PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCHSAAD DAHLAB BLIDA UNIVERSITY -01-

INSTITUTE OF ARCHITECTURE AND URBAN PLANNING

Department of Architecture

Master's thesis in Architecture.

Theme: CLIMAT RESPONSIVE BUILDING IN EDUCATIONAL SETTINGS

F.G.P : Nature-Integrated University Library and Outdoor of the Institute of Architecture and Urbanism, University of Blida 1

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Abstract

In the face of growing climate change impacts, architectural design must ensure thermal comfort while sustainably integrating nature. This thesis explores how a university library at the Institute of Architecture, Blida 1, can be redesigned to improve indoor and outdoor thermal comfort. Using a biophilic design approach, climate analysis, user surveys, and ENVI-met microclimate simulations, various intervention scenarios were tested. Results demonstrate that green roofs and vertical greenery significantly enhance thermal performance. This research proposes an integrated, sustainable, and user-centered strategy for educational buildings.

Keywords

Thermal comfort, Institute Library, Biophilic design, Bioclimate Architecture, Envi-met model.

Résumé

Face aux impacts croissants du changement climatique, la conception architecturale doit garantir le confort thermique tout en intégrant durablement la nature. Cette thèse explore comment une bibliothèque universitaire de l'Institut d'architecture de Blida 1 peut être réaménagée pour améliorer le confort thermique intérieur et extérieur. À l'aide d'une approche de conception biophilique, d'analyses climatiques, d'enquêtes auprès des usagers et de simulations de microclimat ENVI-met, différents scénarios d'intervention ont été testés. Les résultats démontrent que les toitures végétalisées et la végétation verticale améliorent significativement les performances thermiques. Cette recherche propose une stratégie intégrée, durable et centrée sur l'usager pour les bâtiments éducatifs.

Mots-clés

Confort thermique, Bibliothèque de l'Institut, Conception biophilique, Architecture bioclimatique, Modèle Envi-met.

الملخص

في مواجهة الآثار المتزايدة لتغير المناخ، يجب أن يضمن التصميم المعماري الراحة الحرارية مع مراعاة الطبيعة بشكل مستدام. تستكشف هذه الأطروحة كيفية إعادة تصميم مكتبة جامعية في معهد العمارة، البليدة 1، لتحسين الراحة الحرارية الداخلية والخارجية. باستخدام نهج تصميمي بيوفيلي، وتحليل المناخ، واستطلاعات رأي المستخدمين، ، تم اختبار سيناريوهات تدخل مختلفة. تُظهر النتائج أن الأسطح الخضراء ENVI-met ومحاكاة المناخ المحلي والمساحات الخضراء العمودية تُحسّن الأداء الحراري بشكل كبير. يقترح هذا البحث استراتيجية متكاملة ومستدامة ومُركزة على المستخدم للمباني التعليمية.

الكلمات المفتاحية:

الراحة الحرارية، مكتبة المعهد، التصميم البيوفيلي، العمارة المناخية الحيوية، نموذج البيئة والبيئة

Chapter I : General Introduction

Chapter 1 : General Introduction

I.1. Background :

According to the IPCC (Intergovernmental Panel on Climate Change), climate (Bellard, 2014) change is defined as "a variation in the state of the climate that can be detected by changes in the mean and/or the variability of its properties and that persists for an extended period (typically decades or longer)" (IPCC et al., 2007) . In recent years, climate change has become one of the most studied topics. Nearly 100,000 scientific studies have discussed climate change over the past decade (Bellard, 2014) .Climate change refers to a variation in the state of the climate that can be detected by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.It pertains to any change in climate over time, whether due to natural variability or human activity **.**

Among the consequences of these climate changes, the first is that average global temperatures have increased by approximately +0.74°C since 1979. The change in climate is unequivocal with all continents (except Antarctica) experiencing significant warming over the past 50 years. Furthermore, the first decade of the 21st century has been both the warmest and the wettest since 1881**.** Although climate change is often associated with a global increase in temperature, it actually encompasses a wider range of phenomena. Such warming, for example, leads to an average rise in sea levels (Bellard, 2014).

It was in 1979 that specialists first sounded the alarm about global warming. This phenomenon, now more commonly referred to as "climate change" by scientists, corresponds to the complex alterations affecting the weather and climate systems of our planet (BAD, 2012). It is manifested by the rise in average temperatures, extreme weather events, the decline of wildlife populations, the transformation of natural habitats, and the rising sea levels (BAD, 2012).

Climate change is indeed happening. Beyond all we can do to reduce emissions and slow the rate of planetary warming, we must adapt to the effects of these changes to protect ourselves and our populations. The impacts vary depending on where we live. They can include wildfires or floods, droughts, higher or lower daytime temperatures, or rising sea levels (Havard et al., 2010).

There are many ways to adapt to what is happening and what will happen. Individuals can take some simple steps. For example, planting or preserving trees around the home can help keep the interior cooler. Clearing brush can reduce the risk of wildfires. If you own a business, start considering potential climate risks, such as extreme heat preventing outdoor work on certain days, and plan accordingly. Everyone should be aware of the increased risk of natural disasters where they live and the resources available to them if they occur. This might involve purchasing insurance in advance or knowing where to find information and assistance in the event of a disaster (Havard et al., 2010).

Climate change and thermal comfort are intrinsically linked. Climatic transformations alter environmental conditions that directly influence our thermal well-being. Climate change has a direct impact on the thermal comfort of populations around the world. Thermal comfort, which refers to the sensation of well-being experienced by a person in relation to climatic conditions, is influenced by several environmental factors that are altered by climate change.Thermal comfort is an important aspect of human (Bellard, 2014) well-being and productivity, especially in tropical and subtropical regions where high temperatures and humidity prevail each year. However, research on indoor and outdoor thermal comfort in these regions is insufficient compared to other regions, and there is a [1]significant gap in understanding the relevance and application of existing thermal comfort indices (Grosdemouge, 2020).

Thermal comfort is traditionally linked to 6 parameters (CANDAS, 2000):

- 1. Metabolism, which is the production of internal heat in the human body to maintain it at around 36.7°C. A work metabolism corresponding to a particular activity is added to the basic metabolism of the body at rest.
- 2. Clothing, which represents a thermal resistance to heat exchanges between the surface of the skin and the environment.
- 3. Ambient air temperature Ta.
- 4. Average wall temperature TP.
- 5. Relative humidity of the air (RH), which is the ratio expressed as a percentage between the amount of water contained in the air at temperature ta and the maximum amount of water contained at the same temperature.
- 6. Air speed, which influences convection heat exchange. In buildings, air speeds generally do not exceed 0.2 m/s.

I.2. Problem Statement :

the climate change is one of the most pressing global challenges of the 21st century, Algeria is undoubtedly feeling the effects of climate change. The country's varied climate, spanning from Mediterranean in the north to arid desert in the south, is exposing its cities to different levels of vulnerability.

The city of Blida, nestled at the base of the Atlas Mountains, exemplifies the complex interplay between climate change and thermal comfort. Blida is witnessing changes in its thermal conditions due to rising temperatures, urban expansion, and shifts in regional weather patterns…etc. The ongoing impacts of climate change have profound implications for thermal comfort in outdoor spaces between key buildings especially the library making these areas uncomfortably hot during warmer months and inefficient at retaining warmth in cooler seasons.

The library of the Institute of Architecture and Urbanism, University of Blida 1, is being a central hub of academic activity, is typically surrounded by open spaces where students and professors often gather, study, or socialize. It is often subjected to harsh weather conditions driven by climate change.

One of the primary issues affecting thermal comfort in this space is direct solar radiation especially during peak daylight hours, as the climate change has amplified an extremes temperature which can make the institute library unbearably hot during heatwaves.

The lack of sufficient green cover , the sparse and poorly placed trees in the outdoor spaces around the library worsens this issue, by preventing natural cooling mechanism that could offer relief inside the library especially during peak sunlight hours, which make the library an intolerable space in these hours.

Also, this situation becomes even more problematic because of the library is not equipped with efficient air conditioning. Without proper temperature regulation, library users may experience discomfort, difficulty concentrating, and fatigue due to heat stress.

Increased temperatures often coincide with a decrease in air quality , the library can face issues with poor indoor air quality if ventilation systems do not meet demand during warmer months, also it depends heavily on the architectural layout of the space, the library is not designed with large and adjustable windows, or flexible shading systems and open floor plans for natural ventilation, but it’s built with poorly insulated walls and windows that experience higher internal temperatures in summer, while during winter, librarie’s users suffer from heat loss and require more heating, which leads to increased energy consumption.

***How can library design incorporating greenery influence thermal comfort in indoor and outdoor spaces , and how does integrating nature into library design affect thermal comfort outdoors?**

I.3. Hypothesis :

- Incorporating greenery into library design significantly enhances thermal comfort in outdoor spaces. Trees and vegetation provide shade and cool the air, while green walls and roofs insulate buildings (BAD, 2012) .
- Integrating nature helps create cooler microclimates, regulate temperature extremes, and reduce the need for artificial cooling, promoting energy efficiency. Green spaces also enhance visual appeal, reduce stress, and improve mental well-being, making outdoor areas more inviting and enjoyable. Libraries can thus create comfortable, sustainable outdoor spaces that connect users with nature.

I.4. Objectives :

- Assess current outdoor thermal comfort conditions.
- Propose a redesign for optimal thermal comfort.
- Evaluate thermal comfort levels in spaces surrounding the library.
- Design a nature-integrated library to enhance outdoor thermal comfort through biophilic principles.

I.5. Methodology Overview :

The methodology of this study integrates both theoretical and practical approaches to assess and enhance the thermal comfort of the institute of architecture at Saad Dahlab University. The methodology combines, user experience surveys, design simulations, and a review of relevant literature to ensure a thorough understanding of the current challenges and potential solutions :

I.5.1. Theoretical Approach :

The theoretical approach will involve a detailed review of existing literature on thermal comfort in outdoor spaces, focusing on climatic conditions, environmental factors (such as solar radiation, wind patterns, and humidity), and design strategies that promote thermal comfort in university campuses. , a review of case studies and best practices from similar university campuses will be conducted to identify successful design interventions that could be adapted to the site in question.

I.5.3. Practical Approach:

The practical approach will be divided into two main phases (thermal comfort assessments, design simulations) :

- Thermal Comfort Assessments:

The first practical step involves conducting , a survey targeting the perceived thermal comfort and usability of the Institute . This survey will seek insights into how students experience the Library, particularly in terms of comfort during different weather conditions. The data from the survey will be integrated with the environmental measurements to identify the main thermal stressors and areas for improvement.

- Design Simulations:

Based on the findings from the thermal comfort assessments, design simulations will be carried out to test different design strategies for improving thermal comfort. Using ENVI-MET software, various design scenarios will be modeled to assess . ENVI-MET is a 3D microclimate simulation software that allows for detailed analysis of outdoor thermal conditions, including temperature, airflow. This methodology aims to develop a robust understanding of the thermal comfort challenges at Library of Institute of architecture and urbanisme of Saad Dahlab University blida 1 and propose effective, sustainable design solutions. The interdisciplinary approach ensures that the research not only addresses the technical aspects of thermal comfort but also considers the human experience and user-centered design principel

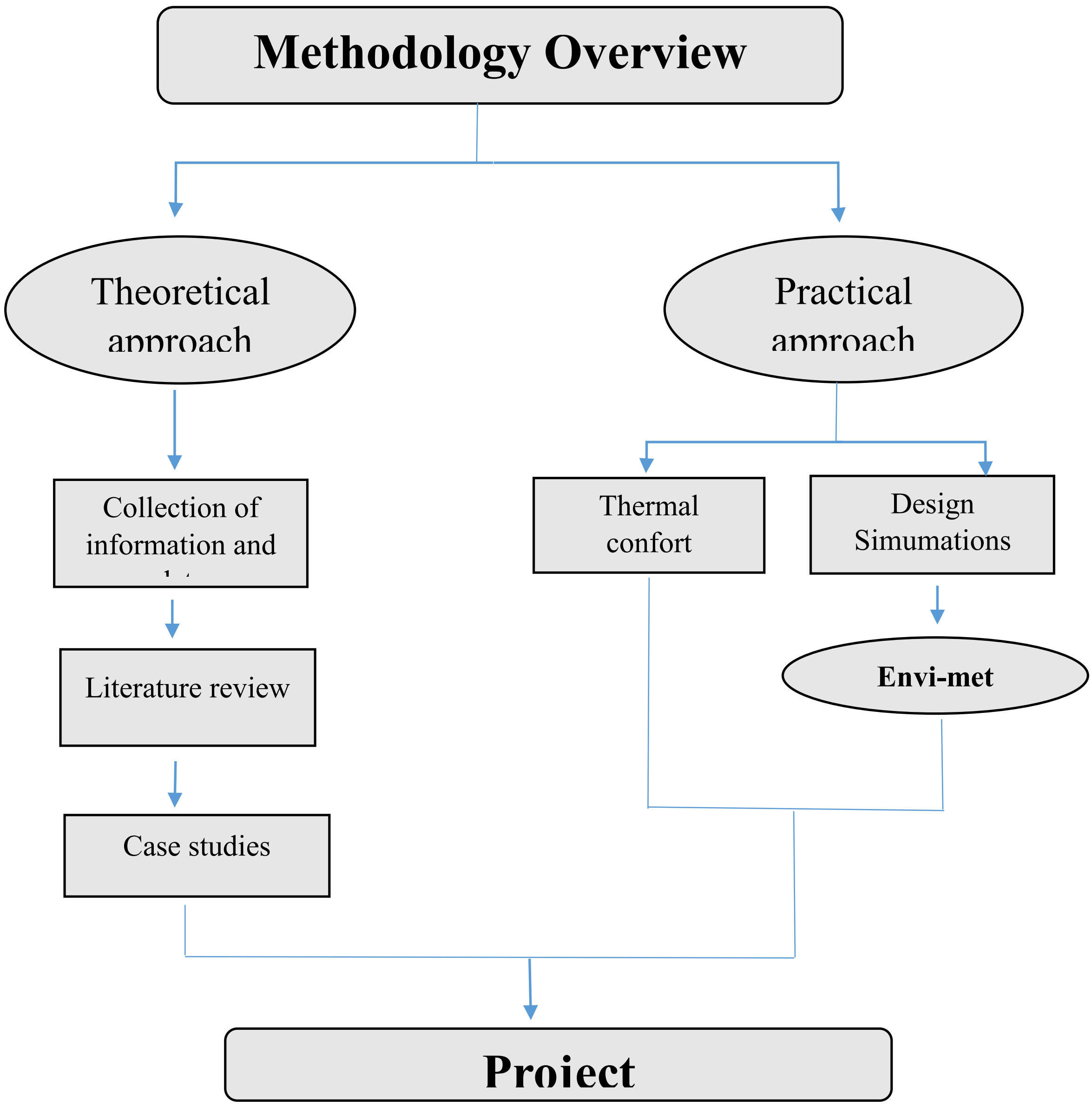
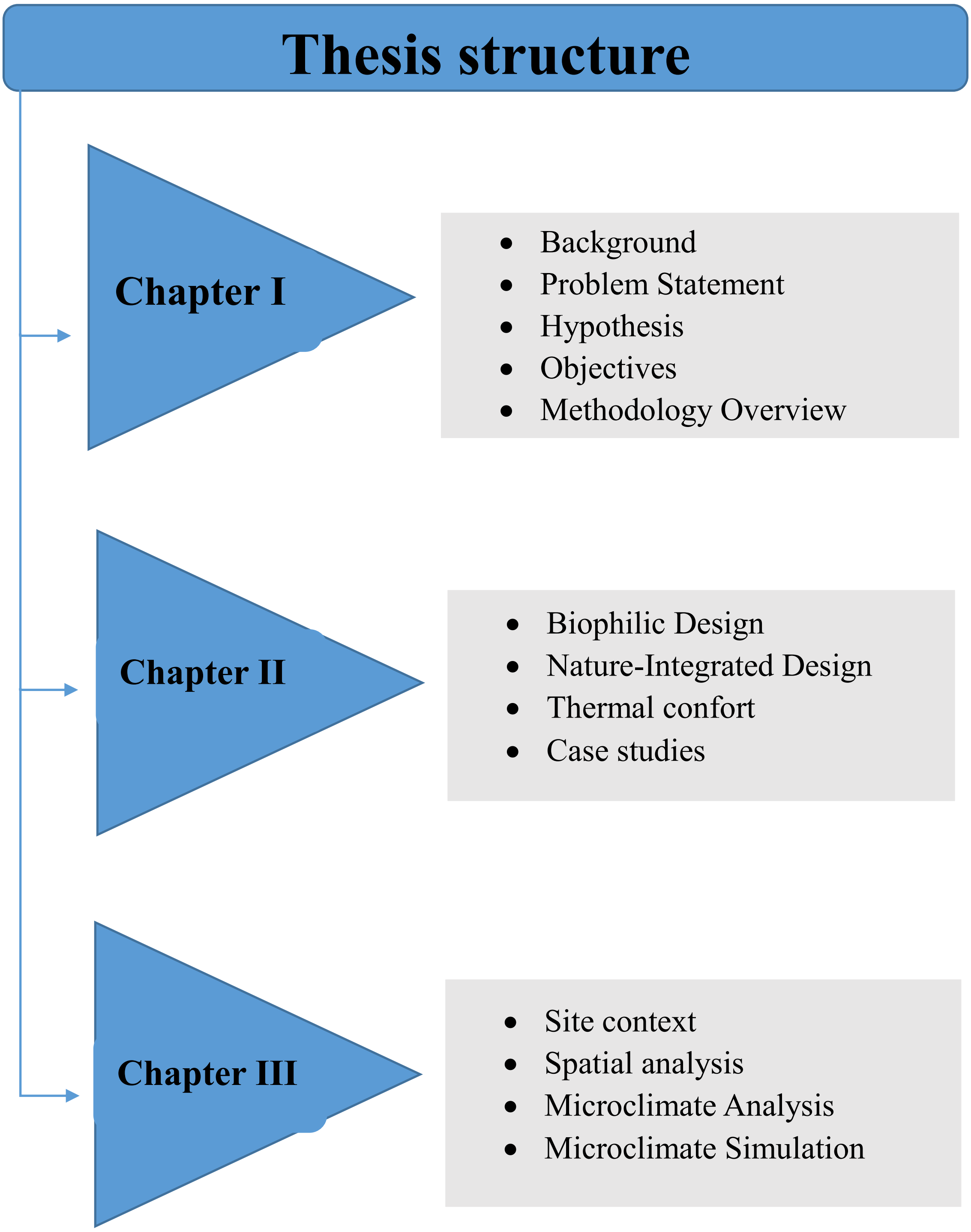


Figure I 1: Methodology overview

I.6. Thesis structure :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Thermal confort
Case studies
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Site context
Spatial analysis
Microclimate Analysis
Microclimate Simulation

Chapter II: Literature Review and Best Practices

II.1. Introduction

Architecture is about more than just building. It's about creating spaces that are in harmony with human needs, environmental contexts and technological advancements. In today's dynamic architectural landscape, integrating best practices and learning from past designs is not just a theoretical exercise—it is a necessity for innovation.

