Topic C5. Thermal comfort and built environments

A Case Study about the Vegetation Influence in Urban Environment Conditions

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SUMMARY

The urbanization process does not always prioritize green areas and trees. This study monitored areas in Aracaju, Brazil, under tropical climate where trees and vegetation may reduce climatic hostilities. Coating surface temperatures, temperature, humidity and speed of air were monitored in a residential area. In addition, interviews were done about preferences in relation to green areas and climate conditions. In most of cases people recognize the importance of trees for microclimate conditions maintenance. However, they chose several reasons not to plant trees or have green area near their house.

INTRODUCTION

Urban environment is the place where phenomena from anthropogenic actions and climate occur. That fact may cause architectural and urban sceneries under influences of specific microclimates. Differently of that, in bordering urban areas, consequences of urban development are not observed due to vegetation presence and low built area density. An important characteristic of tropical cities is urban greenery that creates shading along streets and in residential areas and can assist in the development of adaptation possibilities against climate change (Abreu-Harbich et al 2015).

However, the urbanization process practiced in many Brazilian cities does not respect the climatic condition as well as topography, water drainage, rivers courses and native vegetation. The consequence of that is sceneries repetition, from North to South in the country, where areas are urbanized and causing environmental impacts as inundations, devastation of green areas, effects of heat islands, deficiency of appropriate infrastructure, impermeable soil and shortage of green areas. Mainly in areas where the population have little financial resources, those consequences are more evident as it needs a long time to occur some environmental improvement.

Exception some successful design were executed as, for instance, neighborhoods that followed the model idealized by planners of the city-gardens. In spite of environmental quality due to generous dimensions of urban areas and lands, presence of vegetation those neighborhoods were destined to privileged classes of Brazilian society. But in general, for a great portion of the Brazilian population, the uptowns are projected to assist numbers. The number of people registered by the government's office that don't have a place to live or they

live in terrible conditions. The thought seems to be implicit is for who little or nothing has, that will be great. Sheltering the largest number of residential units, without concern with green areas, preservation of arising river in an area are goals accomplished along many years. And neighborhoods are consolidated and they keep in precariousness for a long time, except for all the existence. That fact has added difficulties that include a whole city, with implications in energy consumption and public security policies for instance.

Adding to the urban subject is the climatic one. Respecting climate conditions is fundamental so that can attenuate impacts of man's action. Generally, populated neighborhoods ignore that subject in the Brazilian scenery. They have just some basic urban infrastructures as water, sewer and electric power facilities. The Figure 1 illustrates the neighborhood Augusto Franco in its inauguration in 1982. It is observed that are just individual units, one beside the other ones without trees or green areas, inserted in humid and tropical climate, with intense direct solar radiation during whole year. The soil appears without vegetation. Water drainage and courses of streams are in areas with minimum dimensions, without vegetation along way or area to feed off rainwater.

Figure 1. Popular neighborhood in 1982. In the left is view of houses and streets; in the right is narrow drainage course without vegetation. In: http://aracajusaudade.blogspot.com.br/2012/12/inaugurando-o-conjunto-augusto-franco.html

Immediate interventions are observed commonly in population appropriation in a new neighborhood that has countless and identical units. And in Augusto Franco neighborhood, the study area, it did not occur differently. It was observed interventions related to do an identification of each unit among the others, guaranteeing the personal character. And also others earlier interventions were related to security, after enlargements for sheltering all inhabitants of the family with comfort in house. Therefore, walls are erect in perimeter of house land as it is illustrated by Figure 2. It is observed that lands continue without any vegetation type. It can be considered as future interventions to become the soil impermeable in remaining free areas in house land. Private and public free areas, as back-and-front yards and paths respectively, receive coatings that obstruct rainwater infiltrations. Without grass and trees present, surface materials in neighborhood receive the solar radiation and they contribute to increase air temperatures and inhabitants' thermal discomfort.

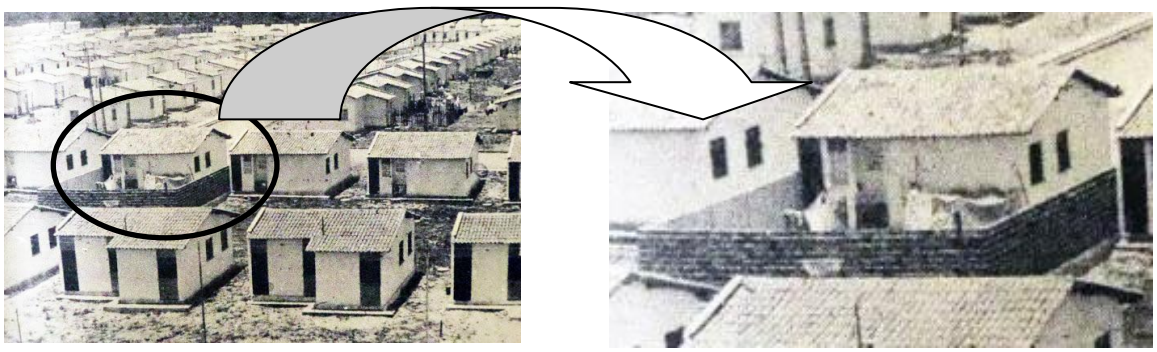


Figure 2. Earlier modifications in house - it has been highlighted walls along the perimeter and without trees. In: http://aracajusaudade.blogspot.com.br/2012/12/inaugurando-o-conjunto-augusto-franco.html

