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Literature Review of UHI Studies to Find the Gaps in Indian Studies in Comparison to International Studies

[1]Pallavi Sharma,
[1,]Teri School of Advanced Studies,
Plot no.10 Institutional Area,Vasant Kunj New Delhi,110070

***Abstract*:- In india most of the urban areas specially metro cities shows a significant amount of UHI approx. 1-5degree Celsius. Although UHI is a global phenomenon occurs almost every part of the world but in India it is in its high potential. Despite of receiving high grade UHI India is not tackling problem as in priority. By reviewing both national and international literature we finds that India is far much behind from international studies in case of UHI. This paper aims to find the gaps in Indian studies in context of UHI studies. Research finds that UHI studies are in its initial stage and need to be addressed shortly by researchers and government agencies. Moreover Applied research and numerical modelling studies are almost negligible in India. So there is need of urgent steps to be taken for implementation of UHI solutions and take it on ground by means of policies and laws.**

Keywords: - Urban heat Island, Indian metro cities, Climate-change, UHI mitigation, Policies,

1. INTRODUCTION

In India, metro cities have undergone rapid urbanization, powered by the diversification of the cities' economic and demographic growth. This population growth is the product of natural growth, migration and spatial expansion across the rural hinterland. India is the country which is in under high migration rate from rural to urban areas. The main factors which are responsible for self-imposed migration are job opportunities in urban areas. City lifestyle and culture is also responsible for attracting migrants towards urban areas. Rural people hear success stories from the people of their community who moved to cities. All these factors act as catalyst for excessive urbanization. Urbanization provides the creation of many serious problems such as the rise in greenhouse gases in the atmosphere, abrupt climate change and temperature increase in urban areas, resulting in urban heat island. This phenomenon act as chain in every area. If a population of a certain area rises the demand of infrastructure and natural resources also rises. To meet the demand of population. Most of the Large Urban Infrastructure are coming towards the hinterland of the metro cities. To be very frank hinterland areas of metro cities are the most valuable areas for the Urban scale project due to availability of population and other resources. Infact, due to population increase demand of infrastructure reaches its peak. Because of high demand we can't resist the urban projects to come, we need to find out the sustainable ways for the urban project to come. The very first thing that comes to mind when considering sustainable solutions to cater to the issue of climate change is to reduce global warming. High temperatures are the most significant factor that is widely observed in metro cities, called Urban Heat Island , the high temperatures in cities from their surroundings.

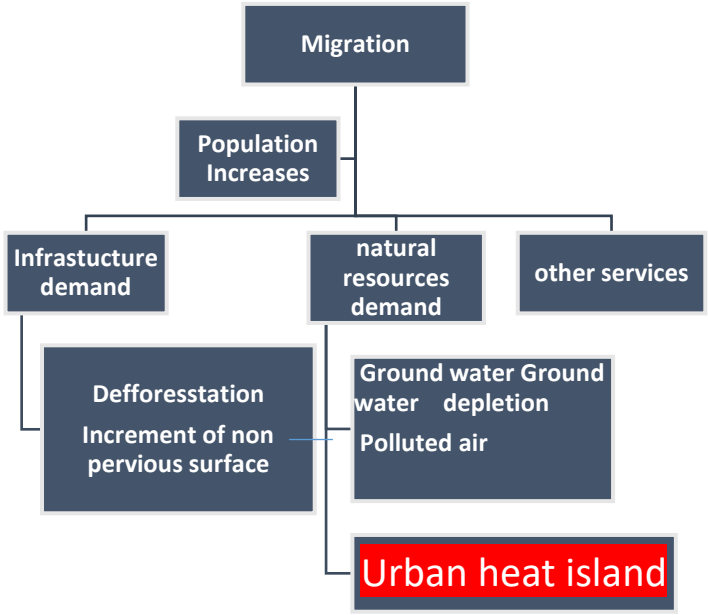

Figure 1

2. URBAN HEAT ISLAND

Definitions

Due to urban development and human activities, the Urban Heat Island (UHI) effect is a kind of heat accumulation phenomenon within urban areas. It is known as the urban climate's most obvious feature. The rise in ground surface temperature induced by the UHI effect would certainly affect the movement of materials and energy flow in urban ecological systems, as well as alter their structure and functions, exerting a range of ecological and environmental impacts on urban climates, urban hydrology, etc.

