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GREEN INFRASTRUCTURE, A THERMAL REGULATOR FOR THE ARID CITY. CASE STUDY OF THE CITY OF BOU-SAADA

Abstract: From a sustainable development perspective, becoming aware of the preservation of green spaces and the creation of green infrastructure is a great challenge for the Algerian arid city, especially in the arid environment. Green infrastructure is multifunctional open space networks aimed at sustainable resource management and environmental improvement. We chose the city of Bou-saada as a case study to demonstrate the need for green infrastructure. This city, with a semi-arid climate, presents a very varied, complex and fragile historical, archeological and natural richness subjected to strong anthropogenic pressures. The overall objective of this research is to assess green infrastructure in the city of Bou-saada using a qualitative barometer. This method uses several themes around the concept of multifunctionality and thermal comfort, also using some sub-themes to break down the themes. Green infrastructure in the city of Bou-saada can withstand the drought and heat emanating from this area, provide shade and reduce heat, prevent soil degradation and desertification by stabilizing the soil and mitigating wind-induced erosion. Through this research, we have also looked at several issues such as safeguarding the natural heritage, combating desertification, and siltation.

Key words: green infrastructure, green spaces, Bou-saada, multifunctionality, qualitative barometer

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Introduction

The green infrastructure is a network of multifunctional open spaces, including formal parks, gardens, woodlots, green corridors, street trees. It includes all environmental resources, so a green infrastructure approach also contributes to sustainable resource management. Urban vegetation has a positive impact on people's quality of life through its health benefits (Faure et al., 2019), social cohesion and the environment (Dehimi & Hadjeb, 2019). Green spaces have a natural heritage and constitute an urban landscape that can reinforce the residents' sense of belonging and identity. protect vulnerable areas.

Vegetation plays a significant role in arid and semi-arid cities (this is the case in our study), where rainfall is low/irregular and wind actions are remarkable and harmful (Gherraz & Alkama, 2020). Researchers have proven that vegetation is the best filter-interchange screen for wind erosion control (Shahabi et al., 2012), soil surface maintenance and particle retention (Ouzir & Khalfallah, 2017). Vegetation also plays a thermoregulatory role, helping to combat the effects of heat islands (Vergriete & Labrecque, 2007) and the creation of the cool islands in the arid zones, this cooling of the ambient temperature is due to both the shade provided by the trees and the evapotranspiration (Dugeny, 2010). Large parks where residential neighbourhoods with extensive vegetation can produce air temperature reductions as large as 10°C (Boudjellal, 2009). Public green spaces are vegetated islands consistent in the urban fabric. Maintained to varying degrees, they can cover a relatively large number of plant species, planted and/or spontaneous, and thus potentially represent an important pole in maintaining biodiversity (animal and plant) in an urban context (Clergeau, 2007). Maintaining this diversity has been recognized as a major environmental issue and a priority internationally as well as locally (Clergeau, 2007).

Trees and plants, as important components of the Earth's system, help regulate the urban climate and mitigate the urban heat island through the creation of a cool effect by giving oxygen (Ouzir et al., 2021), absorbing carbon dioxide (Vida, 2011), minimizing and intercepting solar radiation, generating shadow and absorbing radiation (Gherraz et al., 2020). The progressive degradation and weakening of natural elements from a physical and chemical point of view can lead to instability and fragility of the structures associated with such landscapes, and is responsible for a higher degree of vulnerability of natural ecosystems (Cocean, 2020). The concept of green infrastructure, which involves environmental conservation and the rationalization of the use of natural resources. Green infrastructure has become an increasingly important concept in environmental planning but is very ambiguous in Algeria. The aim of this test is to build and produce knowledge about this concept and its meaning, on what it is based and what it leads to, does it really add value? Why is the term so misused in Algeria?

