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Ilaria Pigliautile · Cristina Piselli ·
Hirushie Pramuditha Karunathilake · Claudia Fabiani *Editors*

Urban Resilience, Livability, and Climate Adaptation

Health, Environmental Dynamics, and Societal Well-Being

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A culmination of selected research papers from the International Conference on Health and Environmental Resilience and Livability in Cities (HERL)—2nd Edition—University of Perugia 2023.

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Preface

Enhancing the resilience and livability of urban spaces while adapting to the growing challenges of climate change has become a topic of global concern in recent times. The urban environments face severe challenges due to the growing population and mass migration, deteriorating infrastructure, changing climatic and weather patterns, and economic stresses. To achieve the long-term vision for climate change mitigation and adaptation, cities' adaptation and resilience are requirements that cannot be further postponed. Indeed, environmental challenges associated with climate change, e.g., heat waves, urban overheating, and air pollution, negatively impact human well-being and health in indoor and outdoor environments. The specific microclimate of cities is characterized by the phenomenon known as the Urban Heat Island (UHI) which further exacerbates the need for building energy use to maintain comfortable indoor conditions thus contributing to the same climate change. More specifically, UHI stands for an urbanized area that experiences significantly warmer temperatures than the rural surroundings, due to the presence of artificial infrastructures—more than natural ones—and human activities.

UHIs are where the majority of our buildings are located, which account for about 36% of total global energy use and the largest contribution of global GHG emissions. Moreover, about 68% of the world population is expected to live in cities by 2050, and the highest share of this future urban population growth will occur in the global south. Therefore, cities are the major contributors to climate change, thus providing fertile ground for the implementation of mitigation and adaptation strategies. In particular, cities in developing countries, which are now the hotspots of urban growth, have a high potential for transformation. We have to rethink the design and planning of our smart cities to take action in efforts to face the harmful effects of and to be resilient to climate change, UHI, and the associated phenomena from multiple frontiers.

However, the analysis and achievement of health, well-being, and livability in our cities have to be not only dependent on the development of technical solutions and innovations. We should also pay the needed attention to the social and environmental dimensions of urban development and sustainability. Research needs to place human needs and experiences at the center of urban development, also through people and community engagement. Health and well-being require a focus on environmental sustainability and climate resilience to ensure that cities are livable and safe for all residents, even in the face of climate change. Furthermore, research needs to be contextualized to the local boundary conditions to meet the specific needs in each context. To this aim, we should develop and take advantage of methods and innovations that are replicable, but also applicable from a local perspective for the analysis and design of tailored and human-centric mitigation strategies. Therefore, with this book, we hope to foster a productive multi-disciplinary discussion that may identify which are the most urgent research lines toward sustainable, efficient, healthy, and just cities.

In this panorama, the book offers valuable insights into the above-mentioned debate based on a range of applications and case studies presented in the key papers from the 2nd International Conference on Health & Environmental Resilience and Livability in Cities (HERL) of IEREK. This book fosters a productive multi-disciplinary discussion that may identify which are the most urgent research lines toward sustainable, efficient, healthy, and just cities. It adds to this topic by collecting perspectives from various countries across the world. More in detail, the book is composed of three parts. Part One is on "Urban Green Infrastructure and Climate Mitigation", containing five chapters. Chapter "Effects of Street Tree Configuration on Urban Heat Island Mitigation" focuses on the effect of street tree configuration on UHI mitigation, and Chapter "The Butterfly Effect Toward a Nature Smart Society" addresses the development of a nature-smart society. Chapter "Spatial Relationship Between Diet Diversity, the Food Environment and Transport: A Case Study in South Africa" presents a South African case study on the spatial relationships between food, environment, and transport, while Chapter "Spatial Analysis of Noise Contour Maps Based on Traffic Speed Using Predictor-LimA Software" discusses spatial analysis of noise contour maps based on traffic speed. Chapter "Critical Factors Affecting the Design and Use of Elevated Urban Spaces: The Sky Garden, London" explores the critical factors affecting the design and use of elevated urban spaces.

Part Two consisting of six chapters, explores a different dimension, centering on the "Human Experience and Well-Being in Urban Environments". Chapters "Assessment of the Impact of the Office Environment on Productivity Based on Employees' Satisfaction" and "Impact of Streetscapes on Anxiety: A Physiological Evidence" discuss how office environments and cityscapes have an effect on the satisfaction and anxiety of individuals, respectively. Chapters "Envisioning Cities of the Future: A Malaysia Youth Perspective Using Concept Mapping" and "Topia—The City, the Livable Place to Be" focus on future cities and the design factors that affect their use and livability. Chapter "Evaluating Daylighting Performance Within Existing Schools Expansion in Egypt" analyzes the daylighting performance of school buildings, whereas Chapter "Revisiting Scientific Theories, Towards Human Well-Being-Oriented Built Environments" more generally discusses the scientific theories on human well-being in the built environments.

Part Three and final part is on the "Adaptation, Livelihood, and Social Dynamics", and comprises six more chapters. The part discusses how communities and social groups need to adapt to climate-resilient, healthy, and livable environments. Chapter "Assessing Community Adaptive Capacity for Climate Resilient Development: A Complex Adaptive Systems Case Study Analysis of Mathare Valley, Nairobi, Kenya" is on the adaptive capacity of communities for climate-resilient development. Chapter "Assessing Street Vendors Liveability—A Comparative Study in Hosur and Vellore" focuses on street vendors' livability, while Chapter "Urban Refugees' Impact on the Urban Fabric Form of the City Structure: The Case Study of Urban Syrian Refugees in the Sixth of October City" assesses the impact of refugees on the urban fabric form. Chapter "Restorative Streets for Healthy Cities: A Critical Review Dissenting the Conventional Narrative of Restorative Environments" discusses the narratives on restorative environments for healthy cities. The final Chapters "Evaluating Users' Satisfaction on Urban Railway Based on Service Quality Model: The Study on KLIA Express in Malaysia" and "Sport as a Tool for the Development of Healthy and Sustainable Cities: A Strategic Documentation Review" analyze tourist satisfaction based on transport systems and the means of using sport as a tool for healthy and sustainable cities, respectively.

Overall, all of these contributions focus on different aspects of the development of livable, healthy, and resilient urban environments, where long-term planning and effective decision-making based on scientific evidence are needed to ensure that global urban centers can successfully withstand the pressures of the present. Further, it is highlighted that urban planning and management need to be a participatory and inclusive process where the needs and challenges of different stakeholder groups need to be taken into account. The content in the individual chapters explores specific case studies spanning different geographic locations, social contexts, and climatic conditions.

All in all, this volume is meant to provide a means for sharing knowledge, experiences, and ideas on how to build sustainable, resilient, and livable cities in the face of climate change. It highlights the latest research and practices in the field by high-profile scientists, policymakers, and practitioners who share their insights and experiences on the conference themes. Therefore, we believe that it will provide a valuable resource for academics, practitioners, policymakers, and other stakeholders interested in the intersection of smart cities, health, and well-being in the climate change era. We believe that by working together and sharing knowledge, we can build cities that are not only smart but also healthy, resilient, and livable for all residents.

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Introduction

In the relentless march of time, the entwined forces of climate change and escalating urbanization pose formidable threats to the very essence of cities—their livability. As humanity confronts the challenges of an evolving world, the focal point of this discourse rests on the shoulders of urban resilience, a linchpin in the quest to construct a livable future for generations to come. The urgent imperative to grapple with these challenges has resulted in a paradigm shift in the realm of urban development, necessitating a concerted focus on adaptation and resilience.

Cities worldwide face complex challenges, including environmental degradation, continuous population growth due to mass migrations, aging infrastructure, and unpredictable climate patterns. The urgency to tackle these issues head-on is underscored by the imperativeness of urban adaptation and resilience becoming the guiding principles in the evolution of urban landscapes. Within urban environments, which pulsate as hubs of human activities and diversity, a dual role unfolds. On the one hand, these environments stand as significant contributors to the anthropogenic factors influencing climate change. Simultaneously, they are highly vulnerable to the effects of climate change, facing issues like intense heat waves and harmful air pollution. This affects the well-being of residents both indoors and in the city. The Urban Heat Island (UHI) phenomenon emerges as a poignant illustration, characterized by markedly elevated temperatures in urbanized areas. This not only disrupts the comfort and well-being of citizens but also casts a long shadow over global energy consumption and greenhouse gas emissions.

