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Passive Urban Cooling Strategies: The Contribution Of Water And Vegetation

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Abstract

This study focuses on evaluating the effect of natural cooling provided by vegetation cover and water in urban areas, as well as their microclimatic impact on the built environment during the hot season, in the humid city of Jijel. More specifically, it aims to compare, in a simplified and concise manner, different strategies proposed as scenarios by the ENVImet numerical simulation software. Compared to the initial case, the results confirmed that the blue and green scenarios produced a cooling effect and mitigated urban heat islands during the day

Keywords: sive cooling, outdoor space, végétation , simulation, water

1. Introduction

Urban areas are increasingly challenged by rising temperatures, particularly during the hot season, due to the combined effects of climate change and the urban heat island phenomenon. The emergence of the concept of green and blue spaces has opened up new fields of thought in terms of public spaces. The notions of urban ecology and control of use have put forward the analysis and the global perception of urban fabrics and more widely, everything that lives and constitutes the city. Green and blue webs seem to be vital strategies to be integrated into the urban development process and have significant positive benefits in urban areas, both in the short and long term in the face of global challenges such as climate change, biodiversity, air pollution and natural resource management and energy consumption [1, 2]

Thus, the green and blue network appears to be a central component in the regulation of thermal comfort in the public environment [3]. The influence of trees and water basins on comfort in urban spaces has been the subject of several experimental studies. Surface temperatures are reduced in the presence of trees and water and comfort is improved [4]. The effective use of vegetation in cities will be able to significantly improve the microclimate by reducing the air temperature by up to 4 ◦C by green roofs, 9 ◦C by using trees, and 12 ◦C by the vertical greening system. Rooftop greenery with trees, shrubs, and grass can reduce the overall building-cooling load by 20.01%, 18.85%, and 9.08%, respectively [5].

These results show that trees and water should be considered as real means for improving microclimatic conditions in outdoor spaces. The synergy of green-blue spaces seems to be effective, the reduction of air temperature was significant in the green-blue space [6], and the cooling intensity was significant not only within the edge of the blue space, but also extended to about 20 m away [7]. As for the blue space, evaporative cooling is an effective microclimatic adaptation strategy and can be chosen as a measure to reduce thermal stress in urban spaces [8].

Urban vegetation lowers the temperature locally, especially in summer. Indeed, urban greenery has a powerful impact on the role of passive cooling through the effect of air humidification and temperature reduction [9, 10, 11] and consequently on the cooling of the built environment [12] if the ventilation behavior of the building is correctly followed [13]. Urban vegetation can also be an effective strategy to reduce energy consumption in urban buildings by regulating the microclimate and shading solar radiation on building surfaces [14, 15]. Indeed, wind direction and speed have a significant effect on cooling [16]. Airflow effects generated by urban morphology, building geometry, and building layout that can rapidly dissipate coolness from the block must be considered [17, 18]. The size, shape and surface area of the vegetation cover influences the intensity of passive cooling [19]. The cooling effect is more effective if the vegetated area is large

[20] and the proportion of trees is high, which generates a mass effect and resistance to warm airflows. Tree cover has a significant cooling impact compared to grass cover; this variability was primarily a function of moisture content [21]. For every 10% increase in shrub and tree cover, the average temperature reduced between 0.07 and 0.04 ◦C.

2. Aims and method

The interest of this study is to propose development solutions to create islands of coolness in summer adapted to the climatic conditions (humid climate) of the city of Jijel (North-East of Algeria). The aim is to evaluate the natural cooling effect of the vegetation cover and water in urban spaces and their microclimatic impact on the built environment. More precisely, it aims at comparing, in a simplified and synthetic way, different bioclimatic strategies of adaptation in hot season. This research follows a methodology according to 5 steps:study context and climate, choice of case study, scenarios definition, numerical simulation and results and discussion

2.1 Study context and climate

This study focuses on the problem of urban warming during the hot season in the city of Jijel with a humid climate [Figure 1]. Some public spaces are so simplified, rudimentary in their development, devoid of vegetation that they contribute to the creation of urban heat islands. They do not have any refuge areas that are comfortable during hot weather.