This chapter definitively explores the intersection of architectural theory and real-world application, offering a comprehensive review of established literature alongside case studies that exemplify design strategies shaping modern architecture. It examines how biophilic and nature-integrated design contribute to the well-being of occupants, optimise environmental sustainability, and redefine spatial experiences.

We will discuss these methodologies in depth to reveal how architects harness nature's principles to create spaces that are aesthetically compelling and functionally restorative. This chapter bridges the gap between knowledge and practice by analysing existing research, theoretical foundations and successful implementations across diverse contexts. It empowers architects to envision the future with a deeper understanding of the past.

II.2. Biophilic Design:

II.2.1. Definition Biophilic Design:

Biophilic design is a human-centred approach to architecture and construction. It promotes the health, safety and productivity of individuals by fostering harmonious and positive indoor environments. It strengthens the fundamental connection between humans and nature and its processes by integrating natural elements into living and working spaces. This approach is clear: contact with nature is vital for physical and psychological well-being. Built spaces must be more in tune with our deep biological needs.(Des, 2018)

Biophilic architecture combines nature and architecture to improve human well-being. It creates spaces that align with our natural needs and aspirations. Biophilic design is the key to successful office layout. It will enhance the atmosphere at work and foster a positive work environment..(*29621aea16e9f23f3da8c3acc177fe71ad4fc854 @ Spoty.Systems*, n.d.)

II.2.2. Nature-Integrated Design:

Nature-Integrated Design recognises and deliberately incorporates elements of the natural world into our built environments and lifestyles.Nature-Integrated Design creates spaces and ways of living that are inseparable from nature. It's about more than just aesthetics. It is clear that this impacts our well-being. A walk in the park is the best way to instantly calm a restless mind. Nature-Integrated Design is the key to creating restorative everyday environments – our homes, workplaces and communities. It is an approach that recognises the significant influence of our surroundings on our mood, productivity and overall health. It is clear that being close to nature is not a luxury, but a basic human need.

(*7b1e7666a788576f164cb3213f0bfcf66c353b7f @ Lifestyle.Sustainability-Directory.Com*, n.d.)

II.2.3. Theories of Biophilic Design:

Biophilic design shows how the built environment should be radically re-conceptualised around the fundamental workings of the human mind. "We must create a richer built environment grounded in the way people actually experience the world around them. This concept is the "missing link in sustainable design". If people do not want to be in a building, it will go to waste. This is unsustainable and contradicts the purpose of "green" design. Bill Browning's text is called "Economics of Biophilic Design"·(Vagal, 2020)

Chapter 2 : Literature Review and Best Practices

Biophilic design is based on a robust evolutionary theoretical framework, but because most of this research is non-experimental, it has not yet shown correlation or causality. It is clear that this is related to the difference between inductive and deductive research approaches. This confusion between restorative and biophilic design is then fueled. (Zhao et al., 2022)

II.2.4. Theories of Nature-Integrated Design:

- Ecological Design Theory is the name on everyone's lips right now. The brainchild of Sim Van der Ryn and Stuart Cowan, this revolutionary theory focuses on the vital integration of human needs with the health of ecosystems. It emphasises sustainable and regenerative practices.
- Permaculture Principles Permaculture is a system of agricultural and social design principles that simulate or directly utilise natural ecosystems. It was developed by Bill Mollison and David Holmgren. We must create self-sustaining habitats that work with, rather than against, nature.
- The Living Building Challenge is a sustainability standard. It was created by the International Living Future Institute. The standard calls for the creation of buildings that function as cleanly and efficiently as nature's architecture. It includes principles like net-zero energy, net-zero water, and materials transparency.

The biophilic design concept is based on the innate human emotional affiliation with nature. It provides a new perspective in the design and management of the living environment for the elderly population. The application of nature in space, natural analogs and the nature of space are key. Biophilic concepts must be incorporated into housing and surrounding environment design to strengthen the social, psychological and ecological aspects of sustainable ageing. (Grazuleviciute-Vileniske et al., 2020)

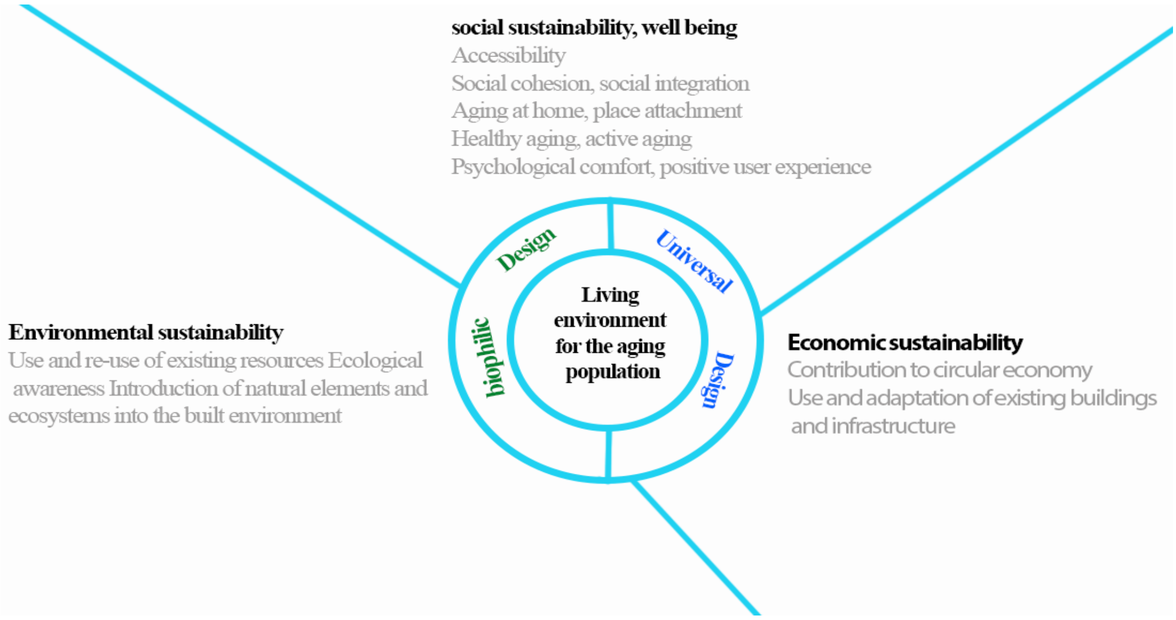

Figure II. 1: *Integration of the universal design and biophilic design concepts for sustainable aging* (Grazuleviciute-Vileniske et al., 2020)

II.2.5. The importance in architectural design:

It is clear that biophilic and nature-integrated design are of the utmost importance in architectural design. It is clear that they also increase productivity and creativity in workspaces, leading to better performance and job satisfaction. Nature-integrated design uses sustainable practices and materials. This promotes long-term sustainability and resource conservation. This is the definitive statement. Such designs undoubtedly enhance the aesthetic appeal of buildings, create inviting spaces, and command higher property values due to their health benefits and sustainability features. Real-world applications clearly demonstrate their effectiveness in healthcare facilities, educational institutions and corporate offices. These principles transform spaces into functional, enriching and sustainable environments.(*29621aea16e9f23f3da8c3acc177fe71ad4fc854 @ Spoty.Systems*, n.d.)

Improving indoor air quality through the use of plants that purify the air of harmful substances.Reducing stress and anxiety by introducing natural elements that have a positive effect on our senses and emotions.Increasing productivity and creativity by creating spaces that foster concentration and relaxation. Improving sleep quality is achieved by introducing natural materials and shapes that have a positive effect on the nervous system.Strengthening a sense of community and social ties is achieved by creating spaces that encourage interpersonal interactions.All these benefits contribute to an overall improvement in the quality of life and physical and mental health of individuals inhabiting biophilic spaces. (*29621aea16e9f23f3da8c3acc177fe71ad4fc854 @ Spoty.Systems*, n.d.)

II.3. Thermal Comfort in Biophilic Spaces:

The relationship between comfort conditions and the incorporation of biophilic design elements in spaces is symbiotic . As shown in Figure , using these elements can enhance the wellbeing of occupants (Al Sayyed & Al-Azhari, 2025) . Biophilic design, which stems from our connection to nature, aims to integrate natural elements and experiences into the built environment. When applied to architecture, it creates spaces that prioritize both physical and psychological comfort . Architectural features, such as windows that frame views of the outdoors and the inclusion of indoor plants, not only bring nature indoors but also contribute to improved thermal comfort and air quality .The visual connection with greenery and abundant natural light reduces stress levels, enhances wellbeing, and improves mental comfort .(Al Sayyed & Al-Azhari, 2025)

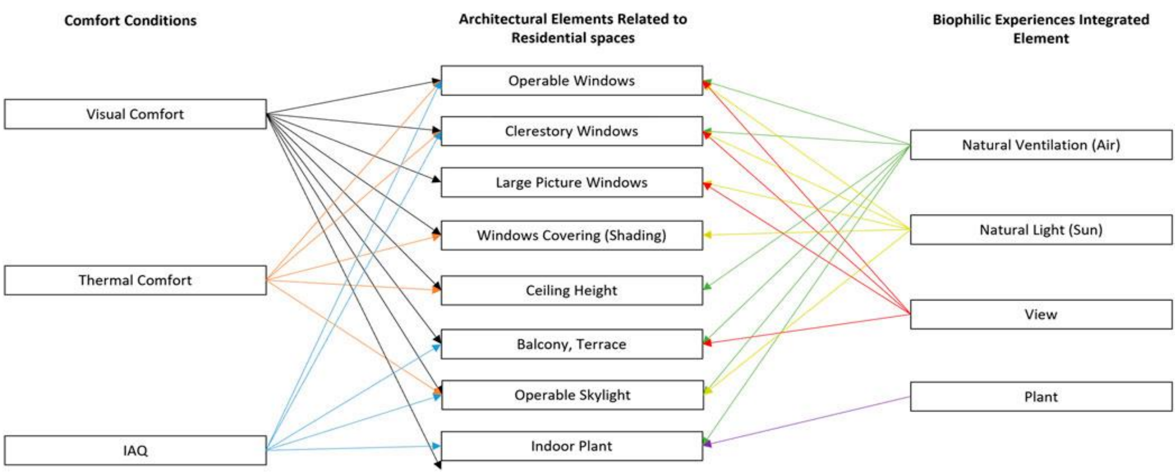

Figure II. 2: *Relationship between comfort conditions and biophilic design elements and applied them in residential spaces through different architectural elements (Source:* (Al Sayyed & Al-Azhari, 2025)*)*

I.3.1. Definitions Thermal Comfort:

Thermal comfort is a complex concept, which can vary greatly from one individual to another. It is defined as the feeling of well-being that people experience in a given space, a feeling influenced by various parameters such as temperature, humidity, air quality and insulation.

- Ambient temperature: This plays an essential role in the perception of thermal comfort. On average, in winter, a temperature of between 19°C and 21°C would be ideal. This can rise to around 24°C in summer.
- Wall temperature: The temperature of surfaces such as walls, floors and windows also affects the feeling of comfort. As you might expect, walls that are too cold or too hot can create an imbalance and affect comfort.
- Air humidity: The relative humidity of the indoor air is another determining factor in thermal comfort. The ideal humidity level is between 40% and 60%. Any higher and you feel colder, which encourages you to turn up the heat.
- Airflow**:** Draughts in a building or a room are something to be avoided. While they may be welcome in summer to help perspiration and cool the atmosphere, when it's cold they can cause discomfort by promoting heat exchange through convection.

Added to this is each person's metabolism and clothing, which also affect the sensation of thermal comfort. The new RE2020 environmental regulations have made thermal comfort an important objective of the energy transition, particularly in terms of summer comfort and the fight against heat leakage

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II.3.2. Thermal Comfort in Indoor Environments :

educed outdoor thermal comfort, and at the building level, they increase indoor temperatures, creating uncomfortable indoor environments and potentially increasing indoor overheating, which can have adverse effects on people's health and well-being.

Most existing studies that link summer heatwaves with indoor thermal comfort or overheating rely on estimates. These estimates come from in-situ monitoring, simulation outputs, or both, rather than actual survey responses. This reliance on estimates is noted in several comprehensive reviews focused on the United States and Europe, particularly the UK. Estimations are typically derived from the adaptive thermal comfort model (e.g. ASHRAE 55–2023, EN-16798) coupled with overheating metrics from CIBSE TM52 or TM59 The majority of these studies emphasize how building or dwelling characteristics (e.g. built period, floor level, orientation, solar shading, natural ventilation, insulation, use of air conditioning, building age) cause indoor overheating

.(*52d82fb4e0d1172c0cbc91cda6ae4a2637244f03 @ Www.Wattsense.Com*, n.d.)

Figure II. 3: Two environmental simulations in VR: (A) Room with non-biophilic elements, (B) Room with biophilic elements (Source:(Al Sayyed & Al-Azhari, 2025)).

II.3.3. Thermal Comfort in Outdoor Environments :

Thermal comfort refers to the human body's degree of satisfaction or indifference to the thermal environment. Different institutions and scholars have different definitions of thermal comfort. The most commonly used definition is proposed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (Johansson et al., 2018), which defines thermal comfort as the condition of mind that expresses satisfaction with the thermal environment . The glossary of terms for thermal physiology defined thermal comfort as subjective indifference to the thermal environment . Gagge et al. mentioned that "Comfort" is a recognizable state of feeling but possesses no identifiable sense organ like the basic five senses (Johansson et al., 2018).

Outdoor thermal comfort is a complex concept affected by many factors, such as environment, individual, and psychology . Among them, environmental factors include solar radiation, wind speed, air temperature, humidity, etc., which directly affect the thermal balance and thermal sensation of the human body . Individual factors include age, gender, physiological activities, etc., which affect the thermal regulation ability and thermal adaptability of the human body . Psychological factors include experience, expectations, activity purposes, etc., which affect the human body's thermal satisfaction and thermal preference . Therefore, when studying outdoor thermal comfort, the role and interrelationship of these factors need to be comprehensively considered. (Johansson et al., 2018)

II.4. Case studies:

II.4.1. Assiut National University, Egypt:

Figure II. 4: Assuit National Univesity , Egypt

II.4.1.1. Background:

Established	**1957**
Location :	Assiut National University is located in the city of **Assiut**, in Upper Egypt. It's situated approximately **357 kilometers** south of Cairo.
Type :	**Public University** : Assiut National University operates as a governmental, non-profit public higher education institution.
Scale	Assiut National University is a **very large-sized institution** with a substantial academic community It enrolls **over 50,000 students** annually. The academic staff includes more than **4,450 members**. The university offers a variety of programs and courses leading to officially recognized higher education degrees such as bachelor's, master's, and doctorate degrees.
Climate Classification	The climate in Assiut is classified as **BWh** according to the **Köppen-Geiger climate classification**, which means it has a **hot desert climate**. In Assiut :

Size	The campus spans a considerable area, encompassing various outdoor zones such as : ***Gardens and Green Spaces** : These cover significant portions of the campus, providing natural beauty and areas for relaxation. ***Sports Facilities** : Outdoor sports fields and courts for activities like football, basketball, and tennis. ***Walking Paths** : Pathways and sidewalks meander through the campus, offering scenic routes for students and faculty to enjoy
Faculties	16 aculties and three institutes
Usage Patterns	The usage of outdoor spaces fluctuates depending on the time of day and year. Common patterns include : **1-Study and Leisure** : Students often use green spaces and gardens for study sessions or leisurely breaks. 2-**Social Gathering** : These areas are popular for informal social gatherings and events. **3-Physical Activities** : Sports fields and walking paths are frequently used for both organized sports and personal exercise routines

***Figure II. 5* :** Assuit National Univesity , Egypt

II.4.1.2. Climatic and Environmental Context :

Assiut National University, located in a hot desert climate (BWh), faces several challenges such as extreme high temperatures exceeding 40°C (104°F) in summer, low humidity levels that exacerbate heat stress, and urban heat island effects that further increase temperatures. During winter, temperatures range between 8°C (46°F) to 20°C (68°F), offering the most comfortable conditions. In spring and autumn, temperatures gradually rise to around 30°C (86°F) and decline from 35°C (95°F) respectively, making these seasons transitional periods requiring shade and cooling amenities. The high summer temperatures significantly reduce outdoor comfort, requiring effective cooling strategies and adaptive measures to maintain usability of outdoor spaces.

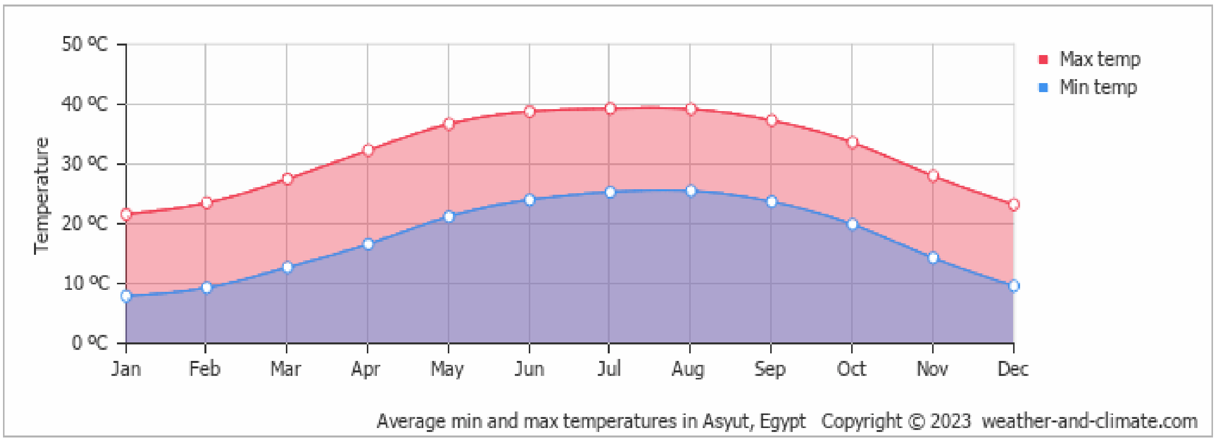


Figure II. 6 : Average min and max temperatures in Assiut, Egypt

II.4.1.3. Thermal Comfort Strategies :

Assiut National University implements various passive design solutions such as shading devices including overhangs and louvers, strategic building orientation to optimize ventilation, and the use of heat-reflective and thermal mass materials to stabilize temperatures. To enhance outdoor comfort, the university incorporates extensive greenery with trees, shrubs, and green roofs, along with water features like fountains and ponds, which help cool the environment. Permeable surfaces like grass paving also aid in reducing heat buildup. Active cooling systems such as misting and evaporative coolers are used in outdoor areas to further enhance comfort. Additionally, the campus features user-centric amenities like shaded seating arrangements, outdoor lounges, recreational areas, and shaded pathways, ensuring a comfortable and inviting environment for students and staff.

II.4.1.4. Observed Outcomes :

Thermal comfort improvements at Assiut National University include air temperature reductions of **1.5–4.9°C**, and significant enhancements in mean radiant temperature and wind speed. User feedback collected through surveys indicated a reduction in thermal discomfort, highlighting that students and faculty appreciated the increased shading and ventilation1. Positive environmental impacts include reductions in energy consumption due to effective passive design strategies and the alleviation of urban heat island effects by enhancing greenery and permeable surfaces.