With cities currently accounting for a staggering 36% of global energy usage, the urgency to address climate-related issues is acutely apparent. As projections foresee 68% of the world's population dwelling in urban areas by 2050, the imperative for decisive action becomes ever more pressing. It is within the expanding urban landscapes of developing countries, undergoing unprecedented expansion, that the potential for transformative actions becomes ripe. To meet the challenges posed by climate change, the UHI phenomenon, and their associated harms, it is paramount to transcend the traditional boundaries of smart city design and planning. This transcendence, however, cannot be confined to the realm of technical innovations alone. A holistic approach is indispensable, one that directs its focus not only on the technological but also on the social and environmental dimensions of urban development. In this intricate dance for the future of cities, engaging communities and relevant stakeholders becomes not just a consideration but a cornerstone. Prioritizing environmental sustainability emerges as a pivotal step in the quest for cities that defy the odds—remaining not just habitable but safe for all inhabitants, resilient in the face of the ever-mounting challenges posed by a changing climate.

In the face of these complex challenges worldwide, this book serves as a guide, offering valuable insights from the 2nd International Conference on Health & Environmental Resilience and Livability in Cities (HERL) organized by IEREK. The book is divided into three parts, exploring essential themes for creating cities that are sustainable, efficient, healthy, and equitable.

The initial part, titled "Urban Green Infrastructure and Climate Mitigation", conducts a comprehensive examination of nature's potential in shaping dynamic urban spaces amidst the continually changing climate. This segment delves into the complexities of microclimate analysis and acoustic quality assessments, providing a nuanced understanding of how nature can be a fundamental element in enhancing urban resilience.

A significant emphasis is placed on microclimate analysis, delving into the detailed climatic conditions of specific urban areas. This exploration aims to unravel the localized impacts of urban green infrastructure, addressing factors such as temperature variations, wind patterns, and moisture levels. The goal is to illustrate how strategically incorporating green elements can serve as a moderator for climate conditions. This analytical depth is particularly valuable for urban planners, offering insights that go beyond generic solutions to tailor interventions that align with the distinctive challenges presented by individual urban environments. Simultaneously, the part extends its exploration to acoustic quality assessment, recognizing the often-overlooked aspect of soundscapes in urban life. Given the prevalent issue of noise pollution in urban areas, this investigation meticulously examines how the integration of green spaces can influence acoustic landscapes. These green elements serve as natural buffers, absorbing and mitigating sound. This nuanced approach acknowledges that the vibrancy of urban spaces is not solely visual but also extends to the auditory experience. It underscores the importance of fostering a harmonious soundscape for the well-being of urban dwellers.

Part Two, "Human Experience and Well-Being in Urban Environments", marks a definitive shift toward a human-centric paradigm in urban planning and design. Here, the spotlight is directed at cultivating environments that advocate the well-being of urban dwellers. The part becomes a proponent of salutogenic design, a meticulous approach aimed at crafting spaces that not only provide to the functional needs of inhabitants but actively contribute to their health, happiness, and overall well-being.

This part goes beyond the traditional architectural considerations and zoning regulations. It delves into the psychological and physiological dimensions of human interaction with the urban environment. Salutogenic environments prioritize health promotion rather than simply preventing illness, recognizing the profound impact that surroundings have on mental and physical wellness. Whether within the sheltered confines of buildings or amidst the expansive urban sprawl, the emphasis is on creating spaces that nurture a sense of community, encourage physical activity, and provide moments of respite. This part explores design interventions that enhance air and water quality, incorporate green spaces, and promote accessibility to amenities that contribute to a healthier lifestyle. The importance of natural light, greenery, and communal areas takes center stage, acknowledging their pivotal role in fostering not just aesthetically pleasing spaces but also those that actively contribute to the holistic well-being of residents.

Part Three and final part, "Adaptation, Livelihood, and Social Dynamics", the focus turns toward a comprehensive investigation into the adaptive capacities of diverse urban communities and stakeholders. This part becomes a nuanced exploration of the intricate social fabric that weaves through city life, acknowledging the pivotal roles played by individuals ranging from street vendors and refugees to tourists. Each group, although seemingly peripheral, emerges as a dynamic force shaping the very essence of the cityscape.

The investigation delves into the adaptive strategies employed by these diverse communities in response to the multifaceted challenges posed by urban living. From the resourcefulness of street vendors navigating economic uncertainties to the resilience of refugees seeking stability in unfamiliar urban environments, each narrative unfolds as a thread in the intricate tapestry of urban life. Moreover, the transient yet impactful presence of tourists introduces a dynamic layer, influencing not only the economic landscape but also shaping the cultural and social dynamics of the city. This part recognizes that the resilience of these communities is not merely a passive response but a proactive force influencing the city's ability to navigate challenges. Their adaptive capacities become a linchpin, a critical element for the city's overall ability to weather the storm of urban complexities. By understanding and harnessing the adaptive capabilities of these diverse groups, urban planners and policymakers can cultivate more inclusive and responsive urban environments.

This collection serves as a catalyst, igniting a transformative multi-disciplinary dialogue that transcends traditional boundaries in urban development. It acts as a crucible where urgent research directions are not only identified but also passionately pursued, aiming to sculpt urban environments that are sustainable, efficient, healthy, and equitable. The diverse perspectives encapsulated in this compilation create a mosaic of global insights, contributing significantly to the ongoing worldwide conversation on the imperative task of building urban spaces that can withstand current challenges while evolving into resilient fortresses of health and livability for all inhabitants.

The significance of this collection lies in its ability to foster collaboration and exchange of knowledge across borders. It recognizes that solutions for urban challenges cannot be one-size-fits-all but must be crafted through a lens that incorporates the varied experiences and contexts of different regions. As readers delve into the subsequent chapters, they embark on a journey that goes beyond geographical confines. This is a journey where shared knowledge and experiences become the driving force, propelling the vision of cities that surpass the conventional definitions of smartness and habitability. The narrative emphasizes not only the need for cities to be intelligent in their design but resilient in the face of a changing climate and adaptable to the evolving urban landscape. The aspiration is not merely to create habitable spaces but to cultivate environments that actively contribute to the health and well-being of all residents. It signifies a commitment to crafting urban spaces that are inclusive, responsive, and considerate of the diverse needs of the global population. In essence, this collection emerges as a beacon, guiding the way toward a future where cities transcend mere functionality, evolving into thriving hubs that embody the ideals of resilience, health, and livability for every individual within their bounds.

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Contents

Adaptation, Livelihood, and Social Dynamics

Urban Green Infrastructure and Climate Mitigation

Effects of Street Tree Configuration on Urban Heat Island Mitigation

Sachini Jayasinghe, Varuni Jayasooriya, and Sandun Dassanayake

Abstract

Urban Heat Island is increasingly affecting cities in developing countries with rapid urbanization. Uncomfortable thermal environments are present in the urban streets of tropical towns due to the need for more urban vegetation. A well-planned street tree configuration can positively influence the thermal environment within metropolitan regions. This study intends to explore the tree configuration impacts on the roadside thermal environment in urban canyons of selected sites in Colombo, Sri Lanka. Field data was collected to identify street canyons' heat patterns considering existing roadside greenery configurations. Suitable tree-planting scenarios to regulate the microclimatic conditions were also investigated. Three different roadside tree configurations in Colombo and its suburbs were considered. Climate data, tree, and surrounding attribute data were measured. The 3D microclimate simulation software ENVI-met Lite version was used to identify heat distribution patterns and carry out scenario simulations. The results indicated that the heat distribution in the roadside area is reduced when the tree configuration of continuous tree rows with densely foliated vegetation is applied.

Keywords

Tree configurations · Street canyons · Thermal environment · Urban Heat Island · ENVI-met

1 Introduction

Accelerating urbanization in developing tropical cities intensifies the undesirable microclimatic and environmental consequences, like the Urban Heat Island (UHI) effect, lowering the quality of life for urban residents. The causes that increase UHI effects include low-albedo and dark-hued urban surfaces, paved and impermeable pavements, and road surfaces (Senevirathne et al., 2021). The increased temperature situation is elevated in a tropical country such as Sri Lanka due to year-round sunlight; solar radiation is high under cloudless sky conditions, and, due to the proximity to the equator, solar elevation is consistently high as well (Halwatura & Ranasinghe & Halwatura, 2012). Most of the asphalt-paved roadways in Colombo, Sri Lanka, a tropical and humid city, are directly exposed to the sun, promoting more significant absorption of solar radiation and heat discharge at night.

