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The Effect of Sky View Factor on the Thermic Ambiances: Case of Batna City

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Abstarct

The urban microclimate influenced by the urban morphology and geometry of the built environment, in particular by the shading effect and the minimization of solar radiation, are among the elements that influence most the urban ambiances during the period of thermal stress.

The quality of outdoor spaces in urban areas is directly related to the regulation of microclimate, which depends on a number of factors of which urban morphology that affects microclimatic parameters.

This study focuses on the impact of the two main geometric indicators: The sky view factor (SVF) and the H/L ratio (the height of the building/ the width of the street) on the external thermal of a semi-arid environment.

We conducted an investigation in an urban fabric of collective housing (500 houses) located in ZHUN II (New Urban Housing Areas) in Batna, Algeria, during the hottest period of summer 2019, followed by numerical simulation of the atmospheric model Envi-met Pro 4, to simulate the four scenarios of our case study with the use of a range of heights; from 15m to 60m, the climatic parameters retained are the air temperature (AT), relative humidity (RH), and wind velocity (WV), as well as the outdoor thermal comfort rating using the PMV Thermal Index (predicted mean vote). The results confirmed that when increasing the height of buildings increases the value of the H/L ratio and decreases the SVF values and leads to better microclimatic regulation in a semi-arid environment.

Key words: urban morphology, outdoor thermal comfort, PMV index, numerical simulation, city of Batna.

INTRODUCTION

Since antiquity, architecture and urban planning reflect man's desire to produce a healthy and comfortable thermal environment [1]. The concept of thermal comfort, studied since 1930 [2], is today an absolute priority for climatologists and urban planners; because the city has become an increasingly complex system and often faces increased climate risks such as urban heat islands, manifesting in climatic divergences with uncomfortable external thermal ambiances, where residents and users are exposed to a higher frequency of heat stress conditions [3]. In this context, the problem of urban morphology and its relationship with the urban microclimate, the subject of this research, and taken into account by two a priori geometric indicators (SVF (sky view factor) and the H/L ratio (building height/street width)), these have been discussed for a long time through numerous works dealing in general with the direct influence of the H/L ratio on lighting and natural warming of the air [4], this work has shown that the H/L ratio can achieve the objectives of controlling microclimatic regulation parameters [5], and in another study the H/L ratio and SVF increased a high correlation with surface temperature by the shading effect of street surfaces [6]. The H/L ratio allowed to calculate the SVF which is defined as the percentage of the sky seen from a fixed point on the ground [5], other researchers define it as the fraction of the visible sky [7-8], it is a parameter with no dimension between 0 and 1, 1; when the sky view is free of any obstructions, down to 0 where the view of the sky is totally obstructed [9]. It corresponds to the portion of sky observed from the surface considered, it is important for determining the surface radiation balance [10].

It is calculated in the majority of simulation programs such as: Envi-Met [11] and Rayman [12], these elaborate simulation programs also provide access to the calculation of thermal indices used in a number of urban morphology research projects to objectively quantify indoor and outdoor comfort (PMV, PET, UTCI, SET* and OutSET*)[13].

In general, this urban morphology is defined as the association of the three-dimensional shape of a group of buildings, its spread, and the volume of the exterior spaces it creates [5], is likely to generate upheavals on the external thermal conditions induced by its geometric indicators: (sky-view factor (SVF) and the ratio between the height of the building and the width of the street (H/L,) which are recognized as two key factors, having an impact on solar radiation and wind direction. [14-17].

Through this research work, we will focus on the existing relationship between the sky-view factor (SVF), the H/L ratio, and microclimatic parameters (air temperature (AT), relative humidity (RH), and wind velocity (WV)) in a semi-arid climate, and subsequently, we will evaluate the levels of external thermal comfort by the thermal index the PMV widely used in the objective quantification of internal and external thermal comfort [3].

Its thermal indices take into account multiple microclimatic parameters (air temperature, relative humidity, wind velocity, mean radiant temperature, and black globe temperature) as well as individual parameters (clothing, position, age).

The numerical approach is an alternative research method used in many studies for two main reasons:

The digital model is particularly suited to highlight the link between urban physical structure, microclimate, and thermal comfort by translating the results into practical design guidelines.

Compared to field measurements, it is faster and cheaper, and also allows comparisons between multiple case studies and project scenarios [18].

As part of this research, we will examine the PMV index which was updated in 1993 and dates back to 1984. It was adopted by ISO 7730-93. It is based on Fanger's work of 1970. It was previously developed by "M. Bruse" to be adaptable to outdoor environments when updating its simulation program. It provides nine (09) comfort levels appropriate for outdoor environments, ranging from -4 to +4 [19], table 1.

Table 1. PMV Scale thermal sensation and physiological stress level. Source: Author.

PMV Scale	-4	-3	-2	-1	0	1	2	3	4
Scale Thermal sensation	Very cold	Cold	Cool	Slightly cool	Comfortable (neutral)	Slightly warm	Warm	Hot	Very hot
physiological stress level	Extreme cold stress	Strong cold stress	Moderate cold stress	Slight cold stress	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

Presentation of Batna City

Our study is on the city of Batna, an area in the eastern part of Algeria, located between 06° and 17° East longitude, and between 33° and 56° North latitude, at an altitude of 1058 m above sea level. The territory of the city of Batna is almost entirely part of the physical ensemble formed by the junction of two Atlases (Tellian and Saharan).