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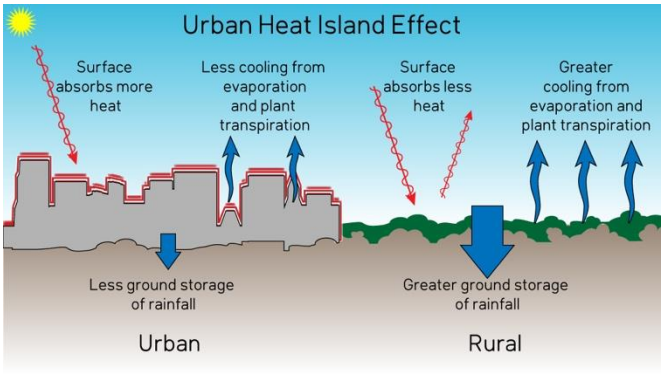

Figure 2: Urban Heat Island

3. TYPES OF URBAN HEAT ISLAND

Surface Urban Heat Island

The term surface UHI(SUHI) is used to specifically differentiate UHIs determined by land surface temperature (LST) measurements. It is observed by the use of thermal infrared data to retrieve surface temperatures on the earth. Typically, similar relationships between the temperatures of the near surface air and the temperatures of the ground surface have been found. Therefore, a reliable measure of an atmospheric urban heat island is the surface urban heat island. Because of variations in surface heat islands, the extent of surface urban heat islands varies with seasons. The height of the sun as well as the ground, season and cover. As a consequence of those things, variation, the islands of surface urban heat are in the summer, usually the highest.

Atmospheric Urban Heat Island

The air of urban areas are usually warmer than the surrounding rural areas air which is much cooler that the air of urban area defines atmospheric Heat islands. Different cooling rates between urban areas and their surrounding rural or non-urban environments mainly result from atmospheric urban heat islands .On clear and calm nights and days when rural areas can cool more quickly than urban areas, the differential cooling rates are most pronounced.

Micro Urban Heat Island

They refer to poorly vegetated parking lots, non-reflective roofs and concrete roads as urban hot spots. Micro-urban heat islands are highly influenced by micro-climate conditions, so remotely sensed data is more useful for heat spot detection than atmospheric data.

4. METHODS USED TO DETECT UHI

Commonly UHI detection studies are carried out by four Methods.

Satellite Data or Remote Sensing

For the UHI analysis, the variants of the LANDSAT satellite are mainly used to get ground surface images. Remote sensing is used to find the surface temperature of the ground, since satellites and the earth are still in motion and it is a dangerous job to capture the shifting air temperature above the ground from the point of precision.

Fixed weather station data

Another means of finding the temperature in urban and rural areas is meteorological weather station data.

The basic information that are received from weather stations include:

- Sum of precipitation
- 2m air temperature
- Maximum of 2m air temperature
- Minimum of 2m air temperature
- Downward directed solar radiation measured at earth's surface (global radiation)
- Duration of sunshine
- Total cloud cover
- Water vapour pressure
- Relative humidity
- 10m mean wind speed
- Snow depth

Field Survey

There can be two types of field survey. Stationary survey and Field survey. In stationary survey a fixed location will be selected for temperature measurements and readings will be taken by using thermometers.