Moreover, the roadside vegetation scarcity and sparse urban vegetation configurations (Aram et al., 2019) alter the urban morphology affecting wind movement, shading effects, and compactness, also increasing UHI effects. Recent studies (Aram et al., 2019; Srivanit & Jareemit, 2020) show the potential of roadside vegetation cover and the configuration of trees in mitigating the UHI effect and drastic thermal environment alterations. Remote sensing research has demonstrated that different tree configurations affect the thermal environment in a significant way. According to Aram et al. (2019), clustered tree configuration had improved cooling effects compared to dispersed tree configuration. In Bangalore, India, sections of streets

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abundant with trees had an average ambient air temperature of 5.6 °C lower than in other segments (Vailshery et al., 2013). Based on a study conducted in a subtropical region, the air temperatures on tree-aligned roadways and boulevards were 1–2.5 °C lower during the day's warmest hours (15:00 h) than on non-vegetated roads (Shashua-Bar & Hoffman, 2004). The temperature-mitigating benefits of varied tree coverage rates on outdoor thermal conditions also have been investigated in several other studies (Klemm et al., 2015).

Many researchers have used the microclimate model ENVI-met to investigate the thermal environment and microclimate. Among various computational modeling software and Energy Balance Models (EBM) such as RayMan, TEB-Veg, SOLWEIG, and green-CTTC, and Computational Fluid Dynamic (CFD)-based models like OpenFOAM, FLUENT, and PHOENICS, ENVI-met is considered to be one of the most effective CFD-based holistic 3D microclimate models used vastly in vegetation thermal effect simulation studies in the world. Field data were utilized by Yang et al. (2013) to assess the model of ENVI-met based on the thermal performance of several surface subtypes. It has been applied to study the effects of urban greening on outdoor thermal comfort and local meteorological parameters. Lee et al. (2016) estimated how trees and grasslands influence the microclimate of a typical residential neighborhood in Friburg, Germany, while Salata et al. (2016) examined the significant impact of vegetation on the moderation of urban heat island in Toulouse, France. Multiple studies have shown that ENVI-met correctly simulates the thermal surroundings of various climates (Forouzandeh, 2021; Srivanit & Jareemit, 2020; Yang et al., 2013).

In the Sri Lankan context, the ENVI-met model has been applied to investigate the effects of green infrastructure on tropical Sri Lankan urban settings as a UHI adaptation approach (Herath et al., 2018). The same model has also been employed to evaluate the effects of different urban design alternatives on air and surface temperatures and outdoor comfort conditions in Colombo (Emmanuel et al., 2007). Local ENVI-met studies relating vegetation and UHI mitigation primarily focus on green infrastructure effects on UHI and thermal comfort levels and the "Building and thermal environment" aspect, not specifically on the roadside tree configurations aspect. The influence of urban green infrastructure (green walls, roofs, etc.) on microclimatic conditions was researched by Herath et al. (2018). Emmanuel et al. (2007) explored the "Building and thermal environment" aspect showing how the aspect ratios of street canyons and different building configurations affect the air temperature mitigation while exploring the added benefits of shade provided by buildings in comparison to established UHI reduction methods using a densely urbanized road in Colombo. It was done by building density modification, albedo enhancement, and shading level adjustment.

Only modest efforts had been adopted in local scientific research to identify improved street tree configurations intended to enhance the urban cooling effect and mitigation of UHI in Colombo. Inspired by the approaches employed in recent similar studies, this study aims to present a model-based identification of improved street tree configurations suitable for Colombo (selected sites) by deriving heat distribution patterns within street canyons incorporating the current roadside tree configurations via the CFD-based 3D microclimatic model 'ENVI-met,' along with validation through field measurements. Hence, this study will investigate the effects of roadside tree configurations on the roadside thermal environments in urban canyons of the selected sites.

2 Materials and Methods

2.1 Data Collection

The major locations around which the study was based are Colombo, Sri Lanka, and its suburb of Ratmalana, representing three different roadside tree configurations in varied environments of urban canyons. These cities represented a typical hot, humid, humid tropical climate as encompassed in the study scope. A tropical monsoon climate, or Köppen climatic type Am, can be found in Colombo. From March to April, the average high temperature is approximately 31 °C ("Colombo weather," October 2009). Rainfall in Colombo is around 2,500 mm (98 in) a year, on average ("World Weather Information Service—Colombo." World Meteorological Organization, February 2017).

2.1.1 Case Study

Three roadside tree configurations (Configurations A, B, and C) in Colombo and Ratmalana were considered, and three sites were selected accordingly. The selected three sites were mainly based on the street tree configurations and also on the nature of the surrounding urban environment, i.e., whether the area is in a heavily urbanized region with institutionally pre-planned vegetation and buildings, whether the site is in a more residential environment with suburban characteristics, or whether the area is in a moderately urban environment representing a main road which facilitates vehicle fleets diverting to/from several directions. The tree configurations observed in these three urban environments represented the most common ones in Colombo and Ratmalana.

Figure 1.1 shows Google Earth and real site images of the selected tree configurations A, B, and C sites. Tree Configuration A consisted of single-lane urban roads with an abundance of roadside trees with high crown density on either side of the road, which are spaced more or less at equal distances. Tree crown shapes of ‘Spreading,’ ‘Layered,’ and ‘Broad’ forms were predominant in this configuration. The site selected for Configuration A representation was Horton's Place, Colombo 07. Tree Configuration B consisted of non-uniformly spaced ‘wayside’ trees which were individual/isolated trees on a single-lane road near a residential area. The trees were of ‘Irregular,’ ‘Open’ crown shapes and were of moderate height. The site selected for Configuration B was Mallikarama Road, Ratmalana. Configuration C represented a very low or minimal presence of roadside trees in the urban road site, and buildings on both sides flanked the road. The site selected for Configuration C was Barnes Place, Colombo 07.

The data collection process commenced on the August 14, 2021, and was done for ten months until June 2022. The onsite data was collected from 11:00 to 14:00 on clear, sunny days. This time was selected to collect different microclimatic data within the peak daytime hours with maximum UHI effect in the tropical climate considering the shadowing effect of trees in the daytime (Srivanit & Hokao et al., 2013; Senevirathne et al., 2021). Clear and cloudless days were selected for data collection, as the ENVI-met simulation model, which was the microclimate model used in the study for thermal environment simulations, does not take the cloudiness of the sky into account, and thus simulation of sunny days may be more realistic (Taleghani et al., 2015). The climate data measurements were done 1.5 m above the ground level (pedestrian height). The study was confined to the urban climate's Urban Canopy Layer (UCL) as the study's focus is on climate-sensitive urban roadside space. It examines the causes and consequences of changing morphology at the street level. In all three sites, the data was collected within a 100 m road stretch, and this particular measurement stretch was selected after carefully examining the surrounding road area ranging 200–300 m of the sites and after confirming that similar tree configuration attributes and repeated urban morphology were present in that particular region. Five points were located 20 m apart on each side of the road for data collection, resulting in 10 measurement points per site. At each of these measurement points, the climate data was measured by taking three replicates of the four parameters with a 5-s interval between each replicate. The average of the three replicates was then calculated. The three sites measured the climate parameter at 11 a.m., 12 p.m., 1 p.m., and 2 p.m.

Table 1.1 shows the data types collected during onsite data collection. A list of the specification details for the instruments utilized for data collection is shown in Table 1.2.

Regarding the tree attribute data, the following are considered. In measuring the tree crown spread measurements, the average crown spreads of the roadside trees identified in the sites were measured by the following method (Eq. 1):

$$A(\text{Average crown spread of trees}) = (\text{Longest spread} + \text{Longest cross spread})/2 \tag{1}$$

Other information on the considered roadside trees of each site was also recorded; whether the tree is cylindric/heart-shaped/spherical, the size of the trunk (large/medium/small), and whether the tree crown is visually

Fig. 1.1 Real street images (above) and Google Earth images (below) of selected sites

Table 1.1 Data types collected

Climate data	Tree attribute data	Data on adjacent environment
Ambient temperature (Ta)	Tree height	Road length and width, Road and pavement materials
Relative Humidity (RH)	Tree-spacing distances	Ground conditions
Wind Speed (WS)	Trunk height	Surrounding building attributes
Wind Direction (WD)	Crown shape	Roughness length

Table 1.2 Instruments used

Instrument	Measurement parameter	Accuracy
Digital anemometer AS816	Wind velocity	±5%
CO2/Temp/RH Data Logger	Ambient temperature	±0.6 °C
	Relative humidity	±3%
Wind Vane Mk2	Wind direction	
Forestry pro II laser range finder/hypsometer	Tree height/trunk height	±0.3 m
Fiberglass measuring tape	Distance measures/tree crown diameter	±0.1 m/s or ±5%

dense or sparse based on the foliage and tree crown spread measurements.

The data on the adjacent environment collected includes the surrounding building attributes such as the building wall material (concrete/glass, etc.), roof material (terracotta/tile, etc.), building height, and ground and soil conditions of the pavements and the roads (loamy soil/asphalt/concrete, etc.).

