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Research Article

Effects of Green Spaces on Microclimate in Sustainable Urban Planning

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Abstract

In recent years, there has been a growing importance placed on the development of various models and scenarios aimed at mitigating the effects of climate change. This approach is gaining prominence in our country as well. This study is based on research conducted in the Yeşilyurt neighborhood within the Tarsus district of Mersin province. The primary objective of this research is to assess the impact of increased green space on microclimate conditions using ENVI-met simulation. Within the scope of this research, a comparison was made between the current situation and a scenario in which the amount of green space was increased. The analysis of green area quantities was conducted using the ENVI-met simulation software, utilizing climate data such as temperature, humidity, wind direction, and speed, which were obtained through measurements. In the scenario involving an increase in green space, the total green area was augmented from its current 2,487 m² to 4,398 m². The simulation results underscore the substantial effect of this augmentation on the microclimate. Average temperature values fluctuate between 31.11°C and 33.04°C, revealing that the expansion of green space leads to a reduction in temperature, thereby positively impacting the environment. This translates to an overall temperature decrease of approximately 0.45°C across the entire area. The research highlights the favorable influence of heightened green space on microclimate conditions, as evidenced by findings derived from ENVI-met simulations. It elucidates how such an increase can contribute to temperature regulation. These outcomes underscore the significance of deliberate green space incorporation in urban planning and design processes, guiding decisions that promote environmental sustainability. Thus, it is recommended that forthcoming strategies of local governments prioritize the expansion of green areas while considering factors related to microclimate and environmental quality.

Keywords: Envi-MET, Green Space, Climate Scenario, Tarsus

Introduction

In many cities across Turkey, the ecological structure has suffered due to rapid and distorted urbanization, resulting in an imbalance in climate conditions. When it comes to urban planning, understanding climate data and utilizing it positively becomes crucial (Çetin et al., 2010; Cetin 2015; Cetin 2016, Cetin et al. 2018; Cetin 2019; Cetin et al. 2019; Cetin 2020; Cetin et al. 2022; Cetin et al. 2023a,b; Degerli and Cetin 2022a,b; Cevik Degerli and Cetin 2023; Cetin 2020; Cetin et al 2023; Gungor et al 2021; Adiguzel et al 2022a,b). The implementation of measures aimed at reducing the impact of climate change—stemming from diminishing green spaces within cities and the escalated utilization of fossil fuels—is predicted to enhance human quality of life (Hammadi, 2017; Acero and Arrizabalaga 2018; Ülker et al., 2018; Mersin et al., 2019; Söğüt et al., 2019). The global phenomenon of climate change has not spared Turkey either. Projections indicate that average monthly temperatures in Turkey could rise by 2-3°C by the 2070s (Söğüt et al., 2019).

Urbanization has led to an elevation in temperatures due to the prevalence of impermeable surfaces in built-up areas. This temperature increase particularly compromises the quality of life in cities with a Mediterranean climate, and it adversely impacts thermal comfort. Thus, the selection of surface materials plays a pivotal role in fostering the development of healthful and habitable cities. Within the realm of flooring options, materials derived from petroleum, concrete, natural stone, and even exposed soil surfaces are advised for limited use within urban settings due to their propensity for significant heat generation. The escalating prevalence of concrete, asphalt, and other hard surface materials is contributing to the formation of urban heat islands and subsequently driving up urban temperatures. These non-permeable surfaces hold the potential to alter microclimate characteristics (Çetin et al., 2020; Bozdoğan Sert, 2022; Varol et al. 2022; Zeren Cetin et al. 2023a,b; Zeren Cetin et al. 2020; Zeren Cetin and Sevik 2020; Deniz Adiguzel and Zeren Cetin 2022; Cetin 2020; Cetin et al 2023; Gungor et al 2021; Adiguzel et al 2022a,b).