The city of Batna belongs to the semi-arid regions of Algeria. whose climate is characterized by hot and dry summers with maximum temperatures reaching 36.4°C in July, and cold and humid winters with minimum temperatures reaching 0.4 °C in January (period 2011-2020 provided by the meteorological station of Batna).

Batna is the main city of the wilaya and the capital of Aures, is the administrative center of the Wilaya and the Daira as well as the communes of Batna, Fesdis and Oued Châaba since the previous territorial revision in 1984, figure 1.

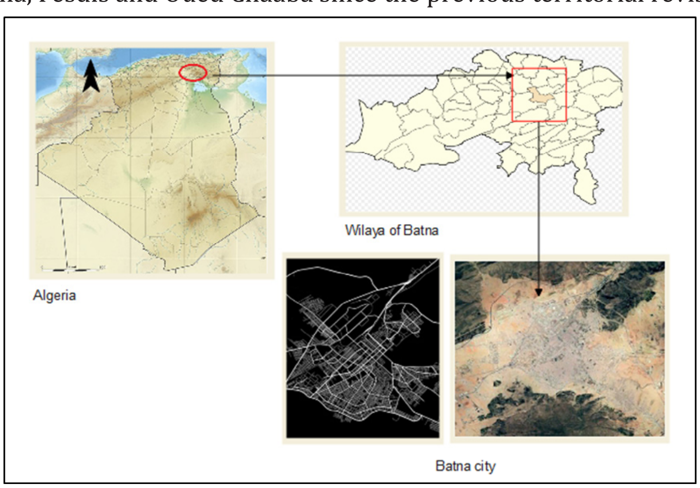


Figure 1. Location of Batna city. Source: Author.

The city of Batna has undergone several changes that have contributed to its urban development over time, giving birth to different urban forms.

The city of Batna has gone through two distinct periods that have marked its urban development. One is the colonial period, which is the period of the foundation of the city, and the other is the postcolonial period (after Independence).

But the period of 1978–1984 marked the city of Batna with rapid urbanization and managed the development of the city, which has seen an urban dysfunction as well as a breakdown of the agglomeration in all directions caused mainly by the migratory flows of the population in search of employment, schooling, and the various services (health, administration, etc.), and to cope with this situation, a PUD master urban planning plan of the city of Batna (supplemented by the urban modernization plan) was promulgated in 1978. The directions of PUD 1978 have been concretized physically by the introduction of a significant program of communal and individual housing, cooperatives, subdivisions, and ZHUN (New urban housing areas).

Presentation of the Case Study: The Investigation Site

The study context is an urban fabric of regular form, presenting a residential area of collective housing (Cite 500 houses) located in the ZHUN II of the city of Batna, built between 1974 and 1984, characterized by its low density (CES = 0.17) and its open form with large multi-purpose outdoor spaces, figure 2.

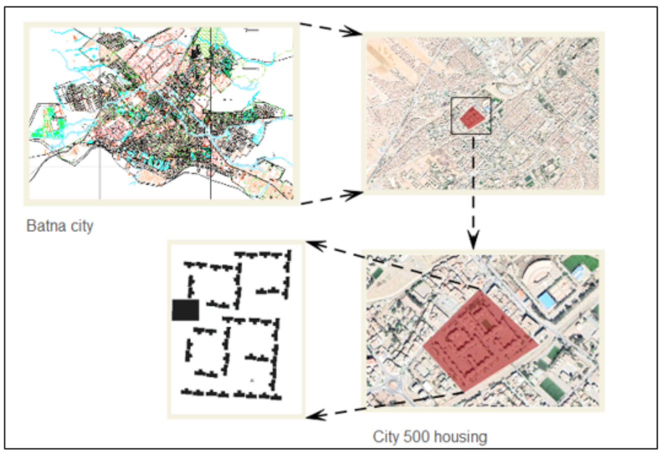


Figure 2. Location of the study area. Source: Author.

Characteristics of the Study Site

The choice of this site was made according to two criteria

a- The urban density.

b- Geometric indicators at the level of the external spaces, which are: the sky view factor (SVF) and the ratio (H/L), table2.

Table 2. Characteristics of the study site. Source: Author.