2.2 ENVI-Met Simulations

The 3D simulation software ENVI-met Lite 4.0 version was used to identify heat distribution patterns within the selected sites. Model simulations were conducted in ENVI-met in each location using the data collected. The simple forcing tool was used during the simulations, which enabled to force or set climatic variables of relative humidity and temperature over 24 h throughout the simulation. Through the simple forcing feature, the measured onsite meteorological data of Ambient temperature, Relative humidity, Wind speed, and Wind direction were input in forcing the model for the simulation for all the sites in consideration.

Major input variables entered for simulations on ENVI-met are shown in Table 1.3.

Table 1.3 Major input parameters for ENVI-met simulations

Metrological input variables	Ambient temperature (Ta) and Relative humidity (RH) Horizontal solar and infrared radiation Specific humidity (2500 m)	Measured average data and EPW data EPW data 7 g/kg*
Total simulation time (h)	Per simulation	1
Wind speed at 10 m height (m/s)—WS		2.5*
Building	Concrete walls	Thermal conductivity—1.6 W/(m·K)*
	Roofs—Terracotta	Thermal conductivity—0.81 W/(m·K)*
	Roofs—Tile	Thermal conductivity—0.84 W/(m·K)*
Vegetation		Differing according to the site
Roughness length (m)	Urban environment	0.01

*Model default

The model simulations required two files for functioning: an Urban configuration file in which the study area is displayed with the vegetation, receptors, buildings, surfaces, and soil, vegetation, soil, and surfaces, and a Climate configuration file with the initialization values and microclimate data of Ta and RH. The general procedure used in the simulations of the three sites is as follows. In preparation for the urban configuration file, a.INX area file was created in the 'Spaces' feature of ENVI-met, using a previously prepared bitmap file of the study site (with located vegetation, buildings, and road) using QGIS software (an open-source, cross-platform GIS application). A grid resolution of 5 m*5 m*5 m was used for digitizing the study area with the model dimensions of 50*50*40, the maximum model size in ENVI-met Lite. The model domain was rotated by the respective degree belonging to each study site to align with the location's North axis. Other major model domain settings were adjusted accordingly with the site in consideration. In Model Location, the location's name, location coordinates, and reference time zone were adjusted.

In digitizing the area after adjusting the model domain settings, the vegetation, buildings, soils and surfaces, and receptors were defined with the help of the background georeferenced bitmap image. The roadside buildings were drawn in with the collected building data of building geometry (building height, roof, and wall materials). The soils and surfaces of the area were also retrieved from the model's database. The following soil profiles with their respective thermal conductivities are used: For the roads: Asphalt Road (0.17–0.2 W/m °K), for the pavements; concrete pavement gray (2.25 W/m °K), for the natural surfaces; Loamy Soil (0.47–2.56 W/m °K). In the representation of vegetation, the most resembling vegetation types were selected from the model database. The vegetation which was to be included can be chosen from the database according to the shape of the tree crown (Cylindric/Heart-shaped/Spherical), Height of the tree (Medium—15 m/ Small—5 m /Large—25 m), and Trunk height (Medium/ Small/Large). The most appropriate vegetation was selected in accordance with the field data collected to represent the actual area better. Receptors were also defined at the site to better identify the assigned measurement points.

After editing the materials and digitizing the area, the climate configuration file was created in the ENVI-guide feature. The forcing file for the simulation was created with an Energy Plus Weather File (EPW file) containing general yearly weather data of Colombo-Ratmalana. This and the onsite data were useful in forcing the Ta and RH values over 24 h. Default values derived by ENVI-met were adopted for Specific humidity (at 2500 m height), and Roughness length (0.01 m) showcasing an urban environment was adopted (roughness length at measurement site—roughness of exterior conditions). Table 1.3 represents the major input parameters included for the ENVI-met simulations. Thus, they were run after creating the respective simulations' urban configuration and climate files. The simulation results and outputs (Atmosphere files) obtained can be used to create 2D or 3D heat distribution maps of the study areas for data analysis.

2.3 Tree Configuration Scenario Analysis

To identify suitable roadside urban forest planning scenarios to regulate the microclimatic conditions within the selected urban canyons, different greening modification scenarios were developed for the selected sites of the three tree configurations, scenario simulations were run, and the results obtained were compared.

Scenario simulations are done for the three Tree Configurations A, B, and C sites, according to the following pre-selected roadside urban forest planting scenarios:

Scenario 1—Base case (original/actual site conditions)
Scenario 2—Control case (no vegetation)
Scenario 3—Widely spaced tree row (sparsely foliated—low LAD)
Scenario 4—Continuous tree row (densely foliated—high LAD).

When adding the vegetation in the scenarios, a constant deciduous tree from the model database was considered in all the simulations: Cylindric, medium trunk, medium height (15 m).

3 Results

The onsite collection of data on the parameters of Ta and RH values for the experimental road sites belonging to the three tree configurations was done for ten months, from August 2021 to June 2022. The below-mentioned results relate to a data set collected on the 26th of January 2022 during the 11 a.m. hour window for Configuration A and a data set obtained on January 31, 2022, during the 11 a.m. hour window for Configuration C.

The selected days for result interpretation were clear, sunny days devoid of precipitation for the day or the previous two days. ENVI-met model simulations were done for the hours and dates of Horton's Place, Colombo 07, of Tree Configuration A, and Barnes Place, Colombo 07, of Tree Configuration C.

The primary input data for Configuration A simulation: Average Ambient Temperature (Ta)—34.2 °C, Average Relative Humidity (RH)—65.7%, Average Wind Speed at 10 m height (WS)—2.5 m/s, Wind Direction (WD)—SW-NE, and Roughness Length—0.01 m.

The primary input data for Configuration C simulation: Ta—33.6 °C, RH—68.9%, WS—2.5 m/s, WD—NW–SE, and Roughness Length—0.01 m.

In identifying the heat distribution patterns within the street canyon of the selected site, the output files (atmosphere files) generated by the model simulation results were analyzed using LEONARDO. The 2D heat distribution maps for Ambient temperature and Relative humidity of the study areas obtained as a result are shown in Figs. 1.2, 1.3, 1.4, and 1.5. The white polygons in the heat maps represent the adjacent buildings on either side of the considered road site.

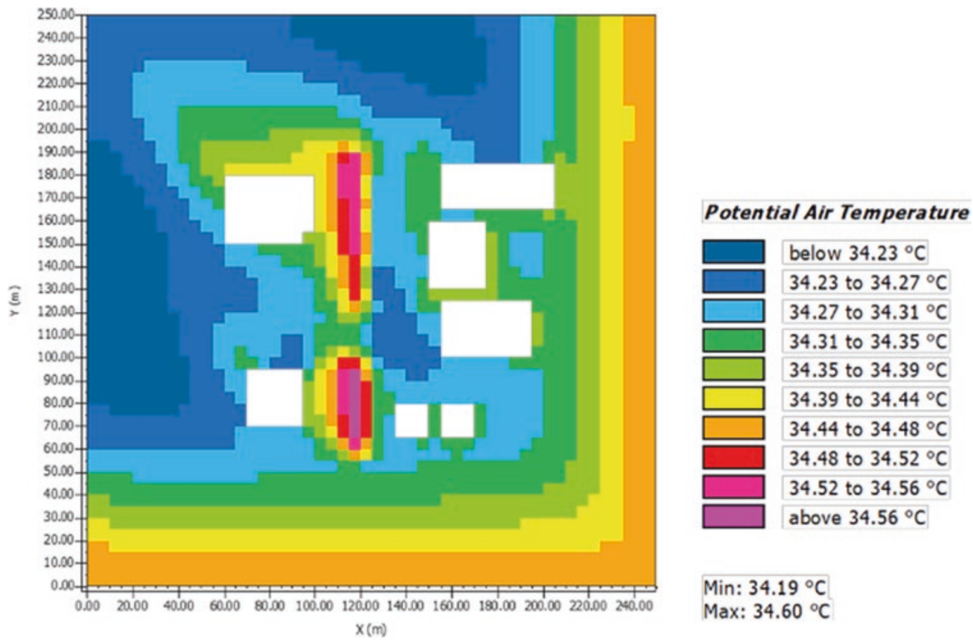

Fig. 1.2 Ambient temperature distribution—Horton's place (11 a.m.)

