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# Impact of vegetation in mitigating the urban heat island effect at Vishrantwadi, Pune, India

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## ABSTRACT

***A growing majority of 55% global population now resides in urban areas, a proportion that is expected to increase to 68% by 2050. One of the consequences of such an increase in urban development may be the empirically observed phenomenon of the Urban Heat Island (UHI) effect. This paper presents the analysis of microclimatic conditions in urban street canyons in a city location Vishrantwadi, Pune, India. A number of field measurements were carried out during summer 2017 aiming at the investigation of the microclimate parameters that affect thermal conditions in the city's streets. The objective of this paper is to investigate the effect of vegetation on UHI mitigation in Vishrantwadi based on field measurements through IR Gun on an area consisted by several building blocks carried out in adjacent greenery and non-greenery spaces during summer time. The recommendation of this study will help Architects and Urban planners to find the manual to know how to use vegetation to mitigate the Urban Heat Island Effect.***

***Keyword—*** *Urban green spaces, Urban heat island, Benefit of vegetation*

## 1. INTRODUCTION- CAUSES OF THE URBAN HEAT ISLAND EFFECT

Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050. Projections show that urbanization, the gradual shift in the residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas with close to 90% of this increase taking place in Asia and Africa. By 2050, it is projected that India will have added 416 million urban dwellers. (United Nations Department of Economic And Social Affairs, 2018)

One of the consequences of such an increase in urban development may be the empirically observed phenomenon of the Urban Heat Island (UHI) effect. In dense urban areas, the climate is affected by "urban thermo-physical and geometrical characteristics, anthropogenic activities and heat sources" (Dimoudi et.al. 2013, p.1). Such changes can also have considerable impacts beyond that on the microclimate, including those on energy use, health, economics, and can become a cause for national concern. Materials such as brick, asphalt, concrete etc. used in urban areas absorb the sun's energy, and then heat-up, and re-radiate that heat into the ambient air, creating urban heat island effects.

Research on the subject of Urban Heat Islands has identified several distinct factors that contribute to the phenomenon. These are – absorption of radiation by ground surfaces as well as roof and wall surfaces of buildings; reduction of ground moisture content from reduced vegetative cover and evapotranspiration; reduction of airflow due to increased built obstructions; heat input from anthropogenic sources such as motor vehicles and air conditioners; and the retention of the heat by the building mass. Studies indicate that the urban heat island effect can increase the temperature of two degrees Celsius and generate a warmer microclimate in the Urban areas.

The purpose of this research is to study the impact of vegetation in mitigating urban heat island effect at Vishrantwadi, Pune. The vegetation can be used on buildings and other surfaces of the urban environment to reduce Urban Heat Island Effect. The research would also focus on solar exposure simulations at various scales using sundials, from a single building to an urban boundary, to understand and visualize such impacts.

Leadership in Energy and Environmental Design (LEED) and The Indian Green Building Council (IGBC) encourages the use of vegetation to reduce microclimates generated by the infrastructures and buildings.

This paper aims to show how vegetation can contribute significant environmental, social and economic benefits to our built environment and highlight several elements that should be considered for their successful implementation around streets.

## 2. PUNE CITY AND URBAN EXPANSION

Vishrantwadi is situated in the Pune City, State of Maharashtra, India. The entire neighborhood of Vishrantwadi lies along the Alandi Road. Other major roads in this locality are the Tingre Nagar Road (Vishrantwadi-Airport Road) and Dhanori Road. The Pune Railway station is about 7 kilometers from

Vishrantwadi while the Pune International Airport at Lohegaon is just about 4 kilometers away. See Figure 1

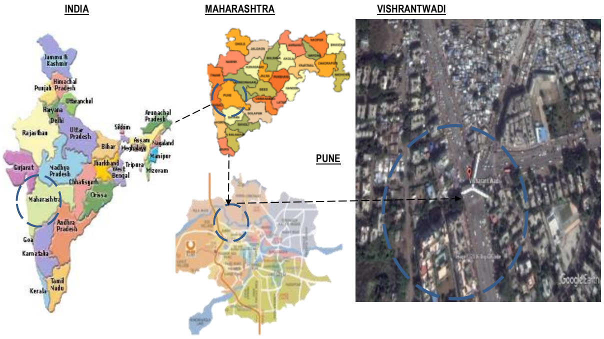



**Fig. 1: Vishrantwadi, Pune**

The Urban Extent of Pune in 2011 was 45,944 hectares, increasing at an average annual rate of 7.5% since 2001. The urban extent in 2001 was 22,065 hectares, increasing at an average annual rate of 13.8% since 2001 when its urban extent was 5,427 hectares in 1991. See figure 2, 3, and 4.