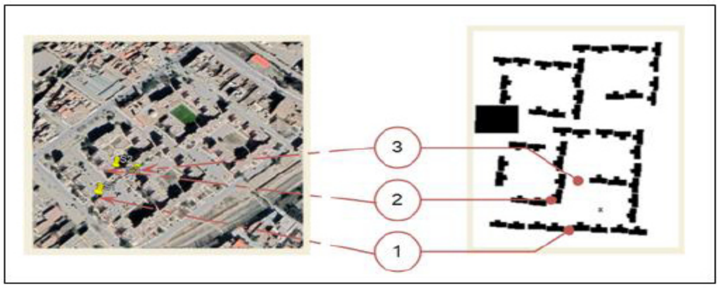
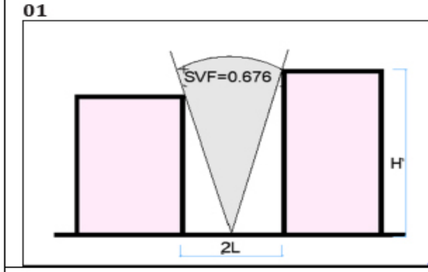
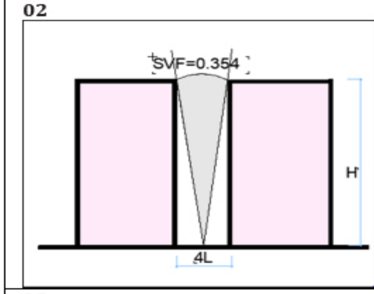
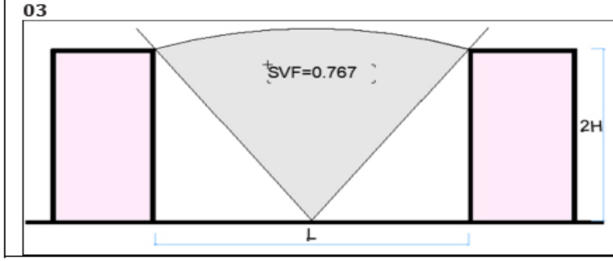
Study site	Site Features
 City 500 houses	Type: collective housing Year built: 1974-1984 Area: 65824 m2 Built area: 11190.08 m Unbuilt surface: 54633.92 m 2 Building height: R+5 CES urban density: 17 %

Location and Description of Measuring Points

The geometric characteristics of each measuring point are presented in the following table.

The measuring points are selected according to their different SVF and H/L ratios; these indicators change due to the change in height and width between the buildings in each point, table 3.

Table 3. The geometric indicators of points 01, 02and 03. Source: Author.

Study case				
				
Points	**SVF**	**H/L**	**Orientation**	**Albedo**
01 	0.676	H=2L	NE/SW	0.20
02 	0.354	4L	NE/SW	0.50
03 	0.767	2H/L	NE/SW	0.20

Working Method

In our study, we used an investigation approach based on the method of quantitative evaluation of the geometric and microclimatic parameters required for the assessment of external thermal environments.

This approach is divided into two parts:

1- In situ measurements,

2- Modeling and simulation using the three-dimensional software Envi-Met software pro version 4.4.6.

As the main objective of this article is to study microclimatic regulation through urban morphology in a semi-arid climate, the simulation of four (04) scenarios with different building heights ranging from 15m to 60m were simulated in this study using Envi-software to acquire a set of microclimatic parameters of the urban fabric: air temperature (°C), relative humidity (%), and wind velocity (m/s), and geometrical parameters: SVF.

Based on the simulation data obtained, the PMV index was calculated using the Bio-met post-processing tool, figure 3.

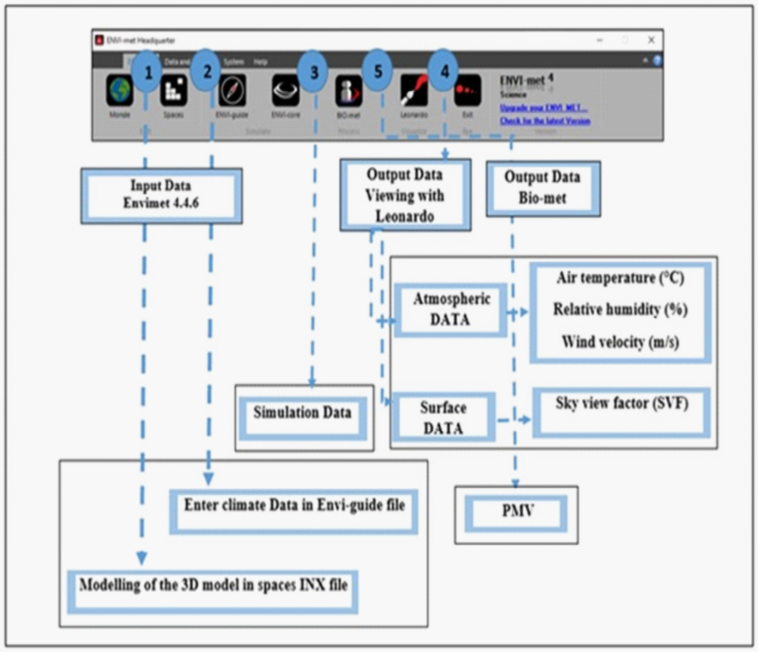


Figure 3. Working method. Source: Author.

The Numerical Simulation

The Envi-met software is a three-dimensional software designed by Michael Bruce in Germany used mainly in climatology to create design or rehabilitation scenarios. The Envi-met pro 4.4.6 software models urban microclimates in complex environments. In a research [20], ENVI-met reproduced the observed data with sufficient accuracy. It has been proven to be a reliable tool to simulate different designed urban scenarios [21], This program is one of the main numerical tools used in outdoor design. Due to its function of predicting microclimatic conditions, it is the only model that aggregates all the factors that influence outdoor thermal comfort; it helps designers to opt for wise choices when designing outdoor spaces [22].

The numerical simulation took place during the summer period selected for the survey between 6 am. and 8 pm. on July 23, 2019.

The evaluation of thermal comfort is based on the numerical calculation of the PMV (Predicted mean vote), this thermal index is widely used in research work.

Simulation Method

We used the site corresponding to the horizontal microclimate in the simulation of the selected model.