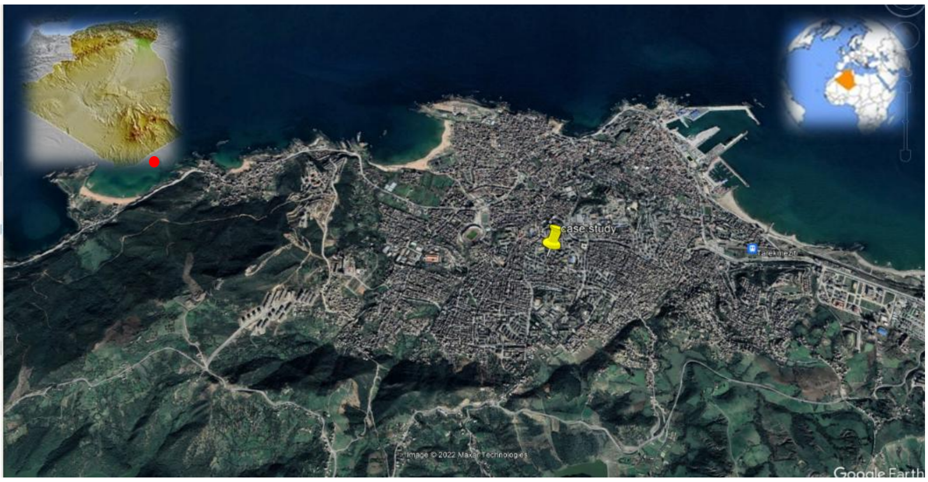


Figure 1. Situation of Jijel. Source: google map.

2.2. Climate

The region of Jijel is considered among the rainiest regions of Algeria. It is characterized by a Mediterranean climate, rainy and cold in winter, hot and humid in summer. Temperatures vary between 20C° and 35C° in summer to 5C° to 15C° in winter [Figure 2]. The highest temperature is recorded in August, which is considered the hottest month, with an average value of 26°C, maximum of 31.3°C and minimum of 20.8°C. In January (the coldest month), temperatures reach their minimum values with a monthly average value of 11.6°C, maximum of 16.3°C and minimum of 6.9°C. The variation in precipitation between the driest and wettest months is 136 mm.

Regarding humidity, the average humidity values are generally very high throughout the year and their seasonal amplitudes are relatively low, the minimum 69% is observed in July and August and the maximum 77% in January [Figure 2]. However, for the region of Jijel, the average evaporation on open water table exceeds 1000 mm / year in August and the minimum in January (40 mm / year). For the winds [Figure 3], the region of Jijel is generally crossed by winds of N-N.W and S-S.E direction:

- N / N.W winds are often strong winds that blow in the fall and winter (October to December and January to March) and affect precipitation.
- S / S.E winds generally blow from May to September