Figure II. 7 : Assuit National Univesity , Egypt

II.4.1.5. Challenges :

At Assiut National University, designing and implementing thermal comfort strategies faced challenges like selecting materials that balance thermal mass and reflectivity, optimizing building orientation, and ensuring effective natural ventilation in a hot desert climate. Key limitations included high initial costs for shading devices and active cooling systems, inconsistent user satisfaction due to seasonal variations, and difficulties in significantly reducing air temperatures due to the urban heat island effect and limited water resources.

II.4.1.6. Lessons Learned :

Assiut National University's project successfully utilized shading devices and natural ventilation to enhance thermal comfort and reduce energy use. Green spaces and water features made the campus more welcoming. However, high initial costs and achieving significant air temperature reductions posed challenges, highlighting the need for a balance between passive and active solutions. The project's failures underscored the importance of thorough planning, adaptability, and stakeholder involvement, emphasizing continuous feedback for improvement.

II.4.2. Federal Centre of Technological Education of the state Parana :

Figure II. 8 : Federal Centre of Technological Education of the state Parana

II.4.2.1. Background:

Location	The Federal Center of Technological Education of the State of Paraná, better known as the Federal University of Technology – Paraná (CEFET), is located in the state of Paraná, Brazil.
Climate Classification	Paraná features a diverse climate, influenced largely by altitude and latitude. Most of the state falls under the **humid subtropical climate** (Cfa) classification according to the Köppen climate classification system, characterized by hot summers and mild winters. The regions at higher altitudes experience a **temperate climate** (Cfb), with cooler temperatures year-round.
Scale	With campuses in thirteen cities across the state of Paraná, including Curitiba, Londrina, and Ponta Grossa, it has over 21,000 students and approximately 1,697 academic staff members. This extensive reach supports a significant impact on regional development, fostering a strong connection with local industries and communities2.
Size	The outdoor spaces vary in size across the different campuses. Generally, these areas include large open courtyards, landscaped gardens, green belts, and designated areas for social and recreational activities.
Usage Patterns	These spaces are frequently used by students and staff for various activities, including studying, socializing, and relaxing. The green

	areas provide a serene environment conducive to outdoor learning sessions and informal gatherings. The inclusion of water features and shaded areas enhances the usability of these spaces, making them attractive spots throughout the year.
Users	The primary users of these outdoor spaces include students, faculty, and staff members3. The inviting atmosphere encourages usage by the entire campus community, fostering a sense of belonging and community interaction.

II.4.2.2. Climatic and Environmental Context:

The climate in Paraná presents several challenges that significantly impact outdoor comfort at the Federal Center of Technological Education of the State Paraná (CEFET-PR).

- Local Climate Challenges :

- High Temperatures : In many parts of Paraná, particularly during the summer months, temperatures can soar, leading to discomfort and increased reliance on cooling systems.
- Humidity : The humid subtropical climate means high humidity, especially in the warmer months, fostering a muggy environment. This high humidity can exacerbate the feeling of heat and cause discomfort.
- Urban Heat Islands (UHI) : Urban areas, including the campuses of CEFET-PR, often experience the urban heat island effect3. This phenomenon occurs when built-up areas are hotter than their rural counterparts due to human activities and infrastructure, making it a challenge to maintain comfortable outdoor spaces.

- Seasonal Variations and Impact on Outdoor Comfort :

- Summer (November to March)**:** High temperatures and humidity dominate, making outdoor activities less comfortable and increasing the need for shaded areas and cooling strategies.
- Winter (June to August)**:** While the winters are relatively mild, with cooler temperatures providing some relief, the drop in temperature can still require appropriate clothing and adjustments in outdoor comfort strategies.

- Spring and Autumn (Transitional months): These seasons offer more moderate temperatures and can be the most pleasant for outdoor activities. However, fluctuating weather patterns can still present unpredictability in terms of thermal comfort

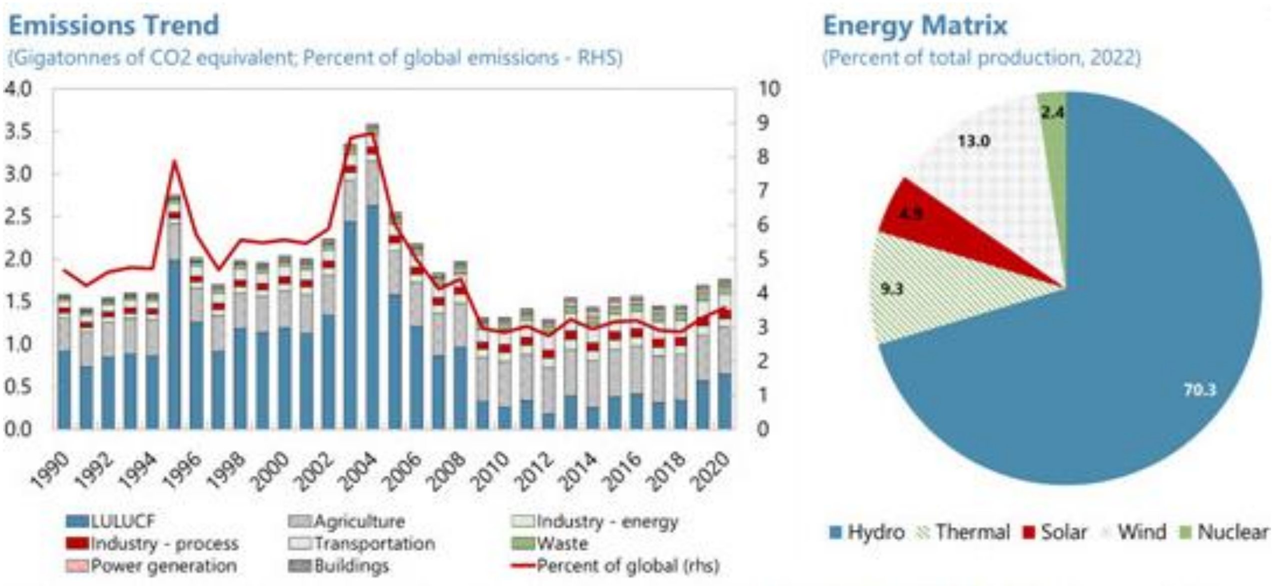


Figure II. 9 :(*Gigatonnes of CO2 equialent, pecent of global emmissions –Rhs) and (Percent of total production 2022)*

II.4.2.3. Thermal Comfort Strategies :

By combining passive design solutions like shading devices, thoughtful orientation, reflective materials, and ventilation strategies, CEFET-PR can enhance comfort and reduce solar gain. Vegetation, such as trees and green walls, along with water features and

permeable surfaces, provide significant cooling benefits and aesthetic appeal. Active cooling systems like misting and evaporative coolers, complemented by user-centric features such as comfortable seating, recreational areas, and shaded pathways, create a sustainable and inviting outdoor environment for everyone.

***Figure II. 10* :** universety Federal Centre of Technological Education of the state Parana

II.4.2.4. Observed Outcomes :

Using passive design solutions like shading devices, green spaces, and water features, the CEFET-PR campus can achieve significant reductions in air temperature. Proper shading and reflective materials can lower mean radiant temperature, while strategic orientation and ventilation improve wind speed. Collecting user feedback on comfort and usability helps inform ongoing improvements. These strategies also reduce energy consumption and mitigate the urban heat island effect, promoting a sustainable and comfortable environment.

II.4.2.5. Challenges :

The design and implementation of thermal comfort at CEFET-PR faced several challenges, including the need to balance thermal mass and reflectivity in materials, integrate new designs with existing structures, ensure effective natural ventilation, and manage high initial costs for shading devices and active cooling systems. Limitations included difficulties in achieving substantial air temperature reductions due to the urban heat island effect and limited water resources, fluctuating seasonal temperatures impacting user satisfaction, and the high costs associated with extensive shading and cooling systems.

II.4.2.6. Lessons Learned :

The successes at CEFET-PR included effective use of shading devices, improved natural ventilation, and incorporation of green spaces, which enhanced thermal comfort. Failures included high initial costs, limited air temperature reductions due to the urban heat island effect, and seasonal variability affecting user satisfaction. Lessons learned emphasized the importance of comprehensive planning, stakeholder involvement, and adaptability to address seasonal conditions and user needs

II.4.3. University Classroom in Anhui:

Figure II. 11: university classroom in anhui

II.4.3.1. Background :

Location	Anhui, located in eastern China
Climate Classification	Anhui, located in eastern China, has a diverse climate zone due to its size. Dominantly, the climate is classified as **Cfa** by the Köppen-Geiger system, denoting a humid subtropical climate. This implies warm, temperate conditions with significant rainfall throughout the year4. Average temperatures in Anhui range from about **0-2 °C (32-36 °F)** in January to around **28 °C (82 °F)** in July.
Type	The International Standard Classification of Education (ISCED
Scale of the Educational Institution	Provides a consistent framework for organizing educational institutions and their programmes. In the context of higher education institutions within Anhui, we could be referring to major universities such as the **University of Science and Technology of China (USTC) or Anhui University,** which are comprehensive institutions offering a wide range of undergraduate, graduate, and doctoral programs.
Size	These spaces can range from **several hectares to large campus areas**

Users	Predominantly used by students and faculty, these spaces also invite community engagement during events. They serve as crucial venues for relaxation, physical activities, and even overarching educational purposes.

Figure II. 12 : University Classroom in Anhui

II.4.3.2. Climatic and Environmental Context :

Anhui's climate, predominantly humid subtropical (Cfa), presents a mix of high temperatures, high humidity, and the urban heat island (UHI) effect challenging outdoor environments.

- High Temperatures : Summer months, notably July and August, can experience temperatures exceeding 30°C (86°F), making outdoor activities uncomfortable.
- Humidity : Being a key feature of humid subtropical zones, Anhui often witnesses high humidity levels averaging above 70%, which exacerbates the perception of heat and can lead to heat stress.
- The rapid urbanization in cities like Hefei contributes to the UHI effect, where human activities and dense infrastructures trap heat, leading to elevated night-time temperatures and reduced cooling.

- Seasonal Variations and Impact on Outdoor Comfort :

- Spring (March-May)**:** Generally comfortable with moderate temperatures (16-25°C**)** allowing for pleasant outdoor activities.
- Summer (June-August) : Characterized by high temperatures and high humidity, making it extremely important to have shaded areas and hydration points. Outdoor activities may need to be timed early in the morning or late afternoon.
- Autumn (September-November) : Similar to spring, offers comfortable temperatures, though later months can start to cool down, necessitating appropriate outdoor wear.
- Winter (December-February) : Cold and can drop below 0°C (32°F), influencing outdoor comfort negatively. Windchill and precipitation (including occasional snow) can further discourage outdoor activities.

II.4.3.3. Thermal Comfort Strategies :

Several strategies used in university classrooms in Anhui, China to optimize energy efficiency and enhance outdoor comfort. Passive design solutions include using shading devices, orienting buildings to minimize sun exposure, and utilizing materials with high thermal mass. Vegetation and landscaping using greenery and water features help reduce temperatures and manage stormwater. Active cooling systems such as misting and evaporative cooling provide additional relief during high temperatures. User-centric features, including comfortable seating, recreational areas, and shaded pathways, further improve the outdoor experience.

Figure II. 13 : University Classroom in Anhui

II.4.3.4. Observed Outcomes .

Thermal comfort performance metrics in university classrooms in Anhui, China show that passive design strategies reduce indoor air temperatures to 20-25°C (68-77°F), lower Mean Radiant Temperature (MRT) through shading and insulation, and enhance cooling by optimizing airflow. User feedback indicates high satisfaction with passive cooling and natural ventilation, pointing to improved comfort in shaded and well-ventilated spaces. Environmentally, these strategies reduce reliance on air conditioning, decrease energy consumption, and mitigate urban heat islands, promoting cooler temperatures overall.

II.4.3.5. Challenges :

Implementing passive design strategies in Anhui university classrooms faces numerous challenges like economic constraints due to initial high costs and technical challenges requiring specialized knowledge. Environmental variations demand adaptable designs, while urban heat islands from rapid urbanization intensify thermal comfort issues. Regulatory and policy barriers may also hinder adoption. High outdoor temperatures and humidity can limit the effectiveness of these solutions, often necessitating supplementary measures like air conditioning. Additionally, inconsistent application and user habits can impact effectiveness, and maintenance and durability issues require regular upkeep.

Figure II. 14 : University Classroom in Anhui

II.4.3.6. Lessons Learned :

Shading devices, natural ventilation, and suitable materials have improved indoor thermal comfort, maintaining desired temperature ranges. By minimizing mechanical cooling, universities reduced energy consumption, lowering operational costs and promoting sustainability. Many students and faculty express high satisfaction with the indoor climate and natural ventilation. Enhanced greenery and permeable surfaces help reduce urban heat islands and improve the campus's environmental footprint. However, higher initial costs, technical hurdles, climate adaptability issues, and regulatory barriers present challenges that must be overcome to maximize the benefits of passive design strategies.

II.4.4. National Library of Singapore :

Figure II. 15 : National Library of Singapore

II.4.4.1. Background :

Location	The National Library of Singapore is located at 100 Victoria Street, Singapore 188064. Singapore is situated just north of the equator
Climate Classification	which gives it a tropical rainforest climate (Köppen climate classification Af). This climate is characterized by uniform temperature, high humidity, and abundant annual rainfall1.
Type	multiple public libraries across Singapore

Scale of the Institution	The National Library functions both as a large reference library and a central part of a network that includes multiple public libraries across Singapore. Managed by the National Library Board (NLB), it spans from the comprehensive Lee Kong Chian Reference Library, occupying several floors, to the Central Public Library, which is housed in the same building.
Green Spaces:	There are 14 landscaped gardens featuring over 120 species of tropical plants. These gardens play a crucial role in regulating the building's temperature and providing aesthetic value.
Public Accessibility:	Of the 14 gardens, two are open to the public daily, allowing visitors to enjoy greenery amidst urban surroundings.
Utilization:	These spaces are designed to foster relaxation, provide a scenic environment for reading and reflection, and enhance the overall visitor experience.

Figure II. 16 : National Library of Singapore

II.4.4.2. Climatic and Environmental Context :

- Local Climate Challenges :

Singapore's tropical rainforest climate presents several specific challenges:

- High Temperatures: With year-round high temperatures averaging around 26-27°C (79-81°F), the National Library needs to integrate strategies to manage heat2.
- High Humidity: Humidity levels are consistently high, often around 70-90%, which can make even moderate heat feel oppressive.
- Urban Heat Islands: The dense urban environment exacerbates heat retention in built-up areas, raising nighttime temperatures. This UHI effect makes cooling strategies for places like the National Library even more critical.

➢ Seasonal Variations and Their Impact on Outdoor Comfort :

Singapore experiences minimal seasonal variation, but it does have distinct monsoon periods:

- Northeast Monsoon (December to March): Features both a wet phase with continuous moderate to heavy rain and a relatively drier, windy phase. The wet phase can cause discomfort outdoors due to frequent downpours.
- Inter-monsoon Periods (April to May, October to November): Characterized by light, variable winds and frequent thunderstorms in the afternoons. Hot afternoons are common, with temperatures exceeding 32°C (90°F).
- Southwest Monsoon (June to September): Occasional short-duration heavy showers and "Sumatra Squalls" with wind gusts.

II.4.4.3. Thermal Comfort Strategies :

Passive design solutions at the National Library of Singapore incorporate shading devices, strategic building orientation, high thermal mass materials, and natural ventilation to enhance outdoor comfort and reduce heat gain. Vegetation and landscaping, including 14 gardens with 120 species of tropical plants and various water features, help provide shade, promote cooler surroundings, and manage stormwater runoff with permeable surfaces. Active cooling systems, such as misting systems and temperatures. User-centric features like comfortable seating, recreational areas, and shaded pathways foster a pleasant and sustainable environment for visitors evaporative cooling, further enhance comfort in high.

Figure II. 17 : exterior of National Library of Singapore

II.4.4.4. Observed Outcomes:

Passive design strategies, such as shading devices and natural ventilation, have effectively lowered indoor temperatures to 20-25°C (68-77°F) at the National Library of Singapore. Strategic shading, insulation, and orientation have decreased Mean Radiant Temperature (MRT), reducing thermal discomfort. Cross-ventilation and stack effect principles have enhanced natural airflow, improving comfort. Users highly prefer naturally ventilated and shaded spaces, as surveys indicate high satisfaction rates. These design elements have significantly lowered energy consumption by reducing reliance on air conditioning and mitigating urban heat islands through the integration of greenery and water features, promoting cooler surrounding temperatures.

Figure II. 18 : Interior of National Library of Singapore

II.4.4.5. Challenges :

Implementing passive design strategies at the National Library of Singapore faces challenges such as high economic costs, technical difficulties due to the need for specialized knowledge, and adaptability issues in Singapore's tropical climate. Rapid urbanization exacerbates the urban heat island effect, complicating the effectiveness of passive measures, while local regulations may not always support these methodologies. Despite benefits, high outdoor temperatures and humidity can overwhelm passive strategies, requiring supplementary air conditioning. User behavior and inconsistent application impact effectiveness, and regular maintenance is essential but costly. Continuous efforts are needed to optimize thermal comfort and energy efficiency.

Figure II. 19 : National Library of Singapore

II.4.4.6. Lessons Learned :

The National Library of Singapore achieved notable successes, including improved thermal comfort through passive design strategies, enhanced energy efficiency, high user satisfaction levels, reduced urban heat island effects, and innovative design that integrates technology like RFID systems. However, challenges included high initial costs, technical implementation hurdles, adaptability issues in the tropical climate, urbanization's impact on thermal comfort, and regulatory barriers. Balancing innovation, user-centric design, and environmental sustainability led to significant outcomes despite these challenges.

II.4.5. National Library of Algeria :

Figure II. 20 : National library of Algeria

II.4.5.1. Background :

Location	Algiers, Algeria
	National library
Established	1835
Climate Classification	The National Library of Algeria is located in Algiers, situated in a Mediterranean climate zone (Köppen classification Csa). This region experiences hot, dry summers and mild, wet winters.
Scale of the Educational Institution	The National Library of Algeria is a significant cultural and educational institution within the country. It functions as the main state library, housing around ten million items including manuscripts, rare books, periodicals, maps, and photographs. The library serves both the general public and academic researchers, featuring multiple departments and facilities1.
Size	1,270,000
Description of the Outdoor Spaces	The National Library's outdoor spaces are thoughtfully designed to enhance the user experience :

Usage Patterns	The spaces are used for reading, relaxation, and social interaction, accommodating diverse user groups

II.4.5.2. Climatic and Environmental Context :

- Local Climate Challenges :

The climate in Algiers, home to the National Library of Algeria, presents several challenges:

- High Temperatures: Summers can be very hot, with temperatures often exceeding 30°C (86°F), making it necessary to implement strategies to manage heat effectively2.
- Humidity: The Mediterranean climate brings high humidity levels, especially during the summer months, which can exacerbate the discomfort caused by high temperatures.
- Urban Heat Islands: The dense urban environment of Algiers can trap heat, raising nighttime temperatures and increasing the overall temperature in urban areas. This makes managing outdoor thermal comfort more challenging.

