

LANDSCAPE DESIGN FOR PASSIVE COOLING AND ENERGY CONSERVATION

by

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(Under the Direction of Katherine Melcher)

ABSTRACT

Urbanization, a defining trend of the 21st century, brings both economic growth and significant challenges, including the creation of urban heat islands (UHIs), environmental degradation, and adverse impacts on human health. This thesis explores how landscape design can mitigate UHIs and enhance energy efficiency through passive cooling in urban environments, using Georgia Square Mall in Athens, Georgia, as a case study. The research examines UHI causes and effects, energy transfer in buildings, and the role of mechanical systems in climate change. It identifies landscaping techniques for passive cooling and heating, considers various climates, and evaluates these strategies using the ENVI-met simulation tool. The findings provide evidence-based recommendations for landscape architects, aiming to integrate landscape and architecture to improve energy efficiency and reduce UHIs.

INDEX WORDS: Urban Heat Islands, Passive Cooling, Thermal Comfort, Microclimate, Landscape Design, Georgia Square Mall

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Bachelor of Architecture, Gujarat University, India, 2019

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment
of the Requirements for the Degree

MASTERS OF LANDSCAPE ARCHITECTURE

ATHENS, GEORGIA

2024

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ACKNOWLEDGEMENTS

I would like to thank wholeheartedly everyone who has been part of my journey and contributed to the completion of my thesis.

Primarily, I would like to acknowledge the tremendous impact my thesis advisor, Katherine Melcher, has had on my academic career. Her wisdom, devotion, and unwavering guidance have been the keystones of this research in terms of its path and scope. The mentorship she provided throughout the thesis-writing process is deeply appreciated; without her honest feedback, perseverance, and guidance, I would never have completed it.

I would also like to thank Jessica Fernandez, Quint Newcomer, and Jose Buitrago for their immense support. I am grateful for the experiences I went through and for the lessons I learned from them.

Lastly, I would like to express my deepest gratitude to my family and friends for being a core source of support and motivation throughout the length of this project.

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CHAPTER 1

INTRODUCTION

Urbanization, one of the defining trends of this century, is rapidly increasing as more of the world's population resides in urban areas. While urbanization fosters economic development and social opportunities, it also poses significant risks to the environment and human welfare. Rapid urban growth has led to the loss of green space, increased energy consumption, and the creation of urban heat islands (UHIs), all of which negatively impact human health and the environment. UHIs are areas within cities that experience much higher temperatures than nearby rural areas due to the use of heat-absorbing construction materials and the lack of greenery. This results in discomfort for residents and increased energy needs for cooling, which in turn raises greenhouse gas emissions.

Recognizing the necessity of landscape integration to address these issues is crucial. Landscaping can mitigate the adverse effects of urbanization, reduce UHIs, and enhance environmental quality and human health. A holistic approach that focuses on the relationship between the built environment and the natural world is essential, as buildings are a major component of urbanization. The UHI effect can be minimized by incorporating landscaping strategies with architectural design and urban planning to create passive cooling spaces.

One of the primary objectives of landscape architecture is to improve the relationship between people and the natural environment that surround them. Urban environments, increasingly recognized as integral parts of the larger ecosystem, should not be viewed as separate from the natural world. By intertwining strategic landscape design with the built environment, we can

actively contribute to environmental sustainability, climate resilience, ecological health, social well-being, and the overall resilience of our communities. Shifting our perspective to integrate landscape design with the built environment is vital for creating sustainable and healthy spaces for both people and wildlife. Achieving this paradigm shift requires a fundamental redesign of our cities.

1.1. Problem Statement

Rapid urbanization in recent decades has introduced numerous challenges, including the formation of UHIs. The urban environment suffers from insufficient green areas and vegetation, which leads to the development of UHIs. This lack of greenery exacerbates UHIs, reduces environmental quality, and increases temperatures, significantly impacting the health and well-being of urban dwellers (Bikis, 2023). These issues underscore the urgent need for effective strategies to mitigate the negative impacts of urbanization.

The built environment is a primary contributor to this problem, as buildings tend to store and radiate heat back into the environment. The use of mechanical cooling systems exacerbates this issue by increasing the energy required for cooling, which in turn boosts greenhouse gas emissions and places additional stress on metropolitan infrastructure. Various approaches, such as increasing vegetation cover, and utilizing reflective materials, have been employed to address these challenges (Bikis, 2023). However, these strategies often face limitations, including fragmented implementation and the prioritization of aesthetics over functionality.

Consequently, there remains a pressing need for comprehensive and integrated solutions that synergistically combine landscape and the built environment. This approach involves the strategic placement of landscaping within urban areas and the built environment to incorporate passive cooling and energy conservation effectively.

1.2. Research Question

How can landscape design effectively mitigate urban heat islands and enhance energy efficiency through passive cooling in buildings?

The research question is divided into sub-questions, each addressed in respective chapters:

1. What are UHIs, their causes and effects? What role do mechanical systems play in exacerbating climate change, and what is the process of energy transfer in buildings?
2. How can landscape design passively cool or heat buildings? What strategies should be considered regarding site and architectural elements, and how do different climate regions influence landscape design strategies?
3. How to implement landscape design strategies for passive cooling and energy conservation in a mixed-use development on the outskirts of a small city in Georgia, incorporating strategies suitable for the southeastern climate of the Piedmont region, and what site analysis is necessary for effective implementation?
4. What are the limitations and trade-offs associated with strategic landscaping?

These sub-questions will guide the research across various dimensions of designing landscaping to mitigate the impact of UHIs formed by buildings.

1.3. Scope, Aim, and Objectives of Research

This research aims to explore and demonstrate how landscape design can achieve passive cooling and enhance energy efficiency in built environment of urban areas, thereby reducing the impact of urban heat islands. This study will cover the following key areas:

Assessment of Urban Heat Islands (UHIs):

- Analyze how UHIs are generated by the built environment, including the process of heat transfer to buildings and its impact on energy consumption and greenhouse gas emissions.

Exploration and Evaluation of Landscaping Techniques:

- Identify and analyze key strategies and design principles for landscaping to mitigate urban heat islands caused by the built environment.
- Evaluate the effectiveness of various landscaping strategies in different urban climates and building elements.

Investigation of Heat Transfer Prevention:

- Examine how landscape design can prevent heat transfer in the built environment through various processes.
- Research on Optimal Placement of Landscaping Elements:
- Determine the optimal placement of landscaping elements to achieve thermal comfort without relying on mechanical systems.

Exploration of Efficient Materials in Landscape Design:

- Identify the types and properties of materials in landscape design that are most efficient in enhancing energy efficiency and reducing UHIs.

Case Study Analysis and Application:

- Evaluate the impact of landscaping on energy savings through case study analysis.
- Apply identified strategies in the design of an urban project, assessing the trade-offs, challenges, and limitations encountered.

While extremely important and necessary, further urbanization issues like infrastructure growth, transportation infrastructure, or socio-economic considerations are beyond the scope of this research study.

By achieving these objectives, the thesis aims to provide evidence-based landscaping strategies for strategically placing landscapes within the built environment. Additionally, it offers guidelines for landscape architects on designing landscapes that contribute to indoor energy conservation and mitigate UHI effects in urban areas.

1.4. Site Introduction

The chosen site for this research is Georgia Square Mall, located on Atlanta Highway in Athens, Georgia, United States (see Figure 1 & 2). Athens, a mid-sized college town with a population exceeding 120,000, offers a relevant context for exploring the challenges and opportunities associated with declining malls and urban heat islands.



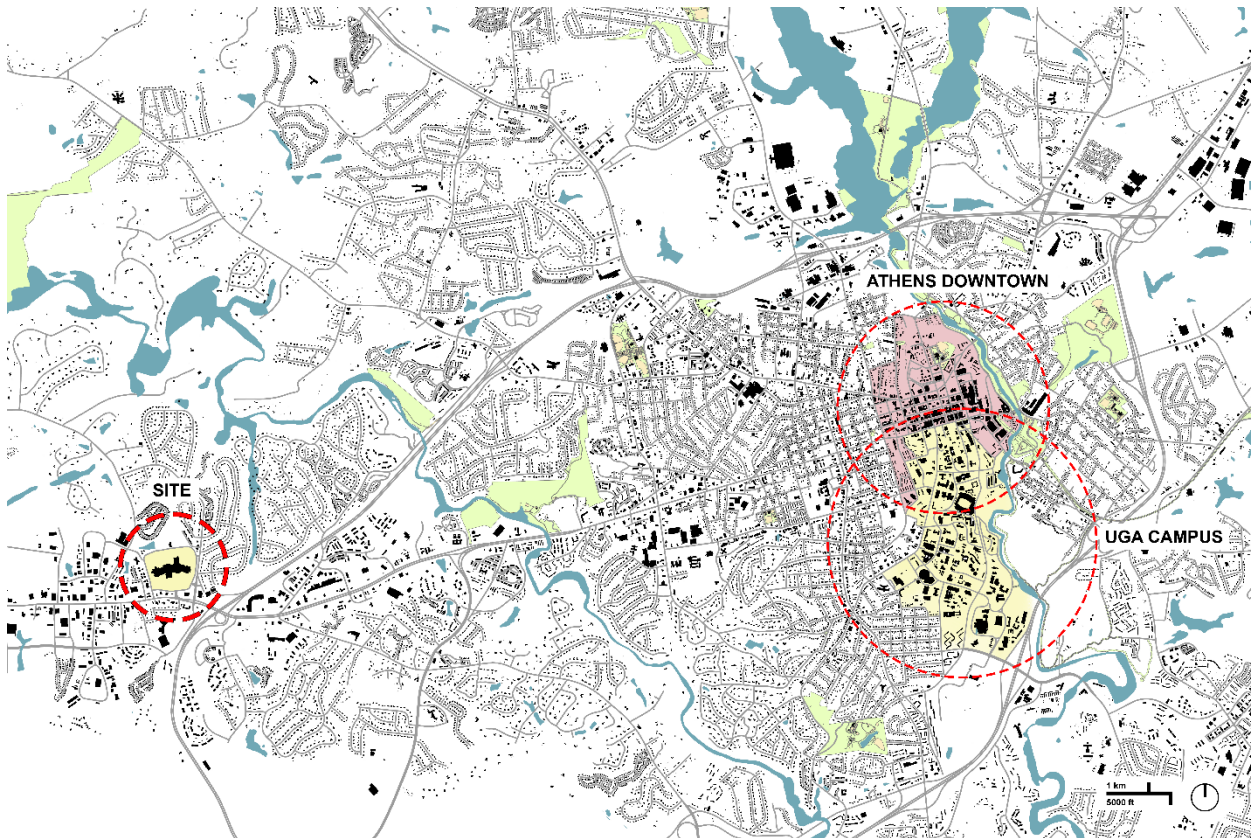
*Figure 1: Location Map
(Source: GIS Geography 2013)*

Justification for choosing this site:

- According to the report “The Death and Rebirth of the American Shopping Mall: Part 1” (2023), the Georgia Square Mall exemplifies the nationwide decline of large shopping

malls in the United States. This mall's situation reflects a broader trend throughout the United States, making it a valuable case study for understanding the environmental and social impacts of such decline (Meier 2023).

- The site's extensive parking lot coverage (80%) poses a significant challenge, as large expanses of asphalt contribute to the urban heat island effect.
- The underutilized state of the mall presents a valuable opportunity to explore redevelopment strategies that integrate landscape design principles.



*Figure 2: Athens Map
(Source: Author)*

By selecting Georgia Square Mall as the project site, this thesis aims to highlight the research findings and apply them to a real-world context, focusing on reducing the UHIs exacerbated by extensive asphalt coverage in parking lots, exploring strategies for sustainable

redevelopment amidst the mall's underutilization, and examining broader implications for urban areas grappling with similar declines and environmental challenges. The project will specifically target strategies to conserve energy and enhance environmental quality through strategic landscape design interventions.

Moreover, there is an ongoing proposal for the site being crafted by W&A Engineering, which is also discussed in my thesis. In the later section, an evaluation is conducted based on three different site designs/conditions: the existing condition, the proposal by W&A Engineering, and the re-imagined master plan developed by me. This evaluation includes a comparison of these conditions using methods such as area distribution analysis and ENVI-met simulation to assess their impact on the site.

1.5. Conclusion

Rapid urbanization poses significant challenges, impacting environmental quality, energy consumption, and human health. This thesis addresses these issues through landscape architecture, focusing on mitigating UHIs and enhancing energy efficiency via passive cooling strategies.

Using Georgia Square Mall in Athens, Georgia, as a case study, this research applies theoretical concepts to a real-world context. The mall's extensive asphalt coverage and decline offer a unique opportunity to implement innovative landscape strategies to reduce UHIs, conserve energy, and improve environmental quality.

This research aims to provide a comprehensive understanding of Urban Heat Islands (UHIs) and effective landscape design strategies. By reviewing literature and applying these strategies in real-world contexts, the study offers guidelines for landscape architects to design landscapes that significantly contribute to passive cooling, energy conservation, and the reduction of UHIs. It is

important to note that the scenarios discussed in this thesis represent an 'ideal scenario,' free from real-life constraints such as budget limitations, client input, and other practical considerations.

In conclusion, integrating landscape design which encompasses strategic placement of landscaping elements, vegetated roof, windbreaks, water bodies, and hardscape material with the built environment can effectively mitigate the adverse effects of urbanization, enhance energy efficiency, and improve urban life quality. This research aims to provide insights for future urban development projects, advocating for a balanced approach that meets human needs while ensuring environmental sustainability.

CHAPTER 2

METHOD

This chapter details the methods used (see Table 1) to explore how landscape design can mitigate urban heat islands (UHIs) and enhance energy efficiency through passive cooling in a mixed-use development on the outskirts of a small city in Georgia. The strategies are tailored to the southeastern climate of the Piedmont region. The methodology aligns with the research sub-questions, objectives, and scope of research outlined in the previous chapter.

This study adopts a mixed-methods approach, combining quantitative data from simulations with qualitative insights from secondary data collection to provide a comprehensive understanding of the impacts of landscape design. The study adhered to ethical guidelines, ensuring data integrity and proper attribution of all sources.

Research Sub-Question	Objectives	Scope of Research	Method
<p>What are UHIs, their causes and effects? What role do mechanical systems play in exacerbating climate change, and what is the process of energy transfer in buildings?</p>	<p>To review and synthesize current theories on the effects of urbanization and the concept of urban heat islands.</p> <p>Analysis of how UHIs are generated by the built environment. This includes examining the process of heat transfer to buildings and its impact on energy consumption and greenhouse gas emissions.</p>	<p>The research will focus on UHIs, their causes, effects, and the role of mechanical systems in exacerbating climate change.</p> <p>It will also encompass the process of energy transfer in buildings and its implications for energy consumption and greenhouse gas emissions.</p>	<p>Data for the research is collected through secondary sources by reviewing existing literature on UHIs, climate change, urbanization, and energy transfer.</p>
<p>How can landscape design passively cool or heat buildings? What strategies should be considered regarding site and architectural elements, and how do different climate regions influence landscape design strategies?</p>	<p>To identify and analyze key strategies and design principles for landscaping to mitigate UHIs caused by the built environment.</p> <p>To investigate the role of landscaping techniques in creating passive cooling spaces and conserving energy.</p>	<p>Investigation of how landscape design can prevent heat transfer in the built environment through various processes.</p> <p>Research on the optimal placement of landscaping elements to achieve thermal comfort without relying on mechanical systems.</p>	<p>Data collection will involve a review of existing literature and case studies on landscape design strategies, passive cooling techniques, and their effectiveness in mitigating UHIs.</p> <p>Analysis of different climate regions and their influence on landscape design strategies is conducted through comparative studies and synthesis of relevant literature.</p>

Research Sub-Question	Objectives	Scope of Research	Method
How to implement landscape design strategies for passive cooling and energy conservation in a mixed-use development on the outskirts of a small city in Georgia, incorporating strategies suitable for the southeastern climate of the Piedmont region, and what site analysis is necessary for effective implementation?	To apply identified strategies in the design of a mixed-use urban project.	Investigation of landscape design strategies for passive cooling and energy conservation tailored to the southeastern climate of the Piedmont region, specifically in a mixed-use development context. Analysis of site-specific factors and necessary site analysis techniques to effectively implement these strategies.	A case study approach is been used in a real-world context to observe the impact of UHI mitigation strategies. The Georgia Square Mall in Athens, Georgia, serves as the case study due to its representative characteristics of UHIs, including extensive paved surfaces, minimal vegetation, and high ambient temperatures. Additionally, the mall's potential for redevelopment makes it an ideal site for the implementation of these strategies.
What are the limitations and trade-offs associated with strategic landscaping?	To assess the trade-offs, challenges, and limitations encountered with strategic landscape design in regard to buildings.	The design outcomes is been assessed by comparing existing and proposed designs. Simulation of the microclimatic impacts is been performed using ENVI-met simulation software.	The assessment involves comparing existing and proposed landscape designs. ENVI-met simulation software is been used to simulate and analyze the microclimatic impacts of these designs.

Table 1: Methodology
(Source: Author)

CHAPTER 3

LITERATURE REVIEW

This chapter dives into the phenomenon of urban heat islands (UHIs). I will examine the mechanisms driving UHI formation, analyze the contributing factors, and their environmental impact (see Figure 3). Additionally, I will explore the connection between UHIs and air-conditioners, which serve as a significant source of greenhouse gases, exacerbating urban heat. Furthermore, the chapter will investigate how UHI-generated heat transfers to buildings and surrounding areas, aiming to develop effective strategies for mitigating heat-related impacts. By understanding what UHIs are, their causes and effects, and the role of mechanical systems in exacerbating climate change, this chapter will set the foundation for exploring how strategic landscape design can be utilized in the following chapter to mitigate these impacts and contribute to sustainable urban planning.

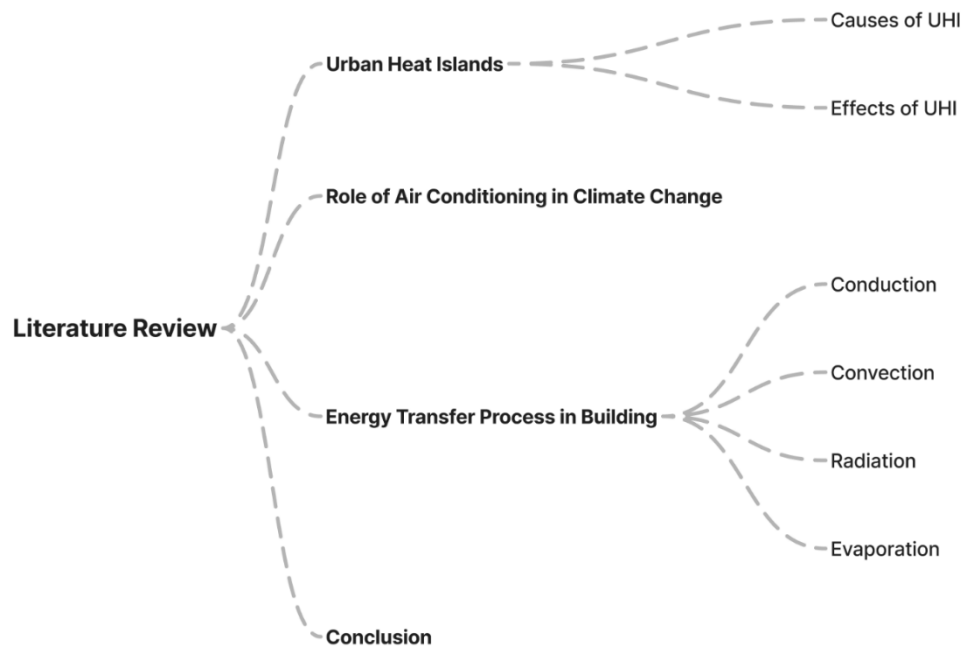


Figure 3: Overview of the Literature Review
(Source: Author)

3.1. Urban Heat Island

The phenomenon known as an urban heat island (UHI) occurs when temperatures in metropolitan areas are noticeably higher than in nearby rural or natural areas (see Figure 4). It occurs due to the modification of the local climate caused by human activities and the built environment.

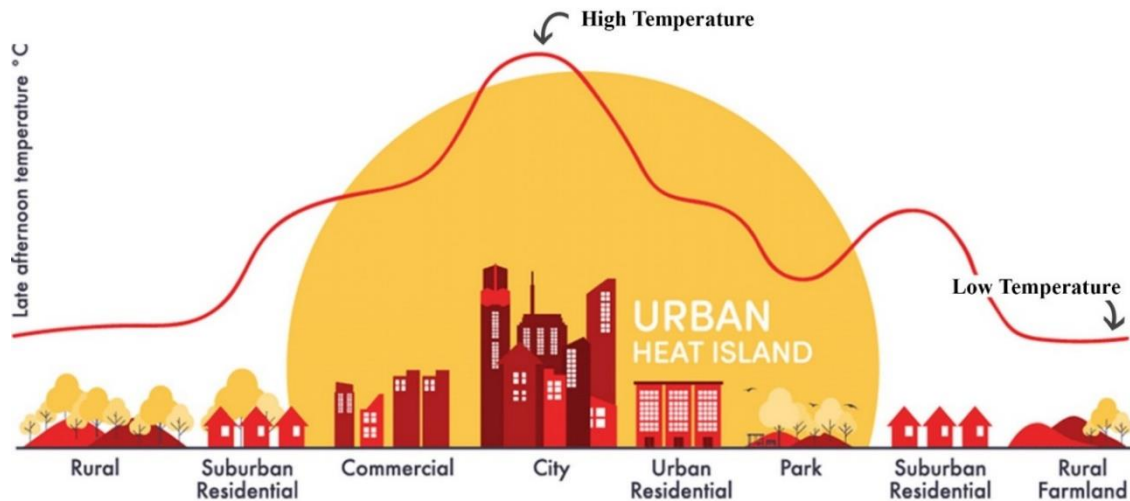


Figure 4: Conceptual diagram illustrating Urban Heat Islands
(Source: Fuladlu, Müge, and Ilkan 2018)

According to research by Bikis (2023), urban heat islands typically develop in densely populated areas with extensive concrete and asphalt surfaces, tall buildings, and a lack of vegetation. The heat island effect causes daytime temperatures in urban areas to be 0.6-3.9°C higher than those in outlying areas, and night-time temperatures to be 1.1-2.8°C higher (US EPA, 2014). The heat island effect will become stronger as metropolitan areas continue to expand and alter in terms of their structure, size, and population density (see Figure 5).

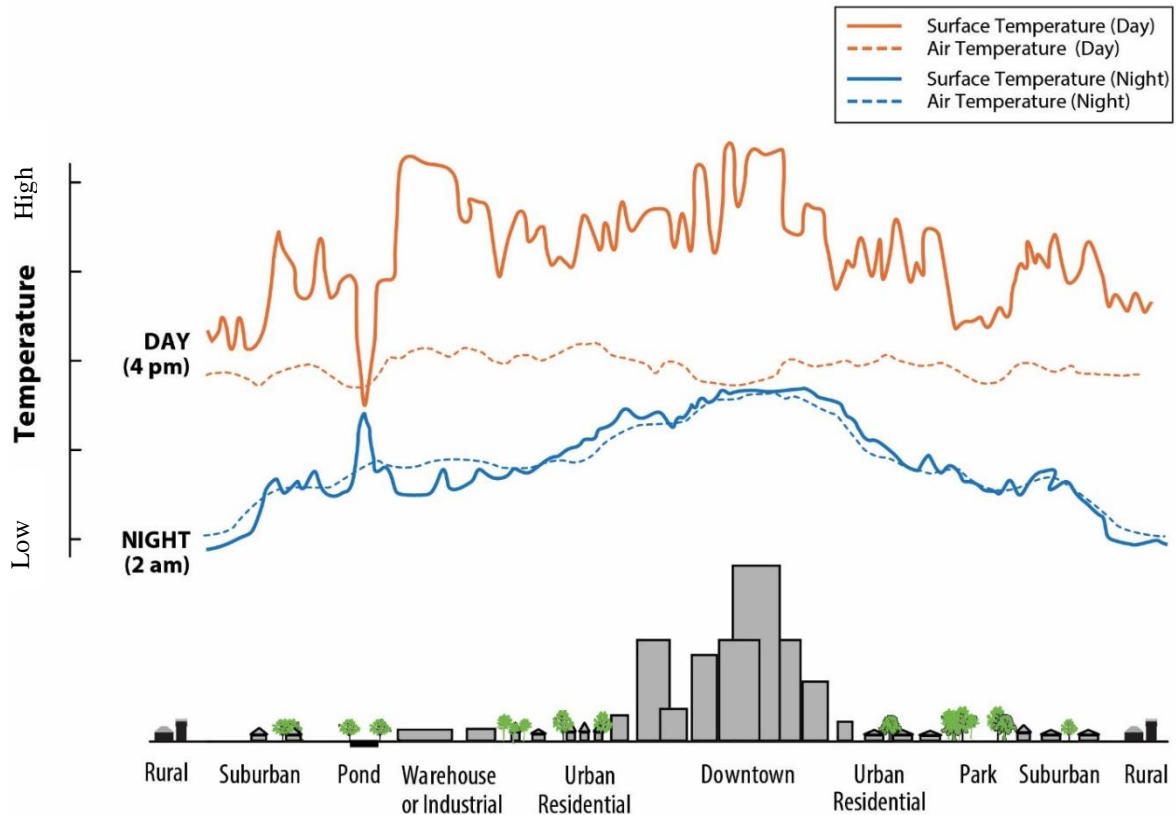


Figure 5: Conceptual diagram illustrating Surface and Air Temperatures
(Source: US EPA, 2014)

3.2. Causes of UHI

According to the US EPA (2014), the main causes of UHIs include:

- **Heat Absorption:** Urban areas have substantial amounts of dark surfaces, such as roads, parking lots, and buildings, which absorb and retain heat from the sun, resulting in higher temperatures. This is also caused by albedo effect (ability of a surface to reflect sunlight). Urban areas have a lower albedo due to presence of dark surfaces.
- **Reduced Vegetation:** The removal of vegetation, including trees and green spaces, to make way for buildings and infrastructure reduces shade and the cooling effect of evapotranspiration (the process by which plants release moisture into the atmosphere).

Green spaces help absorb carbon dioxide, release oxygen, and provide shade, thereby reducing temperatures.

- Human Activities: Activities like industrial processes, vehicle emissions, air conditioning systems, and the concentration of heat-generating sources in cities contribute to increased heat production.
- Urban Geometry: The layout and design of urban areas affect the intensity of heat islands. Tall buildings can create "urban canyons," where the streets are enclosed by high-rise structures. This can restrict air movement, impede natural ventilation, and trap heat within the city, leading to higher temperatures.

3.3. Effects of UHI

According to the report "Urban Heat Islands and Their Adverse Effects on Their Inhabitants" (n.d.), UHIs have several effects on the urban climate, as well as the environment, human health, and energy use. Among the major impacts are:

- Increased Energy Consumption and emissions of greenhouse gases: The urban heat islands make cities hotter, which increases the need for cooling and use of air conditioning. The use of cooling equipment leads to emissions of greenhouse gases and production of carbon dioxide and other pollutants, which contributes to climate change. According to US EPA (2014), peak utility loads in medium and large cities (Phoenix, Las Vegas, Houston, New York) are predicted to increase by 1 to 2 percent for every 0.6°C increase in midsummer temperature (see Figure 6). The warming effect of heat islands during the winter months may even be advantageous for cities in colder climates.

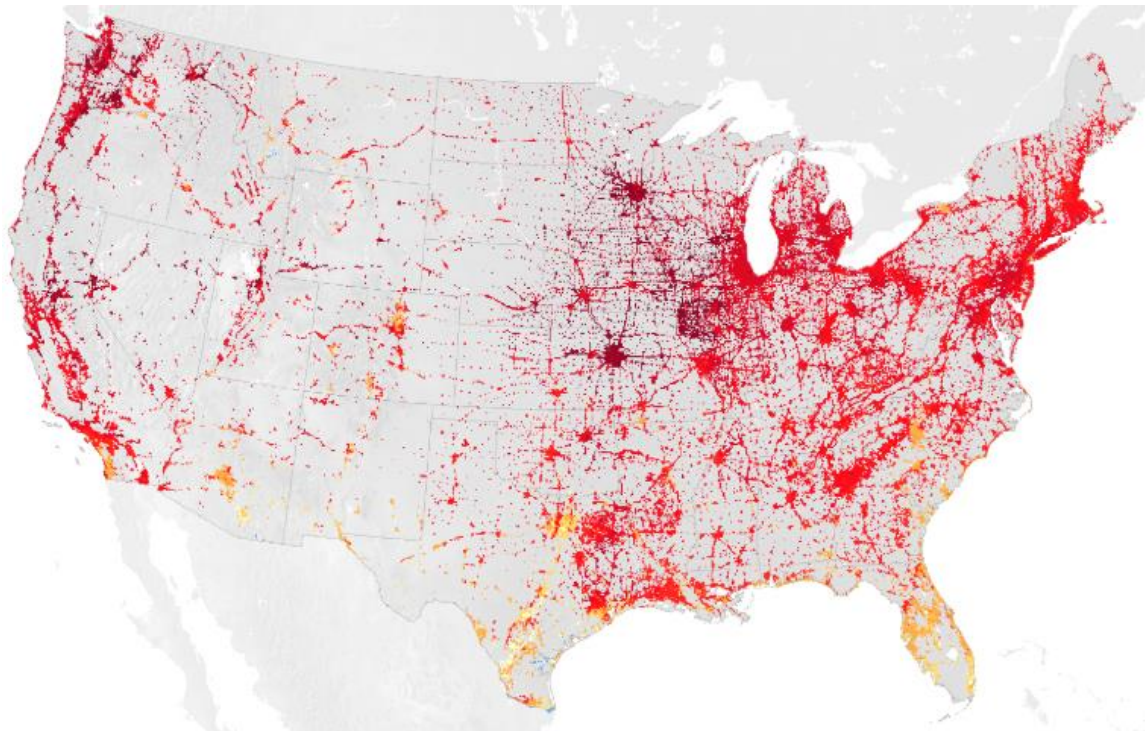


Figure 6: Temperature variation in the United States.
(Source: *Urban Heat Islands*. 2019)

- Air Pollution: Because of the combination of high temperatures, increased energy consumption, and the trapping of pollutants, UHIs can worsen air pollution levels. These pollutants, including volatile organic compounds and nitrogen oxides, interact with sunlight to create smog and ground-level ozone.
- Risk to Public Health: UHIs have higher rates of heat-related ailments such as heat exhaustion and heatstroke, particularly for vulnerable populations such as the elderly, children, and people with pre-existing medical conditions. Research by Morakinyo et al. (2019) indicates heat stress conditions are worsening during the summer months in urban areas, contributing to a rise in heat-related fatalities.
- Urban Ecology: UHIs cause environmental disruption in urban areas by modifying wildlife behavior and lowering biodiversity. The disappearance of vegetation can affect local flora

and fauna and diminish habitats available to birds, insects, aquatic species, and other wildlife.

- Challenges with Infrastructure: UHIs can add to the burden already placed on infrastructure, such as buildings, roads, and transportation networks. Higher temperatures can cause materials to thermally expand, increase wear and tear, and shorten the lifespan of infrastructure parts.

3.4. Role of Air Conditioning in Climate Change

According to Salamanca et al. (2014), use of air conditioners drives a reinforcing feedback loop of Urban Heat Island. While they cool indoor spaces, they release heat outdoors, contributing to UHI. Instead, of helping to mitigate the heat island effect, air conditioning can make it worse. In accordance with the Economic Times (2019), air-conditioning units funnel heat outside, exacerbating the UHIs, which makes cities warmer than the countryside.

As noted by Mamadou et al. (2024), the building sector accounted for 30% of the global energy consumption and was responsible for 26% greenhouse gas emissions worldwide in 2022. A significant portion of this energy consumption is due to space heating and cooling. Since 2000, there has been an average yearly increase of 4% in energy consumption for this purpose. Moreover, the International Energy Agency (IEA) projects a 40% increase in energy demand for building space cooling worldwide by the year 2030.

According to a research article by Miranda et al. (2021), 1.8 to 4.1 billion individuals will require air conditioning to mitigate heat related health risks by 2050, and the electricity demand for cooling will match the current combined consumption of the United States, Japan and Europe. Moreover, in accordance with International Energy Agency (IEA), this equates to the sale of 10 new air conditioners every second for the next three decades.

In the study conducted by Salamanca et al. (2014), several ways in which air conditioning exacerbates the UHI effect were identified. These are as follows:

- Waste Heat: Air conditioners release heat outdoors after removing it from indoor rooms. Millions of air conditioning units in urban areas produce waste heat, which raises the ambient temperature overall.
- Increased Energy Consumption: To operate, air conditioning needs a significant quantity of electricity. The electrical grid is strained due to the increased demand for electricity in urban areas, particularly during the sweltering summer months. The heat island effect is made worse by the additional waste heat and greenhouse gas emissions produced by power plants, which frequently burn fossil fuels.
- Reduced Natural Ventilation: The reliance on enclosed, insulated spaces brought on by air conditioning prevents natural ventilation and air circulation. This lack of ventilation can make it harder for heat to dissipate, which increases the amount of heat that builds up in cities and exacerbates the heat island effect.
- Infrastructure and Heat Absorption: Air conditioners blow warm air close to structures and infrastructure, such as concrete buildings and roads, which tend to absorb and hold heat. The UHI effect is influenced by the accumulation of heat in urban surfaces and building materials.