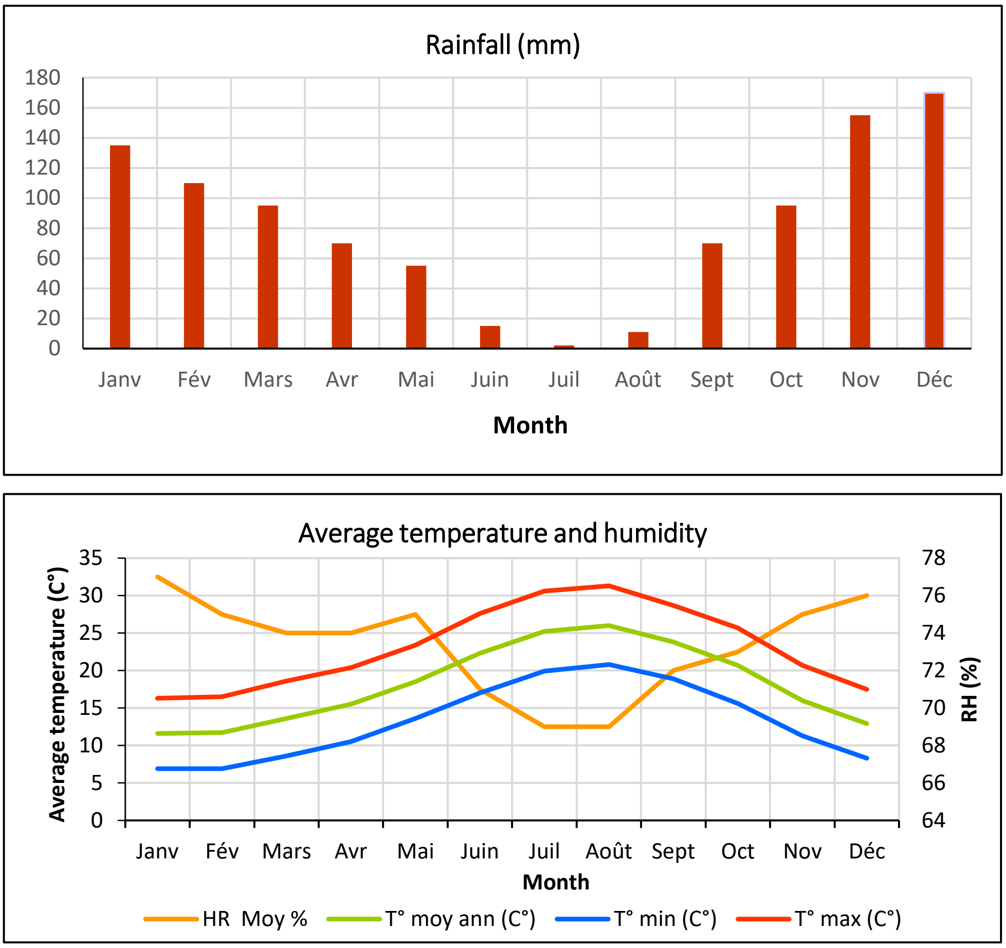


Figure 2. Air Temperature and Air humidity. Period 2010-2020.

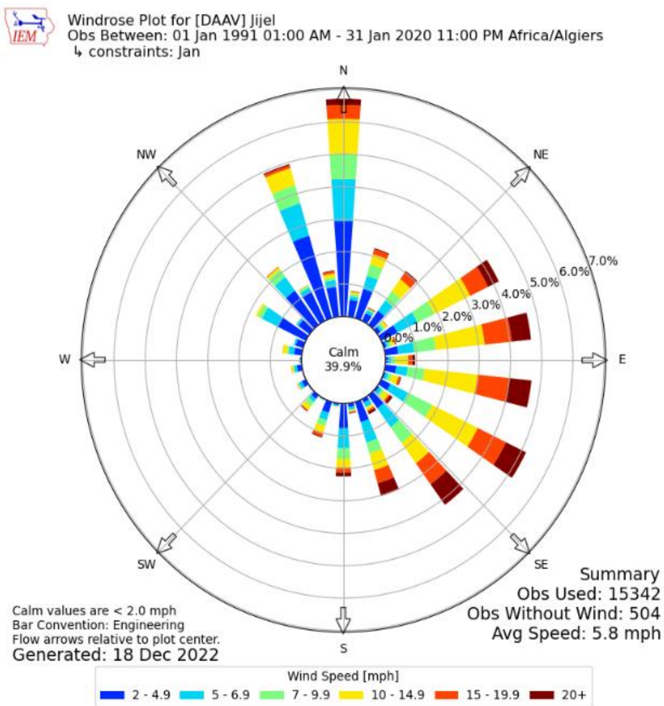


Figure 3. Annual wind rose. Period 1991-2020.

2.3. Study area

The study site is a collective building area located in Jijel. The buildings are assembled in U form creating semi-enclosed courtyards that serve as transitional spaces, landscaped green spaces or even parking areas [Figure 4]. The heights of the buildings do not exceed 15.30 m on 5 levels (R+4).

