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BLUE AND GREEN INFRASTRUCTURES AS A RESILIENT CLIMATE STRATEGIES IN RIVER URBAN REDEVELOPMENT PROJECT

A. Benbrahim S. Abdou

Faculty of Architecture and Urban Planning, Constantine 3 University of Salah Boubnider, Constantine, Algeria, alaben612@gmail.com, saliha.abdou@univ-constantine3.dz

Abstract- Controlling the climatic constraint becomes a major fact consider for architectural and urban compositions. Studying water and vegetation impacts on adaptive greening measures is necessary to strengthen ecological resilience and human well-being in urban context. This paper aims to study and assess how Blue and Green Infrastructure (BGI) can be optimized to mitigate climate change effect, and to enhance local microclimate conditions for users in an urban regeneration project of the banks of the main river in Algiers, Measurements were carried out in eight (08) monitoring points presenting different site characteristics, followed by a simulation phase using ENVI-Met 3.1 Software. Three scenarios were performed A: the current land use, B: without water body and C: more dense vegetation cover by increasing the number of trees. Results were as follow: the maximal temperature estimations were registred in no vegetation areas, the downwind area had significant role for evacuation of hot waves where temperature variations reached 6.7 °C in proximity to water body. The combined binomial presented a cooling effect for air temperature which also decreases the relative humidity till 12%.

Keywords: Thermal Comfort, Outdoor Spaces, Vegetation, Water Body, Ecological Resilience, ENVI-Met.

1. INTRODUCTION

Environmental concerns become a major part in official speeches and urban design policies; due to the degradation of the urban thermal environment[1], the vulnerability of ecological balance caused by an uncontrolled urbanization process. Over 55% of the planet's population are housed in densely populated zones, a percentage that's looked forward to attain 68% by 2050 [2]. Consequently, more constructions and mineral surfaces that lead to the lack of green surfaces, increasing intensity and frequency of heat waves, combined with the urban heat island effects and could have serious implications for human health. Intending to fulfill a prosperous conversion to a livable, resilient and sustainable city [3], saucerful urban design implies the best uses and exploitations of site's natural components, like green belts and water bodies, that could be effective regulating tools at local microclimate scale conjointly for urban planners and decision makers.

Blue and Green spaces are one of the most important areas in sustainable cities, where users can take part in social life, accommodate pedestrian traffic and participate in recreational activities. Even more, the outdoor environment quality affects the livability and the use of these areas[4]. It has been found that renaturing urban Plans has a favorable social and environmental effect in cities, and makes effective possibilities for adaptation to alterations and climate change[5], therefore raising urban resilience to risks, like shortages in water supply, floods and heat waves, along with other possibilities for small-scale climate mitigation [6]. In fact, more than being beautiful places, natural spaces in cities have to be considered as urban infrastructures to be planned, engineered and maintained [7].

Modern architecture and urban planning confronts various threats to demonstrate their ability for adaptation to sustainable development and safekeeping of environment's demands [8]. An assessment of environmental repercussions makes it necessary to relate multidisciplinary knowledge of ecology, geography environmental sciences, biology, and Earth sciences [9].

Several researches focused on the importance of creating comfortable and suitable environments. Where The control of microclimatic conditions directly impacts the thermal comfort, which contributes to the well-being of its users. This state requires deep knowledge of climatic features, and adaptive measures to put in to deal with the constantly developing climate changes risks as planed vegetation, trees as well as larger green networks in combating the phenomenon consequences.

According to [10], strategic implantation of trees allows a reduced air temperature from 2 ºC until 8 ºC. Mainly the heat waves and relative humidity as important natural cooling elements. Vegetation plays a determinant role in the global cities' temperature regulations [11]. From a human-biometeorological point of view, shading by tree canopies is most important [12], particularly in urban open spaces, where trees present advantageous skills to mitigate hot waves through evaporation-sweat mechanism, Decrease air temperature and particularly prevent streets from receiving direct solar variation by providing shading and cooling skills [13].

Water bodies have also been ascertained to be effective methods for mitigating air temperatures in urban contexts. However, in scientific literature the water body effect on thermal urban climate has not been thoroughly studied and assessed as the vegetation impacts. While it can be considered as a major natural cooling element in urban environments. According to [14], a water body has the ability for getting around 2 °C to 6 °C lower in the surrounding area mainly in hot and humid summer days.

In Algiers, a major urban regeneration project at El-Harrach water-front is supported by the Algiers 2029' strategic plan, introducing adaptation and mitigation measures for the water body, and planting more vegetation in surroundings, to create more comfortable green open spaces, better use of the river and urban resilient territories.