The objective of this article is to study vegetation and its functionalities in an arid city, in this case the city of Bou-saada. This assessment is based on several criteria to provide a better understanding of the problems related to their development, by carrying out a diagnosis of these spaces in the city of Bou-saada and by producing a map of the vegetation of the city of Bou-saada on the basis of the use of a vegetation index applied to a medium resolution image MODIS.

Bou-saada is located in an arid zone, the temperatures vary greatly seasonally. In winter, minimum temperatures can reach 6.1°C, while maximum temperatures are around 48°C (2021). Under the threat of increasing urbanization, and the silence of planning

documents, the problem of rational management of green spaces represents for the city of Bou-saada a major focus of reflection.

The aim of the article is to analyse green infrastructure in the city of Bou-saada, three large areas fall within the definition of green infrastructure, which we define here as protected natural open spaces (Hostetler et al., 2011), that have several ecological, social and cultural advantages (Sikorska et al., 2017). They aim to improve the quality of life of inhabitants while protecting ecosystems, in particular by maintaining or creating ecological continuity.

The first area is the palm grove, which is a real human adaptation to the site, and two other green areas of ecological interest, which are managed and reforested by the forest management in collaboration with the inhabitants, protecting them against soil erosion and siltation. In recent years, these green infrastructures have suffered a deficit in terms of combating heat islands, erosion and siltation.

Main research questions are:

- What is the impact of the creation of green infrastructure in urban areas?
- What are the main problems in promoting green infrastructure in the city of Bou-saada?

Green infrastructure: Conceptual Framework and Some Directions

This research is based on several sources but mainly on research that is nevertheless complementary and quite convergent. It is in this favourable general climate that we see a very significant numerical increase in research on the theme of green infrastructure, ecosystem protection and well-being concepts. Possible contributions of green infrastructure systems to the ecosystem include the work of Tzoulas et al. (2007) and Cornet (2020).

The approach to green infrastructure is based on several themes, such as the assessment of the role of vegetation on health, the multifunctionality of green spaces in development plans (park, square, culture) and landscape ecology. They can be included all natural, semi-natural and artificial networks of multifunctional ecological systems (Bruggeman et al., 2020). The objectives of this approach are to improve the quantity and quality of green spaces, their multifunctionality and the importance of possible connections between habitats... Such an approach offers many opportunities for the integration of urban development, nature conservation and public health.

Green infrastructure can reduce this effect; photosynthesis captures some of the sunlight; vegetated surfaces have a better ability to reflect solar radiation (albedo) than asphalt; and evapotranspiration of plants captures some of the sensitive heat and helps reduce ambient temperature (Bruggeman et al., 2020).