Increasing the presence of green spaces within urban areas is widely acknowledged as a significant solution. In this regard, achieving thermal comfort is closely linked to the creation of grassy areas and planting initiatives (Connors et al., 2013; Bozdoğan Sert et al., 2021; Adıgüzel et al., 2022; Bozdoğan Sert, 2022; Cetin 2015; Cetin 2016, Cetin et al. 2018; Cetin 2019; Cetin et al. 2019; Cetin 2020; Cetin et al. 2022; Cetin et al. 2023a,b; Degerli and Cetin 2022a,b; Cevik Degerli and Cetin 2023; Cetin 2020;

Cetin et al 2023; Gungor et al 2021; Adiguzel et al 2022a,b). Bioclimatic comfort-driven design approaches advocate for the development of urban green spaces, where microclimatic climate factors are considered (Tsitoura et al., 2017). Urban green spaces, serving as indicators of outdoor life quality, fulfill a multitude of roles—ecological, economic, functional, aesthetic, cultural, and social. Their significant positive impacts on urban ecology, encompassing the reduction of air pollution, oxygen provision, preservation of natural structures, and support of wildlife, are vital factors that enhance livability (Hammadi, 2017; Söğüt et al., 2019; Bozdoğan Sert and Adıgüzel, 2022; Cetin 2020; Cetin et al 2023; Gungor et al 2021; Adiguzel et al 2022a,b).

Plant materials and water hold paramount importance in designing sustainable and high-quality urban environments. Their strategic distribution and combined application within urban spaces substantially contribute to augmenting thermal comfort in Mediterranean cities characterized by hot and arid summers (Çetin et al., 2020; Bozdoğan Sert, 2022; Varol et al. 2022; Zeren Cetin et al. 2023a,b; Zeren Cetin et al. 2020; Zeren Cetin and Sevik 2020; Deniz Adiguzel and Zeren Cetin 2022; Bozdoğan Sert et al., 2021; Sayad et al., 2021; Cetin 2020; Cetin et al 2023; Gungor et al 2021; Adiguzel et al 2022a,b). Trees wield a considerable influence over urban morphology and climate. For instance, it is widely recognized that vegetative canopies along urban roads significantly enhance thermal comfort. Even trees with lighter and medium foliage, which provide partial shading, are effective in mitigating temperature increases. The benefits derived from such initiatives tend to multiply when city-wide planting endeavors are meticulously executed (Correa et al., 2012; Yılmaz et al., 2018; Söğüt et al., 2019; Çetin et al., 2020; Cetin 2015; Cetin 2016, Cetin et al. 2018; Cetin 2019; Cetin et al. 2019; Cetin 2020; Cetin et al. 2022; Cetin et al. 2023a,b; Degerli and Cetin 2022a,b; Cevik Degerli and Cetin 2023). Conversely, materials such as asphalt, pavement, and concrete utilized for road surfaces in urban settings lead to substantial surface temperature escalation. Conversely, the presence of roadside trees has a cooling effect on surface temperatures (Bozdoğan Sert, 2022; Cetin 2015; Cetin 2016, Cetin et al. 2018; Cetin 2019; Cetin et al. 2019; Cetin 2020; Cetin et al. 2022; Cetin et al. 2023a,b; Degerli and Cetin 2022a,b; Cevik Degerli and Cetin 2023).

The examination of climatic attributes is imperative in the strategic planning of cities and the decision-making process (Adıgüzel et al., 2020; Varol et al. 2022; Zeren Cetin et al. 2023a,b; Zeren Cetin et al. 2020; Zeren Cetin and Sevik 2020; Deniz Adiguzel and Zeren Cetin 2022). Developing scenarios and simulations that encompass current and future urban conditions is pivotal (Bozdoğan Sert, 2022a; Cetin 2015; Cetin 2016, Cetin et al. 2018; Cetin 2019; Cetin et al. 2019; Cetin 2020; Cetin et al. 2022; Cetin et al. 2023a,b; Degerli and Cetin 2022a,b; Cevik Degerli and Cetin 2023). Presenting diverse models and scenarios to assess the efficacy of strategies aimed at ameliorating microclimates and mitigating temperature spikes in urban habitations due to global warming is highly advantageous. In this context, the 3D ENVI-met model serves to generate microclimate simulations within urban environments using parameters such as air temperature, relative humidity, wind speed, and wind direction (Eingrüber et al., 2022). ENVI-met delineates climate change simulations for parks and their immediate surroundings—integral components of urban green spaces—across varying conditions and materials over extended periods. The scenarios fashioned through ENVI-met significantly contribute to proposing feasible alternatives (Yılmaz et al., 2018; Bozdoğan Sert, 2022a). Urban planning decisions are founded upon settlement scenarios constructed with ENVI-met, thereby influencing determinations related to open-green space utilization, selection of plant species, and positioning of structures (De and Mukherjee, 2016; Zhang et al., 2018).

