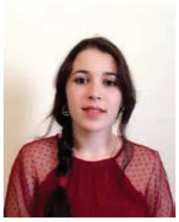
Potential Contribution of Green And Blue Technologies to Reduce Heat Stress In Outdoor Spaces, Case of Guelma City-Algeria



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Abstract: *Green and blue technologies in addition to their aesthetic and structural dimension, it offer the possibility of modifying the urban microclimate by relying on a process of natural regulation. This paper investigates the effect of microclimatic regulation of vegetation and water bodies in outdoor spaces during heat stress, we measured air temperature, relative humidity and wind velocity during the hottest period of 2019. The study simulates four scenarios for the square of martyrs which is situated in Guelma city by using Envi-met model. In scenarios 2 and 3 vegetation and water bodies were removed respectively, it has shown high temperature and low humidity corresponding to heat stress sensation. The scenario of the current outdoor space was ranked second in terms of microclimatic regulation while the scenario of recommended water bodies and vegetation have shown the best microclimatic conditions in heat stress with low temperature and high humidity and cool velocity. The findings show that the combined effect of vegetation and water bodies could lead to an optimal microclimatic regulation, thus it could reduce heat stress in outdoor spaces.*

Keywords: *Vegetation, Water bodies, Heat stress, Microclimatic regulation, Outdoor spaces*.

Yeşil ve Mavi Teknolojilerin Dış Mekânlarda Isı Stresini Azaltmaya Muhtemel Katkısı, Guelma Şehri - Cezayir Örneği

Özet: *Yeşil ve mavi teknolojiler, estetik ve yapısal boyutlarına ek olarak, doğal bir düzenleme sürecine dayanarak kentsel mikro iklimi değiştirme imkânı sunar. Bu makale, ısı stresi sırasında dış mekânlarda bitki örtüsü ve su kütlelerinin mikro iklimsel düzenlemesinin etkisini araştırdı, 2019'un en sıcak döneminde hava sıcaklığını, bağıl nemi ve rüzgâr hızını ölçtük. Kıskançlık modeli. 2. ve 3. senaryolarda vejetasyon ve su kütleleri sırasıyla çıkarıldı, yüksek sıcaklık ve düşük neme karşılık gelen ısı stres hissi gösterdi. Mevcut dış mekân senaryosu, mikroklimatik regülasyon açısından ikinci sırada yer alırken, önerilen su kütleleri ve bitki örtüsü senaryosu, düşük sıcaklık ve yüksek nem ve serin hız ile ısı stresinde en iyi mikroiklim koşullarını göstermiştir. Bulgular, bitki örtüsü ve su kütlelerinin birleşik etkisinin optimal bir mikro iklimsel düzenlemeye yol açabileceğini, dolayısıyla dış mekânlarda ısı stresini azaltabileceğini göstermektedir.*

Anahtar Kelimeler: *Bitki örtüsü, Su kütleleri, Isı stresi, Mikroiklim düzenlemesi, Dış mekânlar.*

1. INTRODUCTION

The adaptation to climate change in urban areas is one of the major concerns of the 21st century, in urban areas, the challenge is to adapt to climate change impacts [1], which all scales of action, from micro to global scale, are solicited, and new modes and strategies of regulation are to be invented [2].

Heat waves and urban heat island (UHI) are the most popular figure of climate change impacts in cities [3, 4]. The UHI effect is a key example, where cities are warmer than their surroundings, caused by releases of heat stored in buildings and roads during the day, but also by anthropogenic sources such as traffic, heating and cooling of buildings. It has been shown that theses releases of heat negatively affect human well-being in summer [5], but little is known about the potential mechanisms that underlie the relationship between higher temperatures and heat stress sensation in outdoor spaces [6]. At the local climate scale, the outdoor adaptation strategy consists of creating urban microclimates that provide a certain degree of climatic comfort to users during hot periods [7].

Green and blue technologies in addition to their symbolic, aesthetic and structural dimension, they offer the possibility of modifying the urban microclimate by relying on a process of natural regulation [8]. The vegetation induces a cooling of the air by shading effects, and by evapotranspiration effect [9]. The magnitude of these effects depends considerably on the type of vegetation concerned and the amount of plant biomass present [10], water in urban areas, i.e. its configuration, lowers the temperature, in short, the existence of water with vegetation helps to mitigate the urban heat islands locally and fighting climate change globally.