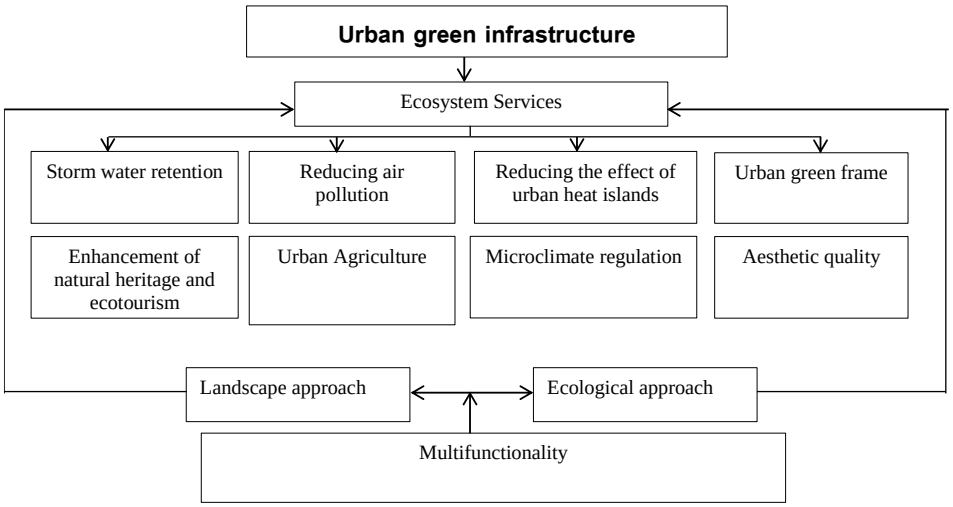

Fig. 1. The conceptual framework for green infrastructure

Methods and Methodology

Several studies have focused on multifunctionality and the evaluation of the contributions of vegetated spaces to the well-being of citizens (Cornet, 2020). But few of them are concerned with the conservation of natural heritage, the protection of fauna and flora and the fight against erosion in arid environments. Three themes were chosen to address the possible contributions of vegetation to thermal comfort: urban quality, environmental quality and landscape and aesthetic quality to analyse green infrastructure in the city of Bou-saada.

This research brings together a set of direct observations, these direct observations are taken in the field so as to obtain objective information that can be classified into defined categories and analysed statistically, it also involves the establishment of a barometer to identify and monitor the dynamics of green infrastructure, but also to estimate certain parameters of plant cover. The formulation of the barometer was based on the conceptual analysis that allowed us to identify several themes that are translated into indicators (Table 1).

Tab. 1. Green Infrastructure Assessment Barometer

Thematic	Subtheme	Indicator	Remarks
Urban supply quality	Accessibility	Private/public land	Promote exchanges, contacts and social meetings by young people in squares and recreation areas. That strengthens the bonds of society. Accessibility for all types of disability: sensory, physical, cognitive, mental or psychic.
		Accessible to all (pregnant women, children, elderly, people with reduced mobility....)	
	Functions and uses of vegetated spaces	Relaxation, meeting other inhabitants, practicing sports, recreation, - regulating heat waves, regulating the local climate. To produce food	
Environmental quality	Plant density	vegetation to soil	Conservation of the natural heritage, protection of wildlife and erosion control.
	Tree species	Selection of tree species according to climatic conditions	
Landscape and aesthetic quality	Attractiveness	design dynamization and animation the presence of street furniture	To speak of urban aesthetics is also to touch several aspects, tourism, the image of an urban brand, heritage, culture, symbol visual, urban signage of the urban environment and urban order.
	Cleanliness	Cleaning green space. The presence of baskets. The maintenance of green spaces	

Presentation of the City

The city of Bou-saada is the first oasis found in Algeria. It is located in the southeast of northern Algeria and 250 km from Algiers and covers an area of 225 km². It is considered a real crossroads between the Mediterranean and the Sahara. Locally, the capital of the Daira de Bou-saada is located south of the Wilaya de M'sila (Figure 2).

