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The Role of Landscape Architecture in Actively Modifying Microclimate in Urban Streets

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Abstract

Urban Streets in Indian Cities are growing rapidly which increases the heat stress, making microclimate-sensitive design essential. The Local Climate of the Street in an urban area can be greatly affected by the urban thermo -physical and geometric characteristics present in the urban street. The interest of micro climate has been raised as they represent important factors in achieving energy conservation and thermal comfort of the human beings inside the cities where the whole people resident in the cities.

The paper examines how the landscape elements such as trees, shrubs, pavements and water body modify the microclimate in the selected urban streets. Four streets with various compositions of the trees, shrubs, pavements and water body has been deliberately chosen, each justified through various landscape characteristics. Based on the presence of Landscape elements in the streets, Landscape cover Index (LCI) was developed to do a comparative analysis to find the influence of these landscape elements across the selected streets.

A particular day was selected and field measurements were conducted on a climatically consistent day to record air temperature, relative humidity, wind speed, and surface temperatures. Additionally secondary climatic data, including the day’s maximum and minimum temperatures, were sourced online for validation. Envi-met Stimulations were also take on the same day to provide spatial microclimate predictions, which were compared with field measurements to assess reliability and highlight correlations.

Finding show that streets with high landscape cover index especially which has dense canopy measurements and water body nearby exhibit lower air and high relative humidity levels. The comparison between field data and Envi-met outputs confirmed consistent trends. Overall, the study demonstrates that strategically planned landscape elements can meaningfully improve thermal comfort and microclimate performance in urban streets, reinforcing the role of landscape architecture in climate-responsive urban design.

Keywords

Microclimate, Landscape Architecture, Landscape Cover Index (LCI), Urban Streets

1. Introduction

Increasing Urbanization and population growth have brought attention to the urban microclimates in recent years. Urban Streets in Indian cities are growing rapidly which increases the heat stress, making microclimate-sensitive design important. The main consequence of the heat generation in the cities is due to air temperature difference between urban and rural area which is called as Urban Heat Island Phenomenon. Urban heat island elevated temperature can affect city's environment and quality of life of a human (1). The Study which relates microclimate and their modifying element in landscape architecture is gaining importance in urban streets (2). Microclimates are defined as the climatic conditions at the 'micro scale' on the earth's underlying surface which is considered from the neighbourhood scale and small community scales of several kilometres to the street canyons of a few meters (2). The Urban thermo physical and geometrical characteristics, anthropometric activities and heat source present in the urban areas are the factors which are responsible for the micro climate of the urban area (1).

Literature Review

Urban areas often become unnecessarily uncomfortable since urban climate generally ascribe little more importance in urban planning and design process (3). Generally urban area can generate more heat than rural areas which leads to increase in surface and air temperature (2). Increased building density, use of materials with inappropriate thermal properties, lack of green spaces is some of the factors which influence urban microclimate. So the main differences between the urban and rural environment microclimate conditions that affect human comfort results from differences in air temperature and wind speeds (4). Applying microclimate concepts in the landscape architectural design process can enhance a design's social, economic, and ecological sustainability. Microclimate analysis is necessary while designing landscape interventions, so small problems such as UHI can be avoided (5). According to some researches, Urban Canopy structures have modified local microclimate by shading direct shortwave radiation, thereby altering the surface energy balance and reducing surface temperature (6). Transpiration in urban green areas can effectively reduce the air temperature, increase the relative humidity, and improve the microclimate of the surrounding environment (7). The research aimed to evaluate how different landscape elements such as trees, shrubs, pavements and water body actively influence and modify the microclimate conditions in the urban streets. The study employs to determine how strategic planning and vegetation structure can be used as active tools to reduce heat stress and enhance micro climate comfort in urban stress supporting by field measurements and simulation based validation.

Problem Statement

The study aim is to understand how landscape architectural interventions (trees, shrubs, pavements, water body) can actively shape the microclimate in urban streets.

Objectives of the Study

1. To classify and collect information about how different landscape elements such as trees, paving materials, water features which influence microclimate of an Urban Street.