**Fig. 2: Urban Expansion, Pune -1991**

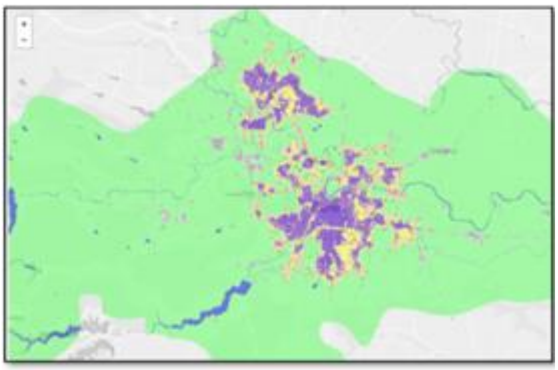


**Fig. 3: Urban Expansion, Pune -2001**

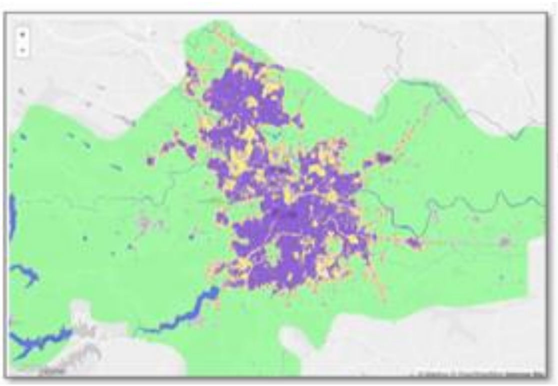


**Fig. 4: Urban Expansion, Pune -2011**

Built-up Area Density in Pune during 2011 was 170 persons per hectare, decreasing at an average annual rate of -4.8% since 2001. The built-up area density in 2001 was 273 persons per hectare, decreasing at an average annual rate of -8.8% since 1991 when the built-up area density was 668.27 persons per hectare. The Urban Extent Density in Pune in 2011 was 120 persons per hectare, decreasing at an average annual rate of -3.4% since 2001. The urban extent density in 2001 was 167 persons per hectare, decreasing at an average annual rate of -6.5% since 1991 when the urban extent density was 323 persons per hectare. (Urban Expansion 2011, Pune)

Pune urbanization contributed to wide changes in many factors during the last 20 years such as population, pollution rate and green area fraction. The population increased rapidly from 1,752,854 in 1991 to 5,509,160 in 2011. Therefore, the CO2 concentration increased. The person's portion from green areas decreased significantly. All these factors contributed to high temperature in Vishrantwadi, Pune, therefore, causing Urban Heat Island Effect.

## 2. 1 Urban Heat Island

The urban heat island effect is a type of microclimate seen in urban areas (Kleerekoper et al., 2012). Urban areas are usually warmer than rural areas because urban areas tend to have more impervious surfaces such as buildings, roads, and parking lots (Winguth and Kelp, 2013). The use of vegetation's can help alleviate the impact of existing or new buildings. They promote biomass to cool urban areas, support the growth of tree canopies, improve air quality, and mitigate stormwater runoff (Greenscreen, 2012).

Figure 5 shows high temperature in the city especially in the downtown of the city and low temperature in rural areas (Gartland, 2008)

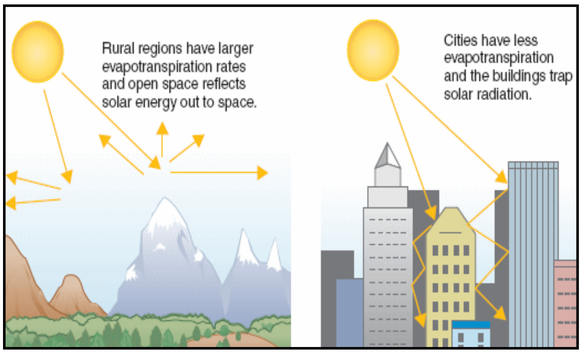



**Fig. 5: The high temperature in the city downtown**

Urbanization has brought about several undesirable environmental changes. In the process of urbanization, land cover change natural surfaces are replaced by the urban fabric which is characterized by higher temperatures than the surrounding rural environment, a pattern described as urban warming. A large body of urban climate studies has shown that thermal, optical and geometric properties of urban surfaces affect heat absorptive and radioactive properties and lead to the so-called Urban Heat Island (UHI) effect (Feyisa, Dons, & Meilby, 2014). Two major phenomena were observed in large cities as compared to its surroundings:

- -a higher temperature or heat content called Urban Heat Island (UHI),
- -an occasional lower temperature called Urban Cool Island (UCI) or Urban Cool Valley (UCV), (Rizwan, Dennis, & Chunho, 2008).

Increasing temperatures and the risk of heat wave events in urban areas have also represented a serious public health concern. The field of UHI has become highly interesting for scientists and engineers due to its adverse environmental and economic impacts on the society and promising benefits associated with mitigating high heat intensity (Bowler, Buyung-Ali, Knight, & Pullin, 2010). The number of studies related to climate change and urban heat island in the world has started to increase since the 1980s.