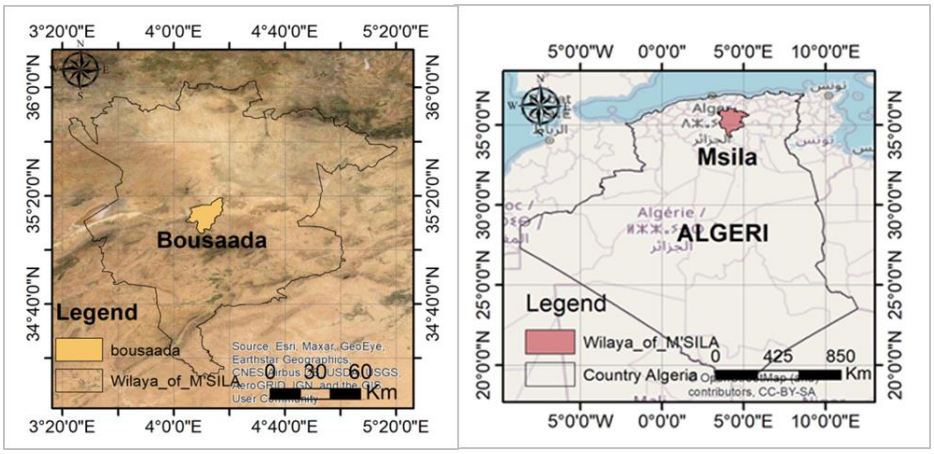

Fig. 2. The location of the city of Bou-saada

The territory of the city of Bou-saada is a varied but superimposed and overlapped territory, it is characterized by ecological elements, very varied landscapes, complex and fragile subjected to strong anthropic pressures. "The wadi, the mountain and the dunes have imposed it where it is, in slope towards the palm grove" (Nacib, 1986).

Bou-saada belongs to a semi-arid zone according to the map of the bioclimatic stages below, between temperate and tropical climates, characterized by a drought and therefore winter, spring and autumn precipitation which are rare and irregular the average being 178.95 mm per year (this data recorded at the meteorological station of Ain Diss and the agency of water resources over the period 1971-2012).

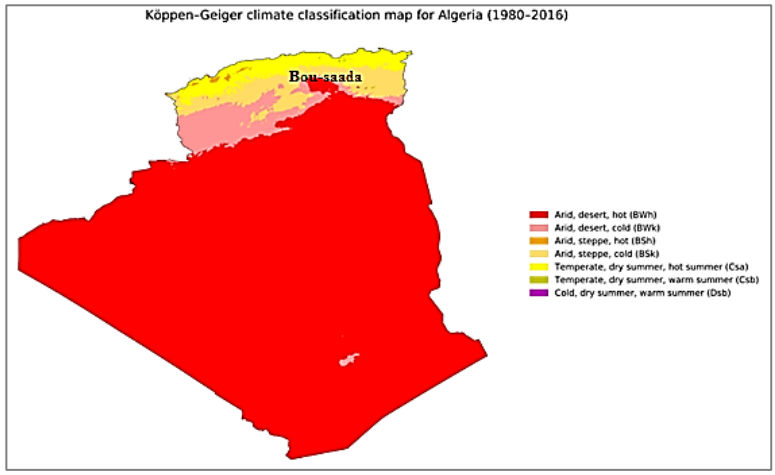

Fig. 3. Map of the bioclimatic stages

The city is located on the edge of a high plateau and desert, as a result of a very hot climate in summer with very strong and intensive solar luminosity, the variations of temperatures between the day and the night are very important from 4°C and 8°C, the winters are cold, the temperatures can drop below zero degrees Celsius.

In order to better define the climate characteristics of the city of Bou-saada (the outdoor conditions), it is useful to use monthly weather data collected at the Ain Diss weather station from 1971-2012.

Figure 4 shows the Ombrothermic Diagram of the City of Bou-saada based on monthly average rainfall and temperature data over a period of 41 years (1971-2012). this diagram shows that the dry season extends from mid-May to the end of August.

