

# **ESTIMATION OF THE URBAN HEAT ISLAND IN LOCAL CLIMATE CHANGE AND VULNERABILITY ASSESSMENT FOR AIR QUALITY IN DELHI**

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## **Abstract**

Delhi experience the effect of high heat compared to the rural surroundings during hot seasons. This phenomenon is known as Urban Heat Island (UHI) which exerts a significant influence on local climate. Urban climate, land cover, land use, vegetation ratio and surface temperature have been cited as the main contributors to the UHI effect. This paper focuses on urban heat islands (UHI) as a specific problem expected to be exacerbated by local climate change. A simple formula has been used to calculate the urban heat island (UHI) from a set of land surface temperature data for observed temperatures by Landsat 7 and 8 and quantifies how this urban heat island effect on local climate change response strategy 2000- 2014. The aim is to identify climate sensitive urban patterns during summer, winter and monsoon months. The study reveals that the intensity of heat island varies from 3 C° to 8 C° and intensity is high during summer season compared to monsoon and winter seasons. In Delhi the formation of heat island is controlled by vegetation density. It has been found that UHI become bigger during cooling at night time. The urban heat island helps to decrease air quality during summer. UHI coupled with high land surface temperature conditions during summer season causes human discomfort and higher death rates in Delhi. These changes reflect sensitivity to variations in regional climate alone, so omit other factors such as changes in land use, emissions, land surface temperature, or synergies on size and shape of heat islands.

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**Keywords:** Urban Heat Island, Emissivity, Air quality, Urban climate

## Introduction

Why cities are matter, already about 50 percent of people live in cities that this number will increase to 80 percent by 2030. In the Indian context, over 27.8% of Indians currently live in urban areas. There are 4,000 cities and towns in India, out of which about 300 cities have a population of more than 1, 00,000. Seven cities viz. Mumbai, Delhi, Bangalore, Kolkata, Chennai, Hyderabad and Ahmedabad have population of more than 3 million. Greater Mumbai still is the most populated city in India, followed by Delhi, Kolkata, Bangalore and Chennai (Census of India, 2011). The trend of urbanization can increase local temperatures, whereas temperatures in less built-up suburban/rural areas generally will remain constant (Rosenweig et al. 2005). In fact people's activities across the cities changed physical view of the cities which cause different temperature between central and surrounding areas. Urban heat island is matters for so many indicators which involve to people life such as health and energy used. Major cities across the world experience the urban heat island effects. Generally urban areas have warmer air temperature relative to suburban areas which depend on ecology background of the city can make weak or strong heat island. Increasing urban temperature in the center can generate difference temperature between center and surrounding urban area non as urban heat island. Urban heat island is varies from city to city. They are several factors like size and ecology contacts of the city can cause heat island. The buildings, amount of vegetation, water bodies, streets and other infrastructure that comprise urban environments typically make cities hotter than surrounding rural areas. This condition of hotter cities than its surroundings is known as an urban heat island. An urban ecosystem affected by human activities which could impacts on environment. Surface urban heat islands (SUHI) are one of the three widely recognized heat island types (the other two being canopy layer heat island and boundary layer heat island) is an important factor in global change studies, in estimating radiation budgets and amount of solar radiation in heat balance studies and as a control for climate models. Delhi is situated between the Thar Desert of Rajasthan to the west and with hills area to the north and east. Delhi being a industrial area with different land use and land cover with a long river inside and also a vulnerable climate in three different seasons (monsoon, Pre monsoon and post monsoon). Urban climate and Meteorological conditions. Air quality, rather than climate itself, was defined as a problem first. The first known urban climate study was published in 1833 by Luke Howard, an alchemist who also provided the first description of cloud types. Using methodologies and equipment the quality of which would not be acceptable today, Howard established differences in climate between London and surrounding countryside. In 1925, the first circulation pattern associated with an urban center was identified in Munich. Urban Heat