2. METHODS AND MATERIALS

2.1. Study area

Guelma is located in north-eastern Algeria, about 65 kilometers from the Mediterranean coast (36° 27' 43 N; 7° 25' 33 E; 840 ft. Elevation), with semi-arid climate (classified as Csa by the Köppen-Geiger system). The square of martyrs is one of the most frequented outdoor spaces in hot season situated in downtown Guelma (figure 1). It is a structuring place from the time of French colonization, mainly composed of low-rise buildings and it covers a total surface area of about 2060 m².

Figure 1. Left: Location of Guelma city, middle: Algeria the square of martyrs location, right: picture of martyrs square. (Source: author 2019).

2.2. Field measurements

A series of on-site measurements were conducted in heat stress period (July 21st, 2019). Three microclimatic parameters were measured Air Temperature, Relative Humidity and Wind Velocity. Using a multifunction hand-held device (Testo 480 – AG 501 1ST, 0563 4800), we obtained record in 3 different locations of the martyrs square (P1: Vegetal point; P2: Wet point; P3: Free point), bi-hourly six times periods from 09:00 to 21:00.

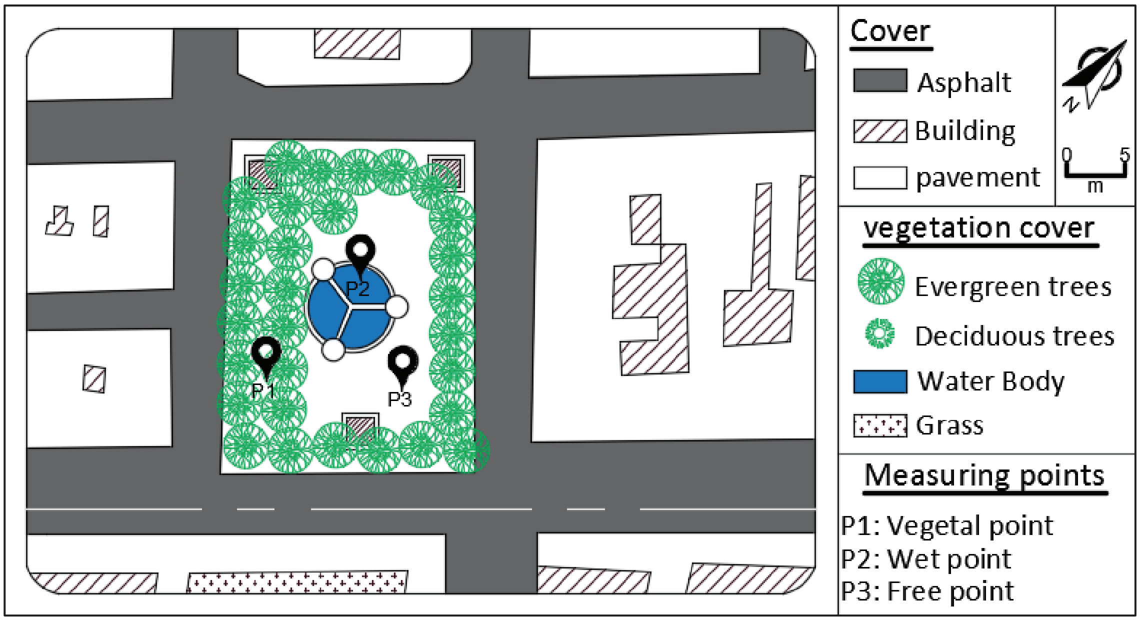
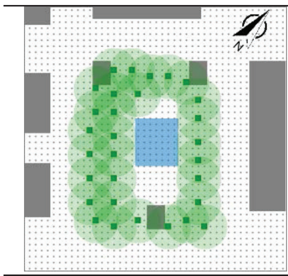
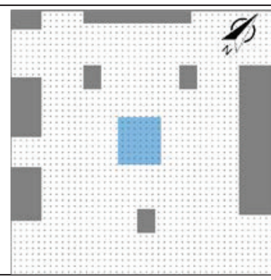
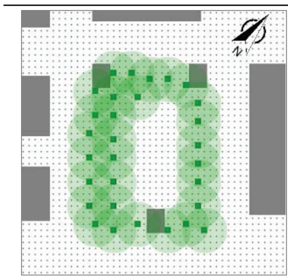
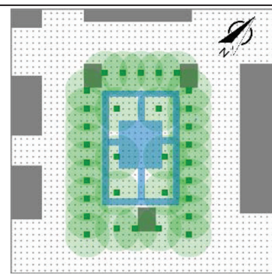