Envi-met Pro version 4.4.6 models the location using an orthogonal geometric grid with directions (x, y) spaced by (2 m, 2 m) and z spaced by 20 m. Soil, plants, and 3D structures are all accurately modeled, as illustrated in table 4.

Table 4. Data from the digital model of the site, modeling by ENVI-met pro version 4.4.6. Source: Author.

Model dimensions	Sample site (City 500 houses)
Horizontal grid of the study area	120 x 140
Horizontal resolution	Δx = 2m Δy = 2m
Vertical grid of the study area	20m
Vertical resolution	Δz = 2m

According to the meteorological characteristics for July 2019, the simulated time period runs from 6 am to 8 pm on 23 July 2019, which is regarded as the hottest day. The meteorological data entered in the file Envi-guide is indicated in table 5.

Table 5. Input configuration data applied in the ENVI-met simulations. Source: Author.

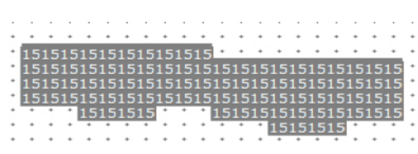
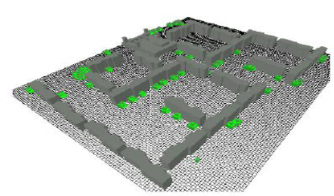
The situation of the site	Batna, Algeria Longitude 6.17 E Latitude: 33.56 N Altitude: 1058m North=45
Type of climate	Climate: semi-arid and dry climate in summer
simulation day	Typical hot summer day, 23.07.2019
Simulation time	From 6 am. to 8 pm
Climatic parameters: Average wind speed (m/s) Wind direction Average Average relative humidity (%) Average temperature (°C)	 2.50m/s 180.00 north 28.50% 30.12°C
Urban data: Urban density **Buildings:** Average height of the site section	 17% 12m-15m

The ENVI-met model it makes possible to design urban configurations for modeling, in two 2D dimensions as well as in 3D (three dimensions). As a result, numerical models for different simulation scenarios of the urban site were designed, according to table 6, and simulation results were visualized using the visualization tool (LEONARDO), table 6.

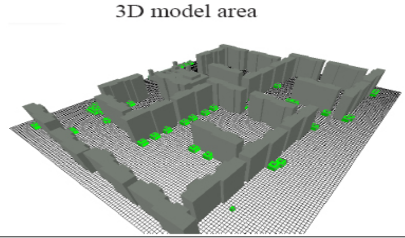
Table 6. Modeling of the four scenarios, 2D model area and 3D model area created using ENVI met, showing the exterior spaces and the buildings. Source: Author.

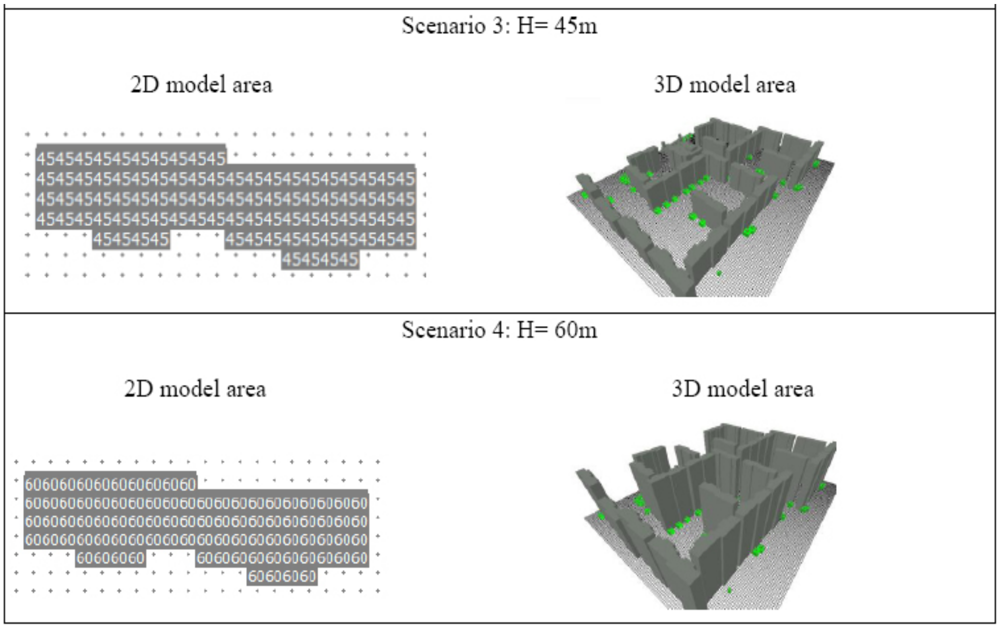
Modeling of the four scenarios with heights (H): 15m, 30m, 45m, and 60m

Scenario 1 (Initial case): H= 15m

2D model area	3D model area
	

Scenario 2: H= 30m

2D model area	3D model area
	



RESULTS AND DISCUSSIONS

Comparison of Microclimatic Parameters in Different Scenarios

The figures 4, 5, and 6 below show the simulation results of air temperature, relative humidity, and wind velocity for the four scenarios from 6 am to 8 pm. For the air temperature results, a maximum value of 34.27 °C is observed in scenario 1 (Initial case) with a maximum building height of 15 m, while the lowest value of 33.17 °C was recorded in scenario 4 with a maximum building height of 60 m.