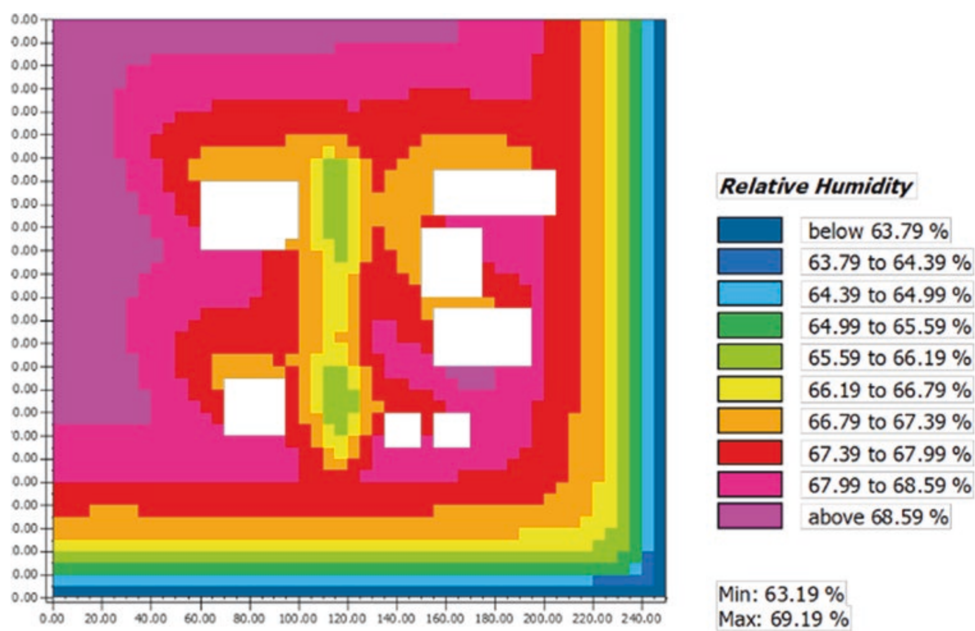

Fig. 1.3 Relative humidity distribution—Horton's place (11 a.m.)

3.1 Tree Configurations A and C

Configuration A:

See Figs. 1.2 and 1.3.

Configuration C:

See Figs. 1.4 and 1.5.

In the study site of Configuration A, an approximately continuous tree row configuration on both roadsides was present with predominating densely foliated trees. According to the results, the value ranges for the ambient temperature distributions of the roadside sites of Configuration A—Horton's place and Configuration C—Barnes place for the considered dates were not significantly different. The values were in the same range of 33–34 °C for both sites at 11 a.m. A higher relative humidity value distribution (Figs. 1.4, 1.5) resulted in the Configuration C site (67.84–69.13%) when compared with that of the Configuration A site (65.59–67.99%). In Configuration A—Horton's place, near the receptor where a large, over 25 m tall densely foliated tree and other associated trees

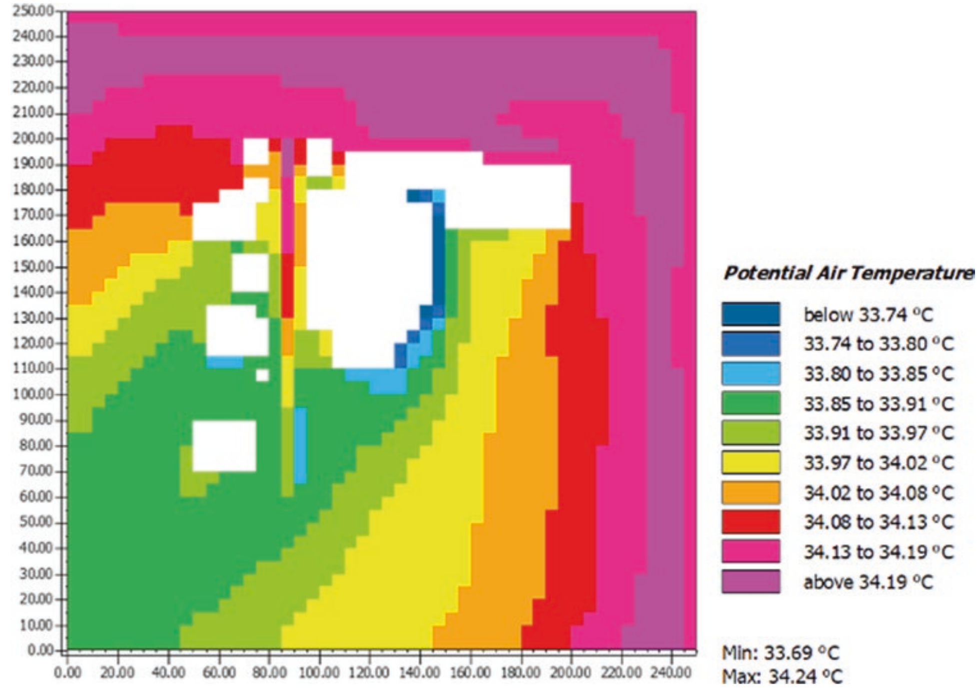

Fig. 1.4 Ambient temperature distribution—Barnes place (11 a.m.)

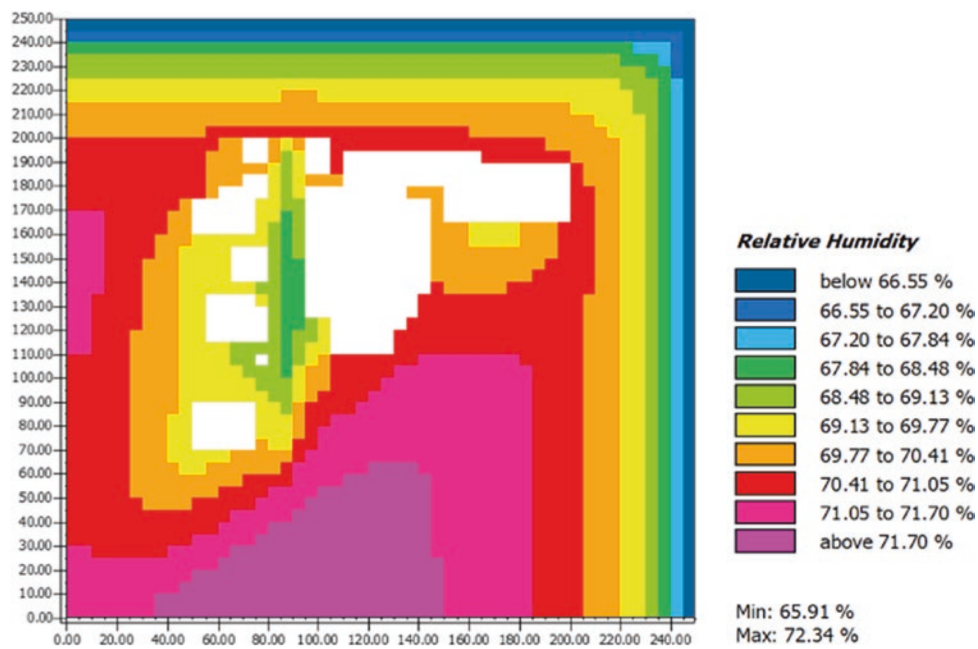

Fig. 1.5 Relative humidity distribution—Barnes place (11 a.m.)

are present, the lowest ambient temperature was observed (below 34.23 °C). The dark blue color distribution to the right side of the road area demonstrates this.

The following ambient temperature heat distribution maps were generated for the scenario comparison, considering four scenarios Mallikarama Road of Tree Configuration B for a particular data set collected on February 3, 2022, at 11 a.m.

3.2 Tree Configuration B—Scenario Comparison

For the scenario comparison, for all four scenarios considered, the following input parameters were made constant in the model according to the actual data obtained: Ta—33.2 °C, RH—72.8%, WS—2.5 m/s, WD—SW-NE, and Roughness Length—0.01 m. When the Base case

(Fig. 1.6) and Control case (Fig. 1.7) were compared, the ambient air temperature at several points on the road and the measurement points were higher in the control case. In Scenario 4 (Fig. 1.9), where a continuous tree row with densely foliated trees was positioned, the ambient temperature and heat distribution above the road area and the pavement regions seem to be thinned out and reduced at several places when compared with Scenario 3 (Fig. 1.8) where widely spaced sparsely foliated tree rows were simulated. In Scenario 3, when sparsely foliated trees were spaced with wide spaces in-between each other at either side of the road, the ambient temperature values averaged 34.04–34.16 °C and above 34.16 °C in the roadside area. In Scenario 4, when densely foliated trees were placed with short distances in-between, the ambient temperature in most of the roadside areas had decreased to 33.66–34.04 °C, which is more cooling than in Scenario 3. However, when the Control case (Scenario 2) and Scenario 3 were compared, the findings indicated no discernible difference in the ambient temperature in the roadside region.

