: Surface structure of rural (left panel) and urban (right panel) sites.

Figure 3 shows the direction of the blowing wind, during the days of data collection. It was mostly from North to North East, North West and East sides. All these days have shown different scenario according to the speed of wind. The speed of wind was medium to the north side, high to the East sides and low to the North-West side. Temperature was low as compared to other days when the wind is blowing. But when the wind was not blowing temperature was high as compared to wind blowing days. So, wind blowing days have minimum UHI as compared to Non-wind blowing days. Results are showing that the speed of wind was maximum at Thursday (3km/hr) and UHI was 5.2°C while on Sunday the wind speed was at its low level (less than 1km/hr) and UHI was 6.2°C. This shows that wind is also playing a major role in the formation of UHI. Whereas, on Friday and Saturday the speed of wind was medium (1-3 km/hr) and the UHI was also normal as 5.4°C and 4.3°C respectively.

Due to the cooling of different urban and rural areas results in atmospheric UHI. The cooling rates were different at calm and clear nights and days as compared to cooler areas that became cool more rapidly than the urban areas. Sometime the intensity of UHI produced during the mid-afternoon or late-afternoon or it may be after the few hours of sunset. In some case studies, it is experienced UHI intensity might not be reached at the peak until morning or after sunrise as it is measured 5.9°C in Adelaide (Australia), however the maximum UHI intensity is measured during the late after-noon, when the variations are 2°C between the CBD and the green urban area (Soltani and Sharifi, 2017). In another study UHI is measured, the study shows the variations in temperature in built-up and rural area, the highest intensity of UHI is observed at Sargodha on Sunday 5.7°C (Sajjad et al., 2015b).

Figure 4 shows the variations of temperature between rural (Sangra) and urban (Mozang) sites from 15 to 18$^{th}$ of January 2015. The interval of data was 30 minutes of resolution. The variations between temporal and spatial temperature can be easily observed. The temperature (23.9°C on Saturday) at rural site (Sangra) was higher in the day-time than that of the urban site (Mozang), which was recorded 22.8°C on Sunday. While on the other hand, the temperature at night-time as it is observed was higher at the urban site (Mozang) and lower at rural site (Sangra). In a study, it is found that the urban-rural temperature can varies 5-10°C under perfect conditions of clear sky and light blowing winds. In many cases, the UHI is substantial at night i.e. a study in Paris summarized that the intensity of the night-time. UHI was up-to 7°C than that of day-time UHI (Lac et al., 2013). Figure highlights the UHI of the study area that is derived after making comparison of urban and rural stations of Lahore from 15 to 18$^{th}$ January 2015 and shows the variability in intensity of the UHI. Thursday on 15$^{th}$ of January, 2015 UHI was 5.2°C, on Friday 16th of January 2015 the UHI was 5.4°C, on Saturday 17th of January 2015 the UHI was 4.3°C and on Sunday 18th of January 2015 the UHI was 6.2°C. It showed that derived UHI of 6.2°C was maximum on Sunday morning about 4:14 am to 6:14 am, while, the minimum 4.3°C UHI was on Saturday. During this period, the range of UHI was 4.3°C to 6.2°C. Hence, the difference between the minimum and maximum temperature was almost 2°C. A study conducted in Singapore shows that in day-time, the order of temperature at different urban places like industrial, commercial, residential areas, parks and airport was higher. On the other hand, the order of temperature at night-time in commercial, residential, industrial areas, parks, and airports was low as compared to day-time (Jusuf et al., 2007). But, it is very interesting to note that this hike in the temperature on Sunday perhaps due to the people focus in the city for shopping on weekly holiday. Rest of the days, the working class of the city remained busy in offices, shops, colleges, universities, and other work places. But, on Sunday they feel relaxed and used the energy consumption machines and appliances without any pressure. As they are free to move for the whole day and night of Sunday.

