https://doi.org/10.37285/bsp.ic2uhi.21

Green Infrastructure Strategies as Countermeasures to Urban Heat Islands with particular reference to the Bangalore Metropolitan Region

Reshmi Manikoth Kollarath[1], *BMS College of Architecture (India)*
Vasseem Anjum Sheriff [2], *BMS College of Architecture (India)*

ABSTRACT

Bangalore the capital of the state of Karnataka is one of the fastest growing metropolises in India. Traditionally it enjoyed a salubrious climate and was referred to as Garden city for its numerous private gardens and parks and Pensioners paradise for its lifestyle. More recently it has emerged as the IT capital and has witnessed a sudden surge in the population seeking economic opportunity. Bangalore, in recent times, is experiencing unprecedented urbanisation and sprawl due to concentrated developmental activities with impetus on industrialization and development of grey infrastructure for the economic development of the region. This concentrated growth and increase in population and consequent pressure on infrastructure, natural resources and ultimately giving rise to a plethora of serious challenges such as climate change, enhanced green-house gas emissions, lack of appropriate infrastructure, traffic congestion, and lack of basic amenities, in many localities leading to change in different land use types. Recent research indicates that Greater Bangalore is an emerging Urban Heat Island. Factors contributing to the Urban Heat Island Effect include Urban Structure, Urban Surface Cover, Urban fabric, Urban Metabolism and distinct lacunae in urban planning. The alarming decline in the vegetation cover and water bodies has contributed significantly to discomforting rise in temperature. This paper seeks to examine green infrastructure strategies at varying urban scales in order to mitigate the impact of the Urban Heat Island Effect.

Keywords: Bangalore, Urbanization, Grey Infrastructure, Urban Heat Island Effect, Mitigation Measures, Green Infrastructure

Introduction

Bangalore with its salubrious climate and many parks was famous as the ‘Garden City’ of India till recent times. The city got the name from 1927 onwards when many parks were constructed along with other public works which were undertaken as part of silver jubilee celebrations of the rule of Krishna Raja Wodeyar IV. Urbanization in Bangalore has been steadily increasing since independence of India when it was declared as the capital of the state of Karnataka. It has accelerated considerably in the past couple of decades as the ‘garden city’ solely transformed into the ‘silicon city’ of India. The population in Bangalore has doubled from 4,301,326 in 2001 to 8,443,675 in 2011 over just one decade. This shows the rapid rate of urbanization in the city. Today Bangalore is a Megacity and ranked third in India in terms of population and has managed to surpass both Kolkata and Chennai over a period of 10 years. The population density of the city is a staggering 12,000 per sq km.

[1] Reshmi Manikoth Kollarath: [reshmimk@gmail.com].

Urbanization and consequent urban sprawl causes loss of agricultural land and ecological habitats. It also impacts urban infrastructure such as healthcare, transportation, energy, water supply etc (Sudhira 2008). There has been an increase of 632% of built up area and decrease of 72% of water bodies in Bangalore between 1972 and 2009. Vegetation has also decreased by 62% between 2002 to 2009 alone (Ramachandra & Kumar 2010). The decrease in vegetation and loss of waterbodies along with increase of impermeable surfaces has had a profound impact on the phenomenon of Urban Heat Island in Bangalore.

Urban Heat Island Effect

Urban Heat Island (UHI) is a phenomenon of higher temperatures experienced in an urban area when compared to its surrounding rural area. Urbanization is an important cause for UHI. Anthropogenic activities and increase in built up areas are the main contributors to UHI. Pavements and rooftops contribute significantly to UHI (Mohajerani et al 2017). Urban Heat Island has a huge impact on the urban climate, hydrology, ecosystems, environment and energy flows. It also has a negative impact on the health of the residents. Concrete, asphalt and other manmade materials trap the solar energy. This is aided by the loss of vegetation and natural surfaces in an urban area.

For every 0.6°C rise in temperature, there is an increase in electricity consumption of about 2%. (Voogt 2004). Increase in temperatures increases the use of air conditioning appliances, resulting in increased emission of harmful greenhouse gasses which has led to global climate change. The harmful gases released from power plants due to increased energy consumptions lead to air pollution. UHI also affects the water quality in urban areas. The surface runoff gets heated due to the increased surface temperatures. This water when it mixes with the water bodies will impact the aquatic eco systems.