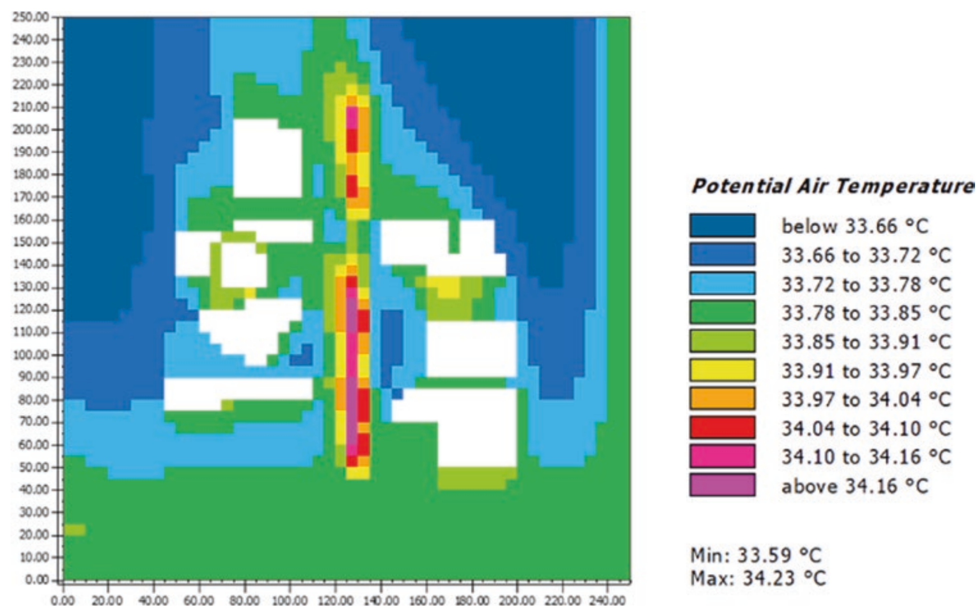

Fig. 1.6 Ambient temperature distribution—Mallikarama road (11 a.m.)—base case; Scenario 1

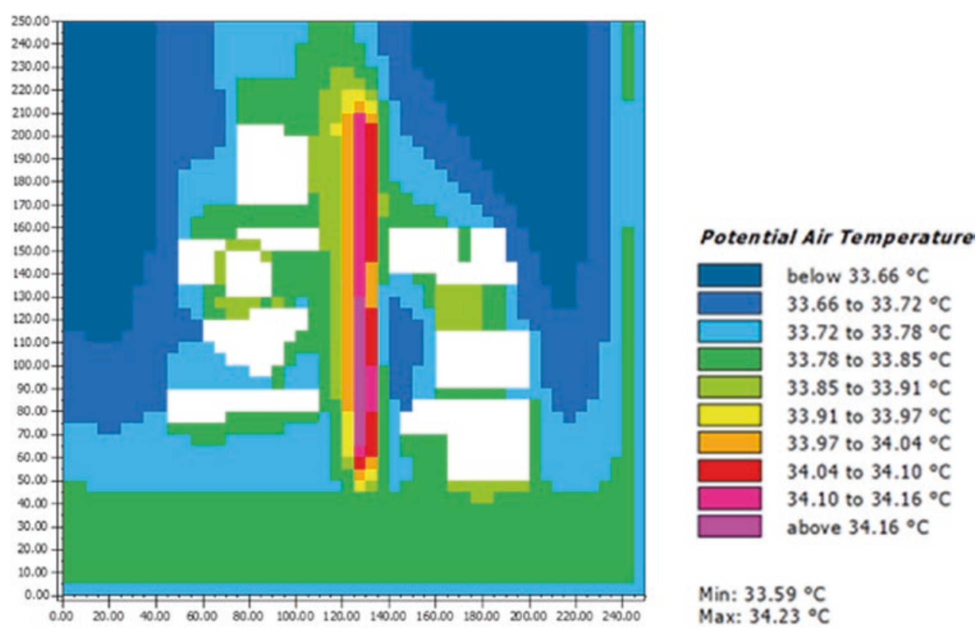

Fig. 1.7 Ambient temperature distribution—Mallikarama road (11 a.m.)—control case; Scenario 2

4 Discussion

The present study evaluated the effects of roadside tree configuration on urban thermal conditions. Evaluating the scenario simulations of the selected site derived using ENVI-met and under the current conditions—according to the results of the comparison between the base scenario (original site) conditions and the control scenario (no vegetation), the base scenario showed cooler regions on the roadside and road area when compared with the control scenario in which any roadside vegetation was included. This result can demonstrate the effect of roadside greening, which reduces the ambient temperature of the considered area. Additionally, the ENVI-met results presented a Ta difference of 0.25 °C between areas with and without greenery in Scenarios 1 (Fig. 1.6) and 2 (Fig. 1.7), respectively. This reduction in ambient temperature and cooling effect could be explained by the shading effects formed by the branches and leaves of roadside trees, which reduces the solar irradiance that enters the region beneath the canopy of the trees.

Furthermore, the evapotranspiration of trees helps lower temperatures in roadside vegetation areas (Srivanit & Hokao, 2013). Moreover, surface temperatures increase when the sun's angle with the surface decreases (Forouzandeh, 2021). During the data collection period section from July to December, the sun did not travel directly over Sri Lanka, which may have reduced the solar angle. Compared to some of the earlier research carried out in comparable tropical nations, this may account for the present study's lower ambient temperature ranges during peak hours.

For the Tree Configuration B site (Mallikarama Road), the base condition (Scenario 1) was compared and contrasted with two greening strategies and a control case without vegetation. This comparison considers only ambient temperature variations and is done to analyze the effect of these modifications to the tree configurations on mitigating the ambient temperature in the study area. For the comparison to be fair and to distinguish hot from cold sections along the roadside area, the temperature range is the same for all four scenarios. The density of buildings, roads, and pavement materials remains constant in all four scenarios, and only the tree configurations are altered. When the heat maps for Scenario 3 (Fig. 1.8) with widely spaced sparsely foliated tree rows on either side of the road are compared with Scenario 4 (Fig. 1.9) with continuous densely foliated tree rows on either side of the road, the ambient temperature distribution has decreased in Scenario 4. This shows that dense green areas with densely foliated trees in close proximity contribute to the cooling effect, which keeps the roadside area cooler during peak hours. The densely foliated aspect of the tree canopy, produced by dense and compacted clusters of leaves which block incoming solar radiation, results in lower surface temperatures and, as a result, lower ambient temperatures (Shinzato et al., 2019). In contrast, hot spots were identified over most of the road areas, as shown with the red-pink color gradient in Fig. 1.8 of Scenario 3, with sparsely foliated trees set widely apart.

Some general inconsistencies in model results and less significant ambient temperature differences among different simulated scenarios may be due to some limitations in the moderately simplified calculation methods related to the tree models and the static wind and cloud settings in the simple forcing function of the ENVI-met model (Yang et al., 2021). The use of model-assumed values instead of using measured data owing to the unavailability of appropriate scientific measuring instruments, including the specific surrounding building thermal attributes relating to specific heat capacity, emissivity, the absorption coefficient of walls, thermal conductivity, and the tree attributes (LAD, foliage albedo, and RAD) (Simon et al., 2018), may have caused irregularities in some ENVI-met output results. Model uncertainty may also have been introduced due to choosing typical (default) vegetation to represent the study area's roadside vegetation systems (Wu & Chen, 2017).

The present study can be thus useful in the identification of heat distribution patterns within street canyons considering selected roadside greenery configurations and determining suitable roadside urban tree planting scenarios to regulate the microclimatic conditions within the urban canyons of Colombo and suburbs, backed by field measurements and the application of the numerical modeling software of ENVI-met. Further research will be required to establish more solid conclusions by considering specific aspects of the roadside thermal environment, such as the surrounding building heat interactions and urban settings, including the aspect ratio differences, the impact derived from pavement and urban surface material variations on road thermal climate, and the impact of locally available tree species specifics (leaf size, branching arrangement, and other micro-scale characteristics) for analyzing their cooling potentials. Moreover, the data is preferable to be supported by an inclusive model calibration and validation through data collection over a more extended period by incorporating continuous daily measurements and mobile measurements capturing the daytime and nighttime impacts of street-side trees on UHI, further including multiple data sites covering a majority of tree and street configurations of Colombo and suburbs.