Without a planning for insert green areas to the urban plan of neighborhood, this action will become more expensive and difficult later, and not always satisfactory in environmental conditions. Changes after construction need analyses of interferences in built elements, as adaptations of free spaces and parking to available tree species, traffic signs, urban infrastructure as electric, telephone, water and sewer system among others. The electric system is aerial in most of cases in Brazilian cities which implicates severe pruning in tree canopy or having trees in just an area of the urban road.

After 20 years of neighborhood construction, significant transformation can be observed in environmental urban landscape. There are few trees along to streams and drainage areas do not configure spaces for people appropriation for leisure or practice of sports. These areas are depreciated by population that accumulates dump and garbage which causes damage and floods. When rain starts the city hall concentrates efforts to clean these areas (Figure 3). Public roads count with some and isolated trees that contribute to improve a little environmental quality for pedestrians of the neighborhood.

Figure 3. Popular neighborhood in 2002. In the left some trees and grass were along the brook which was cleaned. In the right none tree was along the street. Adapted from http://www.institutomarcelodeda.com.br/pma-continua-limpeza-de-canais-do-conjunto-augusto-franco/

Thermal properties of built components have their intensity of values differentiated and thermal balance between surfaces and atmosphere are modified due to substitution of natural coating of soil to build materials (Givoni 1992). In urban environments, the heat island occurs basically due to different values of heat irradiation between high and low built densities where there are more green areas the effects are less monitored. Vegetation has as main function maintenance of temperature and humidity levels in urban space. If the increasing of industrial activities, surfaces as asphalt and concrete, high built density and pollution in downtown intensify heat island phenomenon, in suburban area the behavior is opposed due to increase of presence of vegetation and shortage pavements. However, in Brazilian cities there are few green areas in suburban.

METHODS

The study refers to popular neighborhood, Augusto Franco, located in the southern area of Aracaju, in Sergipe, Brazil. The neighborhood is close to the Sergipe River, swamp vegetation and also to Santa Maria Airport. Aracaju is located in coast of Brazilian Northeast

(10°55'56" South and 37°04'23" West) and the city is under influences of humid tropical climate, understood among the geographical coordinates of (Gois et al 2012). The neighborhood was chosen due to actions of renovation occurred in 2013. It was carried out underground canalization of streams in two avenues in study area (points A and B) and planted trees and grass, paved pedestrians' circulation and bike lane, created areas with banks and physical exercises equipment. However, there is an adjacent square in each of the avenues that were not renovated (Figure 4). The square in the point A is practically arid. It has only 3 trees and the whole floor was paved in concrete. The other ones in point B are forested and have concrete pavement for sidewalks. The avenue of the point A is Doctor Adel Nunes and possesses trees, path for people and bikes (all made in 2013 in renovation action) while the avenue of the point B in Doctor José Tomaz D'Avila Nabuco has some old trees (grass, paths for people and bikes, other equipment were inserted in 2013).