The air temperature decreases in each scenario, with a difference of 0.3 (°C) between scenario 1(Initial case) and scenario 2, 0.87 (°C) between scenarios 1 and 3, and 1.1 (°C) between scenarios 1 and 4.

Overall, it we can deduce that temperatures in all four scenario pass through two distinct periods of 6 am to 4 pm increases and 4 pm to 8 pm decreases, with higher values in Scenario 1 compared to Scenarios 2, 3, and 4, obviously, this is due to direct exposure to solar radiation from the site's large open spaces (Large SVF).

For the humidity results, the highest value was observed in scenario 4 (height 60 m), scenario 3 (height 45 m), scenario 2 (height 30 m), and finally, the lowest value was observed in scenario 1(Initial case) (height 15 m).

For the wind velocity, the lowest velocity is observed in scenario 4 (height 60 m) and the highest in scenario 2 (height 30 m) with a maximum value of 1.9 (m/s), which may mean that the height of the buildings drives the wind flow, figure 4, 5, 6.

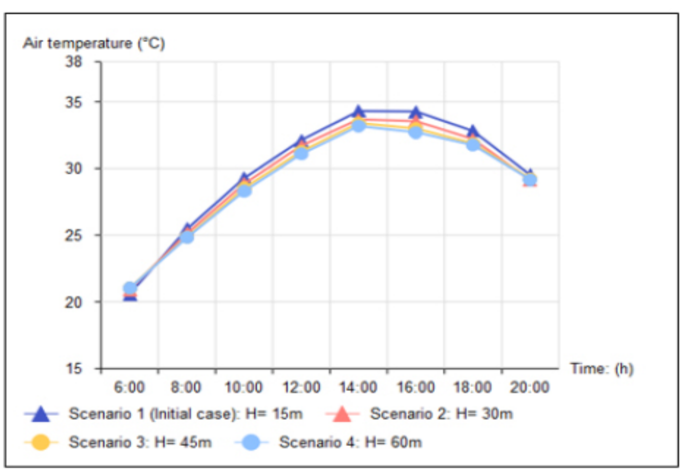


Figure 4. Comparison of air temperature in each scenario from 6 am to 8 pm. Source: Author.

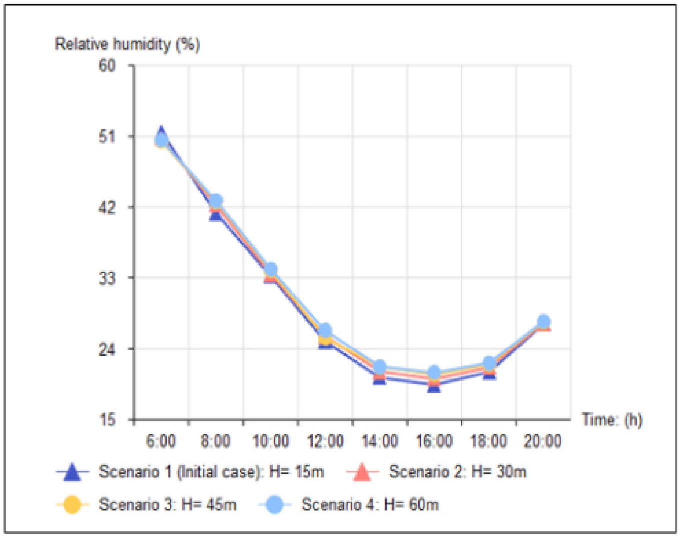


Figure 5. Comparison of relative humidity in each scenario from 6 am to 8 pm. Source: Author.

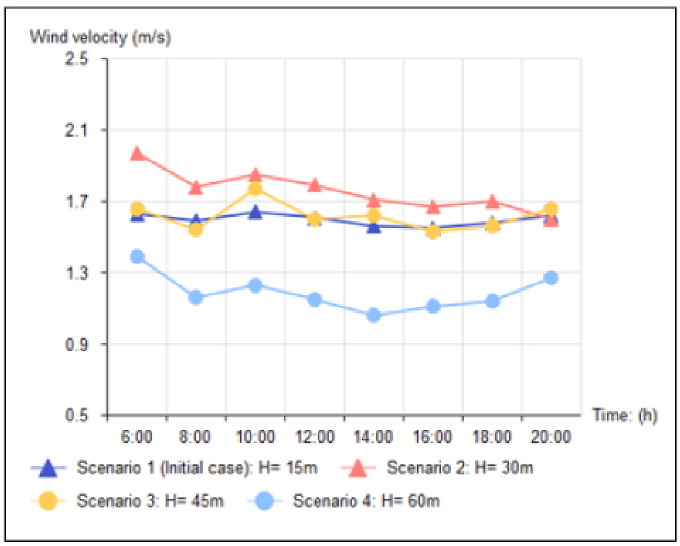


Figure 6. Comparison of wind velocity in each scenario from 6 am to 8 pm. Source: Author.

The Effect of SVF and H/L on Microclimatic Parameters

To study the relationship between SVF, H/L, and microclimatic parameters (air temperature, relative humidity, and wind speed) at the three selected measuring points with the same orientation but with different SVF and H/L values.

