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Assessing the influence of neighborhood urban form on outdoor thermal conditions in the hot dry city of Biskra, Algeria

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ABSTRACT

The quality of the thermal urban environment plays a vital role in outdoor human activities and the overall quality of life in residential neighborhoods. This study investigated the influence of two urban form variables, the height to width ratio (H/W) and sky view factor (SVF), on three outdoor thermal environmental parameters (OTEP), direct solar radiation (DSR), mean radiant temperature (MRT), and air temperature (AT) in three neighborhoods in the hot and dry city of Biskra, Algeria. The research followed a three-step process: Three neighborhoods with varying urban form variables were selected, and field measurements of thermal parameters were conducted at various locations during the hottest period of the year. Numerical modeling, simulation, and validation using Envi-met were then performed to gather the remaining outdoor thermal environmental parameters (OTEP; DSR and MRT). Statistical modeling and regression analysis were conducted to investigate the interaction between urban form variables and OTEP. The results showed that increasing the H/W ratio by 1 reduces MRT and AT by 11.79 °C and 1.49 °C, respectively, while decreasing the SVF by 0.1 reduces MRT and AT by 4.173 °C and 0.479 °C, respectively.

1. Introduction

Human activity is the primary driver of the trends in global warming over the past century [1]. Global average surface temperatures have risen by approximately 0.74 °C in the past century, with projections predicting further temperature increases ranging from 1.4 °C to 5.8 °C in the 21st century. Even if the global mean temperature only increases by 1.4 °C, this will be a larger increase than the past 1,000 years, when global temperature variability was less than 0.5 °C [2]. Urban areas tend to experience significantly higher temperatures due to the replacement of natural soil and vegetation with asphalt and concrete, resulting in the well-known phenomenon of the urban heat island (UHI). This effect is caused by surfaces absorbing solar heat during the day, causing their temperatures to rise [3]. According to an experimental study based on temperature data from rural and urban weather stations, as well as field measurements taken in Barcelona, Spain, temperature differences between urban and suburban locations are reported to be 2.8 °C in winter and 1.7 °C in summer, with temperatures reaching 4.3 °C at street level [4]. Several studies have focused on urban form as a way to mitigate the impact of outdoor environmental thermal parameters. To better understand how urban geometry affects temperature through geographical and temporal fluctuations in (MRT), Lau et al. conducted research in subtropical towns where MRT causes significant heat discomfort. The results showed that urban geometry plays a significant role in intra-urban differences in summer daytime temperatures. In addition, open spaces were found to be warmer than nearby canyons of narrow streets, as open spaces are exposed to intense solar radiation while street canyons are shielded from it by buildings that provide shade. along sunlit walls, where higher MRT is observed due to reflected short-wave radiation and long-wave radiation emitted from sunlit building walls [5]. Emmanuel et al. studied two warm-climate cities, Pettah, Colombo (Sri Lanka) and downtown Phoenix, Arizona (USA), using a micro-scale urban simulation tool to investigate the sensitivity of temperature and MRT in built-up urban cores to urban-area geometry (building density). The results showed that the best temperature levels were found in high-density development [6]. Several studies have used statistical modeling to understand the relationship between urban form factors and outdoor environmental parameters [7]. Kim et al. studied the relationship between sky view factor (SVF) and summertime land surface temperature (LST) for urbanized residential areas ranging from

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highly open to very closed in Seoul, taking external factors into consideration. The results showed that low-rise detached housing had a higher SVF and LST than high-rise multifamily housing due to the ground surface receiving more DSR. However, this relationship was reversed when the SVF was very low (less than 0.2) due to being surrounded by high-rise, high-density flat-type apartments, which resulted in increased anthropogenic heat, lower ventilation performance, decreased green spaces, and decreased longwave radiation even during the day [8] In addition, Unger developed a new approach to reveal the relationship between SVF and (Ta) in an entire city. The results showed a strong relationship between intra-urban variations of these variables, with urban surface geometry being a significant determining factor of AT distribution within a city if the selected scale is appropriate [7].

"Several studies have used Envi-met software as a tool for thermal simulation by modeling the urban environment and validating the results against thermal experiments [9–11], According to Lam et al., who conducted an investigation on 132 papers published between 2006 and 2019, Envi-met was the most commonly used software for simulating outdoor human thermal environments [12]. In addition, the Testo 480 has been used in several studies for field thermal data measurement as a mobile weather station [13–18].

The impact of urbanization on outdoor thermal environments in hot and dry climates has received significant attention in recent years, as global temperatures continue to rise. It is important to understand how the built environment affects outdoor thermal conditions in this climate and to develop strategies for mitigating the negative impacts of urbanization on human comfort [19]. Studies have shown that urban heat islands (UHIs) are common in hot and dry climates, with urban areas experiencing significantly higher temperatures than surrounding rural areas [6].

Biskra is the most populous region in the hot and dry region of Algeria, with over 700,000 inhabitants [20]. As a rapidly growing city, Biskra is facing a number of challenges related to its urban form, including the potential of the increment of the effect of urban heat island [21]. The urban fabric of its main city has a range of patterns due to historical and political changes that have influenced the urban environment [22]. Few studies have examined the relationship between urban form and thermal outdoor conditions in the city of Biskra.

