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Climate Responsive Outdoor Space In Educational Settings: Strategies To Optimize Thermal Comfort In The Institute Of Architecture And Urbanism (Iau), University Of Blida 1

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Abstract
Given the pollution, degradation and urban heat islands that have tended to aggravate with climate change, the design of open spaces in educational settings is integral to environmental thermal comfort as well as activity for health. This research explores how climate responsive design measures can enhance the thermal environment of open spaces in School of architecture by conducting field measurements at different locations within the school premises. With a combination of local climate data, solar and wind simulations, user surveys the research identifies principal spatial and physical determinants for outdoor thermal comfort. The results illustrate large differences in heat between areas, e.g. because of little or no shading, not enough vegetation and the presence of heat-retaining surface materials. These include the intervention of new green spaces, impervious and reflective surfaces, wind corridors and shading devices. These guidelines are aimed at providing more comfortable and sustainable outdoor spaces adapted to the climatic context in northern Algeria. It reflects a replicable model for developing health-promoting and socially connected sustainable campuses.
Keywords: *Outdoor thermal comfort ;Climate-responsive design ;Vegetative cover; Passive design strategies ;Shading Strategies*

INTRODUCTION

Outdoor thermal comfort is an important consideration in the use and experience of open spaces, especially in settings where prolonged outdoor activities are prevalent; with people clearly voicing preferences to support your survey. It is described as the condition of physical and emotional pleasure with the environment, which is generated by variables like air temperature, humidity, wind and solar radiation. Thermal comfort is even more important, for example in educational settings, where external spaces often act as extensions of learning environments. These open spaces provide areas for informal learning, socializing and relaxing, thus become an essential part of the academic experience. On the other hand, even in regions with high temperatures and aridity, transformating the external environment to create thermal comfort is a difficult challenge because despite the harsh weather conditions these spaces are under direct sunlight for a long period of time.

Good design of climate-responsive outdoor spaces in educational institutions contributes to the physical and mental well-being of students and staff. At the same time, by not working find it is meant that spaces not perform properly due to the inadequate appropriation of climate conditions; hence, they remain unused or avoided and do not promote dynamic and diverse activities for which they had been designed. Within this scenario, it is required to find strategies that allow spaces outdoors to become more comfortable. Design strategies like this not only enhance the experience of a user but also help the spaces continue to be high use even in cold months, maintaining them as successful nodes of social interaction and activity.

The thermally comfortable outdoor space strategies should improve in thermal comfort with respect to climate but also take into account the natural and artificial elements, which complement the area function and design. Natural elements like plant material (trees, shrubs, groundcover) are highly effective in reducing heat by shading and even blocking direct solar exposure while further increasing evaporative cooling effects through transpiration. The choice of such plants as well the manner they are placed in

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various geometric patterns constitute an important aspect that contributes towards achieving a lighting-shading balance. It also serves as a water body and can be used to provide features like cooling ponds, fountains, and reflecting pools to enhance the natural cooling effect and transform the environment around outdoor spaces into an ideal microclimate for outdoor comfort. These elements of nature when carefully built in add aesthetic value to the spaces¦. while we also have a comfort level inside these spaces effortlessly¦ and making it look more appealing for eye-to-settle senses so that people tend to like spending time in there doing all sorts of activities.

In addition, furniture, landscaping or engineered features such as pergolas, canopies or shade sails create a purpose and enliven the design. Furniture should be carefully selected providing comfort and inviting users into the areas, a variety of shading elements is required given that the sun can get pretty hot. The selected components must be fully aligned with the thermal strategies so that they as well can work along a design that fits the function requirements of the space.

The buildings, themselves, also greatly affect the demand of outdoor thermal comfort. Sunshades, overhangs and projecting walls effectively block sun radiation, resulting in reduced cooling demand. Green facades or green roofs and water features on the buildings surrounding outdoor spaces help to mitigate heat island effect, and they provide immediately shading / cooling effects for the adjacent areas. It can work to reduce direct solar gain on building surfaces during those hot summer days, by planting climbing plants over walls, or through the use of modular plant systems. When it comes to temperature regulation, green roofs help in absorbing and dissipating heat areal-wise, thus bring an immediate effect of thermal comfort to open public spaces around them.

This article discusses the case of the open spaces of the Institute of Architecture and Urbanism (IAU) at Blida 1, Algeria from a geographical space between heat dry summers and mild winters in Mediterranean climate. These open spaces where students and teachers can be found often doing academic discussions, relaxing or participating in recreational activity. Nevertheless, many of these spaces are poorly-insulated and fail to provide appropriate thermal comfort levels during hot months, rendering them inefficient and uncomfortable for their inhabitants. We must take a more scientific approach rooted in the data, diagnosing our problems and proposing specific remedies to address them.

1. Study Area

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. Figure1(a). 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. Based on the beach/pool score, the best period for hot-weather activities in Blida extends from late June to early September. 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. Figure1(b). 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. These features make the site particularly suitable for testing various strategies to enhance outdoor thermal comfort.

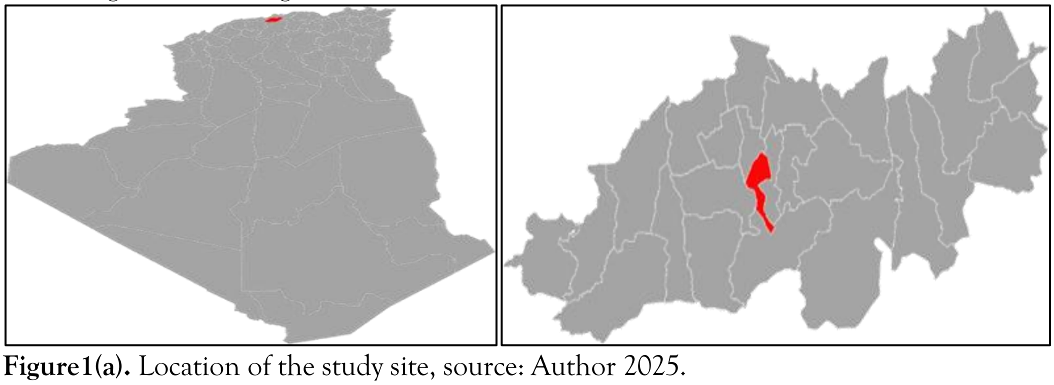

Figure1(a). Location of the study site, source: Author 2025.

