641: Influence of land use and occupation in the urban heat island

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Abstract

This paper describes a research about urban thermal environment in the city of Campinas, Southeast region of Brazil. The aim of the work is to identify urban heat islands and their relation with land use. Data collection was carried out through temperature measurements in fixed points in a central area of the city with different configurations: horizontal occupation mixed with vertical; predominantly horizontal; densely built area with vertical occupation and an area near to urban park. Data were collected in summer and winter periods. The study area was defined through field research, compilation of maps and cartographic bases and aerial photographs, so that the different urban occupation patterns could be identified. The presence of vegetation and water bodies was also verified. Geographical Information Systems (GIS) allowed generating new data, through processing obtained information about sectors with different geographical expression. Interrelationship between climatic parameters and spatial urban organization was the basis for the analysis. Results show that maximum diurnal temperatures were not much affected by the urban configuration, a different behaviour as compared with nocturnal temperatures, which show meaningful variation depending on the urban configuration and land use

Keywords: Urban climate, land use, GIS

1. Introduction

The influence of urbanization in urban climate has been intensely studied. Factors with great influence on urban climate are the position of the city in the region, city size, density of building construction, urban land use, buildings height, orientation and width of the streets, lot division, effects of parks and other green areas and the detailing design factors which affect external conditions. It is observed a decrease in water evaporation caused by lack of vegetation, high soil impermeability and rainwater drainage; the effects of energy transformation within the city, heat production through industrial processes, traffic, housing, in addition to the thermal properties of buildings and pavement materials in relation to absorption of solar radiation and emission of thermal radiation, consequently increasing nocturnal temperatures.

Several authors show a correlation between heat island intensity and urban land use ([5]; [7], [4]; [3], [8]), air pollution ([9]). Other studies ([6]) simulate the phenomenon through physical modeling and computer simulations.

The knowledge of climatic factors and their relation with site characteristics – morphology, topography, presence of vegetation, water bodies is important to the establishing of recommendations for urban planning regarding better thermal conditions in the city.

The aim of this work is to to identify urban heat islands in winter period and their relation with land use in a central area of the city of Campinas, Brazil.

2. Methodology

The study was accomplished in the city of Campinas, Brazil. Campinas is located Northwest of São Paulo city, at 22°53'20" South latitude, 47°04'40" West longitude, and 694 meters altitude. The total area of the municipal district is 796,40 km^2 and the population is near one million inhabitants. ([1]). The local climate is tropical continental, presenting an average annual temperature of 24 ºC, with a hot and humid summer period from November to March, and mild and dry winter from June to August.

The field work was not accomplished in the whole city; a region in the central area was chosen, with a complex urban reality, different building configurations and land use. Measurements were carried out in 12 fixed points well distributed in the chosen study area. The criteria for distribution of points was to looked for areas with different building height, land use, presence of vegetation and water bodies, construction density. The positioning of the points was established after detailed cartographic analyses of the area and field verification. Figure 1 shows the map with building heights classification, showing the fixed measurement points.

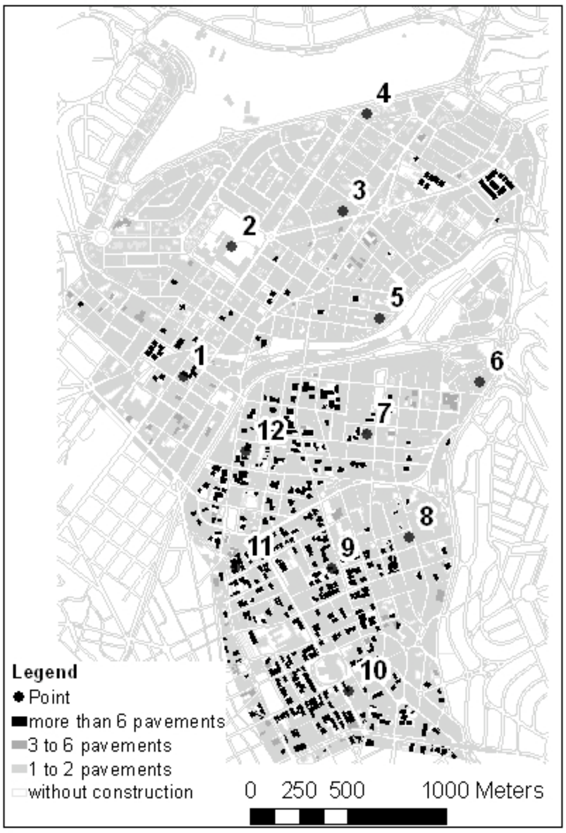

Figure 1: Characterization of the study area according to building heights

A description of the surroundings of each point is given below:

- Points 1, 2, 3: Area with mixed use, little vegetation, predominantly one or two-storey buildings, exceptionally eight storey buildings.
- Point 4: Predominantly residential area with one or two-storey buildings near to green area (urban park) and water body.
- Point 5: Residential area with one or two-storey buildings near to lowland valley
- Point 6: Mixed use, one or two-storey buildings near to lowland valley.
- Points 7 and 8: Mixed use, one to three-storey buildings, little vegetation.
- Points 9 and 10: Mixed use, predominantly above eight-storey buildings, with low-rise buildings, little vegetation.
- Points 11 and 12: Mixed use, predominantly above eight-storey buildings, with low-rise buildings, near to lowland valley.

Temperature data were collected in continuous registrations, through loggers installed at places in the shadow, avoiding direct solar radiation, at a height from 1.5m to 2.0 m.

3. Results

Average values for minimum and maximum temperatures and thermal amplitude in winter period are shown in table 1.

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Table 1: Average values for minimum and maximum temperatures and thermal amplitude – Winter period

Points	Average minimum air temp. (°C)	Average maximum air temp.. (°C)	Thermal amplitude (°C)
1	15.50	24.60	9.10
2	15.60	25.70	10.20
3	16.80	24.50	7.70
4	13.60	23.20	9.50
5	14.70	22.70	8.04
6	12.10	25.00	12.90
7	13.60	22.30	8.70
8	16,00	23.00	7.10
9	16.40	23.60	7.20
10	17.00	22.40	5.30
11	14.30	21.90	7.60
12	15.70	24.20	8.6

The maximum observed difference was 5 ºC between points 6 (12.10 ºC, lowland valley) and point 10 (17.00 ºC, high-rise buildings). Proximity of lowland valley and creek also contributes to nocturnal cooling in points 5 and 11. In spite of the fact that point 11 is located in an area of high-rise buildings and high pavement impermeability, there is an influence of lowland valley area next to a creek. Point 5 is influenced by green area and permeable soil. An urban park in the proximity of point 4 with vegetation and water body explains the behaviour for minimum temperature in point 4.

Points 1, 2, 3, 8, 9, 10 and 12 show the higher values for minimum temperatures. High pavement impermeability and dense built areas, little vegetation contributes to thermal storage so hindering night cooling.

In relation to maximum temperatures, the differences between points were smaller than for minimum values. A difference of 3.80 ºC was observed between points 2 and 11. This point in spite of the proximity of lowland valley received the influence of nearest surroundings. The highest maximum temperature was observed in point 2 (25.70 ºC). In this area the predominance of one or two-storey buildings contributes to a high solar access. The same observation is valid for point 6, with open areas at the lowland valley. The other points show a different behaviour in relation to maximum temperatures. A variation of about 2 ºC was observed between points 1, 3, 12, 4, 8, 9, 5, 7, 10 and 11.

The highest thermal amplitude was observed in point 6 (12.90 ºC), with the smallest minimum and the highest maximum. The vicinity of lowland valley was favorable to a high solar access, so causing a highest diurnal heating. On the other hand, this condition also contributes to a stronger night cooling. The area with great concentration of high-rise building (point 10) showed the smallest thermal amplitude (5.30 ºC). In this case, the solar access is difficult and the heat storage is high, so hindering night cooling.

Isotherms maps for winter minimum and maximum temperatures and thermal amplitude were obtained with the software Surfer 8.0 (figures 2, 3, 4).

It can be seen in figure 1 the tendency to increasing minimum temperatures around point 10 and the smaller minimum temperatures around point 6. In relation to maximum temperatures (figure 2) point 6 shows the highest values. As a consequence this is the point with the highest amplitude (figure 3).

It can be seen that minimum temperatures show meaningful differences (figure 2). By comparing those temperatures with the characteristics of land use pattern it was possible to evaluate the occurrence of urban heat island. To achieve this kind of analysis it was adopted the method proposed by Gómez et al. [2], which establishes the following categories: low intensity heat island when thermal differences oscillate between 0 and 2°C, moderate heat island when differences are between 2 and 4° C, strong one for differences between 4 and 6° C, and very strong heat island when temperature differences are higher than 6° C. Through this method it is possible to obtain the thermal difference for each point, adopting as reference the point with the lowest temperature value, point 6. Points 4, 6 and 7, with few buildings with more than six pavements, show low intensity heat island. Points with a large density of high buildings (points 9 and 10), present strong heat island. For moderate intensity it can be seen two tendencies in the behavior: in the upper area of the map (figure 1), where predominate one to two-storey buildings (points 1, 2 and 5) and the lower area, with high concentration of buildings with more than 6 pavements (11, 12 and 8). Point 3 is an exception in this behavior, since its location is near points 1, 2 and 5, with the same characteristics, but presents a strong intensity heat island. So building height presented meaningful influence on the intensity of heat island.