Boukhabla et al. analyzed the influence of urban form on AT, taking field measurements at five different sites with diverse urban morphologies. The results showed that the urban heat island (UHI) is a widespread phenomenon in Biskra [21]. Benamour et al. conducted a field measurement investigation on three different types of streets: canyon, dihedral, and open. Mathematical calculations were applied to collected data to the relationship between urban form and heat storage of buildings. The results revealed that the sky view factor (SVF) parameter was the most important influencing parameter on heat storage [23]. Naidja et al. studied the effect of geometrical parameters of urban streets on shading requirements in a contemporary urban street in Biskra. Several theoretical urban fabrics representing an urban canyon model were simulated. The results showed that shading requirements can be reduced according to the correct orientation and H/W ratio. In addition, there is a negative correlation between street length, H/W ratio, and shading requirements [24].

Due to the lack of sufficient research using statistical models to investigate the relationship between urban form variables and outdoor thermal environmental parameters in the city of Biskra, this study aims to explore the connection between urban form variables and outdoor thermal environmental parameters in this city.

2. Materials and methods

To investigate the relationship between urban form variables and outdoor thermal environmental parameters (OTEP), this study employed a four-step research methodology. Firstly, three neighborhoods with varying urban form variables were selected. Secondly, field thermal measurements for gathering were conducted on several spots in these neighborhoods during the hottest period of the year on July 25th and 26th, 2021. AT data were collected using a Testo 480 device (as shown in Table 1). In the third step, numerical modeling and simulations of the three neighborhoods were conducted using Envi-met to analyze remaining OTEP such as DSR and MRT. Finally, statistical modeling and regression analysis were performed to identify the interaction between urban density and OTEP.

2.1. The study area

The research area is in the city of Biskra, which is situated at 34°48′ north latitude and 5°44′ east longitude in northeastern Algeria, on the northern border of the Sahara Desert. According to the Köppen-Geiger classification, Biskra city has a hot desert climate, which is characterized by extremely hot summers and moderate winters. Fig. 1 shows the location of Biskra city and the location of the residential neighborhoods chosen to conduct the study; N1, N2, and N3.

2.2. Study sample and in-situ measurements

The research conducted in Biskra aimed to investigate three distinct neighborhoods, namely Al-Istqulala (N1), Al-Nassr (N2), and Al-Zamala (N3), as shown in Fig. 1. Chosen for their contrasting urban form characteristics with varying degrees of density, height-to-width ratios (H/W), and sky view factor (SVF) values as seen in Table 2 and appendix 1 Table A. N1 was selected a low-density urban form with a building density of 12/ha. This neighborhood exhibited spacious open areas and fewer structures, reflecting a dispersed arrangement of buildings. N2, on the other hand, represented a medium-density neighborhood that struck a balance between density and open-ness, with a building density of 35.51/ha. Finally, N3 represented a high-density neighborhood characterized by tightly packed buildings exhibiting a building density of 59.52/ha.

The analysis of key urban form variables, namely the average sky view factor (SVF) and height-to-width (H/W) ratios, provides valuable insights into the distinctive characteristics of each neighborhood. N1 exhibited the highest average SVF value of 0.77, indicating a relatively unobstructed view of the sky. Additionally, N1 had the lowest average H/W ratio of 0.40, reflecting a more open spatial configuration. In comparison, N2 displayed an average SVF of 0.43 and an average H/W value of 1.02, implying a slightly higher height-to-width ratio compared to N1. N3 exhibited the lowest average SVF of 0.22, indicating greater obstruction, and the highest average H/W ratio of 2.18, highlighting a notable difference in height-to-width ratio among the neighborhoods to get an accurate average of the physical characteristics, three spots with distinct street configurations in each neighborhood were chosen to perform field measurements as shown in Fig. 2.

The measurements were taken 1.7 m above ground level every two hours at the warmest months of the year, on the 25th and 26th of July 2021. Fig. 2 and Table 2 reveals all the data corresponding to the spots in each neighborhood.

Table 1
Parameters considered for measurements and the thermo-hygrometer sensor accuracy.

Parameter	Instrument	Accuracy
Relative Humidity (%) Temperature (°C)	Humidity and temperature probe Ø 12 mm, highly accurate humidity measurement with 1 % accuracy*	- ±(1.0 %RH + 0.7 % of mv) (0 to 90 % RH) - ±0.2 °C (+15 to + 30 °C) - ±0.5 °C (Remaining Range)

