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Research Article

STRATEGY FOR THE OPTIMIZATION OF THE THERMAL COMFORT OF THE PUBLIC PLACES OF THE SAHARAN CITIES

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ABSTRACT

"*Outdoor spaces play a very important role in promoting the quality of urban life.*" [1]. According to Hanafi, A. (2010) the abandonment of use of the public place of the city of Biskra, is due to the lack of the thermal comfort, which obliges its users to frequent them occasionally [2]. This article is to seek how and by what means to optimize the thermal comfort of the places as very open urban outdoor spaces and existing, with the objective of creating the shadow within these places, that is to say create a mask against the solar rays that cause discomfort and various skin diseases to people [3]. One will try ; to see the possible solutions relating to the form, to the insertion of the vegetation and water... etc. while seeking the appropriate solution for the public places of the city of Biskra / Algeria, by the combination between the measurements of of the necessary climatic factors "in situ" and the simulation by means of a software.

Keywords: public place; Saharan city; arid zone and hot climate; thermal comfort; architectural solutions; vegetation (urban tree).

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1. INTRODUCTION

To optimize the thermal comfort of a public place of a Saharan city, case of the city of Biskra / Algeria, it is necessary to control the different elements involved in the increase of the temperature of the air and to the decrease of relative humidity within these spaces to know how to avoid them.

We note the morphology of the constructions (urban morphology) and the materials used the speed of the air, the presence of basin of water and the vegetation.

In this objective, we opted to create the shadow in the places of the city of Biskra (Saharan city with hot climate and arid zone). Therefore, we will try in this article to look for and see all possible solutions related to: the form, the insertion of vegetation with its types, the insertion of water and the modification of the floor covering. While seeking the optimal and adequate solution for the public places of the city of Biskra / Algeria.

2. PROBLEMS

The people of Saharan cities, the case of the city of Biskra / Algeria, arid zone and hot climate, seek to shelter themselves from the sun's rays by all available means, especially during the summer period. These people are affected by 'heat stress', by the lack of freshness and shade, it pushes them to abandon public spaces and especially public places, while joining the built and closed spaces and they use the air conditioning which generated a large consumption of energy (electricity).

According to Hanafi, A. (2010) the abandonment of use of the public places of the city of Biskra, is due to the lack of the thermal comfort, which obliges its users to leave them or to frequent them occasionally [2]. Thermal comfort in outdoor spaces influenced by several factors, mostly by solar radiation [4].

The problem; how and by what means we can be optimized the thermal comfort of public places as open urban space and already existing?

2.1. Article Highlights

- To seek how and by what means to optimize the thermal comfort of the places.
- To create the shadow within these places, that is to say create a mask against the solar rays.
- To see the possible solutions, relating to the form, to the insertion of the vegetation with its

types and water

- To seek the appropriate solution for the public places of the city of Biskra / Algeria, a Saharan city (arid zone and hot climate)

3. RESEARCH METHODOLOGY: the optimizations will be do by:

- Optimization by changing the shape of the space.
- Optimization by modifying the floor covering.
- Optimization by the insertion of water.
- Optimization through the introduction of urban vegetation.

4. PRINCIPLES OF DESIGNS AND APPLICATIONS

It is possible to design a comfortable urban outdoor space for its users and it meets the requirements of its population, the challenge is how to improve the thermal comfort of an existing urban outdoor space? In addition, the thermal comfort was not taken into consideration when designing this space.

To optimize (improve) the thermal comfort conditions of an existing urban outdoor space, this requires a rehabilitation of the latter, since the possible solutions to the problem of discomfort felt by users. Before beginning the search for solutions, we must identify the problem of thermal discomfort that is due to the effect of solar radiation. Therefore, the solution is clear in creating the shadow in the public place.

Indeed, in the summer season, the control of the temperature of the air is fundamental to reach the thermal comfort, and the creation of the shadow allows the permanent control of the temperature since it is an essential factor in the comfort of the users.

4.1. Solution 1

Optimization by changing the form of the space. This solution is to put panels at the size of the man within the public place to create shade and at the same time to channel the flow of air, (see figure 1).

Fig.1. Panels used to create shade and channel the flow of air [5]

4.1. Solution 2

Shading the routes of users of public space or the axes of pedestrians by covering passages, they can provide shade during a large period of the day, (see figure 2).