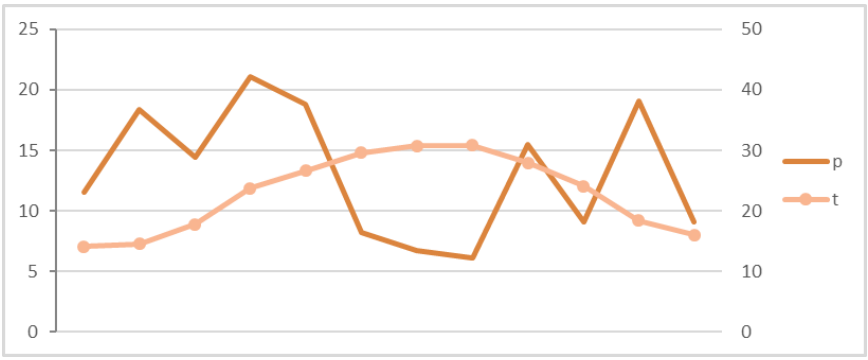

Fig. 4. Ombrothermic Diagram of the City of Bou-saada

Through the Ombrothermic Diagram of the city of Bou-saada and through the use of the xerothermal index which corresponds to the number of days actually dry during the dry period. We can only have 107 dry days to place the city in the X3 regime (Gaussen & Bagnouls, 1952). With these conditions of climatic aridity, we have endeavoured to reflect resistant and adapted tree species, the predominance of the Aleppo pine is very useful mentioning its beneficial matter of the fight against drought and desertification, with the Tipuana tipu, a tree that can reach 18 meters in height and is appreciated for its shade and as ornamental tree. It can withstand a very wide range of growing conditions, bearing the cold up to -4°C, salty soils and drought.

Discussion

The small green areas in Bou-saada city, represent 2.0796 hectares, or 0.036% of the total area of the municipality, making the ratio of square meters of green spaces to the number of inhabitants to the municipality of Bou-saada (the municipality of Bou-saada extends over 111 km² and it encompasses 160,429 inhabitants according to DPSB 2017), the result is 0.01 m² per capita, a figure much lower than the 10 m² per capita recommended by the World Organization of health (Bougé, 2009). One thing is clear: the green spaces in the city of Bous-saada are shrinking and today represent only a small part of the total area of the city.

Analysis of the three green infrastructures

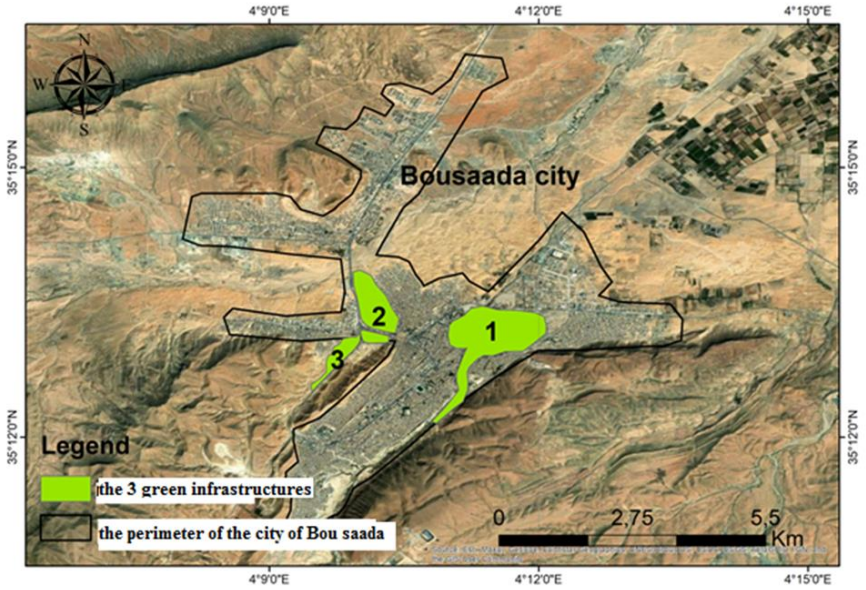

Fig. 5. delineation of the 3 green infrastructures

Analysis of Green Infrastructure 1: The Palm Grove

The palm grove has long played an important beneficial role in the city of Bou-saada, both historical, social and economic, as a friendly space, landscape creator and refreshments in short. The palm grove is a great collective heritage, but the inhabitants do not have the information available on the state of palm grove which does not allow to build their perceptions as well as the problems of degradation, deforestation, but after a few years,

The palm grove of Bou-saada covers 10 ha (Guettouchi et al., 2015) and had more than 30,000 palm trees and other crops (vines, fig trees, cognassiers, apricot trees...), it presented a real source of labour including 857 employees in agricultural activity, so it can be said that the population of Bou-saada lived more from agriculture than from crafts.

The palm grove offered other benefits, it also provided fruits and vegetables for barter with other products, it also offered a raw material (wood especially) for the construction of buildings (arches, beams...). Figure 6 shows the reduction in the area of the palm grove in favour of urbanization.