Numerical Modelling

According to spatial scale models are divided into mesoscale and microscale models [1] Numerical modelling is high computation facilities. Microscale models have generally finer grid resolution. Meso scale models works on planetary scale with grid resolution of 100-200km. Numerical modelling is a system which interact independently from atmosphere, ocean, land, surface, snow and ice.There are many models which come under this system . GCM (General circulation model)it is a type of climatic model which works on mathematical model which gives information about circulation of planetary atmosphere or ocean. For different energy sources (radiation, latent heat), it utilizes the Navier-Stokes equations on a rotating sphere with thermodynamic terminology. The basis for computer programmes used to model the Earth's atmosphere or oceans are these equations. Along with sea ice and land-surface elements, atmospheric and oceanic GCMs (AGCM and OGCM) are main components. It is a global climate model is a planetary-scale mathematical model with a grid resolution of 100 to 200 km and consists of fundamental fluid flow equations derived from physical laws. [1]The regional climatic models (RCMs), which are mesoscale models that focus on the climatic condition over a region or on a smaller spatial scale than GCM or a restricted area of interest, are another subcategory. The Weather Analysis and Forecasting model, WRF, is one of the most commonly used RCMs. But using mesoscale models, the local climate processes cannot be modelled. Due to the topography of that specific region, local climatic changes occur and many RCMs are not able to account for them due to coarser spatial resolution. In such cases, microscale models with finer grid resolution can be used to perform a climate analysis over a city compared to mesoscale models. Significant growth in the production of micro-climate models is occurring as the impacts

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of urbanization are confined to very small areas and a very complex challenge is climate modelling on the city scale. For these purposes, researchers began using CFD (Computational fluid Dynamics) models to simulate the area at the city scale. CFD is a software-based platform that interconnects mathematics, physics and computing and is commonly used by both scientific and technical fields. LES, WRF, ENVI MET are other models which are used by group of researchers to validate their studies. But in India numerical model research is very limited.

5. UHI MITIGATION IN TERMS OF URBAN DESIGN

The UHI mitigation definition can be translated into a multitude of distinctive intervention steps that differ in size and scale, as well as their capacity for execution and compliance with local conditions. [2] In general mitigation initiatives use one of three action strategies: reducing the absorption of solar radiation in urban fabrics; improving air flow through the city; and effectively cooling some components in the built environment. After doing critical literature review the main domains of UHI mitigation research domains are Building Envelope, Landscaping, Pavements, Orientation.

1. Urban Geometry

In comparison to the collective impact of the built environment as a whole, minimizing the singular effect of buildings on the urban microclimate depends primarily on modifications to their external envelopes. The heat consumed by structures as well as the heat they emit to their atmosphere can be decreased by these modifications.

2. Landscaping

In order to cool cities down, changing the urban environment can be used in many ways. Landscaping initiatives should not require improvements to private properties (namely buildings) or to pavement facilities. Instead they are limited to the incorporation into the current urban fabric of new landscaping elements. [2]

Shade trees: since their canopies provide shade, trees minimise the incidence of direct solar radiation on horizontal and vertical surfaces (mainly pavements, roads, and building walls), thus reducing the heat absorbed by those components. In addition to the shading effect, when exposed to direct solar radiation, trees release vapor into the atmosphere through evapotranspiration, increasing the relative humidity and reducing the temperature of the air around them; this in turn, can contribute to a local increase in thermal comfort.

Land vegetation: extensive ground-level planting (e.g., grass lawns) can lower ambient air temperatures locally. Though vegetation-covered soil will absorb large quantities of short-wave solar radiation, it is assumed that most of the heat absorbed will be converted into vapor by evapotranspiration (as long as the soil is well irrigated), thus keeping the soil and its local climate relatively cool. However by evapotranspiration, a decrease in soil moisture from lack of irrigation will change its daytime cooling capacity, resulting in higher near-surface temperatures. In addition, extensive use of ground vegetation can sometimes (and particularly during the night) increase the sensation of discomfort by raising the relative humidity levels in hot and humid cli- mates, although this effect is local and depends on the particular climatic characteristics of the vegetated region.

3.Pavements

Modern paving materials (mainly concrete and asphalt), when exposed to direct solar radiation during the day, appear to absorb significant quantities of heat. During nighttime, much of this heat is emitted as longwave (infrared radiation to the cooler street air, thereby affecting street level thermal comfort significantly. [2] Moreover, common paving materials usually show low water permeability, restricting the absorption of water in the underlying ground layer and reducing the cooling capacity of soil surfaces by evaporation. Therefore the key strategy for improving the negative effects of traditional pavements on the urban microclimate is to minimise heat absorption by pavements, either by altering their material properties or allowing their cooling by evaporation.