The current study explored how do the binomial: water body and vegetation impacts the thermal comfort, especially the variations of temperature and relative humidity, by integrating in-situ measurements and numerical simulations based on modeling approach, by simulating and evaluating interactions potentials between natural components, local environment and climate innovations, in bioclimatic architecture and green urbanism to achieve resilient goals and enhance human wellbeing conditions [3].

2. SITE INVESTIGATION

The current study was conducted in 'Prise d'eau' park at the center of Algiers (Algeria) situated at 36.42 Nord and 3.07 Est. 4 km from the Mediterranean Sea, characterized by a Mediterranean climate; cool and wet in winter, dry and hot in summer, with average maximum temperature of 36 °C occurring at 3 pm and high levels of humidity that can reach 90% in summer. The wind comes relatively from North / North-East in summer, with annual average speed of 4.2 m/s at meteorological station.

This site with varied natural potential was chosen due to several considerations: As an important watercourse in the capital and a part of large urban regeneration project of El-Harrach River in Algiers, where the authorities decided to develop the park for creating more recreational areas, by improving the social and environmental conditions. Characterized by water body as a central element, surrounded by vegetation on west side, small high-rise residential buildings on east side, and street canyons with asphalt (Figure 1). The percentage of blue spaces is 12.5%, vegetation cover is mostly low containing lawn and trees. This variety aims to explore how adapted blue and green infrastructure can improve ecological resilience and enhance local climatic conditions.

3. MATERIALS AND METHODS

Measurements were carried out in eight (08) monitoring points presenting different site's characteristics: vegetation degree, opening site and compact residential area (Figure 1). Each of the selected measurement points presented different characteristics compared to the other points according to a variety of parameters (microclimatic, physical, natural) summarized in Table 1.

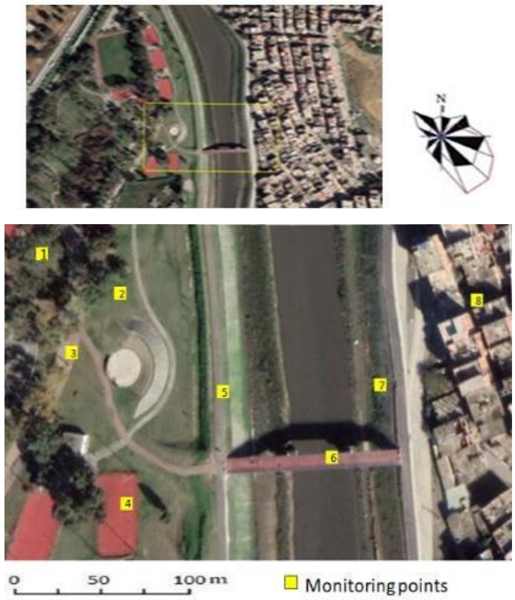


Figure 1. Site investigation 'Prise d'eau park' Algiers [15]

Table 1. Characteristics of monitoring points

Position	Site features	Objective / Impact
P1	Trees shade	Tree's typology
P2	Grass without trees	Trees impact / Green surface
P3	Mineral area	High-Alebdo material
P4	Asphalt area	Material-albedo
P5	Left bank	Water body impact
P6	On the bridge	Interaction: water vegetation / Opening site
P7	Right bank	Water proximity
P8	Compact residential block	Urban morphology

3.1. Site Measurement

Various techniques have been usually used to study the vegetation's effect on thermal urban surrounding: simulations, filed measurements and also thermal remote sensing [3]. At this stage, we want to highlight the impact of water body and vegetation in improving thermal comfort on micro scale through two phases:

Site measurements were performed during July 5, 2019 a typical hot season day, where relative humidity, air temperature, and wind speed were the major microclimatic parameters recorded at a height of 1.5 m for four times intervals along the day from 9 a.m. until 7 p.m., the period in which people more likely to participate in outdoor activities in summer season. The measurements were carried out. using digital instruments (Multifunction instrument (LM800).

3.2. Modeling and Simulation Phases

To assess the effect of the binomial water body-vegetation on the study area, series of simulations were done by ENVI-met 3.1. Three scenarios were generated: the first Scenario A: was the current study case, in the second scenario B: the water body was excluded from the study area, while in the third scenario C: both water body and intensive vegetation (lawn and more number of trees) were included. The aim is to assess and compare the binomial performance and their impact on the thermal environment.

The simulation date was the same July 5, 2019. The meteorological parameters required by ENVI-met were measured in the study area to be used as input for simulation model. Simulation starting time was at 8 a.m. running 12 h. The mesh size was 1×1×1 m and a total of 240×140×30 m gird was set up. Required data for the configuration file of the ENVI-met Software are summarized in Table 2.