Table 1: Minimum and Maximum Temperature of Urban (Mozang) and Rural (Sangra) Sites during observational period.

| Date and Day of the Survey | Sangra (Rural Site) Maximum temperature(°C) | Sangra (Rural Site) Minimum temperature(°C) | Mozang (Urban Site) Maximum temperature(°C) | Mozang (Urban Site) Minimum temperature(°C) |
|---|---|---|---|---|
| Thursday 15-01-2015 | 22 | 5.8 | 22.5 | 8.8 |
| Friday 16-01-2015 | 23.7 | 5.6 | 23 | 9.9 |
| Saturday 17-01-2015 | 23.9 | 6.7 | 22.7 | 10.9 |
| Sunday 18-01-2015 | 23.4 | 4.8 | 22.8 | 10.7 |

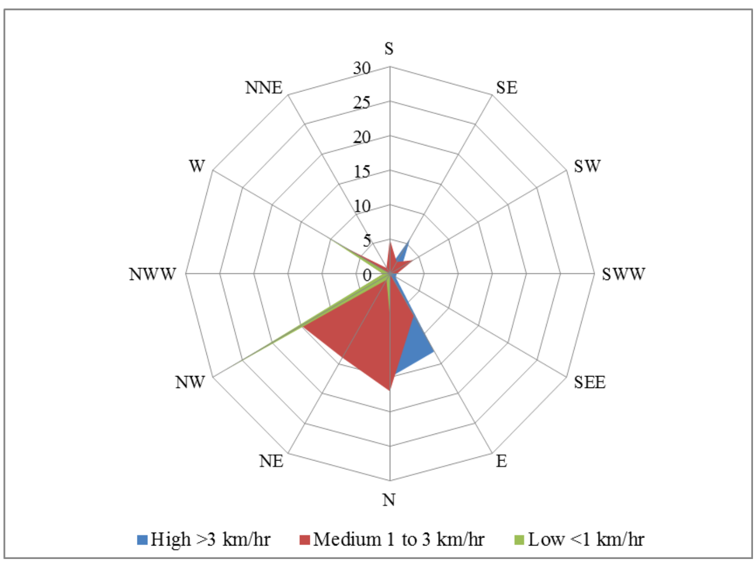


Figure 3: Wind Direction during the Data Collection Days.

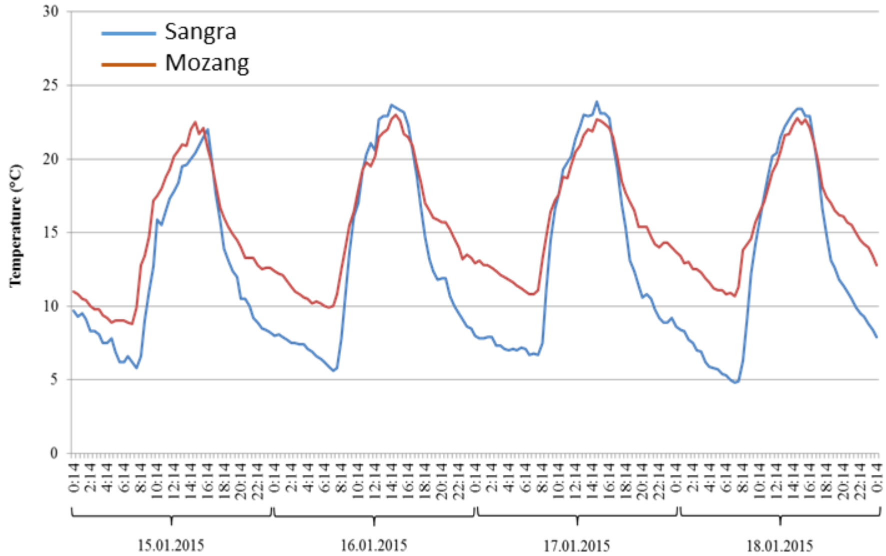


Figure 4: Variability of Temperature of Urban (Mozang) and Rural Site (Sangra).