- Seasonal Variations and Their Impact on Outdoor Comfort :

Algiers experiences distinct seasonal variations :

- Hot, Dry Summers : From June to September, high temperatures and low rainfall dominate, making outdoor spaces uncomfortable without adequate shading and cooling strategies2.
- Mild, Wet Winters : From December to February, the weather is cooler and wetter, which can make outdoor areas more comfortable but also necessitates protection from rainfall.
- Spring and Autumn : These transitional seasons offer milder temperatures and lower humidity, providing more comfortable conditions for outdoor activities.

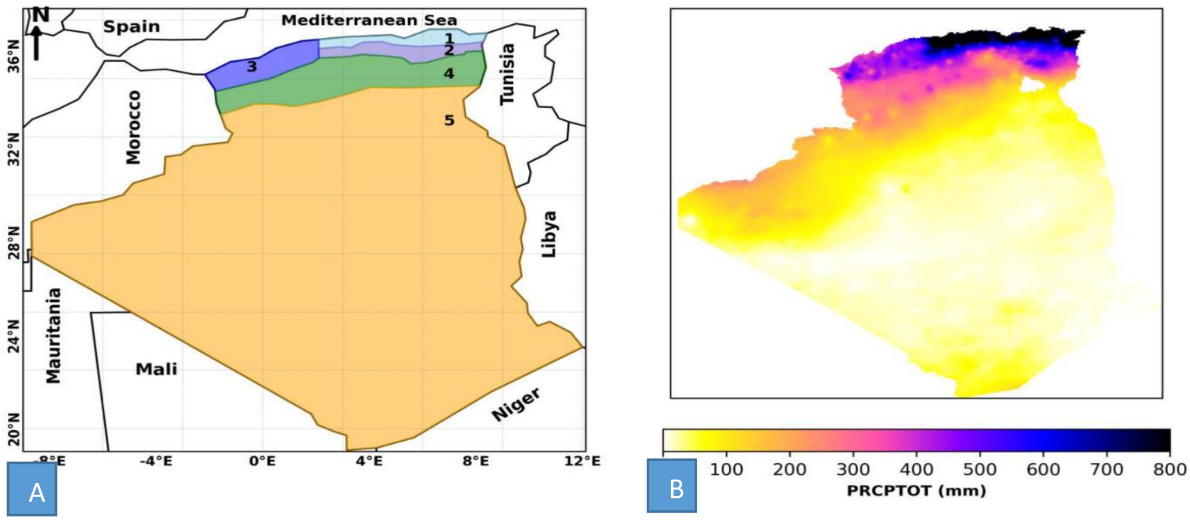


Figure II. 21 : On the left (A) are the boundaries and locations of the five defined geographical zones of Algeria. On the right (B) , mean annual precipitation (1990–2014) in Algeria derived from CHIRPS 0.05° × 0.05° data

II.4.5.3. Thermal Comfort Strategies :

The National Library of Algeria employs passive design solutions, including shading devices, strategic orientation, high thermal mass materials, and natural ventilation to reduce heat gain and enhance comfort. Landscaping with native plants and water features provides shade, mitigates urban heat islands, and maintains ecological balance. Active cooling systems, like misting systems and evaporative cooling, offer additional comfort. User-centric features include comfortable seating, recreational areas, and shaded pathways to ensure a pleasant and functional environment for visitors

II.4.5.4. Observed Outcomes :

Passive design strategies at the National Library of Algeria, such as shading devices and natural ventilation, lower indoor temperatures to **20-25°C (68-77°F)**. Strategic shading, insulation, and orientation decrease Mean Radiant Temperature (MRT), reducing discomfort. Cross-ventilation and stack effect principles enhance natural airflow, cooling the indoor environment. Users express high satisfaction, preferring naturally ventilated and shaded areas. These designs reduce reliance on air conditioning, saving energy and mitigating urban heat islands by integrating greenery and water features for cooler surroundings

Figure II. 22 : Interior National library of Algeria

II.4.5.5. Challenges :

The National Library of Algeria faced significant challenges in implementing passive design solutions due to high initial costs, technical expertise requirements, and the need for adaptability in Algiers' Mediterranean climate. Urban heat island effects and unsupportive local regulations further complicated efforts. Limitations in achieving thermal comfort goals included extreme outdoor conditions, high humidity, user behavior, and the need for regular maintenance. Consistent application across various spaces was also essential to ensure uniform comfort levels.

Figure II. 23 : exterior National library of Algeria

II.4.5.6. Lessons Learned :

The National Library of Algeria achieved significant successes, including enhanced user experience through modern technologies, improved thermal comfort via effective passive design strategies, substantial energy savings through reduced reliance on air conditioning, and positive environmental impact by mitigating urban heat islands with permeable surfaces and greenery. However, challenges included high initial costs, technical expertise limitations, adaptability issues due to diverse seasonal variations, and regulatory barriers hindering passive design adoption. These insights highlight the importance of innovation and adaptability in sustainable design goals.

II.5. Conclusion :

This chapter has explored the theoretical foundations, best practices, and real-world applications of biophilic and nature-integrated design, emphasizing their profound impact on human well-being and architectural sustainability. Through an examination of thermal comfort, both indoors and outdoors, we have highlighted how natural elements enhance not only physical comfort but also mental and emotional well-being. The integration of biophilic principles in architectural design fosters environments that are healthier, more productive, and socially engaging, reinforcing the intrinsic human connection to nature.

The case studies of Assiut National University and the Federal Centre of Technological Education of the State of Paraná have provided concrete examples of how institutions in different climates implement strategies to improve thermal comfort and environmental sustainability. These examples demonstrate the effectiveness of passive and active design solutions, from shading devices and vegetation to advanced cooling mechanisms. While successes have been noted in enhancing user experience and mitigating climate challenges, the studies also reveal inherent obstacles, including high initial costs, urban heat island effects, and seasonal adaptability.

Ultimately, the findings in this chapter underscore the significance of thoughtful architectural interventions in shaping spaces that align with both ecological responsibility and human needs. The lessons learned highlight the importance of an integrative approach—balancing passive strategies with technological innovation, considering user feedback, and ensuring adaptability to diverse environmental contexts. As the discourse on sustainable and human-centered design continues to evolve, the principles outlined here provide a foundation for future exploration and advancement in creating more resilient and harmonious built environments.

Chapter III: Case Study and Design Proposal

III.1. Case Study Analysis :

III.1.1. Site Context and Background :

III.1.1.1. Geographical Location :

The study was conducted in Ouled Yaich city, Blida province, located in northern Algeria on the southern edge of the Mitidja Plain, at the base of the Tell Atlas Mountains. Situated approximately 48 kilometers southwest of Algiers. Blida have a Mediterranean climate characterized by hot, and dry summers with mostly clear skies, and cold winters with partly cloudy conditions. Annual temperatures typically range from 4°C to 33°C, rarely dropping below -1°C or exceeding 37°C.

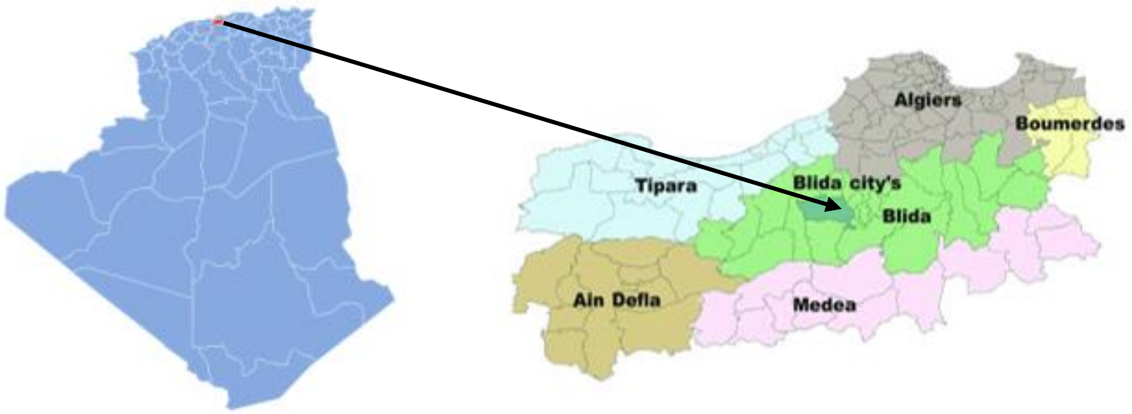


Figure III 1 : national scale and wilayal scale

III.1.1.2. Institute Overview :

The specific study site is the outdoor space of the Institute of Architecture and Urbanism at the University of Blida 1, located in Ouled Yaich city. This rectangular area, measuring approximately 40 x 50 meters and oriented to the northeast, is situated between three medium-sized buildings, each around 10 meters in height. These include the administrative building, the library, and the main studies building, which is the largest of the three. The studies building features a distinctive cubic architecture, composed of three cubes arranged in an L-shaped configuration. The space is relatively sparse in vegetation, featuring six triangular grassy zones with shrubs that do not exceed 1.2 meters in height and 3 to 4 trees randomly planted across the area. The outdoor space serves as a central hub for student activities and provides an ideal setting for relaxation between learning sessions.

Figure III 2 : Location of Blida, the institute A&U

III.1.2. The Accéssibility :

The institute is accessible via the first gate of the university, a mechanical access and pedestrian access via the other pavilions and a secondary access via the residential side gate.

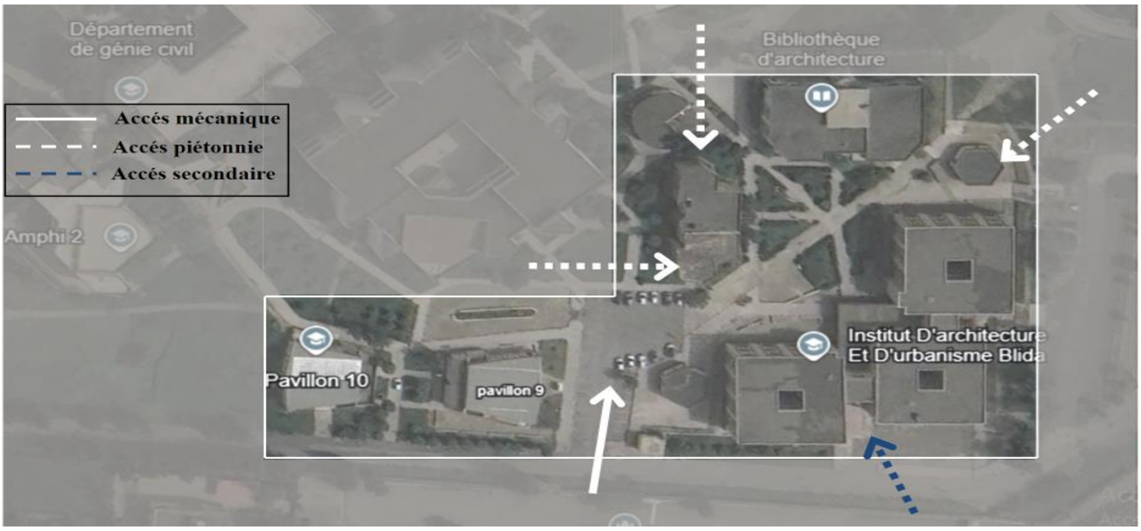


Figure III 3 : The Accéssibility

III.1.3.The shape and morphology of the institute:

Our plot in the form of a trapezoid with a surface area of 15000m². with a gentle slope

- **limited by:**
- parking to the south

- pavillion 13 and 16 to the east
- fence wall to the west
- pavillion 9 to the north

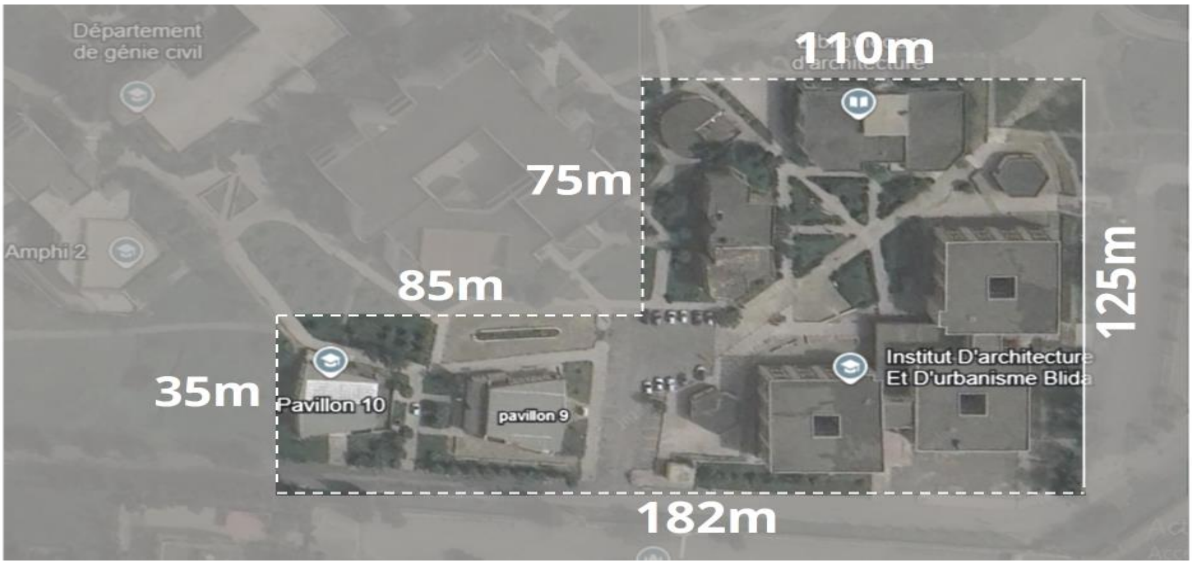


Figure III 4 : The shape and morphology of the land

III.1.4. Natural environment : micro climate

- winds and sunshine:

the land is located on the south sideit is very sunny in the evening with the presence of cold winds in the north and warm in the south

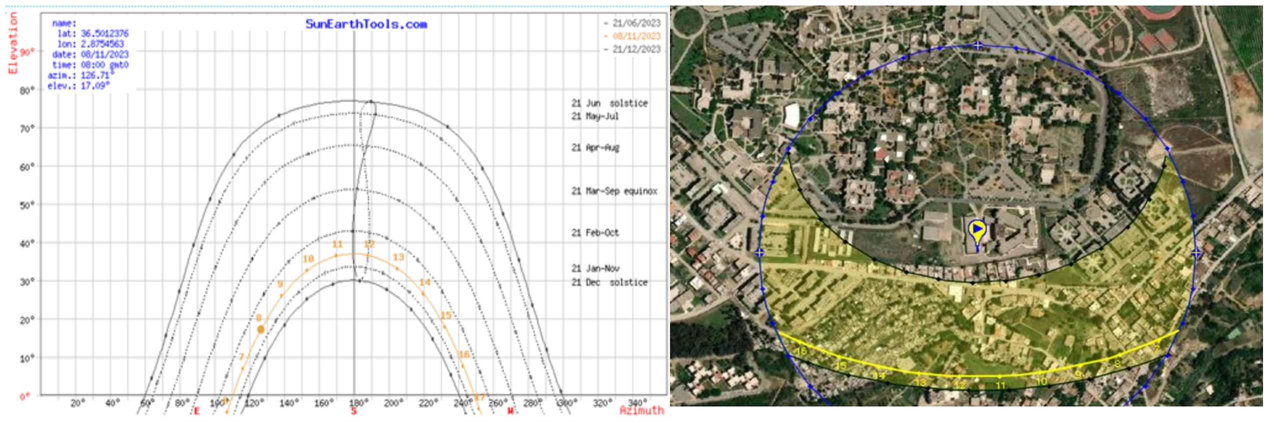


Figure III 5 : winds and sunshine

III.1.5. the built environment:

the institute is surrounded by faculties of a size of R+1/R+2 maximum.

Figure III 6 : the built environment

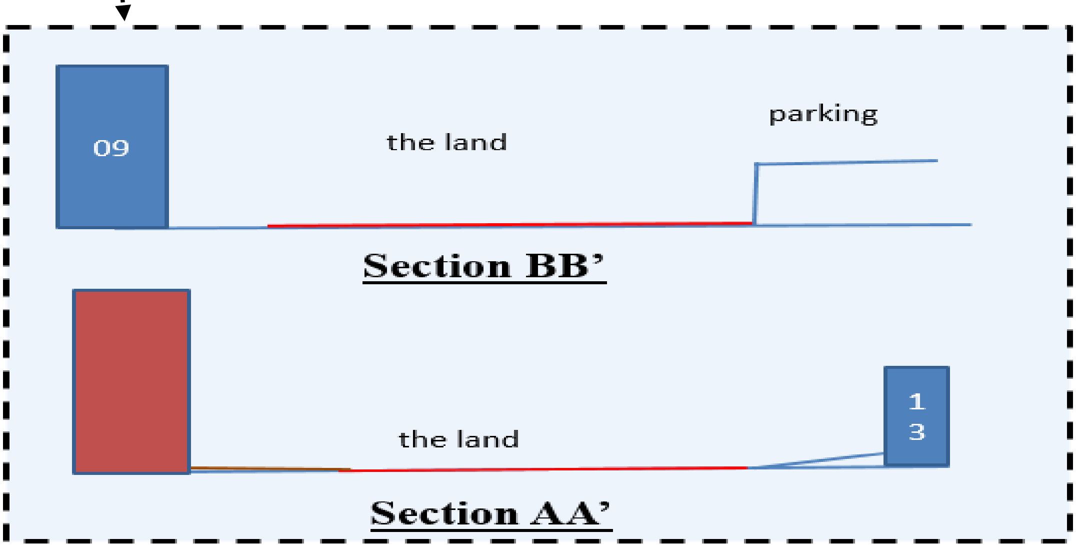


Figure III 7: the section

III.1.6. The land :