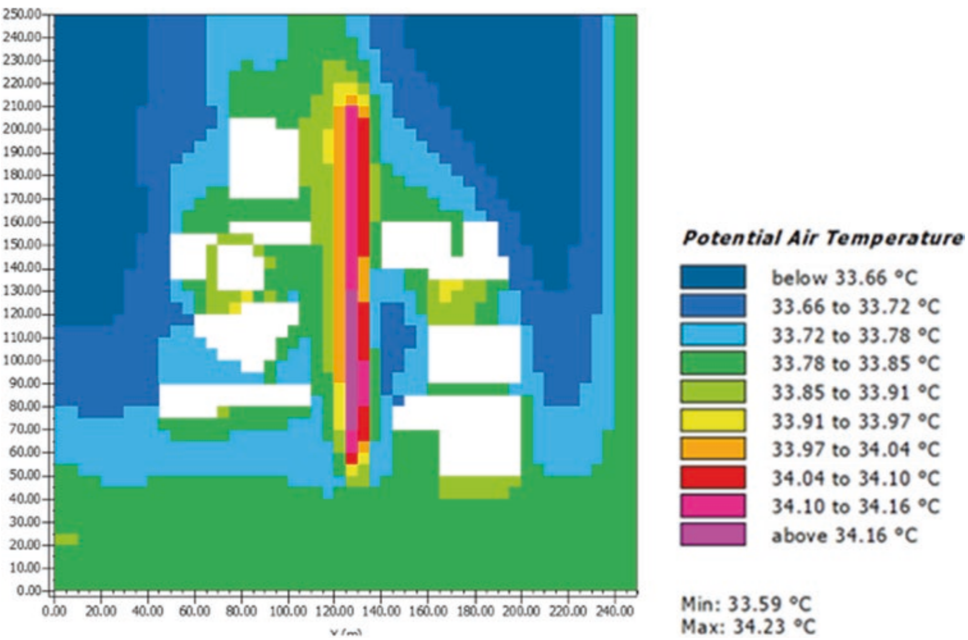

Fig. 1.8 Ambient temperature distribution—Mallikarama road (11 a.m.)—widely spaced tree row (sparsely foliated—low LAD); Scenario 3

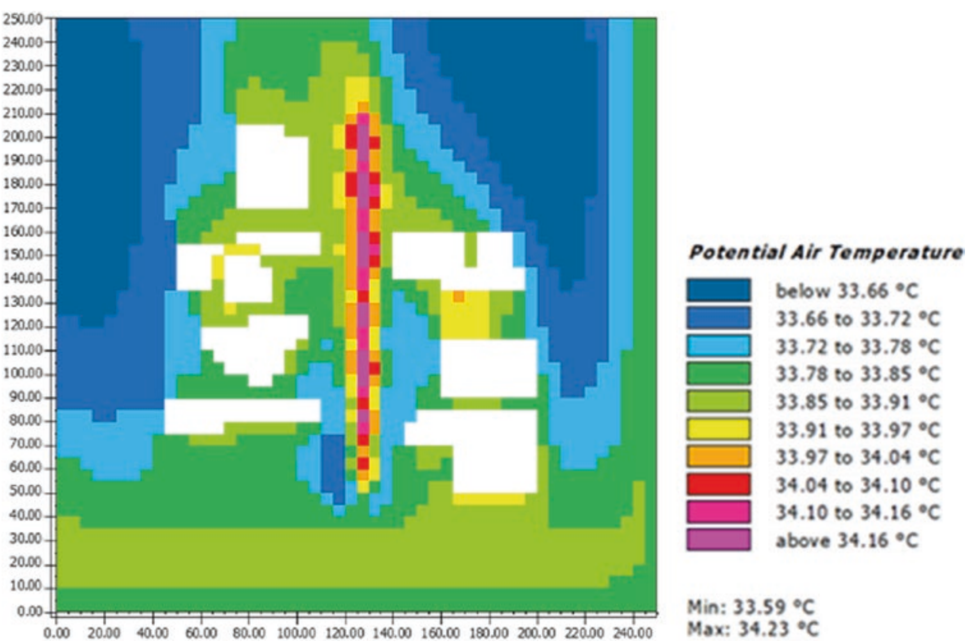

Fig. 1.9 Ambient temperature distribution—Mallikarama road (11 a.m.)—continuous tree row (densely foliated—high LAD); Scenario 4

5 Conclusion

The present study evaluated the effects of roadside tree configurations on the roadside thermal environment in urban canyons of selected sites in Colombo, Sri Lanka, using the 3D microclimate model ENVI-met. The analyzed results and scenarios relating to the effects of street trees on variations in relative humidity and ambient temperature of the immediate thermal surroundings reveal the following conclusions. When comparing the ambient temperature distributions between Tree Configuration A—Horton's place and Tree Configuration C—Barnes place for the selected dates, as shown in the results section, they are not significantly different from each other, and the values are in the same range of 33–34 °C for both the sites at the hour of 11 a.m. This may result from the data of the two tree configurations belonging to two different days contributing to slight climatic differences. A higher relative humidity value distribution is observed in the Tree Configuration C site (without vegetation) compared to that of the Tree Configuration A site.

The following observations are evident in the scenario comparison in the selected site of Tree Configuration B. The absence of trees caused an increase in ambient temperature in the thermal environment. The ambient temperature and heat distribution above the road area and the pavement regions are thinned out and reduced at several places when the tree configuration of a continuous tree row with densely foliated trees (Scenario 4) is used instead of the widely spaced tree row with sparsely foliated tree configuration (Scenario 3), with an overall simulated ambient temperature reduction of 0.5 °C in Scenario 4 when compared to Scenario 3. Based on the aforementioned findings, various roadside tree layouts in urban streets have varying effects on the microclimate at the pedestrian level, underscoring the necessity to formulate urban tree planting recommendations based on these aspects without resorting to ad-hoc roadside planting designs and systems.

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The Butterfly Effect Toward a Nature Smart Society

Anne Stenros and M. Arch

Abstract

We are living in times of great transformation. In a world of multiple crises, a drastic change is underway, and nothing we are used to will stay the same. We need to unleash our creative energies and actively seek for what's the Next and the New Normal in the future. This transformation is clearing the way for a new society to emerge. Only through embracing change and understanding the very essence of human creative capacity and human-nature connection can we build a future for the betterment of humans and the planet. A Nature Smart Society is the way forward, based on the different types of human needs: sense of trust, sense of consistency, sense of belonging, sense of being valued, sense of being heard, and sense of meaning and purpose. To support all levels of human needs is to create a more resilient culture and a more humane society. A Nature Smart Society is a safe and healthy place for all to flourish in all aspects of our lives: to live, love, learn, work, and play well. It is a natural human habitat of wellbeing, wealth, health, harmony, hope, and happiness as a future goal for humanity and the planet.

Keywords

Creative industries · Speculative architecture · Climate emergency · Gen Z · Regenerative architecture · Chief heat officer · Green infrastructure · Civic engagement · Placemaking · Inclusive city · Participatory planning · Net zero economy

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1 Introduction: To See or not to See

Over ten years ago, in 2010, there was a global conference in Shanghai, titled *Partnership for Urban Innovation*, hosted by Cisco. The focus of the conference was on the urban development of cities and their future innovation potential. After the conference, I wrote an essay titled "The Butterfly Effect—Future Trends in Urban Transformation" (Stenros, 2010). Originally, the butterfly effect concept referred to weather conditions, but later it has also been used as a broad term for any situation where a small change is supposed to cause significantly larger consequences. In the introduction of my essay, I stated:

"We usually tend to think that the butterfly effect is something unexpected that happen—in a negative, dramatic sense. What if… a butterfly effect works for the positive purpose, in a good sense—and creates unexpected, yet desired snowball effect for the positive transformation. In that case, the butterfly effect is all about scaling. Scaling for example the social impact—maximizing good in our environment… Creating a circle of happiness which will affect to the well-being and support the pursuit of good life—for all and everyone" (Stenros, 2010).

In my presentation and later in the paper, I also drafted *The Butterfly Model* with the principles of betterness in the built environment: "Betterness in the built environment is about maximizing the good, i.e., the positive impact of architecture and landscape architecture in the urban environment. It begins from the sustainable values and responsible choices. It stands for creating the sense of place—*Genius Loci*—for people to share memories and mementos. In its way, it integrates art with architecture in order to create inspiring all-encompassing experiences. It respects the human scale, thus representing the value set of caring ethics. It shows how cultivating greenery and supporting biodiversity is a source of wellbeing through experiencing the natural cycle of renewal. The strength of the

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Butterfly Model is a constant strive for the betterness of the quality of human life.

The actions taken are following the principle of the soft path as a model of growth" (Stenros, 2010); see Fig. 2.1.