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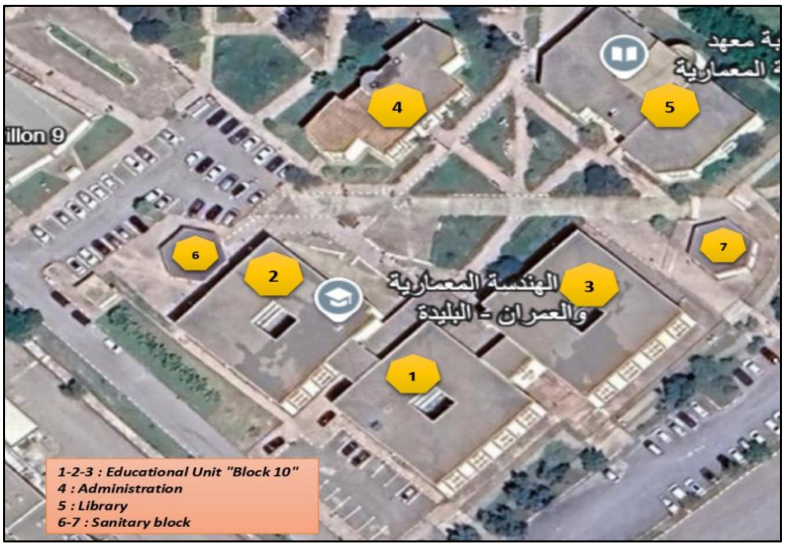
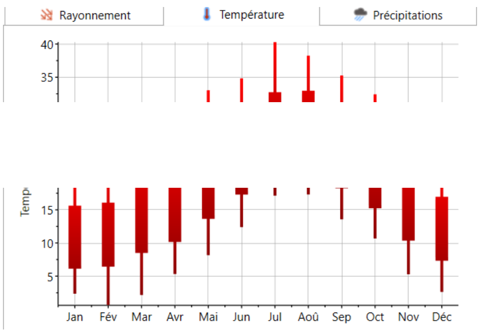
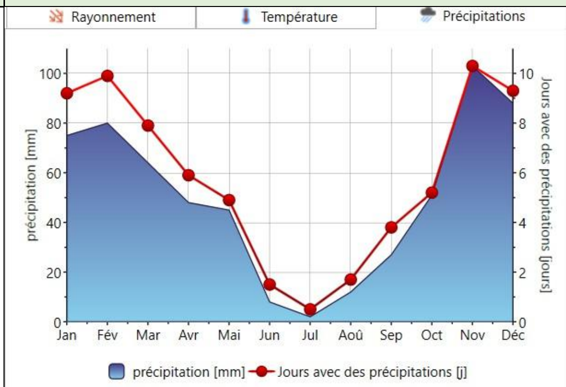


Figure1(b): Study Area source: google earth, edit bu author 2025.

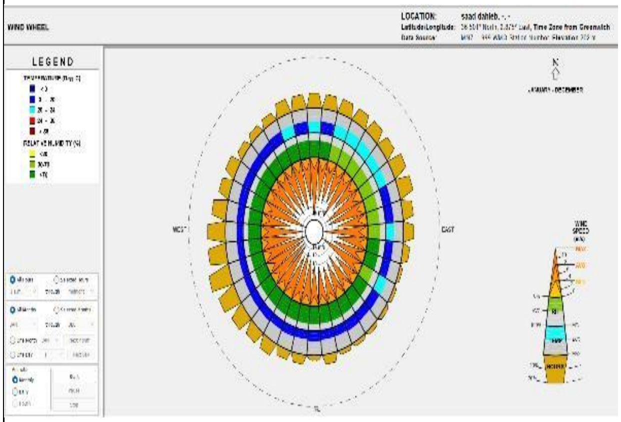
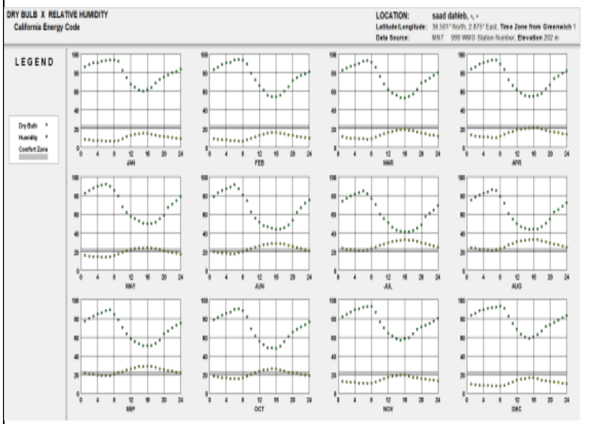
2.1Microclimate Analysis and Visualization

2.1.1. Climate Diagrams: Temperature, humidity, and wind rose diagrams.

Table 1. climate analysis, source : author 2025.

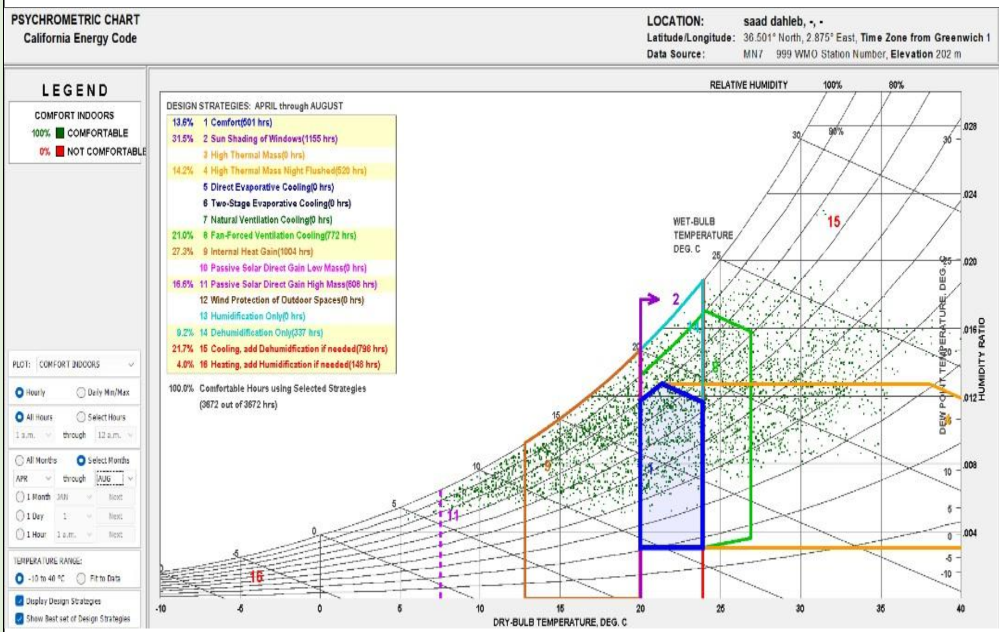
Monthly temperature	Precipitation
 *Figure 2 temperature of the study area. Source: meteonorm*	 *Figure 3 Precipitation in the study area. Source: meteonorm*
The temperature varies between 16°C and 40°C in summer, and between 0°C and 22°C in winter.	The average rainfall is about nine months a year. The amount of precipitation in winter ranges from a maximum of 110 mm in November to a minimum of 95 mm in January, in summer it ranges from 5 mm in July to 40 mm in September.

Wind speed	Humidity

 *Figure 4 wind speed of the study area. Source: climate consultant*	 *Figure 5 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 a relative humidity that varies between 30% and 70%.	Humidity varies between 50% and 95% in the winter month, and between 40% and 90% in the summer month.

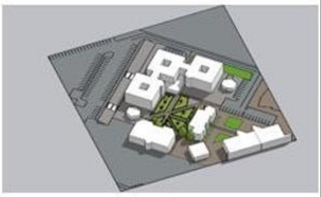
2.1.2. Climate Diagrams: Energy analysis

Table 2. energy analysis, source: author 2025

GIVONI diagram of the summer period	During the summer season, passive methods offer 60% comfort, while active methods offer 40% comfort, thanks in particular to an air conditioning system.
	 *Figure 6 GIVONI diagram of the summer period of the study area. Climat consultant source*
	Taking into account the annual needs in percentage and comfort hours, we observe that passive techniques only provide 60% of 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 representative heating system.

2.1.3. Sun Path and Shadow Analysis: Seasonal variations in shading and solar exposure.

Table 3. sun path and shadow analysis, source: author 2025

Time	Daily shadow path	
10 :00		
12 :00		
14 :00		
16 :00		

2. METHODS

I declare that I have used artificial intelligence -chatgpt- to improve linguistic formulation and to analyze Excel spreadsheets.