Table 2. Data for the configuration file of ENVI-met model [16]

Input category and parameter	Value(s) used
Start simulation day	05.07.2019
Start simulation at time (HH:MM:SS)	08:00:00
Total simulation time in hours	12:00
Wind Speed in 10 m ab. Ground [m/s]	4.8
Wind Direction (0:N..90:E..180:S..270:W..)	45
Roughness Length z0 at Reference Point	0.1
Initial Temperature Atmosphere [K]	301.15
Specific Humidity in 2500 m [g Water/kg air]	5
Relative Humidity in 2m [%]	60%

3.3. Measurement Phase Results

Figure 2 shows the Air temperature, wind speed and relative humidity evolution during measurement phases in eight monitoring points along the day from 9 a.m. to 7 p.m. According to these graphs and by crossing recorded data, the characteristics of each point and its interactions impact differently the microclimatic parameters as Figure 2.

Regarding the wind speed variations diagram as well as orientation (N-NE in summer), urban morphology plays a decisive role, it can be stated that the large opening site is a favorable area for high wind speed that directly influences drop air temperatures as (P6, P3) and reaches variations up to -6.7 °C. Moreover, the wind path mechanism, introduces vertical ventilation [17]

As shown in Figure 2, the vegetation cover and the location of the trees significantly affect the temperature degree, the P4 point without trees recorded the highest temperature of 39.2 °C. also, Air temperature variation between vegetated area and artificial urban materials are important, as P1 recorded the lower values of temperature, and the difference of 4.4 °C lower was recorded between P1 and P4 at 12 p.m.

The presence or proximity of water body modifies the microclimate, particularly in terms of air relative humidity, which exceeds 70%, unlike air temperature degrees which remain relatively lower due to the effect of plant's evaporation-sweat mass and interactions with the surrounding climate conditions.

4. SIMULATION

4.1. Validation of ENVI-Met Model

Envi-Met is a large used simulation software presenting interactive tools that can seeks different aspects of complex microclimate parameters. In our study case, a 3D microclimate model designed to reproduce the vegetation-air-outdoor spaces interactions in the study area, presenting typical resolution down to 0.5 m in space and 1-5 s in time [16]. Enables a deep understanding and fine analyze for some climatic parameters including wind speed, relative humidity, air temperature impacts at local microclimate.

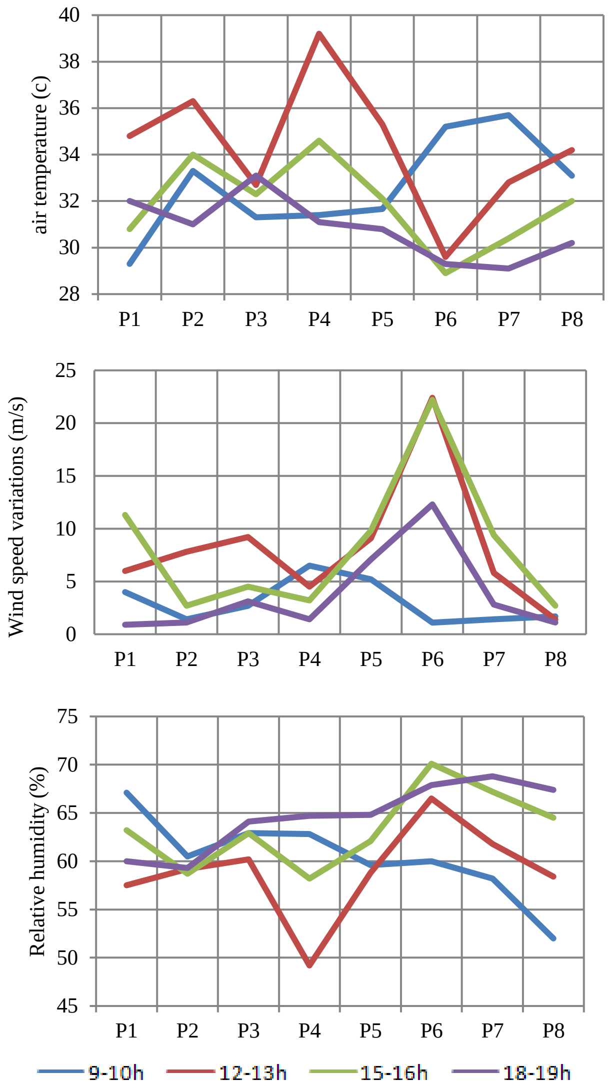


Figure 2. variations of measurement phase: Air temperature, wind speed and relative humidity

The Rootmean Square Error (RMSE) used by Yang et al. (2013)[18], presenting estimation interval error between the measured value and the simulated value. For our case, the RMSE of monitoring points 1-8 is 0.56. A minim value, and then the introduced microclimatic data may be well forecasted.