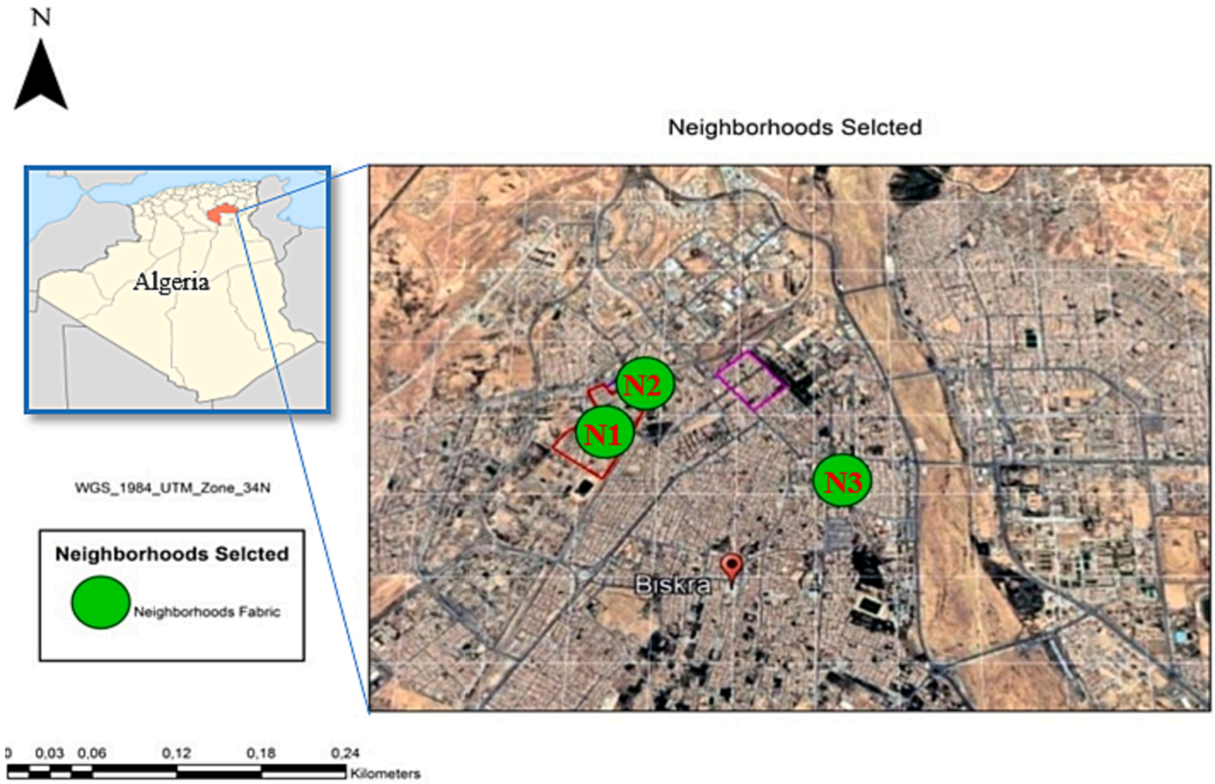


Fig. 1. The location of Biskra city along with the selected residential neighbourhoods N1, N2 and N3.

Table 2
Urban form variables of the spots in the of the three urban Neighborhoods.

	Al-istquala Neighbourhood N1			Al-Nasr -Neighbourhood N2			Al-Zamala Neighbourhood N3		
No of Spot	S1	S2	S3	S4	S5	S6	S7	S8	**S9**
Building density		12/ha		35.51/ha			59.52/ha		
N° of Floors	1	1	1	2 + TR	2	2	2 + TR	2 + TR	2 + TR
H	3,6	3,6	3,6	9	8	8	8	8	9
W	9,8	7,3	9,8	9,5	7,5	7,5	3,8	3,8	3,8
H/W	0,36	0,49	0,36	0,95	1,06	1,06	2,1	2,1	2,36
Street Orientation	Nw/Se	Nw/Sw	Ne/Se	Ne/Sw	Nw/Se	Nw/Se	N/S	N/S	w/e
SVF	0,81	0,71	0,81	0,46	0,42	0,42	0,23	0,23	0,21

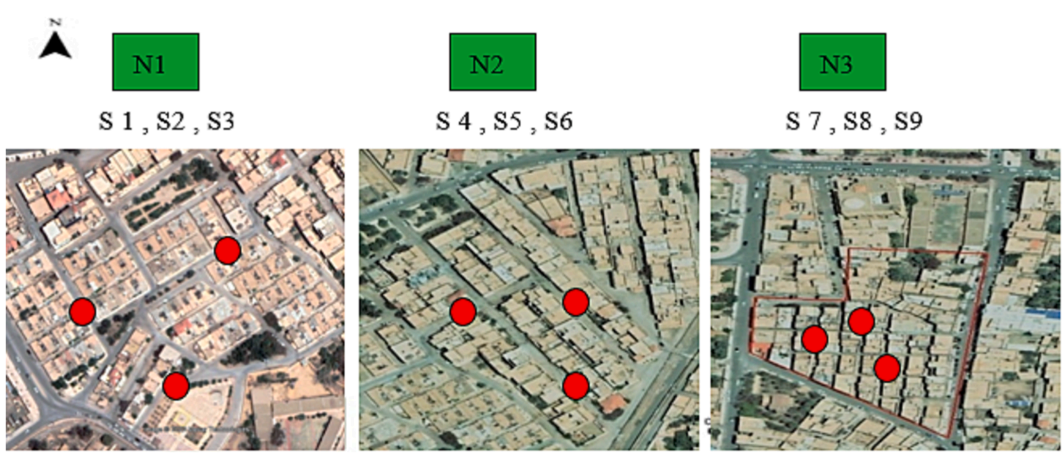


Fig. 2. Thermal measurement spots in the three urban neighborhoods.

2.3. Experimental process

As mentioned above, this research is based on an experimental quantitative method to find out a relationship between urban form variables and outdoor thermal environmental parameters through statistical modeling.