Islands (UHIs) were first identified in the 1800s when the differences between London's temperatures and the surrounding countryside were noted (Howard, 1818; Streuther, 2002). Howard analyzed many of the temporal characteristics of the urban which effect on air temperature observed by him. Although Howard never took simultaneous measurements at different sites in London and its environs he correctly deduced that it was an effect lessened in the suburbs. Furthermore we have to mention the other works which done for Paris during the second half of the 19th century (Renou, 1855), and also Wilhelm Schmidt found these conditions in Vienna early in the 20th century (Schmidt, 1917,1927). In 1956, T.J. Chandler produced the first major description of the London heat island, including spatial distribution maps. The first major urban climate experiment, the Metropolitan meteorological experiment (METROMEX), occurred in St Louis (USA) in the early 1970s. Interest and the literature in urban climates were expanding rapidly. In 1972, P Rao introduced the use of remote sensing from satellites for urban heat island analysis. In that year, the American Meteorological Society held its first conference on the urban environment. In 1974 and 1975, the first detailed work on urban canyons began. Further reviews on urban climate during the 1970s were produced by T. Oke for the WMO. In 1981, Helmut Landsberg's landmark book, *The Urban Climate*, was published by Academic Press, followed in 1985 by *The Urban Atmosphere* by B. Atkinson. The relationship between meteorological conditions and the UHI is generally well known. Morris et al. (2001) and Morris and Simmons (2000) provide a detailed evaluation of the relationship between UHI and meteorological conditions between 2000 and 2010 in Delhi. Comparing a central business district site with three rural air port sites, the UHI detected over the 20 year period averaged  $1.13^{\circ}\text{C}$  and ranged from  $-3.16$  to  $+6^{\circ}\text{C}$ . Negative temperature periods suggested the existence of an urban cool island. On a seasonal basis, the average UHI was 1.29 in summer, 1.13 in spring, 1.02 in autumn, and 0.98 in winter. The differences between spring/summer and autumn/ winter were statistically significant. This study allowed an evaluation of the total range of weather conditions on UHI, rather than just a focus on extreme conditions. The dominant frequency of UHI values occurred between 0 and  $2^{\circ}\text{C}$ . In fact when synoptic conditions are calm or very weak, a local urban circulation, the UHIC, can form, controlled by the difference in temperature between the urban center and the rural surroundings (Haeger- Eugenessen and Holmer 1999). Once it reaches the UHI center, the increased heating and turbulence causes it to rise. The UHIC forms most strongly in the daytime because solar heating favors greater vertical convection (Oke, 1995). Eliasson and Holmer (1990) studied UHI with meteorological conditions over Göteborg. When UHIs were stronger than  $2.5^{\circ}\text{C}$ , an urban circulation system was established over

Göteborg on winter night. UHIC development at night can bring cooler air into the city, reducing the urban- rural temperature gradient, but creating an equilibrium between the city and its rural surroundings that allows the UHIC to continue for several hours (Haeger- Eugenessen and Holmer 1999). Generally different UHI phenomena can be distinguished vertically. Air temperature sensors at weather – screen level (UCL) record something different from those at higher elevation above the surface, in the UBL, and from that derived from remotely sensed surface temperature data. Increasingly, UHI are being studied using remotely sensed surface temperature data. This satellite derived ground temperatures do not always reveal the same spatial and temporal patterns as air temperature survey. In Delhi atmospheric inversion, another vital phenomenon, occurs by trapping of the cold air over Delhi with gaseous pollutant. Vehicular pollution is accountable for almost 70% of the air pollution in Delhi and degradation in air quality noticed, further threatening serious health problems. Positive relationship between existence of green cover and micro climate however land Use/Cover Change monitoring can bring better understanding for status of green cover and Urban Heat Island (UHI). Therefore, it was essential for us to monitor and predict Urban Heat Island as it has impact on the micro-climate of Delhi.