Figure 2. Map of the study square showing the three measuring points.

2.3. Atmospheric simulation

This paper aims to investigate the effect of microclimatic regulation of vegetation and water bodies in outdoor spaces during heat stress. Firstly we compared measured parameters in different locations within the square, secondly, we have simulate 4 (four) scenarios with different configurations of vegetation and water body using the science version (winter19/20) V4.4.4 of Envi-met.

Table 1. Detailed framework of the simulation process of the four scenarios

Specification of the simulation process by Envi-met model	
Simulation date	21.07.2019
Simulation start time	09:00:00 am
Model dimensions	x-Grids: 44 y-Grids: 44 z-Grids: 12
Grid cell	dx= 2 dy= 2 dz= 2
Grid north	-37.00
UCTI index calculation	Biomet process
Results visualization	Leonardo visualization tool
First Scenario: current square	**Second Scenario:** removal of vegetation
 Current square including the existing vegetation cover and the fountain.	 Current outdoor space with removing the existing vegetation cover.
Third Scenario: removal of the water body	**Fourth Scenario:** optimal proposition
 Current outdoor space with removing the existing water body.	 Optimal proposition based on new vegetation and water body configuration.

3. RESULTS

3.1. Comparison of measured parameters in different locations

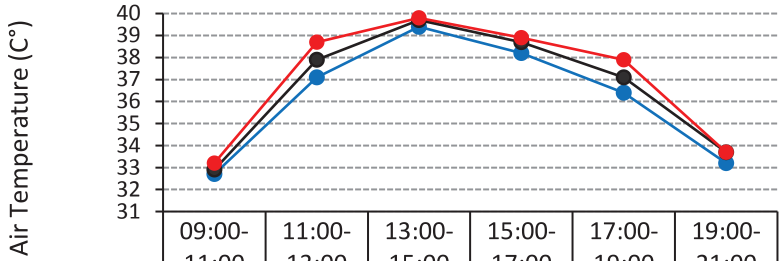
Figure 3, shows the comparison of air temperature, relative humidity and wind velocity in different locations within the square, spinning up six periods from 09:00 to 21:00.

(a) The lowest values of air temperature were observed in location one (P1-vegetal point) with minimum temperature (32.7°) at 09:00, while the highest values were recorded in location three (P3-free point), the mean values were observed in location two (P2-wet point).

(b) The highest values of relative humidity were observed in location one (P1-vegetal point) with maximum of (50.9%) at 09:00, while the lowest values were observed in location three (P3-free point), at the example of air temperature the mean values were recorded in location two (P2-wet point). Noted that from 13:00 to 14:00, the recorded values of air temperature are nearly matched in the three locations (P1, P2 and P3).

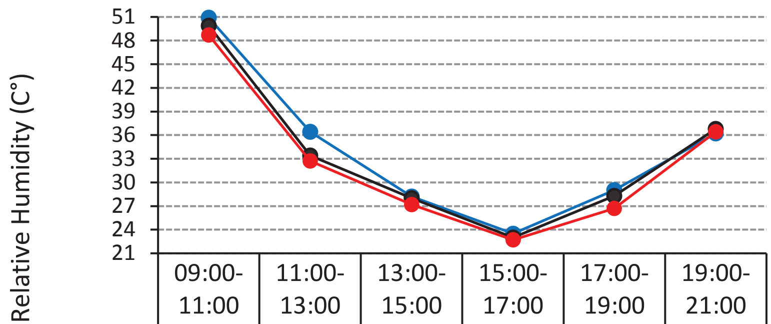
(c) The highest values of wind velocity were registered in location three (P3-free point) with minimum of (0.6 m/s) at 09:00 and maximum of (1.3 m/s) at 19:00. The lowest values were recorded in location one (P1), the mean values were observed in location two (P2-wet point).