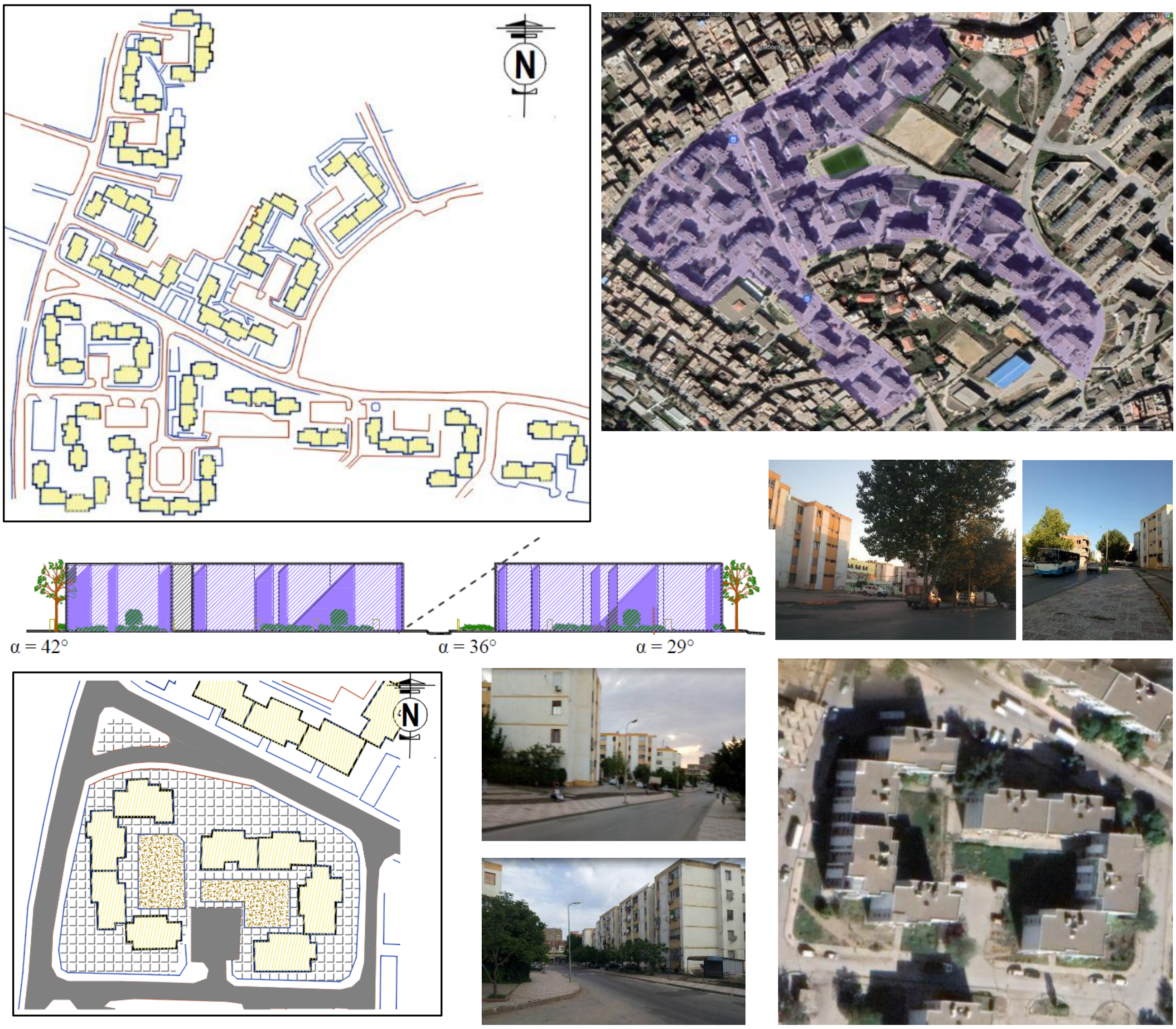


Figure 4. Case study.

3. Numerical simulation

The microclimatic assessment was developed through numerical simulation using ENVI-met software by introducing the following scenarios [Figure 5]:

- Initial scenario: simulation of the study case at its initial summer without any modification of the outdoor facilities.
- Green scenario: Denser and more important vegetation in the central space. The trees used are species already existing in the city, like: Platanus acerifolia (between points P1 and P5), Pinus tree , Cypress
- Blue scenario: replacement of vegetation by water pond. These three water masses are static and dispersed. The depth is 1m for all ponds. The rectangular shape marks the first pond, covers an area of 240 m^2 and a water volume of 240 m^3. The second, has an irregular shape, and cover an area of 200 m^2, and a volume of 200 m^3. The last pond, has a trapezoidal shape, has a surface of 174 m^2 occupying a volume of 174 m^3

All three scenarios have the same sky openness factor 'SVF' [Fig.8]. The urban form variable was not taken into account.

