Synopsis of PhD Research Work

Investigating the Relationship between Urban Heat Island (UHI), Sky View Factor (SVF) and different Local Climatic Zones (LCZs): Case study of Kolkata

Submitted By: Santanu Bajani

Statement of Problem:

The urban climate is warming and continuously deteriorating the urban environment in Indian cities. Urban heat lowers the quality of urban life, increases energy needs, and affects the urban socio-economic environment. Kolkata towards its transformation to a metropolis has experienced a vast change in the local climate which has led to various local climatic zones. Traditional Land Use Land Cover (LULC) mapping approaches do not convey the accuracy at which Local Climate Zone (LCZ) maps depicts the local thermal environment. IPCC AR6 2021 report depicts Kolkata is highest in temperature rise among the other global cities (+2.6°C). Kolkata, like that of other large urban areas around the world described in 'The Evolving Urban Form' series, shows that, given a chance, people reveal their preferences by moving to more space, to construct a better life for themselves and their households. Rapid urbanization is changing the land cover, the urban fabric, and the urban geometry. The urban environment is clearly influenced by urban geometry in a complex way. Urbanization affects the water cycle by producing more precipitation over and downwind of cities, increasing the intensity of surface runoff by transforming natural surface to concrete surface, reducing vegetation cover, open space like parks, playground, etc., water bodies and wet lands, ground-level sky vision, and accumulating heat when high rises obstruct outgoing long-wave solar radiation, as an impact formation of Urban Heat Islands. Numerous research has asserted that factors such as city size, building structure, urban surface, anthropogenic heat emission, topography, city orientation, and regional meteorological conditions significantly influence the nature, pattern, intensity, and persistence of UHI. Few studies have examined the impact of sky view factor on urban heat islands. It is important to understand the relationship between sky view factor and urban heat island for different local climate zones.

Study Area:

Study area is part of Kolkata, the capital of West Bengal, and the third most populated metropolitan city, located in the eastern part of India and linearly along the banks of the Ganges River. Kolkata has an area of 205 Sq. Km. The city nearby to the sea have an average

Professor
Department of Architecture
Jadavpur University
Kolkata-700032

elevation of 6 ft. Kolkata (previously named as Calcutta) with a historical background combined with different land use is vulnerable to atmospheric turbulence and thus has been chosen as the study area.

Aim of Study:

To investigating the relationship between Urban Heat Island (UHI), Sky View Factor (SVF) and different Local Climatic Zones (LCZs) in Kolkata.

Objective of the Study:

The main objectives of this research are as follows:

(1) To study the several facets of SVF and its significance for UHI studies.

(2) To perform a comparative analysis between the LCZ and LULC approaches in UHI studies

(3) Comparative analysis of various SVF calculation method and benefit.

(4) To analyse the UHI effect in relation to various SVF in different LCZ.

(5) To suggest and propose suitable SVF ratios for various LCZs to mitigate the effects of UHI.

Hypothesis:

Limiting the sky's visibility store more solar energy, which raises the surface temperature in different urban climatic zones.

Methodology:

For first objective, digitization of the building footprint in Google Earth Pro was done. Building heights were verified and measured as part of a detailed building survey using Qfield android application.

Next local climatic zone map was created using the technique recommended by WUDAPT. The software used here is Google Earth Pro and ArcGIS.

In the third and fourth objectives, preparation of sky view factor maps and urban heat island maps, and finding the correlation between these aspects was done.

Research Outcome:

In this study distribution of land surface temperature and its variability gives an idea about the surface urban heat island generation in Kolkata in connection with sky view factor. Moreover, location of hot-spots in KMC area gives very close observation of those buildings which have high thermal capacity. Further the study has shown a rapid landscape transformation occurring in the last 15 years. From 2003 to 2017, the vegetated area and water body continuously decreased. There had been an increase in the built up land cover (76.12% to 83.72%) and it is observed that the maximum city land cover transformations occurred in 2010 – 2017 as compared to 2003 – 2010.