(a)



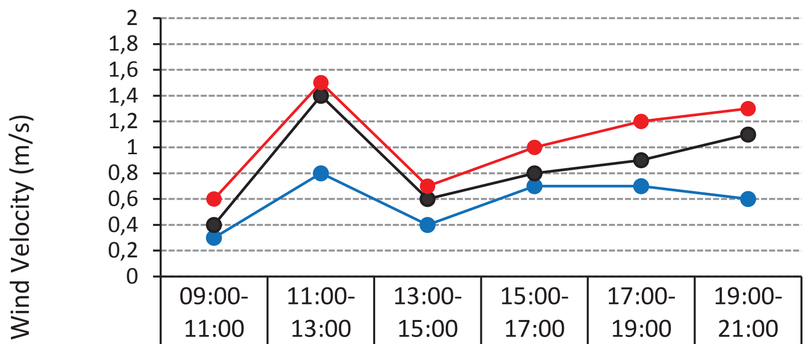
	09:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00
P1-Vegetal point	32,7	37,1	39,4	38,2	36,4	33,2
P2-Wet point	32,9	37,9	39,7	38,7	37,1	33,7
P3-Mineral point	33,2	38,7	39,8	38,9	37,9	33,7

(b)



	09:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00
P1-Vegetal point	50,9	36,4	28,2	23,5	29	36,2
P2-Wet point	49,9	33,4	28	23	28,3	36,8
P3-Mineral point	48,7	32,7	27,2	22,7	26,7	36,4

(c)



	09:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00
P1-Vegetal point	0,3	0,8	0,4	0,7	0,7	0,6
P2-Wet point	0,4	1,4	0,6	0,8	0,9	1,1
P3-Mineral point	0,6	1,5	0,7	1	1,2	1,3

Figure 3. Comparison of measured parameters in different locations within the square of martyrs for the period time (09:00-21:00), (a) Air temperature, (b) Relative humidity and (c) Wind velocity.

3.2. Comparison of microclimatic parameters in different scenarios

Figure 4, shows the results of simulated parameters, air temperature (Tp), relative humidity (RH) and wind velocity (WV) in different scenarios in period time (09:00-21:00).

The highest temperature (38.8° C) was observed in scenario 2 (two) where vegetation cover was completely removed (0% vegetation), while the lowest temperature (36.8° C) was observed in scenario 4 (four) of optimized proposition. It has been observed too that air temperature was low (37.4° C) in scenario 1 (one) with the current vegetation cover and the existing water body. Inversely relative humidity was higher respectively in scenario 4 (new configuration of vegetation and water body), scenario 1 (the current planting design of the square), scenario 3 (removing the water body) and scenario 2 (0 % vegetation). 1.3 m/s was the highest wind velocity observed in scenario 4 (four) and 1 (one) with both natural elements water and vegetation, the second high value 1 m/s was found in scenario 3 (three) where the water body was removed, finally 0.7 m/s in scenario 2 (two) of 0% vegetation.