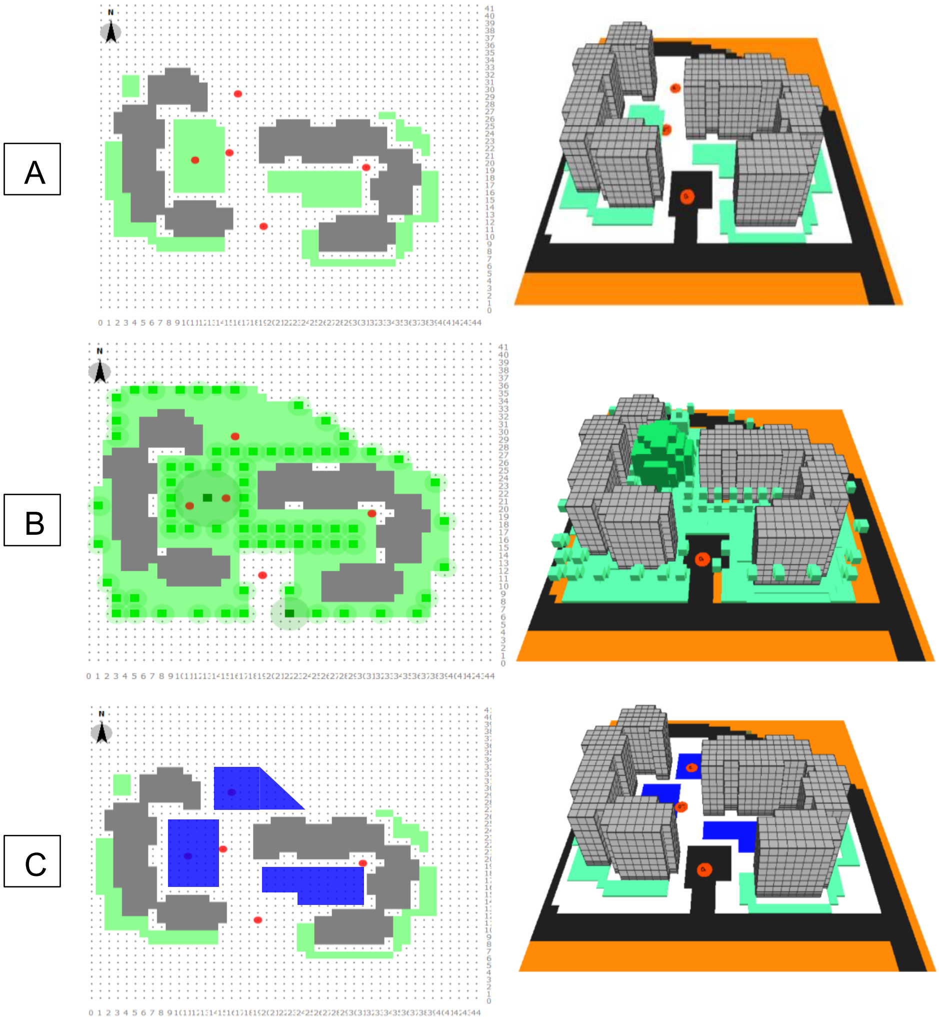


Figure 5. Suggested scenarios. A: Initial scenario. B: Green scenario. C: Blue scenario.

Details of the parameters introduced to the configuration file for simulation

Parameters introduced		
Situation		Jijel, Algeria Longitude : 5° E Latitude : 36°48' Climate: Mediterranean, humid in summer
Simulation period		Summer
Simulation day		21/08/2022
Simulation time		From 8 h to 20h (13 h).
Parameters	Wind speed at 10m [m/s] at 08h	2
	Wind direction	90° Est
	specific Humidity –[g/kg]	8
	Relative Humidity [%] at 08h	60
	Initial temperature of atmosphere [K] at 08h	300.15
Building	Heat transmission of walls [W/m.²K]	1.37
	Roof heat transmission [W/m.²K]	1.3
	Albedo of walls	0.3
	Albedo of roof	0.18
Cut height [k]		3 [1.40 m]

Figure 6. Measurement points.