Figure III 8 : the land

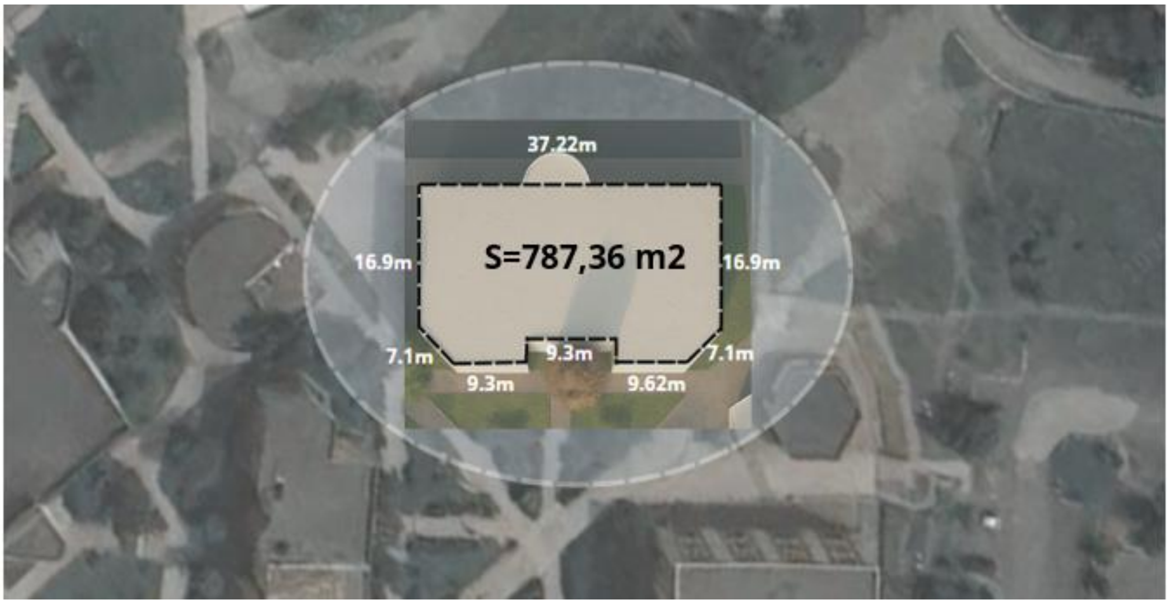


Figure III 9 : the surface of the land

III.2. Spatial Analysis :

III.2.1. Spatial Configuration:

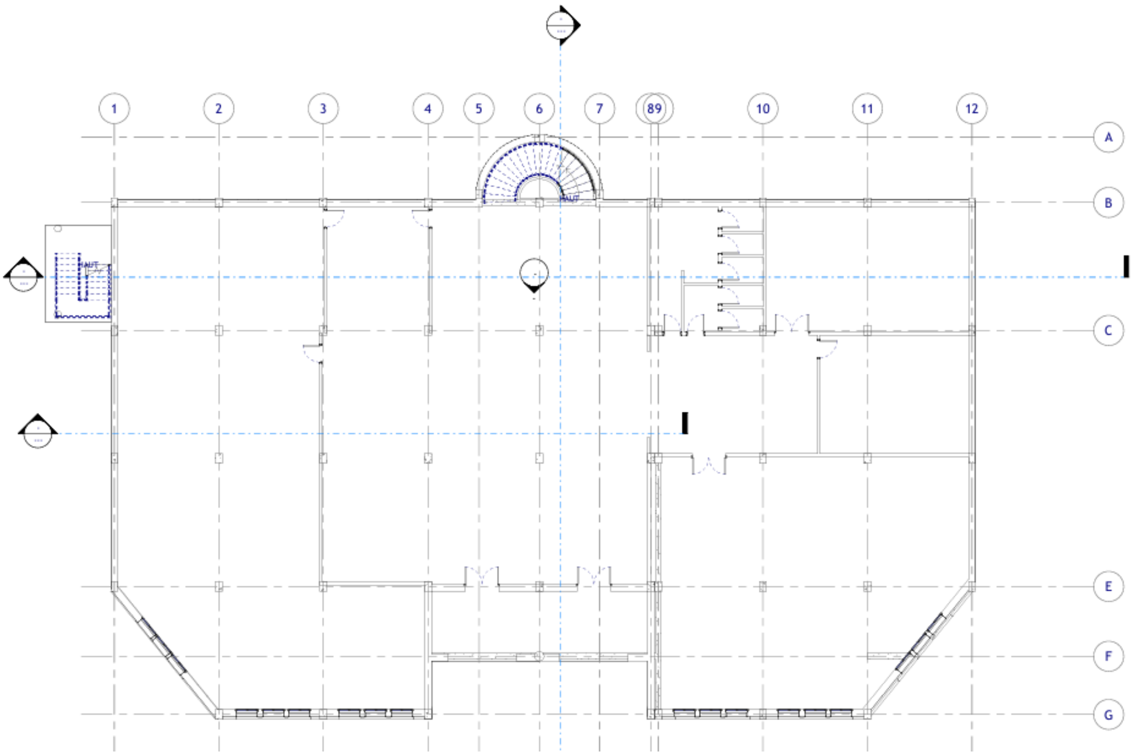


Figure III 10 : Plan RDC

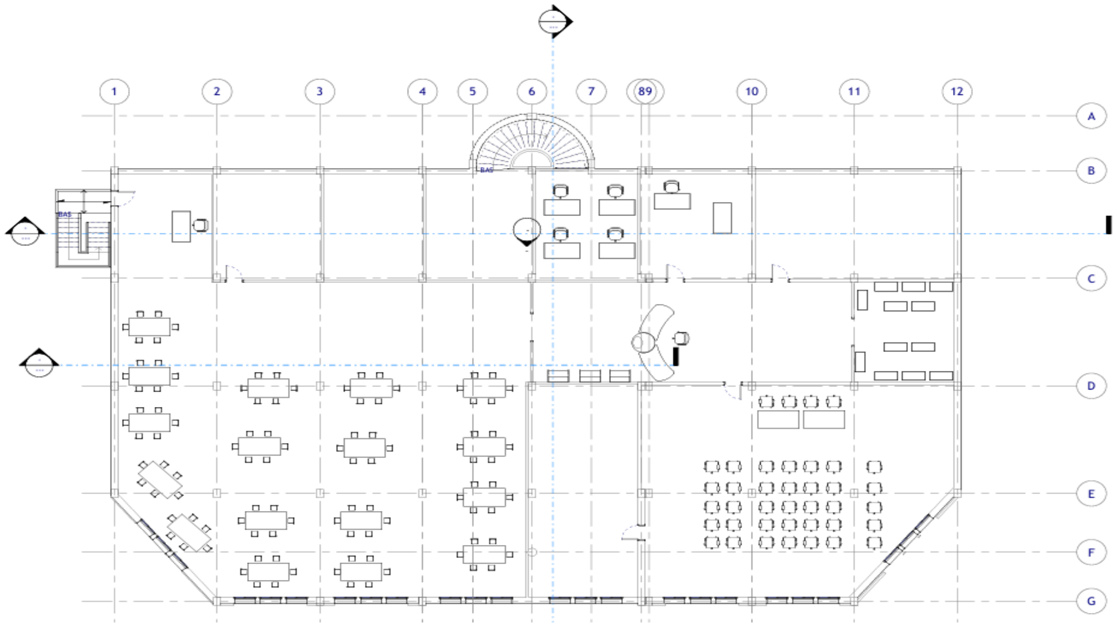


Figure III 11 : plan 1 etage

III.2.2. Materials and Surfaces:

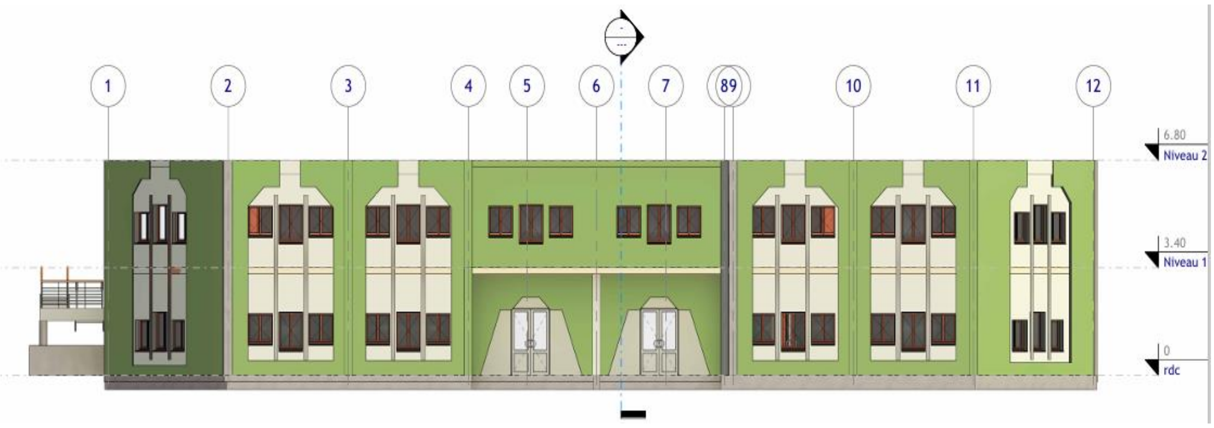


Figure III 12 : Facade pranicipale

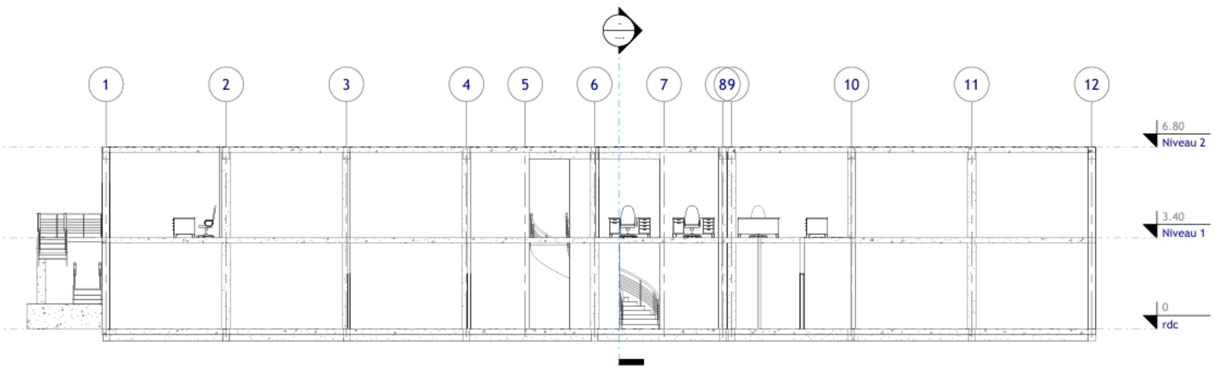


Figure III 13 : section A A'

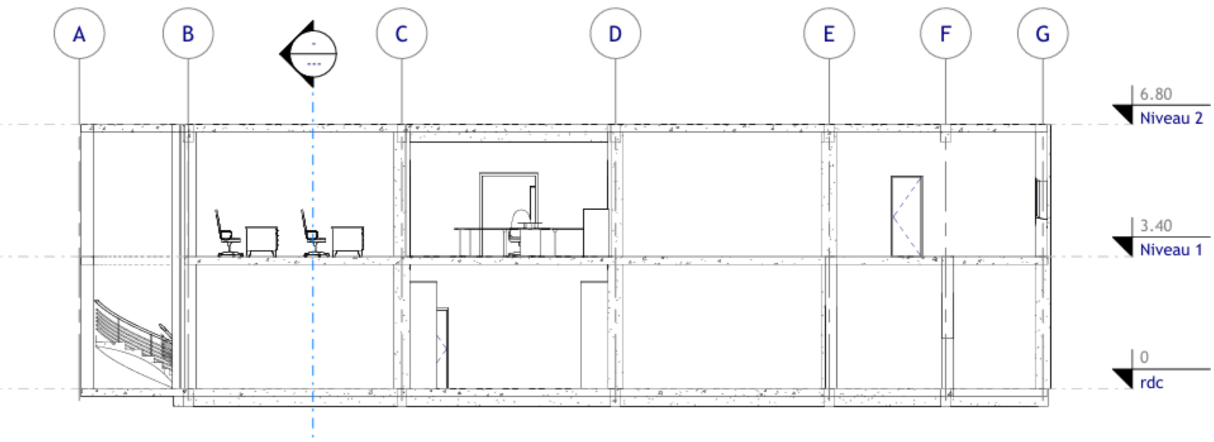
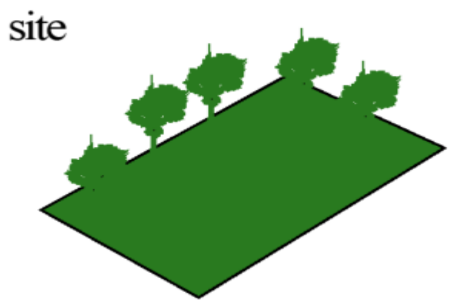


Figure III 14 : section B B'

III.2.3. Genesis of form :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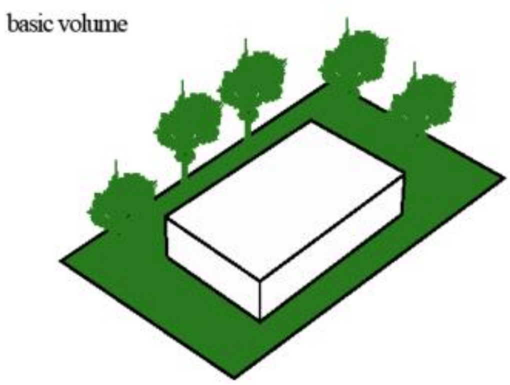
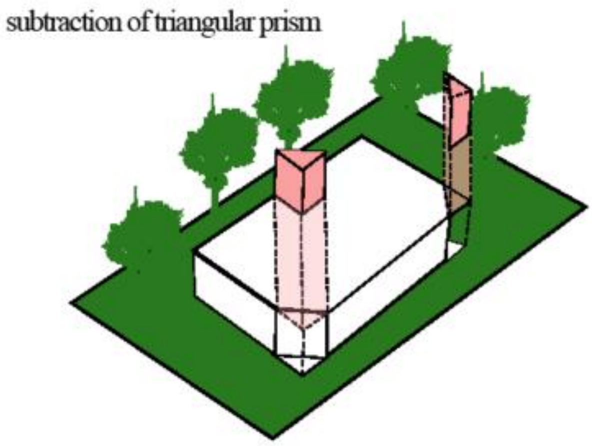
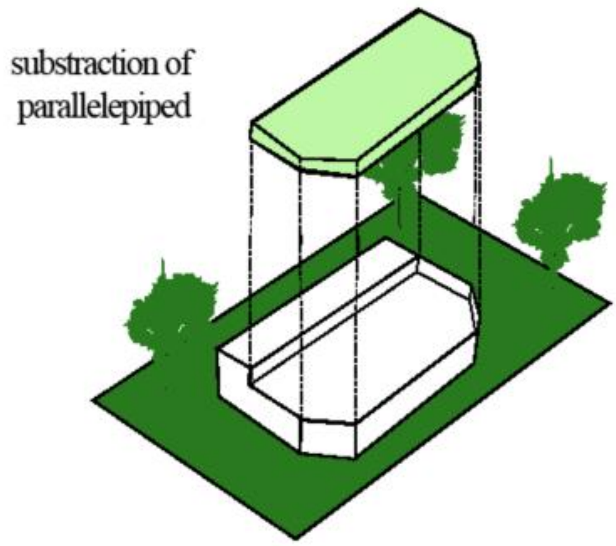
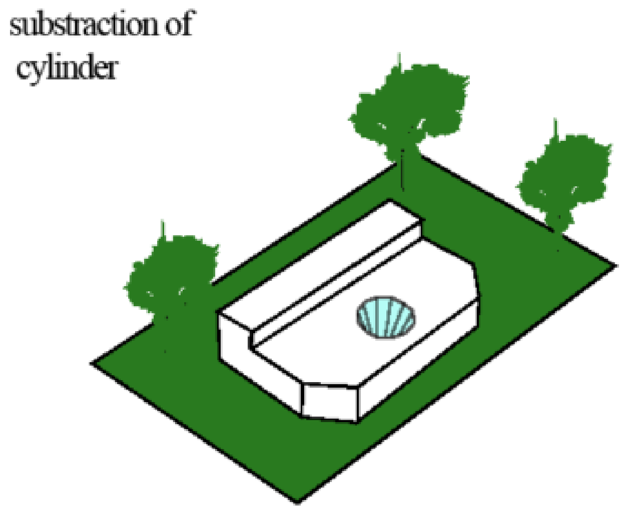
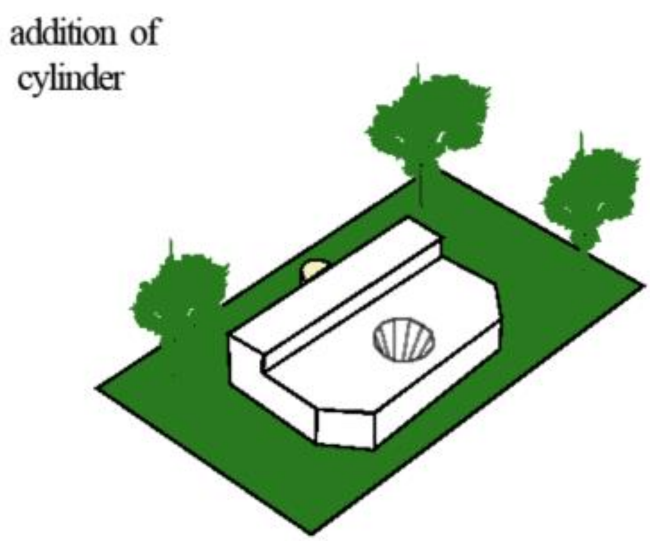