### **Present climate**

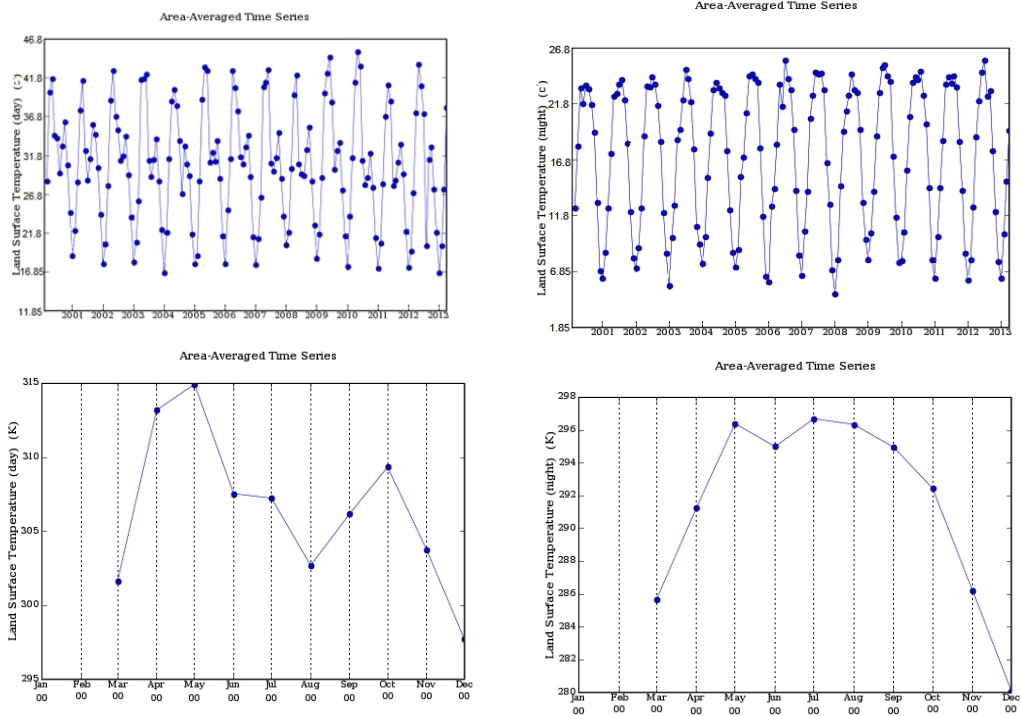
Few studies have discussed the association between the urban heat island (UHI) phenomenon and air quality under synoptic weather patterns conducive to UHI. In this study, the authors used statistical analyses to study this association in the Delhi metropolis region. The air quality data obtained from CPCB observation stations (Average of 9 stations) and temperature field. Delhi's Heat Island can be several degrees warmer than surrounding rural areas due to the urban heat island effect. For example, the average peak temperature difference between the central part of Delhi (Darya Gang) and a rural reference station in Langley (about 30km west) was 5°C over the summer of 1999 (Mallick.,2006). Increased urban temperatures have an impact on the summer cooling demand in relation to the “intensity” of the heat island – defined as the peak difference between urban and rural temperatures. Detailed monitoring indicates that the heat island is most pronounced at night, that it weakens with increasing wind speed and distance from central part of Delhi. Figure 1a, shows that the heat island is also highly changeable from one year to the next (as a consequence of variable temperature patterns), attaining differences of up to 7°C between Mangolpuri (N),(S) and Nangal Raya, Pratap Nagar and Subhash Nagar. The annual number of nights with intense heat islands (defined herein as greater than 5°C) has been climbing at a rate of over four years per decade since the late