4.Orientation

The way streets are oriented and the geometrical relationship between constructed volumes and open spaces can have a significant impact on the city's thermal climate. Due to the slow nature of changes in street network and construction volumes, modifying street geometry of existing urban settings for the sake of UHI mitigation may not become a common mitigation strategy in most cities; however, modifying street geometry may become a viable strategy for generating even short-term UHI mitigation effects in urban areas experiencing rapid transformation. [2]

6. RESEARCH TRENDS IN UHI STUDIES IN INDIA

After reviewing critically important literature studies in India, the following graph is summarized. After reviewing the results, we noted that India only works to recognize the issue and the pace of the problem. In India, numerical modelling research is very limited [1]. Moreover the issue is only discussed by researchers. Basically, scientists in India work only to examine the location and reasons for the UHI.

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Indian UHI Studies

S.NO	Author	Year of study	Methodology	Outcome	Type of Research
1	Paper 1 [3]	2015	Satellite Data Analysis(Comparative study)	Studied the NDVI and compare Noida and Mumbai UHI	Descriptive
2	Paper 2 [4]	2019	Landsat data	Assessment. Detection of UHI in Noida	Exploratory
3	Paper 3 [5]	2018	Satellite Data, Spatial Remote Sensing	Analyze UHI effect and suggest microclimatic changes.	Exploratory
4	Paper 4 [6]	2011	Landsat data	Case study (Analysis)	Exploratory
5	Paper 5 [7]	2016	Metrological Station data and Arc GIS	Analyse UHI Effect and Suggest Building regulations ang laws to cater the UHI	Exploratory
6	Paper 6 [8]	2017	Field temperature measurement SAFAR data	Relationship of UHI with pollutants	Exploratory
7	Paper 7 [9]	2015	Analysis of Landsat Data	Examination & Future Prediction	Exploratory
8	Paper 8 [10]	2014	Analysis of field data	Study	Explanatory
9	Paper 9 [11, p. 2016]	2016	Analysis of weather station data and satellite a data	analysis and detecting factors responsible for UHI	Explanatory
10	Paper 10 [12]	2000	Analysis of mobile survey data	Detection of UHI	Explanatory
11	Paper 11 [13]	2006	field Survey	Study of UHI	Explanatory
12	Paper 12 [14]	2016	Satellite -Landsat data	Temporal Study of UHI	Exploratory
13	Paper 13 [15]	2009	Landsat data	Study of UHI, Suggested UHI mitigation techniques	Exploratory
14	Paper 14 [16]	2012	Satellite data and GIS Technique0 MODIS and TERRA	Analysis	Exploratory
15	Paper 15 [17]	2017	literature study	providing mitigations strategy.	Descriptive
16	Paper 16 [18]	2015	Landsat data, field measurement	Analysis	Explanatory
17	Paper 17 [19]	2015	Field Measurement	Finding about single mitigation measured efficiency	Explanatory
18	Paper 18 [20]	2019	Review Paper	Suggestion Regarding mitigation technology	Exploratory
19	Paper 19 [21]	2013	Landsat data	Changes detection	Exploratory
20	Paper 20 [22]	2017	Field Survey	Detection of UHI	Explanatory
21	Paper 21 [23]	2017	Landsat data , numerical prediction	Numerical modelling	Explanatory
22	Paper 22 [24]	2011	Study of UHI	Tell impact factor for uhi due to urbanization pattern	Explanatory
23	Paper 23 [25]	2012	Landsat data, field measurement	Observations	Explanatory
25	Paper 24 [26]	2012	Landsat data	Detection of relationship of UHI and land Cover	Explanatory
24	Paper 25 [27]	2015	Review Paper	Analyse the relationship of impervious surface and UHI	Explanatory
25	Paper 26 [28]	2012	Satellite data	Proofs relationship between UHI and particulate matter in air	Explanatory
26	Paper 27 [29]	2014	Review Paper	Literature review	Descriptive research
27	Paper 28 [30]	2019	Satellite data	Analysis increasing UHI	Explanatory

Table 1

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7. INTERNATIONAL TRENDS IN UHI STUDIES

After reviewing critically important International literature studies, the following graph is summarized.