In this study, we focus on enhancing thermal comfort in the outdoor space of the Institute of Architecture and Urbanism of University of Blida 1 by adopting a microclimate-based approach. This methodology involves two key steps: first, conducting a comprehensive microclimate analysis of the site to identify existing thermal conditions and challenges; and second, performing microclimate simulations of various scenarios to explore and evaluate effective strategies for optimizing thermal comfort. The diagram below illustrates the methodological framework of our study, providing a visual representation of the steps and processes involved in achieving our objectives. Figure 7.

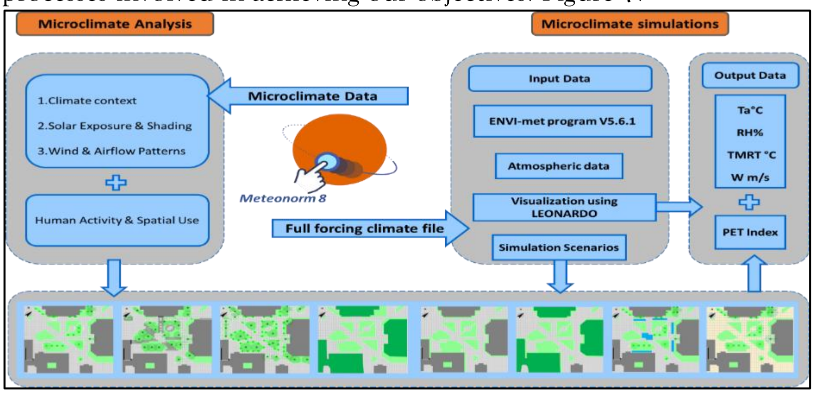


Figure 7: Methodology Diagram.

3.1. Thermal Comfort Surveys

3.1.1. 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 May to July.
- **Distribution Method**: Online forms.
- **Response Rate**: 46.

3.1.2. Structure Questionnaire

This questionnaire was created with both qualitative and quantitative questions specifically for collecting thermal comfort variables. The first part inquired the demographic characteristics and the use of outdoor space frequency to get an understanding from diverse participants. The second part of the survey explored awareness about ohct, and measured perceived outdoor thermal comfortability, testing if there were variations in comfort level by seasons, and also which factors are interested to be considered substantially (ie: sun exposure, wind speeds, vegetation etc.) The third part of the study investigated the determinants of thermal comfort, how air temperature, humidity, wind, clothing and body activity affect human response in an attempt to relate subjective sensations with objective microclimatic data. Into the fourth section, it also collected how they wanted to improved which were more green spaces, shadows and water animating in order to give micro-climatic simulations.

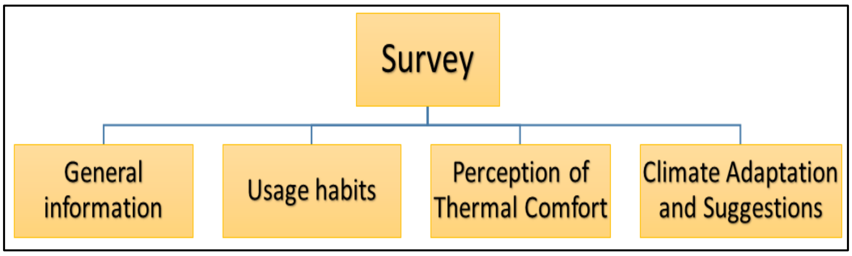


Figure 8. Diagram of the questionnaire structure, source: author 2025.

3.1.3. Questionnaire Results

Those answers gave the study some interesting data points.

Results of the survey show that there is a big gap between urban environment and people comfortable in terms of thermal conditions. More than 70% of participants reported that the outdoor temperatures were as "Hot" or "Very Hot,"and as a result they went to sit in shaded area or locations with fansurrets. This is reflected in the comfort ratings, as many are uncomfortable (49% rated "Uncomfortable") .

The most important and by far the most popular solution, which was chosen by more than half of those who took part (53.6%), is to have additional trees/ planting in conjunction with shade structures. This finding underscores that Nature-based Solutions are not merely aesthetic enhancements but are essential, practical interventions to address thermal stress in warm climates and directly meet the needs of the community for improved urban living.

Category	Finding
Perceived Temperature	42.03% 'Hot'
Thermal Comfort Rating	49.28% 'Uncomfortable'
Adaptation to Local Climate	42.03% 'Not at all suitable'
Most Desired Solution	53.6% 'More vegetation (trees, green pergolas)'

3.2. Microclimate Analysis

Blida the region enjoys a Mediterranean climate with hot, dry summers and mild to moderately wet winters. Between November and March, water samples are evaporated resulting in around 791 mm/year of the average concentration. Summer highs can be 31–32°C and winter lows of 5° to 7°C.

Winter relative humidity is 76% while summer is 56%, and prevailing wind bears northerly and northwestern in nature ; specifically in summers favouring natural ventilation. The sunshine duration is very important (more than 10h/day in summer) : therefore it is advised that shaded areas and reflective elements are inclusive in the design to guarantee thermal comfort.

Designs focus in winter on passive solar radiation and extreme humidity ; outdoor spaces are oriented so as to capture winter sunshine to optimise infiltering of natural warmth.

3.2. Microclimate Simulation

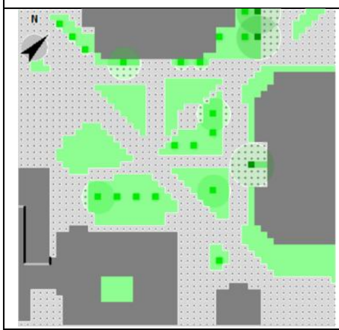
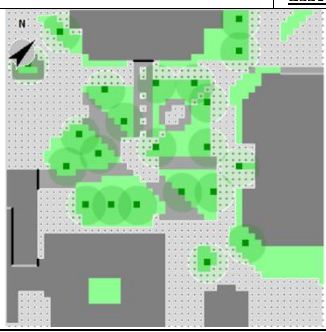
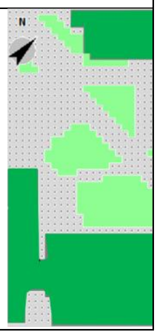
3.2.1. Simulation Protocol

The microclimate simulation was conducted using a licensed version of the ENVI-met software V5.6.1, a robust microclimate model widely recognized for its ability to simulate urban microclimates. The simulation was performed for a typical day, May 13, 2025, identified as the most suitable based on microclimate variations and peak outdoor space usage by students. Climate data for the simulation were derived from Metronom-generated files, ensuring accuracy through the use of a full forcing climate file. We simulated eight different scenarios of the institute's outdoor space under various conditions, including the baseline (existing environment), and strategies such as adding shading elements, integrating vegetation and green spaces, implementing green roofs and green walls (individually and combined), introducing water features, and modifying materials and surfaces with cool and permeable alternatives. Key output parameters included air temperature (Ta°C), relative humidity (RH%), mean radiant temperature (T_{MRT} °C), and wind patterns (W m/s), providing comprehensive insights into the microclimate dynamics. Thermal comfort was evaluated using the index PET (Physiological Equivalent Temperature), offering a detailed assessment of the thermal comfort levels under each scenario.

3.2.2. Modelled Scenarios

As aforementioned, the microclimate simulation involved evaluating eight scenarios to optimize thermal comfort in the institute's outdoor spaces. Scenario 1 established a baseline by assessing current thermal conditions without modifications. Scenario 2 introduced shading strategies, such as pergolas, shade sails, and strategically planted trees, to reduce solar exposure. Scenario 3 focused on integrating vegetation and green spaces, incorporating a mix of tall trees, shrubs, and ground cover to enhance cooling and aesthetics. Scenario 4 simulated the thermal benefits of green roofs on the buildings, testing both extensive and intensive vegetated options. Scenario 5 examined the cooling effect of vertical green walls on sun-exposed building facades, while Scenario 6 combined green roofs and walls for maximum impact. Scenario 7 explored the cooling potential of water features, such as ponds and fountains, strategically placed in high-traffic areas. Finally, Scenario 8 assessed the impact of replacing hardscapes with sustainable materials, including cool pavements and permeable surfaces. The simulations considered key parameters such as air temperature, relative humidity, wind patterns, and solar radiation, providing a comprehensive analysis of each scenario. Table 4 illustrates the different scenarios modelled in the study.