ENVI-met plays a pivotal role in defining the quality and quantity of urban applications. The simulations designed to ascertain the correlation and extent of urban green spaces and water bodies serve as input for the Envi-Met model, encompassing both vegetative and structural design (Sayad et al., 2021; Yucekaya and Tirnakci 2023).

The objective of this study is to formulate alternative urbanization scenarios using ENVI-met to uncover the most optimal settlements and applications for the city of Tarsus.

Materials and Methods

The study area is situated within the Yeşilyurt neighborhood of the Tarsus district in Mersin, which falls within the Mediterranean region characterized by a hot and humid climate. Geographically, the study area is positioned between 36°55′27″ north latitudes and 34°53′16″ east longitudes, encompassing a total expanse of 22,238.7 m² (Figure 1).

Climatic data pertaining to the study area—namely, temperature, humidity, wind direction, and wind speed—were sourced through measurements taken at a height of 1.5 meters above ground level. The software employed for the outdoor microclimate simulation based on this data is Envi-Met 5.1.1. This software is adept at modeling and analyzing the impacts of various small- and medium-sized zones on microclimates, particularly in the context of urban design and planning endeavors (such as urban revitalization, new constructions, and landscaping projects) (Bruse and Fleer, 1998). The climate data input for simulation purposes within the Envi-Met software is outlined in Table 1.

Table 1: Climate Data Utilized for Envi-Met Simulation

Minimum Temperature	23.3 °C
Maximum Temperature	34.1 °C
Wind direction	Southwest (225 degrees)
Wind speed	1.8 m/s
Minimum Relative Humidity	% 37
Maximum Relative Humidity	% 94

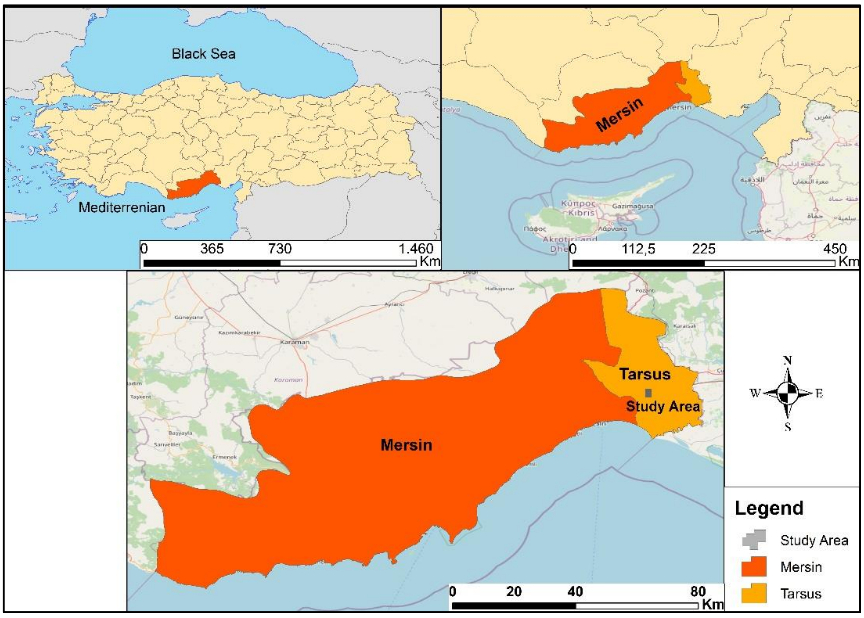

Fig. 1: Study Area Location Map

The data intended for modeling within the Envi-Met software was compiled using ArcGIS software. Two distinct plans were devised for the purpose of modeling. The initial plan encompassed the present conditions, while the subsequent plan was devised with a focus on green space augmentation. This latter model aimed to gauge the influence of green areas on climatic comfort.