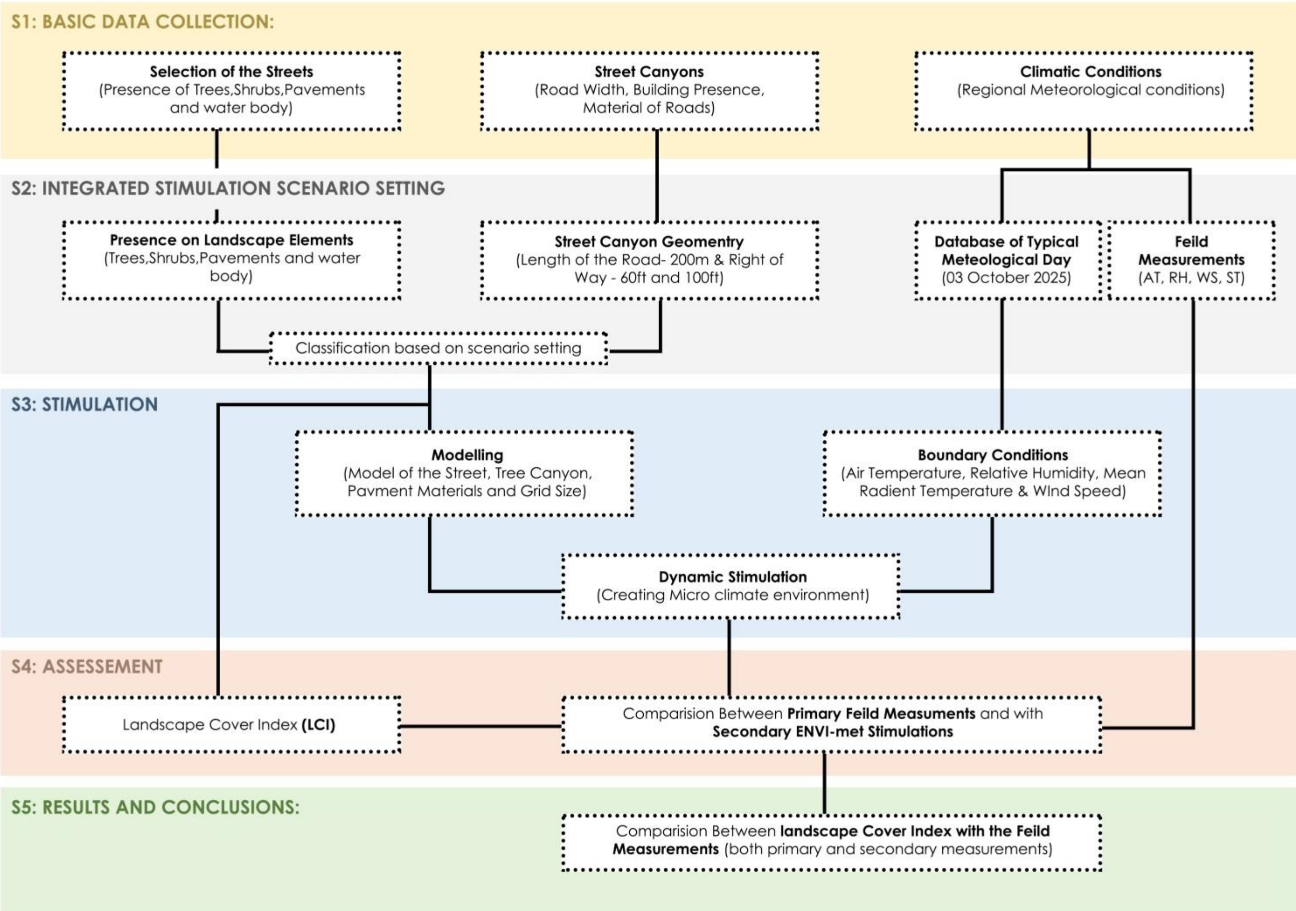
2. To analyse and evaluate the impact of different landscape elements which affect microclimate conditions by comparative analysis study between urban streets.

3. To develop and validate the analysis between the selected urban streets by using recorded field measurements and Envi-met model with corresponding to landscape elements.

Research Methodology

The methodology of the research aims to understand how different streets with different combination of landscape elements affect the micro climate of urban streets. Four streets in Vijayawada were selected which has different landscape elements combinations. The stretch of 200m was identified from the each of four streets which has a unique mix of these elements. Basic information such as are coverage of trees, shrubs, pavements and presence of water body was documented. Regional climatic conditions were also collected using field observations and secondary weather data to establish the baseline climate of the study area. 03th September 2025 was the day with stable climatic conditions was chosen for measuring field measurements which include air temperature, relative humidity, wind speed and surface temperature of landscape elements present in the four selected roads. Measurements are taken at the interval of 100m, at the three points in the street to capture micro climate variations. Then the four streets were modelled in Envi-met to recreate their physical and landscape conditions. Boundary conditions such as mean radiant temperature (MRT), potential air temperature, wind speed and relative humidity were applied and dynamic microclimate simulations were run for the same day. To analyse the influence of the landscape elements, a Landscape Cover Index (LCI) was developed based on the area and presence of the elements in the roads. Then the Field measurements and the Envi-met outputs were compared with the LCI to understand how landscape composition modifies the microclimate of the urban streets.

Figure 1: Methodology of the Research (Source: Author)



Selection of the Streets:

The selection of the streets for this research was based on the presence of the various landscape elements in different parts of Vijayawada. Four streets – ITI / Dr Ramesh Hospital Road, A.S Rama Rao Road, Eluru canal road and MG road were chosen as it has various landscape compositions of elements which allows a meaningful comparative microclimate analysis which makes it a representative example of a heavily vegetated urban street. ITI road which is also known as Dr Ramesh Hospital Road has large tree canopy but doesn’t have proper pavements and water body nearby. AS Rama Rao road which lacks in most landscape elements which make an ideal reference for understanding microclimates in minimal vegetated streets environments. Eluru canal road was selected because it has a water body of Eluru canal adjacent to the road. It doesn’t have dense tree canopy cover but has proper pavement and shrubs planted. The above mentioned three roads have the right of way of 60 feet. The MG road which has shrub lined pavements and a commercial character has the right of way of 100 feet. The difference of right of way between the roads was made intentionally to examine whether the spatial arrangement and width of the street influence its microclimatic behaviour.