basic volume

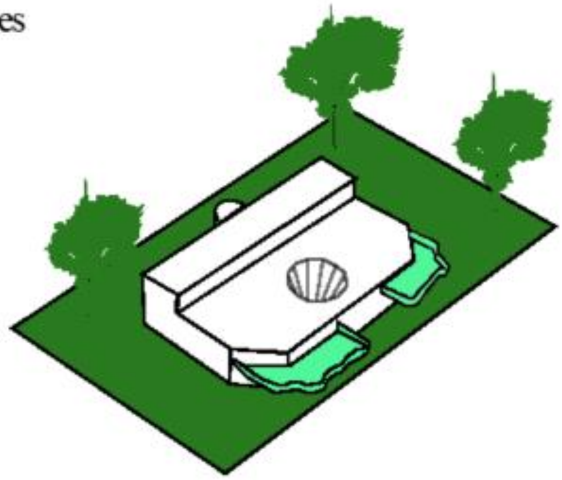

subtraction of triangular prism


substraction of
parallelepiped

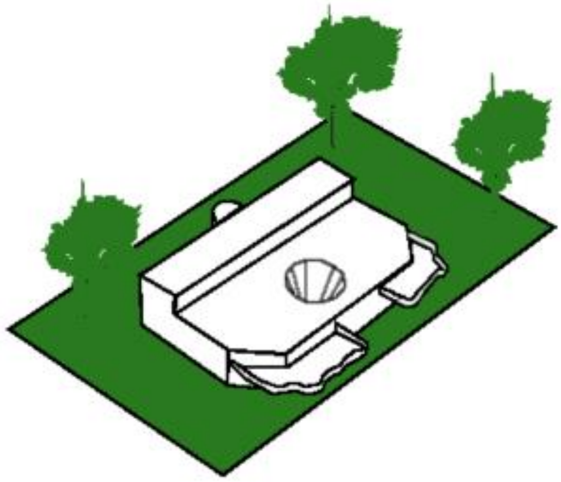

substraction of
cylinder


addition of
cylinder

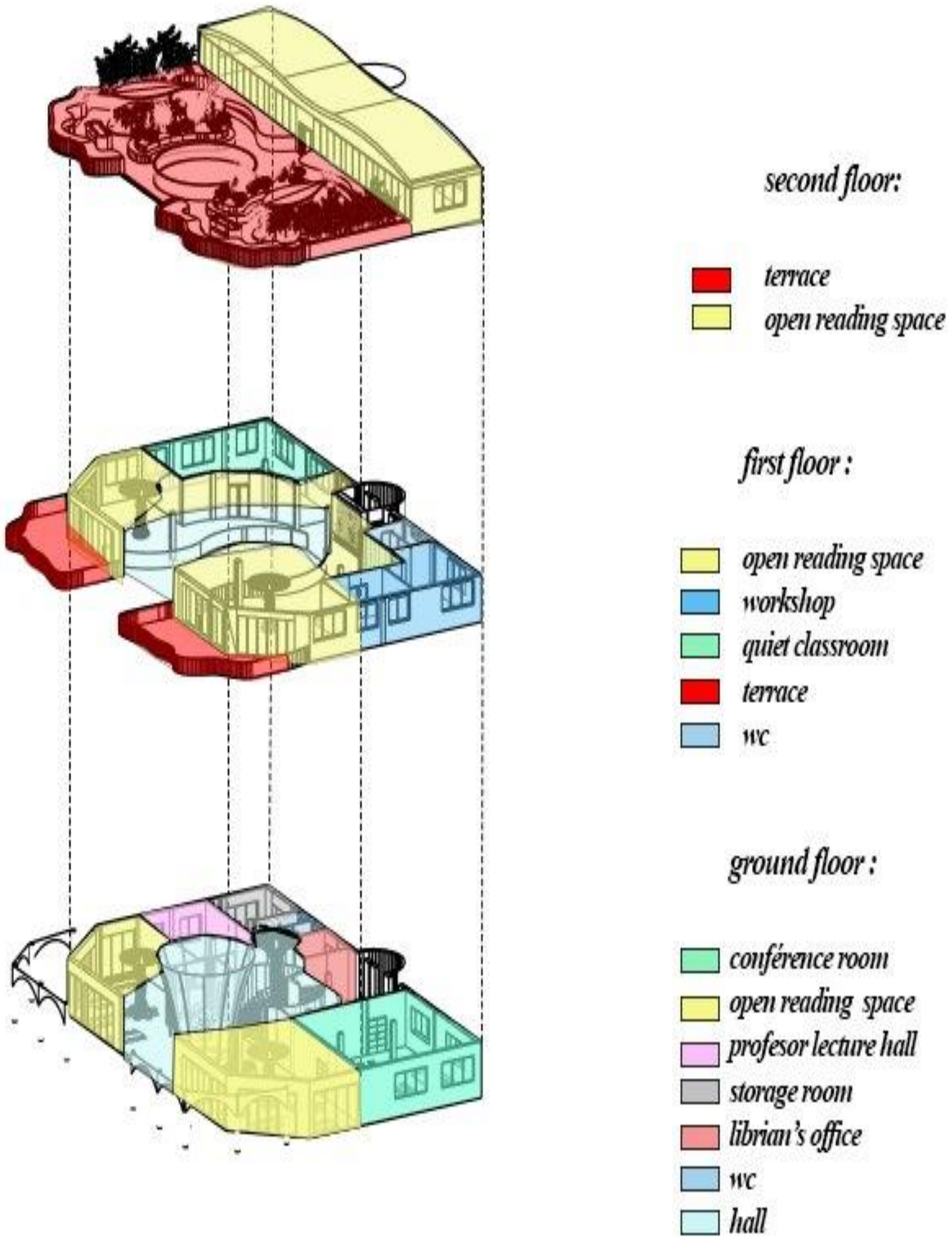
addition of
terraces



final volumetric composition



III.2.4. Spatial organization :

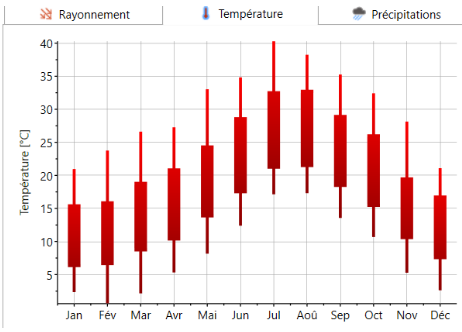
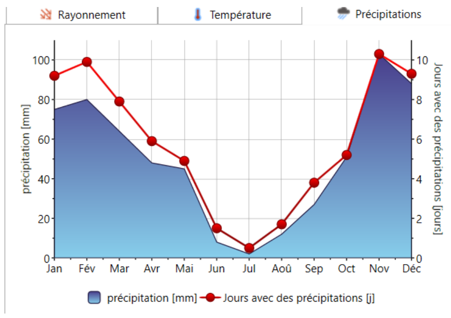
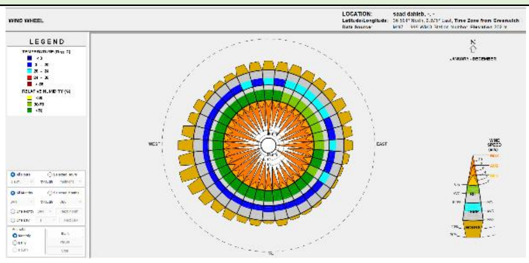
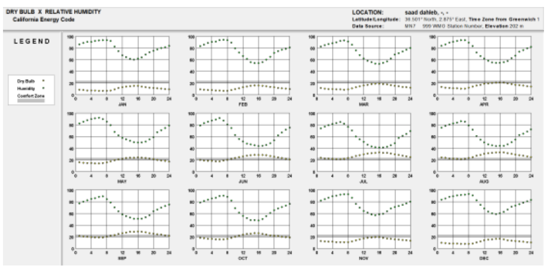


III.3. Microclimate Analysis and Visualization :

III.3.1. Climate Diagrams:

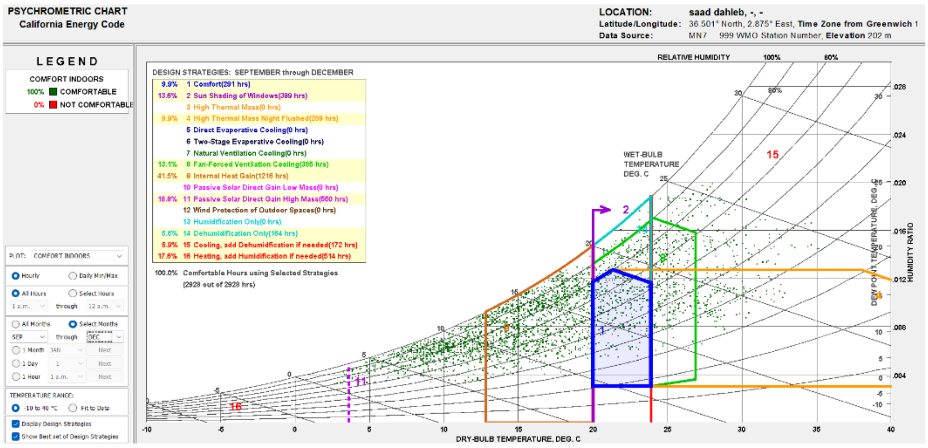
Temperature, humidity, and wind rose diagrams.

2.Table : Climatic analysis of the study area. Source: author 2025

Température mensuelle	**Précipitation**
 *Figure: temperature of the study area. Source: meteonorm*	 *Figure: Precipitation in the study area. Source: meteonorm*
The temperature varies between 16°C and 40°C in the summer season, and between 0°C and 22°C in the winter season.	The average rainfall is approximately nine months per year. The amount of precipitation in winter is between a maximum of 110mm in November and a minimum of 95mm in January, in summer it is between 5mm in July and 40mm in September.
Vitesse du vent	**Humidité**
 *Figure: wind speed of the study area. Source: climate consultant*	 *Figure: humidity of the study area. Source: climate consultant*

The prevailing winds blow in a southwest and northeast direction, with a maximum speed of 16m/s, and a minimum speed of 8m/s. The region is characterized by relative humidity which varies between 30% and 70%	Humidity varies between 50% and 95% in the winter month, and between 40% and 90% in the summer month.

- **Energy analysis**

<table>
<tr><td rowspan="2">GIVONI diagram of the winter period</td><td>During the winter season, passive methods provide only 42% of thermal comfort. In order to achieve 100% complete comfort, active solutions are required for the remaining 58%, including a heating system.

</td></tr>
<tr><td>Figure: GIVONI diagram of the winter period of the study area.climat cosultant source</td></tr>
</table>

GIVONI diagram of the	During the summer season, passive methods offer 60% comfort, while active methods offer 40% comfort, thanks in particular to an air conditioning system.

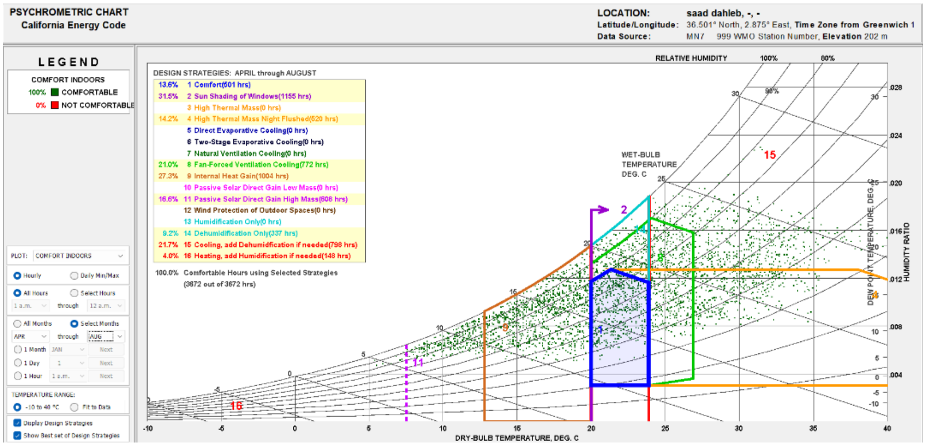
<table>
<tr><td>summer period</td><td>


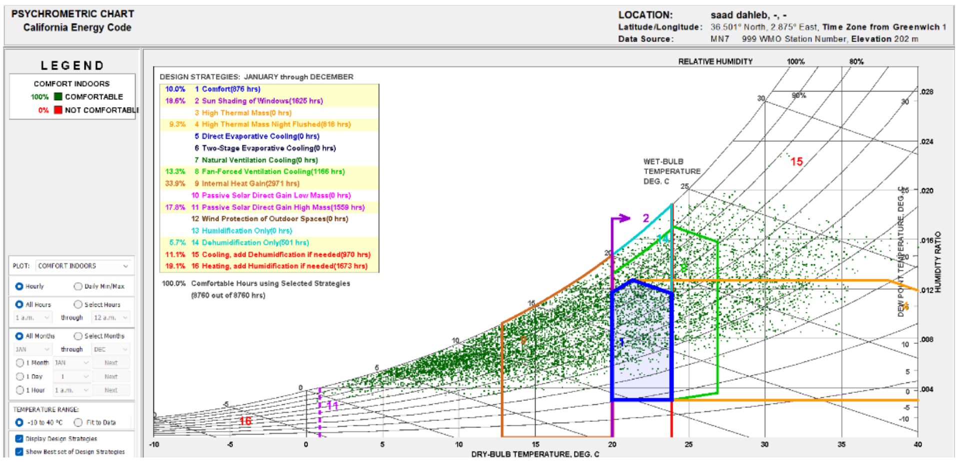
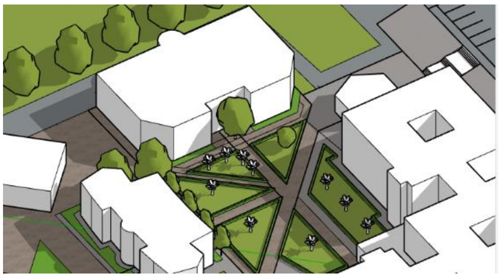
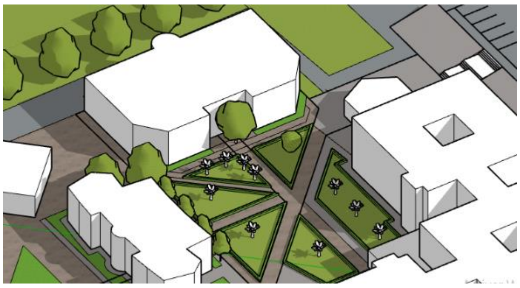
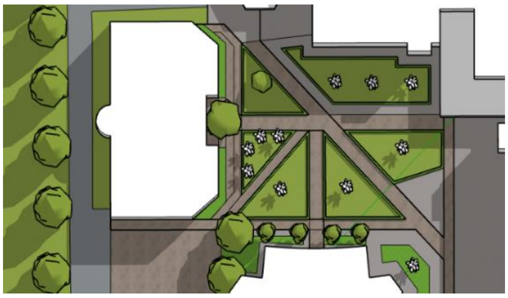
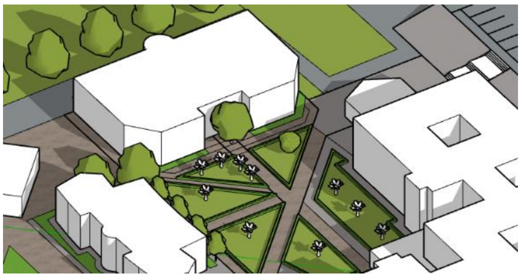
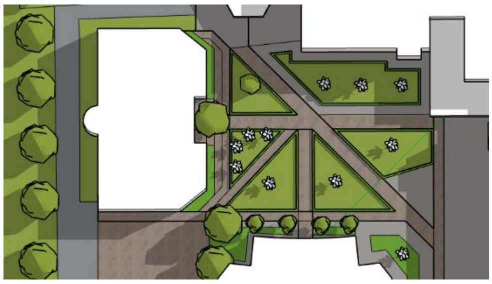
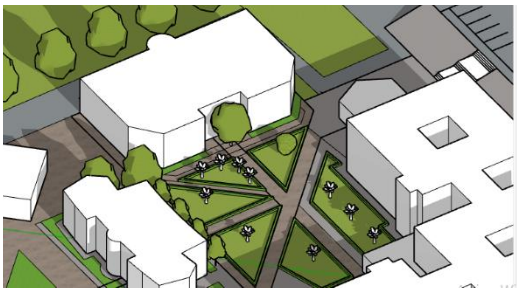
Figure: GIVONI diagram of the summer period of the study area. Climat consultant source
</td></tr>
<tr><td>Annual</td><td>Taking into account the annual needs in terms of percentage and hours of comfort, we observe that passive techniques only provide 60% comfort. To achieve 100% optimal comfort, it is necessary to use active techniques for the remaining 40%. This includes an air conditioning system as well as a heating system representing</td></tr>
<tr><td></td><td>


Figure : Annual GIVONI diagram of the study area. Meteonorm source
</td></tr>
</table>

Figure 4, chapter 3

III.3.2.Sun Path and Shadow Analysis: *Seasonal variations in shading and solar exposure.*

time	Daily shadw path	
10:00		
12:00		
14:00		
16:00		

III.3.2. Methodology and Design Proposals :

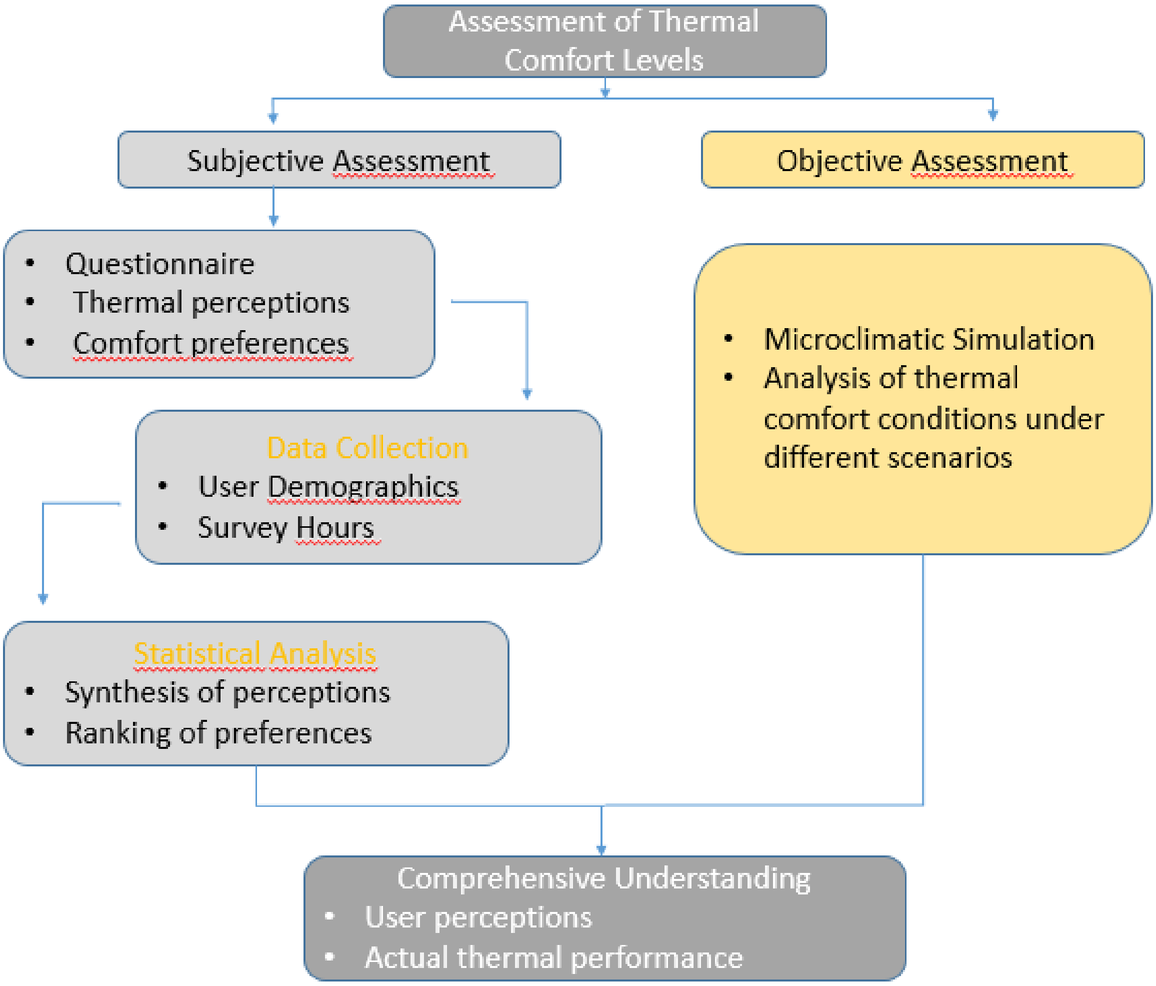


Figure 6, chapter 3 (Diagram showing the methodology)

III.3.3. Thermal Comfort Surveys :

➢ Questionnaire Protocol :

Objective	Users' perceptions of thermal comfort and identify discomfort triggers.
Target Population	Students, faculty, and staff who regularly use the outdoor spaces.
Survey Period	From early October to the mid-November.
Distribution Method	Online forms.
Response Rate	246

➢ Questionnaire Structure:

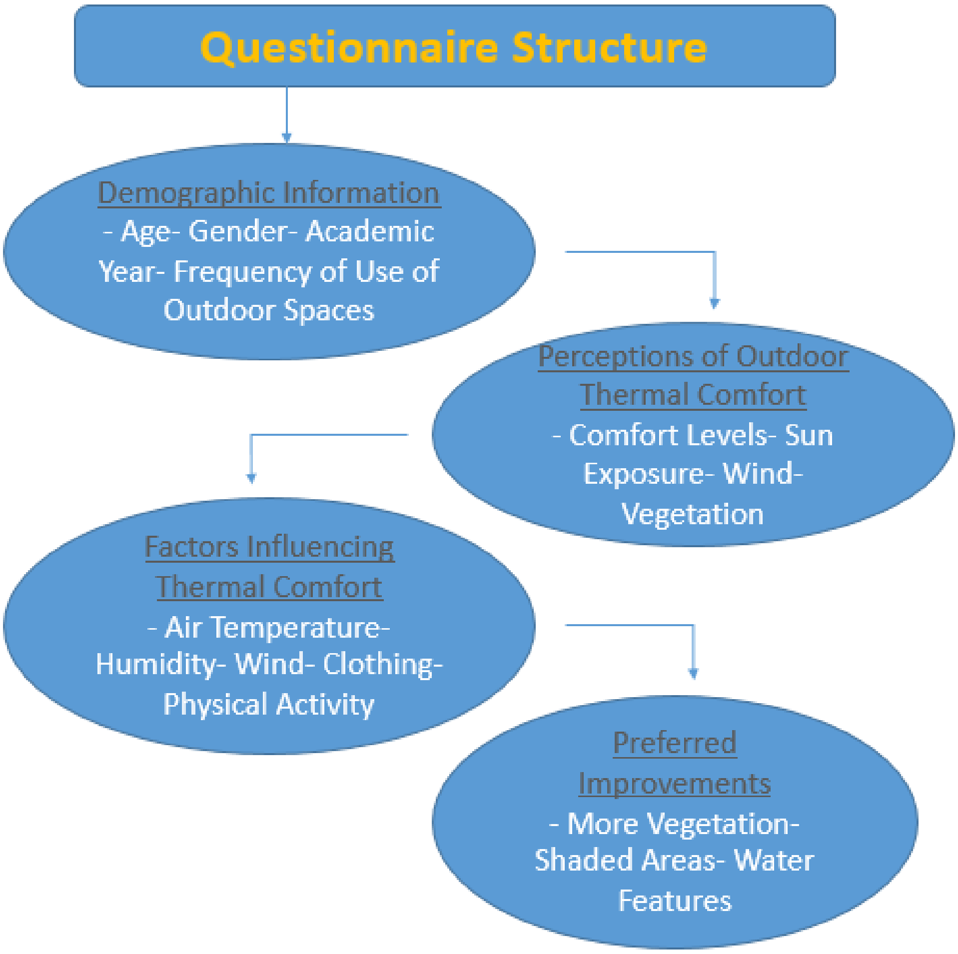


Figure 7, chapter 3 (Diagram of the questionnaire structure)

III.3.4. Questionnaire Results :

The responses provided valuable data points for the study:

- ✓ **Demography:** The majority of respondents were students aged 20–25, spending time outdoors daily or several times a week.
- ✓ **Seasonal Comfort Patterns:** Participants reported high discomfort during summer, with comfort levels increasing in spring and autumn.
- ✓ **Key Discomfort Factors:** The most cited factors were high temperatures, lack of shade, and limited air movement.
- ✓ **Improvement Preferences:** The most requested interventions included more shaded areas, increased greenery, and water features to cool the environment.

III.4. Microclimate Simulation :

III.4.1. Simulation Parameters :

The microclimate simulation, conducted with ENVI-met V5.6.1, used Metronom-generated climate data for October 13, 2024, a peak outdoor usage day. Simulated parameters included air temperature, humidity, mean radiant temperature, and wind speed. Thermal comfort was evaluated with PET, UTCI, PMV, and SET indices.

III.4.2. Simulation Scenarios :

We tested eight scenarios to assess different design interventions' impact on the site's microclimate and thermal comfort levels:

➢ Scenario 1: Baseline Condition

Simulate the existing outdoor space and library area without any modifications, capturing factors like temperature, humidity, wind patterns, and solar exposure at different times of the day and across seasons.

➢ Scenario 2: Green Roof Implementation

Apply green roofs to the library, testing extensive (low-maintenance) and intensive (denser vegetation) systems to measure temperature regulation and their effect on surrounding outdoor comfort.

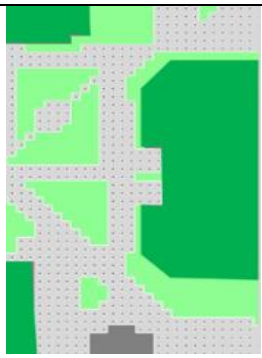
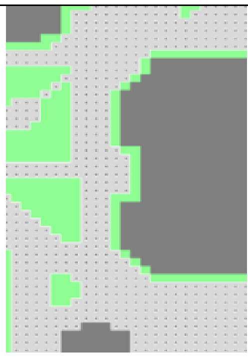
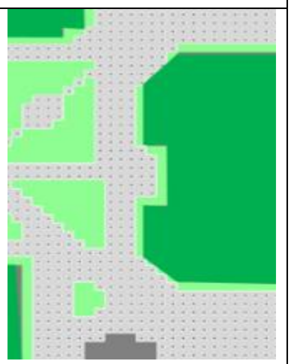
➢ Scenario 3: Vertical Green Walls

Place green walls on sun-exposed library facades to reduce direct solar gain, lowering surface temperatures and contributing to local cooling.

➢ Scenario 4: Combined Green Roofs and Green Walls

Simulate the simultaneous integration of green roofs and vertical gardens to amplify cooling benefits, balancing temperature reduction with aesthetic and ecological value.

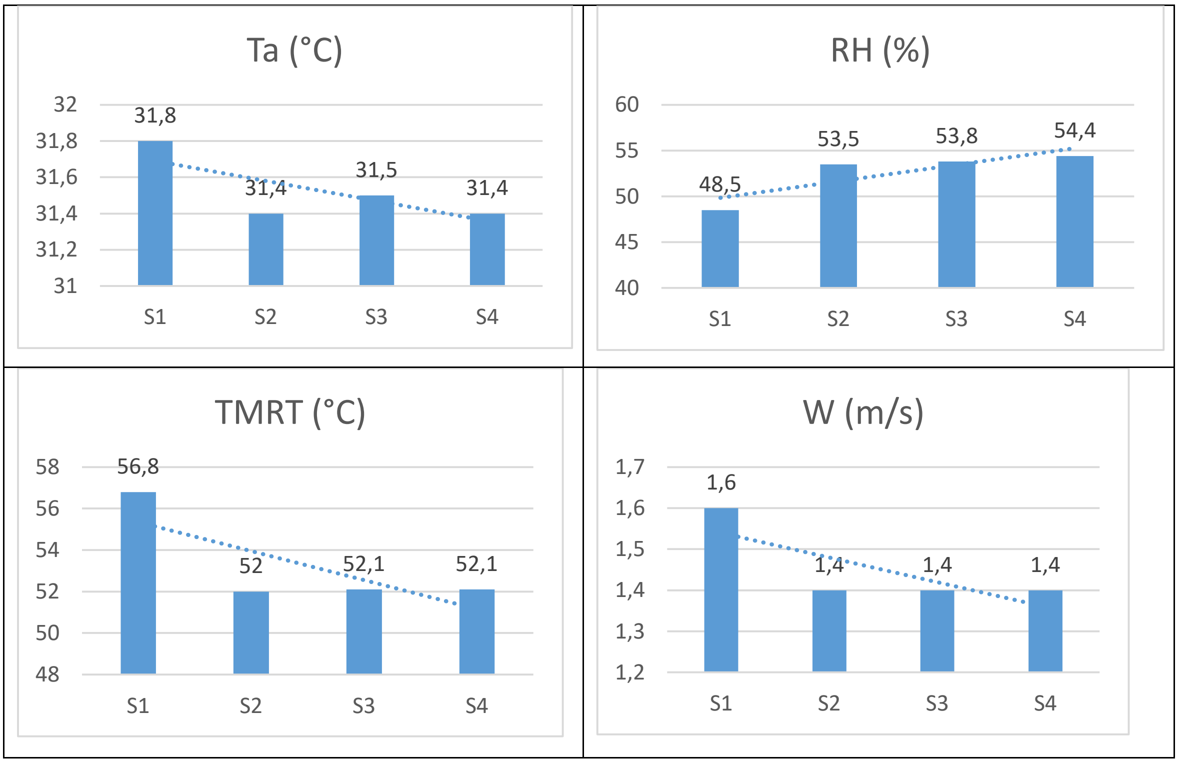
Simulation Details	
	Model: ENVI_met Microclimate **Location:** Institute of Architecture and Urbanism, Blida city **Climate:** Mediterranean climate **Date:** October 13, 2024 **Time:** 8 a.m. to 5 p.m. **Inputs:** Full forcing climate file, Meteonorm 8 **Scenarios:** Eight different scenarios (Figure 3) **Outputs** ▪ Microclimate Parameters: Ta (°C), RH (%), T_{MRT} (°C) and W (m/s) ▪ Thermal comfort Indices: PET (°C) , UTCI, PMV and SET.

Modelled Scenarios			
(S1) Baseline Condition	**(S2) Green Roof**	**(S3) Vertical Green Walls**	**(S4) Green Envelope**
			

III.4.3. Simulation Results :

III.4.3.1. Microclimate Dynamics :

Microclimate parameters	Scenarios			
	S1	**S2**	**S3**	**S4**
Ta (°C)	31,8	31, 4	31,5	31,4
RH (%)	48,5	53,5	53,8	54,4
T_{MRT} (°C)	56,8	52,0	52,1	52,1
W (m/s)	1,6	1,4	1,4	1,4



III.4.3.2. Analysis :

- ➢ Air Temperature (Ta) :

- Scenario S1 has the highest air temperature at 31.8°C, and this decreases slightly in the other scenarios.
- A 0.4°C drop from S1 to S2/S4 may seem minor, but even small changes can impact human thermal perception, especially in urban areas.

<u>Supporting Reference:</u>

- ASHRAE (2017) confirms that minor reductions in air temperature improve thermal comfort, especially when combined with optimised humidity and solar radiation. (ASHRAE-55, 2017).

➢ Relative Humidity (RH) :

- It is clear that RH increases progressively from 48.5% to 54.4%.
- Higher RH reduces the effectiveness of evaporative cooling from sweating, making conditions feel warmer.

Supporting Reference:

- The relationship between RH and perceived temperature is well-documented in the PMV (Predicted Mean Vote) model. (Schaudienst & Vogdt, 2017)

➢ Mean Radiant Temperature (TMRT) :

- It is clear that TMRT is significantly higher in S1, which indicates much more radiant heat exposure.
- A drop of nearly 5°C in TMRT in the other scenarios is a substantial improvement in outdoor thermal comfort.

➢ Wind Speed (W) :

- Wind speed is higher in S1.
- This minor variation will slightly enhance convective cooling in S1.

Supporting Reference:

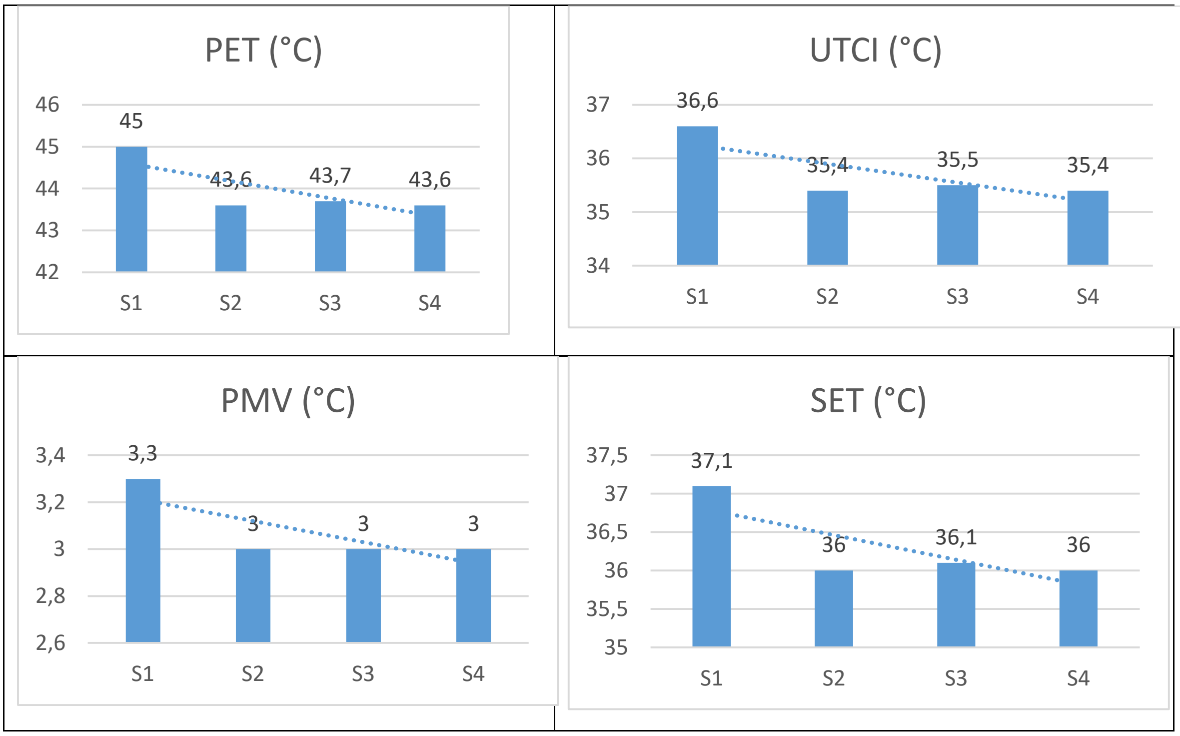
- In hot climates, wind speeds of 1.0–1.5 m/s are key to promoting thermal comfort through convective cooling. (Santamouris et al., 2001)

➢ CONCLUSION :

- Scenario S1 shows the worst thermal comfort due to the high TMRT and moderate RH, despite slightly higher wind speed.
- Scenarios S2–S4 clearly demonstrate improved comfort, mainly due to significant reductions in TMRT, likely due to environmental interventions like shading or surface materials.
- S4 is the most balanced scenario, offering moderate Ta, high RH, significantly lower TMRT, and consistent wind.

III.4.3.3. Thermal Comfort Levels :

Thermal Indices	Scenarios			
	S1	**S2**	**S3**	**S4**
PET (°C)	45,0	43,6	43,7	43,6
UTCI (°C)	36,6	35,4	35,5	35,4
PMV (°C)	3,3	3	3	3
SET (°C)	37,1	36	36,1	36



III.4.3.4. Analysis :

- ➢ PET (Physiologically Equivalent Temperature) :
- All values are above 41°C. This indicates extreme heat stress according to the PET scale.
- S1 has the worst thermal comfort with a PET of 45.0°C.
- Scenarios S2, S3 and S4 show clear improvements, with a reduction in PET of around 1.4°C.

- ➢ UTCI (Universal Thermal Climate Index) :
- All scenarios are categorised as "very strong heat stress" (32–38°C), according to UTCI classification.

- S1 shows the highest UTCI and thus the most severe heat stress.
- S2 and S4 perform slightly better, reducing the temperature by around 1.2°C.

➢ PMV (Predicted Mean Vote) :

- PMV values range from +3 (hot) to –3 (cold); all values here indicate hot conditions.
- S1 is unmistakably close to the "very hot" threshold.
- S2-S4 reduce perceived heat stress.

➢ SET (Standard Effective Temperature) :

- It is clear that SET values above 35°C indicate uncomfortable conditions, especially outdoors.
- Scenario S1 ranks worst.
- S2 and S4 show a clear improvement in thermal comfort, with a temperature drop of around 1.1°C, demonstrating effective environmental mitigation.

➢ Conclusion:

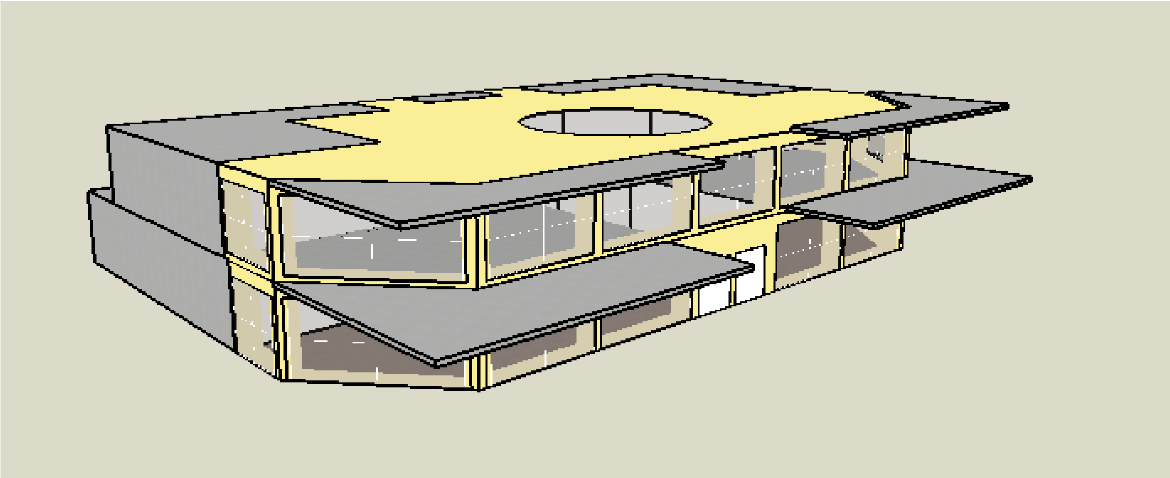
- Scenario S1 is unequivocally the worst. It consistently exhibits the highest stress across all indices.
- Scenarios S2 and S4 deliver the best thermal performance and reduce stress.
- S2 and S4 are clear improvements, with designs including shading structures, vegetation, reflective materials and increased ventilation. These changes result in clear thermal relief.