The numeric datasets created within the ArcGIS software were subsequently imported into the Monde interface of the Envi-Met software. Vector-based

datasets were converted into raster-based formats. The Leonardo interface was employed to simulate the models depicting the current conditions and the scenario involving increased green spaces. This simulation process allowed for the elucidation of the disparities between the two scenarios."

Results and Discussion

The existing land uses within the research area were scrutinized based on the information illustrated in Figure 2. The analyses provided an overview of the present conditions, illustrating the various usage types and characteristics within this region. The total expanse of the area spans around 22,200 m², comprising an array of diverse usage zones. Predominantly, urban roads and rigid surfaces corresponding to residential areas occupy a considerable portion of the landscape. The investigation also unveiled the presence of a 1,911 m² green space within the vicinity. Among the residential buildings, the number of floors ranges from 3 to 8, with 5-story structures being the most prevalent. Furthermore, 6-story buildings are also frequently observed. The tallest building, an 8-story edifice, stands in immediate proximity to the green area. This green expanse is flanked by 5 and 6-story buildings along the northern and eastern directions. On the southern aspect, it mostly aligns with the southwest corner of the 8-story building, while the western side is encompassed by solid surfaces.

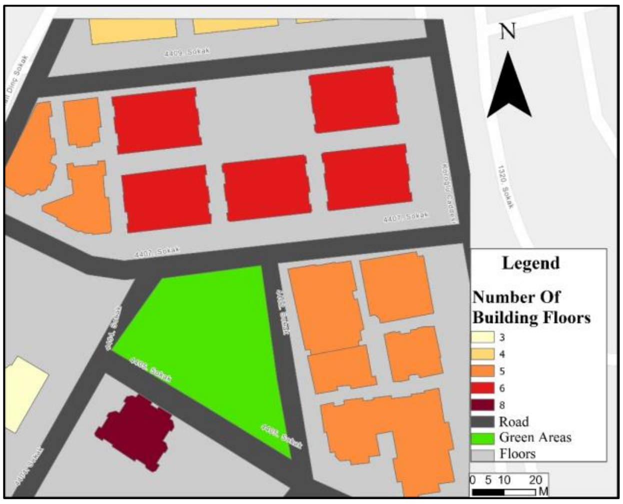

Fig. 2. Distribution of Land Uses in the Research Are

As part of the study, air temperature measurements taken at 2:00 PM on August 15th, 2022 were subjected to analysis. Within this time frame, the air temperature exhibits a range of fluctuation spanning from 31.56°C to 33.12°C. These data insights indicate that the prevailing land uses tend to diminish the favorable impact of green spaces, a phenomenon that can be primarily attributed to the prevalence of solid surfaces. Notably, regions characterized by asphalt and concrete surfaces register notably higher temperature readings, occasionally surging to 33°C. Conversely, locales graced with green spaces observe a decline in temperature, settling around 31.5°C (Figure 3). The study also harnessed ENVI-met simulations to assess the impact of augmented green space on temperature. In this scenario, the green area was expanded by 2,487 m² compared to the existing conditions, culminating in a total of 4,398 m² (Figure 4).