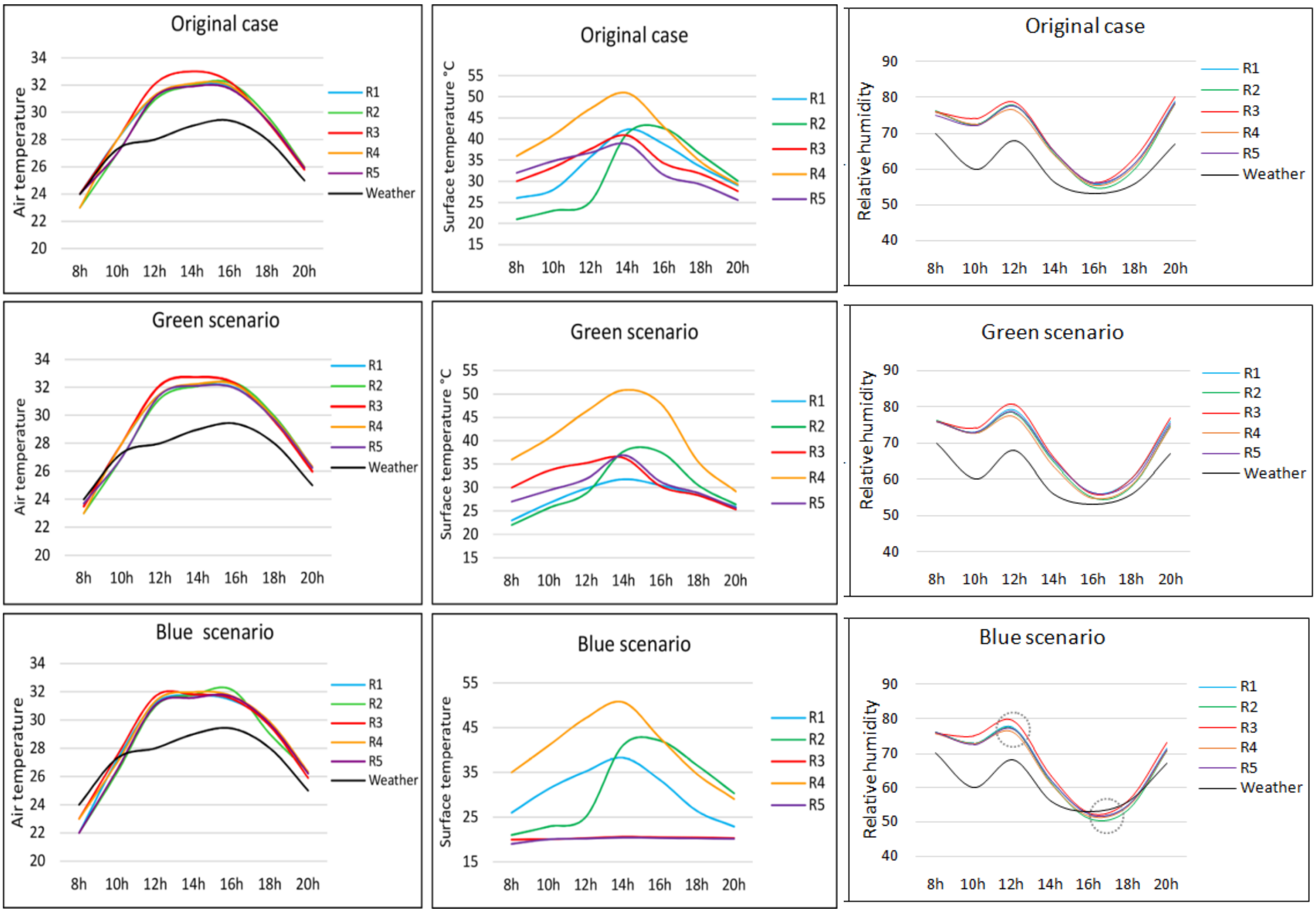
3. Results and discussion

3.1. Comparison of the three scenarios

The results indicate significant temperature heterogeneity throughout the day. The air temperatures in all the points examined for the three scenarios are high compared to the weather data; this will highlight the effect of the heat island except at the beginning of the day in the blue scenario where the temperatures are lower than the weather data [Figure 7]. However, a discrepancy between the minimum and maximum temperatures has been raised in the hottest hours (between 12:00 and 18:00).

By comparing the air temperature maps for the initial case, the green and the blue scenario, it is possible to see that the blue scenario presented the coolest temperatures [Figure 7], especially at points 1 and 5 (which represents an estimated reduction of 1.41°C compared to the initial case). It produced a remarkable cooling effect compared to the initial case. The extension area is more reduced than in the green scenario. In addition, the coolness island induced by the presence of a denser vegetation can be clearly observed in the maps (which represents a reduction of about 0.88˚C compared to the initial case).

The implementation of the three water basins with fountains in the blue scenario and dense vegetation in the green scenario resulted in the creation of two important urban cool islands. Surface temperatures are reduced in the presence of trees and water. The surface temperature recorded at 2pm at point 5 is 20.43°C in the blue scenario [Figure 7], 30.18°C in the green scenario and reaches 32.63°C in the initial case, which will improve comfort.



A remarkable cooling effect can be clearly observing in the maps (which a reduction of temperature compared to the original case)