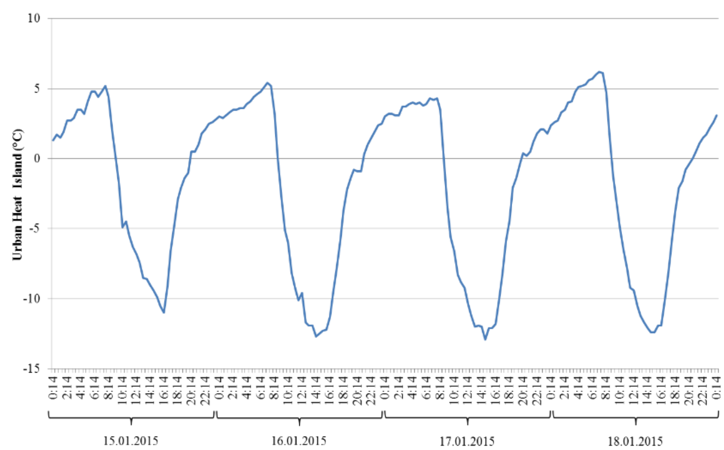


Figure 5: Variations of Urban Heat Island of Study Area during 15th to 18th of January 2015.

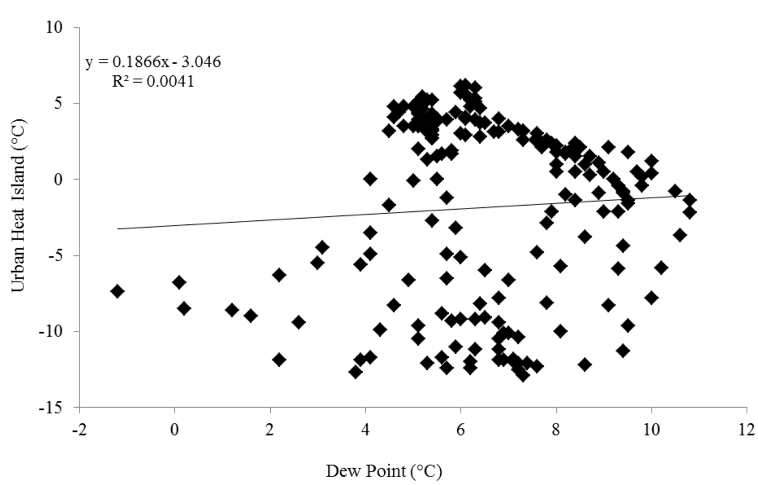


Figure 6: Relationship between UHI and Dew Point at Urban Site (Mozang).

Figure 6 shows the relationship between dew point and UHI of urban site (Mozang). The $R^2$ (coefficient of determinant) value of 0.0041 is found between UHI and dew point at urban site Mozang. Although due to foggy days, the dew point data is not well observed, yet there is a neutral relationship between these two variables and that is positive.

## 4. Conclusion

Lahore is the 2nd largest city of the Pakistan facing serious issues of rapid urbanization and gradual increase in temperature. Increasing temperature is playing a vital role in changing the urban climate greatly as the consumption of more energy resources and the emissions of gasses are resulting in the pollution, greenhouse gasses and urban heat island (UHI) phenomena. Results of the present study strongly evidenced that the UHI is due to the lack of vegetation, rapid increase in urbanization and use of more energy resources. Particularly, the inner urban site Mozang has maximum urban population and energy consumption was facing high temperature and UHI as compare to the rural site Sangra. The notable variations have been recorded in the day-time and night-time temperature between the urban and rural sites. The highest day-time temperature was recorded at Sangra than the urban site Mozang, whereas, the temperature at night-time was higher at Mozang than the rural site Sangra. Similarly, there was a high difference between minimum and maximum temperature and UHI. The highest UHI was recorded on Sunday and lowest on Saturday. Moreover, calm winds also contribute to enhance the UHI and there is also a positive relationship found between UHI and dew point at Mozang that validates the high UHI on Sunday during the morning hours. Hence, it is concluded that the UHI has become an alarming problem for the city of Lahore.

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