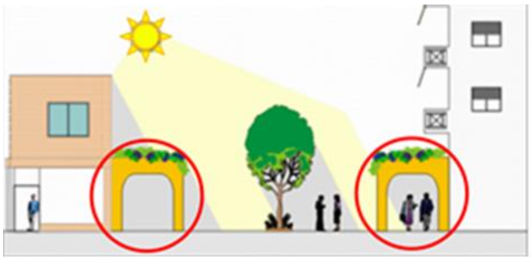

Fig.2. The covered passages lining a route of pedestrian can provide shade [5]

4.2. Solution 3

It consists in touching the urban morphology of the site of the public place; according to Steemers, et al. (2004) "... means the three-dimensional form of a group of buildings and the spaces they create around them" [6]. The semi-buried public place can offer shade at different times of the day, (see figure 3).

Fig.3. Public spaces (public place) semi-buried, to provide shade to users [5]

4.3. Solution 4

The construction of pergolas will allow creating shaded areas within the public place, on its borders or along the routes of users. These pergolas are designed with blades allowing the passage of solar rays during the winter period and prevent the summer period, (see figure 4).

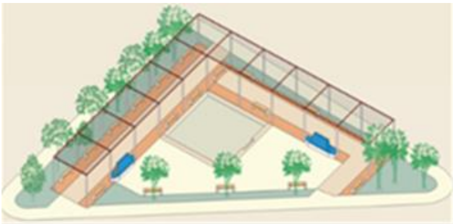

Fig.4. (Example) perspective view of pergola in a public place [5]

4.4. Solution 5

In public space, we can put awnings as a mask against the sun's rays; these promote a specific microclimate and it is recommended to have removable awnings to remove at night to enjoy a night cooling of the public place by radiation to the sky [4], (see figure 5).

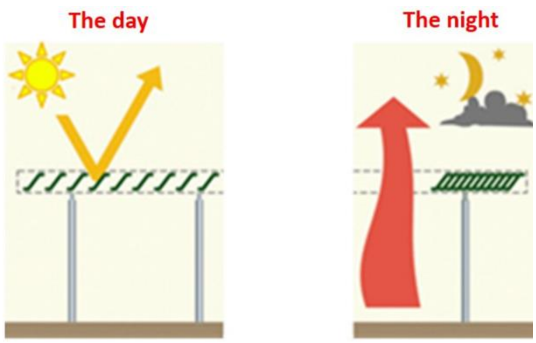

Fig.5. the use of the removable awning against the solar rays [4]

4.5. Solution 6

The insertion of water such as a basin, a fountain, a jet of water, a watercourse ... etc. within the public place in order to refresh this space. According to Reiter, S. (2007) water surfaces presented in the form of water fountains, canals, basin, jet of water; reduce the temperature of the air by evaporation, since "water" acts as a buffer and by its thermal inertia it attenuates the temperature fluctuations, moreover, the water surfaces and the movements of air which the transom can also contribute to convective air cooling [4], (see figure 6).

Fig.6. Influence of water surfaces on air temperature [4]. (a): Humidification of the air by a fountain. (b): Universal Exhibition in Seville in 1992. Photo: Grupo de Termotecnia; 1994. (c): Place and street of the Republic in Lyon. Photo of the place: J-M. Gillon

4.6. Solution 7

Optimization by modifying materials (covering of flooring and facades). In general, in the city we use multitudes of covering materials, either the floor or for facades, but for the floor we use materials such as asphalt for mechanical circulation or tiling, pavement ... etc. for pedestrian lanes. All these impervious materials have low thermal capacities (ability to store heat) and high conductivity; they absorb and release heat quickly, which causes a rise in air temperature and surfaces in the public space, (see figure 7).

The solution against this problem is to choose covering materials having a high 'albedo'; as black surfaces exposed to the sun can be up to 21 ° C more than white surfaces.

Indeed, the materials have an effect on the microclimate in urban outdoor spaces, especially public places that depend on the reflectivity of materials, that is to say the 'albedo'. The latter determines the amount of reflected radiation from the area concerned, in addition to the thermal capacity which determines the amount of energy stored and the time required for the phase shift. Knowing that the urban space is composed of a mosaic of materials, the albedo is evaluated according to an average value calculated according to the albedo of each material and its fraction of occupation [1], (see figure 7).

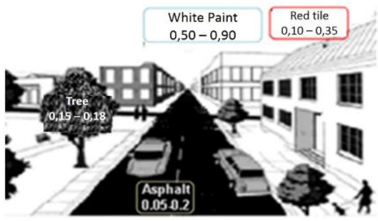

Fig.7. some values of 'the albedo" of coverings of facade and of the street [7]

Studies have shown that impervious floor coverings and dark-colored materials do not reflect solar radiation well, resulting in increased air temperature in urban space, while comparing it with rural space [8], (see figure 8).