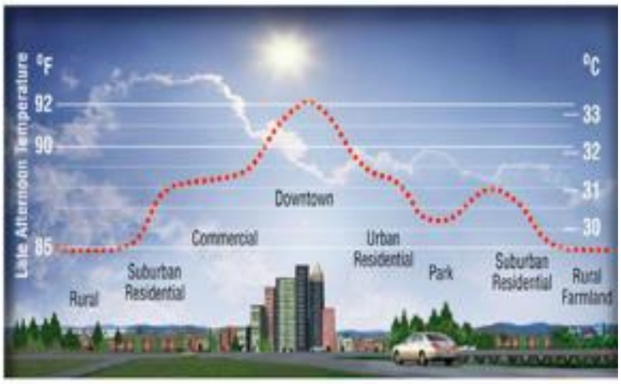



**Fig. 6: Urban heat island effect in downtown**

### 2.2 Urban Heat Island Causes

When a building is built, there is a change in the flow of energy and substance through urban ecosystems, often causing environmental problems (Oberndorfer et al. 2007). Urban areas are usually warmer than rural areas because of a higher ratio of buildings and infrastructure concentrated in the space, causing the temperature to increase (Winguth and Kelp, 2013). The "sensible heat storage of urban surfaces, reduced wind speed, and albedo in response to increased surface roughness, heat contribution from upstream urban areas, and other related factors, like anthropogenic heat flux linked to population density with associated building and traffic heat loss. The climate of the urban boundary layer is determined, at least partially, by the exchanges of momentum, heat, and water with the urban canopy layer." see figure 6 (Landsberg,1981, Christen and Vogt, 2004, Voogt, 2010; Oke, 1987, Zhang et al., 2011 in Winguth and Kelp, 2013,).

The urban heat island effect causes serious climatic unpleasant conditions in human health, animals, and vegetation (Kleerekoper et al., 2011). This effect is seen especially in cities where the summer season is extreme and hot. The moderation of extreme heat in these cities is important for their sustainability and to lower the risks and effects of such conditions. The urban heat island effects have an urban canopy layer that is categorized by small processes that are affected by characteristics of development, such as the urban canyon geometry and the reduction of the sky view factor. The canopy layer reaches its maximum after sunset, particularly when the skies are clear and the wind is low in speed (Winguth and Kelp, 2013).

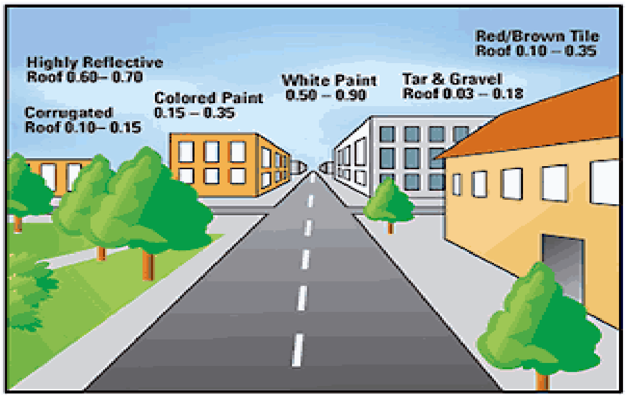



**Fig. 7: Urban Albedos**

Urban heat island is caused due to numerous reasons. See figure 7 Firstly, Materials that are used in the cities and dark impermeable which absorb more heat rather than the materials which are used in rural areas. Secondly, dense buildings in the cities cause deep canyons which trap more heat. See Fig8 Thirdly, lack of green areas and vegetation in the cities. Finally, Anthropogenic heat which is caused due to human activities such as car pollution and air conditioning use.

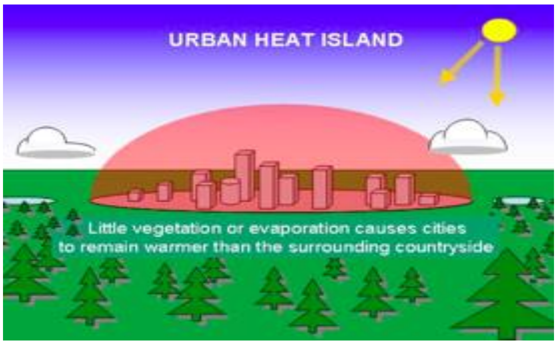



**Fig. 8: Urban canopy layer**

In the urban environment the temperature increases because of the dark and impervious surfaces such as asphalt roads and roofs. Usually, the downtown area of a city that has high-rise buildings and high-density becomes warmer than the surrounding areas.

The annual mean air temperature of a city with one million or more people can be 1.8 to 5.4°F (1 to 3°C) warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 22°F (12°C), (EPA 2012).