Table 1: Comparative Distribution of Landscape Elements in the Four Selected Study Streets

Landscape Elements	ITI/ Dr Ramesh Hospital Road	AS Rama Rao Road	Eluru Canal Road	MG Road
Trees	Present	Absent	Absent	Absent
Shrubs	Absent	Absent	Present	Present
Pavements	Absent	Absent	Present	Present
Water body	Absent	Absent	Present	Absent

Landscape Cover Index (LCI)

To quantitatively evaluate the influence of landscape elements on the microclimate of the selected urban streets, Landscape Cover Index has been introduced. The LCI provides a numerical representation of the presence of various landscape elements in the streets such as tree, shrubs, pavements and water body. For tree canopy, shrub and pavements, the LCI has been calculated based on the area coverage percentage. These areas were then converted into percentage values relative to the total street segment under study. Water bodies were treated as binary variable due to their distinct microclimate impact. If the water body is present the value is assigned as 1 and if it's not present, the value assigned as 0. Based on these components, LCI was calculated as:

$$LCI = \frac{Tree\ canopy}{100} + \frac{Shrub\ cover}{100} + \frac{Pavement\ area}{100} + Water\ Body\ Presence$$

This formula makes meaningful comparisons between streets with various physical characteristics of the street. The percentage values of tree canopy, shrub layer, and pavement cover were divided by 100 to derive ratio values ranging from 0 to 1, which were then summed to obtain the overall Landscape Cover Index (LCI) for each road. By calculating the landscape cover index for the selected roads, the values are shown in the table below.

Table 2: Landscape Cover Index (LCI) calculation for the selected Roads

Name of the Road	Tree Canopy	Shrub Cover	Pavement Cover	Water body presence	LCI
ITI/ Dr Ramesh Hospital Road	23%	0%	0%	0	0.23
AS Rama Rao Road	4%	0%	0%	0	0.04
Eluru Canal Road	0%	10%	23%	1	1.33
MG Road	0%	9%	14%	0	0.23

The Landscape cover index indicates that Eluru canal road has the highest LCI value due to the combined presence of shrub cover, pavement presence and a water body. ITI road and MG road has moderate LCI values, supporting mainly by dense trees but lacking by presence of water body. A S

Rama Rao road has the lowest LCI due to its hardened urban surface condition, likely resulting in higher surface temperature and weaker climatic moderation among all four roads.

Field Measurements:

For the selected four roads in Vijayawada, the field measurements were conducted and documented. Three instruments were used to do the field documentation. Tempnote sensors were used to record the air temperature and relative humidity of the selected roads. Anemometer was used to record the wind speed and infrared thermometer was used to record the surface temperature of the various landscape elements surface temperatures. Air temperature and relative humidity were measured in the height of 1.5 m from the ground level and wind speed was recorded at 2 m above the ground level. All observations were recorded at 12:00 p.m. on 03 September 2025 to maintain consistency across the study. Each road was divided into three recoding points at 0 m , 100 m, 200 m, covering a uniform stretch of 200m to ensure comparable spatial data.

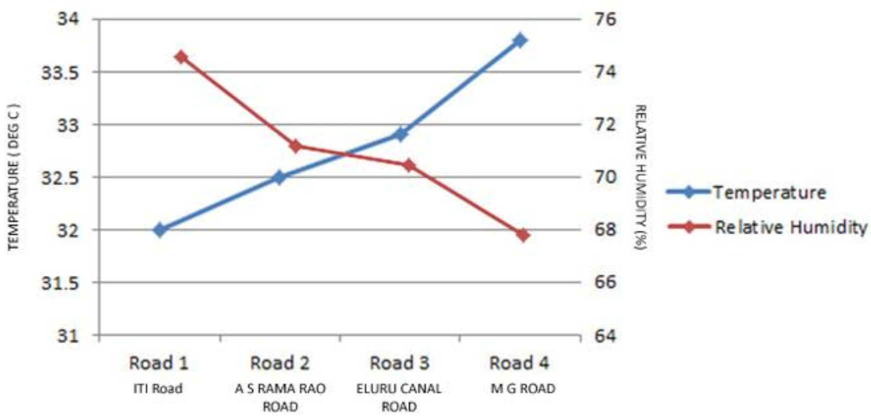
Table 3: Final average field measurements records of the selected roads

	ITI/ Dr Ramesh Hospital Road	AS Rama Rao Road	Eluru Canal Road	MG Road
Air Temperature (°C)	32	32.5	32.9	33.8
Relative Humidity (%)	74.6	71.2	70.5	67.8
Precipitation (mm)	424	424	424	424
Surface temperature (°C)				
Road surface – exposed (°C)	48.3	114.4	86.2	68.4
Road surface – shaded (°C)	40.5	82.8	56.4	57.5
Drainage / Sand / Pavement (°C)	44	102.8	62.5	55.4
Wind Speed				
Wind Speed – Maximum (m/s)	2.45	2.24	2.76	4.69
Wind Speed – Minimum (m/s)	0.15	0.02	0.07	0.02