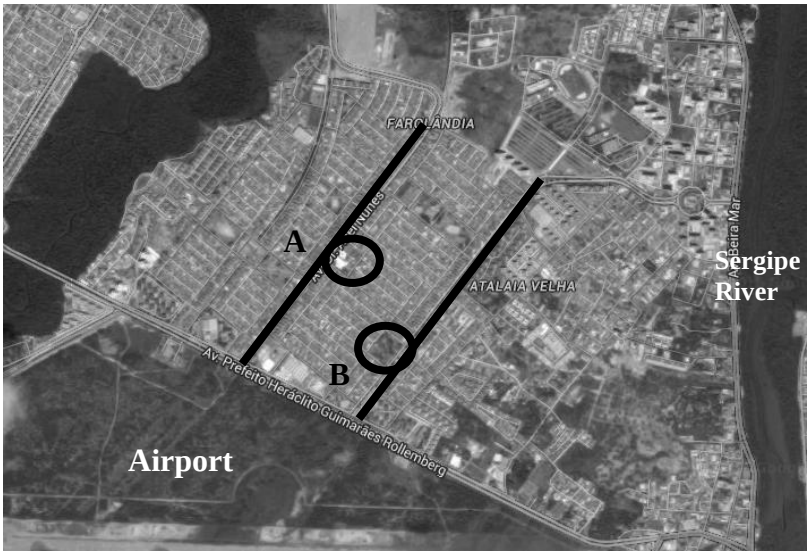


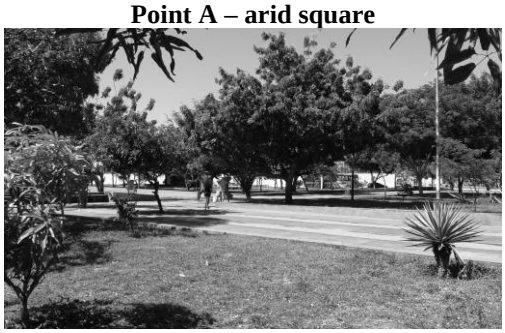
Figure 4. Study area and highlighted point A (Dr. Adel Nunes Avenue and its square) and B (Dr. José Tomaz D'Avila Nabuco Avenue and its square). Adapted from https://www.google.com.br/maps/@-10.9724956,-37.0693093,3125m/data=!3m1!1e3

Data acquisition of the study area was achieved in two stages in summer period. Firstly it was accomplished through values of air temperature (AT) (°C), radiant temperature (GT) (°C), surface temperature (ST) (°C), air relative humidity (RH) (%) and Index of Wet Bulb and Globe Thermometer (WBGT) (ºC). They were monitored points under shadows and sun in the urban roads and squares (Figure 5). Later, interviews were applied about thermal sensations and vegetation. The data was collected in morning and afternoon periods.

Point A - Dr. Adel Nunes Avenue

Point A – arid square

Point B - Dr. José Tomaz D'Avila Nabuco Avenue



Point B – square and vegetation

Figure 5. Study area

RESULTS AND DISCUSSION

The measurements were accomplished in sunny days with presence of cloudiness in some periods. The air temperature and relative humidity data were measured in two situations (under the sun and under shadows), considering that the shadow situation is due to tree presence. The results of the measurements indicate a reduction in air temperature values when measured under shadows in relation to sun exposure (Table 1) as expected. The largest values of air relative humidity were found in the point B (so much under shadows as sun exposure) which demonstrates a relation to vegetation presence that helps in maintenance of values in the middle of the day (with strong solar radiation).

The largest values of WBGT were reached under the sun, in mornings and afternoons periods as expected where there is no vegetation. For WBGT values from 30 °C to 28.5 °C, the physical activities should be among light to moderate; with metabolism variation from 150 Kcal / h to 250 Kcal / h. The values were always registered above 30º C when sun exposure. This fact indicates caution in practice of some activity or physical effort to avoid the thermal stress. Meanwhile globe temperature illustrates as surfaces that store heat and after irradiate to atmosphere in relation to vegetation presence that uses that energy to accomplish photosynthesis.

Surface temperatures were measured in available surfaces in each point, in the morning and in the afternoon as shows in Table 2. Values of concrete pavement reached 58.5 ºC when exposed to solar radiation and while grass reached 41.1 ºC also in the afternoon (point B). The surface temperature of concrete is compatible with values of grass in shadow situation. The smallest superficial temperatures were found in shadow situation in pavement, concrete and grass. Those values are very close to air temperature values monitored in respective points.

Table 1. Values of WBGT, GT, AT, RH to study area

	Climate Variables	Point A1		Point A2		Point B1		Point B2	
		Shadow	Sun	Shadow	Sun	Shadow	Sun	Shadow	Sun
Morning	**WBGT (ºC)**	30.6	31.8	30.7	31.7	31.6	31.8	31.3	32.2
	GT (ºC)	35.4	39.6	37.9	41.3	37.8	40.1	38.5	41.8
	AT (ºC)	31.9	32.9	31.2	32.7	32.4	32.7	31.6	32.3
	RH (%)	81	77.6	80.1	78.9	82.2	78.5	84	81.2
Afternoon	**WBGT (ºC)**	31.6	32.9	31.5	32.1	29.9	31.3	29.6	31.2
	GT (ºC)	37.5	41.1	39.2	40.4	36.9	39.6	32.7	37.9
	AT (ºC)	32.6	34.7	32.2	33.6	30.3	31.6	30	32.1
	RH (%)	78.7	80.6	78.4	76.6	83.7	77.9	87.5	79.9

Table 2. Values of Surface Temperatures (ST) (ºC) to study area

	Surfaces	Point A1		Point A2		Point B1		Point B2	
		Shadow	Sun	Shadow	Sun	Shadow	Sun	Shadow	Sun
Morning	**Concrete**	33.5	51.9	36.6	46.1	35.2	43.5	34.9	41.3
	Grass	-	-	31.7	44.3	-	-	33	38
Afternoon	**Concrete**	37.9	50	35	45.5	35.3	58.5	33.8	43.8
	Grass	-	-	30	40	-	-	30.1	41.1