The urban heat island effect can be reduced by increasing albedo, or by applying more vegetation cover with sufficient soil moisture for evapotranspiration (Bass et al.,2002). According to (Kleerekoper et al., 2012)

1. Absorption of short-wave radiation from the sun in low albedo (reflection) materials and trapping by multiple reflections between buildings and street surface.
2. Air pollution in the urban atmosphere absorbs and re-emits longwave radiation to the urban environment.
3. Obstruction of the sky by buildings results in a decreased long-wave radiative heat loss from street canyons. The heat is intercepted by the obstructing surfaces and absorbed or radiated back to the urban tissue.
4. Anthropogenic heat is released by combustion processes, such as traffic, space heating, and industries.
5. Increased heat storage by building materials with large thermal admittance. Furthermore, cities have a larger surface area compared to rural areas and therefore more heat can be stored.
6. The evaporation from urban areas is decreased because of 'waterproofed surfaces' – less permeable materials, and less vegetation compared to rural areas. As a consequence, more energy is put into sensible heat and less into latent heat.
7. The turbulent heat transport from within streets is decreased by a reduction of wind speed. (Kleerekoper et al., 2012, p. 30). See figure 9

Finally, Urban heat Island is related to urban land uses as industrial areas are characterized by a high temperature in comparison to other land use.

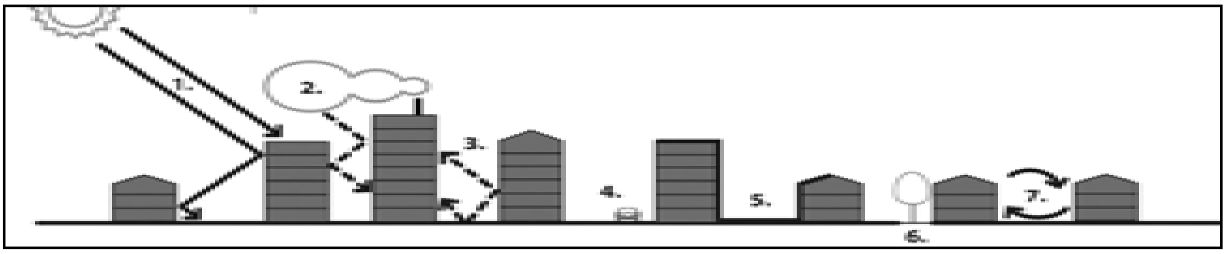



**Fig. 9: Causes of urban heat islands**

## 3. VEGETATION FOR MITIGATING URBAN HEAT ISLAND EFFECT AND ITS IMPLEMENTATION

Vegetation cools the environment through evapotranspiration and also by creating a shading surface that otherwise absorbs short-wave radiation. There are four types of applications of green infrastructure in urban environments: parks, street trees, private gardens, and green walls or roofs (Kleerekoper et al., 2012).

Trees and vegetation are cool urban fabric through evaporative cooling within transforming plants water to water vapour. Therefore, the soil does not trap the heat the adjacent air layer which the pedestrian feel (Oke 1989). Urban vegetation can also contribute to improving the quality of life and enhancing human well-being through exposure to nature (Dallimer, Irvine, et al., 2012; Dallimer, Rouquette, et al., 2012). Integration of green spaces in urban planning and building designs may, therefore, be essential for adaptation to and mitigation of thermal impacts of both local and global warming processes (Feyisa et al., 2014).

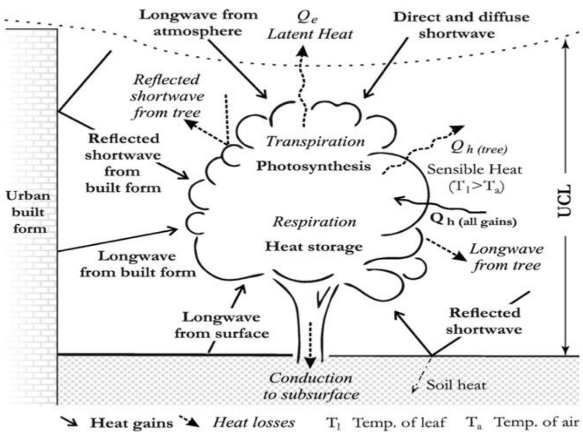



**Fig. 10: Daytime energy exchanges between a tree and urban built form, based on Oke (1989)**

According to Feyisa et al. (2014); complex processes are involved in determining the cooling effect of vegetation on daytime air and surface temperature. The vegetation cools the environment through evaporative cooling, shading effects, and its thermal and optical properties Dimoudi & Nikolopoulou, 2003; Oke, 1988; Compared to impervious surfaces, which generally have high thermal storage capacity and thermal conductivity, vegetation has low thermal storage and admittance (Oke, 1988; Spronken-Smith & Oke, 1999) and is therefore likely to emit less thermal radiation to the environment. However, the cooling impact of plants on air and surface temperature may vary with environmental factors and plant-specific thermal and optical characteristics. Vegetation along with highly reflective surfaces (high albedo) may reduce surface temperature by reducing the amount and intensity of thermal radiation which may also lower local and downwind ambient air temperatures because of smaller convective heat fluxes from cooler surfaces (Taha, 1997).

The benefits of vegetation have been studied since the seventies (Bellomo, 2003). Vegetation's offer improvements in the efficiency of the building, as well as having environmental and ecological benefits. Both systems can help reduce the urban heat island effect and improve air quality; providing shade, and insulation through the evapotranspiration of the plants (Perini et al., 2011).