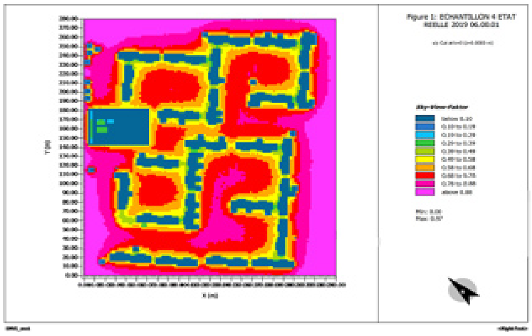
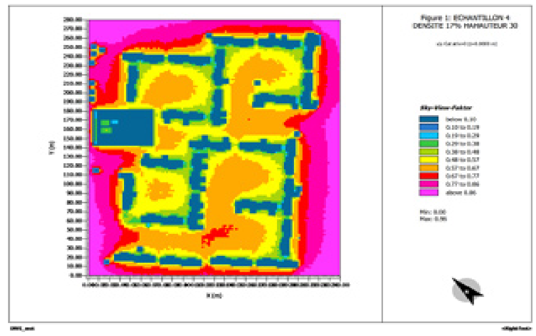
These three points were modeled in scenarios of varying heights from 15m to 60m, using the Envi-Met model, which allows the calculation of the SVF taking into account the spatial characteristics of urban fabrics and their immediate environment. The simulation results are presented in table 7.

Table 7. The SVF values of the three points chosen in different simulation scenarios. Source: Author

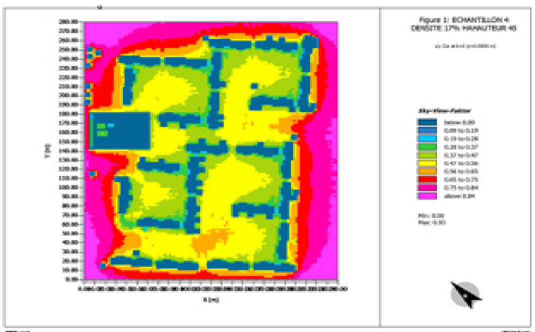
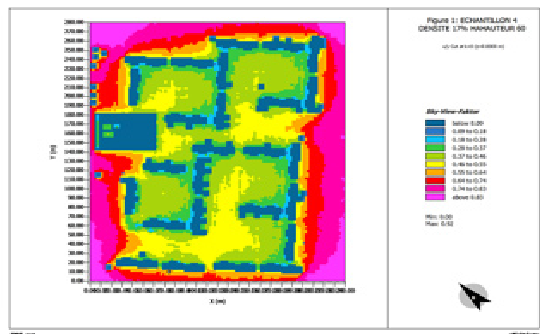
Heights	**(Initial height) H=15m**	**H=30m**	**H=45m**	**H=60m**
The SVF values of the three points				
Point 1	0.676	0.543	0.517	0.499
Point 2	0.354	0.266	0.232	0.191
Point 3	0.767	0.646	0.542	0.488

The maps of the SVF values in the four scenarios

Scenario 1 (Initial case) : H= 15m **Scenario 2: H= 30m**

Scenario 3: H= 45m **Scenario 4: H= 60m**

The SVF results according to simulation maps show that the SVF values change according to the height of buildings. The average sky view factor is very distinct between the four scenarios.

Based on the SVF spatial distribution map between four scenarios, it illustrates high values of the SVF in red color, equal to (0.70-0.80) in scenario 1 (Initial case), where the initial height of buildings is 15m, while the lower values (equal to 0.40-0.50), are represented in green and yellow in scenario 4, where the height of the buildings is 60m. Through these spatial distribution maps, we can observe how the SVF varies each time the height of the buildings changes in turn.

From these results figure 7, It can be observed that the air temperatures of the points with high SVF before any solar gain at 6 am recorded the lowest values, but just after 8 am, the air temperature values increased and varied simultaneously with the increasing SVF values. This situation starts to reverse after 6 pm, where the points with high SVF reach lower air temperature values shortly after sunset.

The correlation plot also shows that the air temperatures are positively correlated with the SVF values, with R2 = 78%, figure 7.

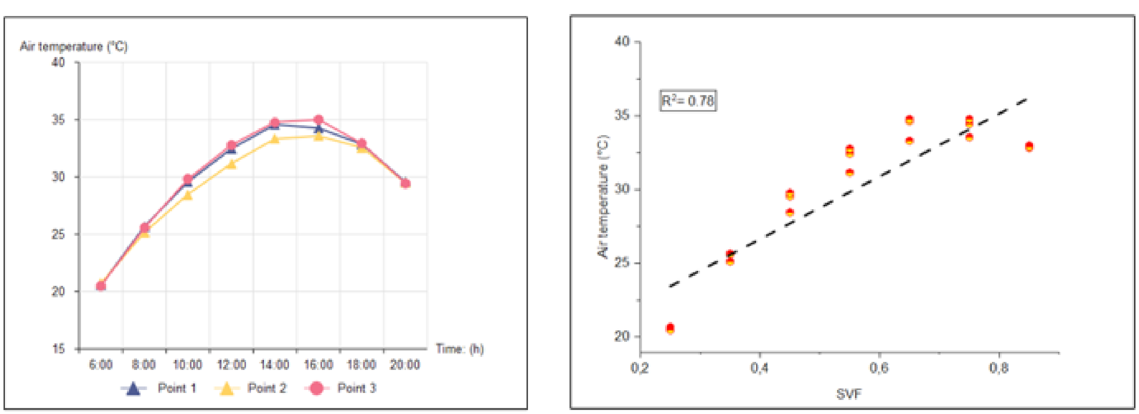


Figure 7. Graph of the air temperature values of each point and the correlation between the air temperature values and SVF. Source: Author.