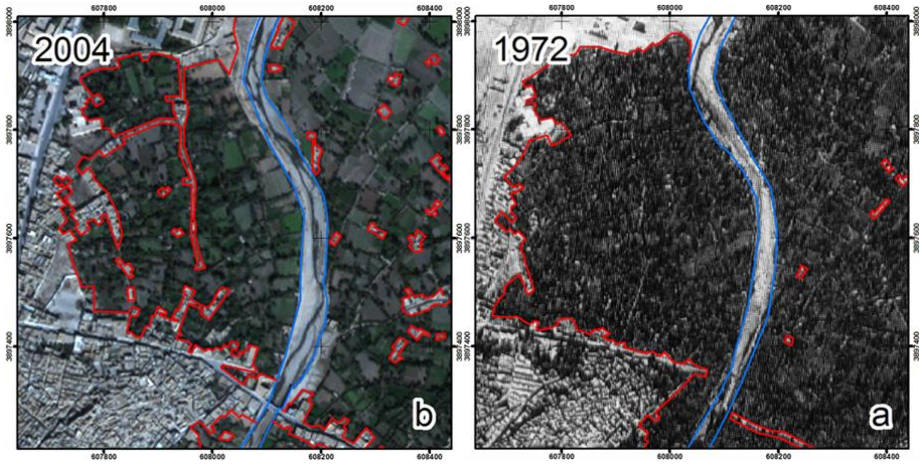

Fig. 6. The decrease in green space in the palm grove

Analysis of Green Infrastructure 2: Orchard Belghizaoui

Orchard Belghizaoui is located between the old and new town of Bou-saada, its total area is 60 hectares. According to forest services, it is considered a Type I forest, and by its strategic location, it plays an important role in the fight against siltation and erosion protection. Orchard Belghizaoui experienced a decrease in its area and a degradation of the vegetation cover.

We have reported strong anthropogenic pressure and rampant urbanization in the town of Bou-saada, which have come at the expense of ecological balances, with increased pressure being exerted by natural resources, in this case Belghizaoui orchard and the dunes, which have already been weakened to meet their basic needs.

Fig. 7. The different forms of degradation of Belghizaoui orchard that are caused by human factors

Analysis of Green Infrastructure 11: Kaisa Park

With an urban green frame and a continuum of urban vegetated spaces (Belghizaoui orchard), this park is located between the old and new town of Bou-saada, its total area is 100

hectares where it is estimated between 4 tree species. This is a place of sharing and conviviality, conducive to relaxation with a rather poor quality of arrangement.

Fig. 8. State of vegetation in the Maiter plateau

Fig. 9. Reforestation operations in the Maiter plateau

To meet ecological and recreational needs and to strengthen urban biodiversity, the urban park has been developed and reforested through several tree planting operations and a forage planting operation. The last operation took place in the second week of October 2021, and young volunteers, associations and civil society all took part in this citizen tree planting initiative.

Results

The territory of the city of Bou-saada is characterized by very varied, complex and fragile ecological and landscape elements subjected to strong anthropogenic pressures. It is characterized by a semi-arid climate with a dry season extending more than 5 months of the year, and average annual precipitation of the order of 158 mm and average temperatures of 22.9 °C. It should be recalled that the relationship between climate and vegetation is a

reciprocal relationship, climate has effects on vegetation availability, and conversely, vegetation can contribute to climate cooling.