Fig.8. Different types of permeable covering floor and their uses. (a): Plate of wood, (b): Natural stone pavers, (c): Concrete pavers, (d): alveoli slabs [9]

4.6.1. Cover soil with grass

Cover the soil by the grass is distinguished from other covering by its permeability of which it warms less the air by thermal convection and the ability to dissipate energy by evapotranspiration (evaporation at the ground and transpiration of plants) since it limits the storage of heat in the soil by conduction [10].

It should be noted that the grassy soil does not change much the thermal comfort in an open outdoor space because the effect on the air temperature is hardly perceptible [11], (see figure 9).

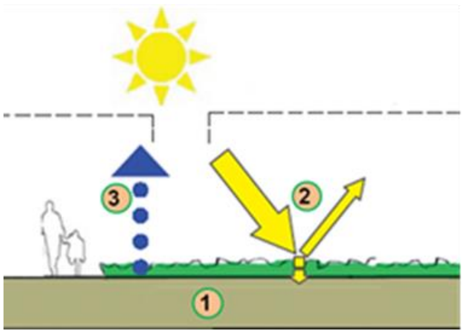

Fig.9. Schema of soil covered by grass (permeable surface) / 1: soil: impermeable surface. 2: solar radiation (About 30% of the incident solar radiation is directly reflected by the grassed surfaces to the sky and the rest is absorbed) And 3: Evapotranspiration (Evapotranspiration is null an impermeable surface) [11]

4.7. Solution 8

According to Kang, et al. (2002) "The two effects of vegetation are the shading effect of solar radiation (most hardwood trees have a low transmissivity to solar radiation, between 2 and 5 %) and the preservation of a foliage temperature near to that of air, is between 20-35 ° C inferior to the surface temperatures of common urban materials, such as asphalt, concrete blocks… etc." [12]. In addition, the benefits of urban vegetation exceed the shading towards the humidification of the air [13], (see figure 10).

Fig.10. Schema of the humidification of the air by the urban tree, 1: Consumption of liquid water (Circulation of water), 2: Evaporation, 3: Evapotranspiration: corresponds to the evaporation of the water contained in the soil and transpiration from vegetation. (Latent heat flow) [11]

4.7.1. The introduction of urban vegetal

• Climbing plants: The construction of pergolas covered by climbing plants will allow creating shaded areas in the public place, either on its edges or according to the routes of users. In addition, according to Reiter, S. (2007) "The pergolas or the plantations whose foliage covers almost the entire space of a relatively confined yard or place serve as a separation between the air above and below its foliage"[4], (see figure 11).

Fig.11. (a) and (b) examples of pergolas covered by climbing plants. Source: website: www.plante-et-cite.fr

• The introduction of the urban tree: As already mentioned above, the shadow is the most important factor in the thermal comfort and allowing the control of the temperature of the air. In addition, there is a large variety of urban trees generating shade in the public space [14], (see figure 12).

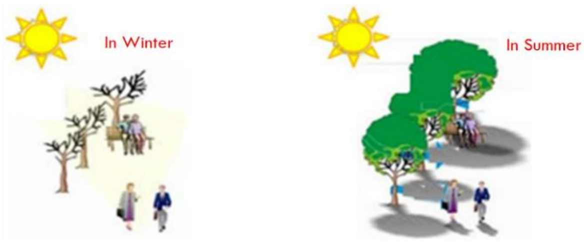

Fig.12. Deciduous trees provide shade in summer; and in winter they allow exposure of the site to the sun [5]

In addition, the urban tree modifies its environment by protecting individuals from direct solar radiation (see figure 13) and the modification of the atmosphere [17], (see figure14).

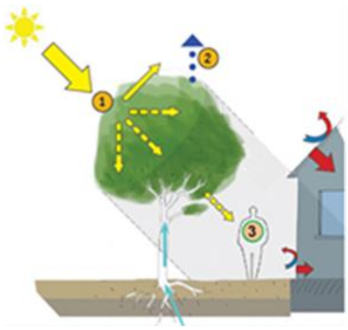

Fig.13. Schema relative of the modification of the solar environment by the urban tree, 1: Radiation, 2: Evapotranspiration, 3: Outdoor comfort (In the summer, the shading of a tree allows a real improvement in thermal comfort by protecting individuals from direct solar radiation) [5]

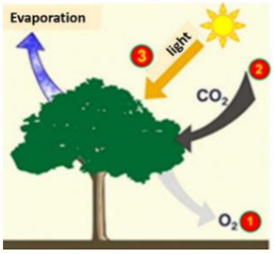

Fig.14. Schema relative to the modification of the atmosphere by the urban tree, 1: The tree has an effect of oxygenation on its surroundings, 2: The tree absorbs ozone, CO_2 and other pollutants; and 3: The tree survives by an exchange of light, water and gas [4]