3.5. Energy Transfer Processes in Building

The built environment is a primary contributor to UHIs, as buildings store and radiate heat into the environment, as detailed in section 1.1. This section explains how energy is transferred into and from buildings, affecting the storage and radiation of heat. Santos and Spirn (1981) identify conduction, convection, radiation, and evaporation as the primary mechanisms through which

structures, spaces, and site areas can gain or lose heat. These heat transfer processes frequently occur simultaneously in buildings. Optimizing building envelope insulation, ventilation systems, and passive cooling techniques requires a thorough understanding of these mechanisms. By effectively controlling conduction, convection, radiation, and evaporation, buildings can increase energy efficiency, improve thermal comfort, and reduce reliance on mechanical heating and cooling systems. The following points briefly summarize these energy transfer processes:

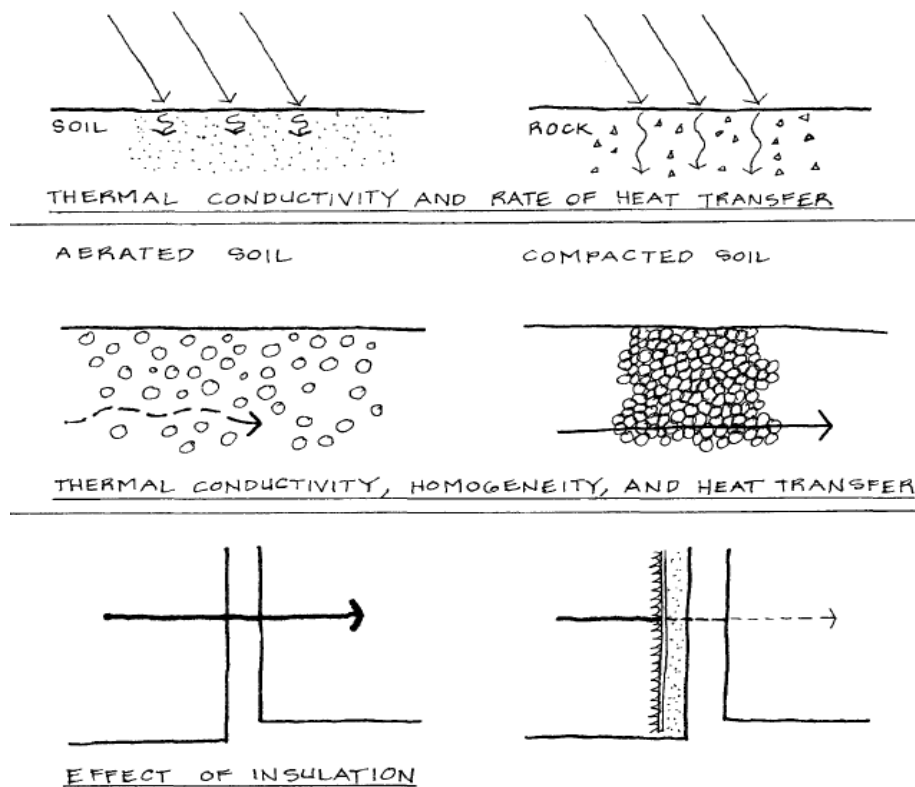


Figure 7: Process of energy transfer through conduction
(Source: Santos and Spirn 1981)

- a. Conduction: Heat can transfer directly between two materials through physical contact (see Figure 7). Heat transfers from the hotter to the colder object when two objects or materials in contact have different temperatures. Conduction in buildings mostly happens through

the walls, floors, ceilings, windows, and other solid parts. Heat is more easily transferred through higher thermally conductive materials like metals than wood, brick, or concrete.

- b. Convection: The movement of fluids (liquids or gases) causes the transfer of heat. Convection frequently happens in structures due to air movement (See Figure 8). Convection occurs when warm air rises and cooler air sinks, creating a circular pattern. Continuous circulation results from cooler air replacing heated air as it goes upward.

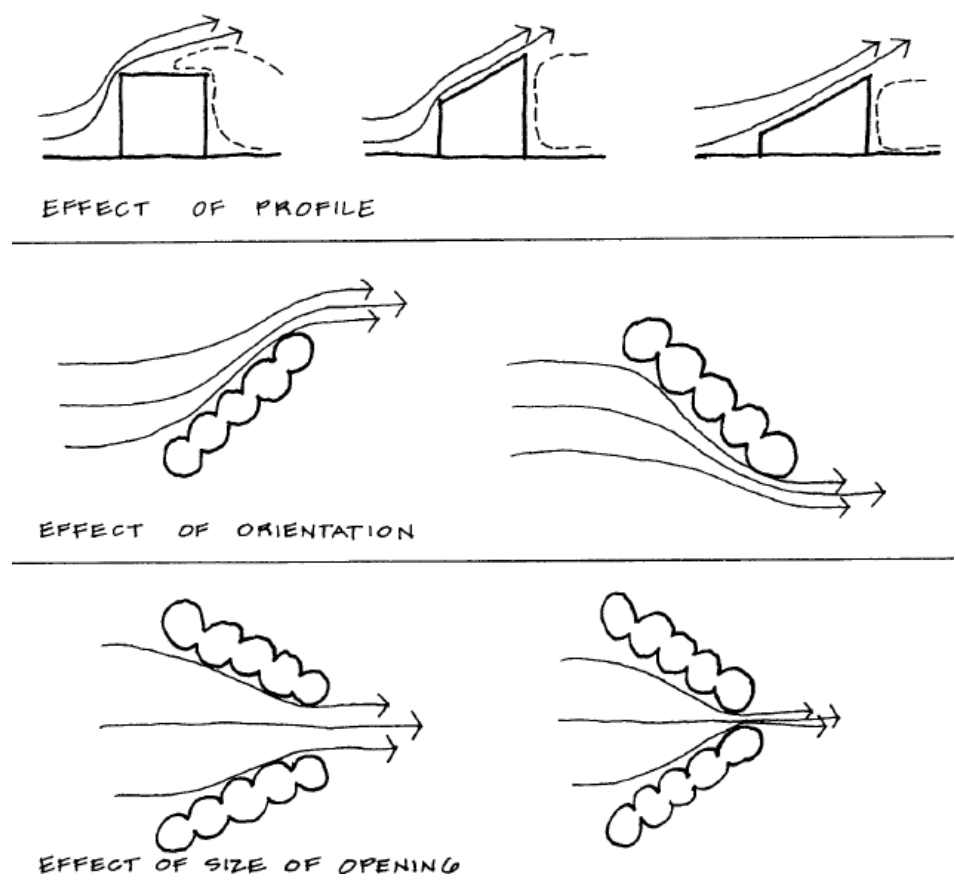


Figure 8: Process of energy transfer through convection
(Source: Santos and Spirn 1981)

- c. Radiation: Without a medium or direct touch, radiation is the transfer of heat through electromagnetic waves. Thermal radiation is emitted and absorbed by all things and is influenced by their surface characteristics and temperature (see Figure 9 & 10). In structures, radiation takes place between various surfaces, including walls, floors, and items inside a space. For instance, heat is radiated back into the area when sunlight enters a room and strikes heated surfaces. The comfort and temperature of indoor spaces are significantly influenced by the exchange of thermal radiation.

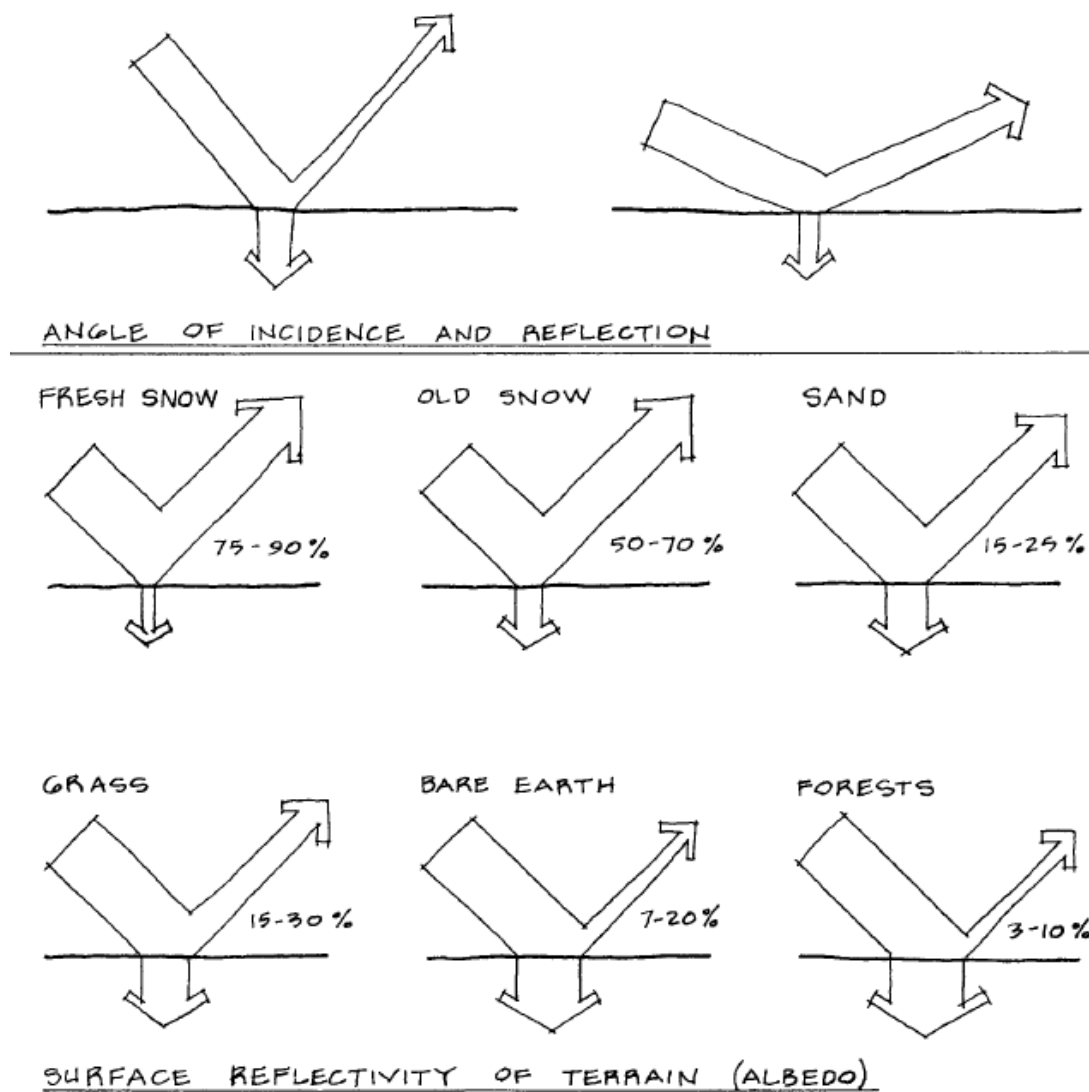
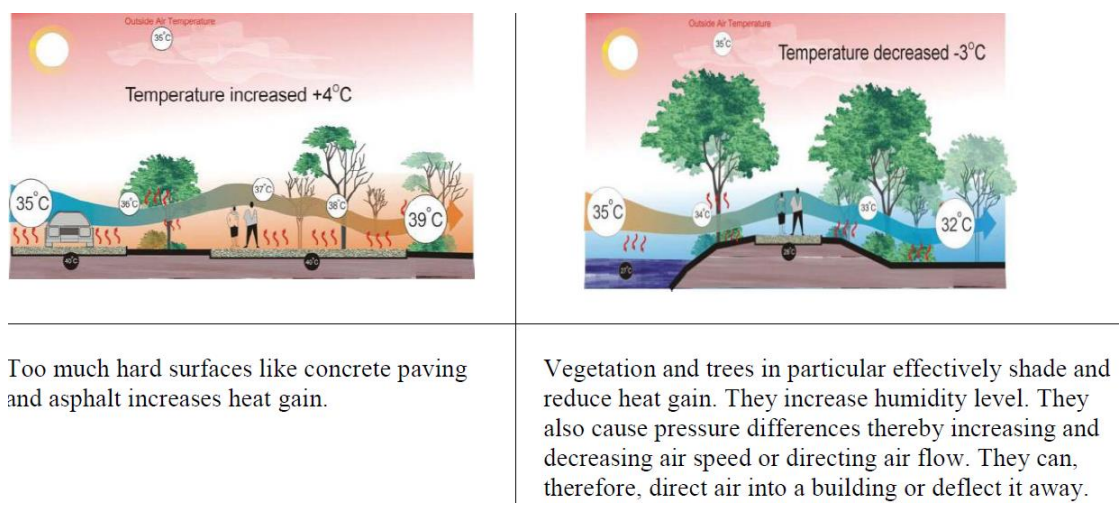


Figure 9: Percentage of energy transfer through radiation on different materials
(Source: Santos and Spirn 1981)



Too much hard surfaces like concrete paving and asphalt increases heat gain.

Vegetation and trees in particular effectively shade and reduce heat gain. They increase humidity level. They also cause pressure differences thereby increasing and decreasing air speed or directing air flow. They can, therefore, direct air into a building or deflect it away.

Figure 10: Energy transfer through radiation
(Source: Girei et al. 2013)

The three processes of energy transfer that happen in buildings are summarized in Figure 11 illustrated below.

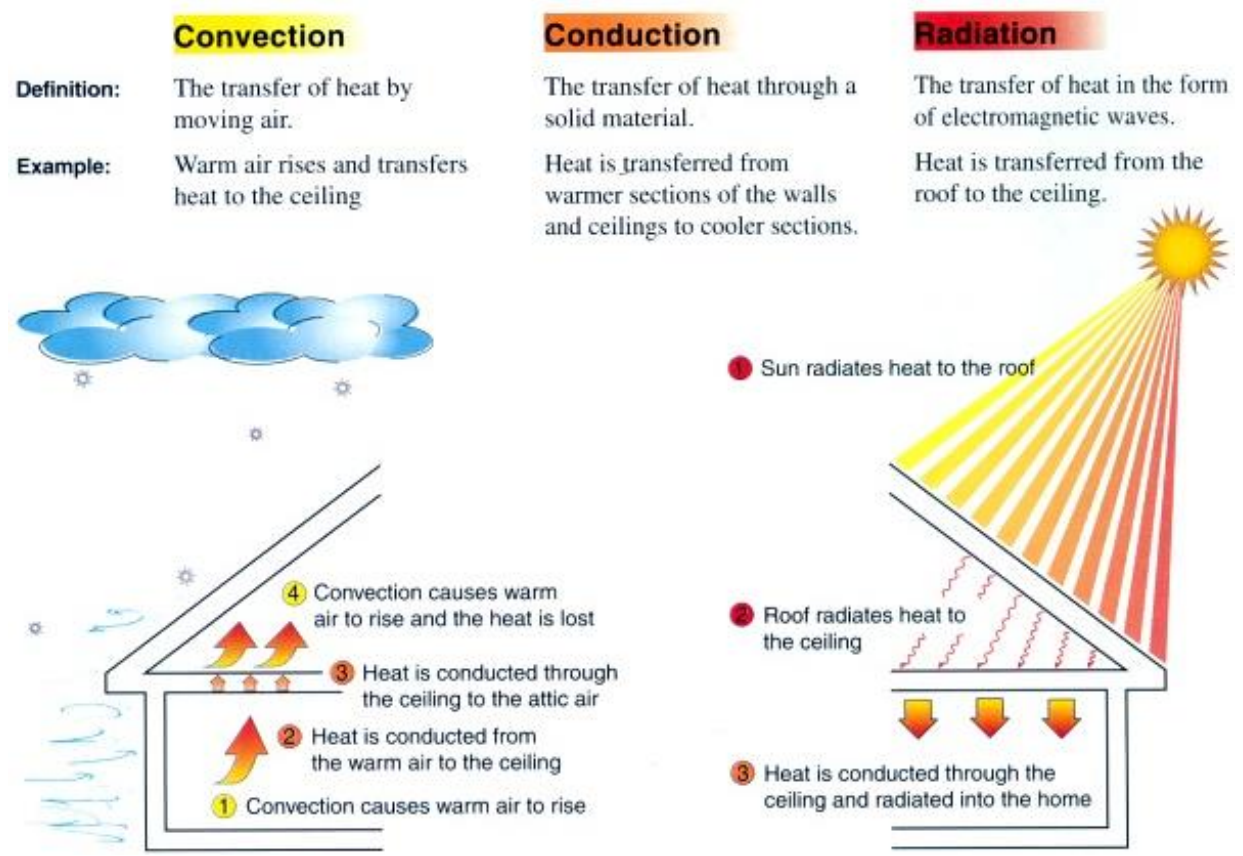


Figure 11: Illustration of heat transfer methods in buildings
(Source: Kumar 2016)

d. Evaporation: Evaporation is the process through which a liquid turns into a gas (see Figure 12 and 13). Evaporation requires a lot of energy, mostly in the form of heat, to complete the transformation. Evaporation hence has a cooling impact. It can contribute to heat loss in specific situations.

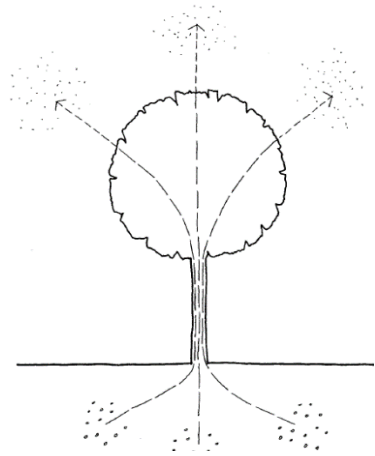


Figure 12: Process of evaporation through tree
(Source: Santos and Spirn 1981)

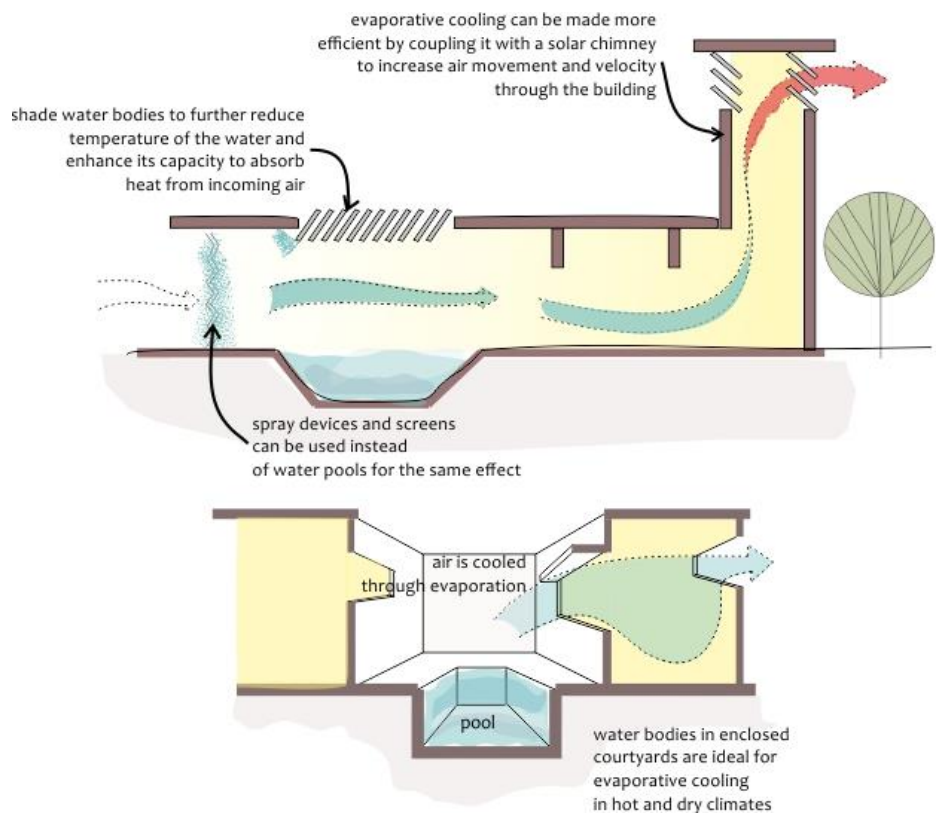


Figure 13: Process of energy transfer through evaporation
(Source: Girei et al. 2013)

3.6. Conclusion

The situation described above regarding heat transfer processes within buildings represents a potential reinforcing feedback loop that occurs in areas affected by the urban heat island effect. As temperatures rise, the demand for air conditioning increases, leading to higher electricity consumption. Unfortunately, this surge in energy usage also contributes to elevated carbon dioxide levels and increased emissions. These emissions from power plants exacerbate global warming, further raising temperatures within affected areas. Consequently, this situation indirectly contributes to discomfort in indoor environments due to external heat influencing building conditions. Understanding these dynamics is crucial for addressing the overarching research question of how UHIs and mechanical systems impact urban climates and building energy use. In the next chapter, I will explore how strategic landscaping can mitigate heat transfer in buildings, reduce the reliance on air conditioning, lower energy demands, and improve thermal comfort in the built environment. This will involve introducing the concept of passive cooling through strategic landscaping techniques, thus addressing how landscape design can passively cool or heat buildings and informing strategies for different climate regions.

CHAPTER 4

LANDSCAPE FOR PASSIVE COOLING

This chapter will explore how strategic landscaping can effectively mitigate the impact of urban heat islands (UHIs) and help create thermal comfort in buildings without relying on mechanical systems such as air conditioning. It will cover techniques to enhance the microclimate of a site and its surroundings. Building on the methods of heat transfer discussed in the previous chapter, this chapter will present the objectives of heat transfer and address them through strategic landscape design. Additionally, it will go through various landscape interventions and examine how they can be applied in different climate zones, determining optimal landscape placement (see Figure 14). By addressing the research question on passive cooling and heating through landscape design, this chapter aims to provide a foundational understanding that will guide the implementation of these strategies in the next chapter's focus on mixed-use developments.

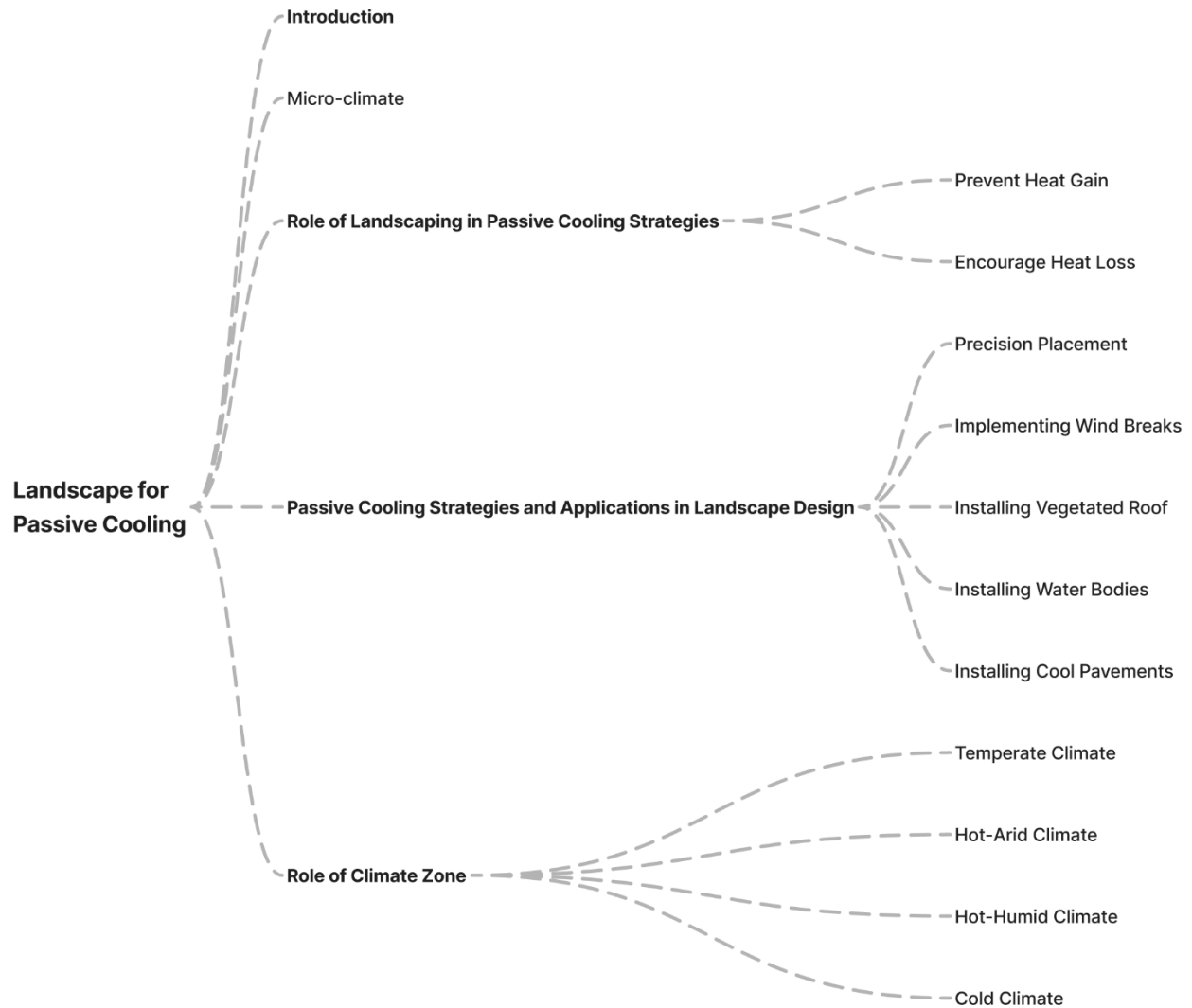


Figure 14: Overview of Landscape for Passive Cooling
(Source: Author)

4.1. Introduction

In the pursuit of sustainable architecture and landscape design, the concept of passive design stands as a fundamental principle. According to McGee (2013), ‘passive design’ is an approach that works with the local climate to create a comfortable indoor temperature without relying heavily on mechanical systems. As noted by Miranda et al. (2021), passive cooling offer advantages by avoiding the use of refrigerants [such as chlorofluorocarbons (CFCs) or hydrofluorocarbons (HFCs)], which harm the ozone layer and contribute significantly to global

warming. Moreover, passive cooling technologies are low maintenance and have lower running costs.

According to research by Liu et al. (2012), increasing the presence of green spaces is an effective strategy to counter the degradation of urban thermal environments and mitigate the heat island effect. Landscaping plays a pivotal role in preventing solar heat from infiltrating indoor spaces, leading to reduced interior temperatures and decreased reliance on air conditioning (Getter and Rowe 2006).

Beyond temperature regulation and energy conservation, landscaping also facilitates microclimate control, enhances visual aesthetics, fosters ecological diversity, mitigates rainwater runoff, protects structures, reduces air pollution and noise, alleviates urban living stresses, and offers therapeutic benefits. Incorporating landscape design into urban areas has proven to be a successful approach for enhancing living standards while achieving essential ecological goals such as energy efficiency and carbon emission reduction (Carter and Keeler 2008). As stated by Akbari (2009), landscapes not only sequester carbon dioxide from the environment but also reduce the need for air conditioning, thus preventing carbon dioxide emissions.

Plants represent just one element within the broader landscape that can be leveraged for passive cooling. Passive cooling techniques can be further enhanced by strategically positioning buildings in relation to water features, land formations, and existing vegetation. Optimal cooling can be achieved by integrating plant design with overall architectural form (Santos and Sprin, 1981). Architectural form plays a crucial role in passive cooling strategies. According to Baruch Givoni (1994), key architectural design elements that influence solar load include building layout, orientation, size of openings, shading devices, color of the building envelope and vegetation near the building. While extensive research has been conducted on these features for passive cooling,

vegetation's role has been relatively understudied in this context. This chapter will delve into this overlooked aspect, exploring how vegetation can effectively contribute to passive cooling strategies.

The role of landscaping in reducing solar and heat radiation cannot be overstated. While landscapes are valued for their aesthetic qualities and provision of shade against direct solar radiation, their potential for passive cooling is often overlooked. Landscaping can effectively enhance the microclimate surrounding a building, contributing to its overall sustainability (Santos and Sprin 1981). As evidenced in a study by Lechner (2015), strategically positioning and selecting appropriate landscape species can demonstrably influence a building's heating, cooling, and lighting requirements, resulting in a decrease in energy consumption by up to twenty-five percent. This effect is particularly notable in buildings located in urban areas with high population density and warm climates, where heat island effects are pronounced.

Passive cooling strategies focus on three key areas: heat gain control, humidity management, and air movement (ventilation). These can be addressed by managing seasonal solar control (access to winter sun and summer shade) and incorporating features for natural ventilation.

4.2. Microclimate

A building site's immediate environment, known as its microclimate, plays a pivotal role in landscaping for energy efficiency. It is crucial to consider both microclimate and the regional climate when planning landscaping strategies for effective climate control (Girei et al. 2013).

Microclimates may experience more or less sunlight, shade, wind, rain, snow, moisture, or dryness compared to typical local conditions. For instance, even if the site is in a cool region, a structure situated on a sunny southern slope might possess a warm microclimate. Similarly, in a hot-humid region, building sites might enjoy a comfortable microclimate due to ample shade and

dry breezes. The nearby bodies of water can influence the site's humidity and air temperature. These microclimatic factors also influence the suitability of various plants for the landscape (Girei et al. 2013).

According to an article by Rodie and Streich (2009), microclimates can be enhanced through these steps:

- Channeling or screening winds;
- Protecting outdoor living spaces and structures from summer heat while allowing exposure to winter sun;
- Increasing or decreasing humidity (or the precipitation of humidity) through adjustments in the air movement.

4.3. Role of Landscaping in Passive Cooling Strategies

According to an article by Parker (1983), the core principle of landscape planning for energy conservation and passive cooling lies in manipulating air temperature, humidity, radiation, and air movement. This manipulation aims to create microclimates that align with human comfort preferences within a specific location and timeframe. By strategically integrating both hard and soft landscape elements, well-designed landscaping can significantly reduce the energy consumption of a building.

The objectives for passive cooling must prevent heat gain and encourage heat loss from the inside and outside of the structure and from the surroundings. Figure 14 shows how landscaping prevent heat gain and enhance heat loss.

As illustrated in Figure 15 and researched by Santos and Sprin (1981), landscaping help in reducing heat gain by:

1. Providing shade to the building and adjacent surfaces.

2. Intercepting radiation reflected or emitted from surrounding surfaces.
3. Acting as insulation for building walls and roofs.
4. Acting as a barrier against hot winds.

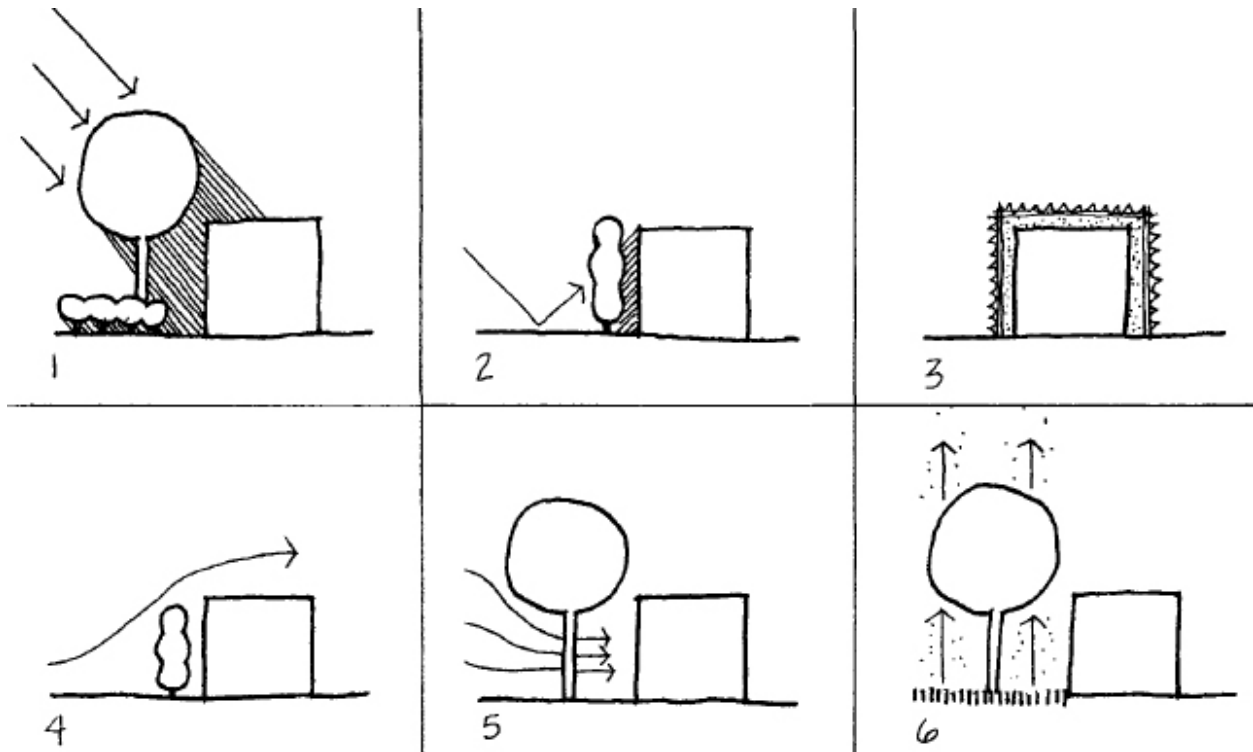


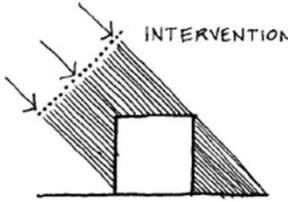
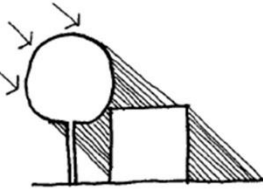
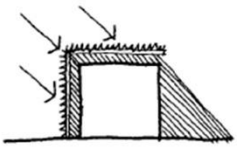
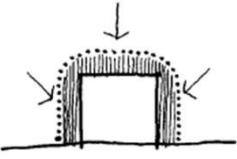
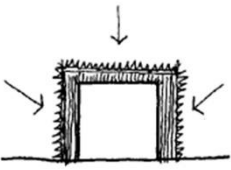
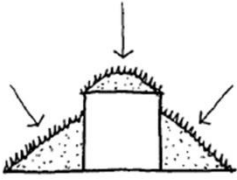
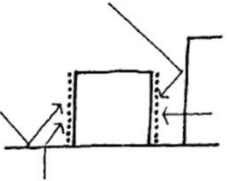
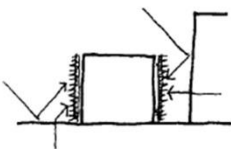
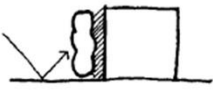
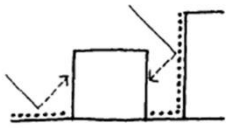
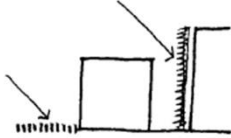
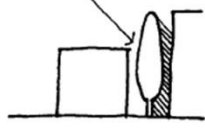
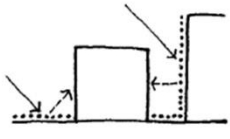

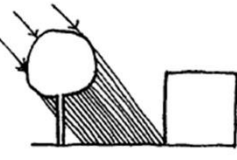
Figure 15: Illustrated Passive Cooling Objectives
(Source: Santos and Sprin 1981)

Landscaping facilitate heat loss by:

5. Directing and augmenting the speed of cool breezes.
6. Extracting heat from the surrounding environment through evapotranspiration.