International UHI studies

S.NO	Author	Year of study	Methodology	Type of Research	Outcome
1	Paper 1 [31]	2012	Numerical Modelling University of Victoria Earth System Climate Model	Applied research	Application of Cool roof as mitigation measure
2	Paper 2 [32]	2005	Experimental Study, Numerical modelling	Explanatory	Numerical Modelling Study for analysis of Street geometry on outdoor climate comfort
3	Paper 3 [33]	2020	Using GIS hill shade function(Author also explains limitation of Hill shade function in evaluation)	Explanatory Research	Examine the shade of trees by remote sensing
4	Paper 4 [34]	2019	Meta-Analysis	Comparative Research	Comparative analysis of Mitigation measures adopted
5	Paper 5 [35]	2011	Building simulation tool Trnsys (Case Study)	Analytical Research	Evaluation of Green roof Technology Performance to mitigate UHI
6	Paper 6 [36]	2014	Experiment by growing different species of plants at wall	Experimental Research	Analysis of Performance of different plant species to mitigate UHI
7	Paper 7 [37]	2014	Spatial remote sensing	Explanatory	Analysis of cool island created by park and influencing factor
8	Paper 8 [38]	2015	Experimental study	Experimental Research	Study the governing factors of increased UHI and effect of form on temperatures
09	Paper 9 [39]	2013	Review Paper	Exploratory	Evaluation of green roofs and strategies used.
10	Paper 10 [40]	2013	Review Paper	Explanatory	Experiment carried out to proof the performance of living wall system to counter elevated temperatures
11	Paper 11 [41]	2010	Experimental study	Survey And simulation Envi-met numerical modelling	Identify nocturnal temperature difference vertical and horizontal and To test the accuracy of model by observed temperature difference
12	Paper 12 [42]	2011	Simulation, CFD calculations with model PHOENICS have been applied for the simulation of the air flow and temperature	Explanatory Research	Simulation shows decrease in temperature by bioclimatic design
13	Paper 13 [43]	2013	Literature Review	Exploratory	Reviewed strategies and its effectiveness
14	Paper 14 [44]	2005	Experimental study	Experimental study	Experiment carried out for validating role of street geometry and traditional design on urban outdoor temperature
15	Paper 15 [45]	2009	Literature Review	Exploratory	Study on Review of mitigation strategies of UHI
16	Paper 16 [46]	2011	Experimental study metrological data	Explanatory	Effects of vegetation on human thermal stress and UHI
17	Paper 17 [47]	1999	Empirical Model, Numerical Modelling	Explanatory	Predicting cooling Effect of trees
18	Paper 18 [48]	2013	Review Paper	Exploratory	Cool Roof policy reviews
19	Paper 19 [49]	2019	Spatial and Temporal data	Exploratory	Tells existence of UHI in Spanish villages

Table 2

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Indian studies Inclination graph

S.No	Indian Studies	Outcome
1	Paper 1 [3] ,Paper 2 [4] ,Paper 3 [5],Paper 4 [6], Paper 5 [7], Paper 6 [8], Paper 7 [9], Paper 8 [10], Paper 9 [11, p. 2016], Paper 10 [12], Study 11 [13], Study 12 [14], Paper 19 [21], Paper 20 [22], Paper 22 [24], Paper 23 [25], Paper 24 [26]	Analyse and Detection of UHI
2	Paper 5 [7],	Talking about Building regulations and laws to decrease UHI
3	Study 13 [15], Paper 17 [19],	Suggest Mitigation Measures
4	Paper 14 [16]	Locating the Areas of UHI
5	Paper 15 [17], Paper 18 [20], Paper 25 [27], Paper 27 [29]	Literature Study, Review Paper
6	Paper 21 [23]	Numerical Modelling Study
7	Paper 26 [28]	Deals with relationship of UHI with other materials or things