Vegetation and urban materials differ in moisture, aerodynamic and thermal properties, and so urban greening could affect temperatures through different processes See Fig10 (Oke, 1989; Givoni, 1991). A key process is an evapotranspiration, which describes the loss of water from a plant as a vapour into the atmosphere. Evapotranspiration consumes energy from solar radiation and increases latent rather than sensible heat, cooling the leaf and the temperature of the air surrounding the leaf (Taha, Akbari, Rosenfeld, & Huang, 1988; (Grimmond and Oke,).

Thus, trees and vegetation's has a significant effect on urban heat island mitigation especially during daytime through evaporation and shading.

## 4. RESEARCH OBJECTIVE AND METHODOLOGY – STUDY


**Fig. 12: Location-A seeks to investigate the role of trees on thermal performance and the second case at Location-B is to investigate without vegetation's**

The research aims to investigate the role of the trees and vegetation in micro urban spaces in Vishrantwadi based on field measurement taken through IR Gun. Location-A seeks to investigate the role of trees on thermal performance and the second case at Location-B is to investigate without vegetation. see figure 12.

Two locations from Vishrantwadi had been chosen. The first case at Location-A seeks to investigate the role of trees on thermal performance and the second case at Location-B is to investigate without vegetation's see Fig13.In each case, one street which is divided to two adjacent sectors, greenery, and non-greenery sector, to fix all the variables that affect urban heat island and thermal performances such as asphalt road, concrete road and stone pavement. Temperature measurements through IR Gun were carried out in each case during the summer month on 18th March 2017. Measurements were carried at five different times a day 10 AM, 12noon, 2 PM, 4 PM and 6 PM to investigate the effect of vegetation during the daytime.

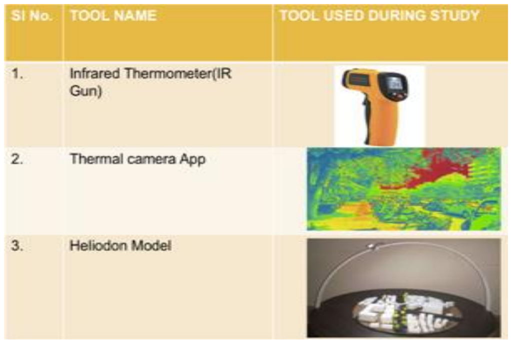

**Fig. 13: Vishrantwadi 2002-20016**

### 4.1.1 Tools and Techniques

**Infrared thermometer:** An Infrared thermometer is a thermometer which infers temperature from a portion of the thermal radiation sometimes called blackbody radiation emitted by the object being measured.

**Thermal Camera App**: Thermal Camera App transforms Android smartphones camera view into powerful Android Thermal Camera views.

**Heliodon Model:** A heliodon (HEE-leo-don) is a device for adjusting the angle between a flat surface and a beam of light to match the angle between a horizontal plane at a specific latitude and the solar beam. See figure 14.



| Sl No. | TOOL NAME | TOOL USED DURING STUDY |
|---|---|---|
| 1. | Infrared Thermometer(IR Gun) | |
| 2. | Thermal camera App | |
| 3. | Heliodon Model | |

**Fig. 14: Tools and techniques used at study area for Temperature measurements**

**Table 1: Typical Solar Reflectance value for standard Non roof materials**

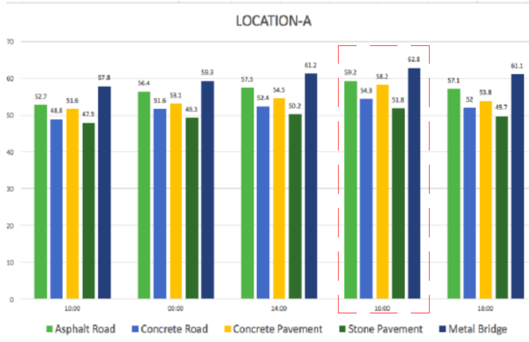
| Materials | Initial solar reflectance | Three years aged solar reflectance |
|---|---|---|
| Grey cement concrete | 0.26 | 0.18 |
| White cement concrete | 0.70 | 0.35 |
| Asphalt concrete | 0.05 | 0.10 |

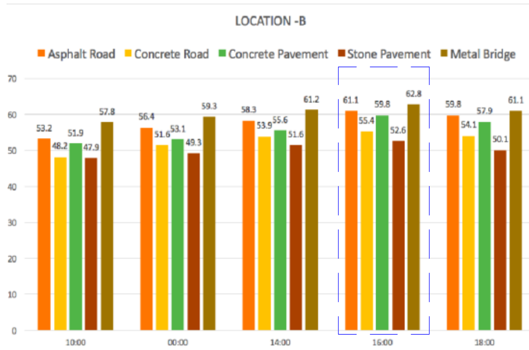
*Source: USGBC LEED interpretation #10411, April1 2015*