Figures 15 and 16 illustrate ways to prevent heat gain and encourage heat loss in buildings, tailored to different objectives. These objectives address the various types of heat transfer processes discussed in Chapter 2: radiation, convection, conduction, and evaporation. Furthermore, Figures 16 and 17 showcase landscape applications corresponding to each objective and the specific medium of energy transfer.

PREVENT HEAT GAIN

Objective: Prevent heat gain through radiation	Application	
<p>a. Avoid direct solar radiation</p> 	 <p>TREE CANOPY</p>	 <p>VINE SCREEN</p>
<p>b. Avoid indirect solar radiation</p> 	 <p>VINE SCREEN</p>	 <p>PLANTED BERM</p>
<p>c. Avoid reflected solar radiation reflected by (i) adjacent, and (ii) surrounding ground and walls.</p> 	 <p>VINE SCREEN</p>	 <p>SHRUB WALL</p>
<p>d. Avoid emitted, stored, and absorbed radiation by ground and walls.</p> 	 <p>PLANT FLOOR/SCREEN</p>	 <p>TREE WALL</p>
<p>d. Avoid emitted, stored, and absorbed radiation by ground and walls.</p> 	 <p>PLANT FLOOR</p>	 <p>TREE CANOPY</p>

PREVENT HEAT GAIN

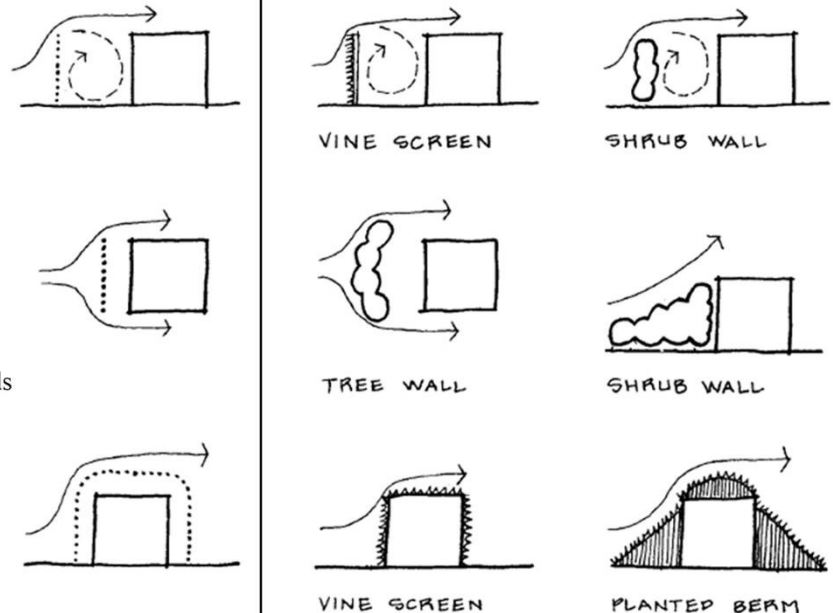
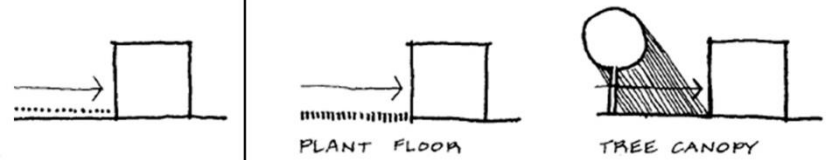
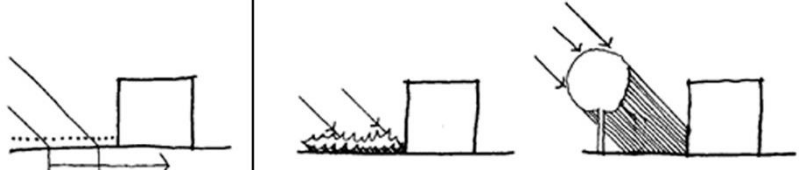
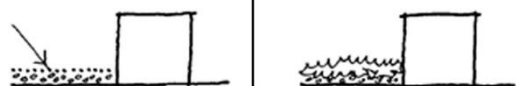
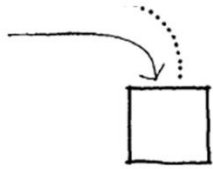
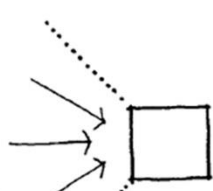
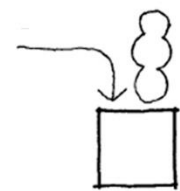
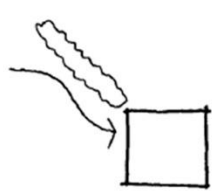


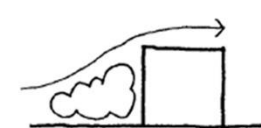

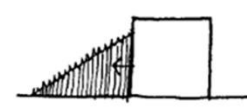


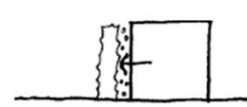
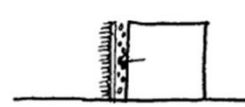
Objective: Prevent heat gain through convection	Application
<p>a. Prevent infiltration of hot winds by (i) reducing wind speed, (ii) deflecting hot winds, and (iii) insulating building.</p>	 <p>VINE SCREEN SHRUB WALL</p> <p>TREE WALL SHRUB WALL</p> <p>VINE SCREEN PLANTED BERM</p>
<p>b. Prevent formation of hot winds.</p>	 <p>PLANT FLOOR TREE CANOPY</p>
Objective: Prevent heat gain through conduction	Application
<p>a. Reduce heat storage in adjacent ground</p>	
<p>b. Cool adjacent ground</p>	

Figure 16: Illustrated ways to prevent heat gain
 (Source: Santos and Sprin 1981)

ENCOURAGE HEAT LOSS

Objective: Encourage heat loss through convection	Application	
<p>a. Increase ventilation by cool breezes by (i) directing cool breezes towards building, and (ii) increasing wind speed.</p>  	 <p>PLANT WALL</p>	 <p>PLANT WALL</p>
<p>b. Direct winds over wall and roof with cooler air.</p> 	 <p>VINE CANOPY</p>	 <p>SHRUB WALL</p>
Objective: Prevent heat gain through evaporation	Application	
<p>a. Increase evaporative surfaces.</p> 		
<p>b. Increase rate of evaporation by using plants which have the potential to transpire large amounts of water, increasing convection over evaporative surfaces, and providing ample water supply to plants.</p> 		

ENCOURAGE HEAT LOSS

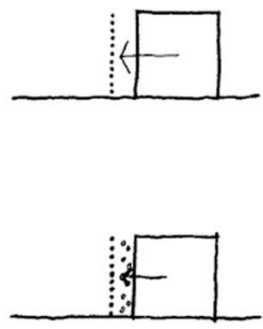
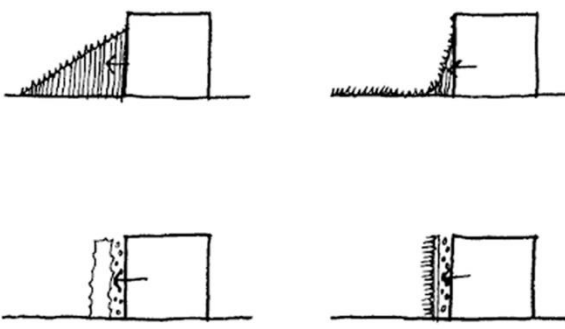
Objective: Encourage heat loss through conduction	Application
 <p data-bbox="219 861 836 997">a. Encourage conduction by heat from building walls and roof by (i) exposing building to cool conductors, and (ii) by trapping cool air by evapotranspiration next to building walls and roof.</p>	

Figure 17: Illustrated ways to encourage heat loss
(Source: Santos and Sprin 1981)

4.4. Passive Cooling Strategies and Applications in Landscape Design

Use of landscape for passive cooling offers a sustainable and cost-effective approach to achieving thermal comfort in buildings without relying heavily on mechanical air conditioning. In accordance with Seckin (2018), landscaping is an effective tool for heating, cooling, and lighting of buildings. In Figure 18, I have outlined five techniques for mitigating heat islands and implementing passive cooling through landscape design, which are further elaborated in the subsequent sections.

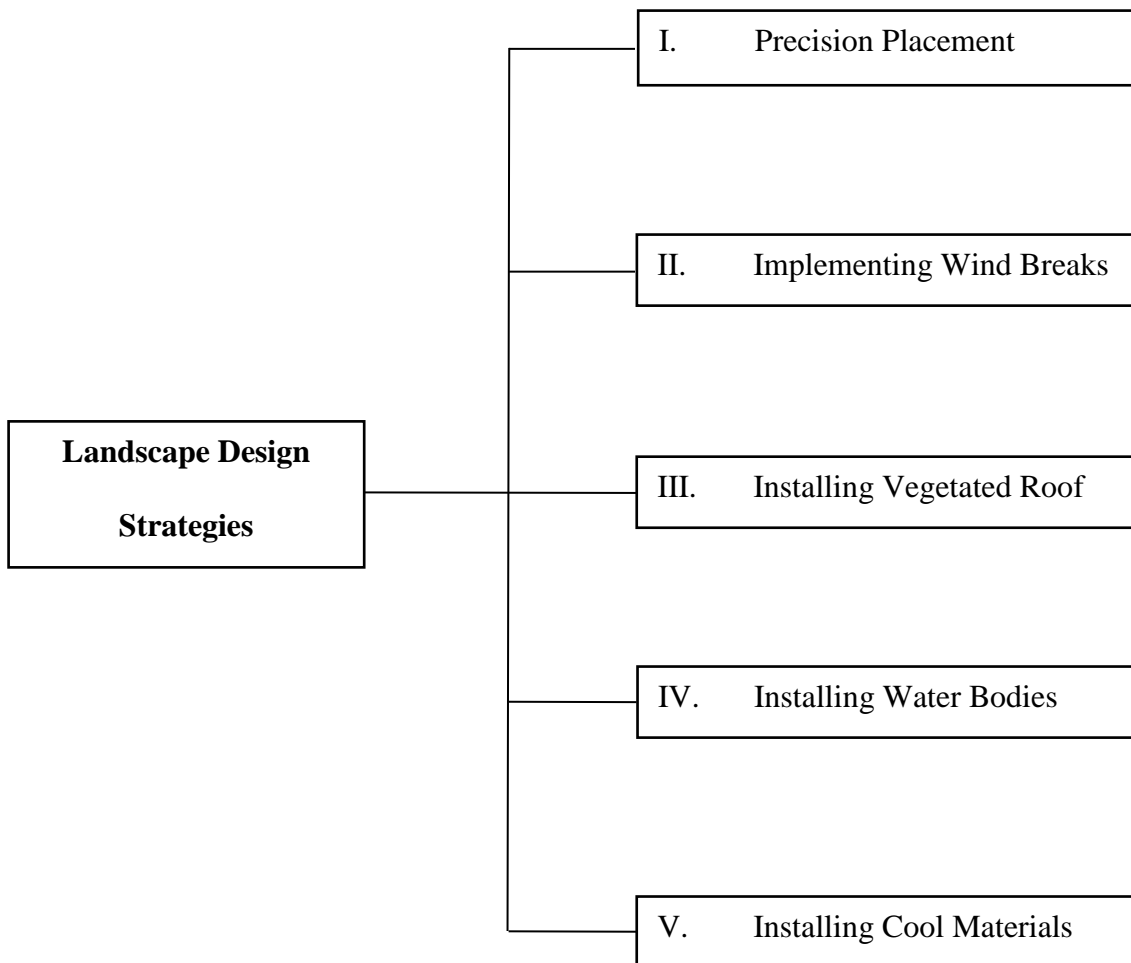


Figure 18: Illustrating heat mitigation strategies

I. Precision Placement of Landscaping

According to the US EPA (2014), strategically planting trees and various vegetation (including bushes, shrubs, tall grasses, and vines) around buildings serves as an effective heat island mitigation strategy. Selecting appropriate landscaping species and precisely placing them is crucial for energy conservation (Kunhs, 2016).

According to research by Akbari (2009), strategic landscaping influences microclimate and building energy consumption in two ways. Firstly, it provides direct benefits by shading buildings

and surfaces, thereby blocking solar radiation and preventing the structures from exceeding ambient air temperatures. Secondly, it offers indirect cooling by lowering the surrounding air temperature through evapotranspiration (evaporation + transpiration). Trees, for instance, can release up to 100 gallons of water through transpiration daily. In hot, dry climates, this cooling effect can be as impactful as running five air conditioners for 20 hours. Strategically planted trees and vegetation near buildings have been shown to reduce summer air conditioning usage by 15-35%, and even up to 50% in specific cases.

As stated by ElHissi (2012), precision placement of vegetation involves considering several factors. These include the type of plant species, distance from the structure, crown spread, foliage characteristics, mature height, number and grouping of species, orientation according to solar path, and climate zone. Some of these factors are discussed below.

Deciduous trees: According to Akbari et al. (1992), selecting deciduous trees is beneficial for energy efficiency as they block solar radiation during summer while allowing it in during winter. This significantly reduces energy demand for cooling in summer and heating in winter (see Figure 19). Deciduous trees with broad, high-spreading crowns are particularly effective for energy conservation, especially if branches are pruned to maximize sunlight exposure in winter (Wong, 2008). While both deciduous and evergreen trees contribute to energy conservation, planting large-canopied deciduous trees on the west side, along with a hedge immediately adjacent to the west wall, can lower west wall temperatures by 15.6°C (Akbari, 2009).

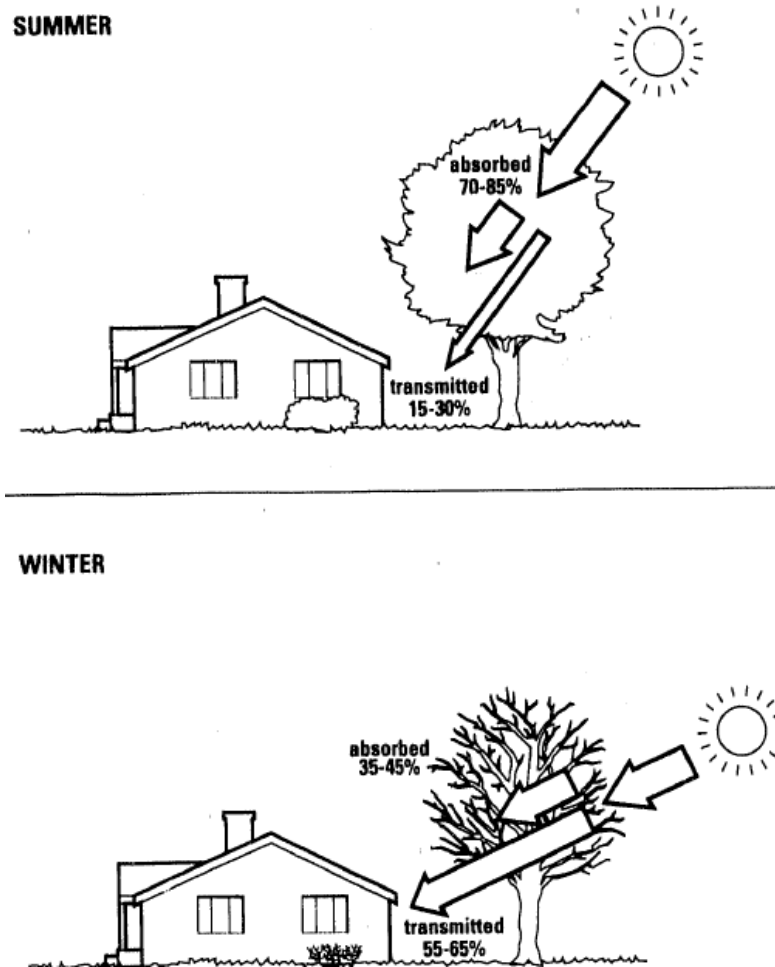


Figure 19: The shade provided by deciduous trees varies between summer and winter.
 (Source: Heisler, 1986)

Canopy Type: When planting trees for shading, large canopies with moderate density are most effective. Oval or columnar trees are ideal for narrow spaces and close proximity to buildings due to their upward growth. Rounded trees with descending branches require significant space, while those with ascending or lateral branches are suitable for areas where clearance for vehicles and pedestrians is necessary. Vase-shaped trees are particularly well-suited for urban environments, as they grow up and out, creating a shaded canopy over streets, walls, and sidewalks (Akbari, 2009).

Canopy Height and Distance from Structure: The mature height of trees plays a crucial role in solar reception. Trees can be classified by height as small (3.6m – 9m), medium (9m-15m), and large (over 15m) (Kevin and Pat, 2009). Trees with mature height of at least 7.5m should be planted 3 to 6m east or west of the structure (Kuhns, 2016). For the northwest or northeast corners of a structure, taller species are recommended to cast a longer shadow (Akbari, 2009). To avoid winter shadowing, trees should be positioned at least 2.5 times their height to the south of a structure.

Foliage Attributes: Ennos and Rahman (2016) highlight that trees with higher Leaf Area Indices (LAI) provide more efficient cooling. LAI, which represents leaf density, plays a crucial role in determining a tree's shading effectiveness. Additionally, Nugroho (2014) notes that leaf color significantly impacts passive cooling. Light-colored leaves have been found to lower both indoor and outdoor temperatures effectively.

The incident solar radiation on a specific facade is determined by the path of the sun and its altitude angle throughout the day and year (Kuhns, 2016). A sun diagram illustrating the sun's movement during different seasons is illustrated in Figure 20, clarifying its movement angle. For a comprehensive understanding of the solar diagram of the site, a detailed solar path diagram is included in Chapter 5. Furthermore, precision landscaping, tailored to the climate zone and solar path, is thoroughly explored in section 3.6 later in this chapter.

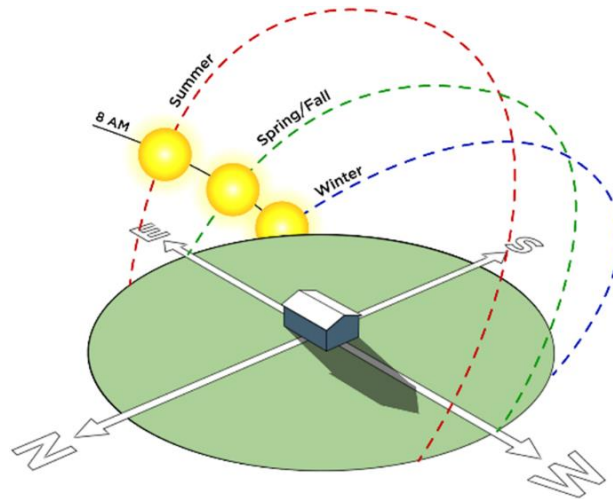


Figure 20: Solar path diagram
(Source: Parker, 1983)

Based on Parker's research (1983), air conditioners significantly contribute to electrical peak demand. Shading the air conditioner unit and the surrounding area is an effective method to reduce energy consumption (see Figure 21). A vine-covered trellis around the air conditioner (ensuring a minimum distance of 1.5 meters) can reduce the surrounding temperature by 3.5°C , potentially enhancing the air conditioner's efficiency by approximately 10% during peak usage periods. Additionally, shading of air conditioning units alone can save up to 10% in annual energy consumption (Akbari, 2009).

According to Sandifer, 2019 and Akbari, 2009), vines can effectively reduce building surface temperatures, shade windows, and improve the microclimate around buildings by providing shade and evapotranspiration benefits. Applying vines to south and west-facing walls, with a thickness of 12-14 inches, can lower surface temperatures to match or even fall below ambient air temperature, negating the effect of surface color. Additionally, a pergola covered with vines can help control surface temperature, provide shade for windows, and create a comfortable outdoor environment. Positioning vines a few meters away from the building allows for an insulating air space (see Figure 22). They are particularly useful while trees and shrubs are

maturing (Akbari, 2009). Using deciduous vines is recommended, as they provide summer cooling while allowing winter sun to warm exterior walls (Sandifer, 2019).

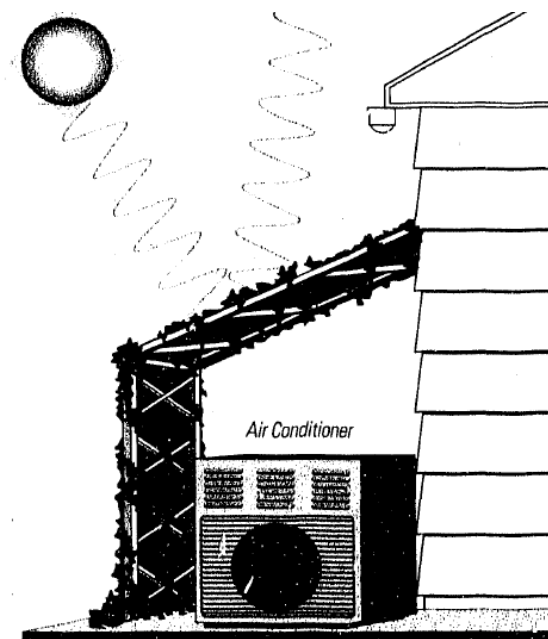


Figure 21: Shading the air-conditioner unit
(Source: Koon, 1989)

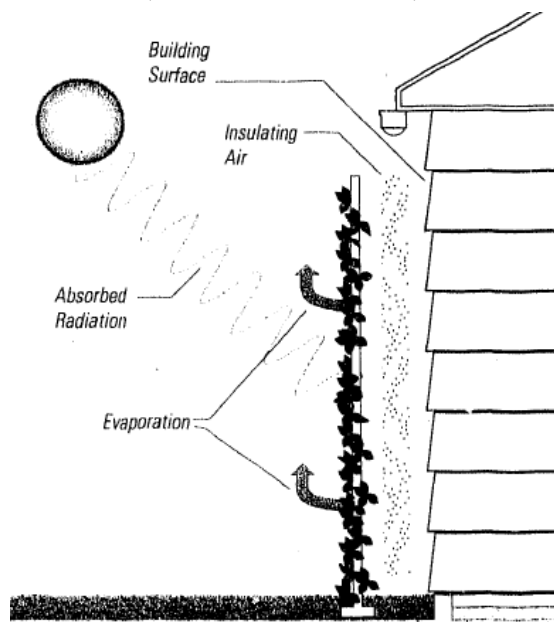


Figure 22: Illustrating vine trellis
(Source: Moffat and Schiler, 1989)

II. Implementing Wind Breaks

Wind is an important climatic element which affects thermal comfort and can be managed for heat gain and loss by implementing windbreaks. Windbreaks play a crucial role in controlling air movement and its impact on buildings (Seckin, 2018). According to Kunhs (n.d.), landscape design, using rows of trees and shrubs, can reduce or redirect air movement through four main methods: obstruction, guidance, deflection, and filtration.

When designing an effective windbreak, one must study the predominant wind directions for all seasons of the year. According to research by Bertauski (2021), the prevailing wind originates from the west. During winter, colder winds come from the northwest, while in the summer, warmer winds blow from the southwest. Windbreaks are particularly efficient at conserving energy in windy climates (Dewalle and Heisler, 1988).

Windbreaks can be created using dense vegetation, fences, or berms to redirect wind, reducing wind velocity near the building and resulting in a calm air pocket. A windbreak can reduce wind speed for a distance up to 30 times its height. Therefore, a 3-meter tall windbreak made of dense trees can slow the wind for up to 90 meters (Bertauski, 2021). Thus, distance of the windbreak from the building depends on the tree height (see Figure 23). The taller the windbreak, the larger area it protects.

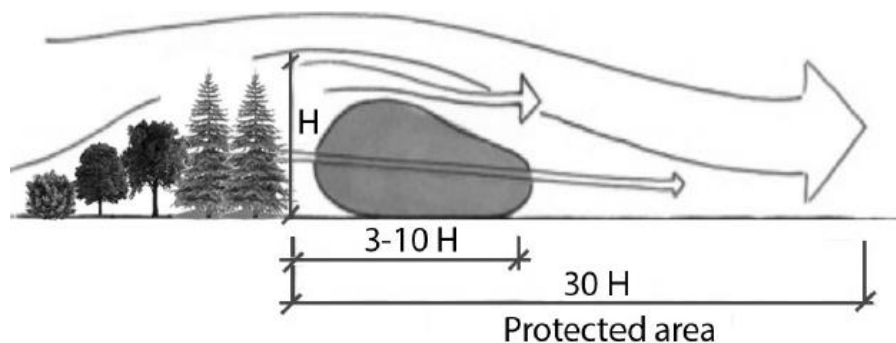


Figure 23: Illustrating the distance windbreaks can shield for a height of “h”
(Source: Seckin, 2018)

According to article by Seckin (2018), evergreen and coniferous species should constitute a significant portion of planting composition for windbreak because they retain their foliage in winter and their crowns reach the ground, which completely creates wind-blocking mass in winter when it is most needed. As these evergreens can divert chilly winter winds, less energy is required for heating. Trees that can be used as a windbreaks in Southeast region of United States include Loblolly Pine, Shortleaf Pine, Poplars, Eastern Red Cedar, Southern Bayberry, Firethorn, Virginia Pine, Caroline Laurel Cherry, Honeysuckle, Southern Bayberry, and Privet (USDA). Deciduous trees can also be used for windbreaks, but they should have low and dense branches, which will help dampen the air (Walker, Langelo, and Newman, 2018).

In accordance with Seckin (2018), windbreaks can be composed of one, two, three, or more rows of trees or shrubs. A single row of evergreens is sufficient when the space is limited. The three-row configuration should include at least one dense row of evergreen trees, while the other rows can consist of deciduous or evergreen plants. A three-row windbreak offers significantly more wildlife value than single or double-row windbreaks due to additional sheltered spaces and greater plant diversity. Windbreaks with four or five rows are more effective as they provide higher levels of protection and species diversity, and they can also incorporate a few rows of deciduous plantings or small shrubs. As stated by Walker, Langelo, and Newman (2018), the recommended spacing between two rows of large trees for a windbreak is approximately 4.5 meters. For smaller trees, the recommended spacing ranges from 1.8 to 2.4 meters, and for shrubs, it ranges from 0.6 to 1.2 meters.

According to an article by Walker, Langelo, and Newman (2018), windbreaks can offer additional benefits by providing insulation to the walls through the creation of dead air space between wall and trees (see Figure 24). Plants planted along the length of foundation are known

as foundation plantings. These plants are approximately 1.5 meters away from the wall, creating a buffer called “dead air space” around the building. This space has slower circulating air, which acts as an additional insulating layer (Seckin, 2018).

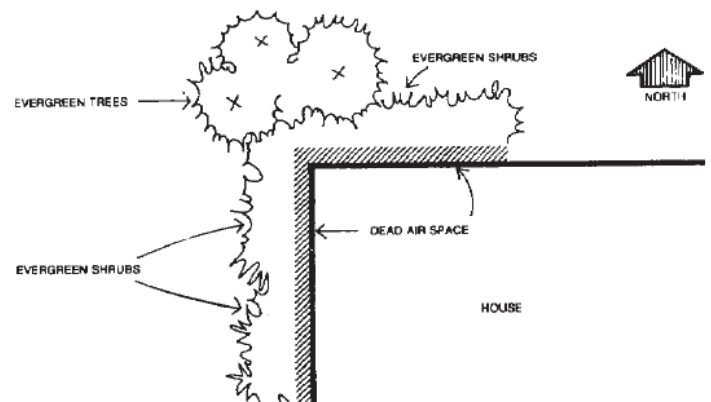


Figure 24: Foundation plantings to create dead air space
(Source: Walker, Langelo, and Newman, 2018)

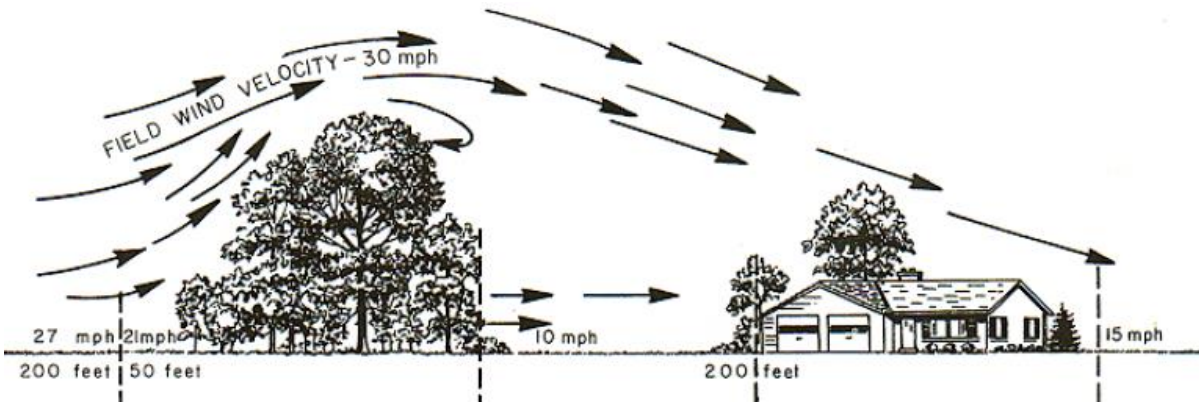


Figure 25: Windbreaks diminish wind flow. Some of the air current is redirected over the tree canopy, while other portion filters through the trees.
(Source: USDA)



Figure 26: Aerial view of windbreak
(Source: USDA)

According to article by Dewalle and Heisler (1988), the following characteristics should be considered while designing windbreak to prevent heat loss and gain. These are:

- Orientation relative to the structure
- Height and distance from the structure
- Length of the windbreak
- Choice of windbreak elements: fence vs. plants
- Number of windbreak rows
- Spacing of windbreak plants
- Plant species used

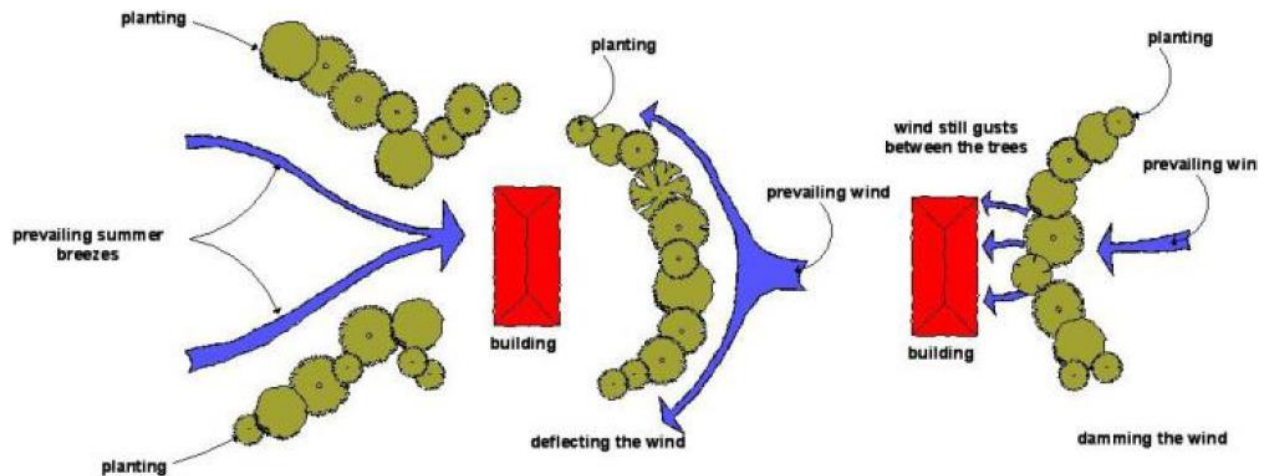


Figure 27: Positioning trees in a concave or convex arrangement relative to the cardinal directions.

(Source: Vasiu, 2013)

Figure 27 illustrates the arrangement of trees designed to mitigate the impact of colder winter winds while allowing summer breezes. These trees can be arranged in linear clusters, straight or curved rows, or a combination of these patterns.

III. Installing Vegetated Roof

According to article by Chidambaram et al. (2020), concrete roofs cause significant heat gain, reducing thermal comfort in buildings. Implementing vegetated roofs is a key strategy for improving the microclimate, mitigating the impact of urban heat islands, and creating a more pleasant thermal environment both indoors and outdoors, without relying on mechanical systems (Peng and Jim, 2013). Vegetated roofs not only provide shade throughout the day but also facilitate nighttime radiation loss by exposing their surfaces to the sky (Sandifer, 2019).

Roofs with dense vegetation experience nearly 40% less heat gain compared to those without vegetation (Oliveri et al. 2013). As described by Niachou et al. (2001), vegetated roofs provide three times the cooling effect in summer and retain heat in winter by increasing the thermal capacity of the roofs.

As described by Wark (2019), the thermal properties of vegetated roofs are enhanced by the landscape and growing medium. While conventional roofs primarily rely on conduction for heat transfer, vegetated roofs utilize a combination of convection, radiation, evapotranspiration, and thermal mass effects to improve the building's thermal comfort and microclimate (see Figure 28).