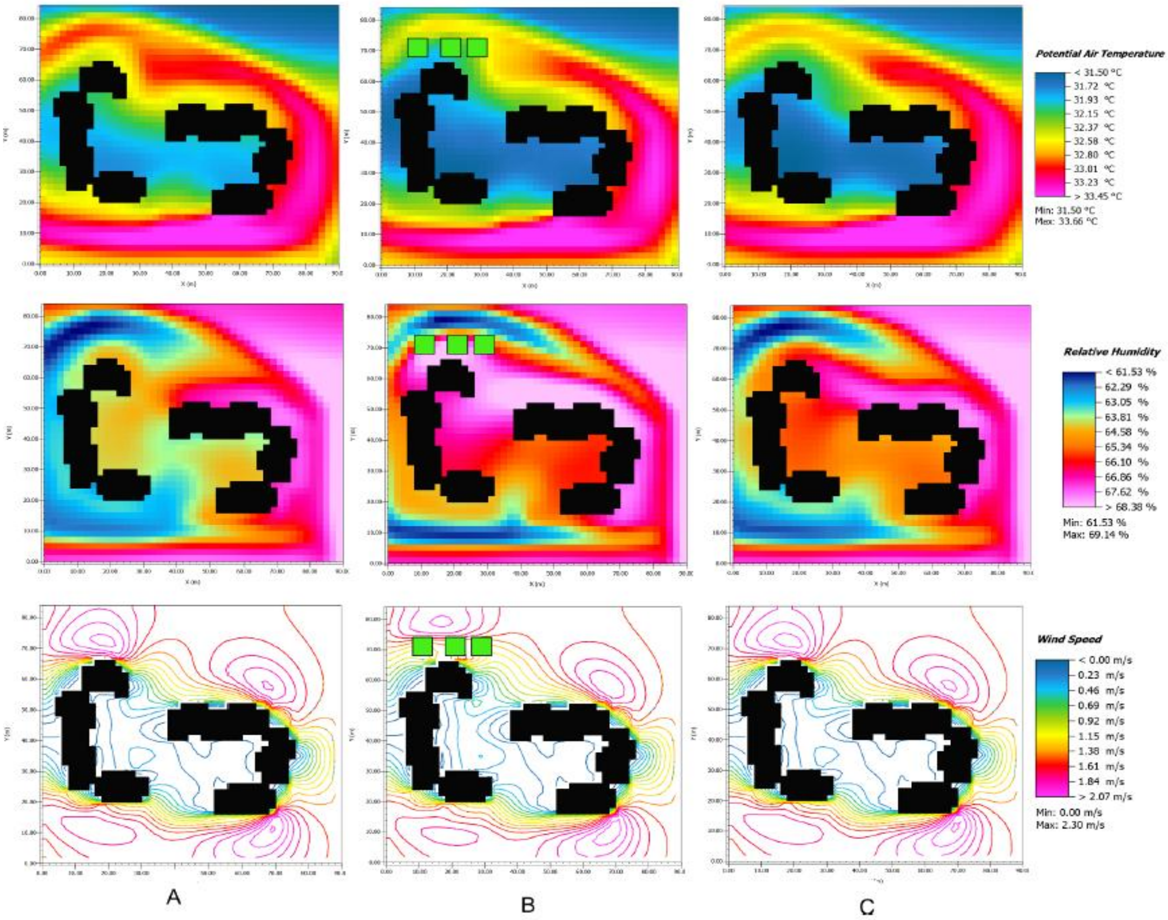
- In blue scenario: the maximum temperature difference between blue zone and the surrounding areas reaches around 2◦C during the day
- As soon as you leave the blue zone, an immediate increase of 2◦C appears.

In green scenario: the maximum temperature difference between the entire green zone and the surrounding areas is about 1◦C during the day. As soon as you leave this green zone, an immediate increase of 1◦C appears.