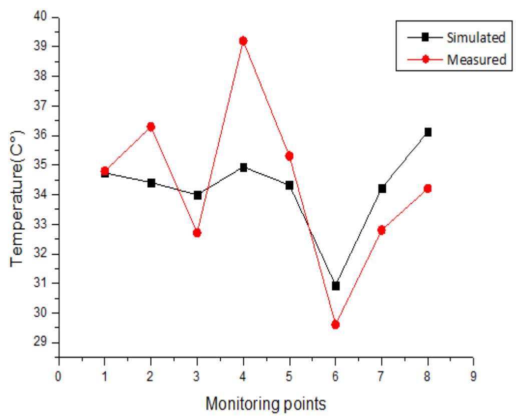
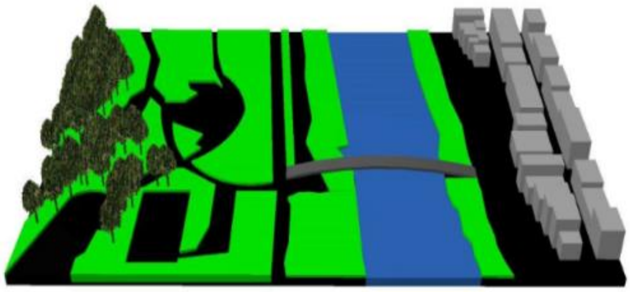


Figure 3. RMSE graph comparing simulated and measured temperatures in 1-8 points at 10 a.m. [18]

4.2. Simulation Scenarios

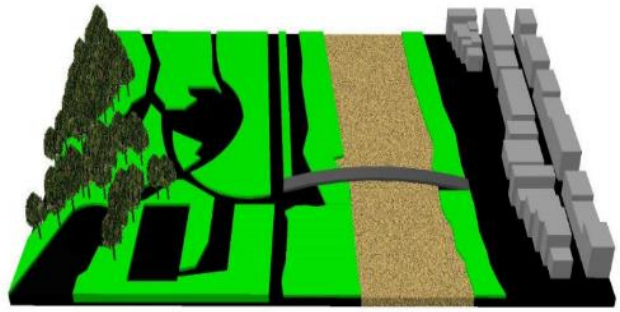
To examine interaction effect of water bodies and vegetation, three scenarios were selected as Figure 4.

Scenario A: current situation (presence of trees and water body)



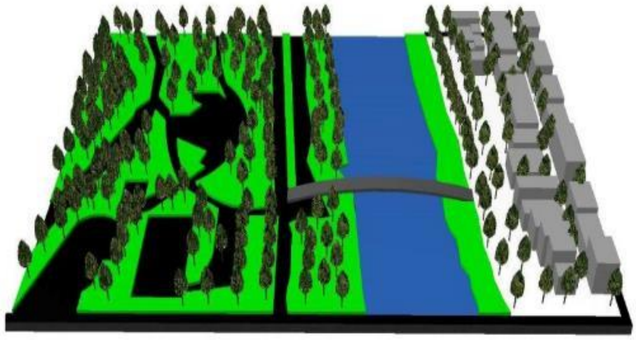
(a)

Scenario B: canceling the water body from Scenario A



(b)

Scenario C: presence of the binomial but introducing the green pathway on the both river banks



(c)

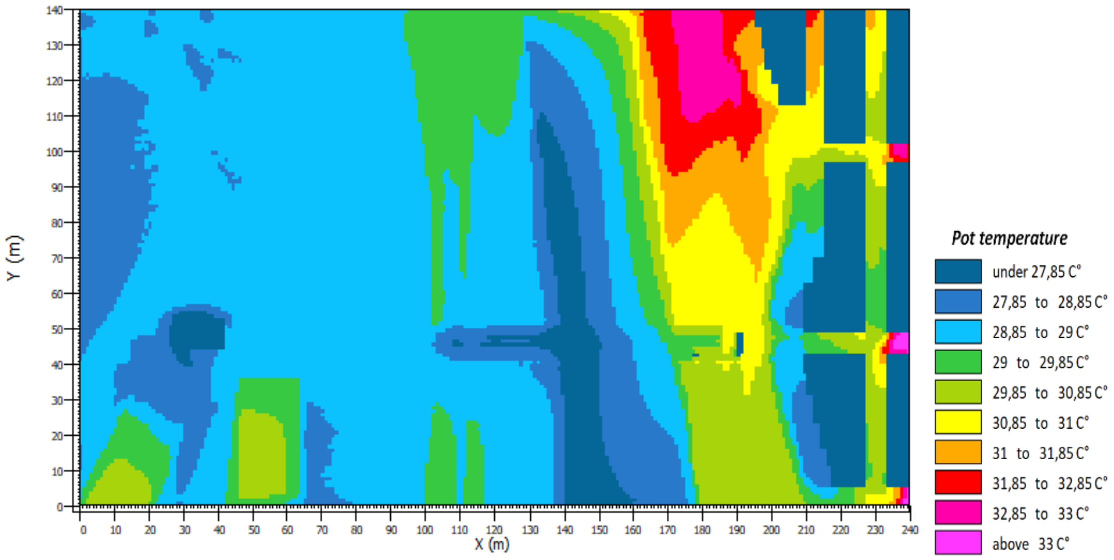
Figure 4. Different configurations for simulation scenarios.