The results in figure 8, indicate a negative correlation between SVF and H/L, which means that SVF and H/L values are inversely proportional and this is valid for all three points, where an increase in building height results in an increase in H/L ratio and a decrease in SVF, which means that shaded areas in outdoor spaces increases. figure 8.

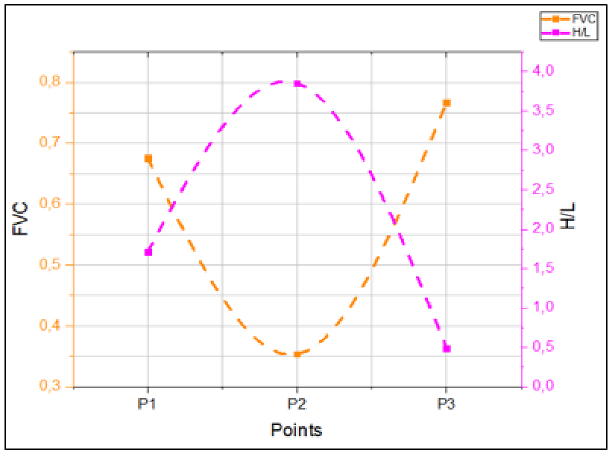


Figure 8. The relationship between SVF values and the ratio H/L values. Source: Author.

Comparison of PMV Index in Different Scenarios

After analysis of the simulation results illustrated in figure 9, it was found that the majority of the PMV (Predicted mean vote) values recorded were positive (between 0 and 5). The minimum PMV values were recorded at the beginning of the day (comfort zone) in Scenarios 3 and 4 (H = 45 and 60 m, respectively), whereas Scenarios 1 (Initial case) and 2 mark the highest values.

Furthermore, the maximum PMV values were recorded between 12 am and 2 pm, reaching 4.87 for Scenarios 1 to 2 pm, 4.54 for Scenario 2, and 4.34 for Scenarios 3 and 4, respectively.

The graph illustrates that all scenarios are in the extreme heat stress zone from 12 am to 4 pm.

The four scenarios are located in stress zones from 10 am to 4 pm and comfort zones from 6 pm to 8 pm, figure 9.

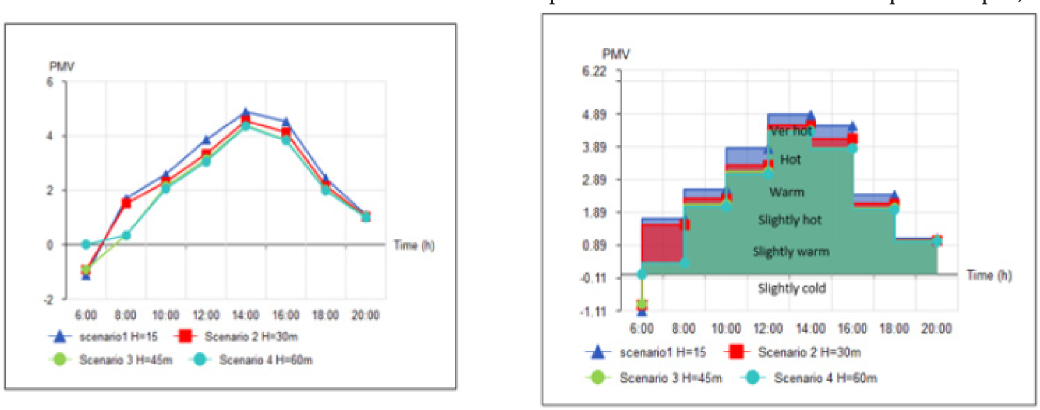


Figure 9. Comparison of PMV (Predicted mean vote) in each scenario from 6 am to 8 pm. Source: Author.

CONCLUSION

Many factors act on the modification of the urban microclimate, of which morphology remains the most important element of this change, as the city is becoming more and more urbanized and overpopulated, this situation incites researchers to find relevant solutions to minimize the vulnerability of outdoor spaces against thermal stress. This study confirms that urban morphology is a controllable variable through geometric indicators that can act as disruptors and/or regulators of microclimatic parameters.

This research work is based on numerical simulation, the objective of which is to understand the impact of SVF and H/L on the thermal comfort in outdoor spaces of new urban forms (ZHUN), and through the results obtained from this work, it appears that the thermal behavior of outdoor spaces is directly linked to the urban morphology with its geometry (its SVF and its H/L ratio); and that there is a proportionality between the SVF and the H/L. In addition, in order to achieve desired degrees of outdoor thermal ambiance for a city like Batna, belonging to a semi-arid climate, a good mastery of the design of the urban morphology is necessary, increasing the H/L ratio and decreasing the SVF can induce more shaded surfaces throughout the day during the overheating period in summer, and therefore affect favorably the thermal ambiances.