Table 4: Simulation Details, including Modelled Scenarios. *ENVI_met V5.6.1*

<table>
<tr><td colspan="4">Simulation Details</td></tr>
<tr><td></td><td colspan="3">Model: ENVI_met Microclimate
Location: Institute of Architecture and Urbanism, Blida city
Climate: Mediterranean climate
Date: MAY 13, 2025
Time: 8 a.m. to 5 p.m. Inputs: Full forcing climate file, Meteonorm 8
Scenarios: Eight different scenarios (Figure 9)
Outputs
▪ Microclimate Parameters: Ta (°C), RH (%), T_{MRT} (°C) and W (m/s)
▪ Thermal comfort Index: PET (°C)</td></tr>
<tr><td colspan="4">Modelled Scenarios</td></tr>
<tr><td>(1) <u>Baseline Condition</u></td><td>(2) <u>Shading Strategy</u></td><td>(3) <u>Vegetation Integration</u></td><td>(4) <u>Green Roof</u></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
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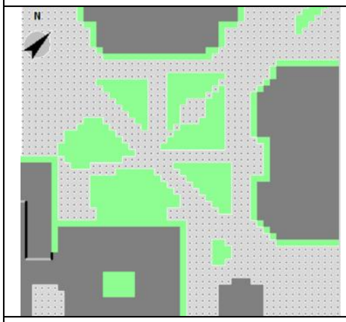
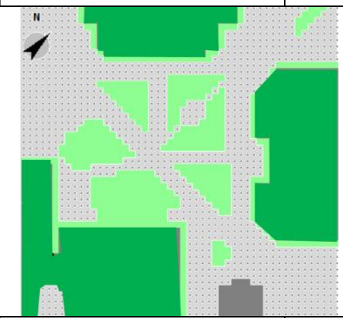
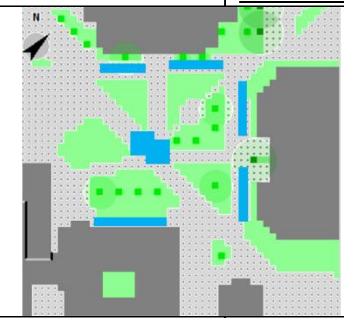
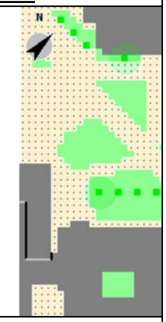
Soil Asphalt road [ST] Pavement light [PL] **Buildings** Concrete walls [C1] [C2] Moderate insulation [MI] **Vegetation**	**Soil** Asphalt road [ST] Pavement light [PL] **Buildings** Concrete walls [C1] [C2] Moderate insulation [MI] **Vegetation**	**Soil** Asphalt road [ST] Pavement light [PL] **Buildings** Concrete walls [C1] [C2] Moderate insulation [MI] **Vegetation**	**Soil** Asphalt road [ST] Pavement light [PL] **Buildings** Concrete walls [C1] [C2] Moderate insulation [MI] **Vegetation**
(5) Vertical Green Walls	**(6) Green Envelope**	**(7) Water Features**	**(8) Surface Alternatives**
			
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3. RESULTS AND ANALYSIS

3.1. Baseline Microclimate Conditions

Here is a comprehensive, targeted analysis of wind directions, sun paths, and shadows within the Institute of Architecture and Urban Planning at Saad Dahleb University – Blida 1:

1. Wind Direction Analysis (Wind Rose)

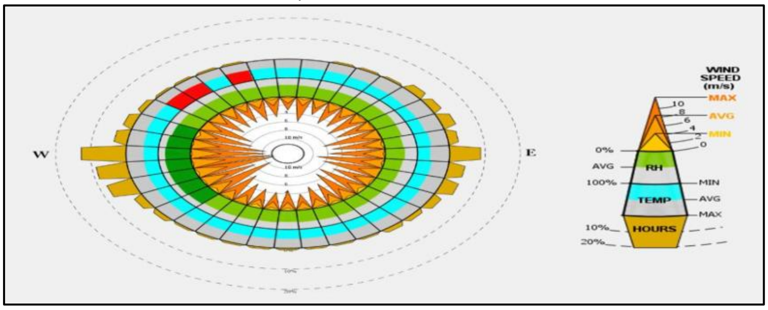

Figure 10. GIVONI diagram of the summer period of the study area. Climat consultant source.

Climatic data indicates that the prevailing winds in Blida come mainly from:

- North and northwest during the winter, with an average speed of around 10–12 km/h Reddit+2whatstheweather.net+2Reddit+2.
- North and northeast during the summer, with speeds occasionally increasing to around 15–20 km/h during gusts whatstheweather. net Reddit.

Throughout the year, the average annual wind speed is around 9–11 km/h weather2visit.comWeather Atlas.

The attached wind rose (image) shows the most common directions, helping to identify where to direct open passageways, windows, and areas that could benefit from natural ventilation.

2. Sun Path and Shadow Analysis

According to the geographic location data (latitude ~36.53° N), the sun moves:

- In the summer at a northward angle (high altitude),
- In the winter at a southward angle (low shadow distribution)

Summer shading is preferred on:

- The southern and western facades of buildings, as they are more exposed to the scorching sun in the afternoon and summer.
- In the winter, the shade is longer (the sun is low) and lasts longer on the northern and eastern sides of buildings during the morning.

3.2. Microclimate Alterations Across Scenarios

1.The evolution of the local climate in the Ouled Yaïch region, located in the Blida province, reflects a dynamic of climate change that is evident both in the short and long term. These variations are manifested in a gradual increase in annual average temperatures, a rise in the frequency of summer heatwaves, and a shift in the rainfall regime.

2.Regional climate scenarios, such as those proposed by the IPCC, suggest that in the near future (by 2050), the region may experience an average temperature increase ranging from +1.5 °C to +2.5 °C, depending on the RCP4.5 and RCP8.5 models. This will directly impact thermal comfort, particularly during summer periods, when maximum temperatures may consistently exceed 40 °C.

3.Simultaneously, the decrease in precipitation, combined with the intensification of dry spells, will exacerbate the effects of the urban heat island, especially in poorly shaded or paved outdoor spaces. Moreover, the observed decline in average wind speed in recent years reduces the effectiveness of natural ventilation—a crucial element for thermal comfort in urban settings.

4.These developments call for the adaptation of planning and architectural design strategies, particularly through the use of high thermal inertia materials, the integration of vegetation, and the promotion of passive cooling solutions.

The two tables show the local climatic data for the site.

Table 5 : Climat annuel moyen (1991–2021) for Ouled Yaïch – Blida by 2050.