Data Interpretation of the Field Measurements:

(a) Temperature and Relative Humidity:

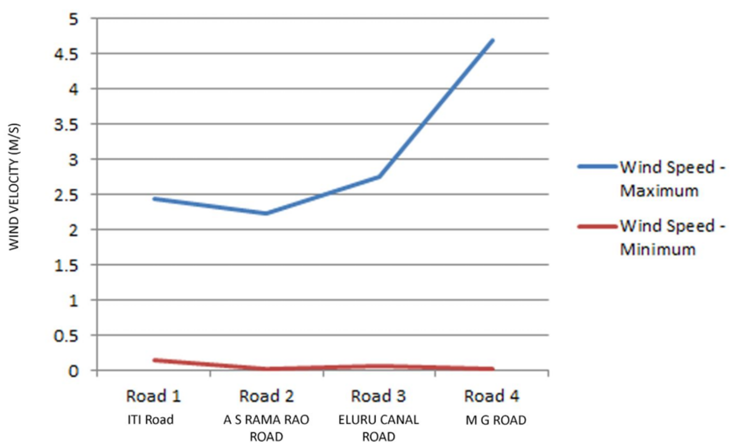
Figure 2: Temperature and Relative Humidity for the selected roads



The result shows an inverse relationship between air temperature and relative humidity across the four selected roads. Spatial arrangement indicates microclimatic variability as MG road has higher air temperature record but lower humidity. ITI road which has larger canopy trees has less air temperature but higher humidity which indicates that presence of trees can actually change a microclimate of a region. These conditions suggest implications for thermal comfort which emphasize the need of landscape interventions to migrate the urban heat stress.

(b) Wind Speed (maximum and minimum):

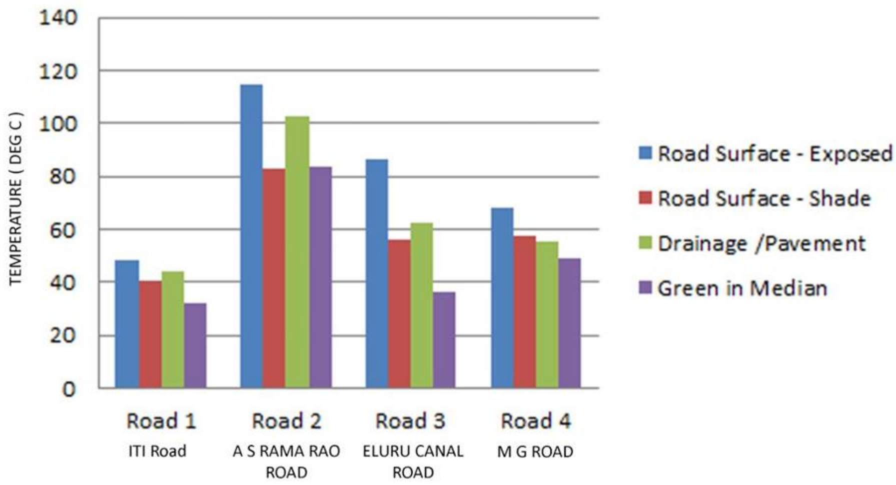
Figure 3: Wind Speed (maximum and minimum)



Maximum wind velocity is recorded on the MG road which has the right of way of 100 feet, indicating the influence of street width and built form. Minimum wind velocity is absorbed on AS Rama road and ITI Road which indicates that the built form and presence of large canopy trees can reduce the wind speed.

(c) Surface Temperature:

Figure 4: Surface temperature of various selected roads

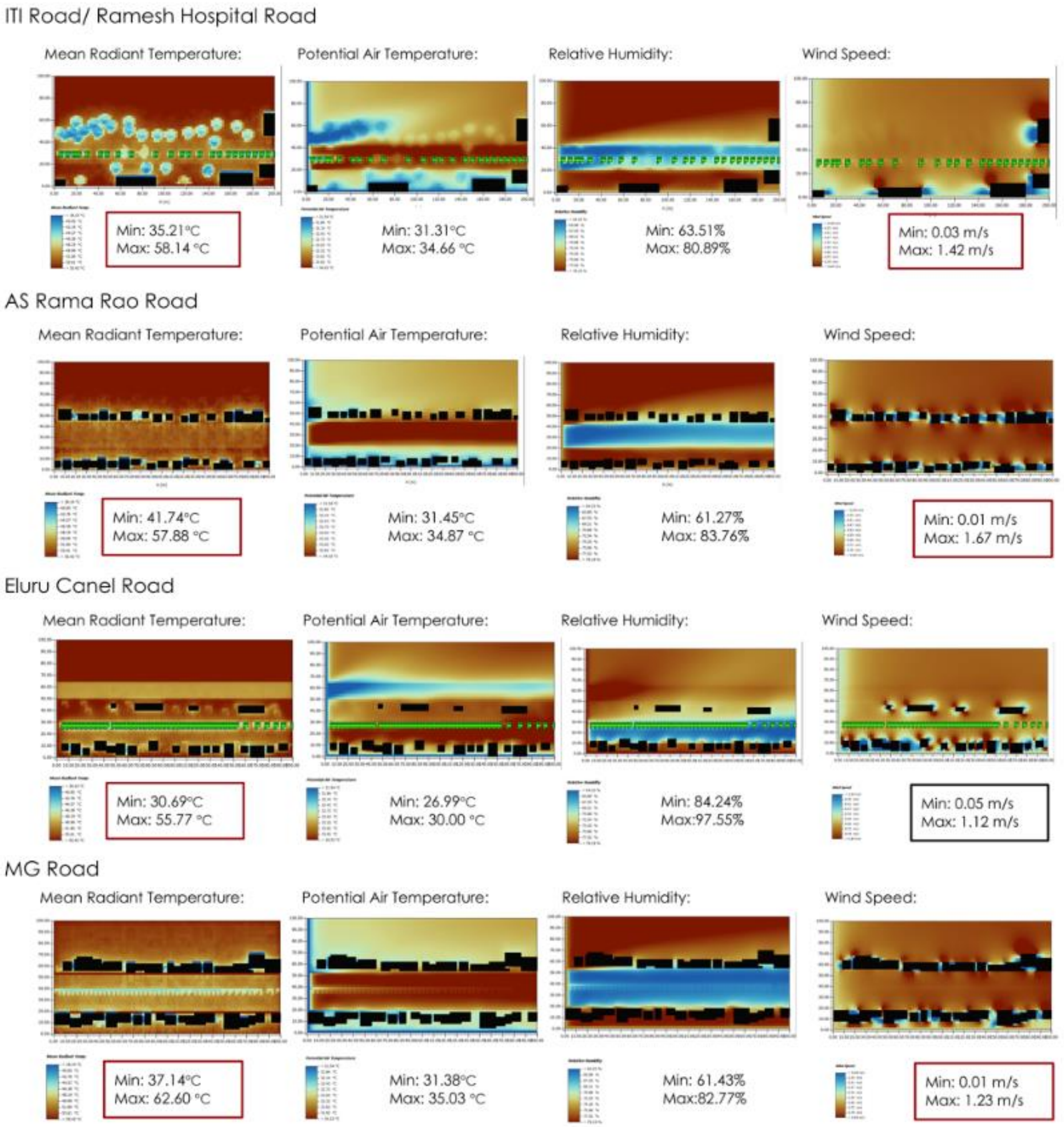


Across the four selected streets, AS Rama Rao road shows the high surface temperature due to presence of exposed hardscapes, dense build-up surroundings and absence of tree cover. ITI road remains cooler because it was supported by tree canopy presence which reduces heat absorption.MG road shows moderate conditions in surface temperature due to presence of balance mix of vegetation and traffic flow. In the overall view, green medians consistently remained cooler in all the selected streets.

Envi-met Simulation:

After completing the recording of the field measurements for the selected four streets, using Envi-met software, further analysis has been made by modelling the landscape features in the software and running stimulation for the selected day and time. Envi-met was used to compute key environmental parameters such as Mean Radiant Temperature (MRT), Potential air temperature, Relative humidity and wind speed. The stimulation followed the same method of recording field measurements, ensuring consistency in data comparison. For every road, three reference points were made at the interval of 100m in the considered 200m stretch road of the study area. Once the stimulations have been done, the final data was calculated as average values to derive a representative microclimate profile for each street. The combined use of real-time field measurement and Envi-met simulation strengthened the study by allowing cross-validation of findings.

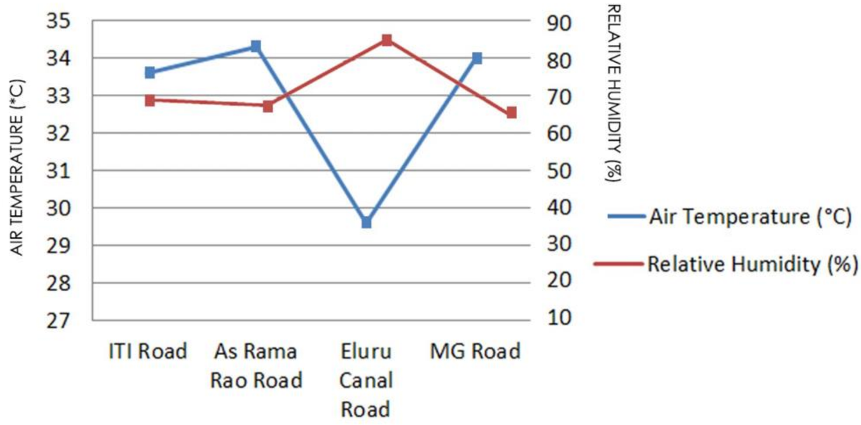
Figure 5: Simulated Microclimate Profiles of the Four Study Roads Using Envi-met Software