Urban form refers to the physical form and structure of a city or town or a street, including its layout, density, and distribution of buildings and other features [25]. Factors such as the sky view factor (SVF) and the height-to-width ratio (HWR) can affect the outdoor thermal environment by influencing the amount of solar radiation that is absorbed and reflected by the built environment, Fig. 3: shows the experimental process,

where:

Sky view factor (SVF) is the ratio of visible sky area to total sky area at a given point in space. It expresses the openness of the urban context to the sky. The range of values for this ratio ranges from 0, which refers to a completely blocked view of the sky, to 1, which represents a totally unobstructed view of the sky. [26,27].

Height-to-width ratio (H/W): it represents the ratio of the street height to the width of the distance between buildings, or the ratio of the height opposite buildings to the width of the street. This ratio decreases as a street narrow, and increases as a street widens. [28].

Direct solar radiation (DSR): The amount of solar radiation in Wh/m2 received directly from the solar disk; this is the solar radiation that has not been scattered in the atmosphere and therefore has a fixed direction when it comes from the solar disk [29].

Air temperature (AT): is the most important element of weather and climate, the temperature of an object, usually measured in degrees Fahrenheit or degrees Celsius, tells us how much heat, or energy, the object has. It is a physical quantity that characters the degree of heating in a physical body, which occurs as a result of the movement of molecules in the body [30].

Mean radiant temperature: (MRT) is the amount of radiant heat exchanged between a body and its surroundings. It is defined as the uniform temperature of a hypothetical enclosure in which radiant heat transfer for the human body equals radiant heat transfer in the actual non-uniform, Because the amount of radiant heat lost or received by the human body is the algebraic sum of all radiant fluxes exchanged by its exposed parts with the surrounding sources, MRT can be calculated from the measured temperature of surrounding walls and surfaces and their positions with respect to the person [31].

2.4. Simulation settings

Simulation models are valuable tools in urban planning studies when certain outputs or variables cannot be effectivly measured due to limitations or complexities. These models estimate and analyze these variables based on known input parameters and mathematical algorithms. Validating the simulation outputs is crucial to establish their reliability and credibility as approximations of real-world conditions [32].

To investigate the outdoor thermal environment Parameters (OTEP) that were previously unmeasured, specifically the DSR and (MRT) in each neighborhood, Envi-met was utilized for numerical modeling and simulations on three neighborhoods. Envi-met is a software tool that allows users to simulate and analyze the microclimate within an urban environment. It can be used to create virtual models of an urban fabric, including buildings, streets, and other urban features, and to predict outdoor environmental thermal parameters. One of the key advantages of Envi-met is its ability to produce detailed and accurate simulations of the microclimate efficiently [33]. In contrast, traditional measurement tools such as sensors and weather stations can be time-consuming to set up and maintain, and may not provide a comprehensive understanding of the microclimate in a given area. Table 3 shows the simulation settings and parameters inputs in the ENVI-met model.

The simulation duration was set to 24 h, which corresponded to the same time period as the measurement data. To ensure consistency, the minimum and maximum temperature values obtained from the site's measurements were used as reference values in the simple forcing meteorological setting. Additionally, the wind speed was based on the average daily value recorded on 25/06/2021 at the nearest airport.

To incorporate the neighborhood model into the simulation domain, a grid arrangement composed of 50 × 50 × 30 cells was utilized. This grid configuration represented an area equivalent to the dimensions of the neighborhood, measuring 150 m × 150 m in both length and width. Each individual cell within the grid exhibited a spatial resolution of 3 m in all three dimensions. Appendix 2: Table A.

2.5. Simulation results and validation

To provide insights into the temporal dynamics of temperature variations within the selected neighborhoods, Fig. 4 presents the simulated potential air temperature distributions at three different time points during the day (10:00, 14:00, and 18:00), At 10:00, the neighborhoods displayed relatively high air temperatures, with noticeable variations observed among them. Specifically, N1 exhibited the highest temperature rates, while N3 showed the lowest temperatures. The impact of daytime heating became more noticeable by 14:00, as the air temperatures further increased. Once again, distinct variations were evident among the neighborhoods, indicating the influence of their unique urban characteristics on thermal conditions. As the day progressed towards evening, at 18:00, a general decrease in temperatures occurred compared to the peak hours. However, discernible differences persisted among the neighborhoods, with N3 consistently exhibiting the lowest temperatures throughout the day.

To validate and assess the reliability of the Envi-met urban model's outputs, a comparison was conducted between the simulated results and the corresponding measurements of the taken points S1, S2 and S3 in each neighborhood on July 25 and 26, 2021 shown in Table 2. The evaluation process followed ASHRAE Guideline 14, which provides

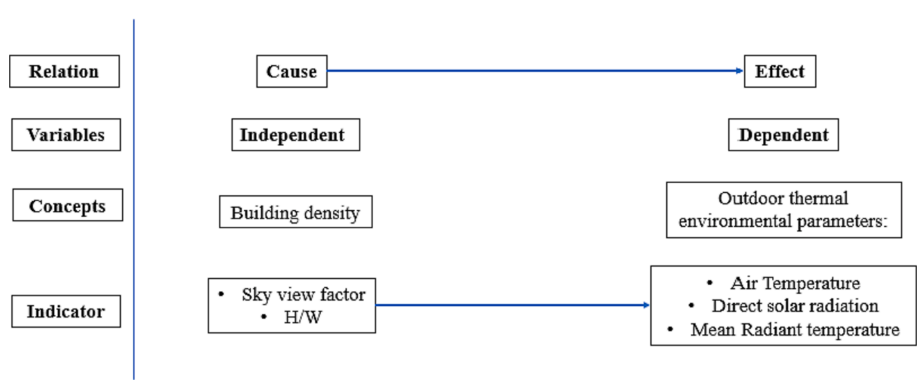
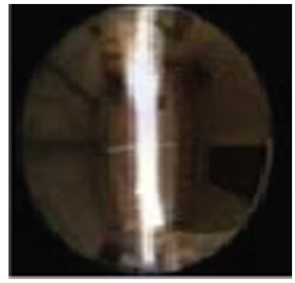
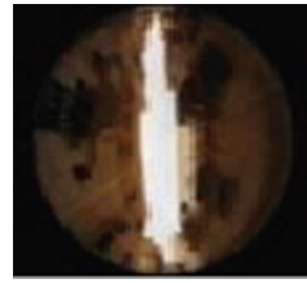