5. THE INVESTIGATION

The approach followed in this work aims to highlight the role of vegetation (urban vegetal), the thermal comfort of the public place (urban outdoor space, very open, of which, H / W <1) [15]. We will see the degree of influence of the vegetation on the decrease of sky view factor (SVF), the mean radiant temperature (Tmrt), the soil temperature (Ts), the attenuation of the global radiation received by the body (Gact). And we calculated: the index of thermal comfort physiological equivalent temperature (PET), the index of predictable mean vote (PMV), the index Average radiant temperature (Tmrt), the soil temperature (Ts) and the global radiation received by the body (G act).

6. METHODOLOGY

Consists of a series of physical measurements of climatic parameters (air temperature, relative humidity of air, wind speed and sky cover); means, the thermal effect, hygrothermal and aerodynamic, which directly affect the outdoor space studied.

The search has hit all the places at the top, but we will just expose Hai Istiqlal / Biskra place as an example, (see Figure 15).

Fig.15. Satellite image of Hai-Istiqlal place / Biskra / Algeria [16]

The day chosen for the measurement campaign was: 15/07/2014; the choice of this day; it was based on the overheating zone of the city of Biskra, indicated on the table of isotherms of the city of Biskra [18]. In addition, the selection of the day of clear sky (without clouds).

The LM 8000A apparatus was used; multifunctional apparatus 4 in 1: anemometer, hygrometer, luxmeter and thermocouple, (see Figure16).

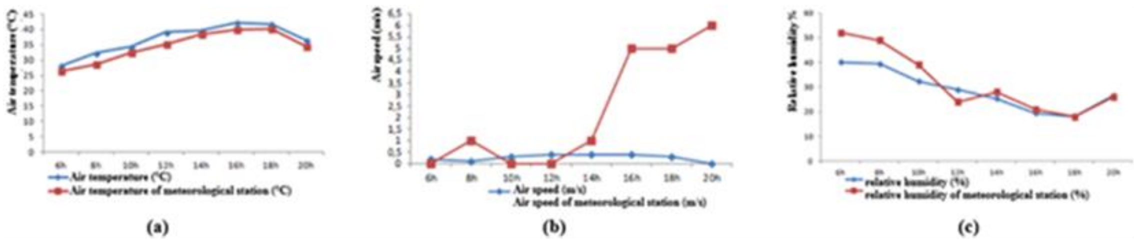

Fig.16. (a): Graph of Air temperature; (b): Graph of air speed and (c): Graph of relative humidity, relating to the hai-istiqlal place / Biskra / Algeria

7. CITY OF BISKRA / ALGERIA; CLIMATIC CONSTRAINTS

The wilaya of Biskra is classified by the Algerian state as wilaya of south, although it is located between the north and the south of Algeria and that gave him the name the "door of desert". It has a population of 869,215 in 2015, which is an average density of 40 inhabitants / square kilometer [5], (see figure17).

Fig.17. Satellite image of the city of Biskra / Algeria. Source website: www.Google Earth.com

7.1. Physical data

The city of Biskra is characterized by a very hot and dry climate in the summer season, with an average temperature of 43.5° C and an average relative humidity of 12%. And a very cold winter with a minimum average temperature of 4°C and an average relative humidity of 89%. The precipitations in this region are rare and does not exceed 31 days per year and cumulative annual rainfall reaches 200 mm [21], (see table 1).

Table 1. Evolution of air temperatures during the year 2011 of the city of Biskra / Algeria [19]

Ta (°C)	January	February	March	April	May	June	July	August	September	October	November	December
Average	9.61	10.7	13.93	20.1]	22.99	27.99	33.26	32.59	22.19	20.14	14.5	10.36
Max	20.1	20.9	25.7	32.9	34.9	41.2	44.9	44	40.5	31.9	24	20.9
Min	-2.1	-1.21	1	7.3	12.2	15.7	22.5	22.1	15.6	7.2	5	0.8

7.2. The insolation

The duration of insolation on the national territory exceeds 2000 hours / year, in the high plateaus and the Sahara it reaches the 3900 hours / year [20]. (See Table 2, 3 and 4)

Table 2. The distribution of solar potential by region [16]

Regions	Coastal regions	High plateaus	Sahara
Area rate	4%	10%	86%
Average duration of sunshine (h/year)	2650	3000	3500
Average energy received (Kwh/m²/year)	1700	1900	2650

Table 3. Average duration of daily insolation of the city of Biskra [21]

	January	February	March	April	May	June	July	August	September	October	November	December
average duration of daily insolation (Hours)	7,3	8,2	9	9,7	10,3	11,2	12,4	11,5	10,5	8,2	7	7

Table 4. Average duration of monthly insolation of Biskra [21].