Data Interpretation of the Envi-met Simulation:

(a) Temperature and Relative Humidity:

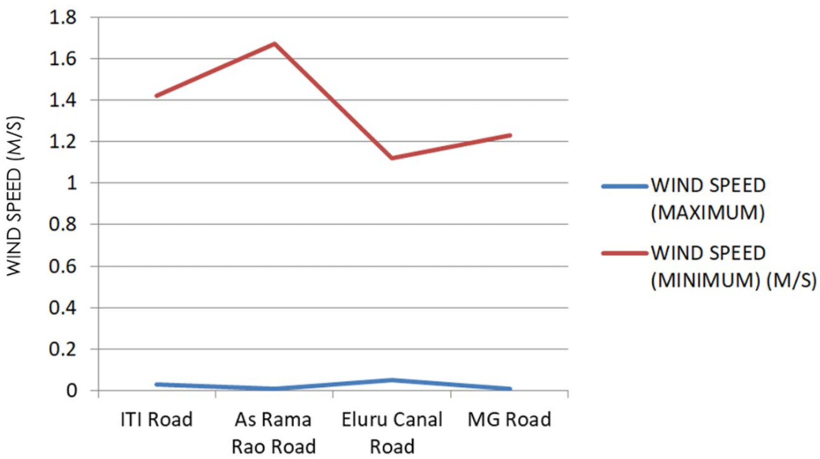
Figure 6: Temperature and Relative Humidity for the selected roads using Envi-met



The Eluru canal road emerges as the distinct cooling pocked due to the impact of the presence of water body nearby. The Eluru canal has less air temperature and high relative humidity while comparing with other roads. AS Rama Rao Road and M.G. Road record higher temperature due to the presence of dense built-up areas and the limited presence of vegetation. The comparison clearly states that streets which have more vegetation and water features experience cooler environment, more humid environment. Meanwhile higher urban corridors with more built up areas with limited green cover record hotter and drier conditions.

(b) Wind Speed (maximum and minimum):

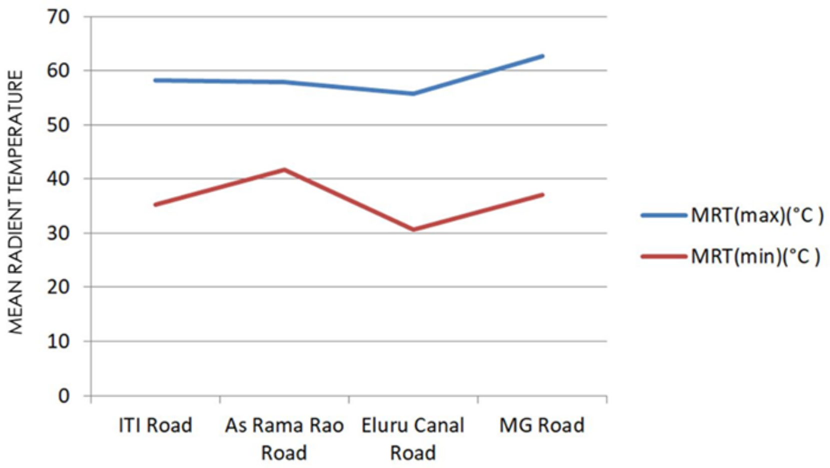
Figure 7: Wind Speed (maximum and minimum) for the selected roads using Envi-met



AS Rama Rao road records the maximum highest winds speed in simulation which reflects its open street geometry and air circulation potential. Eluru canal road shows low maximum wind speed while comparing it to ITI road and MG road. This variation in wind speed across the streets states that the street orientation shape microclimate behaviour. Overall streets with open layout and minimum tree cover records high wind speed and streets with dense build up areas show low wind speed.

(c) Mean Radiant Temperature (maximum and minimum):

Figure 8: Mean Radiant Temperature (maximum and minimum) for the selected roads using Envi-met



The Mean Radiant Temperature (MRT) is defined as the "the temperature of a uniform, the black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure" (8). The MRT analysis of the four roads reveals the spatial variation in radiant heat exposure which is shaped by street geometry, vegetation cover and surface materials. MG road has the highest MRT due to high spatial width of the road and the less vegetation cover while Eluru canal road shows lowest MRT due to presence of water body nearby. AS Rama Rao road shows elevated minimum MRT which reflects intense solar exposure and minimal vegetation cover. As an overall conclusion, streets with stronger vegetation presence shows low radiant temperature while highlights the importance of landscape elements in urban microclimate.