Fig. 3. Link between variables in the experimental process.

Table 3
The simulation settings and parameters inputs in the ENVI-met model.

Parameters	*Al-Istqulal* neighborhood (N1)	*Al-Nassr* neighborhood(N2)	*Al-Zamala* neighborhood (N3)
3D model			
Date of Simulation	25/07/2021	25/07/2021	26/07/2021
Start time	05:00 AM	05:00 AM	05:00 AM
Total simulation time (hour)	24	24	24
Area grid boundary	x-50, y-50, z-25		
Size of grid cells in meter	dx = 3.00 dy = 3.00 dz = 3.00 base height = 0.00		
Wall material	Albedo 0.2		
Roof material	Albedo 0.6		
Soil profile	Albedo values as follow: pavement 0.5, asphalt 0.12, sand 0.31		
Wind speed at 10 m height	1.2 m/s following weather station records of Biskra's Airport		
Wind direction	135o from North		
Roughness length	0.07		
Simple forcing air temperature (°C)	Min 33.00 at 06:00, Max 45.00 at 14:00		
Simple forcing relative humidity (%)	Min 9 at 13:00, Max 21.5 at 06:00		
Nesting grids	None were used since no buildings are placed near the edge of the model.		

criteria for determining the validity of simulation models. It specifies that the simulation model's validity can be evaluated based on two criteria: the hourly mean bias error (MBE) and the hourly root mean squared error (RMSE). The MBE measures the average difference between the simulated and measured values, while the RMSE quantifies the overall deviation between the two sets of values. For reliable validation, the MBE values should fall within the range of +/−10 %, indicating an acceptable level of accuracy, while the RMSE values should be below +/−30 %, indicating good agreement between the simulation and measurements [34]. In the validation process, the average values of the measurements taken at three specific points within each neighborhood were compared to the corresponding average values generated by the simulation Appendix 2: Table A. And the results of the validation process are shown in Table 4.

2.5.1. *Correlation analysis*

Correlation analysis is a statistical method used to analyze the relationship between two continuous variables. It determines if there is a relationship between the variables and measures the strength and direction of that relationship [35,36]. In this research, correlation analysis was used to examine the impact of neighborhood building density on outdoor thermal environmental parameters. The analysis was applied to the variables of (H/W) (SVF) and the mean daily outdoor thermal environmental parameters (DSR) (MRT) (AT) using the following equation:

$$r = \sum (x-\bar{x})(y-\bar{y}) \Big/ \sqrt{\sum (x-\bar{x})^2}\sqrt{\sum (y-\bar{y})^2}$$

r = correlation coefficient.
x = values of the x-variable in a sample.
$\bar{x}$ = mean of the values of the x-variable.
y = values of the y-variable in a sample.
$\bar{y}$ = mean of the values of the y-variable.

Where x is the independent variable, y represents the dependent variable. Therefore, the positive value of R indicates a direct relationship between the variables. In case R is negative, the relationship between the variables is in inverse order.

2.5.2. *The regression analysis*

Linear regression is a statistical technique that is used to analyze the relationship between a variable that is being attempted to be predicted or explained (the dependent variable) and one or more variables that are believed to have an effect on it (the independent variables)). This allows us to make predictions about the dependent variable based on the values of the independent variables and to understand the strength and direction of the relationships between the variables [37,38]. In this study a linear regression analysis was performed on the average values of the independent variables' H/W and SVF in each spot in the three neighborhoods, as well as the average daily values of each dependent variable DSR, MRT, and AT during the daytime period from 6 a.m. to 8 p.m. in all neighborhoods. The regression coefficient (B1) represents the change in the dependent variables (DSR, MRT, and AT) resulting from a change in the independent variables (H/W and SVF).

$$y = \beta_0\beta_1 X + e$$

Where:

y = the dependent variable.
x = the independent variable.
b_0 = the intercept.
b_1 = the slope.
e = the error term.