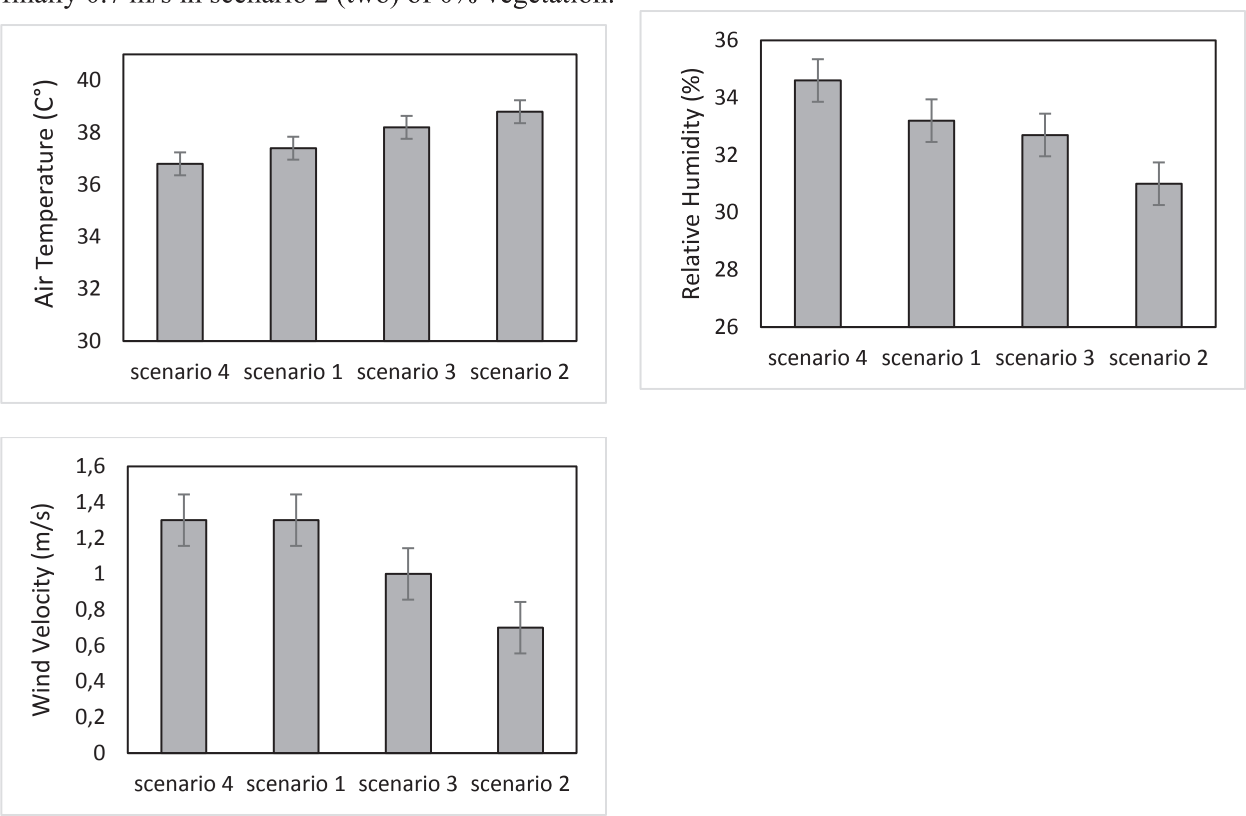


Figure 4. Comparison of simulated parameters, Air temperature, Relative humidity and Wind velocity in the square of martyrs for the period time (09:00-21:00).

3.3. Comparison of UTCI index in different scenarios

We obtained the UTCI index (Universal Thermal and Climatic Index) during the period from 09:00 to 21:00 for the four simulated scenarios; results are presented in Figure 5.

- To begin the lowest values of UTCI index were observed in scenario 4 (four) of the new configuration of water bodies and vegetation, the index was 41.4°> UTCI >32.7°.
- The highest values of the index were obtained in scenario 2 (two) where vegetation cover was removed, the index was 50.1°> UTCI >34.8°.

- Values of the current square (scenario 1) are slightly high compared to the optimized proposition, following the same daily rhythm, increasing from 09:00 to 14:00 where UTCI index was 42° and decreasing from 15:00 to 21:00 so the index was 35.8° at this time.
- In scenario 3 (three) without water body, UTCI values were in between 34.1° and 41.1° for the period from 09:00 to 12:00. The next three hours are the hardest in terms of UTCI, 46.7, 47.7 and 47.8 respectively for 13:00, 14:00 and 15:00.
- The thing to be noticed, the values of UTCI are nearly matched for the four scenarios in the period from 18:00 to 21:00.