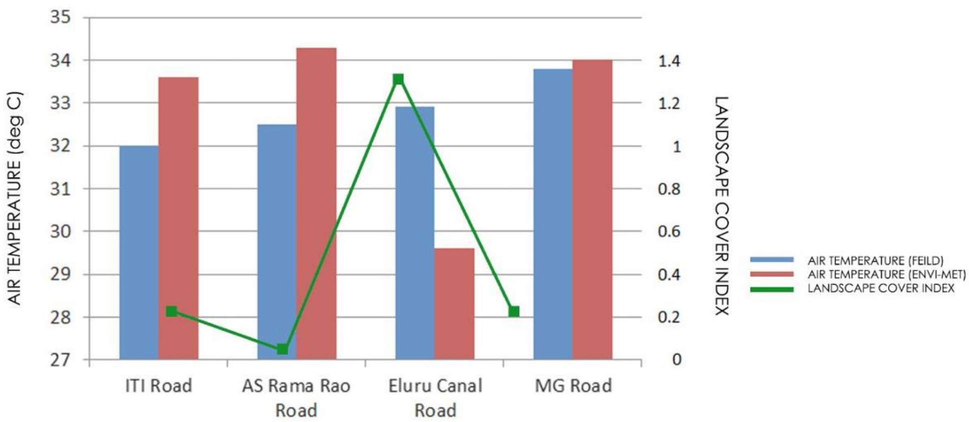
Key Comparison between Field Measurements and Envi-met Simulation:

The Comparison between field measurements and Envi-met simulations reveals a consistent pattern in recorded air temperature and humidity across the selected four streets. Considering Air temperature and Relative humidity, both datasets identified MG road as the hottest as air temperature was recorded high. Due to presence of extensive paved area and reduced green cover which restrict cooling process, is responsible for the record of high temperature. Eluru canal road emerged as the coolest and most humid environment, validating the influence of presence of canal adjacent to the road. As an overall analysis indicates that Envi-met generally underestimates temperature by 1°C - 2°C but aligns closely with the spatial trends observed in the field. On the comparative analysis of the wind speeds across the selected roads, reveals a consistent alignment in identifying the spatial patterns of wind distribution across the selected streets. In both datasets which clearly indicates that MG road exhibits the high wind speed due to its wide spatial arrangement and less vegetation. AS Rama Rao road and Eluru canal road show reduced air flow due to presence of enclosed street canyons, dense vegetation and built form constraints. However Envi-met doesn't consider traffic induced airflow and simplifies turbulence, wind speed gets deviations. This reinforces the importance of calibrating simulation outputs with the field measurements to enhance the accuracy of the results. The comparative analysis between the surface temperature in field measurements and mean gradient temperature in Envi-met simulations reveals the relationship between the landscape elements and the surface heat retention experienced by the people. In A S Rama Rao road both surface temperature and mean radiant temperature are elevated which reinforces that limited vegetation, dense built surfaces and high pavements ratios intensify heat accumulation. In contrast to A S Rama Rao road, streets such as ITI road and MG road demonstrates lower surface temperature in both the datasets which attributes the presence of green medians, continuous shade and tree canopy coverage. The difference between the field measurements and simulated results highlights the strong cooling influence of vegetation and shading elements

Interpreting between Landscape Cover Index and Field Measurements

(a) Air Temperature

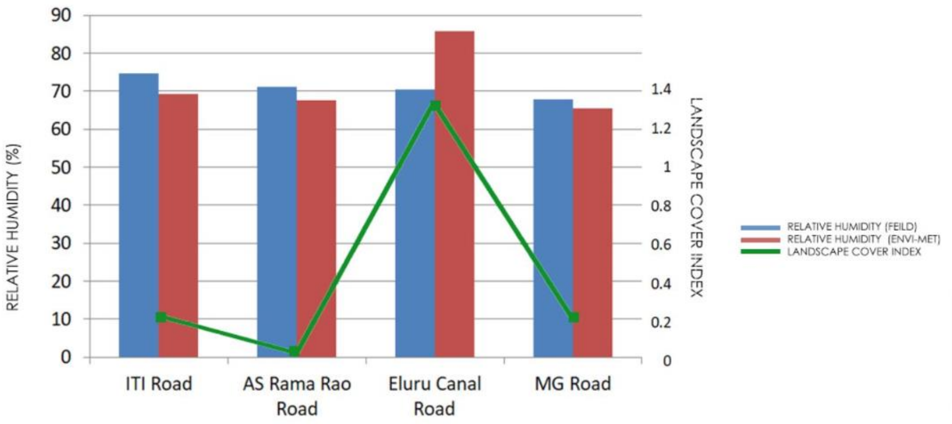
Figure 9: Relationship Between Landscape Cover Index and Air Temperature (Field & ENVI-met)



The comparison of landscape cover index with air temperature patterns in the four streets demonstrates the strong influence of vegetation and water body presence on microclimate cooling. Eluru canal road which has the highest LCI of 1.33 due to presence of a water body and continuous shrub cover, records the lowest air temperature. This highlights the effective cooling contribution of water body and green shrub greenery. A S Rama Rao rod which has low LCI value of 0.04 has almost no vegetation, shows high temperature. Both the datasets confirms that higher landscape cover whether through trees, shrubs or water bodies consistently enhances the microclimate and improves thermal comfort within the urban streets.