4.3. Simulation results

In this section, the variation results for different scenarios of air temperature and Relative Humidity simulations are receptively presented, using spatial maps (contour maps) in the study area. (Figures 5 and 6) were set up utilizing LEONARDO software, a presentation section is involved in ENVI-met. Which exposes the results of the simulated variables in color-coded ranges [12].

4.3. Simulation Results

4.3.1. Simulation Results for Different Scenarios (Air Temperature Variations)



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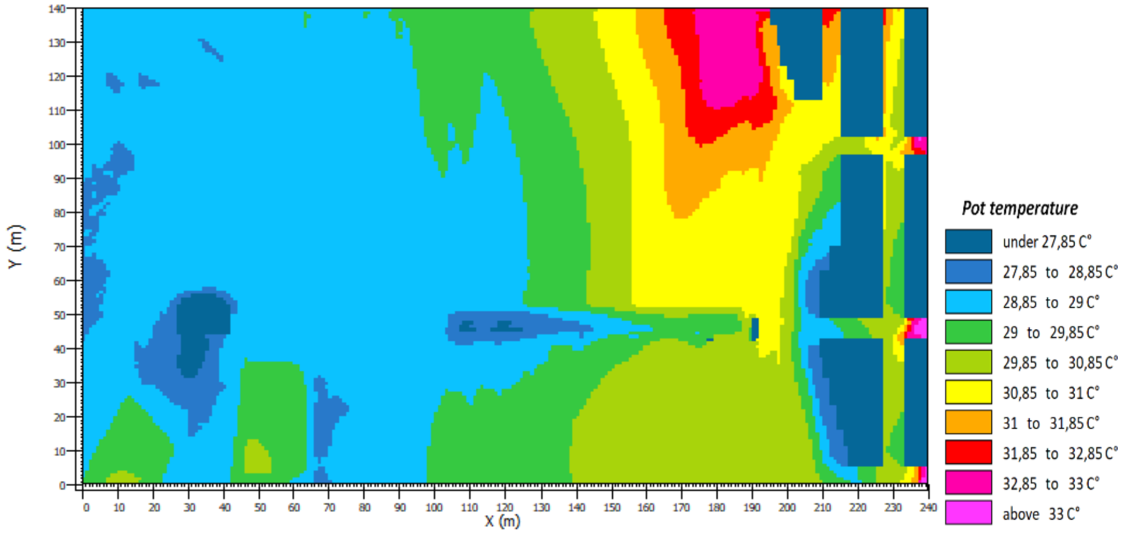