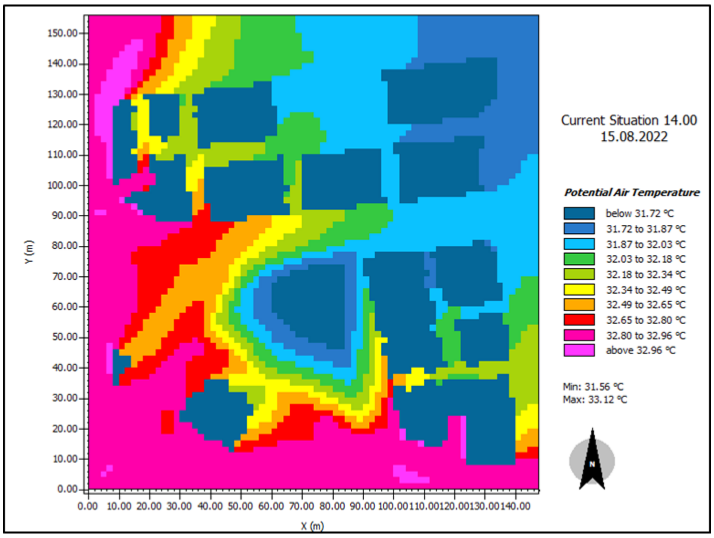

Fig. 3: Air Temperature Variations in the Current State of the Research Area

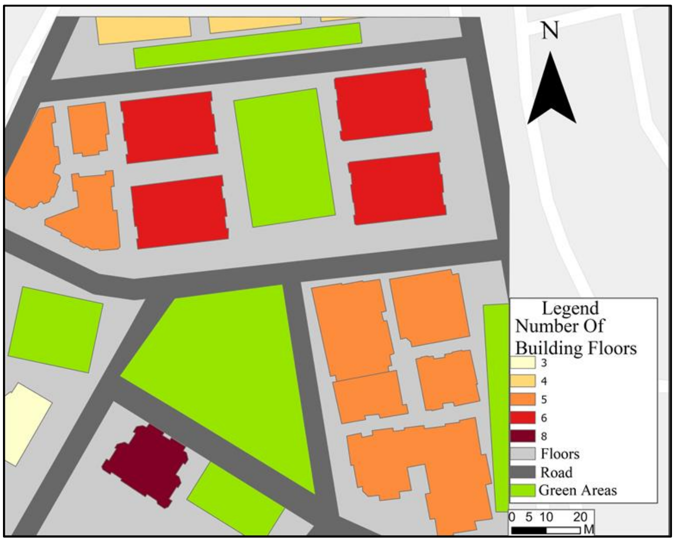

Fig. 4: Enhanced Green Area Scenario within the Research Scope

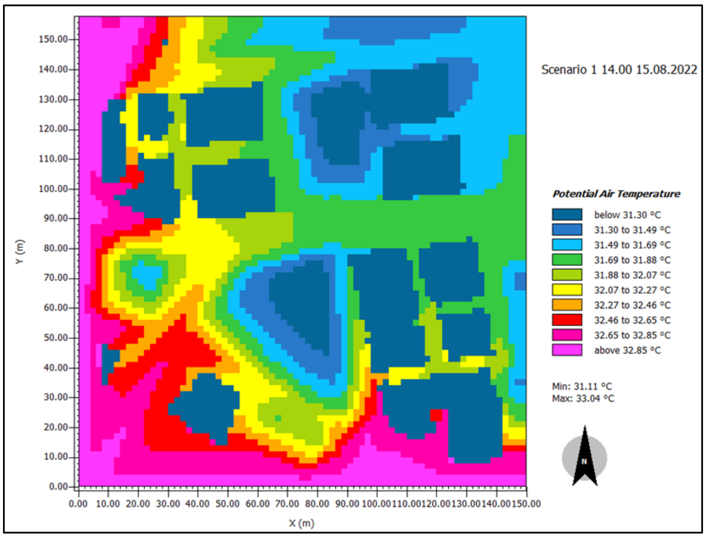

Fig. 5: Temperature Variation in the Scenario Scope

As a consequence of these alterations, a notable shift in temperature patterns was discerned, with temperatures generally ranging between 31.11°C and 33.04°C. This underscores the constructive role of amplified green spaces in temperature reduction and environmental enhancement. Notably, the temperature across the entire region experienced a decline of approximately 0.45°C (Figure 5).