What struck me today—a decade later—is the accuracy of the future vision of urban city transformation we discussed and envisioned at the conference in Shanghai and, further, as a summary in my paper in 2010. All these major trends of urbanity—environmental and social sustainability, biodiversity, partnerships for innovation, citizen involvement, and the rise of creative industries—also show the spectrum of today's lens to look at the city of tomorrow. What if… the audience would have been more responsive? What if… decision makers and influencers had been more visionary? What if… the business world had been more open to new ideas? What if…?

It took a decade to finalize my thoughts about the betterness of the built environment and the future of urbanity within the concept of *The Nature Smart City* (Stenros, 2022). However, the caterpillar poised to transform into the butterfly was already in existence and underway in my presentation at the urban summit in Shanghai in 2010. "It is a city which is both preserving its heritage and creating future at the same time. It is a living entity with a healthy ecosystem of economy, equality, and environment" (Stenros, 2010).

Three years later, in 2013, I conducted a scenario planning process titled *Future Flow 2030* for KONE Corporation. Together with the German Fraunhofer Research Institute and the Finnish VTT Technical Research Center, we created six future scenarios based on the socioeconomic analysis of megatrends. The scenarios clearly showed six plausible paths toward future society, globally; see Fig. 2.2.

Looking back at those times, it's evident the seeds of the future were already hidden in the present. It also tells me how we can see, yet not understand, what we have seen. These examples of futuring or making the future (visible) never got the attention they should have. The future narratives were clear, albeit imaginary, and the lessons to be learned from them were obvious. Yet, nobody paid attention to the storylines illuminated during the process. By coincidence, I met a KONE colleague years later, after leaving the company. He happily told me that they were now doing all those things I explained and talked about several years ago. Sooner or later we all must face the future of our time. By denying the existence of the future we may buy time, but, at the same time, lose momentum and advantage. Therefore, building future narratives should be a lifetime, on-going path rather than a project or a process. Getting the message when the future is spelled out to you is key to leadership. Exploring IS understanding futures. Seeing the signals, reading the trends, and analyzing alternative narratives will provide a head start and allow first-mover influence when facing future challenges. It is the very difference between a forerunner and a follower. The only way to tackle change is to go with the flow—but be fully aware and prepared for where one is heading. Future speaks to us in the present—or whispers, rather—but it takes a lot of attention, skills, and experience to truly hear what it is saying.

Professor Helga Nowotny has said that one of the metanarratives of modernism is that we are able to make our future (Nowotny, 2016). It is not about good fortune or ill fortune, rather it is all about our actions. Over ten years ago, I tried to speak about the "Pebble Power" of small actions on a large scale and "a small footprint with a large impact". I also pointed out to a future vision of "Smart Cities & Smart Growth" with characteristics such as biodiversity,

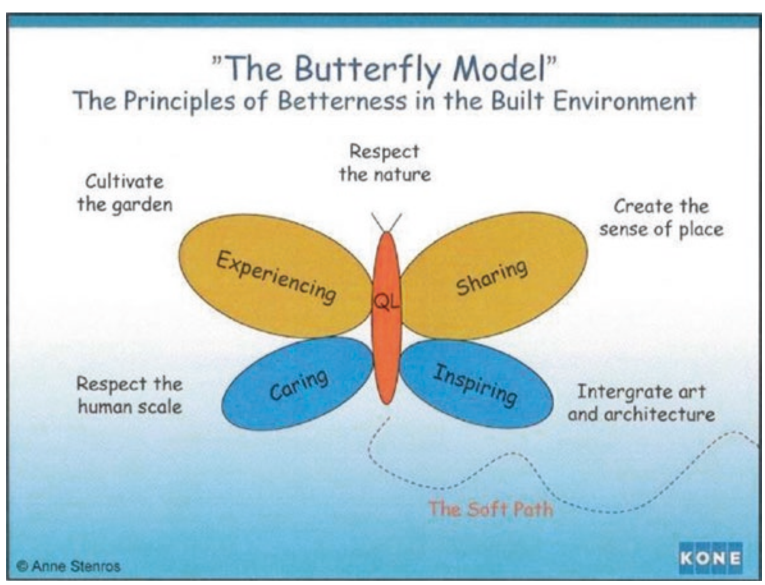

Fig. 2.1 The butterfly model of the built environment. © AS, 2009

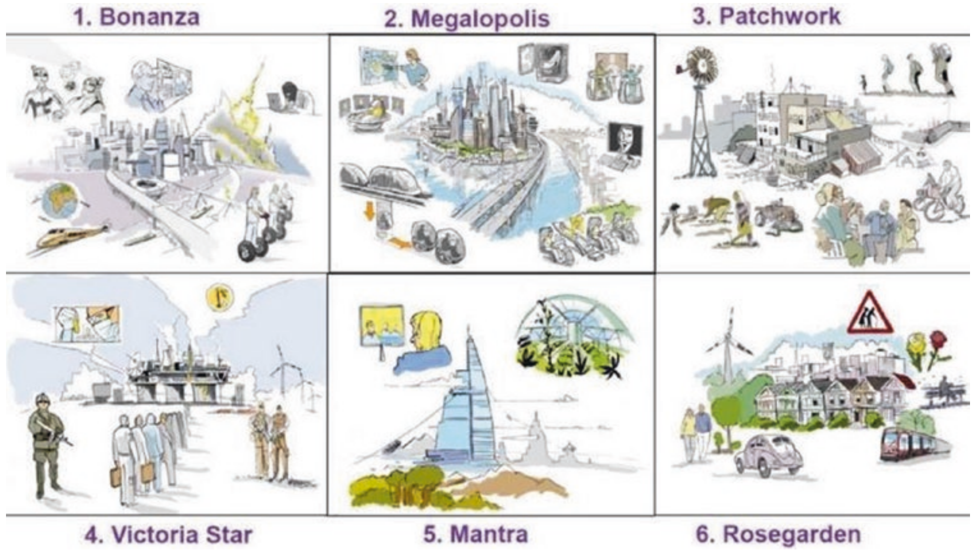

Fig. 2.2 KONE future flow 2030. © KONE Corp., 2013

living sustainably, urban agriculture, eco-sustainability, cultivating communities, social relations, design-sensibility, hybrid typologies, and post-sustainability. Now is the moment for the true butterfly effect—the one that will change our path from crises to creativity, from disaster to dialogue, from chaos to coherence and consistency. It is up to us what the future holds for us. But first, we must SEE the future as it is unfolding in front of us. For those of us who can see… the future momentum is open but only for a short time—*carpe diem*!

> Never let a good crisis go to waste.—Winston Churchill

2 The Method: Speculative Architecture and Futuristic Activism

In 2022, a few architects, engineers, and designers formed a group called Power Animals and entered a proposal in the competition for the Finnish Pavilion at the Venice Architecture Biennale 2023. We titled our entry *NATURE WISE CITY—Rewilding Architecture and Urban Design*. The idea was that the Nature Wise City narrative happens around and in the Finnish pavilion, dressing it up as the future Finnish pavilion of the year 2059 (Stenros et al., 2022); see Fig. 2.3.

The framework of our proposal was *regenerative architecture*. Regenerative architecture focuses on revitalizing natural systems by utilizing the living systems that exist on a site. It also addresses climate change and social inequality. The method chosen was *speculative architecture and design*, which tells a story and sets up a scene, and narratives on how different drivers could shape space and culture in the future. It combines architecture fiction, design futures, architectural design thinking, and critical thinking to create alternative futures through stories, artifacts, scenarios, and environments. Our proposal is an example of creative and futuristic activism by activist-planners, architects, and designers representing the future metamorphosis of architecture in 2050 and beyond.

The future world is based on human and planetary wellbeing. Rewilding and oneness with nature are the new building blocks of holistic wellbeing, a healthy life, and a healthy planet. Restoring and rebuilding the human-nature connection is the very essence of human and planetary wellbeing. How to design a happy future in harmony with nature? In our future narrative, architects are gardeners enabling Nature to take over the built environment. Rewilding has replaced digitalization as a paradigm. Food is not processed but coproduced in co-ops by citizens in different ways and forms. The youth is involved in city design—future making is a collective effort based on a shared vision. The prevailing metanarrative, *The Narrative of Progress*, has given way to *The Narrative of Metamorphosis*, moving from globalization to micro-localism and from progress to circularity.

Through our proposal we tried to answer the crucial question: how to rebuild community spirit, the human-nature connection, and restore a sense of purpose?—that is the next big agenda in urban development. How to create a city that is coproduced by its people, especially by the youth, since they represent the future and the next generation of citizens and the city? (Stenros et al., 2022); see Fig. 2.4.

Today, future-minded and creative activists are proposing a more livable and lovable, more sustainable and inclusive, healthier and happier, and less consuming and destroying society. They are not building just imaginary