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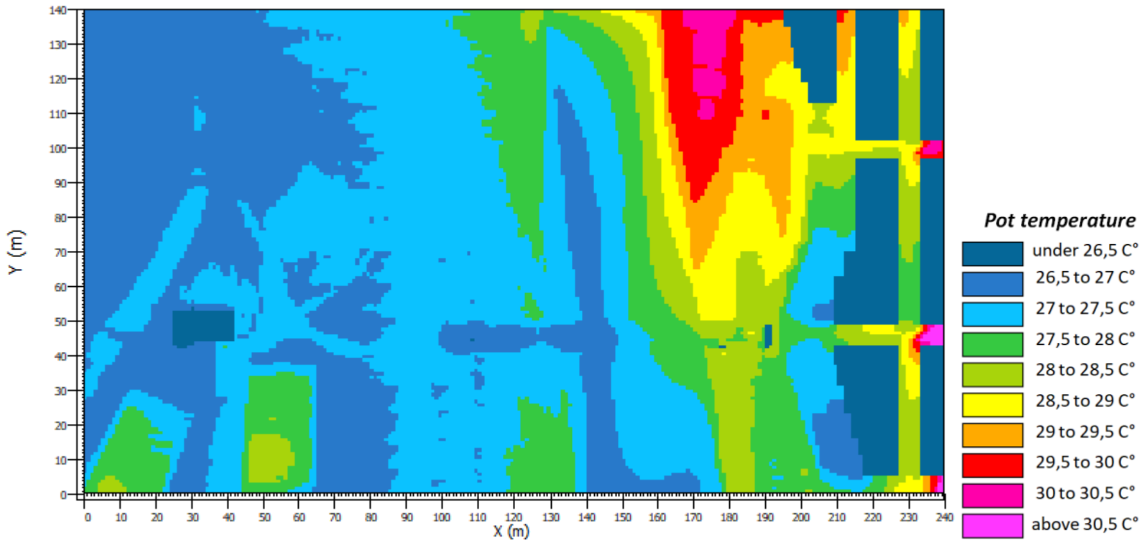
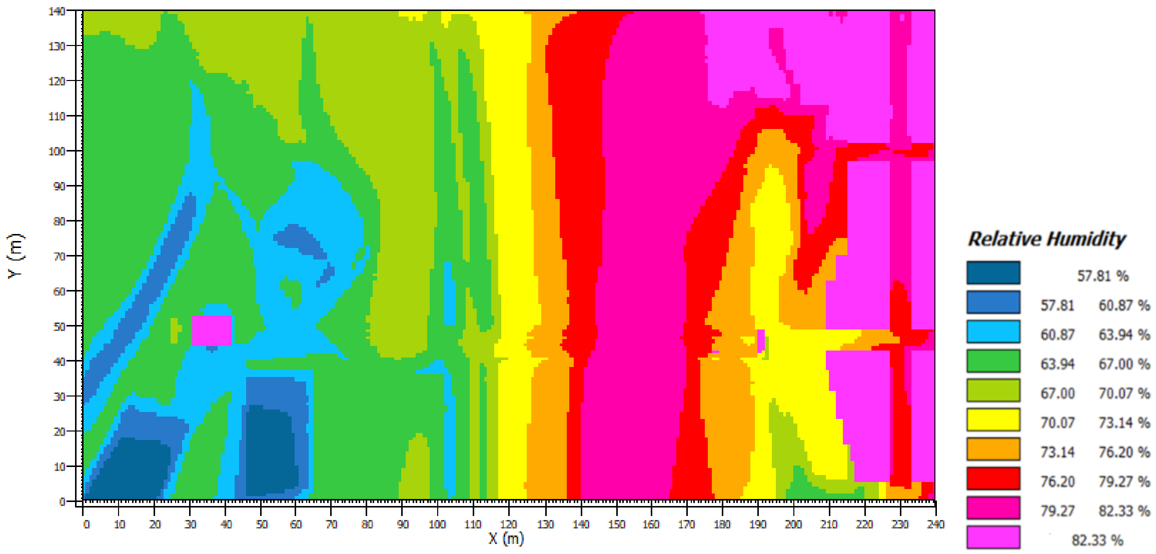


c

Figure 5. Simulation results for different scenarios (Air temperature variations) a: Scenario A current land use, b: Scenario B without water body, c: Scenario C Green pathway + water body

4.3.2. Simulation results for different scenarios (Relative humidity variations)



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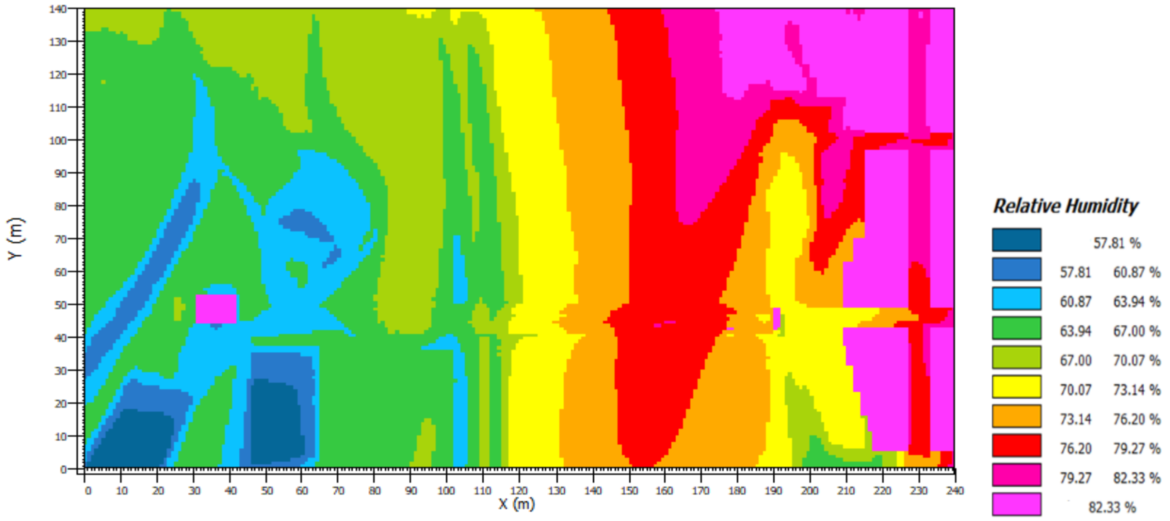