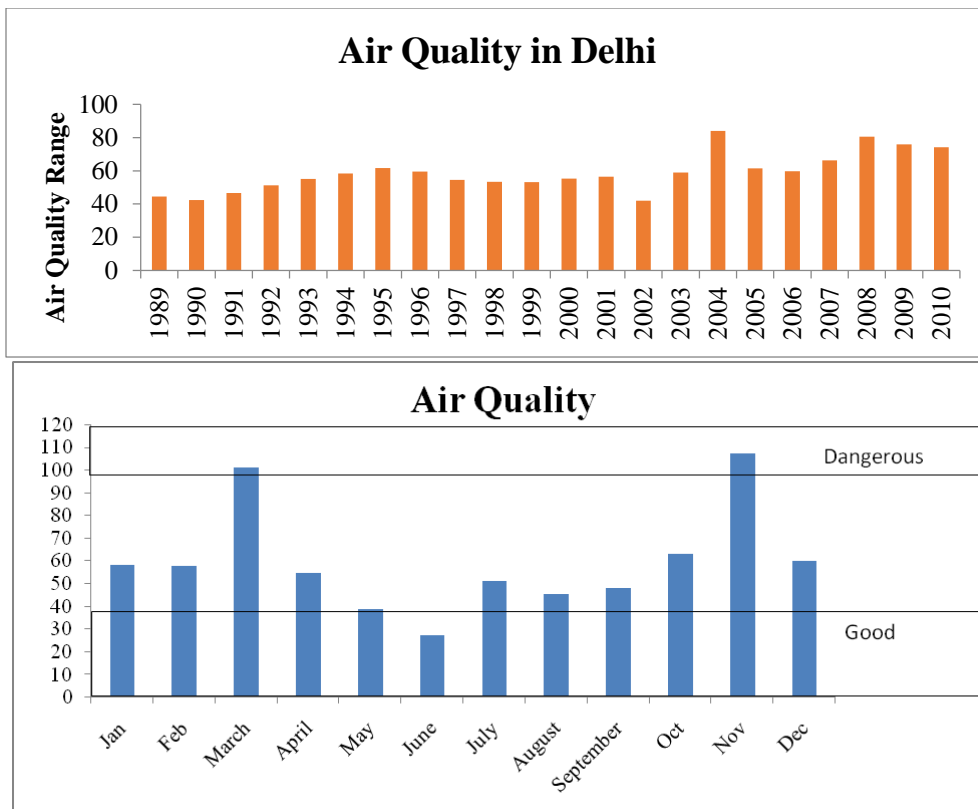
2006s (Figure 1b). The average nocturnal heat island intensity increased at the rate of 296-286K per month over the same period. Conversely, the number of intense day-time heat-islands has declined from May to December (Figure 1b). Figure 1c Difference in Year (1-1) and Monthly air quality (1-2), Annual average air quality is increased from 2004, and fair air quality increased from August to November.

Figure 1a, Difference in day average (left column) and night-time average (right column) daily temperatures between 2000-2014. 2000. 41.5, 44.5, 46.1 Day-time heat island (deg C) night-time 25.6, 24.6, 26.5 heat island (deg C).

Figure 1b Monthly frequency of month with day heat island intensity greater than 5K (left column), and monthly average nocturnal heat island intensity (right column) greater than 4 K 2000-2014. Heat island intensity (tenths Kelvin).

Figure 1c As in Figure 1b, but for day-time maximum temperatures. Figure 1c, As in Figure 1c, annual average of air quality is increase from 2004 (1-1) and Monthly average air quality is increase from July to November (1-2)