In tandem with the positive influence of green spaces on microclimates, the study also identified environmental merits. Green spaces are instrumental in ameliorating air quality, curtailing carbon dioxide emissions, and mitigating urban heat. Trees and plants offer shading, aiding in the reduction of surface temperatures and offsetting the impact of solar radiation. Furthermore, green spaces play a pivotal role in storm water management, thereby mitigating flood risks.

This research is underpinned by models and analyses executed via the Envi-Met simulation software. Envi-Met serves as a potent instrument for comprehending and optimizing the interplay between urban domains and microclimates. The findings of this study furnish empirical grounding for decision-making, evaluating the effects of both the prevailing conditions and enhanced green spaces on microclimates.

This research showcases the outcomes of a study undertaken within the Yeşilyurt district research area. Through an examination of the present state, it has been ascertained that the prevalence of compact, solid surfaces and multi-story edifices contributes to temperature escalation. Conversely, augmenting green space yields favorable outcomes pertaining to temperature moderation and ecological sustainability. These findings underscore the paramount significance of green spaces in the blueprinting and configuration of urban landscapes, lending momentum to the formulation of policies and methodologies geared towards nurturing a more salubrious, comfortable, and sustainable environment.

In the progression of this research, cognizance was taken of insights gleaned from comparable studies. Diverse articles corroborate the impact of green spaces on urban microclimates. For instance, the work of Smith et al. (2018) delved into the role of green spaces in temperature regulation within New York City. The findings from their investigation demonstrated a tangible reduction in urban warming and temperature levels attributable to the presence of green spaces. It was discerned that surface temperatures exhibited a decrease, while the influence of trees' shading effect resulted in diminished wind speeds.

"In a similar vein, a study conducted by Johnson et al. (2020) scrutinized the influence of green spaces on urban microclimates. Their research unveiled the pivotal role of green spaces in temperature moderation, leading to reductions in temperature values. Moreover, it was discerned that these areas had a dampening effect on wind speed and contributed to an elevation in relative humidity levels. Furthermore, the study by Scott et al. (2017) delved into the repercussions of green spaces on temperature regulation. Their findings underscored the substantial cooling impact of urban parks, which translated into heightened thermal comfort. Correspondingly, the research indicated a decline in wind speed and an increase in relative humidity levels within these parks. These outcomes lend robust support to the affirmative influence of green spaces on urban microclimates.

In the study conducted by Zhou et al. (2019), the focus shifted to the impact of green spaces on air quality. Their research divulged a reduction in air pollution and an enhancement of air quality within areas encompassed by trees. It was deduced that green spaces effectively absorbed air pollutants, captured dust particles, and generated oxygen. These findings accentuate the pivotal role of green spaces in safeguarding health and nurturing urban sustainability.

The research undertaken by Lee et al. (2021) centered on the interplay between green spaces and mental well-being. Their findings demonstrated a tangible link between access to green spaces and improved mental health. Time spent in these verdant areas correlated with stress reduction, mental revitalization, and an overall elevation in life quality. These insights underscore the role of urban green spaces as a crucial factor in fostering human well-being.

These findings corroborate the affirmative impact of green spaces on urban microclimates, aligning with the outcomes derived from the study undertaken within the Yeşilyurt district. Green spaces wield a positive influence on urban comfort through mechanisms encompassing temperature regulation, shading, wind speed reduction, and elevation of humidity levels.

Furthermore, the ecological merits of green spaces are equally noteworthy. These spaces, integral to fostering an ecologically responsible water cycle, contribute to the collection of precipitation water and foster natural filtration processes. Moreover, green spaces bolster biodiversity by serving as habitats, enhance air quality, mitigate noise pollution, and positively impact mental well-being.

Collectively, these insights accentuate the paramount significance of integrating green spaces within urban planning and design paradigms. Amplifying the extent of green spaces within urban domains constitutes a pivotal stride towards establishing a sustainable and healthful environment. As such, the formulation of policies and strategies aimed at safeguarding, augmenting, and seamlessly integrating green spaces within urban landscapes becomes a necessity.