(b) Relative Humidity

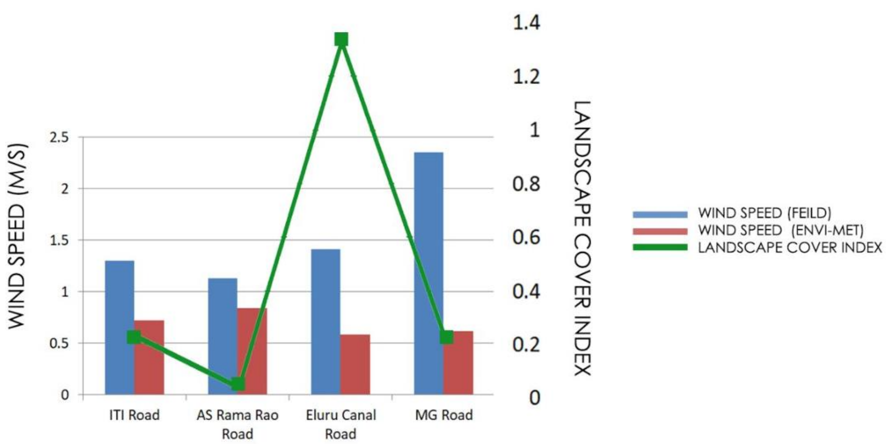
Figure 10: Relationship Between Landscape Cover Index and Relative Humidity (Field & ENVI-met)



The correlation between moisture levels and the presence of vegetation and water bodies are show by the relationship between LCI and relative humidity across the four streets. In Eluru canal road which has LCI value of 1.33 has highest humidity levels due to presence of water body. This highlights how water surfaces enhance the atmospheric moisture through evaporation which contributes to the cooler and more confortable microclimate conditions. Due to lack of vegetation in AS Rama Rao Street, it’s drier than other streets. ITI road and MG road, with the moderate LCI values, shows intermediate humidity levels, reaffirming that even moderate vegetation contributes to increased air moisture. As an overall analysis which confirms that the streets with higher green or water body supports greater humidity which improves thermal comfort and microclimate stability.

(b) Wind Speed

Figure 11: Relationship Between Landscape Cover Index and Wind Speed (Field & ENVI-met)



The variation in wind speed across the four selected roads shows the strong relationship between Landscape Cover Index and street geometry. MG road which has the moderate LCI of 0.23 shows the highest wind speed which reflects the wider right of way and few physical obstructions that allow stronger wind penetration. In Eluru canal road which has the highest LCI records average wind speed that indicates that surrounding greenery and built edges obstruct and stabilize airflow. Streets with lower LCI consistently show reduced wind movements in both field measurements and simulation data in A S Rama Rao road. As an overall comparison highlights how urban morphology and landscape elements influence air circulation and the microclimatic potential of urban streets.

Conclusion

As an overall conclusion of the analysis of the research, streets with higher LCI, such as Eluru canal road which has high continues vegetation and presence of water body exhibits a cooling effect of nearly 4°C - 5°C compared to highly build up street such as A S Rama Rao road which demonstrates the thermal efficiency of green and blue infrastructure. The combined shading, evapotranspiration, and evaporative cooling from trees, shrubs and water body reduce the heat gain and lower ambient temperatures. Moisture retention also varies with Eluru canal road shows 12%-18% higher relative humidity while AS Rama Rao road is comparatively dry at around 67% which highlights the role of vegetation and water body in enriching and improving comfort. MG road which has right of way of 100 feet shows higher wind speeds whereas Eluru canal road shows lower wind speed due to presence of dense vegetative edges and build up spaces. This indicates that the strategically spaces trees and open airflow corridors enhances ventilation where compact structures of green cover and build up spaces reduces the speed of the wind which collectively shape the microclimate performance of urban streets. To make a quantitative correlation between landscape cover and micro climate, this study uses simple rate of change method to calculate the difference in change. By analysing changes in air temperature and relative humidity across the streets with varying LCI values, the research derives values measurable coefficients that how microclimate responds to the landscape elements. The formula which the research used for empirical basis of the findings is

$$Change\ in\ AIr\ Temperature\ per\ 0.1\ LCI = (Tlow\ LCI - Thigh\ LCI)/(LCIhigh - LCIlow/0.1$$

$$Change\ in\ Humidity\ per\ 0.1\ LCI = (RH\ high\ LCI - RH\ low\ LCI)\ /\ (LCI\ high - LCI\ low)/0.1$$

By calculating the change in air temperature and relative humidity per 0.1 Landscape cover index, the research concludes that for every 0.1 increase in landscape cover index corresponds to an average 0.8 °C – 1 °C decrease in air temperature and 2% - 3% increase in relative humidity.

Future Scope of the Research

The scope of the research can be expanded through long term temporal analysis, moving beyond a single day analysis to annual datasets. So we can calculate the average findings of the field measurements. This approach would allow a deeper understanding of how landscape cover interacts with the varying climatic conditions. Additionally, this research incorporates all the landscape elements such as trees, shrubs, pavements and water body as a unified system rather than isolated element. In future this combined assessment would enable a more comprehensive evaluation how various elements collectively influence temperature, humidity, wind movement, and overall microclimatic performance in urban streetscapes.

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