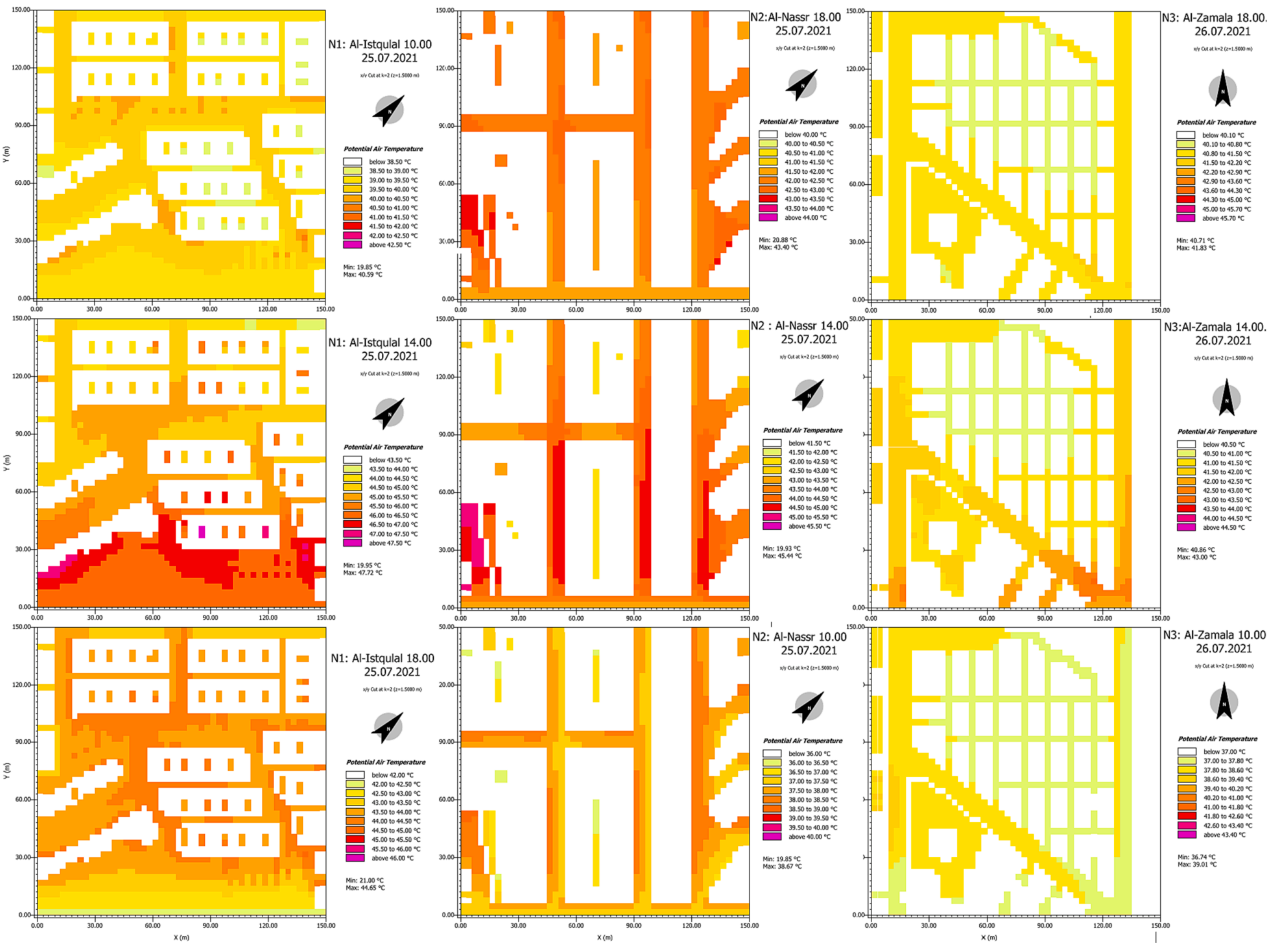


Fig. 4. ENVI-met Map Output Results at 1.5 m for the Three Neighborhoods at 10:00, 14:00, and 18:00.

Table 4
Accuracy of a simulation Envi-met model.

Simulation model validation						
Indices	(N1)		(N2)		(N3)	
RMSE	0.78	3.26 %	0.61	2 %	0.67	2.43 %
NMBE	−0.15	−0.78 %	0.08	0.43 %	0.19	1.02 %

3. Results and discussion

3.1. Simulation results

The results of the simulation of all outdoor environmental thermal variables in each neighborhood are presented in Appendix 1, The results shows that N1 had the highest amount of sunlit time, approximately 12 h, followed by N2 with approximately 8 h and N3 with approximately 2 h. Table 5 displays the average DSR, MRT, and AT for each neighborhood.

Table 5
Average daily values of DSR, MRT and AT in the three neighborhoods.

	Average H/W	Average SVF	Average DSR W/m^2	Average MRT C°	Average AT C°
N1	0.56	0.78	726.56	67.59	41.04
N2	1.02	0.43	537	50.96	39.75
N3	2.17	0.22	195.3	43.41	38.28

Furthermore, an increment of H/W ratio by 1.6 or a reduction of SVF by 0.56 can reduce the average daily DSR, MRT and AT by more than 530 W/m^2, 24C° and 2.5C° respectively.

Fig. 5 and Fig. 6 the average daily DSR, MRT, and AT in each spot in the tree neighborhood and their relation to SVF and H/W ratio, respectively. The results indicate that N3 which has the lowest SVF (0.21–0.23) and the highest H/W ratio (2.1–2.6), has the lowest average DSR, MRT, and AT. In contrast, N1, which has the highest SVF (0.71–0.81) and the lowest H/W ratio, has the highest values for average DSR, MRT, and AT. (See).

3.2. Results of correlation and regression analyses

The statistical Table 6 shows the result of the correlation and regression analysis between urban form variables (SVF, H/W) and the outdoor thermal environmental parameters (DSR, MRT and the AT).