Mois	**Temp. Moyenne (°C)**	**Max (°C)**	**Min (°C)**	**Précipitations (mm)**	**Humidité (%)**	**Jours de pluie**	**Heures de soleil/jour**
Janvier	9.5	13.8	5.9	85	76	8	6.6
Février	9.8	14.2	5.9	71	74	7	7.3
Mars	12.4	17.0	8.1	73	72	7	8.4
Avril	14.8	19.6	10.1	72	71	7	9.7
Mai	18.1	22.9	13.0	60	69	5	10.9
Juin	22.4	27.7	16.8	12	61	2	12.4
Juillet	25.8	31.4	20.0	3	56	0	12.5
Août	26.0	31.7	20.7	11	57	2	11.6
Septembre	22.7	28.0	18.0	35	64	4	10.2
Octobre	19.3	24.4	14.9	58	67	6	8.9
Novembre	13.7	17.9	10.2	83	73	9	7.1
Décembre	10.7	14.8	7.4	78	76	8	6.6

Table 6: Regional Climate Projections for Ouled Yaïch – Blida by 2050.

Climate Parameter	**Current Values (2020)**	**RCP4.5 Scenario (2050)**	**RCP8.5 Scenario (2050)**
Annual Average Temperature (°C)	18.5 °C	20.2 – 21.0 °C	21.5 – 22.3 °C
Maximum Summer Temperature (°C)	38 – 40 °C	40 – 43 °C	43 – 45 °C
Annual Precipitation (mm)	600 – 700 mm	500 – 580 mm	430 – 500 mm
Number of Days >35 °C / year	15 – 20 days	30 – 45 days	50 – 65 days
Average Wind Speed (m/s)	3.0 m/s	2.7 – 2.9 m/s	2.3 – 2.6 m/s
Average Relative Humidity (%)	60 – 65 %	55 – 60 %	50 – 55 %

Source of Data: Synthesis of regional climate models (IPCC, MED-CORDEX, Blida Local Meteorological Data – 2020)

3.3. Thermal Comfort Levels

This study assesses the performance of different microclimate intervention scenarios within May to July season in the region of Institute of Architecture and Urbanism - Blida, Based on four commonly used thermal comfort indices as; Physiological Equivalent Temperature (PET), Predicted Mean Vote (PMV), Universal Thermal Climate Index (UTCI) And Standard Effective Temperature SET* journals

1. Physiological Equivalent Temperature (PET)

The **PET index** measures human thermal comfort by combining air temperature, humidity, wind, and radiation.

- **Scenario 3 (Vegetation Integration)** showed the most significant PET reduction, dropping it below 40°C, providing meaningful thermal relief compared to the baseline (Scenario 1).
- **Scenarios 2 (Shading)** and **6 (Green Roofs + Green Walls)** also demonstrated improved conditions. These interventions are effective as they reduce both air temperature and mean radiant temperature.

Values from the Table :

- **Scenario 1 (Baseline) :** 45.0 °C
- **Scenario 2 (Shading) :** 41.8 °C
- **Scenario 3 (Vegetation Integration) :** 40.2 °C
- **Scenario 6 (Green Roofs + Green Walls):** 43.6 °C

2. Predicted Mean Vote (PMV)

The **PMV index** expresses thermal sensation on a scale from cold (−3) to hot (+3).

- **Scenario 3 (Vegetation)** demonstrated the most favorable PMV shift, indicating a move toward thermal neutrality.
- While other scenarios (such as 2, 4, 5, and 6) also slightly reduced PMV, their impact was less pronounced. Vegetation not only moderates temperature but also enhances relative humidity, contributing to this balance.

Values from the Table :

- **Scenario 1 (Baseline) :** 3.3
- **Scenario 2 (Shading) :** 2.9
- **Scenario 3 (Vegetation Integration) :** 2.4
- **Scenario 4 :** 3.0
- **Scenario 5 :** 3.0
- **Scenario 6 (Green Roofs + Green Walls):** 3.0

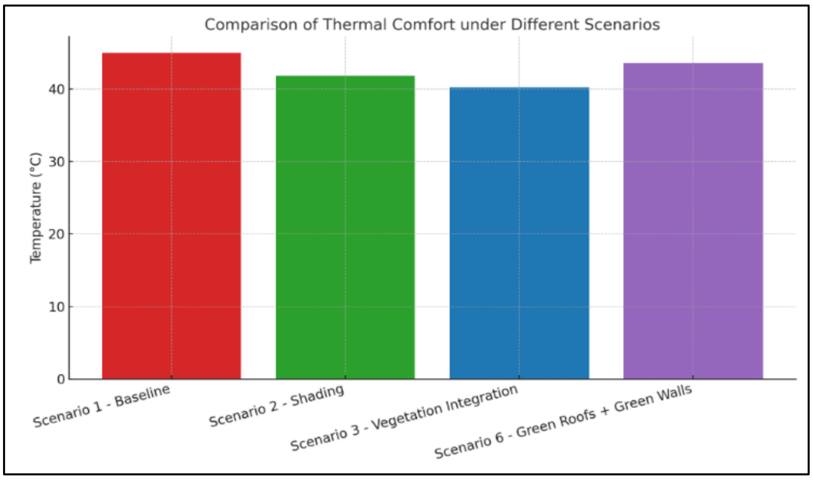

Figure 12. Physiological Equivalent Temperature (PET).

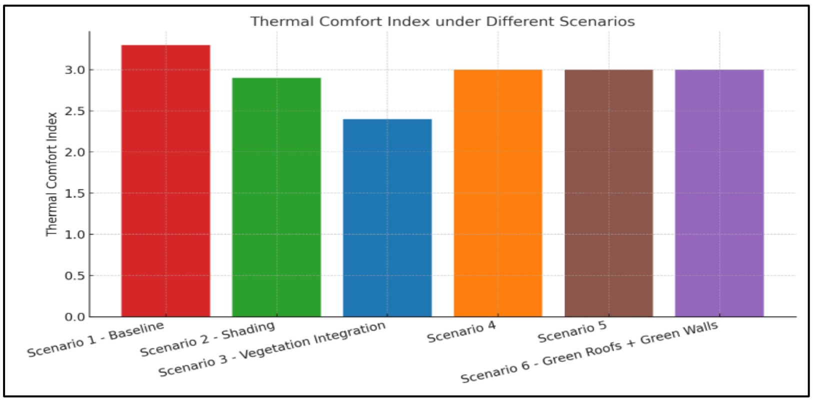

Figure 13. Predicted Mean Vote (PMV).

3. Universal Thermal Climate Index (UTCI)

UTCI provides a comprehensive outdoor comfort measure based on a dynamic physiological model.

- **Scenario 3 (Vegetation)** again achieved the best reduction in UTCI values, indicating substantial thermal relief.
- **Scenario 2 (Shading)** followed closely. These findings align with their impact on other physical parameters like air temperature, humidity, and radiation, confirming their suitability for warm climates.

Values from the Table :

- **Scenario 1 (Baseline) :** 36.6 °C
- **Scenario 2 (Shading) :** 34.0 °C
- **Scenario 3 (Vegetation Integration) :** 33.6 °C

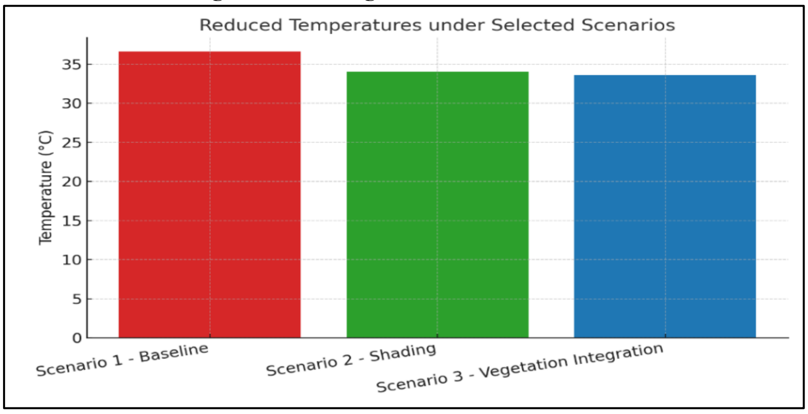

Figure 14. Universal Thermal Climate Index (UTCI).