The findings from the analysis highlight the significance of urban morphological elements in SVF and SUHI at the local level. Because of this, the SUHI intensities rise as building density or the percentage of impermeable surfaces increases. This outcome is in strong agreement with the increase of vegetation the SUHI intensities decrease as the vegetation cover ratio rises latent heat fluxes in the air through evaporation and transpiration. Surface area ratio has a negative impact on SUHI, showing that areas with greater building shadowing and higher building heights have lower SUHI. Building height increases have a detrimental effect on SUHI as SVF lowers and congested or densely populated areas reveal. **The SUHI intensity for Kolkata is $\Delta TLCZ_{1\text{-}10} - LCZ_{B\text{-}G} = 0.73℃$. The SUHI intensity was calculated by "Average LST value of all available built up LCZs - Average LST value of all available natural LCZs**". The positive values indicate the presence of SUHI at Kolkata (Shi et al., 2019). Built up LCZs are categorized as per various urban morphological factor into two groups, one group is with LCZ 2, 3, 4, 7, 8, and 10 and another group is with LCZ 1, 5, 6, and 9. Classifying LCZs of a similar type into a data group for analysis could yield significant information for the construction of urban built-up regions. It is important to note that LCZ E, which forms SUHI, LCZ 9 and other naturally occurring LCZs (LCZ B, C, D, F, and G) are generating surface urban cool islands. SUHI intensity on LCZ 2, 3, 4, 7, 8, and 10 is $\Delta TLCZ_{2, 3, 4, 7, 8, 10} - LCZ_{B\text{-}G} = 1.17℃$ and LCZ 1, 5, 6, and 9 is $\Delta TLCZ\ 1, 5, 6, 9 - LCZ_{B\text{-}G} = 0.29℃$. The factors of sky view factor and building density revealed significant correlations in LCZs 2, 3, 4, 7, 8, and 10. There are a low positive correlation is observed with LCZ 1, 5, 6, and 9.

The main findings from the analysis are as follows.

A) Local climate zone 7 (lightweight low rise), 8 (large low rise) and local climate zone 10 (heavy industries) has maximum impact of SVF over UHI.
B) Surface UHI of Local climate zone 1 (compact high rise), zone 2 (Compact midrise), 3 (Compact low rise), and 4 (open high rise) is moderately impacted by SVF.
C) Low impact of SVF on UHI is observed on the Local Climate zones 5 (open midrise), 6 (open low rise).
D) Almost negligible impact of SVF on UHI is noticed Local climate zone 9(sparsely built) and on all natural local climate zones.
E) Local Climate Zone E (Bare rock or paved) may have very low SVF value but when surface Heat Island is considered it shows a warming potential as hard surface absorbs the heat and stores them, which releases during later hours.
F) The heat islands in an urban context can be formed by specific land uses and properties, including densely populated areas close to ports.

This research was seen as a stepping stone in the research process since the findings will be used to provide the complete picture of the urban surface features in the study location. Along with identifying the locations that were found to be hot spots or cold spots of the surface temperature along the study region, the data was also used as a basic map to identify the various types of existing urban structure. The urban spaces are actually divided into various zones by the variability of the intra-urban spatial distribution of land surface temperature. Urban climate is an open system with energy continuously coming from space as solar radiation, with some of this solar energy converting to heat or terrestrial thermal radiation that warms the city air through convection, conduction, and advection processes. An important factor in creating climate-sensitive cities, particularly in tropical regions, is the regulating the urban surface heat. Urban planning currently gives great importance to sustainable urban growth and ecological balance. Urban climatic study has taken into consideration the identification of urban thermal zones in the city area and the spatial identity of Kolkata in terms of the urban thermal behaviour of various built-up areas.

The mean minimum atmospheric temperature over Kolkata is 2°C to 3°C higher than the rural surroundings. Urban heat islands and the sky view factor superimposed on local climate zones provided a clear indicator of which local climate zones are susceptible to urban heating.

Positive correlation exists between the sky view factor and urban heat island. The fact that there is a modest association suggests that other factors, such as street orientation, wind flow, building and roof materials, appliance use, vehicle emissions, the presence of flora and water-bodies, etc., may also be at play. The correlation bars between SVF and UHI on each LCZ in Figure 61 reveal that LCZ 7 has the most influence from SVF, whereas LCZ 2, LCZ 3, LCZ 8, and LCZ 10 have a moderate impact. The impact of SVF on heat generation is minimal in LCZ 1, LCZ 4, LCZ 5, LCZ 6, and LCZ 9. Natural LCZs LCZ B, LCZ C, and LCZ D have minimal effects on SVF, but LCZ E, LCZ F, and LCZ G have insignificant effects.

The study will implements diverse possibilities and will useful for future urban studies. The morphological factors, which are important for influencing urban climate in order to know and understand the process. This research was seen as a stepping stone in the research process since the findings will be used to provide the complete picture of the urban surface features in the study location.

14/8/24