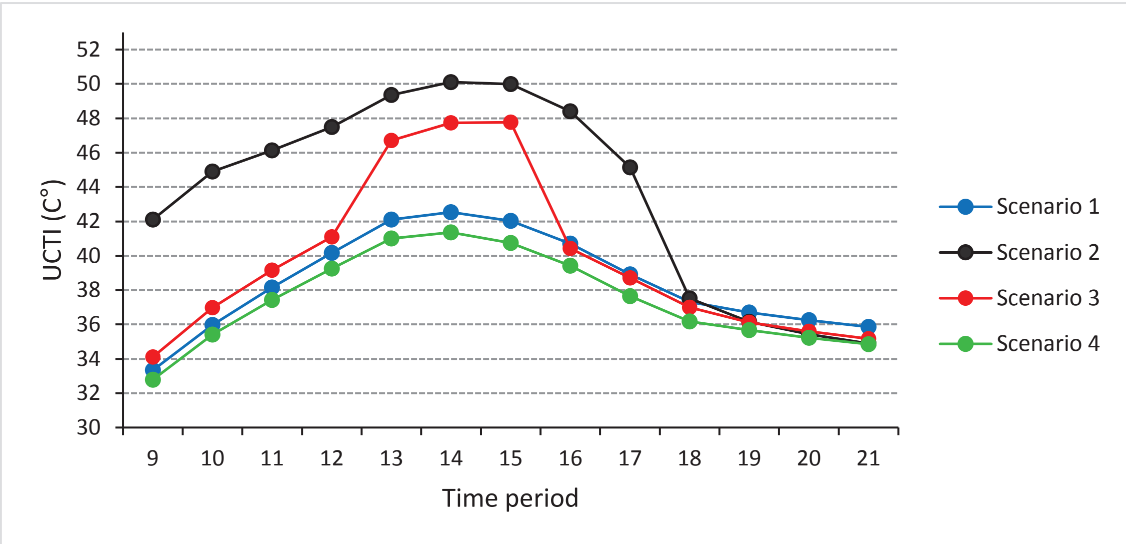


Figure 5. Comparison of different scenarios in terms of UCTI index in the square for the period time (09:00-21:00).

4. DISCUSSION

4.1 The influence of the surrounding on atmospheric conditions

In our investigation, the first step was to conduct a field microclimatic measurement in different locations within the square case of study. We measured Air temperature, Relative humidity and Wind velocity in different locations, P1 a vegetal point located under a tree, P2 a wet point near the water body and P3 a mineral point in a free location.

Measurements under tree have shown the best atmospheric conditions with the lowest values of air temperature and highest values of relative humidity and mean wind velocity values. Regarding the benefits of trees in summertime, these conditions could be interpreted as the way that the large shaded area provides by *Carpinus betulus* tree has blocked the radiation and reduced the local temperature. Moreover, the process of decreasing air temperature increases the relative humidity through transpiration effect of *Carpinus betulus* leaves.

The measurements in location tow, P2 near the fountain have shown good atmospheric conditions, the primary impact of water in urban areas is its thermal capacity to cool down the air temperature through evaporation and as a surface, it emits less radiation. This could interpret the flowing results, low values of air temperature (min 32.7°, max 39.7°) and high values of humidity (min 23%, max 49.9%).

Compared to the previous locations, the location three has shown hard atmospheric conditions with maximum temperature 39.8° and minimum humidity 22.7%, the direct exposure to solar radiation and the dominant minerality (soil) are the two main factors that cause high air temperature.

For the wind velocity, the lowest values (max 0.8 m/s at 11:00 o'clock) goes to location 1 (one) which under trees, while in location 2 (two) and 3 (three) the maximum holds 1.5 m/s at 11:00 o'clock. Trees have acted as a physical obstacle to block winds in location 1 (one) at the contrary in the other locations where the wind speed was higher.

4.2. The effect of microclimatic regulation of natural elements

After having an over view on atmospheric conditions in different locations within the square, the second step was to conduct a series of atmospheric simulations. In our study, four scenarios with different configurations of natural elements (water and vegetation) were simulated. Scenario 1 (one) simulates the current outdoor space including the existing vegetation cover and the existing water body in order to highlight the impact of natural elements on cooling down the air temperature and to confirm comparison results. Scenarios 2 (two) and 3 (three) simulate removing respectively the vegetation cover and the water body. Scenario 4 (four) proposes a mixed configuration of natural elements.