4. Standard Effective Temperature (SET*)

SET* reflects perceived temperature based on thermoregulation and heat exchange.

- **Scenario 3 (Vegetation)** once again yielded the greatest decrease in SET*, followed by **Scenario 2** and **Scenario 6**. The combined effects of shading, evaporative cooling, and improved airflow explain the strong performance of these scenarios in perceived comfort.

Values from the Table :

- **Scenario 1 (Baseline) :** 37.1 °C
- **Scenario 2 (Shading) :** 35.8 °C
- **Scenario 3 (Vegetation Integration) :** 34.4 °C
- **Scenario 6 (Green Roofs + Green Walls) :** 36.0 °C

Overall, **Scenario 3 (Vegetation Integration)** consistently demonstrates the most effective performance in improving thermal comfort levels across all four indices, making it a promising intervention for mitigating heat stress in warm climates. Scenarios incorporating **shading (Scenario 2)** and a combination of **green roofs and green walls (Scenario 6)** also showed significant improvements.

4. DISCUSSION

4.1. Strategies to Optimize Thermal Comfort

Almost always, the valuation of solutions is made based on the economic costs. We are not looking to do studies that cannot be implemented and put into practice, either because there is not enough money or because of reality on the ground. We are not trying to enshrine this in a scientific paper, so could care less about metrics such as these ; hence we based our choice on the level of response from the authorities to the proposed solutions. We then provision our Summary as so :

In Blida the dry and hot climate is severe and provide extreme thermal conditions, therefore it is essential to develop suitable architectural and landscaping strategies to ensure thermal comfort in outdoor campus spaces. The best solutions are those of increasing the amount of shaded spaces with lightweight structures (Figure 15: yellow space highlights where shaded areas can be created) or planting dense trees to reduce the direct solar radiation and aero-thermal temperature.

It ensures the natural ventilation by proper building orientation in designing open spaces to allow air movement past them and this makes it dissipates the heat from you. And last but not least : Using low-entropy materials for flooring and street furniture, complementing it with permeable and cooling surfaces (like lawns or filtered paving stones), can lead to a decrease in the perceived temperature as well.

In addition, the circles (shallow pools and fountains) can be seen as redesign options to implement these solutions in a longer term vision gutting these concepts on roofs of buildings, notably the main building from teaching wing 10 and also in Library Building (Figure 16), with beneficial function for evaporative cold. And lastly, smart planning that considers shaded pedestrian paths, solar orientation and occupancy schedules so the design can respond to real user usage. The overall effect of these strategies combined provides sustainable thermal comfort and quality of life, hard to get by in educational environments in hot climates.

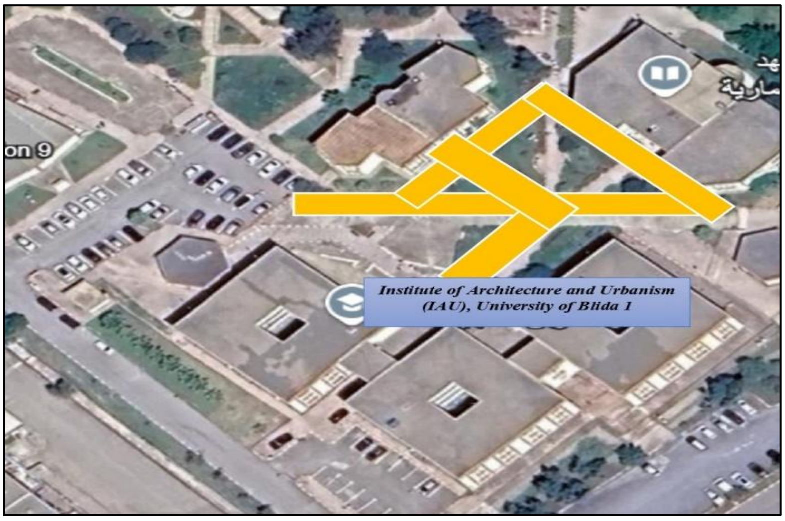

Figure 15: Suggested places for shading.

Figure 16: Suggested locations for fountains.

The following improvements can help you resort the focus on

- Rehabilitating Vegetation
- Improves biodiversity : Planting native shade trees (e.g. Fiscus, Jacaranda, or Cypress) will attract a diverse range of animals and birds into your backyard.

- These are the miniature gardens that help in air-conditioning by evaporation and that provide nice view.
- Lighter, longer-lasting canopy solutions made of treated wood or perforated aluminum.
- Aligning these structures to the path of sun to ensure a proper shading during peak hours.
- Using Surface Cooling Materials
- Replacing current tiles with high-reflectivity (albedo) materials such as reflective coatings or cool flooring.
- Incorporating permeable materials that encourage water to evaporate and Quench Reflected Heat Radiation
- Improving Air Flow
- Vents in perimeter walls (or partial open design)
- The way you plant trees in such a manner to channel wind & and flow of air it naturally pass.
- Evaporative Cooling Solutions
- Incorporating small solar-powered water fountains.
- Positioning seating near evaporative cooling plant beds.

4.2. Simulation Results

5.2.1. Air Temperature (Ta °C) – Reduction of Ambient Heat

The implementation of various design strategies led to measurable improvements in air temperature across the courtyard. Compared to the baseline condition, all scenarios contributed to temperature mitigation, with the most significant reduction observed in Scenario 2 (Shading Strategy) which decreased the average air temperature by nearly 0.9°C. Scenario 3 (Vegetation Integration) also performed notably well due to its evaporative cooling effect. These strategies proved most effective in minimizing heat buildup and promoting a more thermally comfortable environment.

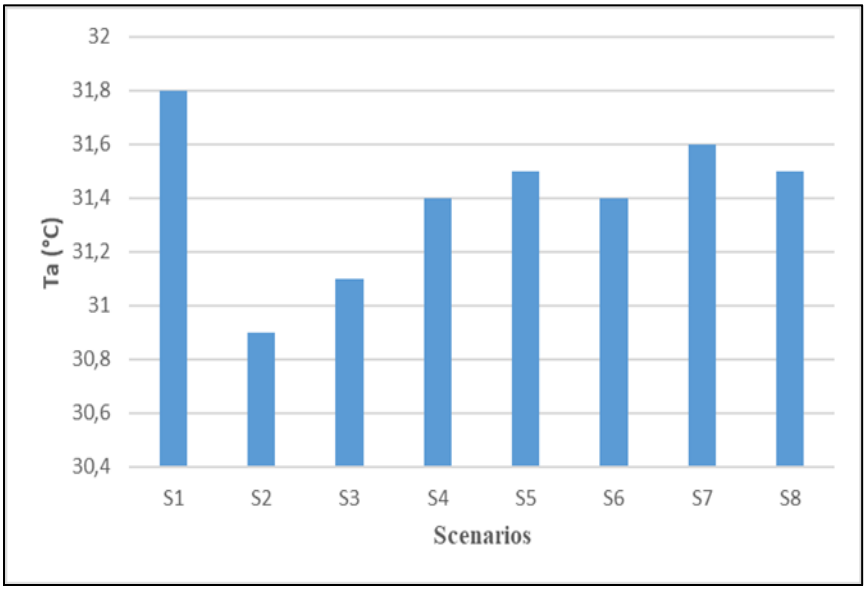

Figure 17. Diagramme Air Temperature (Ta °C) – Reduction of Ambient Heat.