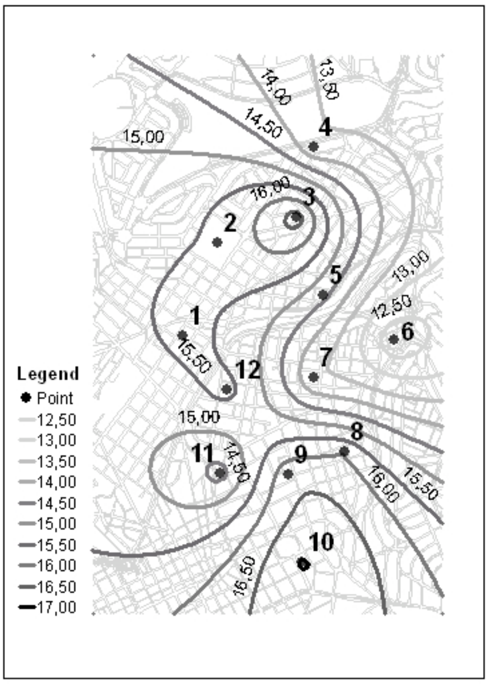

Figure 2: Thermal map: Minimum temperature in winter (Celsius)

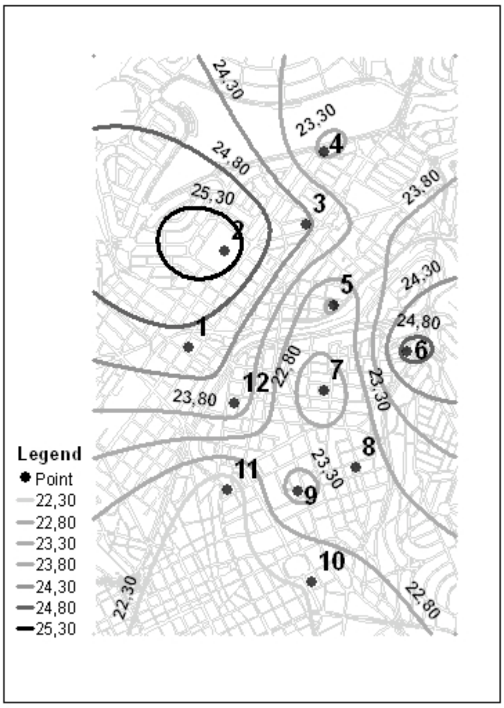

Figure 3: Thermal map: Maximum temperature in winter (Celsius)

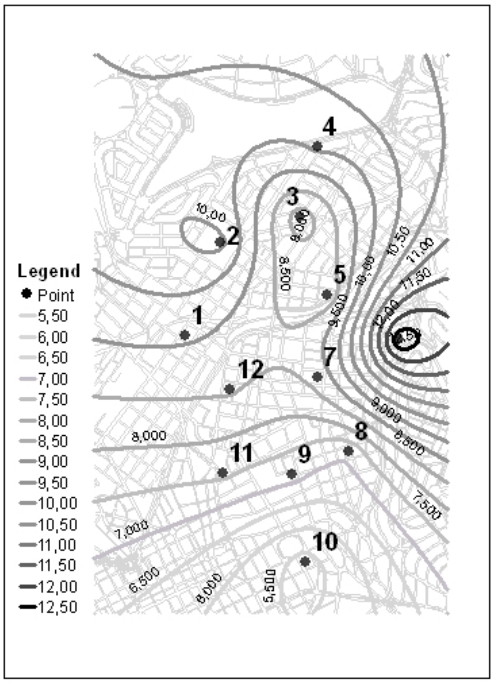

Figure 4: Thermal map: Temperature amplitude in Winter (Celsius)

4. Discussion

It is important to observe that points located in areas with similar urban configuration of land use present similar thermal behaviour. Areas near to lowland valleys show meaningful thermal differences in the urban region.

Areas with greater solar access show the highest maximum temperatures. These occur in the afternoon when the effect of solar incidence if strongly observed.

In the period of night cooling the hottest areas in the city are those with predominance of one to two-storey buildings or those with high buildings, both with little vegetation, intense traffic, high pavement impermeability. Those are factors that contribute to the intensification of nocturnal heat island. It is worth noting the high amplitude in the points near to lowland valley (12.90 ºC), in comparison with points in dense built areas (5.30 ºC).

The analysis of obtained data for winter period allows to conclude the strong association between the thermal environment and the urban morphology and lad use.

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