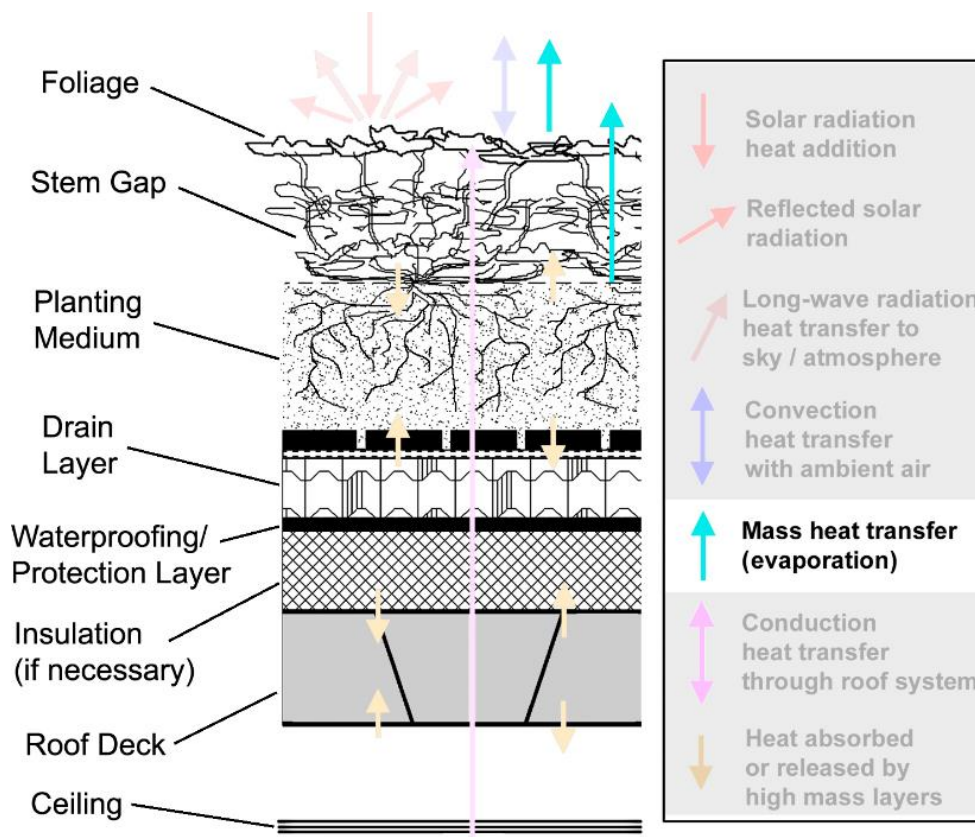


Figure 28: Vegetated roof as a thermal system
(Source: Wark 2019)

In accordance with Chidambaram et al. (2020), hard concrete roofs absorb solar radiation, transferring heat through conduction into the buildings. Terrace gardens, by replacing heat-absorbing surfaces with plants and shrubs, shade the roof from solar radiation, cool the air through evapotranspiration, and provide insulation to the building. Convection occurs within vegetated roofs as air and water flow through the growing medium and vegetation, scattering incoming solar radiation and providing shade to the roof. Additionally, evaporation and evapotranspiration from

the vegetation remove heat from the surrounding environment, effectively cooling the surface. Moreover, plants have higher albedo (solar radiation reflectivity) and it also enhances the thermal performance of concrete, which has lower conductivity compared to metals.

Vegetated roofs help regulate indoor temperatures, moderating them by approximately 2-4.5°C during winter and 5-7°C in summer, while also reducing roof surface temperatures by 15-45°C (see Figure 29). Additionally, vegetated roofs can reduce building energy consumption by up to 80% (Peng and Jim, 2013). Furthermore, tall and dense plants have a greater cooling effect compared to smaller ones (Chidambaram et al., 2020).

	Winter	Summer
Mean Temperature	0°C	18.4°C
Temperature under membrane of conventional roof	0.2°C	32°C
Temperature under membrane of green roof	4.7°C	17.1°C

Figure 29: Study of temperatures under membranes of a conventional and a vegetated roof
(Source: Hossam and Luis Fernando, 2015)

There are three main approaches to designing a vegetated roof, as detailed in articles by Hossam and Luis Fernando (2015) and Seckin (2018). These are as follows:

Extensive roof: These lightweight systems feature a shallow growing medium (2-15cm). They are typically planted with low-maintenance, drought-tolerant plant species, requiring minimal irrigation. Extensive roofs can support smaller-size plants (see Figure 30). These roofs are good choice for retrofitting existing rooftops or where weight is a concern. While not designed for foot traffic, they may be accessed for maintenance purposes.

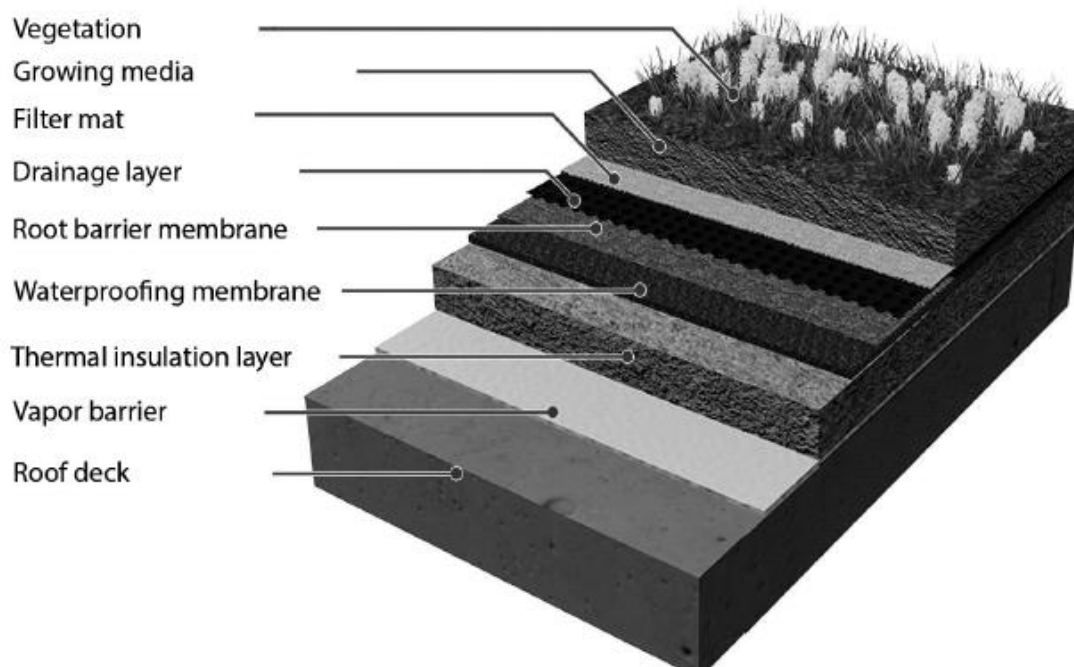


Figure 30: Extensive vegetated roof
(Source: Seckin 2018)

Intensive roof: This type of roof offer a deep (over 30cm) growing medium that supports a diverse range of vegetation (see Figure 31). From trees to shrubs to herbaceous plants and even lawns, the possibilities are vast. This depth also allows for the incorporation of roof ponds and water features. Unlike extensive roofs, intensive designs are accessible for people, offering the same ecological benefits as a traditional garden, including recreation and wildlife habitat (Seckin, 2018).

However, due to significant weight intensive roofs are not suitable for retrofitting existing buildings (Hossam and Luis Fernando, 2015). The trade-off for this weight is a potentially greater benefit in reducing urban heat islands and creating a more favorable microclimate around the building.

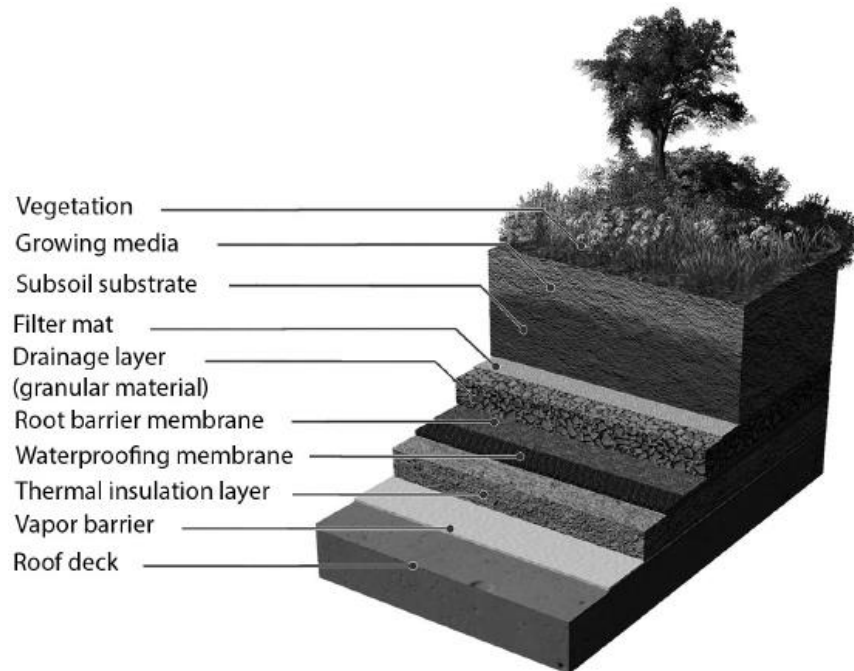


Figure 31: Intensive vegetated roof
(Source: Seckin 2018)

Semi-intensive roof: Striking a balance between extensive and intensive options, semi-intensive green roofs offer a growing medium depth of 15-30cm (see Figure 32). This allows for a wider variety of plants compared to extensive roofs, with the potential to include larger herbaceous perennials and shrubs or even trees in containers. These roofs are accessible to people.

According to Sandifer (2019), to maximize a vegetated roof for passive cooling, consideration of the following key elements is necessary. These are as follows:

- Soil should be completely covered with vegetation. Dense greenery, thick turf, no gaps in foliage cover.
- For conserving water, application of 2” soil mulch and shade the soil surface until the plants totally shade it.
- Spray/mist irrigation system.

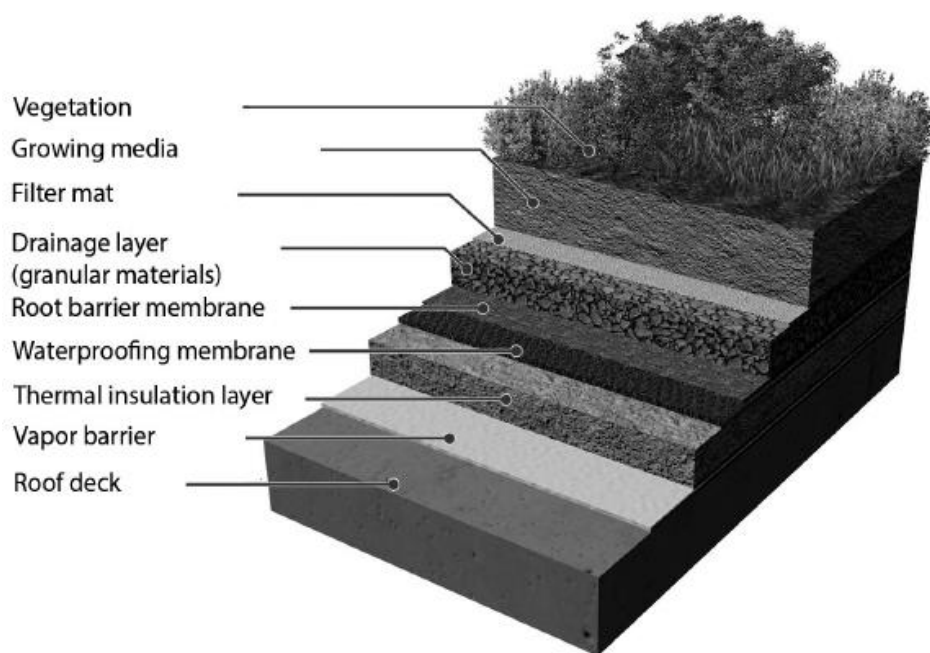


Figure 32: Semi- Intensive vegetated roof
(Source: Seckin 2018)

To conclude, deeper soil allows for better absorption of solar radiation, resulting in cooler temperatures and reduced heat load on buildings. Intensive roofs, with their capacity to support diverse tree and shrub species, are ideal for mitigating the urban heat island effect, influencing microclimates, and providing passive cooling. These roofs not only absorb greenhouse gases but also offer insulation and effective shading. Additionally, their ability to retain more water through irrigation enhances the cooling capacity of vegetated roof systems.

IV. Installing Water Bodies

According to Oke (1992) and Wong et al. (2012), water bodies excel at absorbing radiation. Despite absorbing significant heat, water functions effectively as a heat sink due to its limited temperature increase, attributed to its thermal inertia and the cooling effect of evaporation. Moreover, evaporative cooling from water features remains one of the most efficient passive cooling methods (Manteghi, Limit, and Remaz, 2015). Water bodies exhibit two main categories:

static and dynamic. Static water bodies include rivers, lakes, and ponds. These remain relatively stable over time. Dynamic water features encompass water fountains, water curtain walls. Unlike static bodies, they are in constant motion, creating visual and cooling effects (Chen, 2016). The direction and speed of the wind are crucial in dispersing the cooling effect of water bodies (Kim et al., 2008). While water bodies do not influence wind speed, they notably impact mean radiant temperature within a 1-2 meter radius (Albdour and Baranyai, 2019).

Additionally, Sandifer's research (2019) suggests that the cooling effectiveness of a water body depends on its size and the degree to which its surface is shaded from direct sunlight. Shading the water body during the day with landscape or artificial elements is crucial to prevent solar heating, while leaving it uncovered at night facilitates nocturnal cooling. This dual system can also be reversed for winter heating (Hossam and Luis Fernando, 2015). Moreover, for a water body to significantly affect the microclimate, resulting in a 2-3°C temperature reduction, it must be large (over 18 inches deep) or incorporate spray features.

In conclusion, maximizing the potential of utilizing water bodies as passive cooling elements (Sandifer, 2019) depends on prioritizing the following factors:

- Ensuring that the water surface remains shaded (30-50%) by plant material or artificial shade.
- Incorporating pond elements with significant depth or deep chambers because they have more heat capacity.
- Locating ponds close to buildings (10-30 meters).
- Designing features that promote air circulation over the water surface.
- Using fountain sprays enhances evaporative and radiative cooling effects.

- Establishing a heat transfer mechanism ensuring cool energy flow from the water body to the building's interior, utilizing either water or air as the transfer medium (see Figure 33).
- Ensuring the water body remains exposed to night sky allowing it to cool down overnight, enabling it to absorb heat from the building during the day.

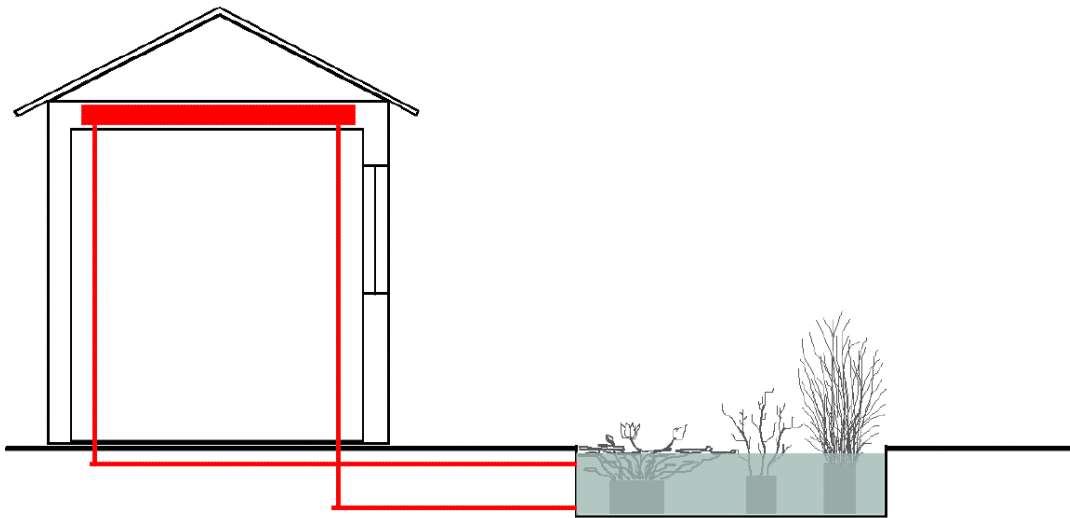


Figure 33: Illustrating an interior space connected by heat exchangers to transfer cooling energy from a water body to the building's interior.

(Source: Sandifer, 2019)

V. Installing Cool Materials

Urban surfaces, such as pavements, play a major role in the urban heat island (UHI) effect by absorbing, storing, and emitting solar radiation, which impacts building surfaces and thermal comfort (see Figure 34). According to Suk Jin Jung (2024), the increased use of synthetic materials and darker surfaces with low reflectivity are primary contributors to UHIs. Research has shown that over 60% of urban surfaces are covered by synthetic, heat-absorbent materials, with pavements making up approximately 40% of this coverage. Satellite mesoscale images have highlighted urban pavements as significant sources of thermal activity and heat radiation.

Therefore, addressing the role of pavements is essential in mitigating the UHI effect and conserving energy (Santos and Spirn, 1981; Pomerantz, 2000; Santamouris, 2013).

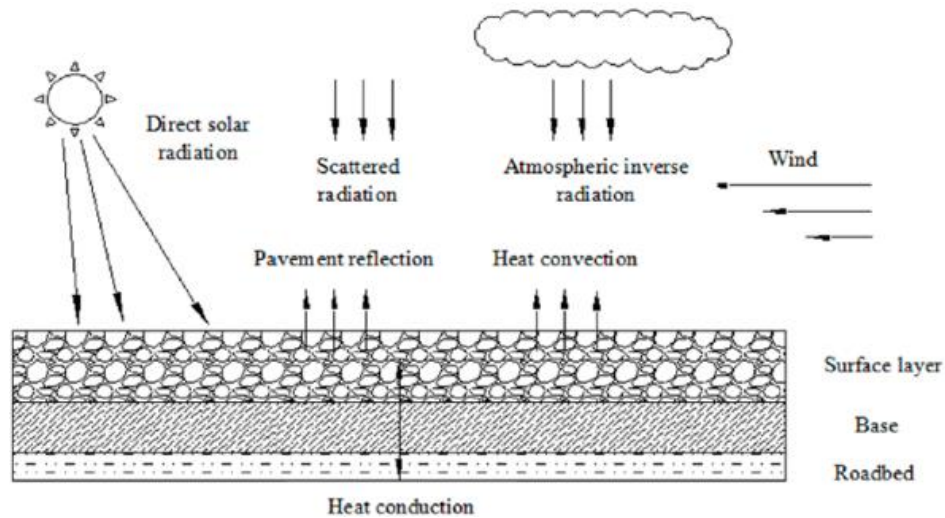


Figure 34: Heat transfer process of pavement
(Source: Zheng et al. (2020))

According to Del Serrone, Peluso, and Moretti (2022), the thermal properties of pavement materials significantly influence the formation and manifestation of urban heat islands (UHIs). Each surface either absorbs or reflects a portion of the sunlight it receives. Albedo and emissivity are two crucial parameters that affect the thermal behavior of road pavements under solar radiation.

In accordance with Suk Jin Jung (2024), Emissivity is the relative measure of the total energy emitted across all wavelengths by a surface compared to a blackbody at the same temperature, ranging between 0 and 1. Research indicates that emissivity increases with surface roughness, impacting surface temperatures, particularly at night, as the absorbed heat during the day is released into the air.

According to Akbari (2009), albedo is the measure of a surface's ability to reflect incident radiation. Darker surfaces typically have lower albedo values than lighter ones. A perfect blackbody has an albedo of zero, meaning it absorbs all incident radiation, while a white surface

has an albedo of one, reflecting all incident radiation. High-albedo surfaces reflect most of the incoming solar energy, whereas low-albedo surfaces absorb it. Refer to Figure 35 for albedo values of various urban surfaces. The term "absorptivity" is the opposite of albedo, referring to a surface's ability to absorb incoming radiation. Generally, light-colored surfaces have high albedo, and dark-colored surfaces have low albedo. However, some dark-colored surfaces can have high albedo, reflecting significant portions of infrared solar radiation (Suk Jin Jung, 2024). For example, green grass reflects infrared radiation well, with albedos ranging from 0.25 to 0.30. Texture and geometry also affect albedo, with rough, bumpy surfaces absorbing more radiation than flat ones of the same material.

Materials with high reflectance to solar radiation and high emissivity are known as "cool" materials. Pomerantz (2000) and Santamouris (2013) suggest that cool pavements with higher albedo can effectively lower surface and air temperatures. Studies indicate that high-albedo paving not only reduces air temperature but also decreases energy demand (Sailor, 1995).

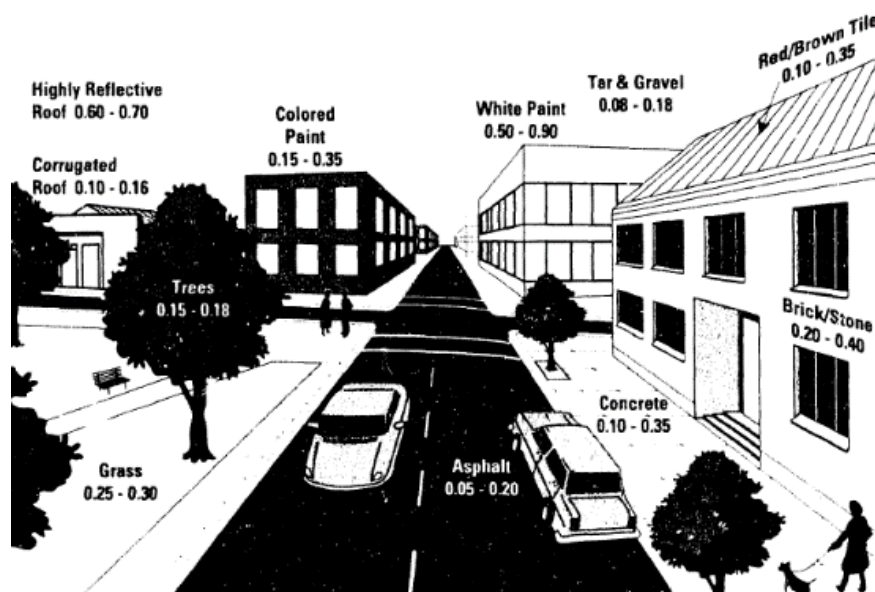


Figure 35: Illustrating albedo values for different surfaces in an urban community.
(Source: Akbari, 2009)

Asphalt and concrete are the most commonly used materials in pavement construction. Asphalt surfaces consistently exhibit higher temperatures compared to concrete surfaces. According to Zheng et al. (2020), black asphalt pavement has a strong heat absorption capability, particularly under intense summer sunlight. Refer to Table 2 for the thermal characteristics of different materials.

PAVEMENT MATERIAL	ALBEDO	EMISSIVITY	TRANSMITTANCE
Asphalt	0.1	0.9	
Light Concrete	0.8	0.9	
Interlock Block	0.2	0.9	
Granite	0.4	0.9	
High-albedo granite	0.6	0.9	
Grass	0.2	0.97	0.3

*Table 2: Summary of the properties of various materials used for pavement.
(Source: Del Serrone, Peluso, and Moretti, 2022; Suk Jin Jung, 2024)*

According to Santamouris et al. (2012), the use of reflective pavements has been shown to potentially decrease peak daily ambient temperatures by up to 1.9°C during a typical summer day, with surface temperatures experiencing reductions of up to 12°C. Del Serrone, Peluso, and Moretti (2022) suggest that optimal results were achieved with light concrete slabs or a complete grass layer in parking areas, indicating that even greater mitigation of the urban heat island effect can be achieved by combining these two approaches.

4.5. Role of climate zone

Landscape strategies for energy conservation are contingent upon the geographical location. It is essential to select trees, plants, shrubs, and landscaping methods that align with the local climate and environmental conditions. According to research by Seckin (2018), heating, cooling, and lighting are much affected by the site's location and climate zone.

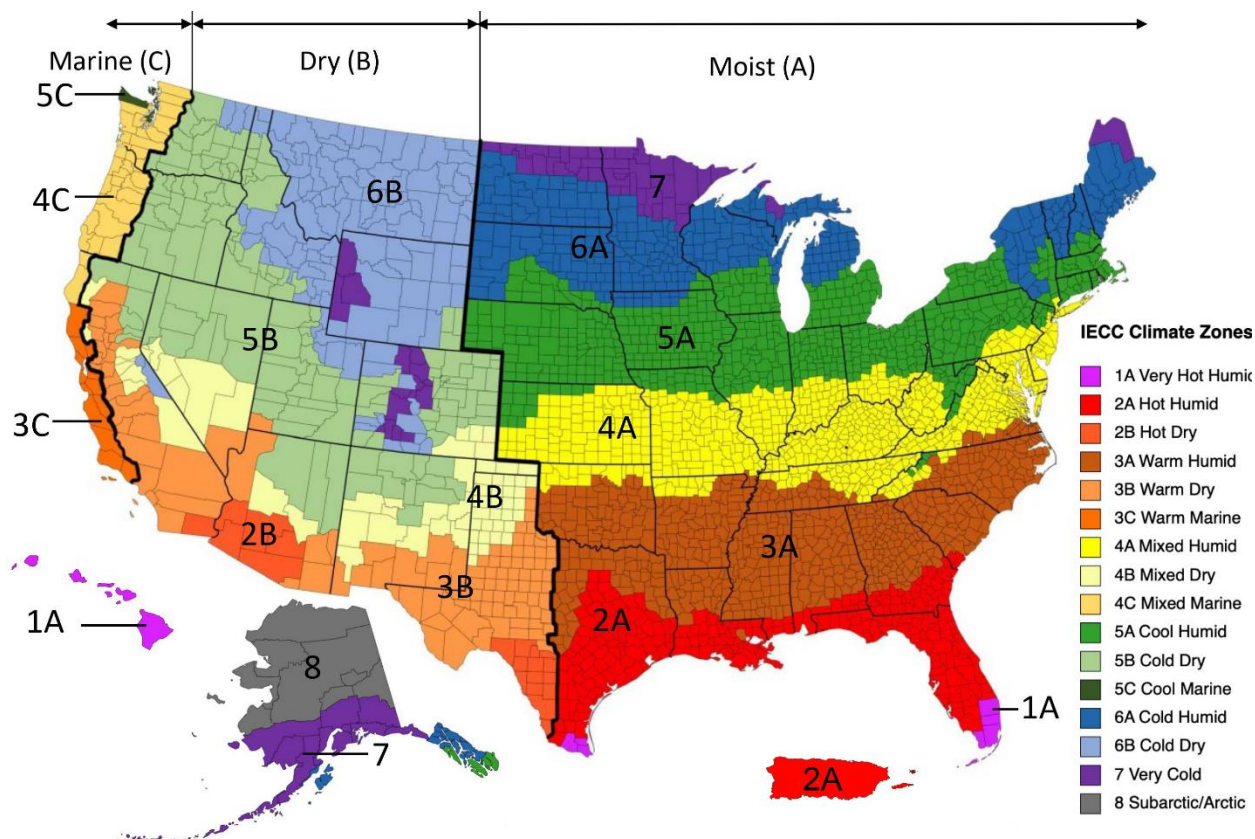


Figure 36: Climate zone map of the United States
(Source: IECC, 2021, edited by Author)

Figure 36 depicts climate zone map of the United States, which can assist in ascertaining the site's specific climate zone.

The following points outline landscape strategies to prevent heat gain and encourage heat loss across various climate types.

Temperate Climate:

The primary objective for temperate climates is to retain solar heat during colder months and optimize shading during the summer. This can be achieved through several strategies (Seckin, 2018; "Energy-Efficient Landscaping," n.d.):

- Installing overhead trellis with deciduous vines on the south side to provide seasonal shading.

- Using windbreaks of low branching evergreen trees and shrub clusters on the north and northwest sides to divert cold winter winds away from the buildings.
- Creating dead air space for insulation on the north and northwest sides of the structure.
- Positioning high-canopy, high-branching deciduous trees on the east and west sides to direct summer breezes toward the building. This arrangement will allow summer breezes and the warmth of the winter sun to penetrate while protecting from the high summer sun (see Figure 37).

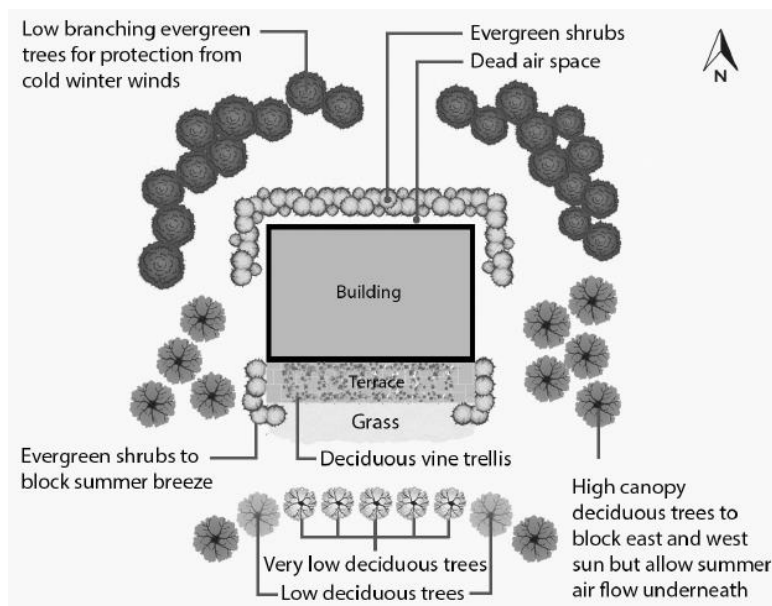


Figure 37: Landscaping techniques for temperate climate
(Source: Seckin, 2018)

Hot-Dry Climate:

The primary objective for hot and dry climates is to maximize shade, especially during the late morning and late afternoon hours. This can be achieved through several strategies (Seckin, 2018; “Energy-Efficient Landscaping,” n.d.):

- Locate high-canopy deciduous trees on the east and the west sides to maximize shade, particularly over the roof, to protect the structure from high altitude sun.

- Plant shrubs and climbing vines on the east and west walls to reduce heat gain in the morning and afternoon. Climbing vines will immediately cool the air adjacent to the building through convection.
- Enable natural cooling through the access of summer winds to the building, thus avoid planting trees on the north and south sides of the structure (see Figure 38).
- Choose indigenous and drought-resistant landscaping to minimize outdoor watering requirements.
- Adding water features to channel hot winds across the water body, creating a cooling effect for the building.
- Reduce the amount of paving and dark colored materials to reduce heat absorption.

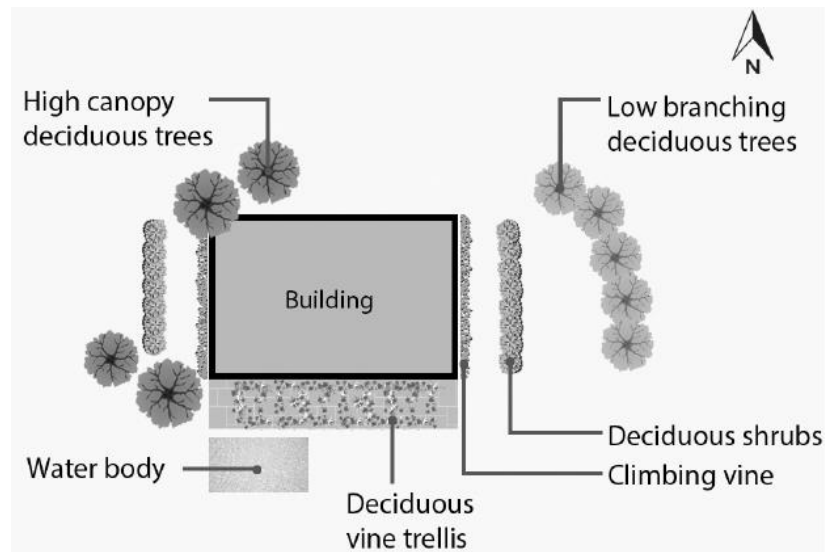


Figure 38: Landscaping techniques for hot-dry climate
(Source: Seckin, 2018)

Hot-Humid Climate:

The primary objective for hot and humid climates is to maximize shade throughout the year and encourage air movement. This can be achieved through several strategies (Seckin, 2018; “Energy-Efficient Landscaping,” n.d.):

- Channel summer breezes towards the building.
- Maximize summer shading trees that permit the passage of low-angle winter sunlight.
- Locate high-canopy trees on the east and west sides to maximize shade while allowing air movement underneath the canopies.
- Avoid planting beds close to the building if they require frequent watering, as damp conditions can affect air infiltration and indoor humidity levels.
- To maximize shade and prevent heat infiltration, install trellis with deciduous vines on the north and south sides (see Figure 39).

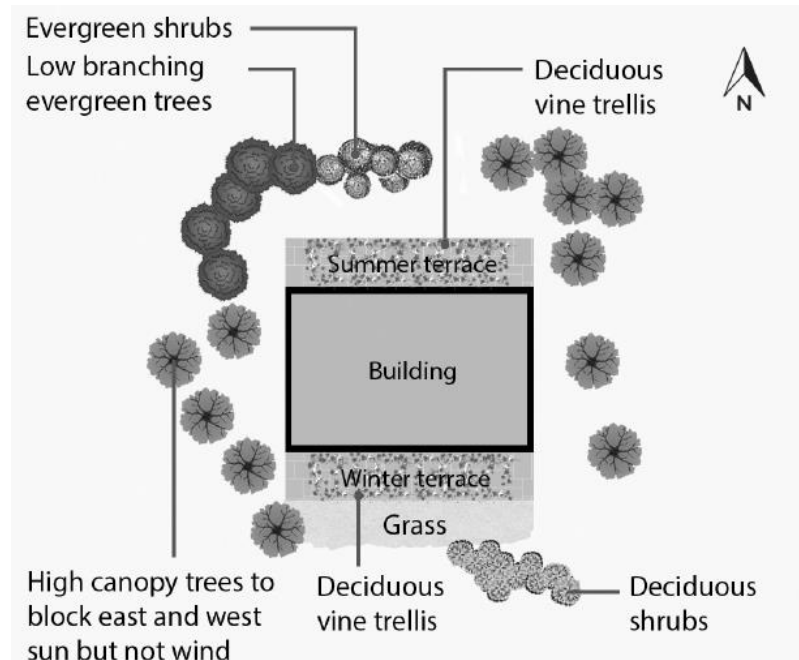


Figure 39: Landscaping techniques for hot-humid climate
(Source: Seckin, 2018)

Cold Climate:

The primary objective for cold climates is to protect the building from northern winter winds. This can be achieved through several strategies (Seckin, 2018; “Energy-Efficient Landscaping,” n.d.):

- Utilize dense windbreaks to shield the structure from frigid winter winds.