5.2.2. Relative Humidity (RH %) – Enhancing Air Moisture Content

The addition of vegetation and water features notably improved relative humidity levels across the courtyard. Scenario 3 (Vegetation Integration) achieved the highest increase in RH, reflecting the role of plants in enhancing atmospheric moisture through evapotranspiration. Scenario 6 (Combined Green Roofs and Walls) and Scenario 7 (Water Features) also contributed significantly, supporting a more humid and comfortable microclimate in a hot-dry context.

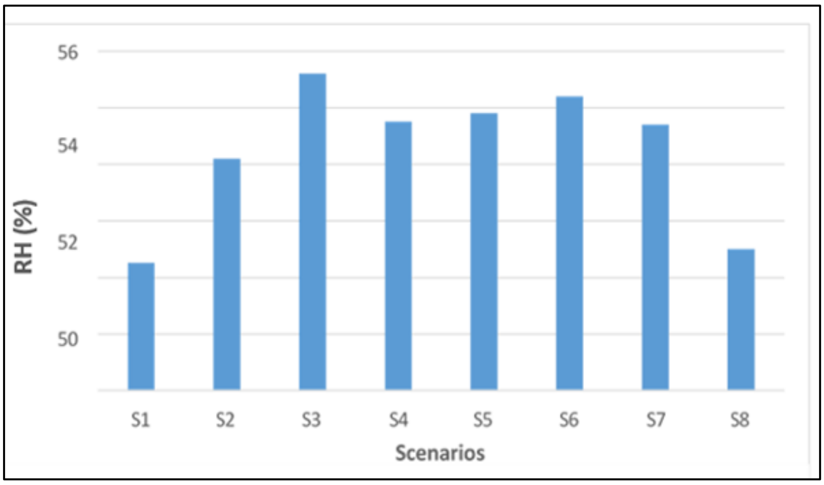

Figure 18. Diagramme Relative Humidity (RH %) – Enhancing Air Moisture Content.

5.2.3. Mean Radiant Temperature (Tmrt °C) – Reducing Radiative Heat Stress

All proposed interventions contributed to lowering mean radiant temperatures when compared to the baseline, indicating enhanced shading and surface cooling. Scenario 3 (Vegetation Integration) demonstrated the greatest reduction in Tmrt, attributed to tree canopy shading and cooler surface temperatures beneath vegetation. Scenario 2 (Shading Strategy) also showed strong performance, confirming the efficiency of artificial shading in blocking solar radiation.

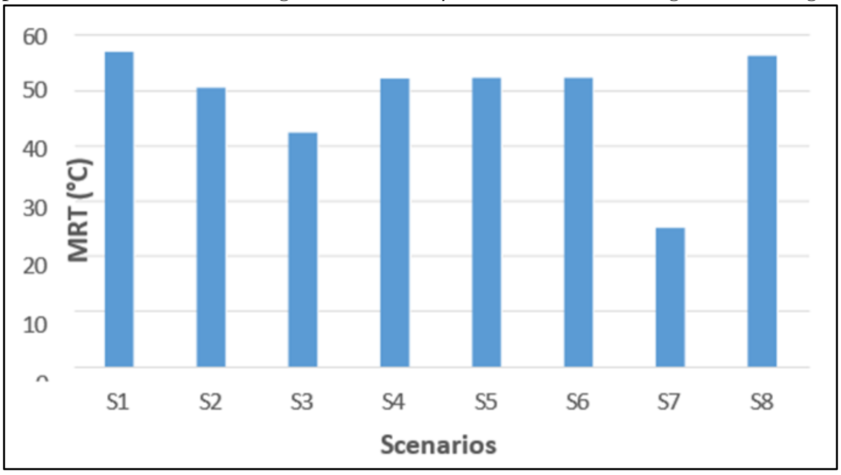

Figure 19. Diagramme Mean Radiant Temperature (Tmrt °C) – Reducing Radiative Heat Stress.

5.2.4. Wind Speed (W m/s) – Preserving Air Circulation

Wind flow was moderately impacted by the introduction of physical elements. While dense vegetation and shading slightly reduced wind speed, green infrastructure scenarios such as Scenario 4 (Green Roof), Scenario 5 (Green Walls), and Scenario 6 (Combined Green Roofs and Walls) maintained balanced airflow while still improving thermal conditions.

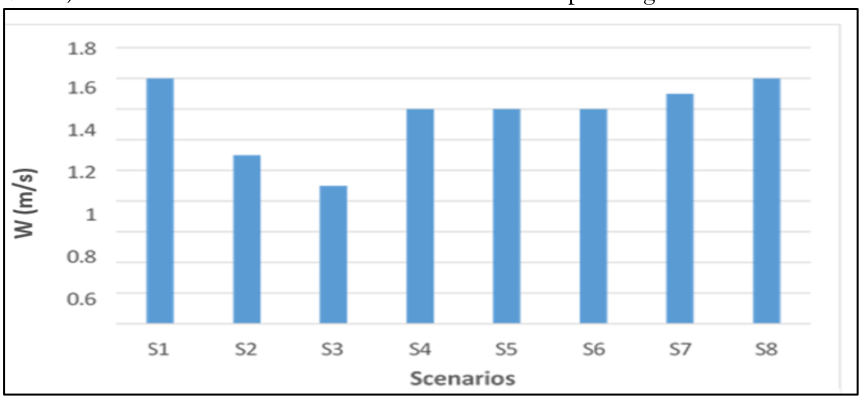

Figure 20. Diagramme Wind Speed (W m/s) – Preserving Air Circulation.

4.3. Limitations and Future Perspectives

- Even with the considerable amount of information gathered and analyzed, this study has certaine limitation. Firstly, the collection of local climate data was confined to a specific timeframe, and thus, may not capture all seasonal variations. In addition, the survey sample of 46 individuals, though relevant, is small.
- In addition, the study was limited to a specific geographic region (Ouled Aich district, Blida), which may restrict the applicability and generalizability of the findings to other urban or rural regions with differing characteristics.
- In the future, it would be useful to conduct the analysis over a full year and include additional environmental factors such as relative humidity, direct solar radiation, and urban heat island effects. Also, a larger sample size would be more beneficial, incorporating numerical simulations (CFD, thermal modeling), to more accurately assess the impact of urban design on outdoor thermal comfort.
- Ultimately, local climate adaptation strategies would be enhanced with the interdisciplinary input of climatologists, urban designers, and energy specialists, making the recommendations more robust and effective.

The findings of this study can be utilized in future research in outdoor thermal comfort in educational environments in a few manners.

To begin with, researchers now have the opportunity to broaden the seasonal and temporal scope of simulations.

5. CONCLUSION

A thermos-study demonstrates that the users of outdoor space are insensitive to variation of humidity, as they are used to low relative humidity (RH= 25-35%) during summer months where high ambient temperature is experienced at The School Architecture Institute in University Blida1 which locates in a hot-dry summer time climate.

Sunburn, on the other hand, posed great discomfort to users although field measurements and studies were done in relatively shaded sites. The balanced camp measurements of 1.1 and 1.6 m/s velocity winds are low even though the observed wind speeds are more frequent than the relief-oriented dwell type, they were not enough to adequately enhance natural ventilation in outdoor spaces.

So it is highly recommended redesigning the open spaces with more of natural (as vegetation), and artificial (as canopies) shading, along with can also ensure that effective ventilation strategies like airways and urban orientation are inlaced within the design to enhance thermal comfort level in open spaces.

Field measurements revealed that the PET (Physiologically Equivalent Temperature) for sunny spaces at noon was higher than 42°C, while that of neutral comfort temperature was determined to be around 29.5°C which indicates a large gap on heat burden felt by users.