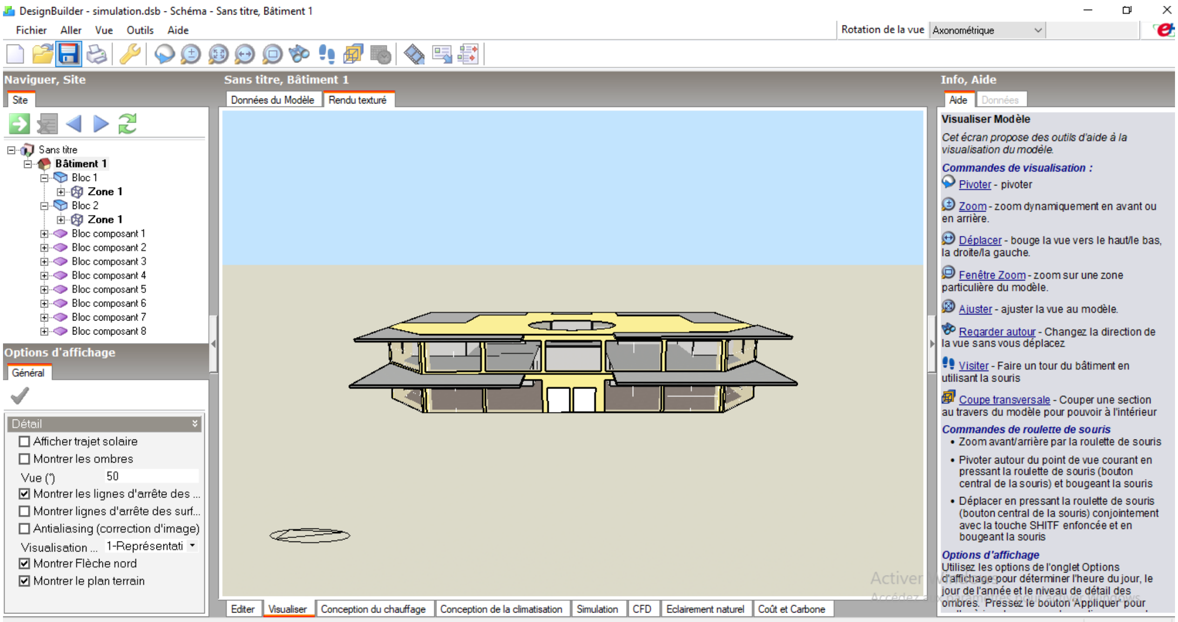
III.5. Thermal Comfort Analysis – DesignBuilder Simulation:

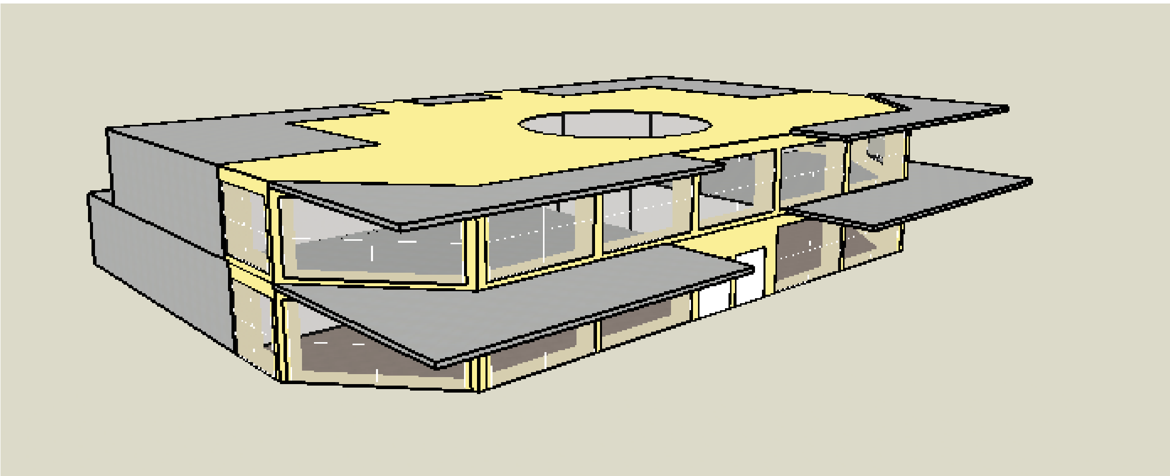
🏛 **Building:** Bioclimatic Library – Institute of Architecture and Urbanism, Blida

Simulation Period: September 1st – May 31st

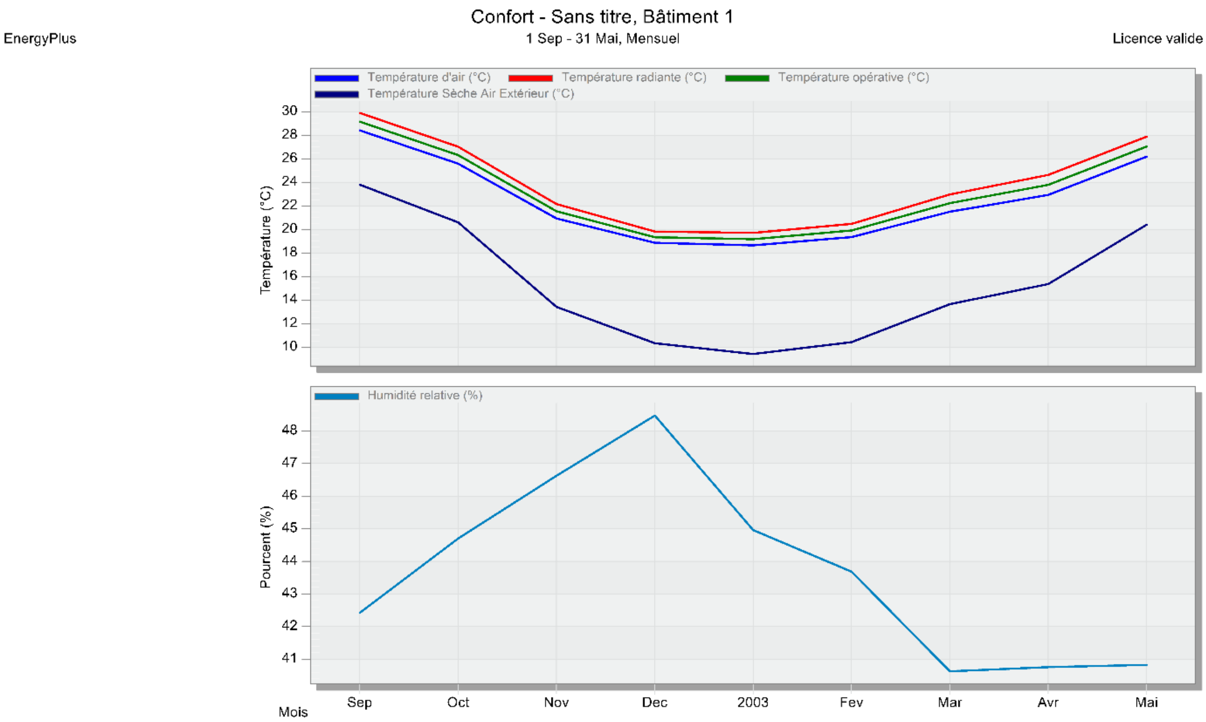
Methodology: Monthly simulation using DesignBuilder (EnergyPlus)




DesignBuilder - simulation.dsb - Schéma - Sans titre, Bâtiment 1
Fichier Aller Vue Outils Aide
Rotation de la vue Axonométrique
Naviguer, Site
Site
Sans titre
Bâtiment 1
Bloc 1
Zone 1
Bloc 2
Zone 1
Bloc composant 1
Bloc composant 2
Bloc composant 3
Bloc composant 4
Bloc composant 5
Bloc composant 6
Bloc composant 7
Bloc composant 8
Options d'affichage
Général
Détail
Afficher trajet solaire
Montrer les ombres
Vue (°) 50
Montrer les lignes d'arrête des ...
Montrer lignes d'arrête des surf...
Antialiasing (correction d'image)
Visualisation ... 1-Représentati
Montrer Flèche nord
Montrer le plan terrain
Sans titre, Bâtiment 1
Données du Modèle
Rendu texturé
Editer
Visualiser
Conception du chauffage
Conception de la climatisation
Simulation
CFD
Eclairement naturel
Coût et Carbone
Info, Aide
Aide
Données
Visualiser Modèle
Cet écran propose des outils d'aide à la visualisation du modèle.
Commandes de visualisation :
Pivoter - pivoter
Zoom - zoom dynamiquement en avant ou en arrière.
Déplacer - bouge la vue vers le haut/le bas, la droite/la gauche.
Fenêtre Zoom - zoom sur une zone particulière du modèle.
Ajuster - ajuster la vue au modèle.
Regarder autour - Changez la direction de la vue sans vous déplacez
Visiter - Faire un tour du bâtiment en utilisant la souris
Coupe transversale - Couper une section au travers du modèle pour pouvoir à l'intérieur
Commandes de roulette de souris
• Zoom avant/arrière par la roulette de souris
• Pivoter autour du point de vue courant en pressant la roulette de souris (bouton central de la souris) et bougeant la souris
• Déplacer en pressant la roulette de souris (bouton central de la souris) conjointement avec la touche SHITF enfoncée et en bougeant la souris
Options d'affichage
Utilisez les options de l'onglet Options d'affichage pour déterminer l'heure du jour, le jour de l'année et le niveau de détail des ombres. Pressez le bouton 'Appliquer' pour



III.5.1. Scenario 1: Comfort Provided by Passive Design Only (No HVAC Systems)



Mois	Sep	Oct	Nov	Dec	2003	Fev	Mar	Avr	Mai
Température d'air (°C)	28,42	25,59	20,93	18,86	18,65	19,35	21,50	22,93	26,19
Température radiante (°C)	29,90	27,03	22,16	19,82	19,71	20,48	22,97	24,64	27,88
Température opérative (°C)	29,16	26,31	21,54	19,34	19,18	19,92	22,24	23,78	27,04
Température Sèche Air Extérieur (°C)	23,80	20,60	13,42	10,33	9,42	10,43	13,65	15,36	20,40
Humidité relative (%)	42,42	44,70	46,63	48,47	44,96	43,69	40,63	40,76	40,83

- **Interpretation:**

Radiant temperature analysis (°C):

September to October:

The radiant temperature is 29.9°C in September and 27.03°C in October, above the thermal comfort zone. This indicates possible overheating in the building during these months.

November to February:

The values gradually drop to a minimum of 19.71°C in February, slightly below the comfort zone. This shows that thermal comfort is not ensured during the winter despite the use of insulating or high-inertia materials.

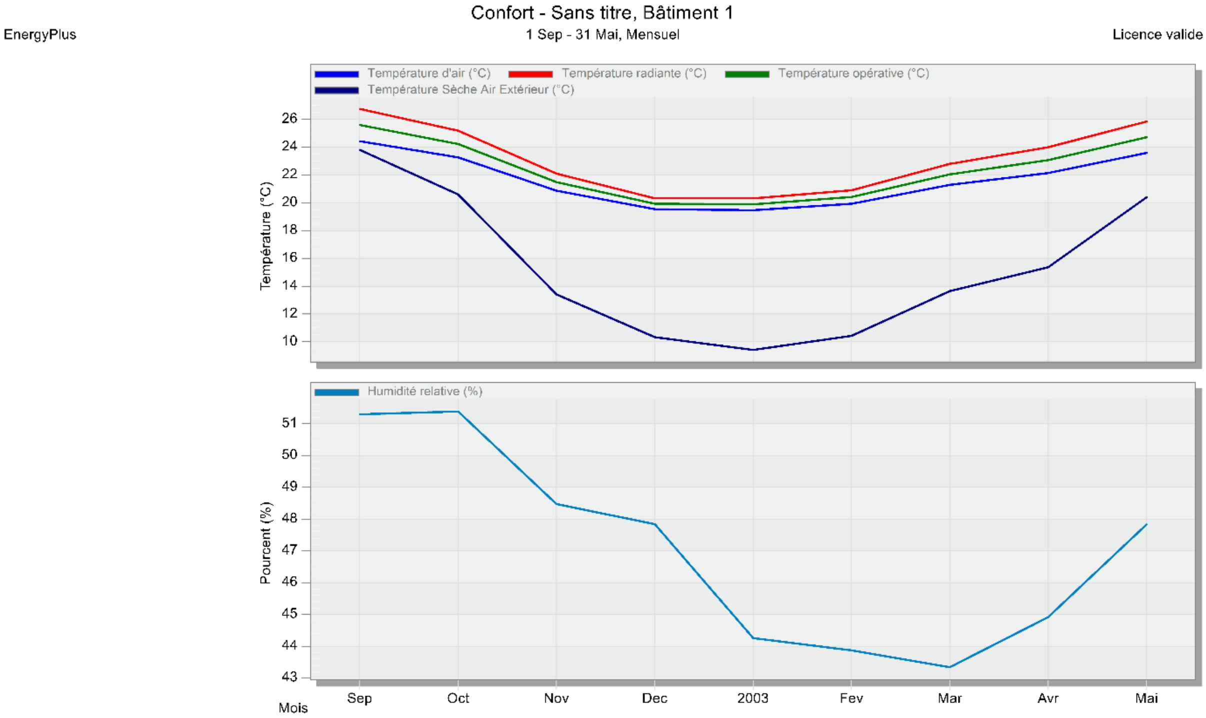
March to May:

Temperatures rise again and reach 27.88°C in May. This excess suggests a resumption of overheating in the spring.

Overall interpretation:

The radiant temperature varies between 19.71°C and 29.9°C, which means that thermal comfort is not ensured year-round. The lack of active systems (heating/air conditioning) makes the building dependent on external climatic variations. Heat peaks are observed in summer and slight discomfort in winter.

III.5.2. Scenario 2: Comfort Achieved via Passive Design + HVAC Systems (Heating/Cooling)



Mois	Sep	Oct	Nov	Dec	2003	Fev	Mar	Avr	Mai
Température d'air (°C)	24,43	23,27	20,87	19,54	19,47	19,94	21,29	22,14	23,59
Température radiante (°C)	26,75	25,19	22,10	20,32	20,32	20,90	22,80	24,00	25,84
Température opérative (°C)	25,59	24,23	21,48	19,93	19,89	20,42	22,04	23,07	24,72
Température Sèche Air Extérieur (°C)	23,80	20,60	13,42	10,33	9,42	10,43	13,65	15,36	20,40
Humidité relative (%)	51,30	51,39	48,48	47,84	44,26	43,87	43,34	44,92	47,83

- **Interpretation:**

Radiant Temperature Analysis (°C):

September to October:

Temperatures are 26.75°C and 25.19°C, slightly above the comfort zone. This can be interpreted as a slightly high air conditioning setting or a high internal thermal load.

November to March:

The radiant temperature remains very stable between 22.10°C and 20.32°C, well within the thermal comfort zone. This demonstrates very good thermal regulation by the heating systems.

April to May:

Temperatures rise slightly to 24.00°C and 25.84°C. The May value is close to the upper limit, which may require adjustment of the air conditioning setpoints.

Overall Interpretation:

The integration of active systems (heating/cooling) ensures a comfortable indoor temperature throughout the year, regardless of external climatic variations.

This scenario guarantees optimal thermal comfort, especially during winter, without exceeding acceptable humidity levels.

III.6. Conclusion:

The thermal simulations conducted using DesignBuilder provided a clear understanding of the building's indoor environmental performance under two distinct scenarios: passive design alone and passive design combined with active HVAC systems.

In the first scenario, where comfort was solely ensured through bioclimatic strategies and building materials, the results showed notable temperature fluctuations. While passive solutions were effective during mid-seasons, thermal comfort was not guaranteed during colder months, particularly between November and February. Radiant and operative temperatures fall below acceptable comfort thresholds, leading to potential discomfort for users, especially in a library setting where prolonged occupancy is expected.

In contrast, the second scenario, which integrated heating and cooling systems, demonstrated stable and optimal indoor conditions throughout the year. The use of HVAC systems successfully maintained both air and radiant temperatures within recommended comfort ranges. Additionally, relative humidity remained within acceptable levels, enhancing overall indoor comfort.

General conclusion

General conclusion

1. Summary of Results:

This thesis is part of a desire to adapt university architecture to contemporary requirements in terms of sustainability, thermal comfort, and quality of life, in an increasingly restrictive climate. The bioclimatic library project at the Institute of Architecture and Urban Planning of Blida 1 allowed us to test, through an integrated approach, how nature can be harnessed to promote the thermal and environmental well-being of users.

The first phase consisted of assessing the existing situation: outdoor spaces exposed to intense direct sunlight, little effective vegetation, a poorly ventilated built environment, and a library suffering from overheating in summer and heat loss in winter. This situation led to significant thermal discomfort, confirmed by the results of user surveys and climate analyses (Givoni diagrams, wind roses, simulations).

In light of this observation, several scenarios were designed and tested through simulation using ENVI-met and DesignBuilder. The integration of green roofs, green walls, and in-ground vegetation resulted in a significant drop in average radiative temperatures (up to -4.8°C), an improvement in relative humidity, and a reduction in heat stress (PET, UTCI). The combined scenario (roof + green walls) proved to be the most effective, with a lower ambient temperature, better regulated humidity, and an overall reduction in heat stress indices.

DesignBuilder simulations, for their part, highlighted the limitations of passive comfort alone: although certain periods are bearable, the lack of effective natural ventilation and appropriate bioclimatic solutions leads to periods of overheating or winter discomfort. The addition of natural elements extends passive comfort periods while reducing the need for mechanical systems.

In short, the results clearly show that integrating plants into architectural projects improves thermal comfort both indoors and outdoors. It also promotes reduced energy consumption, improves the image of the site, and contributes to the mental and physiological well-being of users.

2. Critical Reflections:

The approach undertaken presented several methodological and conceptual strengths. From a theoretical perspective, it is based on a convergence between bioclimatic design and the principles of biophilic design, which gives it scientific soundness and environmental coherence. The intersection of microclimatic analysis (ENVI-met), energy assessment (DesignBuilder), and usage surveys allows for the construction of a comprehensive, quantitative and qualitative vision of thermal comfort.

Among the strengths of this work, it is worth highlighting the richness of the tools used (3D modeling, comfort indices, thermal mapping), the precision of the intervention scenarios, and the relevance of the case studies chosen upstream (Assiut University, Singapore Library, etc.), which provided models adaptable to the Algerian context. The proposed project is therefore not a simple replica, but rather a reasoned adaptation to Blida's semi-continental Mediterranean climate.

However, certain limitations must be acknowledged. First, the simulations, although advanced, remain modeling: they do not replace actual on-site experimentation. Parameters such as the actual albedo of surfaces, the aging of materials, and the variability of human behavior are only partially taken into account. Second, the development scenarios remained limited to the immediate outdoor spaces and the building envelopes. Further consideration of hybrid systems (assisted ventilation, photovoltaic systems coupled with natural cooling systems) would have broadened the range of solutions.

Finally, budgetary, regulatory, and institutional constraints were not addressed in detail. However, in the Algerian university context, they represent a significant obstacle to the effective implementation of this type of project.

3. Future Perspectives:

The avenues opened up by this work are numerous. It would be relevant, as a first step, to extend this research with a full-scale experiment using one or more of the scenarios tested. A real-life implementation of green walls or green roofs within the Institute's context would allow for observation of the real impacts on thermal comfort, local biodiversity, and user perceptions over the long term.

On a scientific level, further simulations could include full seasonal dynamics, the cumulative effects of long-term climate change, or even a life cycle analysis of the biophilic materials used. The interdisciplinarity between architecture, urban ecology, and energy engineering could also enrich the assessment tools.

General conclusion

Finally, this research calls for the widespread adoption of bioclimatic and biophilic approaches in all Algerian university campus projects. The Ministry of Higher Education could thus initiate a national program for the sustainable transformation of academic spaces, based on the principles highlighted in this study: reclamation of outdoor spaces, greening, natural ventilation, and user involvement in the design.

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