Urban Heat Island impact on climate change

Climate change refers to changes in the global climate system which causes changes to weather patterns. Climate change phenomenon is increasingly being experienced across the world with changes in precipitation patterns and an overall increase in global temperatures. The impact of Urban Heat Island on the other hand is localized and limited to specific area. But as the global temperatures increase as a result of climate change it augments the heat island effect. This will expose urban dwellers to extreme heat events which in turn will adversely impact the health of the residents. This will highly impact the economically and socially vulnerable groups who don’t have adequate housing and are more exposed to working outdoors.

Urban Heat Island does have an impact on the local climate as well. Urban Heat Island influences the wind pattern in the urban area. It can change the rate of precipitation and aid in the causing fog and clouds. UHI can induce additional rain as well as thunderstorms. Urban Heat Island causes low pressure areas which are conducive to cloud formation.Urban Heat Island can increase precipitation rate in urban areas by as much as 51%.

Urban Heat Island and Urban Flooding

Urban Floods are a result of both natural and manmade activities. Some of the reasons for urban floods are

i. **Planning issues:** Increasing population, habitations coming up in low-lying areas and encroachment of catchment and drainage areas.
ii. **Technical issues:** Increased imperviousness leading to increased runoff. Lack of proper waste disposal resulting in clogged drains, high intensity – high load of runoff.
iii. **Meteorological issues:** Climate Change, resulting in extreme events, Urban Heat Islands.
iv. **Policy issues:** Absence of integrated flood control and implementing agency

Increased rate of precipitation combined with increased surface runoff due to increase in impervious surfaces can result in urban flooding in many urban areas and Urban Heat Islands are one of the main contributors to urban flooding.

Urban Heat Island Effect in Bangalore Metropolitan Region

The Impact of Urban Heat Island

In a remote sensing based study carried out by Shrinidhi Ambinakudige in 2011, the effects of UHI in Bangalore have been analysed with respect to the relationship betweeen vegetation cover and temperature in context of BangaloreThe study showed that temperatures varied by 1 ^{o}C to 7 ^{o}C within different land cover classes in the urban core. The study also showed that the core area of the city also had lesser mean temperatures than the suburbs and outgrowths. This was because of the presence of water bodies and vegetation in the core city while the uncontrolled urban sprawl towards the outskirts had very less green cover.

Most of the water bodies have been encroached or have dried up. This has led to increased temperatures in the outgrowth areas.

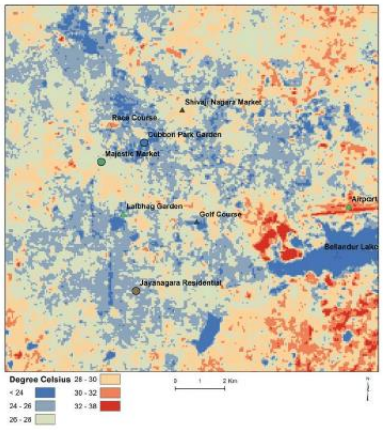


Figure 1. Land Surface temperatures in Bangalore. *Source*: Ambinakudige, Shrinidhi (2011)

The Tank system in Bangalore

The Garden city image of Bangalore was enhanced by its many lakes which also made it known as "The City of Lakes". Kempegowda, the founder of Bangalore was a visionary who by constructing the many reservoirs and lakes along the natural terrain of Bangalore ensured that the city had its own supply of potable water as well as water for cultivation. This was especially important in the context of Bangalore in the absence of any other source of water or a reliable river system. Ulsoor lake was one of the earliest lakes constructed by Kempegowda in the 16th century. This was later maintained bt the British. Sankey Tank, Miller's tank are other lakes used for water needs by the people of Bangalore.

Bangalore's has an average rainfall of 850 mm. This rainwater was traditionally captured by the cascading system of lakes. The outlets connecting these lakes to each other were called Raja Kaluves . The water moves from from one lake to the other till it is finally emptied into one the three main valley systems of Bangalore.