Table 3

International Studies Inclination graph

S.No	International Studies	Outcome
1	Paper 3 [33], Paper 4 [34], Paper 5 [35], Paper 6 [36], Paper 9 [39]	Examine the potential of mitigation measure
2	Paper 7 [37], Paper 8 [38], Paper 11 [41], Paper 1 [31], Paper 2 [32], Paper 12 [42], Paper 17 [47]	Analyse the UHI by numerical Modelling
3	Paper 14 [44], Paper 16 [46], Paper 19 [49]	Experimental Study
4	Paper 10 [40], Paper 13 [43], Paper 15 [45], Paper 18 [48]	Literature Study, Review Paper

Table 4

Above table shows that research inclination of India and other countries. Above graph indicate that maximum researchers are working towards the analysis and detection of UHI whereas in international studies are focussed towards the modelling studies and policies and mitigation reviews measures.

8. INDIAN STUDIES VS INTERNATIONAL STUDIES

S.NO	INDIAN STUDIES	INTERNATIONAL STUDIES
1	Working towards detection	Working towards implementation of mitigation policies
2	Work towards mitigation policies are negligible	Already started working towards policy reviewing
3	No policies studies related to UHI	Implemented Policies for UHI
4	Initial Stage	Already applied the mitigation measure
5	Few are reporting and experimenting towards mitigation measures	Most of the studies are towards reviewing the performance of mitigation measures applied
6	Descriptive Research	Applied Research
7	Numerical modelling research is limited	Most of the studies are based on numerical modelling

Table 5

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9. GAPS IN INDIAN STUDIES

We notice that UHI studies are in their initial phase in India after review of both national and foreign research literature we find that Indian researchers are still working to define the UHI and its speed, and some are working to find the UHI's reasons and some of them are working towards the finding factors and in defining the relationship of factors with UHI. We find that in India, despite receiving high UHI in Indian cities, only researchers work towards the phenomenon, no stakeholders are interested or involved in tackling the issue. Also research work is limited by the detection of UHI only. Few researchers report the mitigation steps, but there is still a lack of thorough study or experimentation of any UHI mitigation step. Ground level work is missing in India only researchers are working. Numerical modelling studies are very limited in India. Most of the researchers use satellite data ,field survey and weather station data for their studies. If we talk about the applied research related to UHI in India, India is far away from the destination. Researchers should therefore expand their reach of UHI research and should aim to introduce mitigation steps.

10. CONCLUSION

If we do year wise comparison of UHI studies ,a study was published in year 2000 aims at detection of UHI phenomenon in India [12] in contrast to international literature, a study was published in year 1999 is talking about the predicting cooling effect of trees by numerical modelling [47] means they are talking about mitigation measures in year 2000. In span of 20 years Indian studies are still inclined towards the detection and potential of phenomenon in contrast International studies are expanding their wings and cover all aspects of UHI including mitigation measures and policies, and building byelaws related to UHI moreover they started reviewing the mitigation measures and policies as they had already implemented the mitigation measures and policies whereas india is expanding the research area wise .Indian Researchers are only studying area impact and intensity of UHI . Not even a single research is published in india for implementation of policies of UHI and its review because india have not cross the initial stage of UHI research after doing research from 20 years in particular area. Indian researchers need to widened the scope of studying UHI and should start working towards the implementation of mitigation measure. As we already discussed in the paper that Indian studies are in its initial stage of UHI and numerical studies in field of UHI is very limited. [1] After critical literature survey and comparing both national and international studies we concluded that there is huge Gaps in Indian studies of UHI. Foreign researchers already studied and implemented the policies and mitigation measures for UHI in their countries in contrast Indian researchers are still working on finding the potential o f UHI and its impacts. India needs researchers should work on applied research for UHI . Applied research is almost negligible in india. Policy makers should also need to draw their focus towards UHI and its implementation in india to mitigate it and rising temperature in cities under UHI. Internationally the researchers and government had already made the policies and laws to mitigate the phenomenon but in india we are not even the path of implementation . So urgent action is needed for implementation of UHI studies as policy and laws to counteract the Problem.

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