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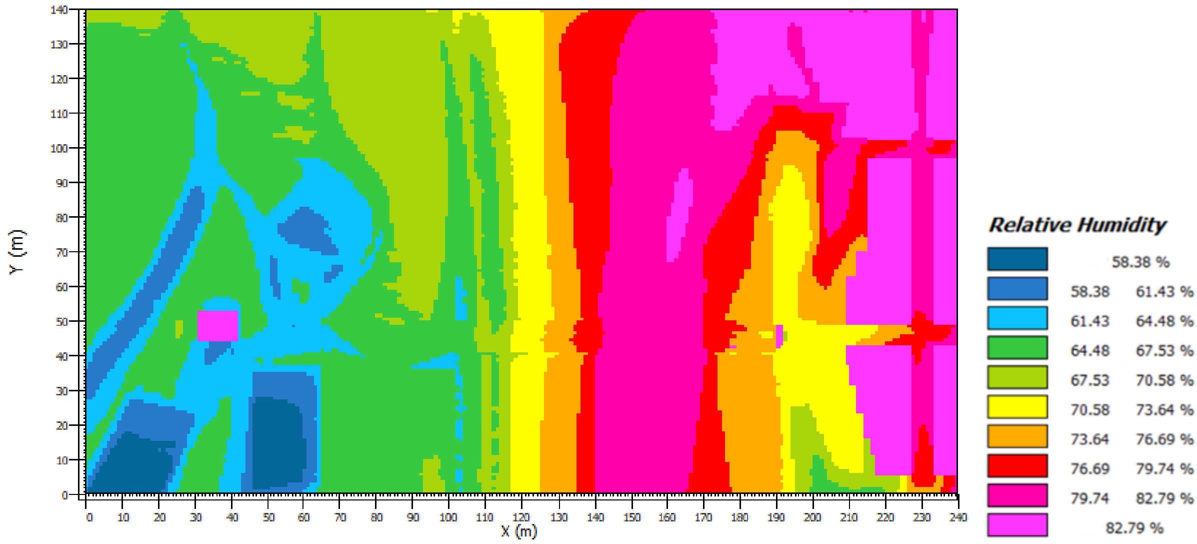

c

Figure 6. Simulation results for different scenarios (Relative Humidity variations) a: Scenario A current land use, b: Scenario B without water body, c: Scenario C Green pathway + water body

5. DISCUSSION

5.1. Current Land Use Configuration

Simulation results of air Temperature as well as relative humidity are respectively shown in (Figures 5-6) via spatial variations of the study area in three different scenarios.

The spatial variations of temperature can be observed in three major sections of the site: the compact urban canyon, the water body surrounding area and the vegetated area. In the right river bank, superior temperatures are observed, while were lower in the vegetated area, which explains that trees moderates air temperatures in the surrounding areas. The difference is caused not only by the vegetation cover but also due to the proximity of the water body.

The variety of temperature rates in scenario (a) was 27-33C°, representing the highest range comparing to other scenarios. The highest temperature (3.85 °C) this result is due to reflection of building materials and the absence of vegetation in the east area.

5.2. Water body effect

As Figure 2 shows in the second scenario, when water body was excluded; the mean temperature is getting higher and the cooled area shows a decreasing trend (39.1 % for 26-28 C° temperature range), what explains the significant cooling effect of waterbody on the surrounding area, The effects are larger above the water surface than in the other levels and confirm its greatest effect on temperature reduction. According to K.R. Gunawardena et al. (2017)[19], the waterbody's characteristics as well as its interactions with local microclimatic conditions are influential factors for the capacity to decrease local air temperatures.

5.3. The effect of Green Pathway and Water Body

The different segments of simulation field have demonstrated that the left river bank presents the greatest cooling effect, this is mainly due to the raised number of vegetation cover. In scenario C, by adding the green pathway on the left side, and a row of trees on the right one, the range of lower temperature (less than 27.5 °C) was expanded to 35.7% of the total area, mainly in the left river bank with increased vegetation. On the one hand, because of the direct overshadowing of solar emissions by trees located on vegetated areas [12], on the other hand, the photosynthesis mechanism significantly helps to lower and evacuate heat in surrounded area [20]. It also confirms that trees submit better shading efficiency compared to other cooling processes [21].

To further compare the cooling effect of each greening scheme scenario, Figure 7 shows a proportions histogram of different temperature variation grades for simulation scenarios. In scenario 2, the temperature range (26-28 °C) was 39.1%, and then expanded to 68.7% in scenario (water body + green pathway) where the percentage of lower temperature values had definitely increased. The proportion of other temperature range (above 30 °C) had gradually decreased conjointly with the rise of other proportions (22.8% to 26.4 to 13.5%) respectively from Scenarios 1, 2 to 3.