With the contamination of sewage into the lake water it soon became prohibited for consumption.In 1960 there were 262 lakes in Bangalore which have come down to 81 now of which only 34 are identified as live lakes. Lakes also form an important ecological system supporting many forms of life in Bangalore.

Traditionally the kere system in Bangalore has functioned as an efficient water management system in Bangalore by collecting the rainwater through a series of interconnected lake system. In the present time most of them have gone dry, or have been filled in and the remaining lakes have become waste and sewage dumps. The traditional linkages in the water systems have been disrupted due to urbanization. Adding to this are the effects of climate change which leads to higher intensity of rain in lesser number of rainy days which causes urban flooding in many areas in Bangalore.

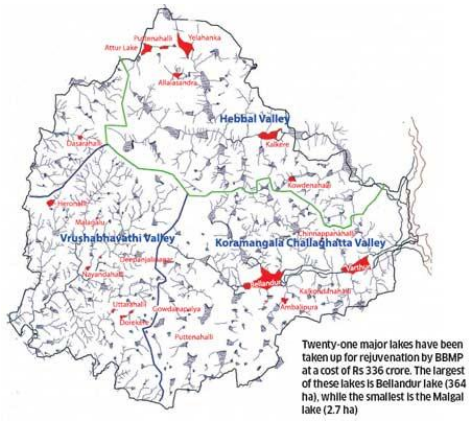


Figure 2. Tank System in Bangalore. *Source*:Kollarath (2013)

Impact of water bodies on Urban Heat Island Effect

The study of Land Surface Temperatures show a remarkable drop in temperatures near heavily vegetated areas and water bodies. The following studies undertaken by Ramachandra T V and Uttam Kumar (2010) show the significance of the tanks in Bangalore in reducing the Urban Heat Island effect.

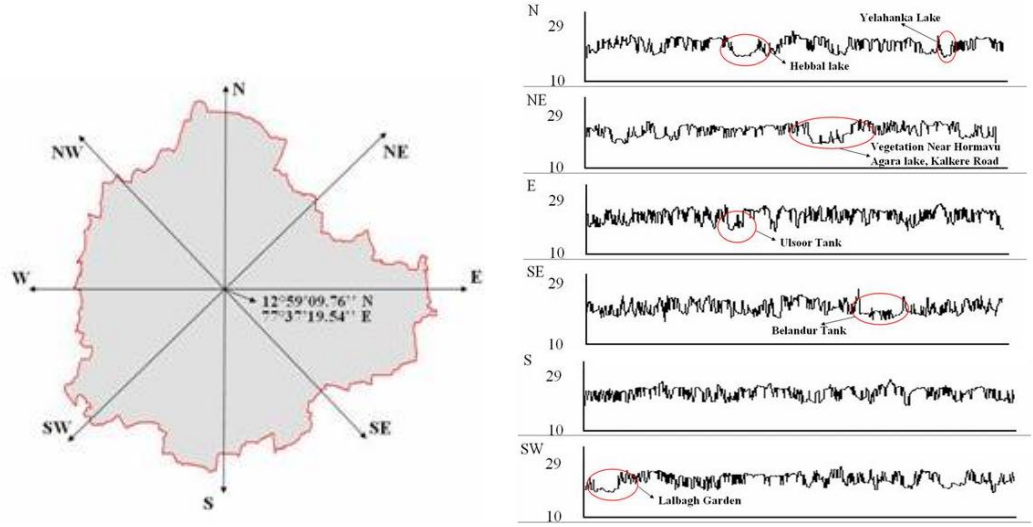


Figure 3. LST Studies in Bangalore Metropolitan Area. *Source*:Ramachandran & Kumar (2010)

Case of flooding in Bangalore

Urban Flooding has been becoming an increasing phenomenon in Bangalore in the recent years Unplanned and rampant urbanization has had a major impact on the existing natural systems. Infiltration capacity reduces with the expansion of impermeable surfaces. With installation of piped sewage systems the quality of natural retention in the catchment areas are reduced.

With increasing urbanization there are changes in the floodplain elevations which is a cause for urban floods. Infiltration capacity of the ground is reduced during summer time. In urban areas sudden rains are common in summer which is a result of the Urban Heat Island effect.