	January	February	March	April	May	June	July	August	September	October	November	December
average duration of monthly insolation	226	230	278	290	320	337	383	355	314	254	210	219

7.3. Solar radiation

The incident solar radiation is very intense and of the order of 7680 wh/m² on a horizontal plane during the month of July which corresponds to a duration of sunshine of 383 hours and which can exceed 12 hours per day [21].

8. PUBLIC PLACES STUDIED IN THE CITY OF BISKRA / ALGERIA

The city of Biskra contains only a limited number of public places, while eliminating the clearances in our study. The public places studied are: Hai-Istiqlal place, Houria place, Zouaka place, Ben Badis place and Dhalaa place, (see figures 18 and 19).

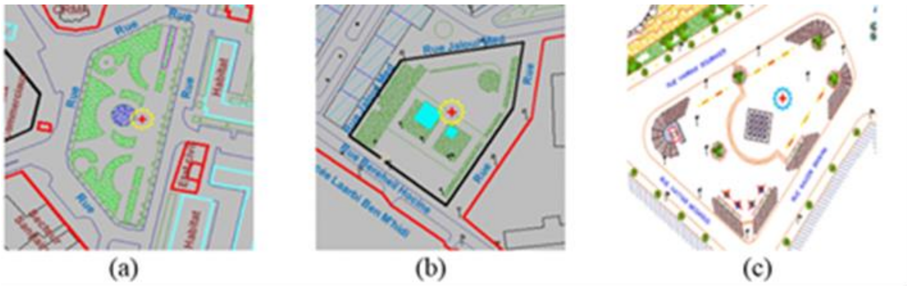

Fig.18. (a) Ben Badis Place / Biskra / Algeria; (b) Hai-Istiqlal Place Biskra / Algeria; (c) Dhalaa Biskra Place / Algeria; source: P.D.A.U / Biskra

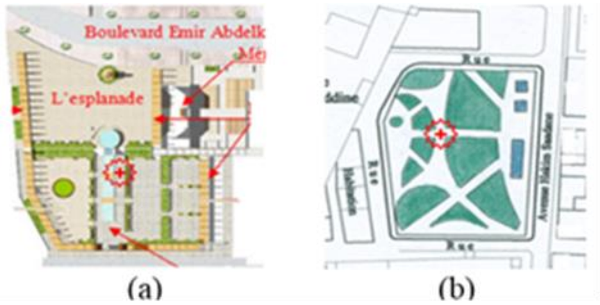

Fig.19. (a) El-Houria Place / Biskra; (b) Zouaka Place / Biskra. Source: PDAU / Biskra

9. THE SIMULATION

It is made by the software "RayMan, 1.2" [22], this software of 3D, calculates the global radiation, soil temperature, PMV, PET, SET. It takes into consideration the geographical coordinates of the studied site, the climatic parameters (air temperature, wind speed, relative humidity and type of sky) in addition the physical environment: simple or complex (building and tree).

The simulation, as already mentioned before, had been well to touch the role of vegetation on thermal comfort; this was do in two situations in Hai-Istiqlal / Biskra place [16].

- The first situation of the place it was before the insertion of the urban trees. (The real state of the place studied / Hai-Istiqlal place / Biskra / Algeria).
- The second situation of the place it was after the insertion of urban trees; it is the optimal solution; to improve the thermal comfort of Hai-Istiqlal place / Biskra / Algeria.
- By the RayMan software, the shadow was trace for each period of the day and the SVF was determined, (see figure 20).

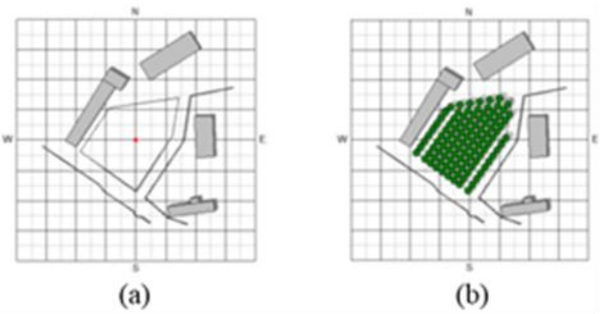

Fig.20. (a): situation of the place before urban trees are inserted (The real situation), (b): situation of the place after the insertion of the urban trees, it's the optimal proposition

Recalling that our study aims to produce shade by the insertion of the vegetation (the urban tree) within the Hai-Istiqlal place / Biskra. Therefore, the role of the urban tree is the protection against the rays solar in the summer season. The urban tree chosen was the "ficus", species: Ficus retusa, family: moraceae, his common name is ficus. It is of category tree, of tropical origin, of persistent tree type, of port form erected dense and of a fast growth. In addition, it exists to the city of Biskra for a long time and resists to its climate [23], (see figure 21 and 22).