- Installing an earthen berm on the north and northwest sides can further protect against winter winds and blowing snow.
- Positioning low-branching evergreen trees and shrubs on the north, east, and west sides.
- Plant high-canopy deciduous trees on the south, southeast, and southwest sides to admit low winter sun rays and provide summer shade.
- To further capture winter sun, a sunken terrace can be created on the south side with light-colored paving materials.
- Shading south and west windows and walls to mitigate excessive summer heat.
- Additional evergreen shrubs can help creating dead air space, providing insulation in both winter and summer time (see Figure 40).
- Furthermore, dark-colored paving materials can capture warmth and promote snowmelt.

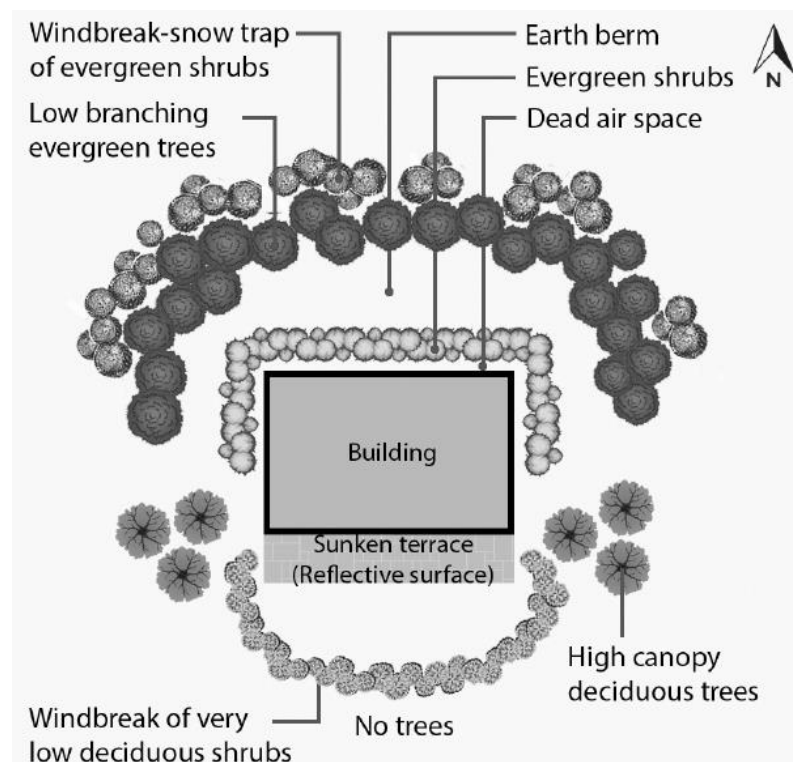


Figure 40: Landscaping techniques for cold climate
(Source: Seckin, 2018)

4.6. Conclusion

This chapter demonstrated the transformative power of strategic landscaping elements in mitigating urban heat islands. It explored various modes of heat transfer in buildings and how landscaping can achieve these objectives, considering the role of precision placement, windbreaks, vegetated roofs, water bodies, and pavements which are summarized in Table 3 (see Page 62). Moreover, strategic landscaping for different climate zones was also discussed. By understanding how landscape design can passively cool or heat buildings, we gain valuable insights into creating thermally comfortable and energy-efficient environments. This knowledge sets the stage for the next chapter, which will explore the practical implementation of these strategies in a mixed-use development on the outskirts of a small city in Georgia. The forthcoming site analysis will be crucial for effective implementation, considering the southeastern climate of the Piedmont region.

Landscaping Strategies for Passive Cooling in Buildings

I. Precision Placement

Strategic Placement of Vegetation:

Plant trees and various vegetation (bushes, shrubs, tall grasses, and vines) around buildings to mitigate heat islands. Choose appropriate species and place them precisely for optimal energy conservation.

Direct and Indirect Cooling:

Provide shading to buildings and surfaces to block solar radiation.
Use evapotranspiration to lower surrounding air temperatures, potentially matching the effect of multiple air conditioners.

Reduction of Air Conditioning Usage:

Trees and vegetation near buildings can reduce summer air conditioning by 15-35%, and up to 50% in some cases.

Deciduous Trees:

Use deciduous trees for seasonal energy efficiency: block solar radiation in summer, allow sunlight in winter.
Plant large-canopied deciduous trees on the west side and a hedge adjacent to the west wall to reduce wall temperatures significantly.

Canopy Type and Height:

Select trees with large canopies and moderate density for effective shading.
Use oval or columnar trees for narrow spaces; rounded trees need more space.
Plant trees with a mature height of at least 7.5m at 3 to 6m east or west of the structure.

Foliage Attributes:

Prefer trees with higher Leaf Area Indices (LAI) and light-colored leaves for efficient cooling.

Shading Air Conditioning Units:

Use a vine-covered trellis to shade the air conditioning unit, improving its efficiency and reducing annual energy consumption.

Use of Vines:

Apply vines to south and west-facing walls to reduce surface temperatures and enhance the microclimate.
Use deciduous vines for summer cooling and winter warming.

II. Implementing Wind Breaks

Designing Effective Windbreaks:

Study predominant wind directions for all seasons.
Use dense vegetation, fences, or berms to redirect and reduce wind velocity near buildings.

Placement and Species Selection:

Place windbreaks to reduce wind speed for a significant distance relative to their height.
Use evergreen and coniferous species to block winter winds and reduce heating energy requirements.

Row Configurations and Plant Spacing:

Utilize single, double, or multi-row configurations for windbreaks.
Ensure proper spacing between rows and select appropriate plant species for effective wind protection.

Landscaping Strategies for Passive Cooling in Buildings

Foundation Plantings:

Plant vegetation along the building foundation to create a dead air space for additional insulation.

III. Installing Vegetated Roofs

Types of Vegetated Roofs:

Extensive Roof: Lightweight with shallow growing medium, suitable for low-maintenance plants.

Intensive Roof: Deep growing medium supporting diverse vegetation, ideal for new buildings.

Semi-Intensive Roof: Intermediate depth supporting a variety of plants, accessible to people.

Thermal Benefits:

Vegetated roofs reduce heat gain by 40%, moderate indoor temperatures by 2-7°C, and cut energy consumption by up to 80%.

Key Design Elements:

Ensure complete vegetation cover and use soil mulch to conserve water.

Implement spray/mist irrigation systems.

IV. Installing Water Bodies

Cooling Effectiveness:

Use water bodies as heat sinks with limited temperature increases due to thermal inertia and evaporation.

Static (ponds) and dynamic (fountains) water features can reduce temperatures effectively.

Design Considerations:

Shade water bodies during the day and expose them at night for optimal cooling.

Ensure water bodies are large enough or incorporate spray features for significant cooling effects.

Proximity and Air Circulation:

Place water bodies close to buildings (10-30 meters) and design features to promote air circulation.

V. Installing Cool Pavements

Material Selection:

Use materials with high reflectance to solar radiation and high emissivity.

Choose high-albedo surfaces to reflect solar energy and reduce heat absorption.

Pavement Types:

Asphalt and concrete are common, but asphalt absorbs more heat.

Utilize cool pavements to lower surface and air temperatures, reducing energy demand.

Thermal Properties:

Focus on albedo and emissivity when selecting pavement materials to mitigate urban heat islands and conserve energy.

Table 3: Summary of landscaping strategies

(Source: Author)

CHAPTER 5

SITE INVENTORY

The chosen site for this research is Georgia Square Mall, located on Atlanta Highway in Athens, Georgia, United States (see Figure 1 & 2). Athens, a mid-sized college town with a population exceeding 120,000, offers a relevant context for exploring the challenges and opportunities associated with declining malls and urban heat islands.

The site's extensive parking lot coverage (80%) poses a significant challenge, as large expanses of asphalt contribute significantly to the urban heat island effect. Additionally, the underutilized state of the mall presents a valuable opportunity to explore redevelopment strategies that integrate landscape design principles.

By selecting Georgia Square Mall as the project site, this thesis aims to highlight research findings and apply them to a real-world context, focusing on reducing the UHIs exacerbated by extensive asphalt coverage in parking lots, exploring strategies for sustainable redevelopment amidst the mall's underutilization, and examining broader implications for urban areas grappling with similar declines and environmental challenges. The project will specifically target strategies to conserve energy and enhance environmental quality through strategic landscape design interventions.

In the previous chapter, we explored the phenomenon of UHIs, their causes, effects, and the role of mechanical systems in exacerbating climate change. We also discussed the process of energy transfer in buildings and how these factors contribute to increased temperatures in urban

areas. This background sets the stage for our current focus: applying this knowledge to a specific site to develop practical solutions for mitigating UHI effects.

In this chapter, I will conduct a site analysis (see Figure 41) of Georgia Square Mall, examining both its natural and built environments. The analysis will cover how the site impacts the environment and contributes to increased temperatures in the city. Based on the research from the previous chapter, important elements for site analysis will include climate factors like temperature, humidity, precipitation, wind patterns, and solar radiation. Understanding topography, including slope, elevation, and landforms, is also crucial. Vegetation, including the type, density, and distribution of plants, and existing infrastructure such as roads, utilities, buildings, height, and accessibility, are essential components to consider for reducing UHIs. Based on this analysis, guiding principles will be identified that will shape the next chapter on design. This analysis will ultimately guide us toward creating a sustainable and thermally comfortable design for the site. Additionally, I will also discuss the current proposal by the W&A Engineering group for the Georgia Square Mall.

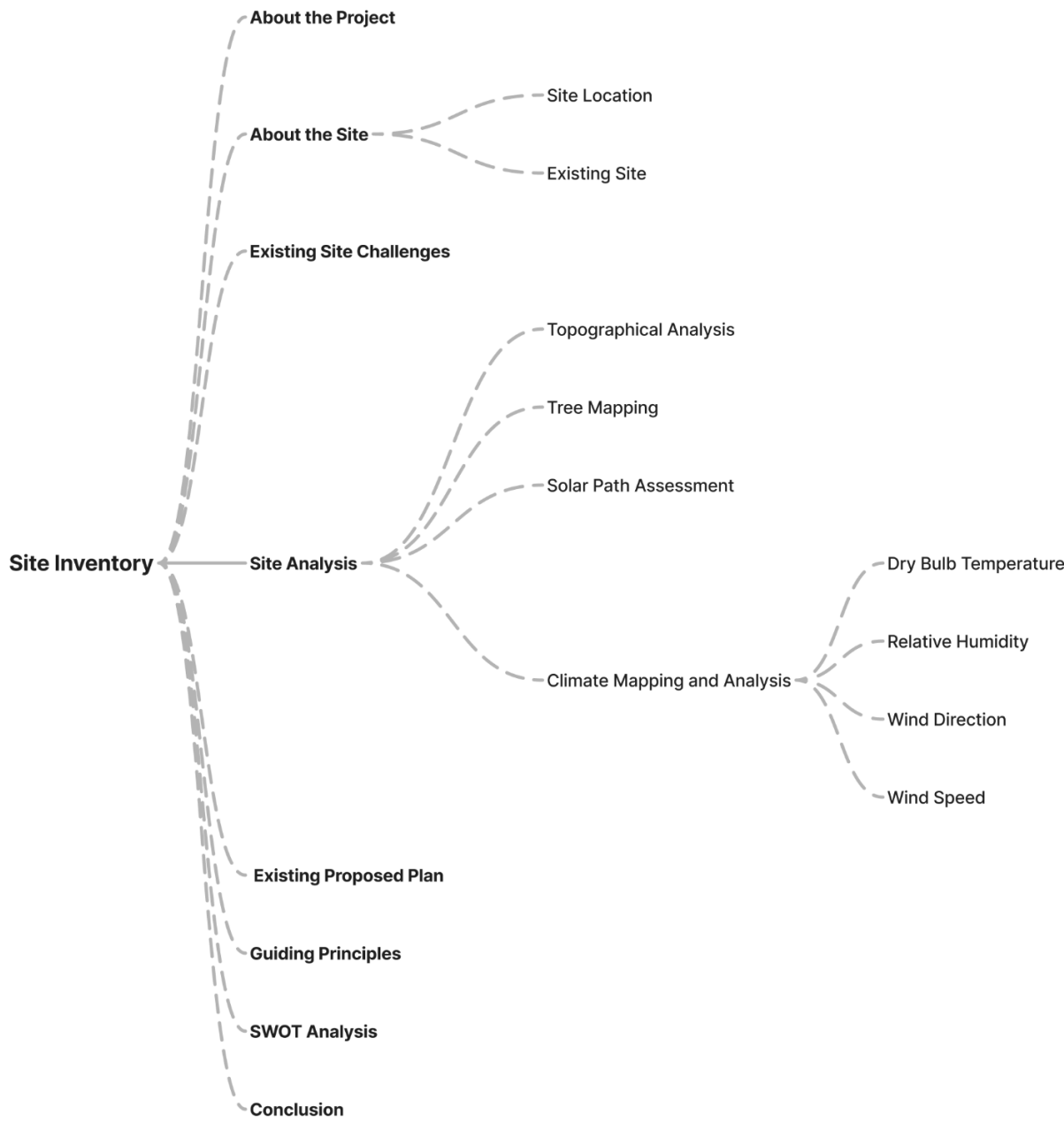


Figure 41: Overview of Site Inventory
(Source: Author)

5.1. About the Project

The transformation of Georgia Square Mall into a mixed-use development presents an opportunity to address several urban challenges while promoting community well-being. Located

in the heart of the Peach State, this project aims to revitalize the existing space and mitigate the urban heat island effect, contributing to sustainable and resilient urban environments (see Figure 42). W&A Engineering Group has developed a comprehensive redevelopment plan to rejuvenate the site into a vibrant mixed-use area.

5.2. About the Site

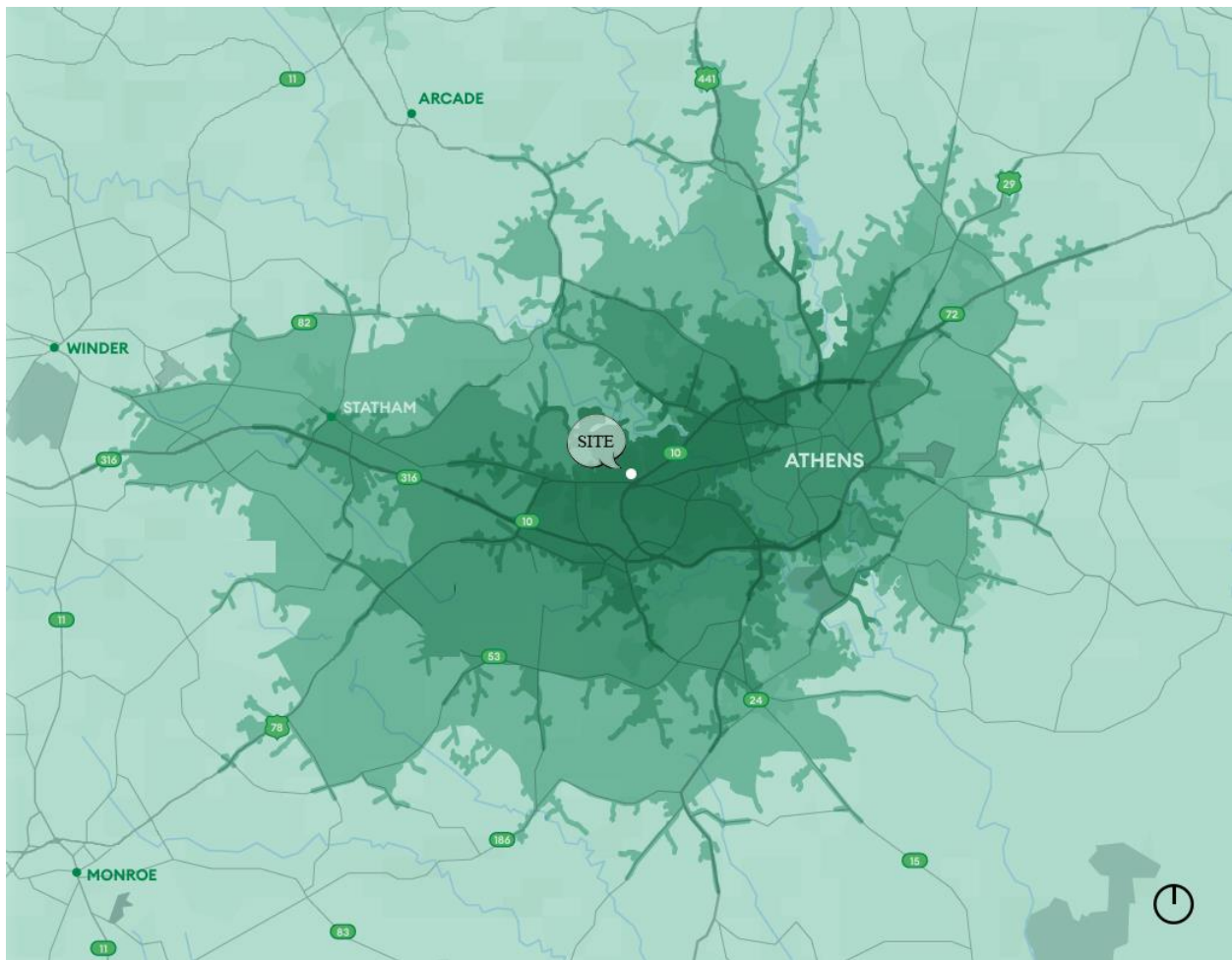


Figure 42: Site Location- Regional Level
(Source: Hendon Properties, 2024)

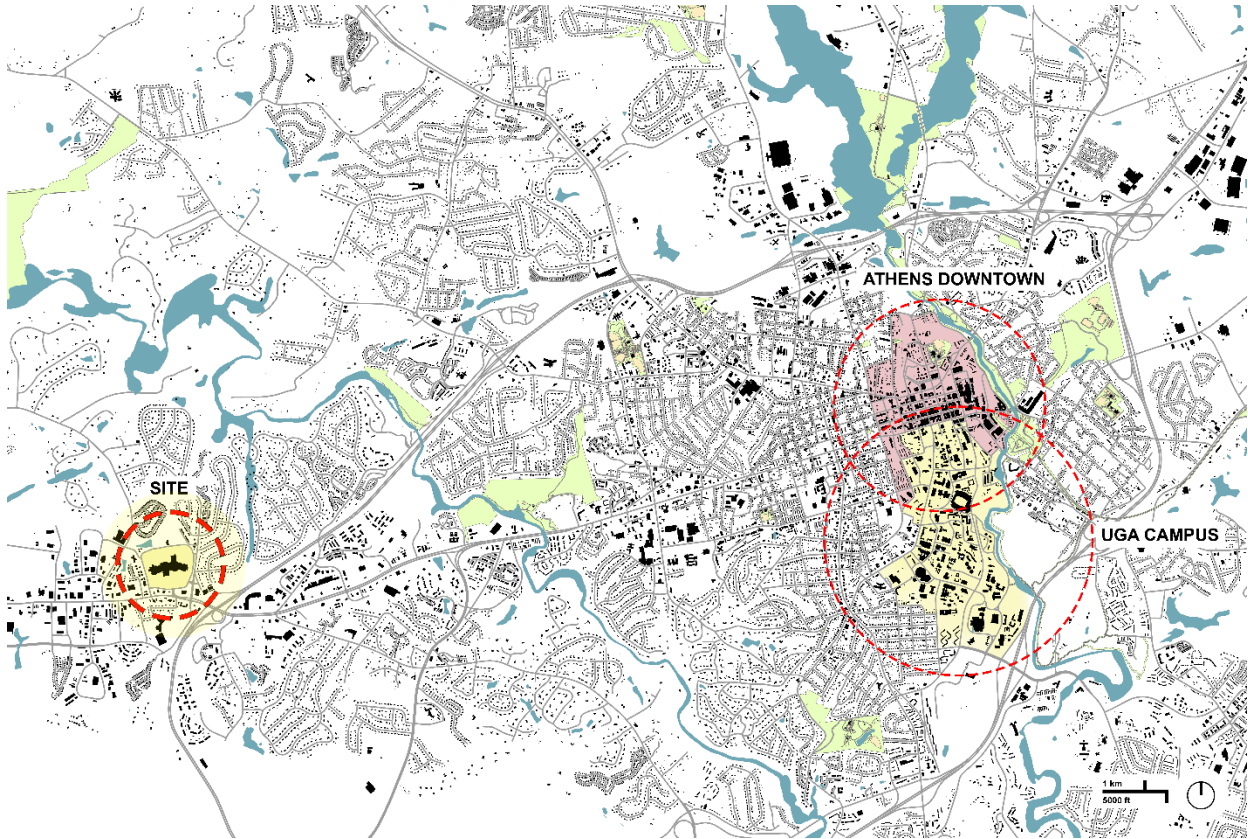


Figure 43: Site Location
(Source: Author)

Site Location: 3700 Atlanta Hwy, Athens, Georgia, United States, 30606

Coordinates: 33.9439° N, 83.4674° W

Elevation: 194 meters above sea level

Climate Zone: Warm-Humid

Site Area: 74.77 acres

Plant Hardiness Zone: 8a, 8b (USDA, 2023)

The Georgia Square Mall, built in 1981, is located in west Athens, Georgia. Athens is renowned as the South's best college town, largely due to the presence of the University of Georgia, which is situated just five miles from the site (see Figure 43). Like many other college

towns, Athens boasts a diverse population of 128, 671 (U.S. Census, 2020), comprising individuals from various backgrounds. The town's growing residential and student communities, along with the presence of people from different ethnicities, enrich its cultural fabric.

Over the years, the Georgia Square Mall has experienced numerous vendor closures and has remained largely vacant without any replacements. Consequently, 74.77 acres of prime real estate with significant community potential have been dormant for several years (see Figure 44 and 45). The demographic diversity of Athens presents a unique opportunity for revitalizing the mall site to better serve and reflect the needs of the community.



Figure 44: Existing Site Photographs
(Source: Peters 2023)



Figure 45: Aerial View of Georgia Square Mall
 (Source: Hendon Properties, 2024, edited by Author)

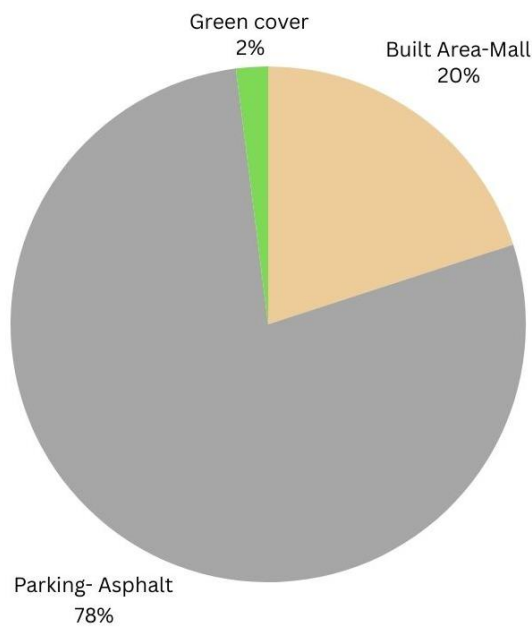


Figure 46: Existing Area Distribution
 (Source: Author)



Figure 47: Aerial view of the site illustrating access points.
(Source: Google Earth, Date Accessed Feb, 2024)

The existing use of the site is 78% parking and 20% built area (see Figure 46). The majority of the site is covered in asphalt, which has low albedo and low reflectivity, significantly contributing to the urban heat island effect. As discussed in Chapter 2 on the causes and effects of urban heat islands, this site is a prime example of significant impact on the environment. Additionally, there are more existing challenges related to the site that affect the environment, ecology, and human health, which are discussed below in Section 5.3.

5.3. Existing Site Challenges

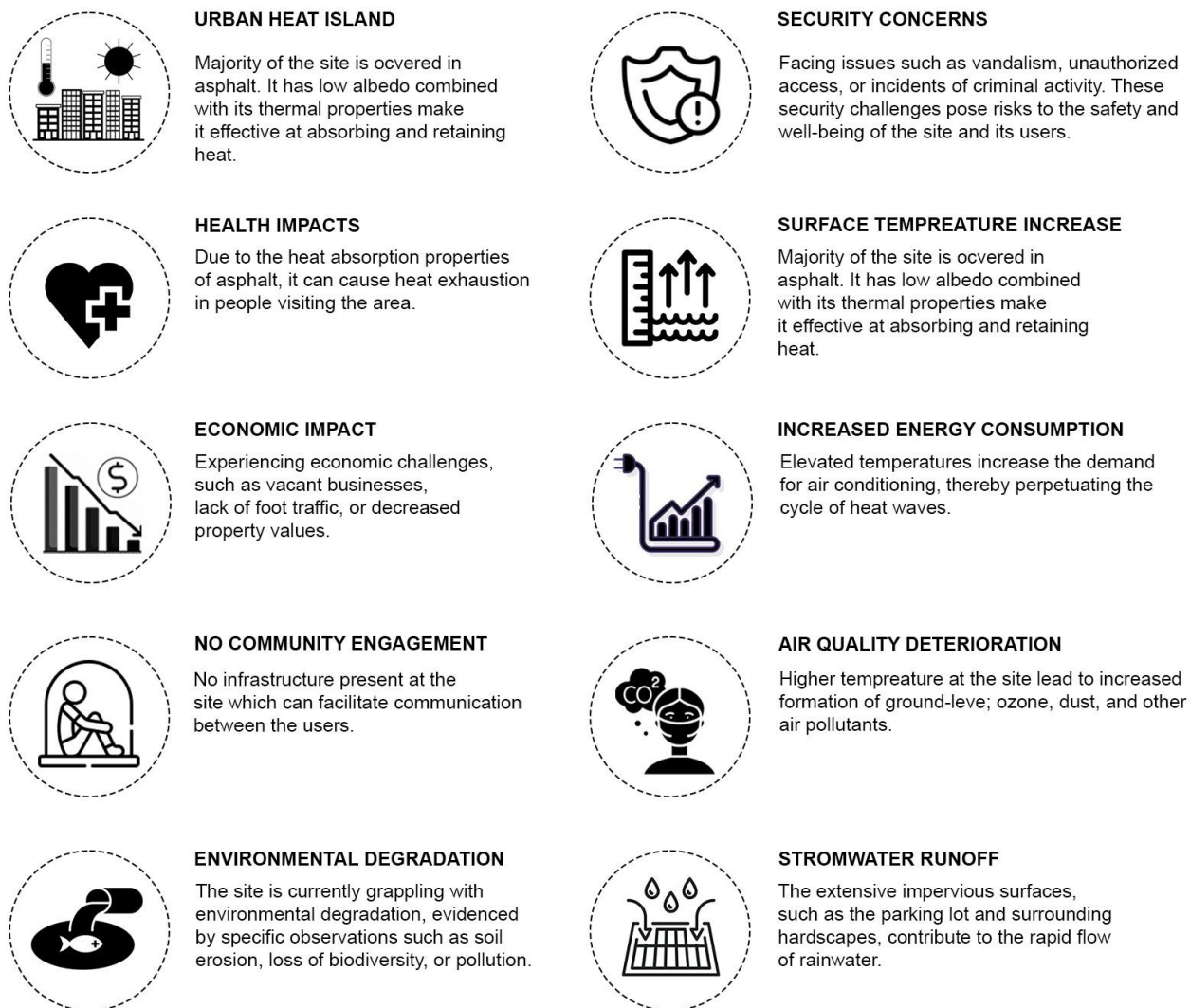


Figure 48: Illustration for site challenges
(Source: Author)

Extensive analysis of the site layout has revealed inherent challenges (see Figure 48). These challenges are primarily identified through combination of on-site surveys, thorough assessments of climate impact, building usage patterns, and environmental analysis. To overcome these challenges, redevelopment is necessary to mitigate their negative impacts and optimize the site's functionality.

5.4. Topographical Analysis

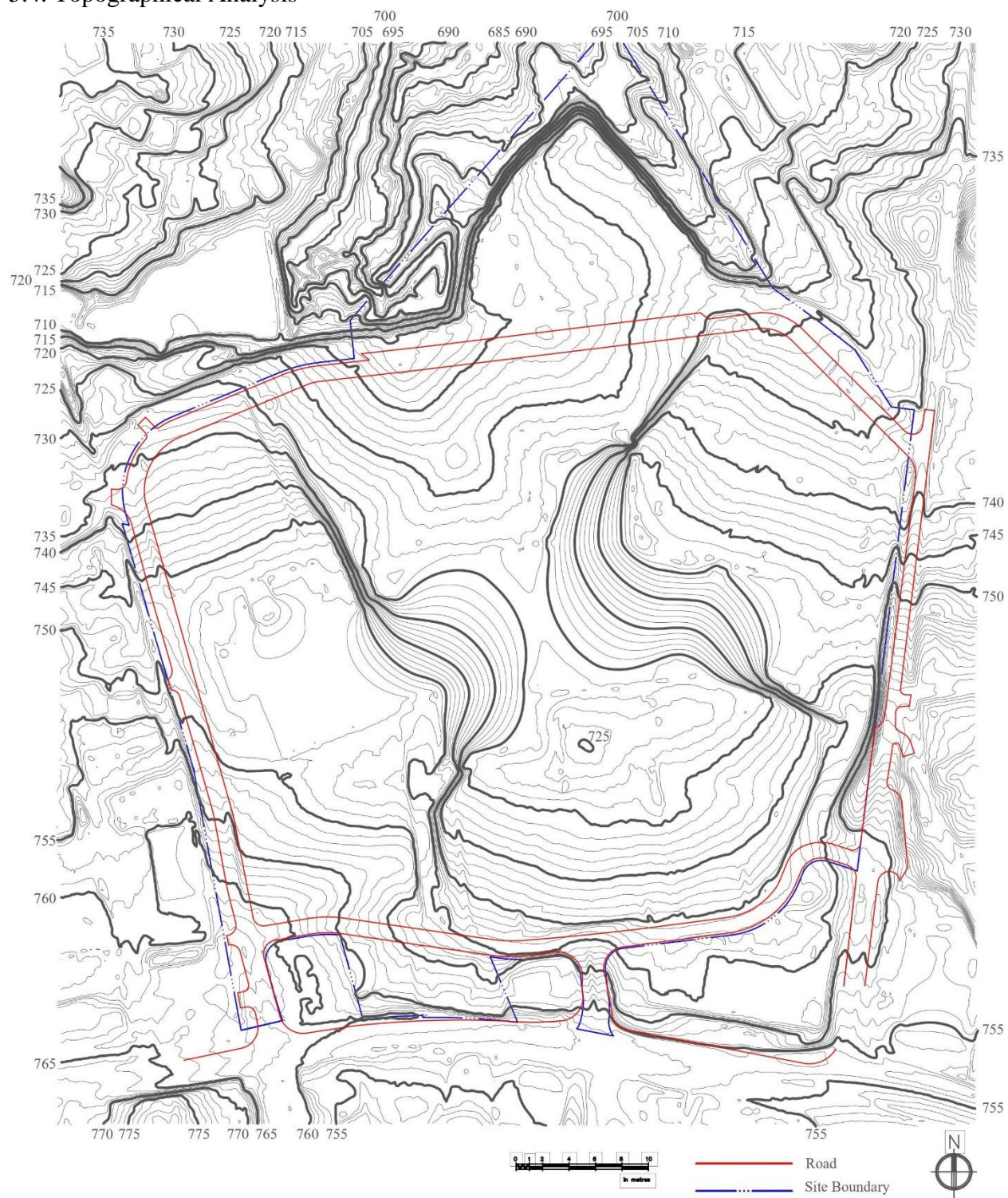


Figure 49: Plan illustrating existing contour lines
(Source: Athens-Clarke County Open Data, accessed April 2024, edited by Author)