Scenario 2 (two) and 3 (three) have shown that natural elements play a key role on microclimatic regulation and removing the vegetation cover has negatively influenced the atmospheric conditions with hot temperature 41° and humidity 24.1 % at 15:00, while removing the water body has less influence with 40.3° and 25.4%.

In terms of microclimatic regulation, scenario 4 (four) of the optimal proposition showed the best results. The main idea of this proposition is to minimize the mineral area within the square, using the same type of tree (*Carpinus betulus*), and opting for linear water bodies. The scenario 1 (one) that simulate the current square was ranked second compared to other scenarios, which is interpreted by the wise choice of *Carpinus betulus* as main type of the vegetation cover and the central place of the fountain, thus the combined effect of water and vegetation can significantly contribute to cooler atmospheric conditions in outdoor spaces in summertime.

4.3. The influence of natural elements on reducing heat stress

Green and blue technologies are widely used as strategies of urban cooling during heat stress. In our study, we have demonstrated that natural elements offer the possibility of modifying the urban microclimate by relying on a process of natural regulation. Several indices have been developed by researchers to evaluate the effect of vegetation and water in reducing heat stress, for example, PET (Physiological Equivalent Temperature), UTCI (Universal Thermal and Climatic Index) and PMV (Predicted Mean Vote).

In our study UCTI index was calculated on a seven-point thermal sensation scale. The results in the graph that scenarios are in the following order; scenario four, scenario one; scenario three and scenario tow. The period between 12:00 to 16:00 is the most critical values in scenario of optimal proposition the index was 41.3°> UTCI >39.2°, in scenario one of the current space the index was 42.5°> UTCI >40.1° corresponding very strong heat stress. In scenario three and tow where natural elements were removed, the index was 50.1°> UTCI >46.7° corresponding extreme heat stress. At this level, it can be concluded that natural elements could reduce the heat stress in outdoor spaces.

5. CONCLUSION

As the main purpose of this study is to investigate the effect of vegetation and water bodies on reducing heat stress in outdoor spaces. The investigation carrying out on Martyrs square in Guelma city was organized in three steps. Firstly, we compared the microclimatic parameters in different locations within the selected square; these are the main findings:

- The vegetation affects thermally the atmospheric conditions through two effects shading and transpiration.
- Physically urban trees act like obstacle to winds in outdoor spaces.
- Water affects the urban microclimate through evaporation effect, which increases the relative humidity (+ 0.8%).
- Water surfaces have a lower emissivity compared to mineral surfaces.
- Mineral soils affect negatively atmospheric conditions in outdoor spaces, by decreasing the relative humidity (-1.6 %) and increasing the air temperature (+2.8° C).

Secondly, we opted for an atmospheric simulation of four scenarios with a different configuration of natural elements including the current square, some of the previous findings are confirmed and new results are found

- Vegetation and water bodies play a key role on microclimatic regulation.
- Vegetation is the most influential natural element in terms of microclimatic regulation, by cooling down the air temperature (-0.6°C).
- The combined effect of water and vegetation can significantly contribute to cooler atmospheric conditions in outdoor spaces in summertime (-0.6°C to -1.4°C).
- Maximize the shaded area in outdoor space can reduce the heat stress in summertime; planting 03 more trees can reduce 0.6 °C.
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Finally, the comparison results of the universal thermal and climatic index (UTCI) for the four scenarios confirm that the combined effect of water and vegetation can significantly contribute to reducing heat stress in outdoor spaces.

This study is entitled “Potential contribution of Green and Blue Technologies to reduce Heat stress in Outdoor spaces”, the terms “natural elements” or “vegetation and water bodies” where used in the investigation steps, results in scenario 4 (four) and 1 (one) are almost matched expect in the period from 13:00 to 15:00. The comparison of UTCI index for both scenarios highlight the difference between the two terms, vegetation and water bodies are the natural components of urban microclimate, while green and blue technologies represent the methods of improving the urban microclimate that takes into account ration, type and configuration of natural elements in outdoor spaces.

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