The analysis showed that PET was suitable for modeling and expectation value for outdoor spaces design in this climate, i.e., every 3.5°C that occurred in the PET changes one unit in the thermal sensation.

Using the findings from this study, factors like the PET can be used to inform design decisions regarding campus outdoor spaces and work towards improving quality of life in an educational environment as well as student/teacher heat stress reduction.

Based on these findings, the study suggests that the concept of climatic comfort be adopted as a basic criterion in the design and rehabilitation of Algerian university open spaces and encourages sustainable local climate-based solutions.

REFERENCES

1. Givoni, B. (1998). *Climate Considerations in Building and Urban Design*. Wiley.
2. Olgyay, V. (1963). *Design with Climate*. Princeton University Press.
3. Santamouris, M. (2001). *Energy and Climate in the Urban Built Environment*. Earthscan.
4. ISO 7730: Ergonomics of the Thermal Environment.
5. نتائج استبيان ميداني، يوليو 2025، معهد الهندسة المعمارية – جامعة البليدة 1.
6. Anber, M. F. A., & Abdelsalam, O. F. (2022). *A study of the thermal comfort perception on campus outdoor urban spaces: Special reference to hot arid climatic zones*. The Higher Institute of Engineering – Elshorouk City.
7. Ahriz, A. (2018). *Outdoor thermal comfort: Concepts and theories* (1st ed.). London : e-Kutub Ltd. ISBN : 978-1388138301.
8. IPCC, 2021. Climate Change 2021 : The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge : Cambridge University Press. Available at: https://www.ipcc.ch/report/ar6/wg1/ [Accessed 13 Jun. 2025].
9. Oke, 1987. Boundary Layer Climates. 2nd ed. London : Routledge.

10. World Health Organization (WHO), 2021. WHO Guidance for Climate-Resilient and Environmentally Sustainable Health Care Facilities. Geneva : World Health Organization. Available at: https://www.who.int/publications/i/item/9789240036727 [Accessed 13 Jun. 2025].
11. Kabisch et al., 2015. Human–Environment Interactions in Urban Green Spaces : A systematic review of contemporary issues and prospects for future research. Environmental Impact Assessment Review, 50, pp.25–34. https://doi.org/10.1016/j.eiar.2014.08.007
12. International Energy Agency (IEA), 2022. The Future of Cooling : Opportunities for energy-efficient air conditioning. Paris : IEA. Available at : https://www.iea.org/reports/the-future-of-cooling [Accessed 13 Jun. 2025].
13. IUCN, 2020. Nature-based Solutions and Climate Change. Gland, Switzerland : International Union for Conservation of Nature. Available at : https://portals.iucn.org/library/sites/library/files/documents/2020- 020-En.pdf [Accessed 13 Jun. 2025].
14. UN-Habitat, 2014. Planning for Climate Change : A strategic, values-based approach for urban planners. Nairobi : United Nations Human Settlements Programme (UN-Habitat). Available at : https://unhabitat.org/planning-for-climate-change-a-strategic-values-based-approach-for-urban-planners [Accessed 13 Jun. 2025].
15. Kelz, Evans & Röderer, 2015. The Restorative Effects of Redesigning the Schoolyard : A study of greenery and outdoor space in educational settings. Environment and Behavior, 47(3), pp.259–284. https://doi.org/10.1177/0013916513499580
16. OECD, 2006. Environment and School Initiatives : Education and the environment. Paris : Organisation for Economic Co-operation and Development. Available at : https://www.oecd.org/education/environment-and-school-initiatives.htm [Accessed 13 Jun. 2025].
17. Ali-Toudert & Mayer, 2007. Effects of Asymmetry, Galleries, Vegetation, and Materials on Outdoor Thermal Comfort. Solar Energy, 81(6), pp.742–754. https://doi.org/10.1016/j.solener.2006.10.007
18. Gaitani, Mihalakakou & Santamouris, 2007. On the Use of Bioclimatic Architecture Principles in Order to Improve Thermal Comfort Conditions in Outdoor Spaces. Building and Environment, 42(1), pp.317–324. https://doi.org/10.1016/j.buildenv.2005.08.018
19. ASHRAE, 2020. ANSI/ASHRAE Standard 55 : Thermal Environmental Conditions for Human Occupancy. Atlanta, GA : American Society of Heating, Refrigerating and Air-Conditioning Engineers.
20. Fanger, 1970. Thermal Comfort : Analysis and Applications in Environmental Engineering. Copenhagen : Danish Technical Press.
21. Nicol et al., 2012. Adaptive Thermal Comfort : Principles and Practice. Abingdon : Routledge.
22. De Dear and Brager, 1998. Developing an adaptive model of thermal comfort and preference. ASHRAE Transactions, 104(1a), pp.145–167.
23. Johansson et al., 2016. Outdoor thermal comfort in Nordic cities : Microclimate simulation and field measurements. Urban Climate, 17, pp.170–186. https://doi.org/10.1016/j.uclim.2016.05.002
24. ASHRAE, 2017. ASHRAE Handbook—Fundamentals. Atlanta, GA : American Society of Heating, Refrigerating and Air-Conditioning Engineers.
25. Ali-Toudert & Mayer, 2006. Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Building and Environment, 41(2), pp.94–108. https://doi.org/10.1016/j.buildenv.2005.01.013
26. Kastner-Klein & Plate, 2004. Wind tunnel study of thermal comfort in city canyons. Meteorologische Zeitschrift, 13(5), pp.379–386. https://doi.org/10.1127/0941-2948/2004/0013-0379
27. Thorsson et al., 2007. Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. International Journal of Biometeorology, 51(2), pp.169–183. https://doi.org/10.1007/s00484-006-0064-1
28. De Freitas & Grigorieva, 2015. A comprehensive catalogue and classification of human thermal climate indices. International Journal of Biometeorology, 59(1), pp.109–120. https://doi.org/10.1007/s00484-014-0823-3
29. ISO 7730, 2005. Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. Geneva : International Organization for Standardization.
30. Höppe, 1999. The physiological equivalent temperature – A universal index for the biometeorological assessment of the thermal environment. International Journal of Biometeorology, 43(2), pp.71–75. https://doi.org/10.1007/s004840050118
31. Matzarakis et al., 1999. Applications of a universal thermal index : Physiological equivalent temperature. International Journal of Biometeorology, 43(2), pp.76–84. https://doi.org/10.1007/s004840050119
32. Matzarakis, Mayer & Iziomon, 1999. Applications of a universal thermal index : Physiological equivalent temperature. International Journal of Biometeorology, 43(2), pp.76–84. https://doi.org/10.1007/s004840050119
33. Nikolopoulou & Steemers, 2003. Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy and Buildings, 35(1), pp.95–101. https://doi.org/10.1016/S0378- 7788(02)00084-1
34. Bröde et al., 2012. Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). International Journal of Biometeorology, 56(3), pp.481–494. https://doi.org/10.1007/s00484-011- 0454-1
35. Jendritzky et al., 2012. UTCI—Why another thermal index ? International Journal of Biometeorology, 56(3), pp.421–428. https://doi.org/10.1007/s00484-011-0513-7
36. Norton et al., 2015. Planning for cooler cities : A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134, pp.127–138. https://doi.org/10.1016/j.landurbplan.2014.10.018
37. Oke, 1988. Street design and urban canopy layer climate. Energy and Buildings, 11(1–3), pp.103–113. https://doi.org/10.1016/0378-7788(88)90026-6
38. Shashua-Bar et al., 2011. The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. International Journal of Climatology, 31(10), pp.1498–1506. https://doi.org/10.1002/joc.2177