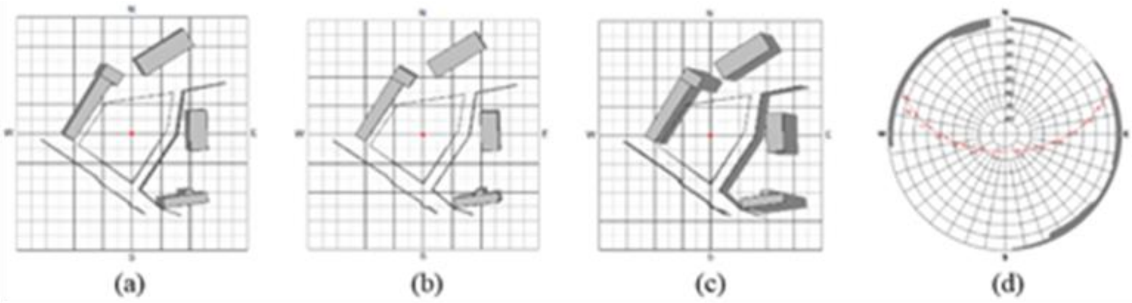

Fig.21. Situation of the place before the insertion of the urban trees (the real situation), (a): trace of the shadow at 8 h a.m. (b): trace of the shadow at noon, (c): trace of the shadow at 18 h p.m.; (d) polar diagram SVF = 0.946

We observe that in the second situation (optimal situation), the SVF could be reduced considerably by the insertion of the vegetation and by the disposition it was arranged (green cover), this attenuated the global radiation, (See figure 22).

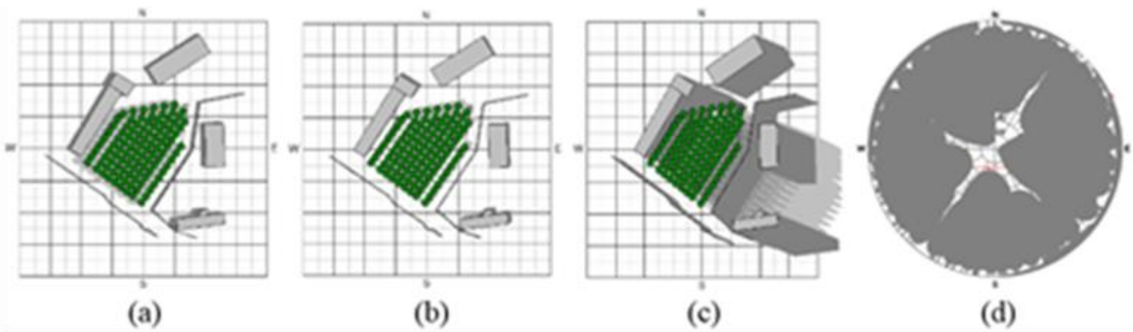

Fig.22. Situation of the place after the insertion of the urban trees, (a): trace of the shadow at 8 h a.m. (b): trace of the shadow at noon, (c): trace of the shadow at 18 h p.m.; (d) polar diagram SVF = 0.081

We note that the global radiation has dropped to the optimal proposition, compared with the initial situation of the place, before the insertion of the urban trees. Which it decreased at 615 w/m² at noon with a difference of 138 w/m², (see figure 23).

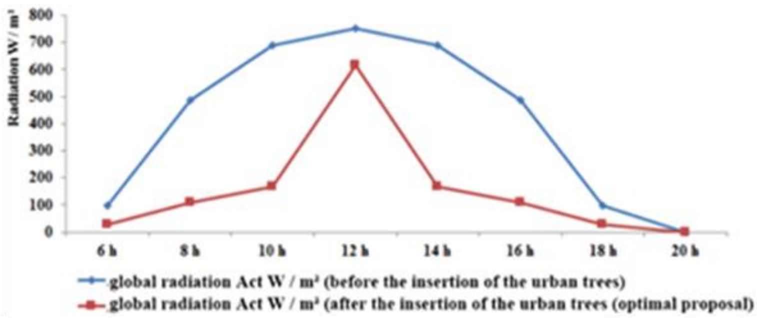

Fig.23. graph of global radiation of the Hai Istiqlal place / Biskra for the two situations: before the insertion of the urban trees (the initial situation of the place) and after the insertion of the urban trees (optimal proposal)

Before the insertion of the urban trees (the state initial of the public place / Hai-Istiqlal /Biskra / Algeria), the temperature of the soil (Ts) began with 47.1° C to 8 h a.m. to reach 66.5° C at noon and then it lowered until it reaches 32.7° C towards the sunset since the space of the place is exposed to the sun without any protection and the ground with a low albedo.