Bangalore city has in recent times been facing the problem of urban floods with many low lying areas flooding in a matter of few hours which have been mainly due to short bursts of rainfall with high rate of precipitation.

Koramangala Valley	**Hebbal Valley**	**Challaghatta Valley**	**Vrushabhavathi**
City Market Area	Brindavananagar below Matthikere Tank Market	Millers Tank, Chinnappa Garden	Gubbanna Layout
Sulthan Palya Main Road	KEB Compound Maththikere	Shivajinagar, Munireddy Palya	Shankarappa Garden Gopalapura
Jayanagar 3rd Block LIC Colony	Tannerana Halli	Saraswathipuram - Jogu Palya	Cholurpalya
Krishnapa Garden	Anandanagara	K R Garden	Bapujinagar
Arekempannahalli	Ring Road	Millers Tank, Chinnappa Garden	Minerva Mill
Jurist Colony	New - Bangalore Layout		Dhovi Colony
Marehalli Tank	Brindavananagar below Matthikere Tank Market		Tank Slum Area
Bismillanagar - Agencies			Binny Mill Tank Area
Pillappa Garden			Markandayyanagar
Arekempannahalli Area			Sanjaya Gandhi Slum Area
Jurist Colony			Rudrapa Garden
Marehalli Tank			Gubbana Layout

Table 1: Low lying and Floodprone areas in Bangalore.

Urban Heat Island Mitigation Strategies

Strategies for reducing Urban Heat Island effects include

- Vegetation
- Urban Geometry
- Water bodies & Features
- Materials & Surfaces
- Shading

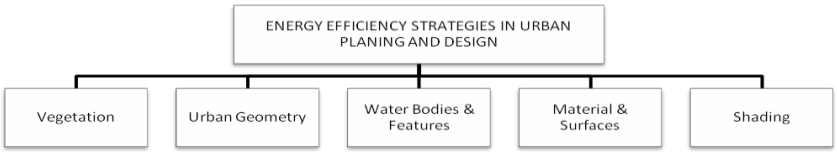


Figure 4. Energy Efficiency Strategies in Urban Planning and Design

Vegetation

As a mitigation strategy of 'urban heat island'(UHI) effect, Vegetation has extensively been used worldwide. High albedo and low heat admittance that have the effect of reducing accumulation of incoming solar energy in the urban area are the properties of vegetation. Additionally, to improve thermal comfort certain types of vegetation such as trees which can provide shade may be incorporated to reduce the heat gain from solar radiation. Also, the energy consumption for indoor cooling purpose can be reduced by the ambient air temperature reduction and building shading by vegetation.

Vegetation can be divided into three categories such as

i) Planting greeneries
ii) Parks and Open Spaces
iii) Green Corridors

Urban Geometry

The arrangement of various elements such as the building layout, the location of urban elements, the building height and geometry are variables that condition the thermal performance of the urban area and affects the spatial coverage of the shadowed areas as well as the wind environment

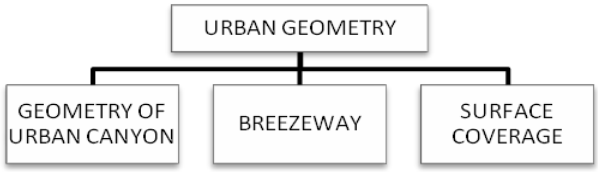


Figure 5. Types of Urban Geometry

Water bodies & Features

To improve the overheating of building environments to some extent Water bodies and features may be incorporated as countermeasures. The effect of water is related to its surface

temperature, which does not increase as much asthe rest of the urban area. Thus, it can be considered as a cool sink. Ponds are an accumulation of water that prevent the overheating of urban surfaces. They can be located on ground floor areas or on building roofs.

Water bodies are essentially of two types

i) Natural
ii) Manmade

Materials & Surfaces

The Urban climate and thermal balance of a city may be affected by the change in urban surface and materials. Cool pavements could be obtained by implementing lighter coloured asphalt on streets and roads and also by the use of cool tiles or special coatings on urban pavements. Materials and Surfaces in an urban environment mainly includes those of

i) Streets
ii) Open Spaces
iii) Buildings

Shading

Shading leads to the reduction of air and surface temperature and can therefore result in cooling. It is relevant during daytime, especially around noon when the sun angles are at the highest.