The statistical correlation reveals that the H/W variable has a strong and statistically significant inverse relationship with the DSR, MRT and the AT variables according to the results ($R = -0.973$, $R^2 = 0.947$, $p < 0.05$), ($R = -0.895$, $R^2 = 0.801$, $p < 0.05$) and ($R = -0.985$, $R^2 = 0.971$, $p < 0.05$) respectively. On the other hand, the analysis indicates that the SVF variable has a statistically significant positive relationship with the DSR ($R = 0.941$, $R^2 = 0.881$, $p < 0.05$), the MRT ($R = 0.979$, $R^2 = 0.959$, $p < 0.05$), and the AT ($R = 0.978$, $R^2 = 0.956$, $p < 0.05$). For the regression analysis, the H/W ratio was found to be negatively correlated with DST, MRT, and AT. As a result, the regression model for H/W is entirely negative for H/W and DST, MRT, and AT, in that order,

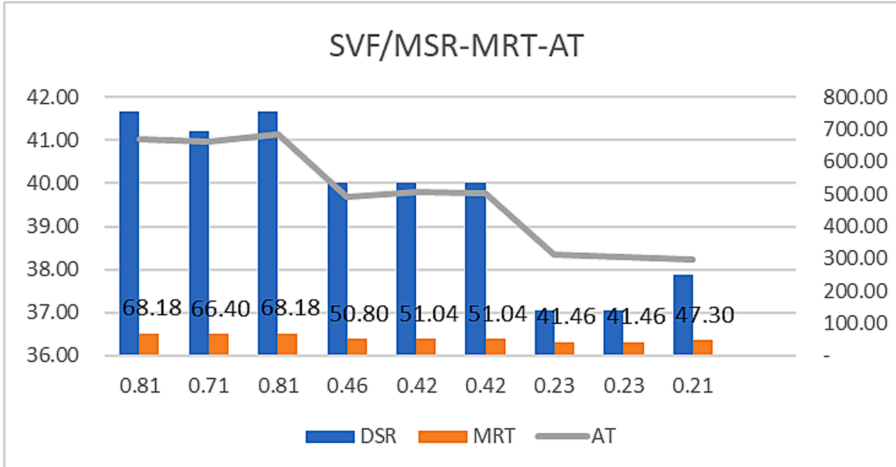


Fig. 5. The simultaneous effects of SVF on MSR, MET, and AT Variables.

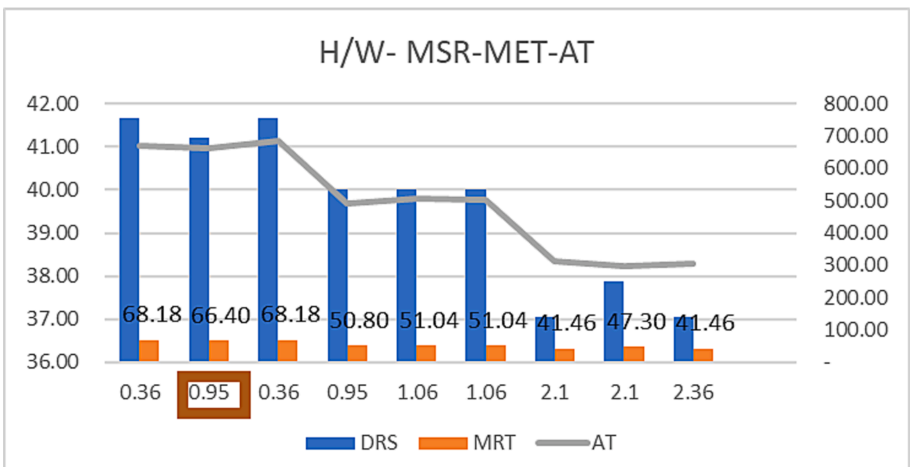


Fig. 6. The simultaneous effects of H/W on MSR, MET, and AT Variables.

Table 6
Regression analysis results.

Independent Variables	Dependent Variables	R	R2	Constant	B	SIG
H/W	DSR	−0.973	0.947	852.65	−306.68	0.00
	MRT	−0.895	0.801	67.79	−11.79	0.001
	AT	−0.985	0.971	41.49	−1.49	0.00
SVF	DSR	0.941	0.886	24.78	959.63	0.00
	MRT	0.979	0.959	33.64	41.73	0.00
	AT	0.978	0.956	37.4	4.79	0.00

are as follows: $Y = 852.65 - 306.68X$, $Y = 67.79 - 11.79X$, and $Y = 41.49 - 1.49X$ As the SVF variable was positively correlated with DSR, MRT, and AT variables, the entire regression model for S.V.F is positive, where the Models of SVF with DSR, MRT and AT are **Y = 27.78 + 959.63 X, Y = 33.64 + 41.73 X** and **Y = 37.4 + 4.79 X** respectively Table 7.

Table 7
Linear regression models.