**Table 2: Temperature level on materials at different location**

| Materials | Location-A | | Location-B | |
|---|---|---|---|---|
| | 2PM | 4PM | 2PM | 4PM |
| Asphalt Rd | 57.5 | 59.2 | 58.3 | 61.1 |
| Concrete Rd | 52.4 | 54.3 | 53.9 | 55.4 |
| Concrete Pavement | 54.5 | 58.2 | 55.6 | 59.8 |
| Stone pavement | 50.2 | 51.8 | 51.6 | *52.6* |
| Metal bridge | 61.2 | 62.8 | 61.2 | 62.8 |

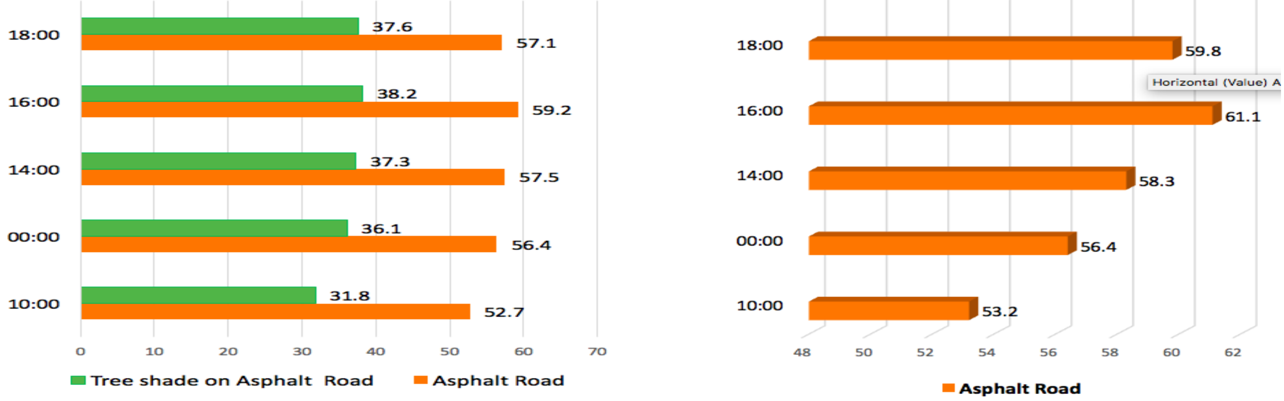
**Graph of Temperature level on different materials**



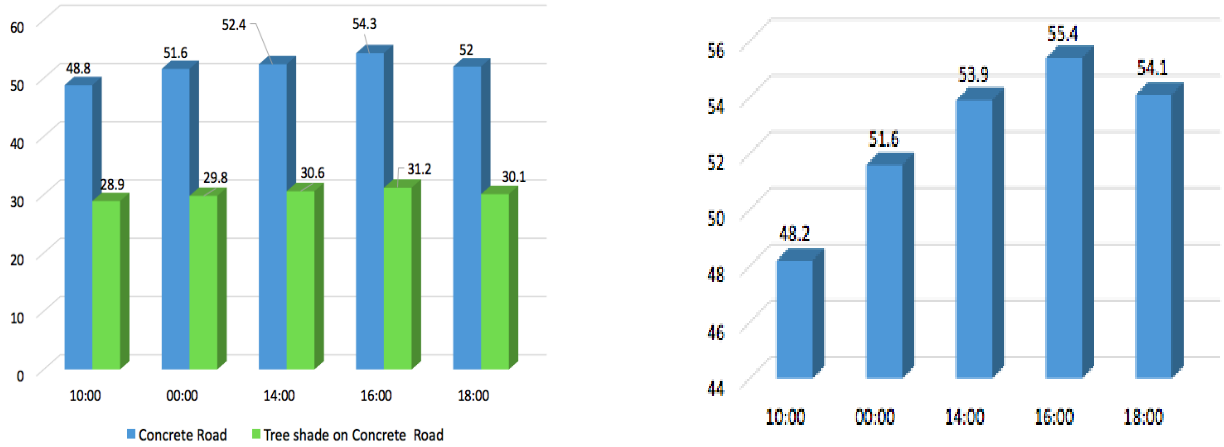
**Location- A** **Location- B**

**Fig. 16: Temperature level on different materials at Location -A and Location-B measured by Thermal camera App**




**Location- A** **Location- B**

**Fig. 17: Comparison of Temperature levels on Asphalt road and at Tree shaded areas on Asphalt road**




**Location- A** **Location- B**

**Fig. 18: Comparison of Temperature levels on Concrete road and at Tree shaded areas on Concrete**


**Fig. 19: Comparison of Temperature levels on Concrete road and at Tree shaded areas on Concrete road using Helidon Model at different time**

## 5. RESULTS

The temperature in the planted sector is lower than the temperature in the non-planted sector during daytime by 20-degree C due to shade factor. The peak temperature of 59.2-degreeC at location A is reduced to 38.2-degree C due to vegetation thus reducing the Urban Heat Island effect. This leads to improved thermal performance in outdoor space and provides thermal comfort for pedestrians.