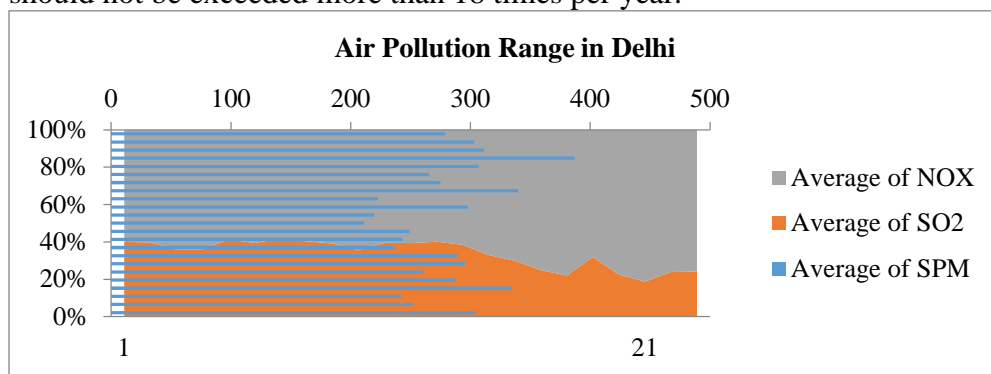


**Delhi’s Air Quality**

Delhi’s Air Quality (ORAQI) represents defined levels of air quality which avoid significant risks to health for 3 pollutants (Sulfur dioxide, nitrogen dioxide and sulphur dioxide). Air quality is monitored by the National Automated Monitoring Networks and Non-automatic Networks at over 9 sites across the Delhi, with data available as far back as 2000 for some sites. The reliable detection of air quality trends is complicated by the brevity of data sets, changes in instrumentation, representativeness of monitoring sites and the strong control exerted by weather patterns on pollution episodes .Air quality remains at unacceptable levels in many parts of Delhi. The Air Quality Index (AQI) or ORAQI is an index for reporting air quality. A study on the annual and monthly variations of Air Quality Index over a period of 14 years (2000-2014) based on monthly averaged concentration data of criteria air pollutants has been conducted for Delhi. An attempt has been made to quantify the changes in the ORAQI on annual and monthly is showing the best air quality was depicted by industrial areas, indicating that policy measures relating to the industries in the city during past years have helped in improving the air quality. Increased traffic density seems to have resulted into the worst air quality at residential areas in the city amongst all

the monitoring stations. There is a shift for the bad air quality in the city from winter to summer season in period of twenty years. Change of season for bad air quality from winter to summer may also be likely due to increased photochemical reactions playing major role with change in the nature of emissions. The air quality from 2004 to 2010 become better just in the time of monsoon that is due to high rainfall more that 120mm during in this period (Babazadeh, 2013)(Figure2).

Figure2, Yearly maximum hourly average sulfur dioxide concentrations (ppb) from 2000-2010. Note: the National Air Quality Standard for nitrogen dioxide is 300 ppb for a one hour mean. This limit should not be exceeded more than 18 times per year.



## Future climate

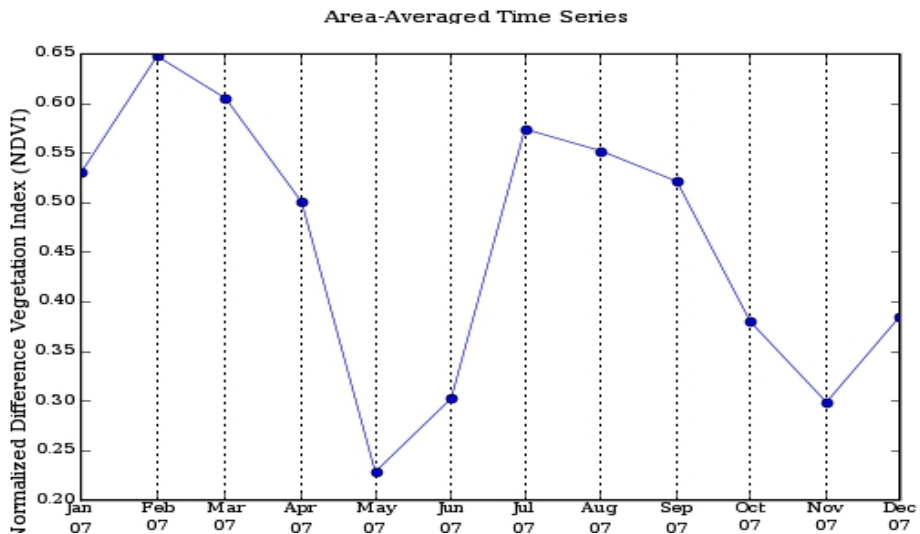
### Projected changes in the urban heat island

Heat waves may increase in frequency and severity in a warmer world. Urban heat islands exacerbate the effects of heat waves by increasing summer temperatures by several more degrees Celsius relative to rural locations. This can lead directly to increases in mortality amongst sensitive members of the population (Kunst et al., 1993; Laschewski and Jendritzky, 2002). For example, the heat waves in the summers of 2004 and 2010 were associated with a 15% increase in mortality in Delhi (Babazadeh, 2013). Early surveys of Delhi's heat island indicated that the peak usually lies South of central Delhi, reflecting the density of urban development, and the displacement of the heat-island by prevailing Northwest winds (Babazadeh, 2013). More recent monitoring has highlighted the mobility of the peak in relation to hourly shifts in wind direction (Graves et al., 2001). The thermal centre typically moves by several kilometres in line with the change in wind direction, therefore, future changes in the frequency of different wind directions could have an impact on the future location of the thermal centre.