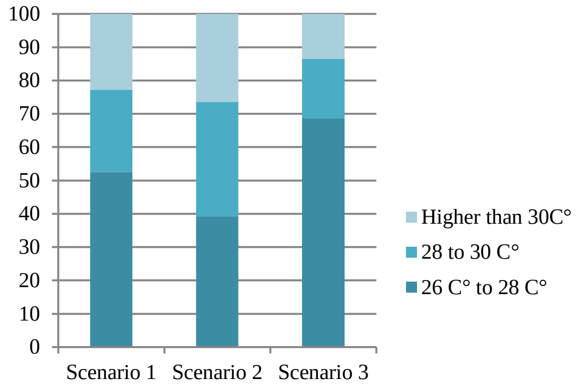

Figure 7. Proportional distribution of temperature range variations

Different scenarios did not seem to exert a significant impact on relative humidity, higher values were observed in all simulation scenarios. In the right river bank, values were more important than in the left one and exceed 82%, it can be ensured that introducing more number of trees did not enhance relative humidity values in significant way; nevertheless it can effectively decrease the air temperature values (Figure 7). What confirm the statement of Herath et al (2018) [20] that augmentation of existant water and vapor in air can increase the relative humidity, resulting in reversed lower air temperatures in the site.

5.4. The Wind Flow Effect

Wind, other fundamental cooling factor in the waterbody surrounding areas, its direction and strengthens can modify the proportions of the cooled surfaces [22]. The maximum cooling value observed -6.7 °C when the downwind directly impact the green pathway in the left river bank, what explain that interactions between evaporation-sweat and wind velocity impact, it's a key factor to moderate the high air temperatures. Also confirm that wind flow provides major assets for the high rates of humidity, since it helps to evacuate the saturated air. Furthermore, wind velocity can also positively affect the leaf boundary-layer and improve the water potential gradient[23].

The variables discussed above revealed that greening scheme must consider wind flow interactions with air temperature and relative humidity as efficient cooling mechanism.

5.5. Urban Design Implications

Recently, a few analyses take into account the complementary role for both blue and green spaces, acting as integrated infrastructure networks able to provide comfortable solutions mainly for environmental requirements. In external urban environments, where different complex buildings and contrasting surface materials, vegetation and water bodies should be considered as efficient alternative for mitigating Urban Heat Island. On the one hand, because effect of the moderate heat transfer effect between water and vegetation (combining shading, evaporation and ventilation interventions), on the other hand, it has recently considered as imperative occasion to promote resilient greening schemes [7] which can settle urban and ecological issues discussed above, and must take part in various figures of urban greening plans to provide better performance design [12].

6. CONCLUSIONS

This paper has highlighted the importance of blue and green infrastructures combination in urban redevelopment project of Oued El-Harrach in Algiers, as a natural process in combating urban heat effects. During the three scenarios, different cooling effects were observed, in air temperature degrees and also the size of cooled area as follows:

The results showed that the combination of vegetation and water body is more effective in mitigating air temperature, offering better cooling ranges among different sections which enhance the thermal environment than other scenarios.

In Mediterranean climate, the downwind direction and wind velocity are important factors that affect positively the microclimates conditions, mainly the high rates of relative humidity.

Vegetated spaces via trees showed a synergistic cooling effect, where shading, evapotranspiration and ventilation are natural key processes and explain the average differences in different sections of the case study. Yet like other urban sustainability approaches, Blue and Green infrastructure considered as 'nature based solutions' can be a good efficient strategy to support urban climate change resilience, not only to improve the thermal environment conditions, to promote social, economic and wellbeing sides [7], but it may be efficient strategy which consider all aspects of livability and sustainability in the urban environment.

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BIOGRAPHIES

Ala Eddine El Mahdi Ben Brahim was born in Batna, Algeria, 1988. He received the B.Sc. and M.Sc. degrees in the field of Environmental Quality, Architecture and Landscapes (2017) from Polytechnic High School of Architecture and Urbanism in Algiers, Algeria and preparing his Ph.D. degree in the field of Bioclimatic Architecture and Environment with specialization in Cities and sustainable Environment at Constantine 3 University Salah Boubnider, Constantine, Algeria. His research activities are in urban sustainability, cities and the environment.

Saliha Abdou graduated from Department of Architecture, Constantine University, Algeria. She received the M.Phil. degree (CARDO) from University of Newcastle, England in 1987, and Ph.D. degree in Bioclimatic Architecture from Constantine 3 University, Algeria in 2004. Currently, she is a full Professor and permanent member in 'Bioclimatic Architecture and Environment Laboratory' at the same university. Her research interests are urban sustainability, heat island, thermal comfort, outdoor and indoor simulations vegetation impact.