The results of this research can be of great help to designers and planners to come up with new ideas and make optimal choices in terms of collective housing design for a better environment.

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Data Availability Statement: (PDAU Batna, 2011, 2017).

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Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. Givoni, B: L'homme, l'architecture et le climat. Éditions du moniteur (1978), Paris.
2. Taleghani. M; Tenpierik. M; Kurvers. S; van den Dobbelsteen. A: Renewable and Sustainable Energy Reviews 26 (2013) 201–215, doi.org/10.1016/j.rser.2013.05.050.
3. Sayad B, Alkama D. Microclimatic regulation of palm trees in semi-arid environment during heat stress. J. Fundam. Appl. Sci., 2021, 13(2), 694-707.
4. Oke T R., 1982.- Overview of interactions between settlements and their environments. Rapport, experts meeting on Urban and Building climatology, Genève.
5. BOUCHERIBA Fouzia. L'urbanisme durable à travers l'interaction: formes urbaines/climat cas de l'habitat individuel à la ville d'Ain Smara (Algerie). Algerian journal of arid environment, vol. 11, n°2, Décembre 2021: 139-154. P-ISSN 2170-1318/ E-ISSN 2588-1949.
6. Bourbia. F, H. Awbi (2004) Building cluster and shading in the urban canyon for the hot dry climate, Part 1: Air and surface temperature measurements.Renewable Energy 29 (2):249-262.
7. Theeuwes et al., 2017 N.E. Theeuwes, G.J. Steeneveld, R.J. Ronda, A.A. Holtslag A diagnostic equation for the daily maximum urban heat island effect for cities in northwestern Europe Int. J. Climatol., 370 (1) (2017), pp. 443-454jan 2017. ISSN 10970088. https://doi.org/10.1002/joc.4717.
8. Zeng et al., 2018. L. Zeng, J. Lu, W. Li, Y. Li. A fast approach for large-scale sky view factor estimation using street view images. Build. Environ., 135 (2018), pp. 74-84. may 2018. ISSN 03601323. https://doi.org/10.1016/j.buildenv.2018.03.009.
9. M. Dirksen, R.J. Ronda, N.E. Theeuwes, G.A. Pagani, Sky view factor calculations and its application in urban heat island studies, Urban Climate, Volume 30, 2019, 100498, ISSN 2212-0955, https://doi.org/10.1016/j.uclim.2019.100498.
10. Bruce. M, (2009) http://www.envi-met.com/.
11. Matzarakis. A; Rutz. F, Mayer. H (2007). Modeling radiation fluxes in simple and complex environments—application of the RayMan model. Int J Biometeorol (2007) 51:323–334.
12. Honjo.T: Thermal Comfort in Outdoor Environment. Global Environmental Research (2009) AIRIES 13/2009:43-47 printed in Japan.
13. Ali-Toudert, F, Djenane. M, Bensalem. R, Mayer. H (2005) Outdoor thermal comfort in the old desert city of Beni-Isguen, Algeria. Climate Research 28 (3) : 243-256.
14. Ali-Toudert, F, Mayer. H, (2006) Numerical Study on the effects of aspect ratio and orientation on an urban street canyon on outdoor thermal comfort in hot and dry climate February (2006), Building and Environment 41(2):94-108.

15. Johansson, E. (2006) Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. Building and environment41(10):1326-1338.

16. Fouzia Boucheriba. Adaptation of Urban Law to Micro-Climate parameters Inalgeria-Case of Collective Housing in a Semi-Arid Area. Int J Innov Stud Sociol Humanities. 2022;7(6):42-52. DOI: https://doi.org/10.20431/2456-4931.0706005.

17. DJAGHROURI Djamila, ZERAIB Salah, et al. The Impacts of Morpho-Climatic Parameters on Pandemic Proliferations of Covid-19 between Expansion and Confinement in Semi-Arid Areas: Case of Batna City (Algeria). Int J Innov Stud Sociol Humanities. 2022;7(7):69-85. DOI: https://doi.org/10.20431/2456-4931.070707.

18. Benamouma, D. (2018): L'impact de la géométrie des espaces sur le confort thermique extérieur (Cas de la ville de Batna). Mémoire de magister (2018). Département d'architecture-Université Mouhamed kheider de Biskra.

19. Djaghrouri Djamila (2021). Fluctuation des ambiances thermiques extérieures sous l'effet du végétal dans les zones arides. « Cas d'une placette à Biskra ville ». Thèse de doctrat. Département d'architecture- Université de Mohamed khider , Biskra.

20. Lahm, E., & Bruse, M. (2003). Microclimatic Effects of a Small Urban Park in Densely Built-Up Areas: Measurements and Model Simulations. In 5th International Conference on Urban Climate (pp. 273-276), Lodz.

21. Yang X., Zhao L., Bruse M., and Meng Q, 2013.- Evaluation of a microclimate model for predicting the thermal behavior of different ground surfaces. Building and Environment, 60: 93-104. https://doi.org/10.1016/j.buildenv.2012.11.008

22. Tsitoura, M, Michailidou, M, Tsoutsos, Th, 2017. A bioclimatic outdoor design tool in urban open space design. Energy and Buildingshttp://dx.doi.org/10.1016/j.enbuild.2017.07.079.

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