At the second situation, after the insertion of the urban trees (optimal proposal), thanks to the presence of the green cover (the urban trees) the differences were considerable; about 18.7 ° C at 10 h a.m. and 17.5 ° C at 4 h p.m. note that at noon the difference was minimal, 0.3 ° C, since the sun is at the zenith, (see figure 24).

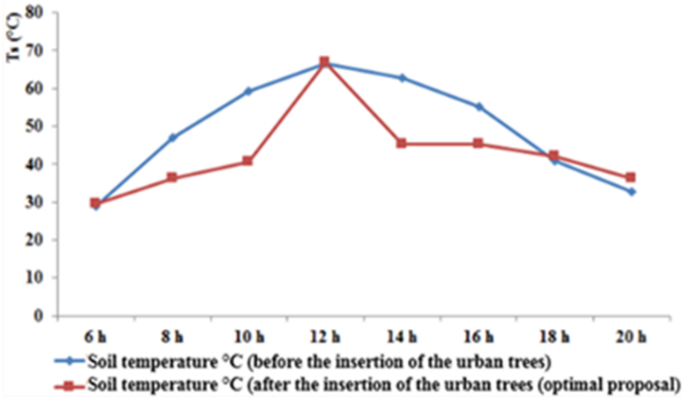

Fig.24. graph of the soil temperature (Ts) of the Hai Istiqlal place / Biskra for different situations: before the insertion of the urban trees (the initial situation of the place) and after the insertion of the urban trees (optimal proposal)

Compared to the mean radiant temperature (Tmrt) at the optimal situation, after the insertion of urban trees, it did not exceed 39° C all the day, except at noon where it had 58° C. In the initial situation, before the insertion of the urban trees we note a change in the mean radiant temperature (Tmrt) from sunrise until noon, where we mark 48.8° C at 8 h a.m. 62.2° C at noon and 55.3° C at 4 p.m, (see Figure 25).

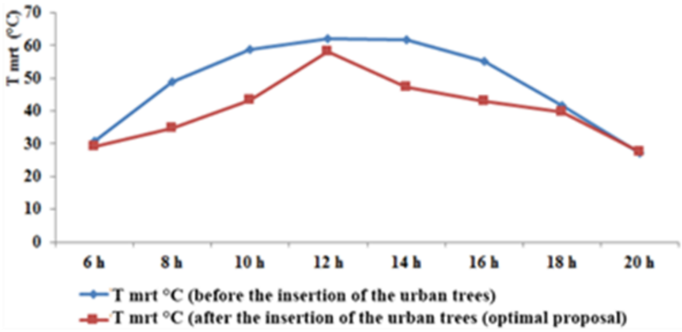

Fig.25. graph of the mean radiant temperature (Tmrt) of the Hai Istiqlal place / Biskra for different situations: before the insertion of the urban trees (the initial situation of the place) and after the insertion of the urban trees (optimal proposal)

The predicted mean vote (PMV) obtained for the second situation (after the insertion of the urban trees, optimal proposal) shows a significant reduction compared to that obtained in the situation before the insertion of the urban trees. The maximum PMV is 4.5 at noon and 5.7 at the initial situation of the public place. The rest of the day it did not reach the limit of the hot sensation, the band: G. On the other hand, to the initial situation, the PMV almost all the day to the very hot zone (the band: H) of 8 h a.m. until 6 h p.m, (see Figure 26).

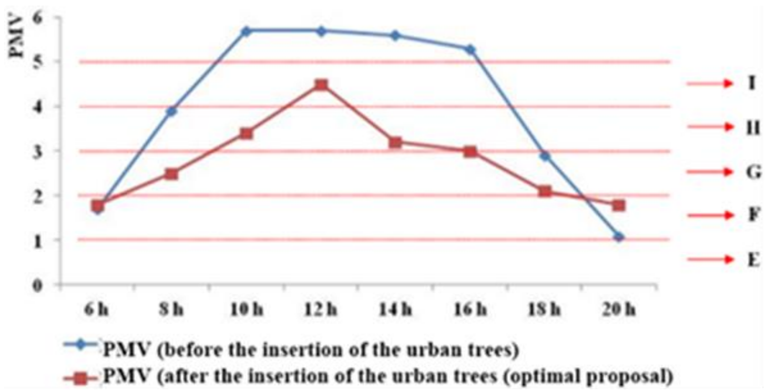

Fig.26. graph of predictable mean vote (PMV) of the Hai Istiqlal place / Biskra for different situations: before the insertion of the urban trees (the initial situation of the place) and after the insertion of the urban trees (optimal proposal)

For the physiological equivalent temperature (PET), the results obtained for the situation after the insertion of the urban trees in optimal proposal, show a significant attenuation compared to the results obtained in the other situation, before the insertion of the urban trees.