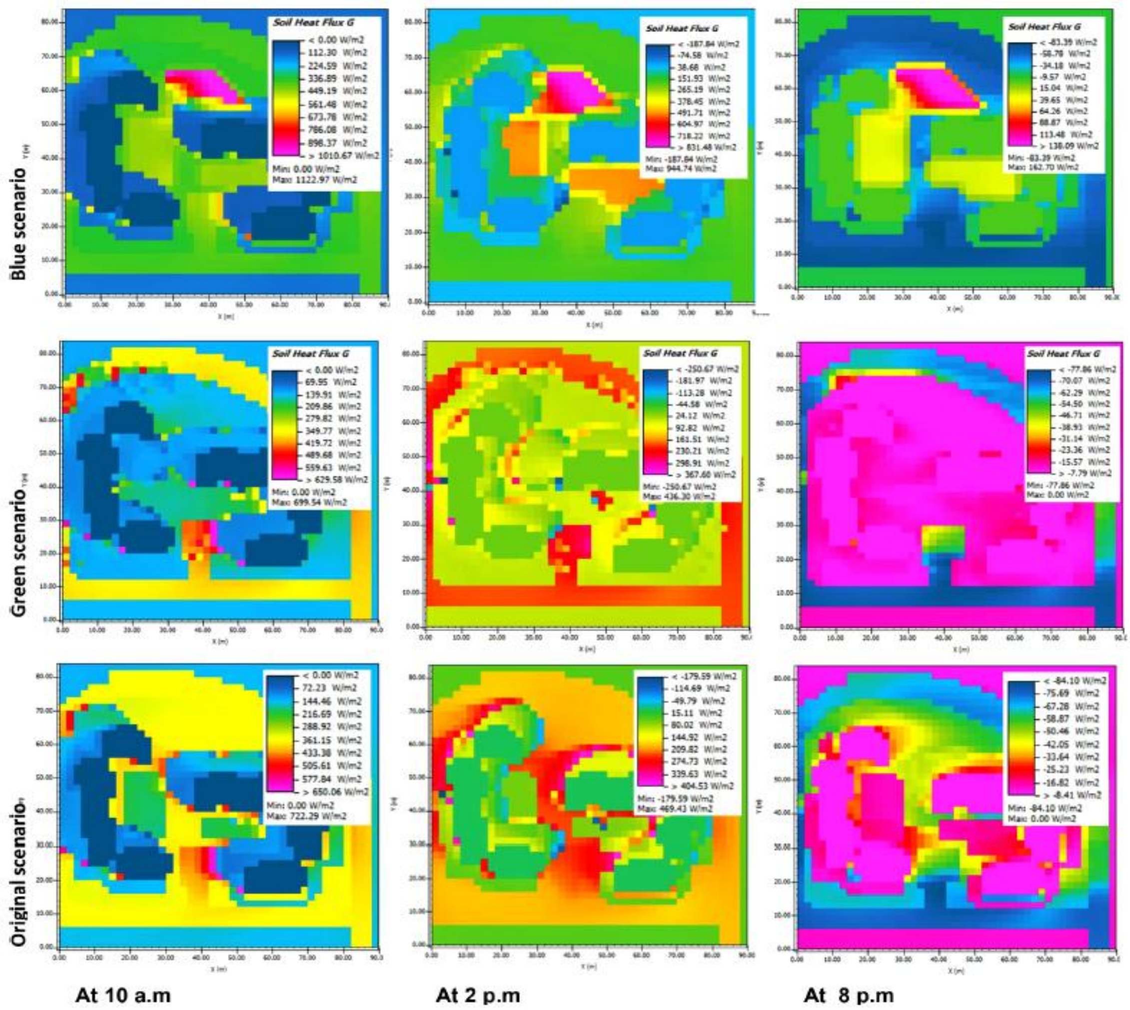
Also, the simulation show that:

The cooling effect of the water pond varies depending on the time of day. These variations can be explaining by the diurnal variations of the evaporation flux. Thus, during the evaporation of a water zone, a large part of the solar energy input is lost in the form of latent heat.

This is why the temperature of the water in the two ponds P3 and P5 is then lower than that of the air during the day (does not exceed 20◦C).



Air temperature, relative humidity and wind speed data results (at 2 p.m). A: Original scenario. B: Green scenario. C: Blue scenario.



Soil Heat flux in the three scenarios.

4. Conclusion

The numerical simulations carried out on the initial case and the proposed scenarios have made it possible to compare the devices and their influence on the mitigation of daytime urban heat islands in hot periods.

The benefits of vegetation for the cooling of public space can be summarized as the provision of shade and humidity, the absorption of CO2 and pollution by the foliage as well as of water by the soil, the stabilization and enrichment of the ground. In addition to lowering temperatures, the reintroduction of nature in the city promotes biodiversity through the diversification of wildlife and provides a more pleasant environment for residents. Moreover, water is an ecological solution allowing humidification and hydration by evaporation. It absorbs strong solar radiation and plays the role of a thermal regulator

Indeed, the vegetation cover of urban spaces and water bodies (ponds and fountains) are devices that reduce overheating, create an urban coolness island effect (IFU) and produce outdoor thermal comfort conditions very close to the ideal for pedestrians, as well as a relatively significant overall reduction in the energy demand of surrounding buildings. It is through these effective passive strategies to reduce the effects of heat islands that environmental and energy savings goals must be generated.

The cool island is therefore proving to be one of the most effective passive tools in the urban environment. It has aroused a sudden and shared interest because it involves issues that cut across public health, the economy, social ties, etc. The health crisis of Covid-19 amplifies the challenge of developing at the scale of municipalities a strategy of urban resilience based on the place of nature in our public spaces given the increase in the use of green spaces.

Declaration of conflicting interests

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