**Fig. 20: Reference image**

### 5.1 Precautions to prevent and reduce the formation of urban heat island effects

In last years, urban heat island became one of the important problems generally in big cities as a part of climate changes and is a sort of reflection of global warming in local scale. As an outcome of global warming, urban heat island has negative effects on public health, quality of life and energy consumption.

In urban scale, precautions to prevent and reduce the formation of urban heat island effects in residential areas of the cities could be described as follows:

- Climate maps should be created in cities,
- Information systems following the city climate's current development should be established. (with remote sensing and GIS)
- During the preparation process of urban development plans, a composed team from different disciplines (urban planners, architects, climate scientist, geographer, geomorphology, sociologists, landscape architects, etc.) should be inside the study.
- Existing open green spaces in cities should be protected and the use of impervious surfaces should be reduced.
- The gardens of the public buildings in the city (government agencies, school gardens, military areas, etc.) should be planted.
- Roadside planting should be done in the streets to prevent street canyon effect.

## 6. CONCLUSION

The urban microclimate of the cities changes as more buildings and infrastructures are built. It is important to consider options to mitigate the urban heat island effects caused by the urban microclimate and to study how wind and sun play a role in this discussion. "According to Akbari and Taha (1992), in general, climatic factors that affect outdoor thermal comfort are (1) surface and air temperature;(2) relative humidity; (3) solar radiation; and (4) wind velocity, climatic elements and its relation with local climate should be fully understood" (Thani et al., 2012, p. 441). The literature illustrates that by adding vegetation into the urban environment, the urban heat island effects can be mitigated (Kleerekoper et al., 2012)

The purpose of this research was to study the impact of vegetation in the urban microclimate and their effects in mitigating the urban heat island effects. This research fulfilled testing certain aspects about the effects of vegetation on the urban microclimate. The temperature measurements obtained from the IR Gun helped to obtain information about the relationship of the sun with the urban heat island effects, and how, when placing vegetation, wind can flow better and the effects of solar radiation can be mitigated.

In this case, Vishrantwadi, Pune, was used as the area of study. The influences that these type of green infrastructures have in reducing the urban heat island effect by alleviating the solar exposure was determined.

In summary, adding vegetation suggests potential impact. Using trees and vegetation is significant in urban heat island mitigation due to its evaporation and shading.

This conclusion can be shown as design guidelines accordingly to the following points:

- It is necessary to study the relationship between space ration and trees spread while the design process to provide shade during daytime and make the heat escape to the atmosphere during nighttime.
- Native trees like Ashoka with LAI 4.5 and Neem tree with LAI 5.5 are significant elements that could be used to provide shade and keep sky view open. Thus reducing the Urban Heat Island effect.

## 7. REFERENCES

[1] Figure 1, Vishrantwadi,.Pune. https://en.wikipedia.org/wiki/Vishrantwadi
[2] Figure 2, Urban Expansion 1991, Pune http://atlasofurbanexpansion.org/cities/view/Pune
[3] Figure 3, Urban Expansion 2001, Pune http://atlasofurbanexpansion.org/cities/view/Pune
[4] Figure 4, Urban Expansion 2011, Pune http://atlasofurbanexpansion.org/cities/view/Pune
[5] Figure 5, Sandesh Adhikari, March 6, 2018, Urban Heat Island, Its Effects and Mitigation Measures, http://www.publichealthnotes.com/urban-heat-island-effects-mitigation-measures/
[6] Figure 6, Urban heat Island effect in downtown cities produce what's known as the urban heat island effect: It's significantly warmer there https://www.nsf.gov/news/mmg/mmg_disp.jsp?med_id=75857&from=
[7] Figure 7, Reflective surfaces (climate engineering) https://en.wikipedia.org/wiki/Reflective_surfaces_(climate_engineering)
[8] Figure 8, Urban Heat Island http://www.weatherquestions.com/What_is_the_urban_heat_island.htm
[9] Figure 9, Kleerekoper et al., 2012, p. 30How to make a city climate-proof, addressing the urban heat island effect http://www.theurbanclimatologist.com/uploads/4/4/2/5/44250401/kleerekoperetal2012citiesclimateproof.pdf
[10] Figure 10, Oke, 1989 T.R. Oke The micrometeorology of the urban forest Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci., 324 (1989), pp. 335-349
[11] Bass, B., Stull, R., Krayenjoff, S., Martilli, A., 2002. Modelling the Impact of Green Roof Infrastructure on the Urban Heat Island in Toronto. Green Roofs Infrastruct. Monit. 4 (1), 2–3.
[12] Bellomo, 2003, Dalit Bielaz Sclar Bowler, Buyung-Ali, Knight, & Pullin, 2010, Urban greening to cool towns and cities: A systematic review of the empirical evidence Landscape and Urban Planning 97 (2010) 147–155, https://is.muni.cz/el/1431/jaro2014/Z0132/um/47486984/u

rbanGreening.pdf?studium=150956Dallimer, Irvine, et al., 2012;