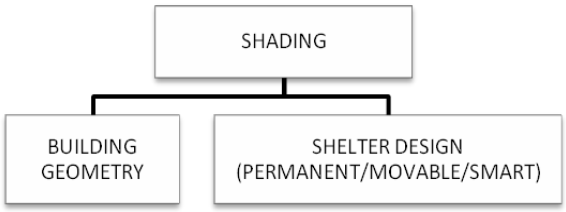


Figure 6 :Methods of Shading

Green Infrastructure Strategies to counter Urban Heat Island Effect

Green infrastructure is an important aspect of planning along with grey infrastructure, social infrastructure and other physical infrastructure. It refers to planned network of green spaces according to the Countryside Agency which can help to combat climate change as well as act as important components for disaster mitigation. It can also significantly reduce the Urban Heat Island Effect.

Countries like Singapore have been successful in creating efficient green infrastructure which helps to reduce urban heat island, cater to water requirements of the population and also prevent instances of flooding through a well defined system of collection, storage , conveyance and reuse of rain water.

Green infrastructure also serves other purposes including promotion of biodiversity, provide important lung spaces in the city and improve quality of life of its inhabitants. They also act as important places for recreation in the city and improve well being of the residents.

It consists of 'hubs and links' and should connect the whole city together. They can also become important economy generators. Green infrastructure planning if done properly can act similar to natural drainage system and help in recharge of groundwater as well as rejuvenation of existing water bodies.

Green Infrastructure strategies can also include

i) Urban Afforestation
ii) Increasing Pedestrianisation and enouraging bicycling

Green Infrastructure Strategies uses the combination of two main UHI mitigation measures – the use of vegetation and water bodies. In the Bangalore context, the existing kere system can be developed into an efficient blue green infrastructure combining both these features which will also help to preserve the remaining water bodies. The existing kere system of Bangalore can be effectively utilized to reduce UHI and create a green infrastructure network in the city. This in turn can become pedestrian and bicycling networks effectively reducing the carbon footprint in the city.

Current Scenario in Bangalore

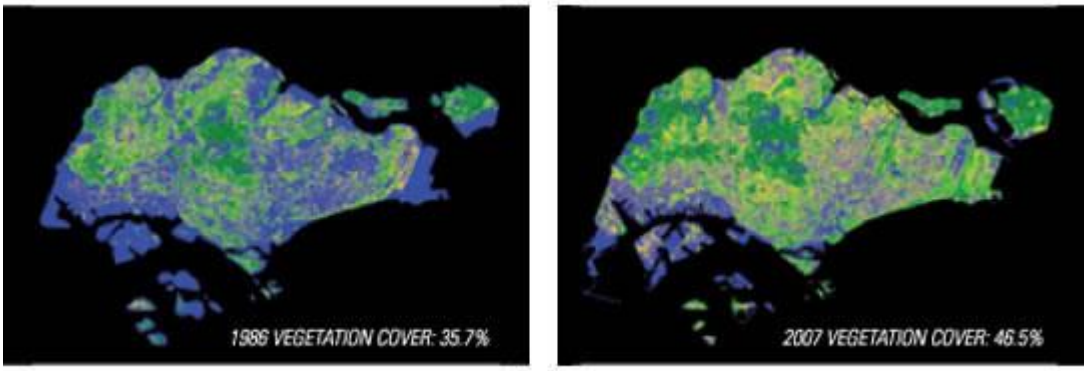
Bruhut Bangalore Mahangara Palike (BBMP) is set to receive 250 crores for rejuvenation of lakes within the city limits. The Bangalore Development Authority (BDA) and BBMP has mainly been involved in desilting the lakes along with fencing and making jogging tracks around the lakes. But the work has been slow and there is a need for spending money on maintenance of these cleaned up lakes along with the money spend on developing lakes. Lot of times sewage continues to be discharged in the rejuvenated lake thus interfering with all the work that has been done. In many cases the sewage is diverted to the lake downstream as the lake is getting rejuvenated which results in more pollution in the downstream lakes such as Bellandur and Varthur lakes.