The maximum of the PET is 47.4 ° C at noon but all the day it does not reach 39° C, means, it is in the hot band 'G' with a sensation of moderate heat stress.

At the initial situation almost from sunrise at sunset the PET and an average of 42° C, and it had not dropped from the very hot band (the band: H) with a strong sensation of stress of heat, (see figure 27),

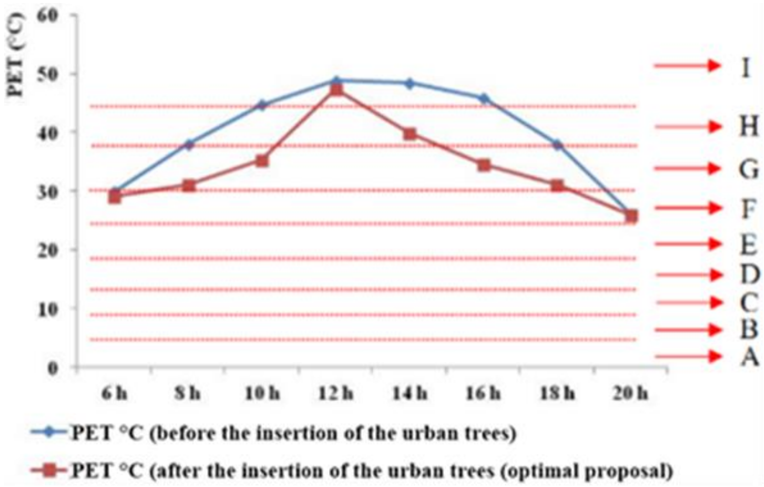

Fig.27. Graph of the physiological equivalent temperature (PET) of the Hai-Istiqlal place / Biskra for different situations: before the insertion of the urban trees (the initial situation of the place) and after the insertion of the urban trees (optimal proposal)

10. CONCLUSION

Promoting the quality of urban life of urban dwellers is relative to the comfort offered by urban public spaces and particularly public places [1]. The latter are of major interest in contributing to increasing isolation and social exclusion as they favor the meeting, gathering and reunion of the population.

The permanent use of urban public spaces or public places depends on the quality and the physical properties of the environment of these places in addition to their thermal comforts that can increase, decrease or change their uses throughout year. After analysis on the use of the public places of the city of Biskra, the solutions relating to the needs of the comfort of the urban dwellers are necessary and pass in the first occupation [2].

This research has brought nine solutions that encompass: changing the form of space (geometry of space), the modification of the covering of floor (depending of the thermal properties of the surfaces), the insertion of water (basin or surface) and the introduction of urban vegetal (the urban tree). So, we opted to be analyzed and critique each proposed solution, and to search the optimal and adequate solution among them. To fill the thermal discomfort found in the public places of the city of Biskra.

Recalling that the main climatic parameters are: air temperature, air speed, humidity, precipitation and solar radiation [24]. In Saharan cities with an arid climate, such as the city of Biskra, the objective is always to avoid direct solar rays and to search the shade and coolness. As a result, solar radiation is the primary factor causing thermal discomfort in public spaces.

So, we looked for different means for protect against the solar rays and the creation of the shadow. For this, and after analysis of all the solutions, the solution relating to the introduction of the urban vegetal (the urban tree) is the adequate solution for the optimization of the thermal comfort of the public places of the city of Biskra / Algeria [16].

Concerning the simulation, it was to see the degree of influence of the urban vegetal (urban tree) on the decrease of the sky view factor (SVF), mean radiant temperature (Tmrt), soil temperature (Ts) and the attenuation of the global radiation received by the body. In addition, to calculate the indices of the thermal comfort: PET, PMV, Tmrt and Ts. Indeed, the results were appreciable considering that the global radiation received by the body, the temperature of soil (Ts) and the mean radiant temperature (Tmrt) are at the optimal proposal inferior to the initial state of the place public. In addition, it was the same for the indices of the thermal comfort: PET, PMV calculated by the software 'RayMan' were inferior to the situation of the place without vegetation.

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