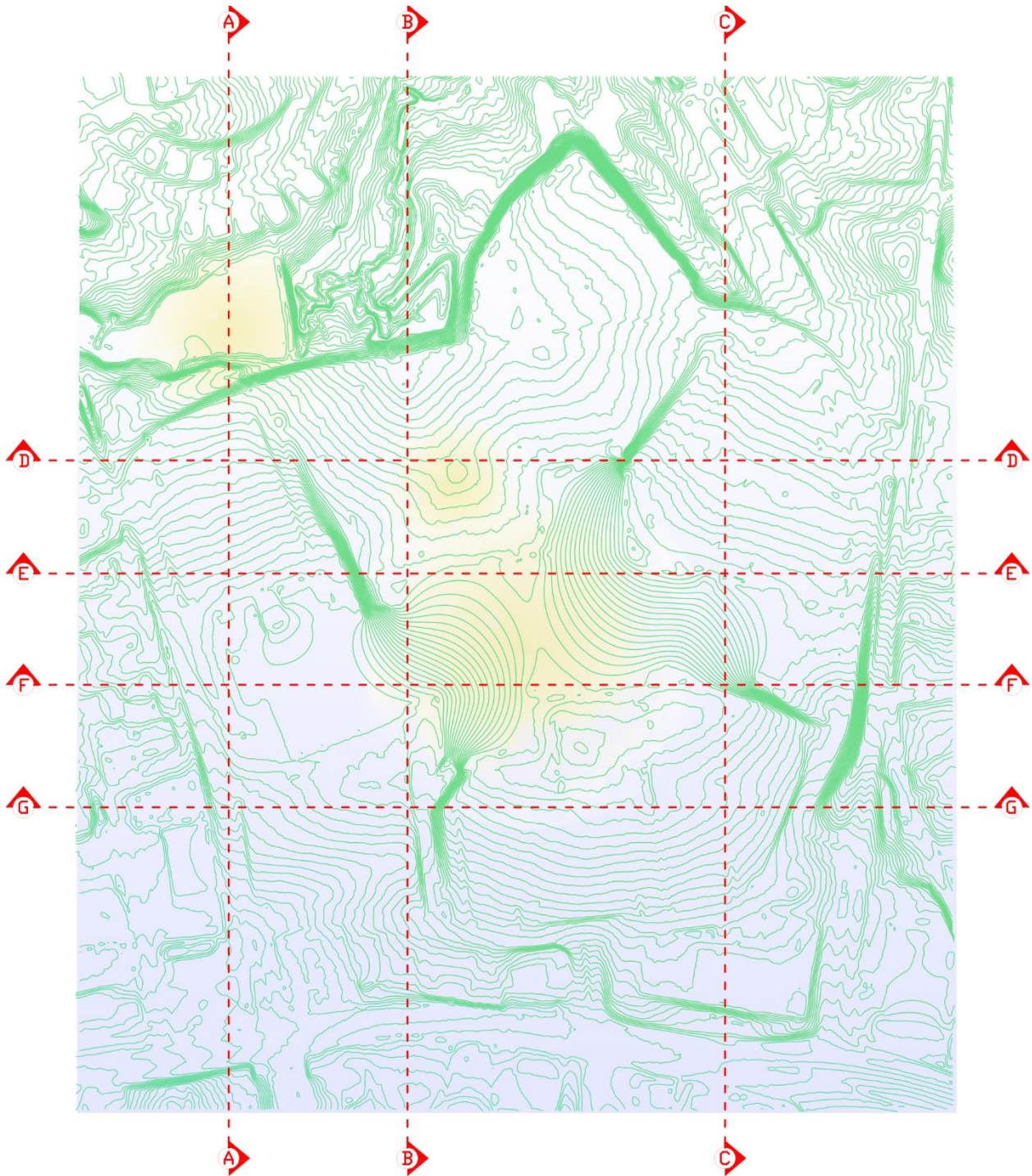
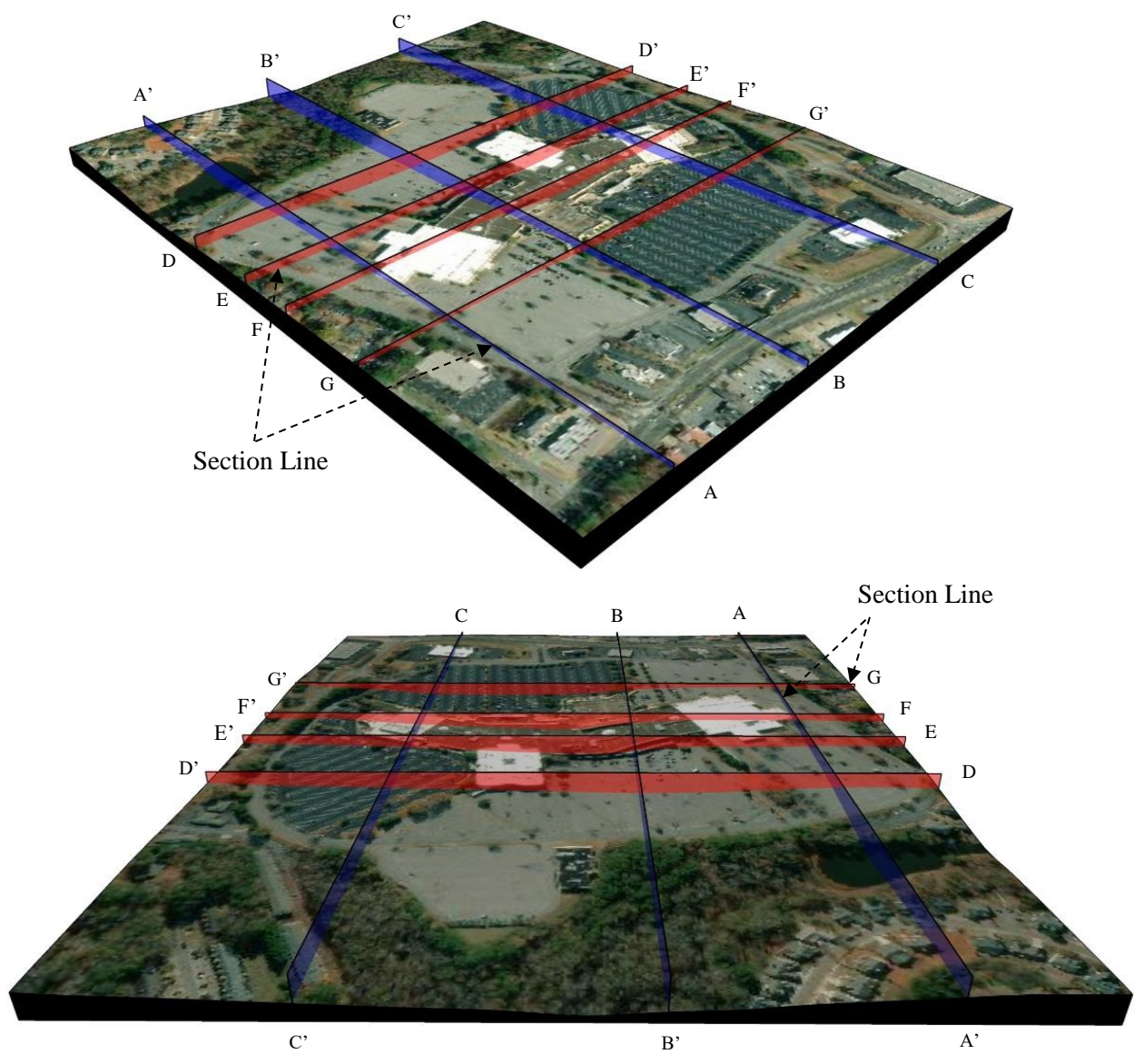


Figure 50: Plan illustrating existing topography with low and high points
 (Source: Athens-Clarke County Open Data, accessed April 2024, edited by Author)

Figure 49 illustrates the existing contour map of Georgia Square Mall, which sits on a fairly flat site. The contour lines are spaced at one-foot intervals. The highest contour line corresponds

to an elevation of 760 feet, whereas the lowest contour line represents an elevation of 730 feet. The south side of the site is at the high elevation, gradually sloping down toward the north (as depicted in the gradient in the Figure 50). Moreover, the lowest area within the site is highlighted in yellow. Additionally, various section lines have been drawn to emphasize differences across the site. To provide a more comprehensive understanding, I have included perspective views of the topography (see Figure 51). These figures likely depict the elevation changes from different angles, offering a clearer picture of the land's variations.



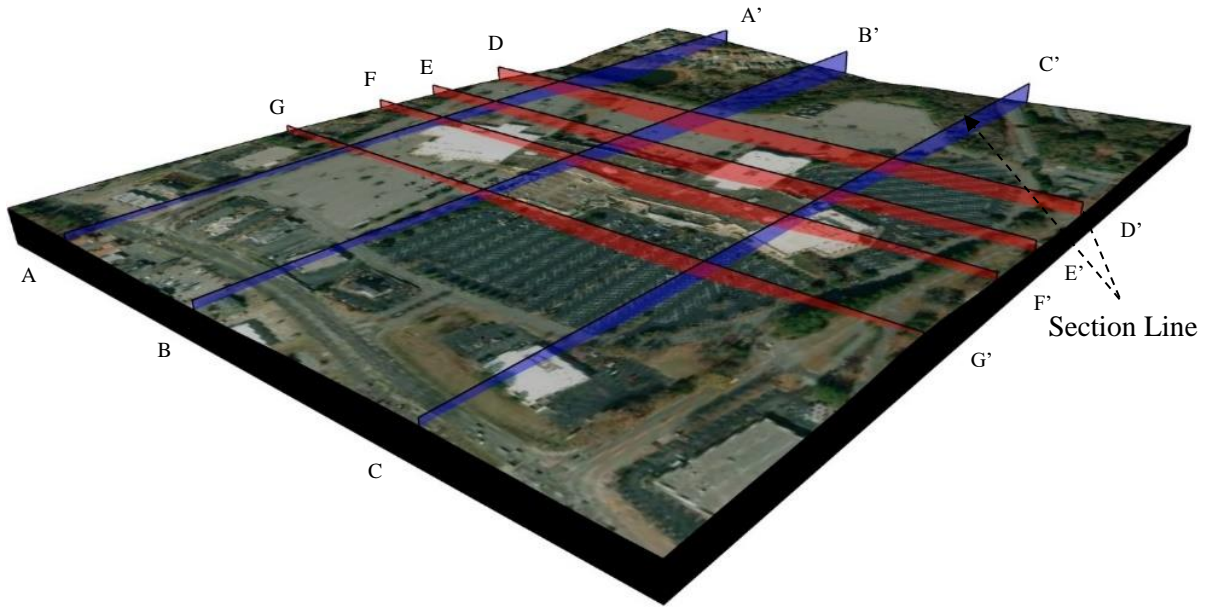


Figure 51: Perspective View illustrating Topography
 (Source: Google Earth Pro, accessed April 2024, edited by Author)

5.5. Solar Path Assessment

Solar path diagram illustrates the sun's position in the sky at different times of the day and throughout the year. Mapping the solar path is essential in optimizing solar heating and cooling strategies.

During summer, the sun reaches a mid-latitude position, as shown in Figure 52. The solar path diagram for Athens, Georgia, illustrates that the sun rises in the northeast, reaches its peak altitude during midday, and sets in northwest, indicated by red line (see Figure 53 & 54). The high elevation angle during the summer means that solar radiation predominantly impacts rooftops, with less light reaching the south side elevation. Shadows are shorter during this season, resulting in higher temperatures on exposed surfaces.

Consequently, it is crucial to design shading elements to block excessive heat, particularly on east and west facades, to maintain comfortable indoor temperatures and reduce cooling loads. Effective shading helps to minimize the amount of direct sunlight entering the building, thus reducing the need for air conditioning.

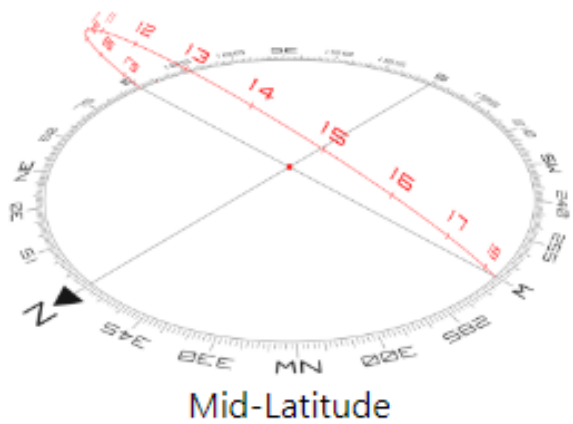


Figure 52: Latitude height illustrating path for summer sun
(Source: Andrew Marsh)

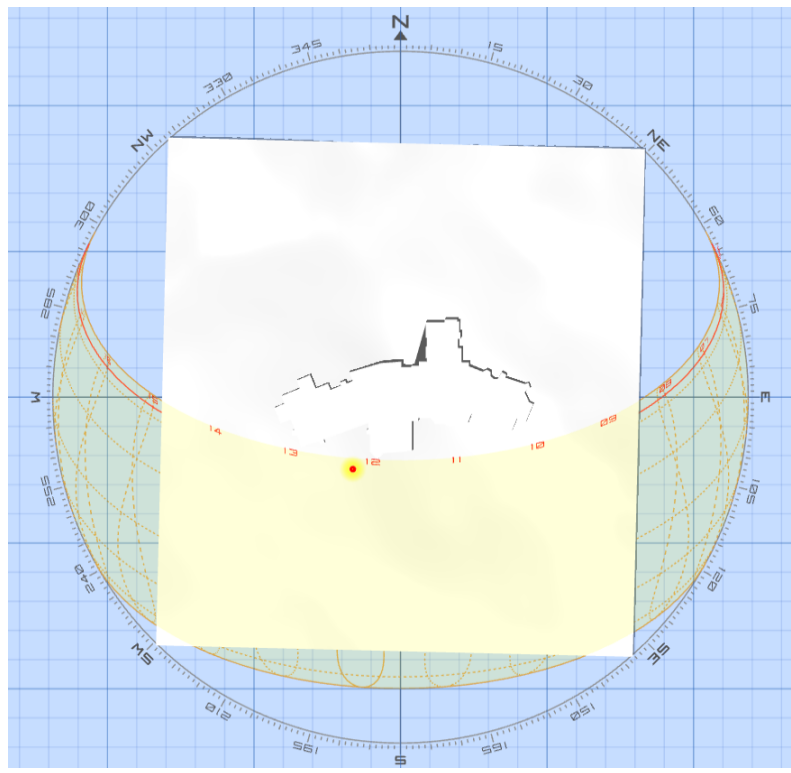


Figure 53: Solar Path Diagram for hottest day of Athens, Georgia- Top View
(Source: Andrew Marsh)

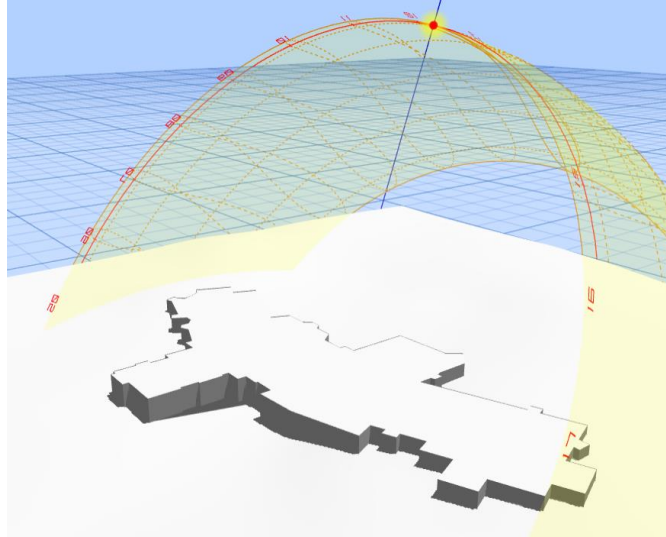


Figure 54: Solar Path Diagram for hottest day of Athens, Georgia- Perspective view
(Source: Andrew Marsh)

Conversely, during the winter months, the sun follows a much lower path, as illustrated in Figure 55. It rises in southeast and sets in southwest, with the sun never reaching as high as it does in summer (see Figure 56 & 57). This results in longer shadows and less direct sunlight on south-facing facades. Additionally, it allows sunlight to penetrate deeper into building interiors. Therefore, to optimize winter heating, it is essential to maximize solar gain through strategic orientation and minimize shading on the southern side of the buildings. This approach ensures that buildings receive the maximum amount of sunlight during the colder months, enhancing natural heating and reducing reliance on artificial heating systems.

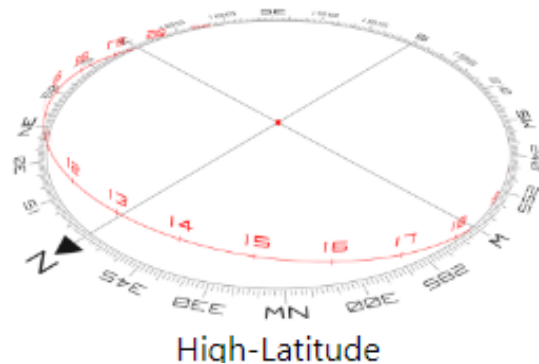


Figure 55: Latitude height illustrating path for winter sun
(Source: Andrew Marsh)

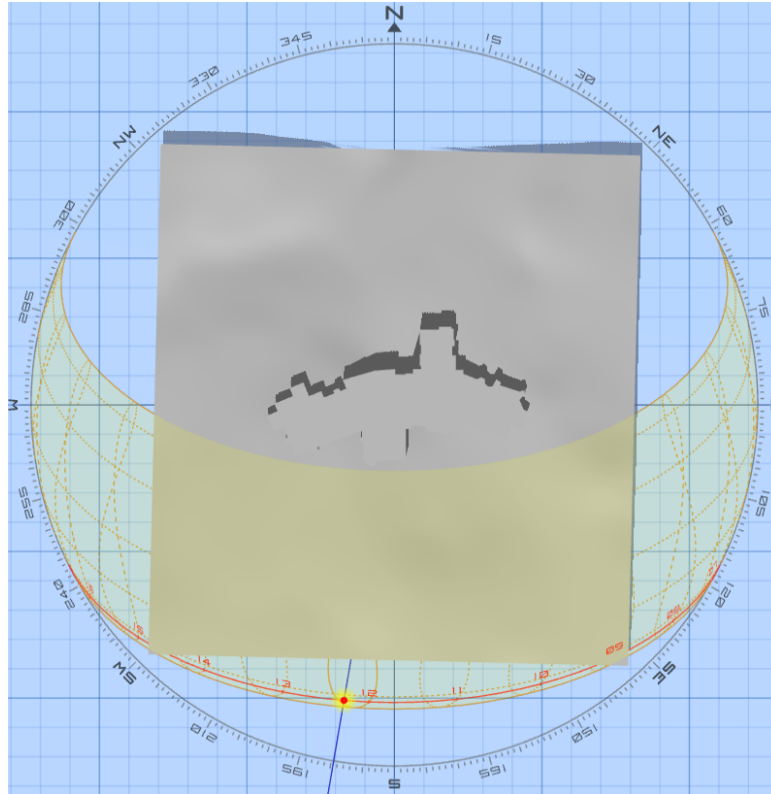


Figure 56: Solar Path Diagram for coldest day of Athens, Georgia- Top View
(Source: Andrew Marsh)

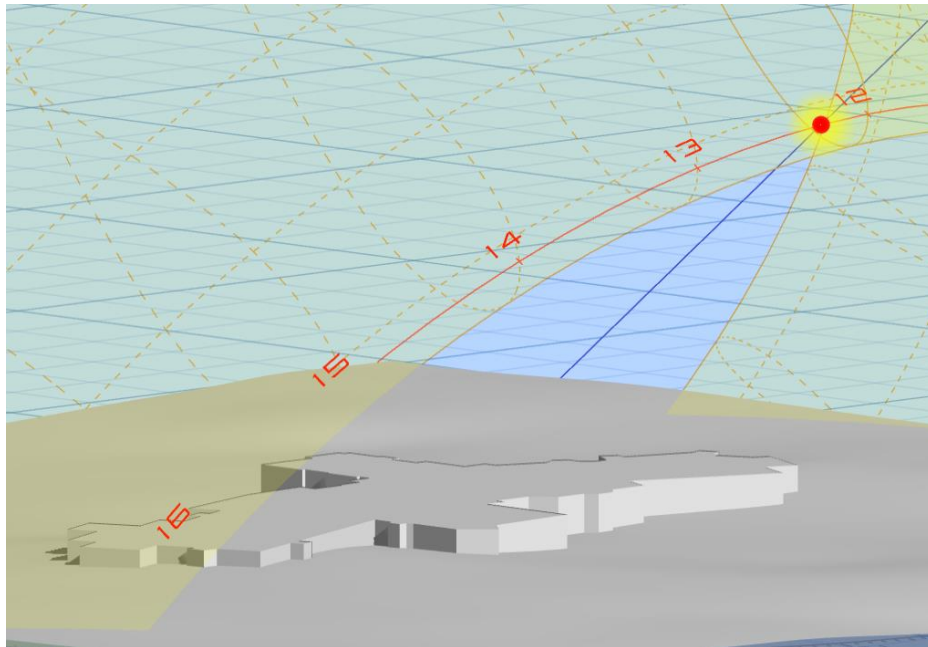


Figure 57: Solar Path Diagram for coldest day of Athens, Georgia- Perspective View
(Source: Andrew Marsh)

5.6. Climate Mapping and Analysis

This section will discuss the impact of dry bulb temperature, relative humidity, wind direction, and wind speed on the site and its microclimate. Figure 58 provides a comprehensive graph of annual weather data for Athens, Georgia, for the year 2023. Additionally, I will explore each aspect of climate mapping highlighted in the graph, emphasizing its significance in designing strategic landscaping for energy conservation.

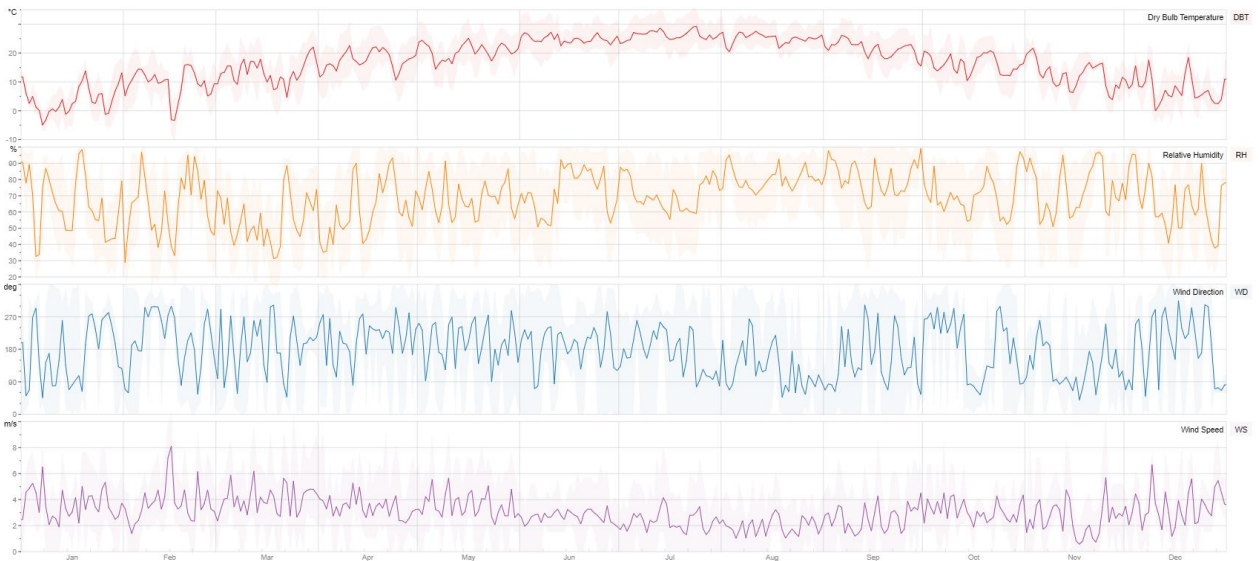


Figure 58: Annual Weather Data illustrating Dry Bulb Temperature, Relative Humidity, Wind Direction, Wind Speed for Athens, Georgia
(Source: Andrew Marsh)

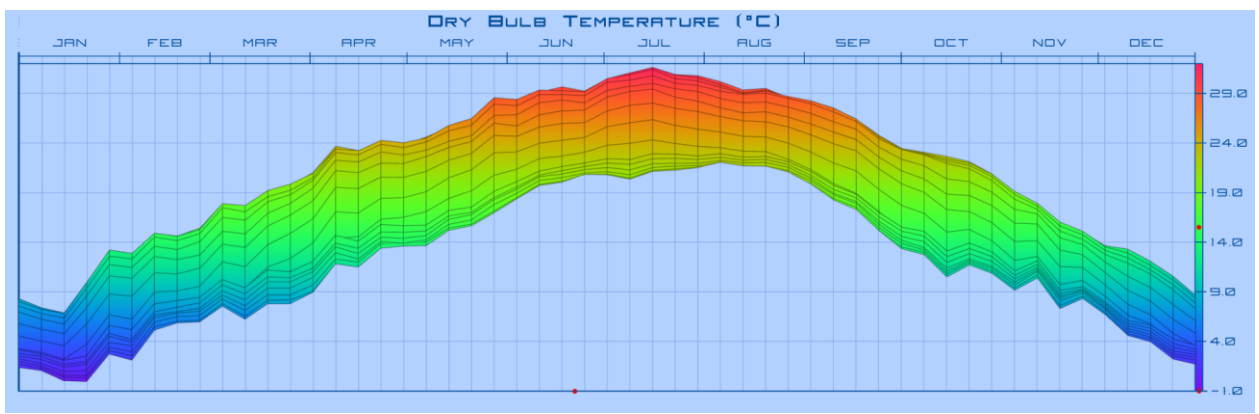


Figure 59: Dry Bulb Temperature for Athens, Georgia in °C - 2D View
(Source: Andrew Marsh)

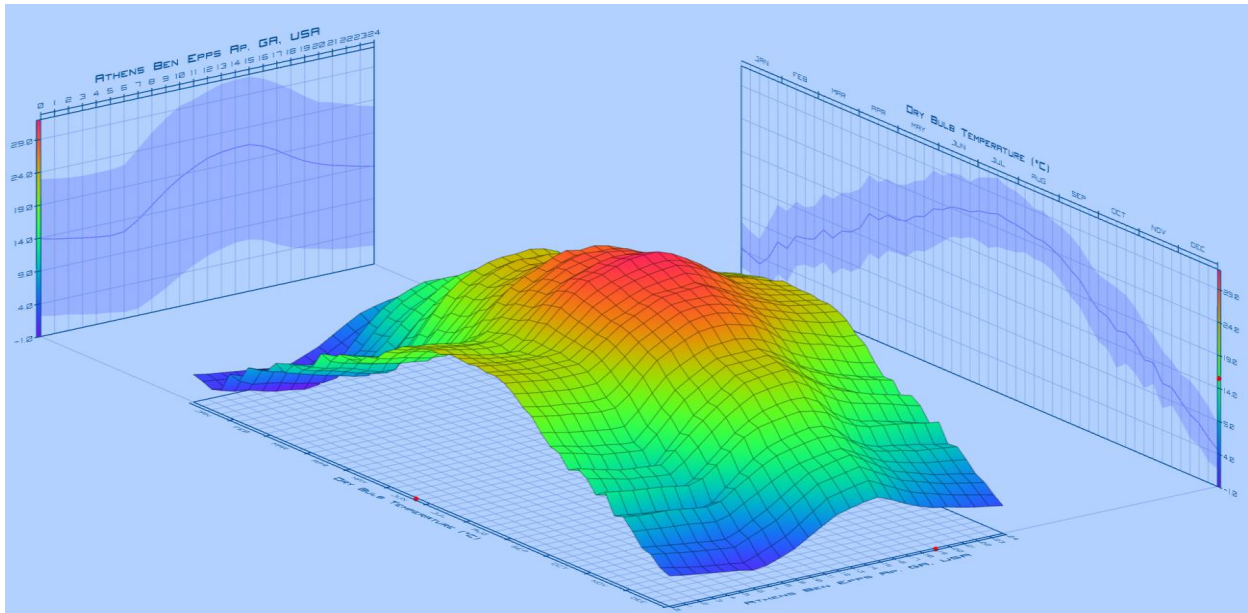


Figure 60: Dry Bulb Temperature for Athens, Georgia in °C - Perspective View
 (Source: Andrew Marsh)

Dry bulb temperature, also known as ambient air temperature, is crucial for understanding the climate characteristics of a region. Figure 59 & 60 illustrates the dry bulb temperature data for Athens, Georgia, for the year 2023, detailing weather patterns across 12 months and 24 hours per day. It shows that July is the hottest month in Athens, with temperatures reaching approximately 33°C between 12 p.m. to 3 p.m. Conversely, January being the coldest period, with temperatures dropping to around 2°C.

Mapping dry bulb temperature is vital for strategic landscaping because it helps understand when maximum solar radiation occurs and reveals the solar patterns for each month. This information is essential for determining the heat tolerance and cold resistance of plant species, designing effective shading and orienting landscaping features. Moreover, the layout can be designed to provide cooling during peak temperatures, enhancing the thermal comfort.

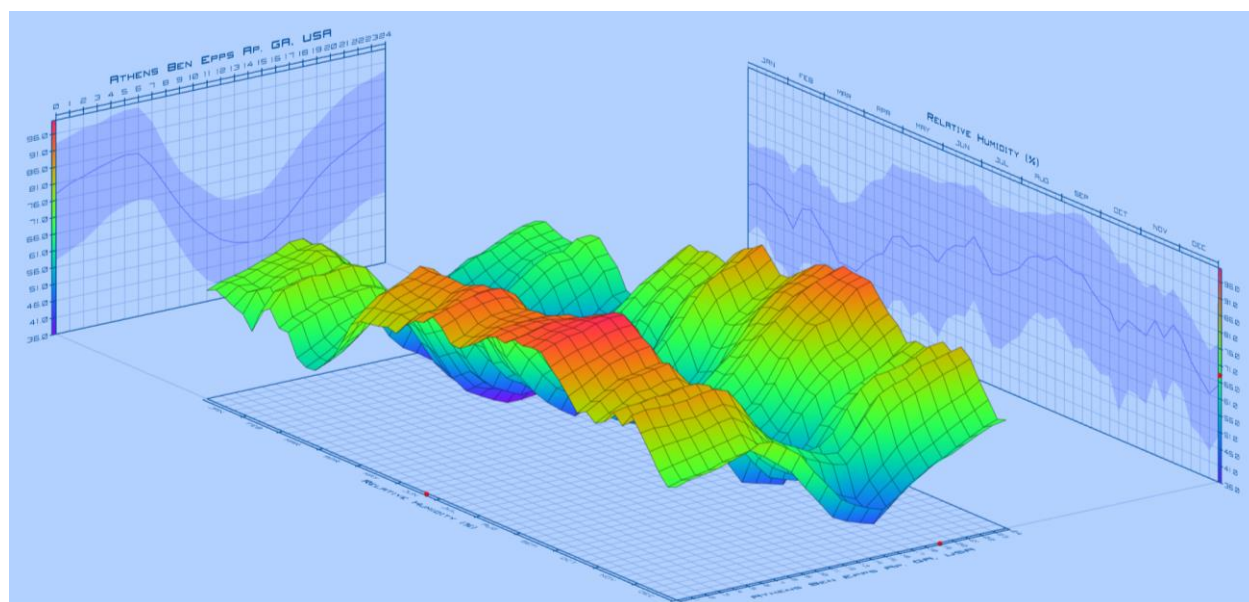


Figure 61: Relative Humidity for Athens, Georgia in % - Perspective View
(Source: Andrew Marsh)

Relative humidity is also crucial for understanding the climate characteristics of a region. It represents the percentage of moisture in the air relative to the maximum amount the air can hold at a given temperature. Figure 61 illustrates the relative humidity for Athens, Georgia, for the year 2023, detailing weather patterns across 12 months and 24 hours per day. It shows that late August has the highest humidity levels, reaching approximately 83%. The relative humidity is highest around midnight and decreases starting from 6 a.m. This pattern occurs because warmer air can hold more moisture, causing relative humidity to decrease as temperature increases, and vice versa.

Mapping relative humidity is crucial for strategic landscaping for multiple reasons. It aids in managing moisture levels, pinpointing when and where maximum evaporation is needed to optimize humidity. This knowledge is vital for selecting plant species that thrive in specific humidity conditions. Low humidity enhances evaporative cooling efficiency, a significant advantage for Athens, where low humidity levels prevail. Thus, implementing evaporative cooling in the windward direction proves beneficial in such conditions.

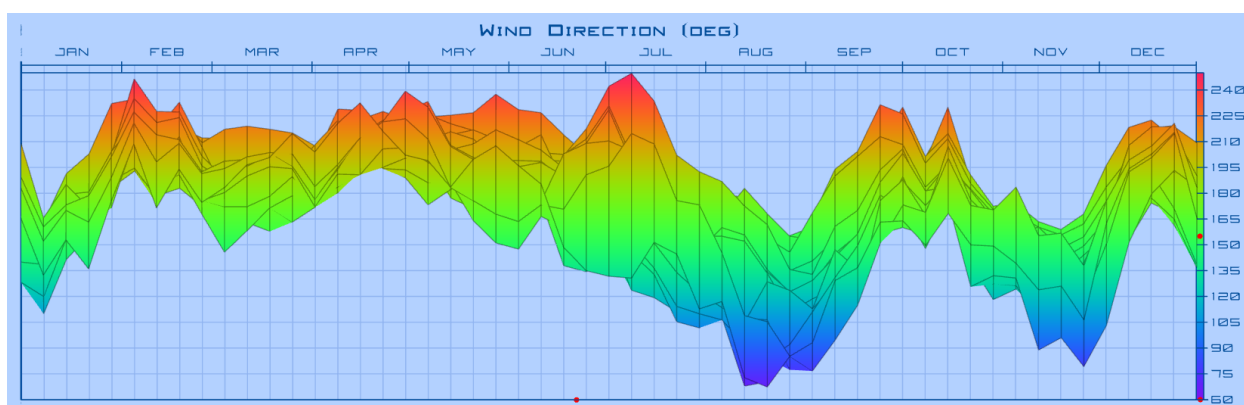


Figure 62: Wind direction for Athens, Georgia in degree – 2D View
(Source: Andrew Marsh)

Wind direction indicates the prevailing winds of a region. Figure 62 & 63 illustrates the wind direction for Athens, Georgia, for the year 2023. It shows that winds predominantly come from the southwest (240 to 250 degrees) from May to mid-July. In August, the wind direction shifts to 75-150 degrees, and from September to October, it returns to approximately 230 degrees (southwest). During the winter months, the wind direction varies between 150-240 degrees (south, southwest, southeast). Throughout the year, the wind direction ranges from 70 to 250 degrees (east to southwest).

Mapping wind direction is crucial for strategic landscaping as it informs the orientation of plant species, the placement of windbreaks, and the design of features to either channel or deflect wind, optimizing the microclimate and enhancing comfort.