As expected grass presented low values to surface temperature. To minimize the surface temperatures of the urban surfaces it is interesting to block the direct solar radiation in those materials. To use materials with high albedo may promote a reduction to heat island (Akbari et al 2012). However, it may cause a luminous discomfort to pedestrians if white or light colored materials are applied. While there are no available technologies (cool or selective materials) as described in Santamouris et al (2011), it is important that one can offer more comfortable urban environment designing urban spaces with sun protection. The vegetation can make that paper very well. They are unquestionable benefits that trees and green surfaces can provide to human being and environment. In Abreu-Harbich et al (2015), the study shows the benefits for the microclima, especially attenuation of temperature and elevating the humidity of the air in places with trees agglomerated. It is proven also about influence ray of trees that depends on the number of plants in the place, of the size and format of their canopy. In addition to the thermal comfort, it has the benefits for the visual comfort in green areas that they can attract small birds and insects and to promote the rainwater infiltration, aiding in the maintenance of the local water cycle.

It was applied interviews to users and it was composed of following items: Part 1 composed of gender, age, anthropometric data, activity, thermal resistance of closet; Part 2 composed by perception of current time conditions, thermal comfort sensations and trees presence users' residences. Likert scale about thermal sensations of seven points (variation from -3 to +3) and its corresponding values to Fanger index, PMV (Predicted Mean Votes) and PPD (Predicted Percentage Dissatisfied) were applied in study area and they are described below (Table 3).

For evaluation of thermal comfort conditions for each pedestrian at places corresponding to Points A and B were analyzed data that represent thermal sensation votes becoming from the interviews and compared to PMV values obtained by Fanger method. It was interviewed men and women in squares of A and B points, with age group from 17 to 65 years.

Table 3. Scale for PMV e PPD.

PMV	**- 3** Cold	**- 2** Cool	**- 1** Slightly cool	**0** Comfort	**+ 1** Slightly warm	**+ 2** Warm	**+ 3** Hot
PPD	**100 %**	**78 %**	**26 %**	**5 %**	**26 %**	**78 %**	**100 %**

Regarding to sensation of users' thermal comfort in the moment of interviews, it was observed 20 % of interviewees declared to be in neutrality situation in point B and 0% in the point A. From 100 % of votes that were in discomfort situation in the point A, 84.2 % declared vote corresponding to value of + 3 (hot) and 15.8 % declared vote equal to scale + 2 (warm). 55 % of users opted for vote + 3 and 20 % for vote + 2 in the point B.

When pedestrians were questioned about there are trees in their residences, 60 % of users answered YES in the point B, while 63.1 % say NOT in the point A. About total, only 84.2 % would like to plant tree if they had space in their residences.

In spite of interviewees declared some thermal discomfort, when questioned about degree of tolerance in relation to be exposed to climatic conditions, 80 % declared to be easily tolerable in the point B and 63.15 % in the point A. They were walking in the point B (80 %) while they were in rest or accomplishing light activities in the point A (84.2 %) in the interview time. It was observed certain conformity of population in relation to current situation and it was observed a contradictory aspect that some people demonstrate appreciate trees, but they do not have ones in front their houses. Others live in apartments and they don't have area to make a green area. The public space is space of all and of each one also, when pedestrians understand that and apply principles of environmental education, maybe there is a place that doesn't suffer microclimate hostilities.

CONCLUSIONS

In tropical climate, air temperature is higher for the whole year and solar radiation is intense. It was observed higher values of air and surface temperatures. In spite of the neighborhood being in an area different from downtown (higher built mass), the data monitored by Kohler et al (2014) for downtown show air temperatures from 28.7 ºC to 32.3 ºC, temperature range not very different from it found in the neighborhood and its shortage of vegetation. This fact may be explained due to tall buildings shade urban surfaces in the morning and afternoons which reduce the time of direct solar exposure. And other point observed in both studies, in worst hours of day (between 11 a.m. to 3 p.m.) it is almost impossible to apply interviews because there were few people in spaces and they were not receptive. In this direction, vegetation may contribute to improve better conditions to urban environment and consequently for buildings and human beings.

In this case, the cultural barrier is needs to be worked, since pedestrians associate the trees presence to demand of constant maintenance, need of cleaning of the dry leaves, prunings, etc. Areas with vegetation are small and punctual then their benefits are also limited in the local study and that scenery repeats in city. Therefore, it causes a dependency of air conditioning system in vehicles for urban space appropriation. It will expect those data may guide future studies or inspire new approach for working with cultural barriers in thermal comfort in urban environment.

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