There have been several citizen groups which have been involved in lake rejuvenation works in Bangalore such as The Lake Revivers Collective and The Better India. It is easier to clean up and revive lakes in the suburbs with lesser inflow of sewage compared to lakes inside the city which have more discharges polluting them. There is a need for a collective effort in the lake rejuvenation efforts and it is necessary to see each lake as a part of the larger watershed area. It is not enough to rejuvenate lakes separately without giving consideration to the overall network of *keres*.

The tree plantation drives organized by citizen groups in the city have done little with the green cover in the city coming down from 68% in 1973 to a mere 6% in 2017 according to a recent study conducted by IISC. Much has to be done to increase the green cover in the city.

Case Study of Singapore

Singapore is a densely populated country with an area of 722.5 sq kms is almost the same size of Bangalore. The population in Singapore has grown by 68% between 1986 and 2007. At the same time the green cover in the city has increased from 35.7% to 47.5%.



Source: NParks

Singapore has achieved this through a visionary approach to increase green cover which has also been incorporated in the Master plan of 2003 which envisioned a 15 year strategy. Singapore has implemented the park connector network by connecting the smaller and larger parks and providing recreational corridors for its citizens, this has also helped to expand the green cover in the city. Currently the city has 0.8 hectares of park space for every 1000 population.

Singapore is a very good example in the implementation of green infrastructure strategies which include increasing the green cover as well as the area of water bodies for reducing the urban heat island effects. Unlike Bangalore Singapore didn't have a system of water bodies and lakes. Singapore which was largely dependent on Malaysia for its water supply has gradually increased the water resources in the country by tapping rain water and increasing its reservoirs.

Singapore has also made huge strides in green building technologies and use of alternative energies. And they have managed to go forward in this direction in spite of various problems of urbanization and population pressures due to the political will of the administration and effective urban planning.

Conclusion

Urban Heat Island mitigation strategies are important in order to reduce greenhouse gas emissions and reduce energy consumption in urban areas. Green Infrastructure Strategies which involve increasing the vegetation cover and creating continuous linkages of green spaces can significantly contribute towards Urban Heat Island mitigation.

Bangalore has an existing natural flood control mechanism in the form of its tank system which needs to be recognized, protected and developed. In addition to flood control and disaster mitigation this system when developed into a blue green infrastructure will also enhance the quality of life in the city in addition to providing various economical, ecological and social

benefits. Most importantly conservation of these large water bodies and the green cover around them can significantly cool the localities around them.

It is important to recognize the relevance of the already existing green infrastructure and augment it as required so that it can become an effective method to cooling Bangalore Metropolitan area. The lakes and the sloping terrain of the city create a natural drainage mechanism in the city and it is necessary to implement efficient green infrastructure strategies in accordance to reduce the temperatures in Bangalore and once again transform it into a 'Garden City'. This can only be achieved through policies and legal mechanisms to increase the green cover and protect the water bodies in the city with a strong partnership between the civic authorities and the local community.

References

Ambinakudige, Shrinidhi (2011),Remote sensing of land cover's effect on surface temperatures:a case study of the urban heat island in Bangalore, India.. 1, Mississipi State : Applied GIS, 2011, Vol. 7.

Mohajerani et al(2017), The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete, Journal of Environmental Management, Volume 197, 15 July 2017, Pages 522-53(https://doi.org/10.1016/j.jenvman.2017.03.095)

Ramachandra T V & Uttam Kumar (2010), Greater Bangalore: Emerging Urban Heat, Island, GIS Development, Volume 14, Issue 01, Jan 2010. (http://www.gisdevelopment.net/application/urban/sprawl/Greater-Bangalore-Emerging-Urban-Heat-Island.htm).

Sudhira (2008). Studies on Urban Sprawl and Spatial Planning Support System for Bangalore, India, 12, May 2008.

T V Ramachandara and P P Mujumdar,(2009) 'Urban floods'

Voogt, James A.(2004), Urban Heat Islands: Hotter Cities. *Actionbioscience.* [Online] 2004. http://www.actionbioscience.org/.