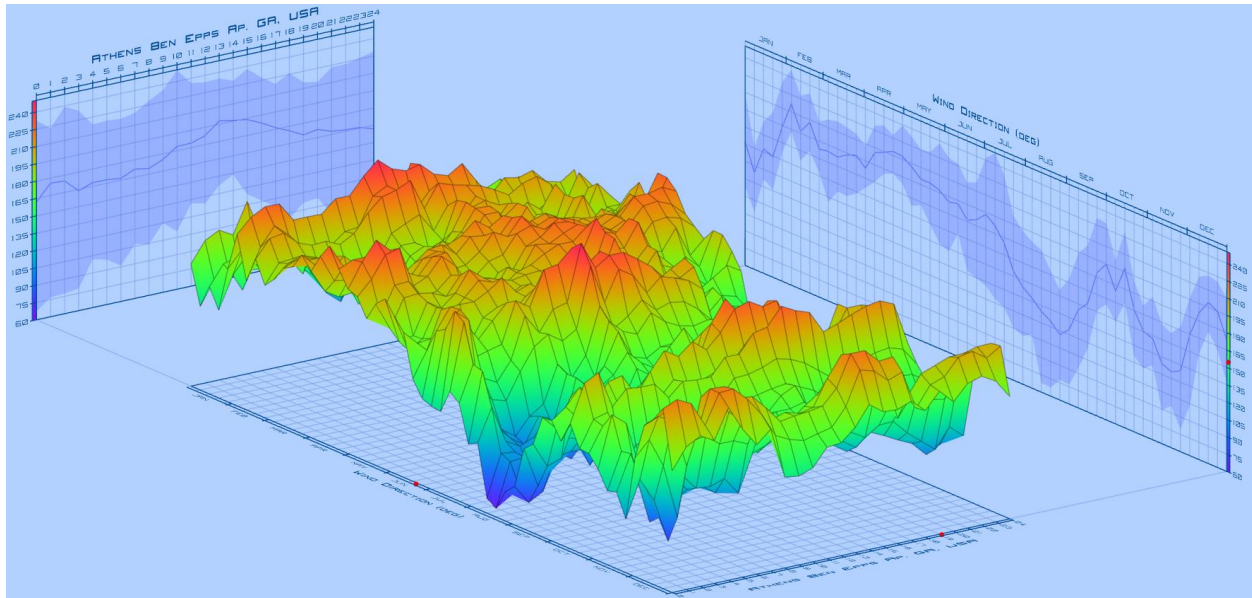


Figure 63: Wind direction for Athens, Georgia in degree – Perspective View
(Source: Andrew Marsh)

Moreover, mapping wind speed is essential for understanding the dynamics of airflow in the region. Figure 64 indicates that the maximum wind velocity occurs in March, reaching approximately 4 m/s, while the lowest wind velocity is observed from August to September, around 2 m/s. Throughout the year, the average wind velocity is about 3.5 m/s. The graph also details the daily variations in wind speed, showing that wind velocity begins to increase around 5 a.m., peaks between 12 p.m. and 2 p.m., and then decreases to about 2.5 m/s during the evening and night.

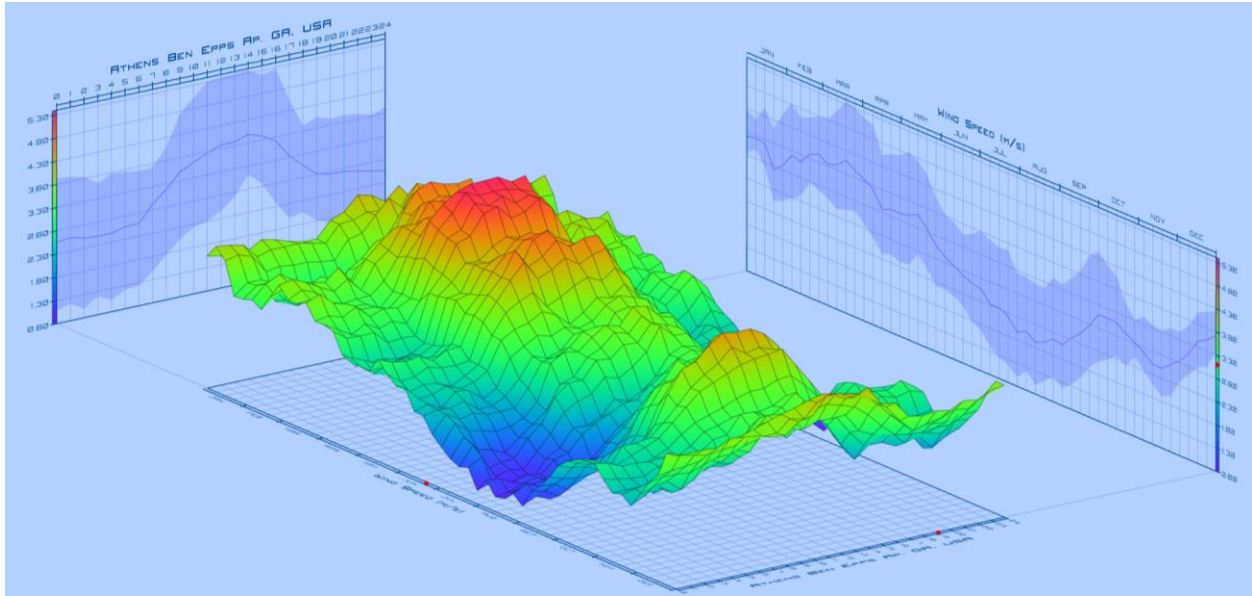


Figure 64: Wind speed for Athens, Georgia in m/s – Perspective View
(Source: Andrew Marsh)

Understanding climate and solar pattern is crucial for making informed design decisions that enhance energy efficiency and occupant comfort. By strategically orienting the landscape, integrating shading elements, selecting appropriate materials, and positioning windows effectively, designers can optimize natural sunlight, shading, wind patterns, and humidity levels. These considerations ensure that buildings achieve better thermal performance, reducing the need for artificial cooling and heating.

5.7. Existing Proposal by W&A Engineering

In this section of the chapter, I will delve into the current proposal for the Georgia Square Mall, crafted by the W&A Engineering group. Figure 65 presents the envisioned site plan, which encompasses a diverse program. The proposed program integrates a redeveloped mall area, retail outlets, office spaces, townhomes, multi-use residential units, senior living facilities, transit options, ample parking spaces, areas designated for storm water management, and various green spaces. Figure 66 compares the existing condition and proposal by W&A Engineering for better understanding.

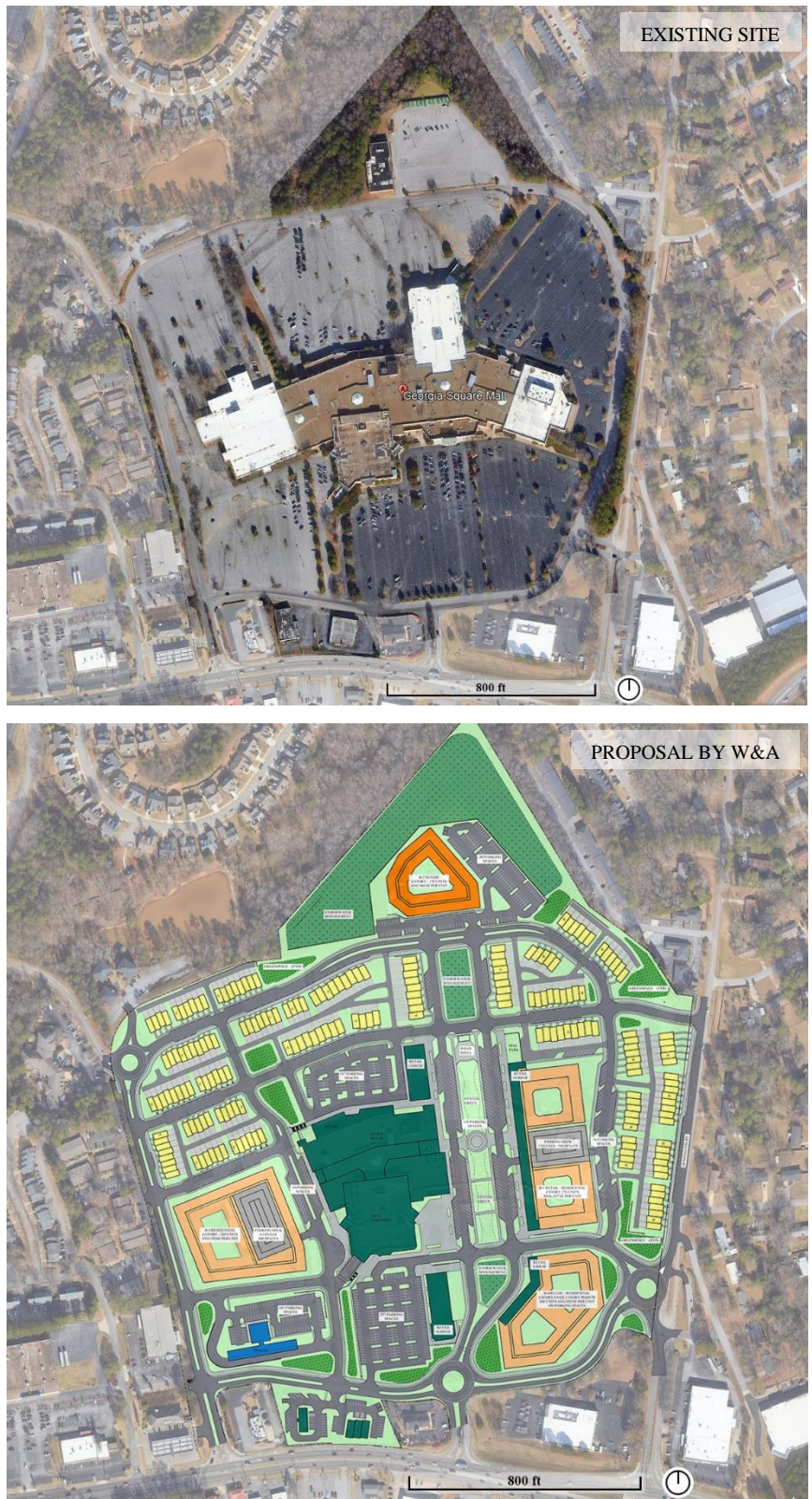


Figure 66: Comparison between existing and proposed site plan by W&A Engineers
(Source: Google Earth Pro and W&A Engineering, 2024)

5.8. Guiding Principles

The guiding principles are formulated based on the program requirements by the Athens-Clarke County (ACC), existing challenges (primarily the urban heat island effect), and the rich diversity and culture of Athens, aiming to benefit both people and the environment.

- Mitigate the urban heat island effect through strategic landscaping.
- Improve thermal comfort and the microclimate, reducing the reliance on air conditioning for heating and cooling.
- Incorporate retail spaces to cater to the varied interests of students and residents.
- Provide housing options (multi-family, senior, town homes) to accommodate the growing population.
- Encourage social interaction through a lush, inviting environment.

5.9. SWOT Analysis

The transformation of Georgia Square Mall into a mixed-use development offers several strengths that can significantly benefit the community. Located in Athens, Georgia, a culturally rich and diverse college town, the project's strategic location ensures strong community engagement. The large site provides ample space for diverse uses, including retail, housing, and green areas, fostering social interaction and economic growth.

However, the project also faces notable weaknesses. The mall's current vacancy indicates potential difficulties in attracting new tenants and visitors. Additionally, the predominance of asphalt and parking areas contributes to the urban heat island effect and environmental degradation, requiring substantial initial investments for mitigation.

Despite these weaknesses, the project presents numerous opportunities. It offers a chance to create a space that demonstrates how urban heat islands can be mitigated through passive cooling and strategic landscaping. This approach can set a precedent for future developments, reducing the reliance on air conditioning for heating and cooling. Moreover, creating a space that reflects and serves Athens' diverse population, fostering community pride and involvement.

Nevertheless, the project is not without threats. Addressing extensive environmental issues might be much expensive than a conventional development.

Overall, the transformation of Georgia Square Mall presents a balanced mix of strengths, weaknesses, opportunities, and threats, which I will address in next chapter.

5.10. Conclusion

The site inventory in this chapter lays the groundwork for the design process. It explores various aspects of the project, including its character, location, current use, climate zone, surrounding context, and environmental considerations. The inventory identifies existing challenges and evaluates a balanced mix of strengths, weaknesses, opportunities, and threats. Guiding principles derived from this evaluation will inform the design process detailed in the next chapter.

CHAPTER 6

RE-IMAGINED DESIGN

This chapter delves into the intricacies of design responses for the Georgia Square Mall, offering a comprehensive overview of the design process developed by me (see Figure 67). It begins with zoning of spaces based on climate considerations, leading to the development of re-imagined master plan that aligns with the program requirements of Athens Clarke County. Building upon the site inventory conducted in the previous chapter and the analysis of shadow patterns, a landscape zoning plan is meticulously crafted. Furthermore, the chapter explores planting plans and strategies, examining their role in improving microclimate and enhancing thermal comfort indoors. Concluding with visualizations, this chapter aims to provide valuable insight into the design journey.

The design responses explored in this chapter are informed by the research questions from previous chapters, specifically focusing on how landscape design can passively cool or heat buildings. The insights gained from understanding UHIs, their causes and effects, and the role of mechanical systems in exacerbating climate change have shaped the approach to creating a sustainable and thermally comfortable design for Georgia Square Mall. By integrating climate-responsive zoning, site planning, and strategic landscaping, this chapter aims to address the overarching research question: How can landscape design effectively mitigate UHIs and enhance thermal comfort?

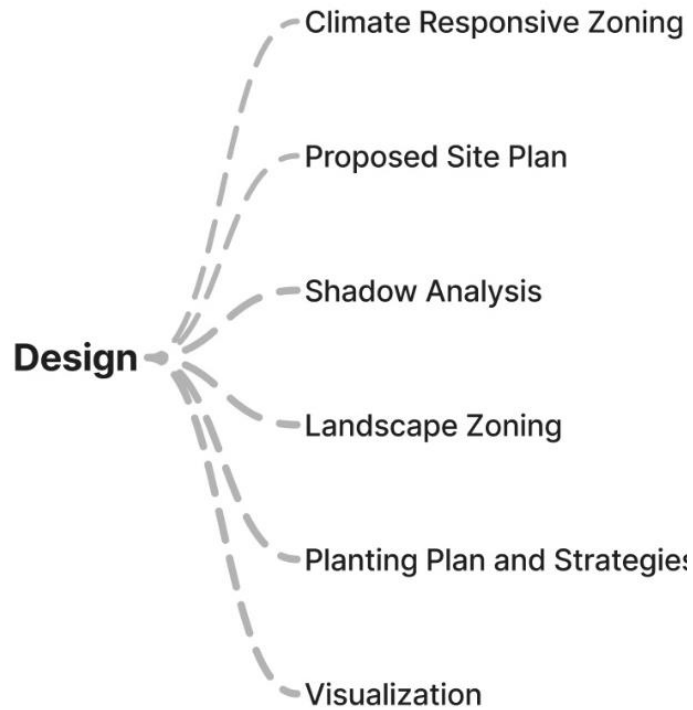


Figure 67: Overview of structure
(Source: Author)

6.1. Climate Responsive Zoning

The zoning map (see Figure 68) is crafted by me based on existing site conditions. The map integrates climate conditions and findings from the site inventory conducted in the previous chapter. It strategically allocates program areas to specific locations, taking into account the prevailing wind directions and solar path movements in Athens, Georgia.

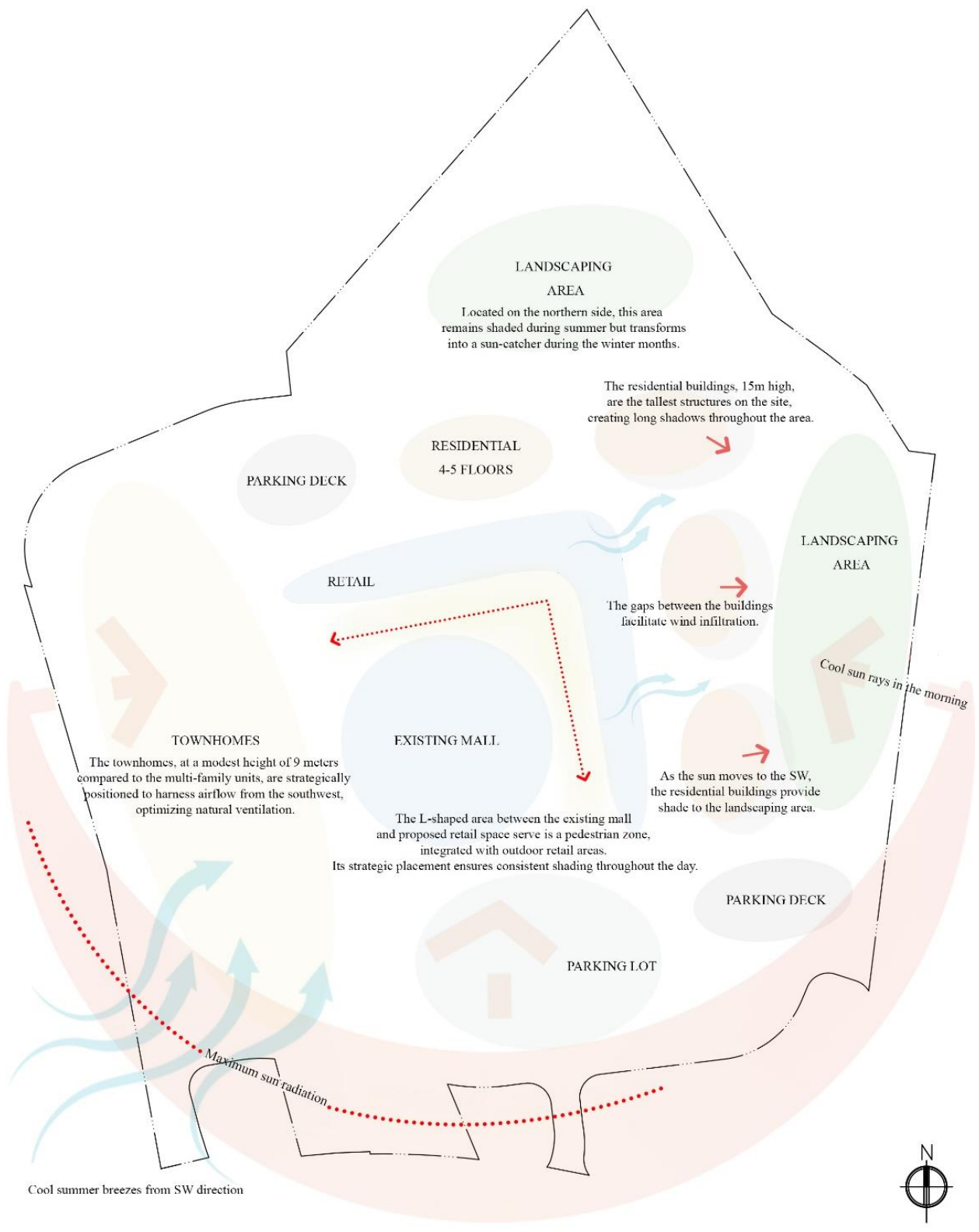


Figure 68: Climate Responsive Zoning Map
(Source: Author)

6.2. Re-imagined Master Plan Proposal

LEGEND:

- 1. Existing Mall- Retail- 16, 479 sq.m
- 2. Proposed Retail- 8,132 sq.m
- 3. Multi-Use Residential- 10,712 sq.m per floor
- 4. Senior Residential- 3.800 sq.m per floor
- 5. Parking Deck- 10,137 sq.m per floor
- 6. Transit
- 7. Residential- Townhomes- 202 units
- 8. Parking Lot + On Road Parking - 1,214 spaces
- 9. Landscaping Area (Sport Courts + Dog Park + Pool)- 33,664 sq.m
- 10. Pedestrian Retail Area- 13,942 sq.m
- 11. Storm Water Management
- 12. Entry from Huntington Road
- 13. Entry from Atlanta Highway
- 14. Entry from Marilyn Farmer Way

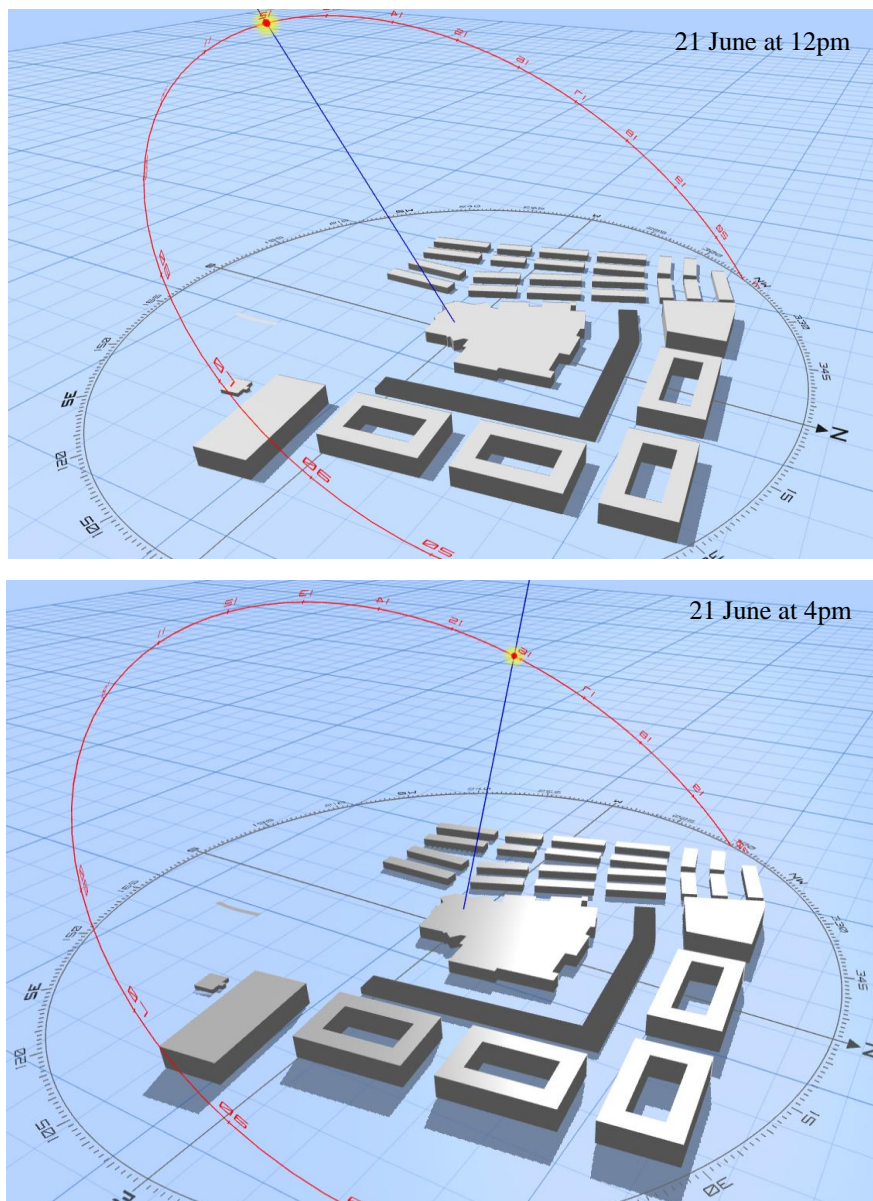


Figure 69: Site Plan
(Source: Author)

The re-imagined master plan proposal (see Figure 69) is developed by me based on the insights from the zoning plan. The program for the site has been proposed by Athens Clarke County.

6.3. Shadow Analysis of Built Mass

To guide the landscaping design, I have investigated how solar path movement affects the buildings (see Figure 70). This analysis covers various time periods, including the hottest and coldest days in Athens, Georgia.



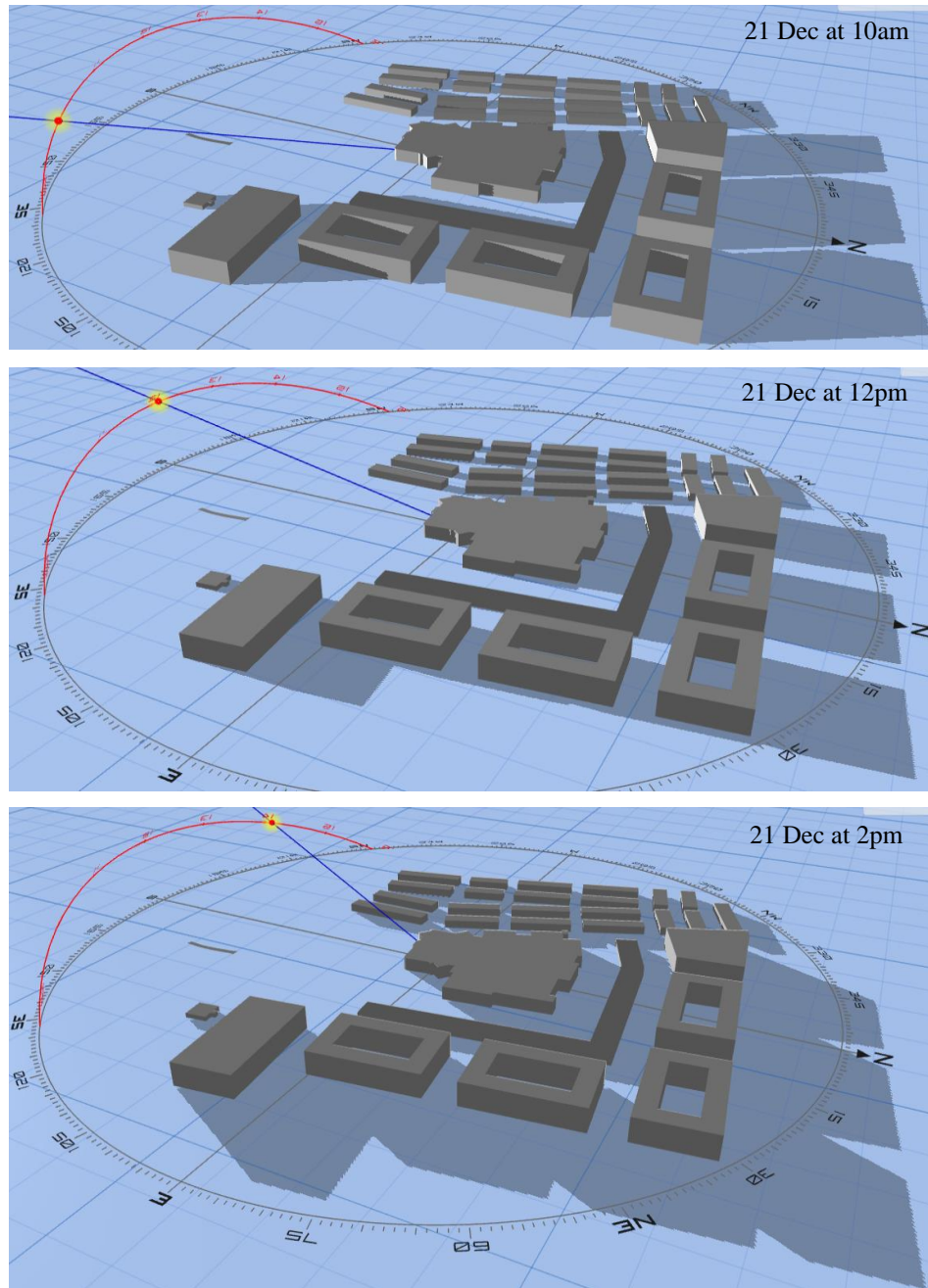


Figure 70: Solar Path Movement
(Source: Andrew Marsh)

6.4. Zoning of Landscape

Drawing from insights into sun path movement, shadow analysis, building orientation, and prevailing weather conditions, I strategically crafted a zoning diagram for landscaping species aimed at enhancing indoor thermal comfort, as depicted in Figure 71.



Figure 71: Zoning of Landscaping
(Source: Author)

The landscape zoning plan delineates the optimal selection and placement of trees, shrubs, vines, and groundcovers to enhance thermal comfort within the buildings. These selections are based on various factors including density, branching type, light requirements, leaf characteristics, and whether they are deciduous or evergreen.

The area labeled as number 9 in the site plan (see Figure 69) has been excluded from the landscaping design process as it falls outside the scope of the research question. Only areas directly impacting buildings have been considered.

Furthermore, a comprehensive planting plan (see Figure 72) has been developed in alignment with the zoning plan. The chosen trees and landscaping species are native to Georgia, United States, falling within hardiness zones 8a and 8b.

6.5. Planting Plan and Strategy

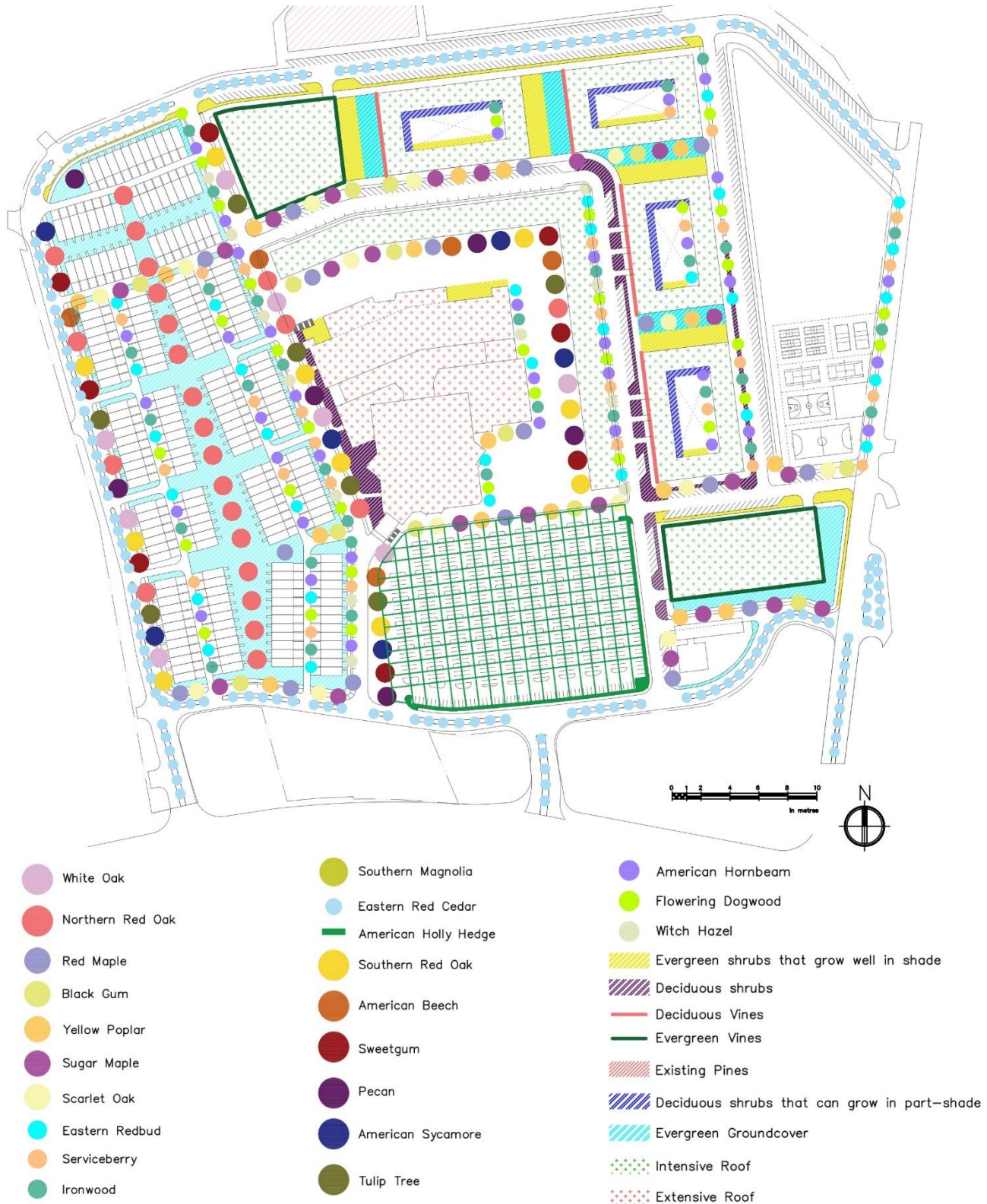


Figure 72: Conceptual Planting Plan
(Source: Author)

This section details the strategic placement of native trees and shrubs to create a comfortable and energy-efficient indoor thermal environment, thereby reducing the reliance on air conditioning.

Southwest and west side: The southwest side, subject to prolonged sun exposure and the highest temperatures, benefits from dense canopy, high-branching deciduous trees. These trees effectively provide shade during the hottest part of the day (afternoon sun), significantly mitigating solar heat gain on building walls and decreasing the need for air conditioning. Moreover, their configuration allows summer breezes from SW, S, SE directions to flow through the high branches, facilitating natural ventilation.

South side: Direct overhead sunlight from 11 am to 1 pm on the south side predominantly impacts the roof rather than the walls. Here, medium-density, high-branching trees are strategically placed to offer shade and minimize heat radiation on walls. This deliberate positioning aids in cooling the building envelope and reduces the load on air conditioning systems.

East Side: On the east side, where morning sun intensity (8-11 am) is lower and shade persists from 11 am onwards, I have chosen less dense, high-branching deciduous trees to adapt to this pattern. These trees are specifically selected to thrive in shaded conditions and provide morning shade while still allowing for passive solar heating during winter months.

North Side: Given that the north side remains shaded year-round (see Figure 68), trees are intentionally avoided to prevent excessive shading. Instead, evergreen shrubs have been strategically placed to ensure year-round greenery and aesthetic appeal.

Winter Wind Protection: To address winter winds primarily coming from the south side, strategic placement of evergreen trees and hedges has been implemented to obstruct and deflect these winds. Southern Magnolia, with its dense canopy and low ground clearance, effectively

blocks winter winds and serves as an efficient wind barrier. Additionally, a south-facing American Holly hedge further deflects winds, enhancing building insulation during winter.

Parking Lot and Driveways: Evergreen trees and shrubs have been strategically placed along the driveways to provide shade throughout the year. In the parking lot, however, trees alone are insufficient to prevent direct heat gain. Therefore, a trellis has been designed with evergreen creepers to complement the existing landscaping. This approach is particularly advantageous given that asphalt tends to absorb and radiate solar energy consistently, including during the winter months.

Vine Usage: Deciduous vines on trellises are designed on the west side of residential buildings, positioned 0.9 to 1.2 meters away to create an insulation air gap. These vines offer shade and protect upper floors from heat gain, while also allowing for sun exposure during winters.