Dependant Variables (Y)		DSR	MRT	AT
Independents Variables (X)	H/W	$Y = 852.65 - 306.68X$	$Y = 67.79 - 11.79X$	$Y = 41.49 - 1.49X$
	SVF	$Y = 24.78 + 959.63X$	$Y = 33.64 + 41.73X$	$Y = 37.4 + 4.79X$

3.3. Statistical relationships and design implications

The simulation results indicate that streets with higher height-to-width ratio (H/W) experience lower levels of DSR. This decrease in DSR leads to a decrease in surface temperatures, which in turn results in a decrease in ATs. The link between AT and (MRT) is influenced by both thermal convection and radiation processe. Additionally, statistical analysis has shown that an increase of one unit in the H/W ratio can decrease DSR, MRT, and AT by 306.68 W/m^2, 11.79 °C, and 1.49 °C, respectively.Furthermore, the sky view factor (SVF) is negatively correlated with the HWR. In other words, as the HWR increases, the SVF decreases. Therefore, a lower SVF leads to lower exposure and lower mean radiant and ATs. Morover according to the stastical analysis a decreament in 0.1 unit of SVF which is 10 % can lead to decrement of DSR, MRT, and AT by 90.963 W/m^2, 4.173 °C, and 0.479 °C, respectively. To sum up, urban design guidelines for streets in hot and dry climates should prioritize creating a comfortable outdoor thermal environment for all users. Based on the findings of this research, the most effective way to achieve this is by designing urban streets with a higher H/W ratio and lower SVF. These factors have a significant impact on the outdoor thermal environment, as shown by the results of this study. Increasing the H/W ratio by 1 can reduce AT by 1.49 °C, while decreasing the SVF by 0.1 can reduce AT by 0.479 °C. The results of this study have practical implications for urban designers working in hot and dry climates. The findings demonstrate the numerical relationship between urban form factors and outdoor thermal environmental parameters in the built environment, providing valuable insights for designing comfortable conditions.

4. Conclusions

In the present period, where addressing climate change is of urgent concern, a critical issue revolves around the direct impact experienced by urban areas. This impact primarily results from the escalating urban temperatures, which worsen the "UHI" effect. Consequently, resource consumption increases, along with higher carbon emissions in the pursuit of thermal comfort. This increase will have led to the creation of more environmental issues, thus perpetuating a detrimental cycle continuously. To address this matter and mitigate this cycle through a conscientious approach to urban planning and design, the purpose of this study was to analyze the relationship between two urban form variables, H/W ratio and sky view factor, and three outdoor thermal environmental parameters, DSR, MRT, and AT, in three neighborhoods in Biskra., Algeria, a hot and dry region. The research was conducted using field measurements with Testo 480 tools, modeling and simulation with ENVI-met software, and statistical analysis including correlation and regression. Based on the research findings, it is recommended to prioritize the afternoon time range when designing urban streets in hot and dry climates. This period is marked by intense solar radiation and high temperatures, posing challenges to pedestrian comfort. To address this, creating a comfortable outdoor thermal environment is crucial. Key factors to consider in the design process are the height-to-width (H/W) ratio and the sky view factor (SVF) of the urban streetscape. The H/W ratio plays a critical role in determining the outdoor thermal conditions of streets. As observed in the research, a higher H/W ratio contributes to a more favorable thermal environment. The study reveals that increasing the H/W ratio by 1 can led to a significant reduction in the ambient temperature (AT) by 1.49 °C. This indicates that streets with taller buildings and narrower widths provide a degree of shade and obstruction to solar radiation, thus mitigating the heat impact on the street microclimate. In addition to the H/W ratio, the SVF of the urban street design also plays a vital role in influencing the outdoor thermal conditions. The research findings demonstrate that a lower SVF is associated with a more comfortable outdoor thermal environment. Specifically, reducing the SVF by 0.1 can result in a decrease in AT by 0.479 °C. This highlights the importance of incorporating elements such as tree canopies, shading devices, and urban greenery to optimize the SVF and provide effective shade and cooling in hot and dry urban environments. These findings contribute to the literature and can serve as a guide for urban planners designing comfortable cities in hot and dry climates.

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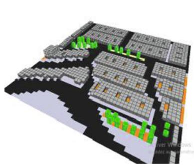
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Table A. Fisheye Lens Photography at Measurement Points S1, S2, and S3 across Three Neighborhoods



Appendix 2

Table A. ENVI-met models and simulation outputs

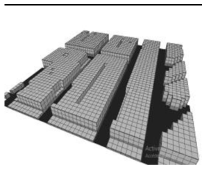


Table C. Simulated direct solar radiation (DSR)

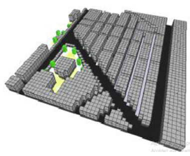
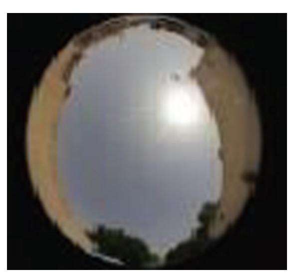
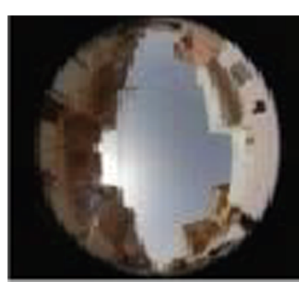


Table D. Simulated mean radiant temperature (MRT)

Table E. Simulated Air temperature (AT)





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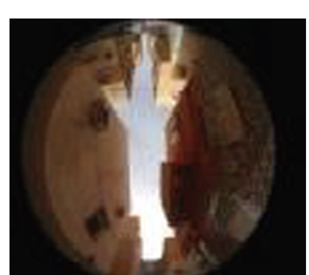

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