[13] Dallimer, Rouquette, et al., 2012). Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness *BioScience*, Volume 62, Issue 1, 1 January 2012, Pages 47–55, https://doi.org/10.1525/bio.2012.62.1.9

[14] Dalit bielaz sclar, The impact of green walls and roofs to urban microclimate in downtown dallas, texas: learning from simulated environments, https://rc.library.uta.edu/uta-ir/bitstream/handle/10106/24068/BielazSclar_uta_2502M_12471.pdf?sequence=1&isAllowed=y (2013)

[15] Dimoudi & Nikolopoulou, 2003, Vegetation in the Urban Environment: Microclimatic Analysis and Benefits Volume 35, Issue 1 January 2003, Pages 69-76 http://dx.doi.org/10.1016/S0378-7788(02)00081-6

[16] Dimoudi et.al. 2013, p.1 Investigation of urban microclimate parameters in an urban center Energy and Buildings 64 (2013) 1–9 http://dx.doi.org/10.1016/j.enbuild.2013.04.014

[17] Feyisa GL, Dons K, Meilby H. Efficiency of parks in mitigating urban heat island effect: an example from Addis Ababa. Landscape and Urban Planning. 2014;123:87-95. Available from, DOI: 10.1016/j.landurbplan.2013.12.008

[18] Gartland, 2008. Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide [accesses13.11.17]. https://www.sciencedirect.com/science/article/pii/S2095263517300432

[19] Grimmond, M. Roth, T.R. Oke, Y. Au, M. Best, R**.** Betts, *et al.*Climate and more sustainable cities: climate information for improved planning and management of cities (producers/capabilities perspective) Prog. Environ. Sci., 1 (2010), pp. 247-274

[20] Greenscreen, 2012. Considerations for Advanced Green Facade Design, White Paper version: September 2015 http://greenscreen.com/docs/Education/greenscreen_Advanced Green Facade Design_White Paper.pdf

[21] Kleerekoper et al., 2012,p. 30How to make a city climate-proof, addressing the urban heat island effect http://www.theurbanclimatologist.com/uploads/4/4/2/5/44250401/kleerekoperetal2012citiesclimateproof.pdf

[22] Landsberg,1981, Christen and Vogt, 2004, Voogt, 2010; Oke, 1987, Zhang et al., 2011 in Winguth and Kelp, 2013,.The Urban Heat Island of North-Central Texas DOI: 10.1175/JAMC-D-12-0195.

[23] Urban heat island https://www.nationalgeographic.org/encyclopedia/urban-heat-island/

[24] Oberndorfer et al. 2007, Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services http://www.mit.edu/people/spirn/Public/Granite Garden Research/Plants/Oberndorfer et al 2007 Green Roof Ecosystems.pdf

[25] Oke, 1988 T.R. Oke The urban energy-balance Prog. Phys. Geogr., 12 (1988), pp. 471-508

[26] Oke, 1989 T.R. Oke The micrometeorology of the urban **forest** Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci., 324 (1989), pp. 335-349, CrossRefView Record in Scopus

[27] K. Perini, M. Ottele, A.L.A. Fraaij, E.M. Haas, R. Raiteri Vertical greening systems and the effect on air flow and temperature on the building envelope Build. Environ., 46 (2011), pp. 2287-2294View Record in Scopus

[28] Rizwan, Dennis, & Chunho, 2008, A review on the generation, determination and mitigation of Urban Heat Island, Journal of Environmental Sciences 20(2008) 120–128,https://www.megujuloenergiapark.hu/docs/mekut/11_1-s2.0-S1001074208600194-main.pdf

[29] Spronken-Smith & Oke, 1999 Scale Modelling of Nocturnal Cooling in Urban Parks November 1999, Volume 93, Issue 2, pp 287–312 DOI: 10.1023/A:1002001408973

[30] Taha, 1997. Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat Energy and Buildings 25 ( 1997) 99-103 https://pdfs.semanticscholar.org/38e1/5545b6785035cc6def9fef952d22e2c03dca.pdf

[31] Taha, Akbari, Rosenfeld, & Huang, 1988; Residential cooling loads and the urban heat island—the effects of albedo Volume 23, Issue 4, 1988, Pages 271-283 https://doi.org/10.1016/0360-1323(88)90033-9

[32] United Nations, 2014, Human Development Report 2014, http://hdr.undp.org/en/content/human-development-report-2014

[33] United Nations Department of Economic And Social Affairs, 2018 Revision of the World Urbanization Prospects, https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

[34] US EPA Heat Island Impacts. 2015 Available online: https://www.epa.gov/heat-islands/heat-island-impacts.

[35] Winguth, A. M. E., and B. Kelp, 2013: The urban heat island of the north-central Texas region and its relation to 2011 severe Texas drought. J. Appl. Meteor. Climatol. 52, 2418–2433, doi:10.1175/JAMC-D-12-0195.1.