Groundcover: Evergreen groundcovers have been incorporated into the design to reduce reflected radiation from the sun. The selected species feature dense growth and dark green foliage, providing effective ground coverage, which helps reduce soil temperature and minimizes heat reflection. The dark foliage absorbs more sunlight rather than reflecting it, contributing to a cooler environment. Additionally, these species spread prolifically, ensuring continuous coverage with no bare spots that could reflect heat. Moreover, as Athens experiences high humidity, as shown in Figure 61, evergreen groundcover will also help maintain soil moisture levels and stable humidity around the building.

In conclusion, the planting strategy meticulously considers factors such as sun exposure, wind patterns, and seasonal changes to enhance thermal comfort and aesthetics. Through careful selection and positioning of trees, shrubs, groundcover, the strategy aims to optimize shading, reduce heat gain, and block cold winds, all while taking into account the unique environmental

conditions of Athens, Georgia. A comprehensive list of plant species used in the design and their specific roles can be found in the provided table (see Table 4 on Page 103).

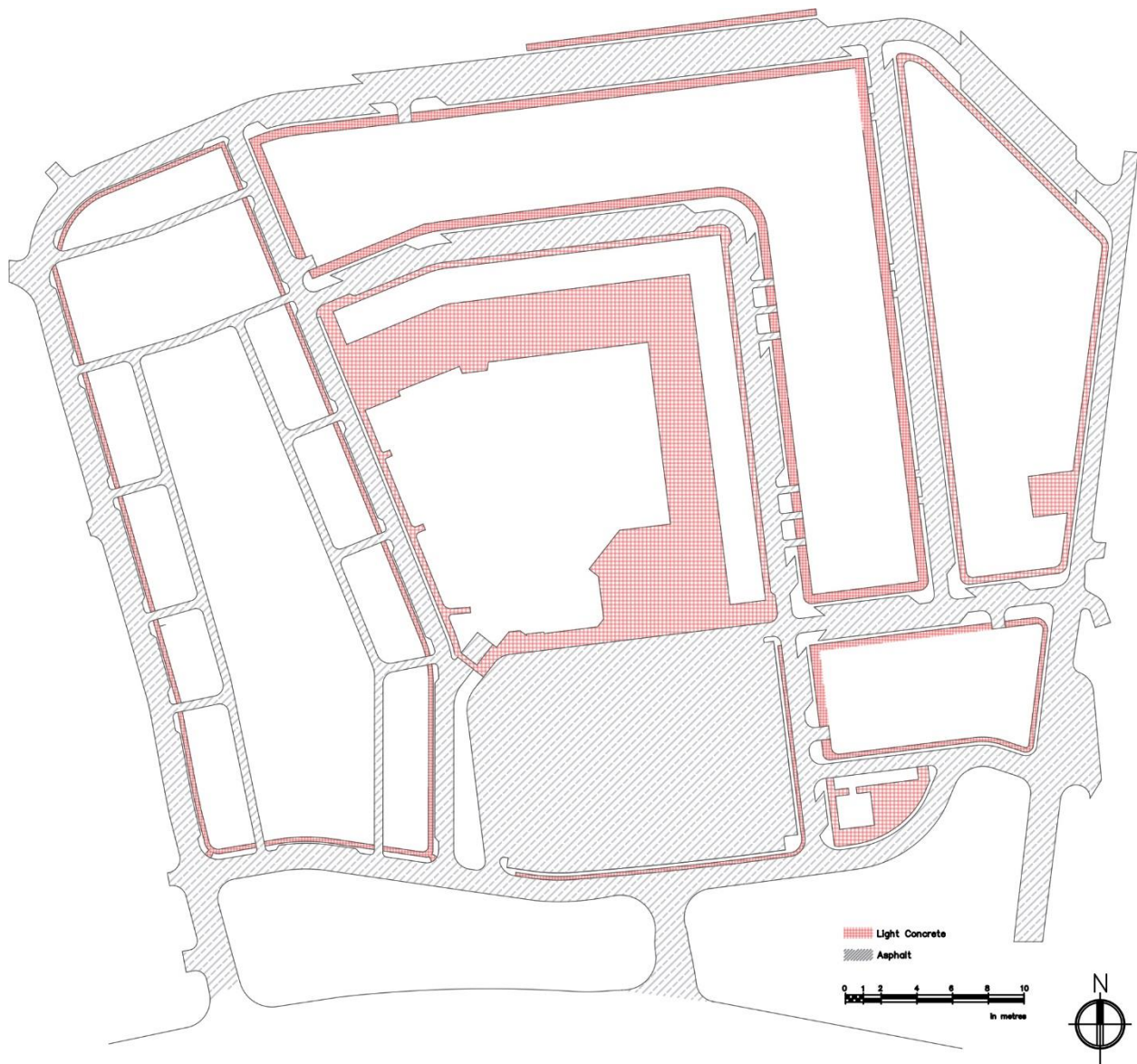


Figure 73: Conceptual Hardscape Plan
(Source: Author)

The hardscape plan, as illustrated in Figure 73, incorporates strategic landscaping to shade hardscape surfaces as much as possible with evergreen plant species. Asphalt, with its very low albedo of 0.15, significantly contributes to the urban heat island effect by absorbing a large portion of incoming sunlight and radiating heat. To mitigate this, reflective coatings have been applied to

the asphalt making it a cool pavement, increasing its albedo to 0.5, which helps to reflect more sunlight and reduce heat absorption.

In addition to shading driveways, high albedo materials have been used for other hardscape elements such as pavements and walkways. White concrete, with its very high albedo of 0.8, has been selected for these areas. This material reflects a larger portion of sunlight, thereby reducing heat absorption and helping to maintain a cooler environment. This choice not only contributes to the overall thermal comfort of the area but also helps in minimizing the urban heat island effect.

PLANTING DETAIL

Common Name	Scientific Name	Width/Spread (in m)	Optimal distance from building to achieve effective shading (in m)	Clearance from ground (in m)
High density canopy, high branching deciduous tree				
Southern Red Oak	Quercus falcata	12_15	6_7.5	3_4.5
American Beech	Fagus grandifolia	12_18	6_9	3_4.5
Sweetgum	Liquidambar styraciflua	12_18	6_9	3_4.5
Pecan	Carya illinoensis	12_18	6_9	3_4.5
American Sycamore	Platanus occidentalis	20_30	10_15	3_4.5
Tulip Tree	Liriodendron tulipifera	12_18	6_9	3_4.5
White Oak	Quercus alba	15_24	7.5_12	3_4.5
Northern Red Oak	Quercus rubra	15_24	7.5_12	3_4.5
Medium density canopy, high branching deciduous tree				
Red Maple	Acer rubrum	12_18	6_9	3_4.5
Black Gum	Nyssa sylvatica	12_18	6_9	2.4_3.7
Yellow Poplar	Liriodendron tulipifera	12_18	6_9	3_4.5
Sugar Maple	Acer saccharum	12_18	6_9	3_4.5
Scarlet Oak	Quercus coccinea	12_18	6_9	3_4.5
Low branching evergreen tree and hedges				
Southern Magnolia	Magnolia grandiflora	9_15	-	2
Eastern Red Cedar	Juniperus virginiana	2.4_7.6	-	0.6_1.2
American Holly Hedge	Ilex opaca	1.5_3	-	-
Deciduous Vines/ Creepers/ Groundcover				
Trumpet Creeper	Campsis radicans	1.5_3	0.9_1.2	9_12
Virginia Creeper	Parthenocissus quinquefolia	1.8_2.7	0.9_1.2	9_15
Crossvine	Bignonia capreolata	1.5_3	0.9_1.2	9_15
American Wisteria	Wisteria frutescens	3_6	0.9_1.2	7.6_9
Yellow Jessamine	Gelsemium sempervirens	0.9_1.8	0.9_1.2	6_9
Mondo Grass	Ophiopogon japonicus	0.3_0.6	0.5_1	0.15_0.25
Periwinkle	Vinca minor	0.10_10.30	0.5_1	0.15_0.20
Asian Jasmine	Trachelospermum asiaticum	1_3	0.5_1	0.15_0.30
Deciduous shrubs				
Oakleaf Hydrangea	Hydrangea quercifolia	1.8_2.4	1.8_3	-
Beautyberry	Callicarpa americana	0.9_1.5	1.2_2.1	-
Virginia Sweetspire	Itea virginica	0.9-1.5	1.2_2.1	-
Spicebush	Lindera benzoin	1.8_2.4	1.8_3	-
American Hazelnut	Corylus americana	1.8_2.4	1.8_3	-
Smooth Hydrangea	Hydrangea arborescens	0.9_1.5	1.2_2.1	-

Table 4: List of Plant Species
(Source: Author)

6.6. Visualization

In this design section of the chapter, I have utilized 3D visualization to present the site comprehensively. The three-dimensional images (see Figure 74 to 82) of the site were created to illustrate the design concepts and spatial arrangements effectively. These visuals provide a clear and detailed representation of the proposed design, facilitating a better understanding of its elements and layout.



Figure 74: Top View
(Source: Author)



Figure 75: View from retail area towards multi-family.
 (Source: Author)

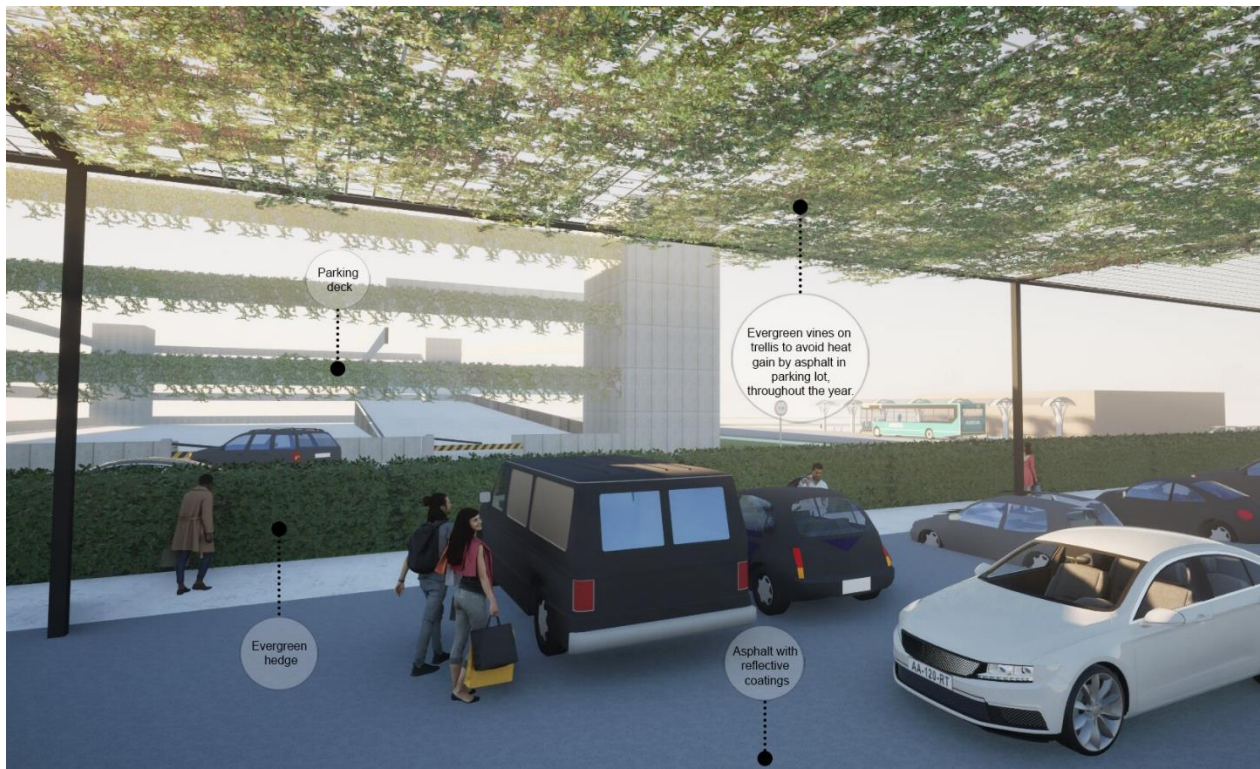


Figure 76: View of parking lot near the entrance of the site.
 (Source: Author)



Figure 77: View of multi-family.
(Source: Author)



Figure 78: View of townhomes near the retail area.
(Source: Author)



Figure 79: View of court in the retail area
(Source: Author)



Figure 80: View of court in the retail area
(Source: Author)



Figure 81: View of rooftop of multi-family.
(Source: Author)



Figure 82: View of walkway near the retail area
(Source: Author)

6.7. Conclusion

In this chapter, I have explored the design responses formulated for the proposed project, providing a comprehensive overview of the design process. The journey began with climate-responsive zoning of spaces, leveraging insights from the site inventory and shadow pattern analysis that assisted to develop a site plan that meets the specific program requirements of Athens Clarke County.

The landscape zoning plan focused on optimizing thermal comfort and enhancing the microclimate through strategic placement and selection of plant species. Each plant's characteristics and placement were carefully considered to maximize shading, minimize heat gain, and block cold winds.

This chapter concluded with visualizations that illustrate the proposed design. It showcases the thought and precision involved in planning and serves as a guide for future projects that aim to harmonize built environments with their natural surroundings. By addressing these elements, the analysis provides a comprehensive understanding of how to design an environmentally responsive and sustainable development for Georgia Square Mall.

Moving forward, the next chapter will investigate the limitations and trade-offs associated with strategic landscaping and how to evaluate its performance.

CHAPTER 7

EVALUATION

This chapter delves into the various elements that contribute to understanding the project's potential, specifically exploring the extent to which strategic landscaping can impact the passive cooling and heating of buildings. It evaluates whether the goal of achieving indoor thermal comfort through landscaping design has been met by comparing the results of existing and proposed plans using area distribution and ENVI-met simulations. ENVI-met is a three-dimensional microclimate modeling software that simulates the interaction between urban surfaces, vegetation, and the atmosphere. These simulations help to visualize and analyze the effects of landscaping on thermal comfort and environmental conditions. Additionally, this chapter includes a recommendation list to assist landscape architects in creating effective landscaping for passive cooling. I have assessed which aspects of the design proved feasible and effective, as well as the limitations (see Figure 83).

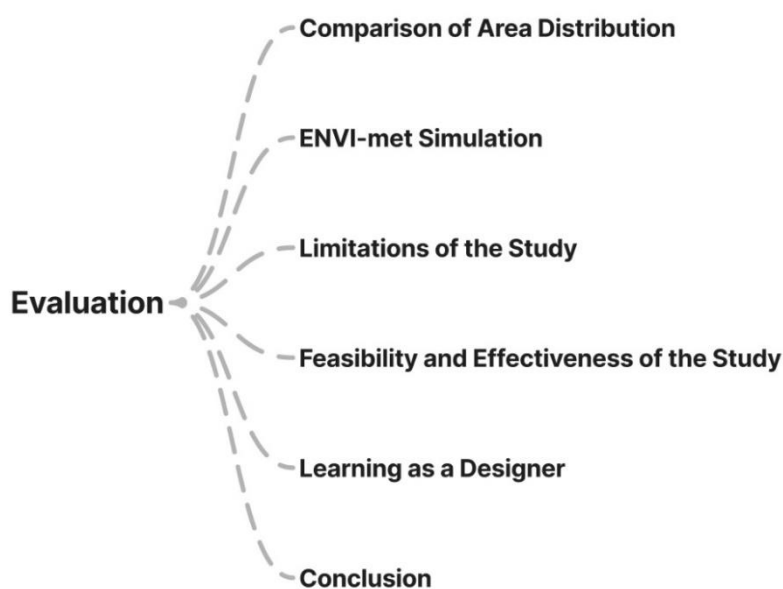


Figure 83: Overview of evaluation
(Source: Author)

7.1. Comparison of Area Distribution

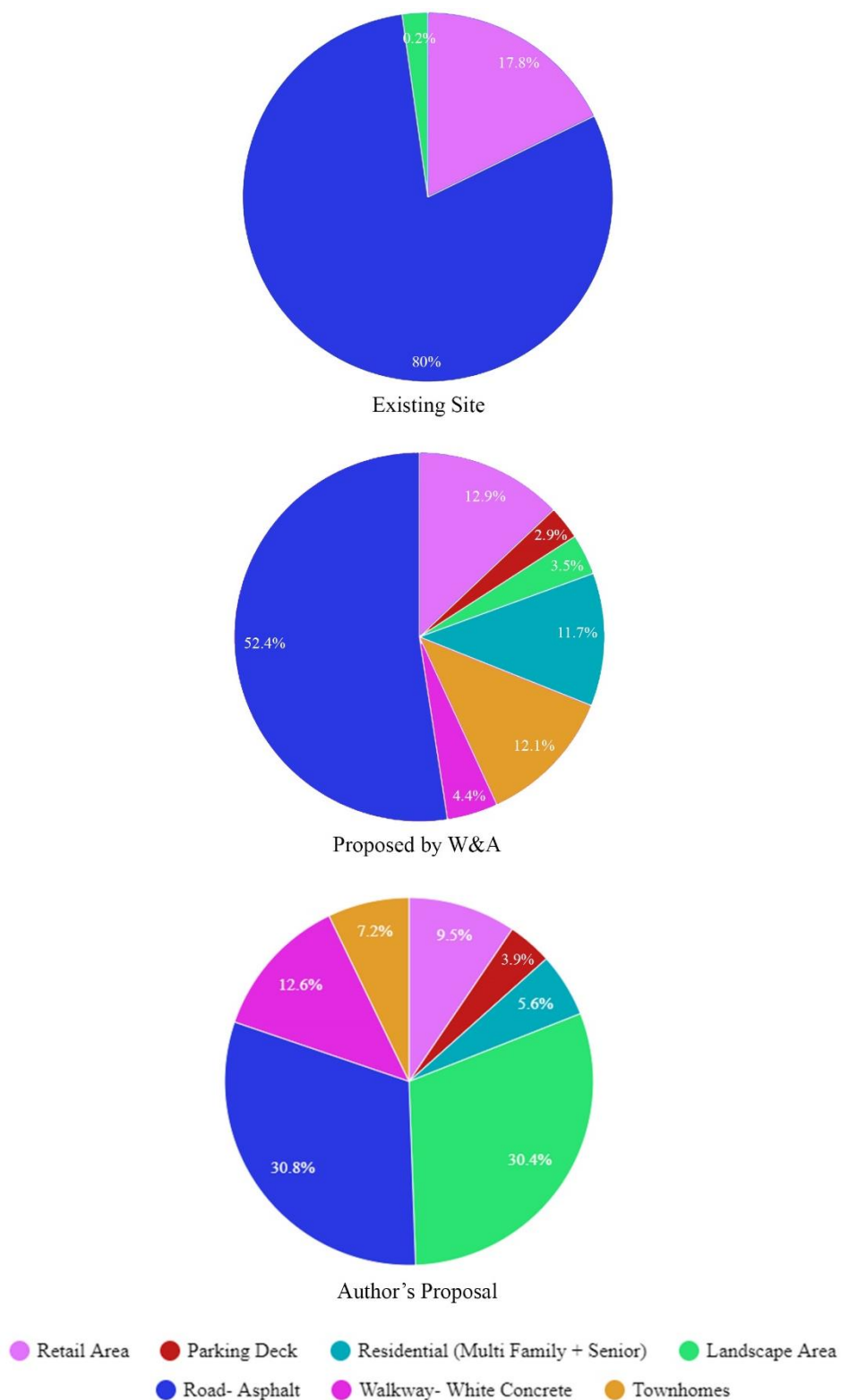


Figure 84: Area Distribution
(Source: Author)

The pie charts in Figure 84 illustrates the area distribution of the site under three different scenarios: the existing condition, the proposal by W&A Engineering Group, and my proposal.

In the existing condition, the site has a predominant usage of asphalt, covering 80% of the area, while landscaping occupies a mere 0.2%. The proposal by W&A Engineering Group introduces various programs to the site, as indicated in the legend. In this proposal, the asphalt area decreases to 52.4%, and landscaping increases to 3.5%.

The pie chart depicting my proposal shows a significant reduction in asphalt coverage to 30.8%. Despite incorporating all the program requirements, the landscaping area is notably increased to 30.4%.

This comparison highlights the distribution of areas in various sections of the site. My proposal demonstrates a more efficient approach to reducing the urban heat island effect by substantially increasing the landscaping area and reducing the use of asphalt and heat absorbing materials, thereby promoting a healthier microclimate.

7.2. ENVI-met Simulation

To simulate the urban environment, I have utilized ENVI-met software, creating models for all three conditions to study and analyze their behavior under various environmental and temporal conditions. ENVI-met considers factors and variables such as air temperature, wind speed, humidity, radiation, and the interactions between urban surfaces and vegetation. It models the microclimate in high resolution, capturing the effects of buildings, trees, and other landscape elements on the thermal environment. However, ENVI-met has several limitations. It does not evaluate indoor temperatures, focusing solely on outdoor conditions. Additionally, it primarily uses graphs for data representation, which can sometimes be vague and not fully accurate. The

accuracy of the simulation also depends on the precise placement, size, and species of plant materials, which may not always be perfectly replicated in the model. This section compares air temperature across three scenarios: the existing condition, the proposal by W&A Engineering Group, and my proposal. While ENVI-met includes many of the factors discussed in the first three chapters, such as thermal comfort and environmental impacts, it does not encompass every aspect, particularly those related to indoor climate conditions and certain detailed specifics of vegetation.

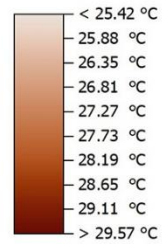
Figure 85 illustrates the air temperature in °C for each scenario, specifically evaluated on June 21, 2021, at 2 pm, the hottest time of the year in Athens. The existing conditions show an average temperature of approximately 27.79°C, while the W&A Engineering proposal reduces the average temperature to 23.44°C. Remarkably, my proposed plan achieves the lowest average temperature at 20.01°C. This significant reduction is due to the strategic landscaping discussed in section 6.5. However, areas near the mall and residential buildings exhibit higher temperatures due to the absence of trees, and the ENVI-met simulations do not account for the impact of vines used in those areas. Additionally, the pedestrianized retail area experiences elevated temperatures, which could be mitigated by incorporating roof overhangs to provide shade against direct solar radiation during peak hours from 12 pm to 2 pm. It's important to note that the ENVI-met simulations has not included the effects of green roofs, vines on façades, or trellises, which could further enhance cooling.



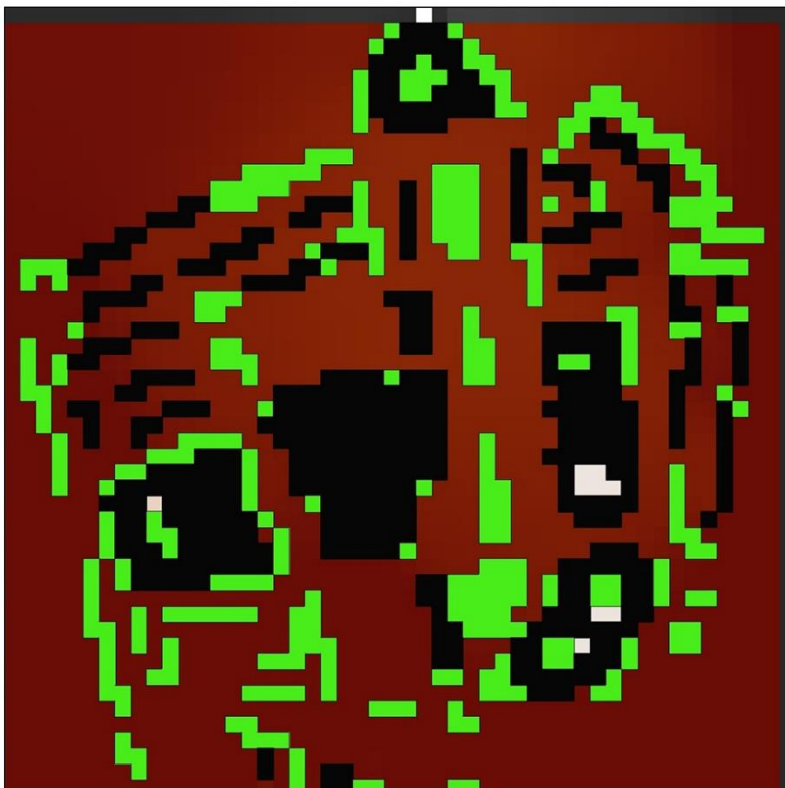
Existing Site

Figure 1: New Simulation
14.00.00 01.07.2021
x/y Cut at k=0 (z=0.2000 m)

Potential Air Temperature



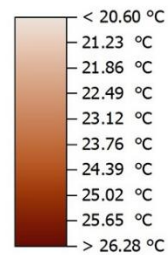
Min: 25.08 °C
Max: 30.51 °C



Proposed by W&A

Figure 1: New Simulation
15.00.00 01.07.2021
x/y Cut at k=0 (z=0.2000 m)

Potential Air Temperature



Min: 20.20 °C
Max: 27.04 °C



Author's Proposal

Figure 1: New Simulation
14.00.01 01.07.2021
x/y Cut at k=0 (z=0.2000 m)

Potential Air Temperature

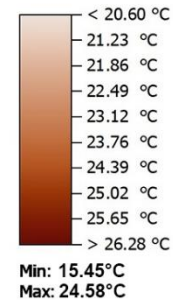


Figure 85: ENVI-met Simulation
(Source: Author)

7.3. Limitations of the study

I have identified several limitations in this study. Firstly, incorporating an additional simulation tool to evaluate indoor temperatures and assess how landscaping affects thermal comfort inside buildings would provide a more comprehensive analysis, rather than focusing solely on outdoor conditions.

Additionally, landscape species often take several years to reach their mature height and density. During this period, they may not significantly impact indoor comfort, necessitating continued reliance on mechanical systems for cooling and heating.

Wind directions are unpredictable and variable, meaning that trees and shrubs, even when strategically planted, may not always be effective. Consequently, relying on wind patterns for passive cooling can be unreliable.

Furthermore, passive cooling strategies, including extensive landscaping, incur higher initial costs. As this landscaping approach is non-commercial—focused on functional rather than purely aesthetic or regenerative purposes—it demands significant maintenance and associated costs.

These limitations highlight the need for a multi-faceted approach and consideration of long-term sustainability and cost-efficiency in landscape-based thermal comfort strategies.

7.4. Feasibility and Effectiveness of the Study

This study investigates the potential of mitigating urban heat island effects and reducing reliance on mechanical systems for indoor heating and cooling through strategic landscaping, thereby conserving energy. This evaluation chapter demonstrates that strategic landscaping effectively lowers ambient temperatures and counters the urban heat island effect, as illustrated in Figure 85. The research provides a comprehensive guide for designing landscapes to achieve indoor thermal comfort without depending on mechanical systems.

This section emphasizes the importance of landscaping design that prioritizes climatic and temporal factors, rather than focusing solely on aesthetic and sustainability. Additionally, it provides guidelines (see Table 5) to ensure the feasibility and effectiveness of strategic landscaping. Landscape architects can use these guidelines while designing for indoor thermal comfort and energy conservation. The recommendations are adaptable to meet specific site

requirements, ensuring practical application and flexibility. Moreover, some guidelines in the table align with the existing sustainability metrics such as LEED, STARS, etc.

Passive Cooling Strategies

Vertical Greenery: Apply thick layers of climbing vines on south and west-facing walls for additional cooling and insulation.

Rooftop Cooling: Consider a green roof with turf or a trellis system for additional insulation.

Building Orientation: Orient the structure to minimize exposure to harsh sunlight, especially south and southwest sides, depending on the climate zone.

Ventilation Openings: Maximize window and door openings on the windward side for natural ventilation.

Wind Tunnel Effect: Utilize strategic planting of trees and shrubs to create wind tunnels that channel prevailing winds for natural ventilation in desired areas.

Shading Structures: Incorporate pergolas, shade sails, or other structures with climbing vines to create shaded areas for outdoor seating and activity zones.

Planting Strategies

Water-Wise Grouping: Group plants with similar water needs to reduce overall watering requirements.

Low-Water Lawns: Consider alternative groundcovers like native grasses or drought-tolerant perennials instead of traditional water-intensive lawns.

Plant Diversity: Promote biodiversity by using a variety of plant types with different heights, canopy structures, and water needs for a resilient and ecologically balanced landscape.

Site Analysis

Directionality (N,S,E,W): Identify the cardinal directions of the site to plan for sun and wind exposure.

Climate Zone: Determine the specific climate zone in which the site is located.

Site Usage: Map out the intended use of different areas throughout the day. Zone activities based on sun and wind patterns.

Microclimate Assessment: Evaluate existing microclimate conditions like temperature, humidity, and wind patterns.

Passive Cooling Strategies

Wind & Water Placement: If applicable, consider site slope and place water bodies (bio-retention ponds, splash pads/pools) strategically on the windward side to cool down incoming winds.

Shaded Pathways: Design narrower pathways with overhead shade structures for pedestrian comfort.

Seasonal Deciduous Trees: Plant lines of deciduous trees at a suitable distance (10'-25') from buildings to provide summer shade and allow winter sun penetration, considering the climate zone.

Winter Wind Protection: Plant groups of native evergreen trees on the windward side to act as a windbreak during winter.

Reflected Heat Reduction: Incorporate light-colored materials with good thermal properties for buildings and consider increasing wall thickness.

Additional Strategies	Courtyards for Ventilation: Sculpt out courtyards within the architectural design to facilitate hot wind passage.
	Wind Shafts: Consider incorporating wind shafts within the building design to promote natural ventilation.
	Parking Lot Optimization: Design parking lots for the minimum required capacity.
	Permeable Surfaces: Utilize permeable pavers for internal roads and parking areas. Consider grass pavers, trellises, or shade trees to minimize heat absorption and reflection.
	Long-Term Planning: Select plants with mature sizes in mind for adequate shade and wind protection as they grow. Develop a long-term maintenance plan for plant health and optimal cooling benefits.

Table 5: Recommendation for landscape architects
(Source: Author)

7.5. Learning as a Designer

The most crucial lesson I have learned as a designer is how to seamlessly integrate research findings and research questions into the design process. This experience also highlighted the importance of flexibility in design decisions, recognizing the dynamic nature of the site and potential future needs. An adaptable and flexible design is essential to accommodate various circumstances.

I have encountered challenges in integrating landscape elements with architectural structures to regulate the microclimate of the site and in selecting the appropriate plant species.

Despite these challenges, the evaluation of area distribution and simulations demonstrated that the proposed design is efficient and effective.

7.6. Conclusion

This chapter evaluates the project's potential to mitigate urban heat island effects and enhance indoor thermal comfort through strategic landscaping. By comparing the existing conditions with the proposals from W&A Engineering Group and my own, significant improvements in area distribution and reductions in air temperature are demonstrated.

The area distribution analysis shows that my proposal significantly reduces asphalt coverage while increasing landscaping area, promoting a healthier microclimate. ENVI-met simulations further validate that strategic landscaping can lower ambient temperatures, despite not fully capturing the impact of green roofs and façades.

Identified limitations include the need for additional simulation tools to evaluate indoor temperatures, the time required for landscape species to mature, the variability of wind patterns, and the high initial costs of passive cooling strategies. Despite these challenges, the study highlights the importance of designing landscapes with a focus on climatic and temporal factors to achieve indoor thermal comfort without over-reliance on mechanical systems.

The feasibility and effectiveness of the proposed design are supported by comprehensive guidelines for landscape architects. The evaluation confirms that the proposed design is both efficient and effective, providing valuable insights for future design endeavors.

CHAPTER 8

CONCLUSION

The research presented in this thesis offers significant implications for addressing the challenges posed by urbanization, particularly in mitigating the adverse effects of UHIs, improving urban climate, and enhancing human health. The significance of this research lies in its holistic approach, which emphasizes the integration of landscape design with the built environment to tackle these challenges effectively.

By recognizing the built environment as an integral part of the larger ecosystem, this research proposes innovative strategies to create more sustainable and resilient urban spaces. The key contribution of this work is the exploration of passive cooling and energy conservation techniques within urban landscapes. By harnessing the synergies between landscape design and the built environment, practical solutions are offered to reduce reliance on mechanical systems, thereby mitigating the UHI effect and lowering greenhouse gas emissions.

The selection of Georgia Square Mall as a case study site further enhances the relevance and applicability of this research. The proposed landscape design strategies, such as strategic placement of vegetation, and the use of cool materials, demonstrate the potential for creating more comfortable and energy efficient urban environments.

8.1. Significance and Impact

In summary, this research offers a comprehensive guideline for reducing UHIs through landscape design interventions. By promoting passive cooling and energy conservation, the proposed strategies contribute to the creation of more sustainable and livable urban spaces, ultimately improving the quality of life for urban dwellers.

The findings of this research have far-reaching implications for urban planners, architects, landscape designers, and policymakers. By adopting the principles and strategies outlined in this work, cities can become more resilient to the impacts of climate change, reduce their carbon footprint, and enhance the overall well-being of their residents.

8.2. Future Research Directions

While this research has made significant contributions, there are several avenues for future exploration:

Indoor Thermal Comfort Evaluation: As the ENVI-met simulation tool primarily focuses on outdoor microclimate analysis, future research could focus on evaluating the impact of strategic landscaping on indoor thermal comfort. Investigating the ways in which landscape design influences indoor temperatures and thermal comfort levels would provide valuable insights for building design and energy efficiency.

Plant Selection and Landscape Characteristics: Further research is needed to explore the specific characteristics of plants and landscape elements that play a crucial role in passive cooling

and UHI mitigation. Understanding the optimal density, species selection, and arrangement of vegetation could enhance the effectiveness of landscape design strategies.

Climate Zone-Specific Strategies: Future research could explore the applicability of strategic landscaping in various climate zones. Developing climate-specific guidelines and strategies would ensure the optimal implementation of passive cooling techniques across diverse geographic regions.

By addressing these future research directions, the field of landscape architecture can continue to evolve, offering innovative solutions to the pressing challenges of urbanization and climate change, ultimately contributing to the creation of more sustainable, resilient, and livable cities.

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