We can clearly see that the green spaces in the city of Bou-saada are shrinking and today represent only a small and small part of the total area of the city. The results obtained using the evaluation barometer is presented in Table 2:

Table 5. Assessment of green infrastructure in the city of Bou-saada

Indicators		*Zone 1 (palm grove)*	*Zone (Belghuizaoui orchard)*	*Zone 3 (Maitar Plateau)*
The surface		*120 ha*	*60 ha*	*100 ha*
Urban supply quality	accessibility	Semi-accessible (private land)	Accessible	Accessible
	Functions and uses of vegetated spaces	Heat island reduction A factor of tourist attraction Regulation of heat waves Regulate local climate Produce power	to regulate local climate	Sports activities Leisure activities Health (prevention of cardiovascular disease, stress, obesity,) Regulate local climate
Environmental quality	Plant density	Dense	Low	Medium
	Tree species	2147 palm trees, the vine fig tree, cognassier apricot...	Tipuana tipu	Pinus halepensis Juniperus Seriphidium herba-alba Stipa tenacissima Artemisia campestris
Landscape and aesthetic quality	Attractiveness	A friendly space, unique environment Landscape designer Heritage and landscape potential A special atmosphere	A degraded orchard (broken trees) needs maintenance	Places for relaxation and recreation play areas for children (games, rides, small train) Many benches are installed throughout the park
	cleanliness	Clean (with waste from rehabilitation or demolition sites)	Pile of waste burned or surrendered	Exposure to air and noise pollution from road traffic (proximity to national road 46)

Through the analysis, we have shown a decline in vegetation in the palm grove, which is mainly due to the change in lifestyle, including the new technologies that farmers have pushed to leave the palm grove and the conversion to other profitable and advantageous sectors. Not forgetting the remote level of local/national tourism and the lack of recreational activities or the reduced accessibility due to the privatization of the land.

The Concretization of the Palm Grove for the benefit of urbanization, moreover it has become a fragile ecosystem and weak in terms of use and more particularly with the proliferation of waste within this natural heritage. This situation is a strong indication of the detachment of the inhabitants to their palm grove in a way a disinterest of the population.

The second green infrastructure (Le verger Belghuizaoui), by its location, can play a very important role in combating desertification and siltation. But as we've shown, it's experienced a decrease in area due to the blending of space by excessive urban sprawl, and a degradation and deterioration in recent years.

The third green infrastructure is a natural and semi-natural vegetated area, it has several urban and ecological functions; it is a recreational area but also protective against siltation and desertification. In order to increase the greening potential and reforest this low-density vegetated area, several operations were launched in 2021 by residents and associations. The third infrastructure can play a very important role in the fight against wind erosion and its corollary the fight against siltation by forming a natural barrier to limit the speed of the wind.

Conclusion

Through this research, we have shown the importance of vegetation on the formation of the microclimate, and this is due to its ability to reduce the impact of sun rays and winds, as well as its effect of cooling the air by the action of evapotranspiration and the reduction of heat stress during the summer period. Green spaces also have an aesthetic and decorative role, a hygienic and sanitary role and a social and educational role. (Fadel et al., 2016).

We have shown that through quantitative research of green spaces, the city of Bou-saada has nearly 0.1 m2 of green space per capita and with a proportion not exceeding 3.5% of the area of the city, that is to say it is poor compared to the national standard which is of the order of 10 m2 per capita. Moreover, the green spaces in the city of Bou-saada are often poor-quality biotopes.

The production of the green infrastructure can accommodate several activities, offers a multitude of benefits and societal and environmental. The management of the three infrastructure in the city of Bou-saada was then increasingly oriented towards the rehabilitation and reforestation to species suitable for climate data in order to improve the comfort and safety of users and promote climate resilience. So, it is necessary to think about creating and developing new green spaces in the city and restore the palm grove to its value as a rare factor. This requires a systematic mapping of land capacities and the creation of an urban forest.

The infrastructure in the city of Bou-saada require a development plan, to meet the objectives of multifunctionality, attractiveness and conviviality. Like this state, the green infrastructure in the city of Bou-saada, must be attached to the model of the edible and green city, integrating renewable energies and contributing civil society to transmit and enrich the culture of protection of the natural heritage.

Conflicts of Interest: The author declares no conflict of interest.

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