Conclusions and Suggestions

This study encompasses an evaluation conducted on August 15, 2022, at 2:00 PM within the Yeşilyurt neighborhood—an urban locale nestled in the heart of Mersin province, specifically the Tarsus district. Spanning an area of roughly 22,200 m², the research examines both the extant conditions and a scenario devised via ENVI-met, with a particular emphasis on augmenting green spaces. Through this analysis, temperature readings were ascertained.

Within the present scenario, characterized by a green area measuring 1,911 m², a distinct scenario was envisaged employing ENVI-met, wherein the green space was expanded by an additional 2,487 m². This supplementary green space enactment yielded a noteworthy reduction in temperature levels. The integration of ENVI-met-facilitated scenarios holds potential for steering the course of city planning and advancement, augmenting the urban environment's quality and sustainability.

The escalation of building surfaces and the proliferation of solid floors within urban landscapes stand as pivotal factors driving temperature elevation. Consequently, a strategic approach for augmenting green spaces becomes imperative. Nevertheless, it's essential to recognize that constraints in the horizontal plane might curtail the creation of green expanses. In such circumstances, local governments endeavor to devise solutions by formulating an array of strategies. Green facades and roofs emerge as viable tactics, capable of curbing urban heat and bolstering environmental sustainability.

The application of simulation tools like ENVI-met within urban planning endeavors equips local governments to arrive at informed decisions. These models enable the evaluation of the impact of green spaces and other ecological elements on urban comfort, achieved through a comprehensive analysis of city microclimates. Such an approach empowers the planning process, thereby enhancing the attainment of objectives such as temperature moderation, air quality enhancement, and an improved quality of life.

In conclusion, the findings derived from this study underscore the capacity of augmenting green spaces to mitigate the urban heat effect, and simulation tools like ENVI-met offer a potent resource within the planning paradigm. It is imperative that local governments proactively cultivate strategies for green space expansion and adopt decisions that align with the aims of environmental sustainability, thereby fostering improved urban microclimates and more comfortable living environments.

Drawing from the outcomes of this research, the subsequent recommendations can be posited:
Augmentation of Green Spaces: The research conclusively demonstrates that amplifying green space quantity holds the potential to curtail the urban heat influence. As such, prioritizing the augmentation of green areas should constitute a focal point within urban planning endeavors. Local governments must formulate strategies to convert vacant urban spaces into verdant zones while concurrently safeguarding existing green expanses.

Integration of Green Facades and Roofs: Green facades and roofs manifest as efficacious measures for mitigating heat impact within cities. These applications entail incorporating vegetation onto building exteriors and roofs. Local governments should institute policies and incentives that foster the proliferation of green facades and roofs.

- Ponding and Circulation Zones: Implementing ponding and circulation zones can offer a tangible reduction in the urban heat effect. These areas foster cooling through water evaporation. Local governments should embrace design strategies that incorporate ponds and circulation spaces within urban layouts.
- Thoughtful Plant Selection: Optimal plant selection holds key significance in attenuating temperature effects. Trees and sizable shrubs, by delivering ample shade, can effectively lower ambient temperatures. Simultaneously, a preference for indigenous plant species and water-resistant varieties that harmonize with the local ecosystem is paramount.
- Reevaluation of Urban Surface Materials: The role of rigid surfaces in temperature escalation cannot be overstated. Materials such as asphalt and concrete absorb solar radiation while failing to reflect or dissipate heat. Consequently, local governments should embark on the refurbishment of urban surface materials, opting for more reflective alternatives.
- Strategic Design of Public Spaces: The urban temperature impact should be a pivotal consideration in the scheming of public spaces. Elements such as shading trees, seating arrangements, and water installations can collectively contribute to tempering the heat effect within these areas. Hence, in devising public space plans, local governments should enshrine environmental sustainability and comfort criteria.

"These recommendations furnish a roadmap to thwart temperature escalation within cities and to cultivate more congenial living environments. By assimilating these suggestions into their urban planning processes, local governments can stride towards the realization of more sustainable and climate-resilient urban landscapes.

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