The intensity of Delhi's nocturnal heat island has been modeled using Monthly minimum temperatures for central part of Delhi (rural reference station 30 km to the southwest). The average nocturnal heat island intensity

for the period 2000 to 2010 was +5.8°C, ranging from +10.0°C (on 2004) , with 5% of month having an intensity of 5°C or more. In comparison, the average month heat island intensity was just +0.3°C, ranging between +11.7°C . The monthly minimum temperature differences between South east and central for Delhi. Significant correlations were found between the intensity of the heat island and NDVI. For example, Figure 3 shows the relationship between the nocturnal heat island intensity and NDVI from May. Interestingly, the nocturnal heat island intensity is only weakly correlated with regional temperatures, suggesting that future changes in the heat island will be largely independent of projected temperature changes.

Figure3, NDVI across Delhi, Generally we face to decrees on Normal Difference Vegetation Cover from August to November



### Projected Changes in Air Quality

Air pollution is already a serious health problem in many cities even under the current climate (Anderson et al., 1996; COMEAP, 1998). Climate change is expected to cause further deterioration in air quality in large urban areas. This is because future weather will have a major influence on the production, transport and dispersal of pollutants. Any increase in the frequency of hot, anticyclones weather in summer will favor the creation of more temperature inversions trapping pollutants in the near surface layer of the atmosphere. For example, it has been estimated that a 1 degree Celsius rise in summer air temperatures (also a proxy for the amount of catalyzing sunshine) is associated with a 14% increase in surface ozone concentrations in metropolitan (Lee, 1993). Higher air temperatures increase natural and man-made emissions of volatile organic compounds (VOCs) (Sillman and Samson, 1995), exacerbating the health effects of ozone pollution (Sartor et



al., 1995). Climate change is also expected to affect the seasonality of pollen-related disorders such as hay fever (Emberlin, 1994). Meteorological factors are shown to exert strong controls on the start date and length of the pollen season (Emberlin, 1997), as well as the total pollen count (Takahashi et al., 1996). Acute asthma epidemics have also been linked to high pollen levels in combination with thunderstorms (Newson et al., 1998). Finally, deteriorating air quality as a result of climate change could have secondary impacts on the vitality of urban forests and parkland. For example, SPM has adversely impacted the structure and productivity of forest ecosystems throughout the industrialized world (Krupa and Manning, 1988). Levels of sulfur dioxide deposition are also closely linked to the frequency of large-scale weather patterns across the Delhi. As noted previously, weather patterns are a strong determinant of ambient air quality and pollution episodes (O'Hare and Wilby, 1994). Therefore, future air pollution concentrations in Delhi will reflect local and regional patterns of emissions, as well as the frequency of large high-pressure systems over the south.

## **Results**

Analyzing the results of the LST (Land Surface Temperature) in day and night for the study area, it is occlude that in the urban area of Delhi observed temperature are much higher than the temperature of rural areas. In specific, the mean Temperature value for Delhi is calculated 35°C. This also observed different in temperature can be explained by the difference in Air quality and NDVI.

## **Conclusion**

This study examined the relationship between air quality, NDVI with land surface temperature (day- night) of an urban environment of across Delhi city. Specific temperature patterns (LST) not only exacerbate the UHI effects but also deteriorate air quality due to high amount of pollutants. Statistical analyses showed that these patterns can also easily strengthen the UHI effect. Temperature patterns under which clear UHI developed over the Delhi characterized. The statistical analyses revealed that under the same weather pattern, the concentrations of many air pollutants increased with the UHI intensity (decrease air quality). The convergence phenomenon usually generated in the nocturnal period due to the UHI causes the accumulation of air quality (increase amount of pollutants), as well as other air pollutants, thereby affecting the air quality during the subsequent daytime period. land surface temperature indicates considerable inter-annual variability in the frequency of summer air quality episodes, and caveats related to future UHI by decrease in NDVI apply. Notwithstanding significant reductions of diffuse emissions over north-west of Delhi, the still

indicative of deteriorating air quality conditions for Delhi under future climate change.

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