URBAN HEAT AND URBAN COOL ISLANDS: INFLUENCES OF VEGETATION AND SOIL SURFACE IN SOME CITIES, SOUTHERN BRAZIL.

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Abstract.

Urban climate can be observed in two scales: the urban boundary and the urban canopy layer. To the first dimension, the regional landscape is very important to identify urban heat or urban cool islands. The land use, mainly soil covertures, influences the thermal inertie and air temperature. On the second scale, the intra-urban landscapes, with an important heterogeneous land use and urban functions, the UHI and UCI in lower dimension, are formed simultaneously influenced by mineralization and vegetation of the ground covertures. These aspects are observed in Londrina and Maringa, two cities located in the south of Brazil.

Key-words: Land use, urban heat / cool islands, Brazil.

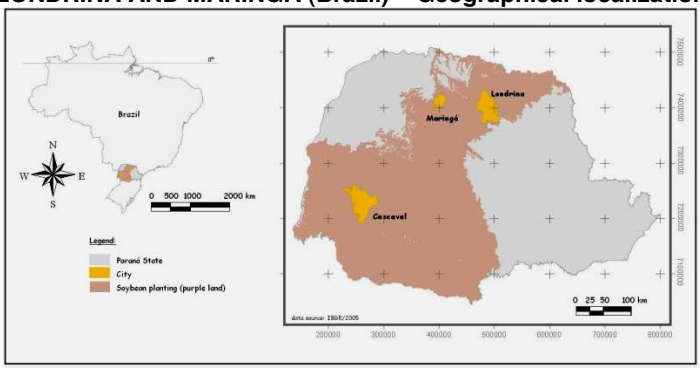
1. INTRODUCTION

The urban climate, conceived as SCU (System Urban Climate - MONTEIRO, 1976), is composed by three subsystems that present narrow interaction between themselves: the thermodynamic, physic-chemistry and the hydrometeorology. They can be studied in two distinct and complementary scales: urban boundary layer and urban canopy layer (OKE, 1978).
In the scope of the thermodynamic subsystem, the flows of heat from the solar radiation are studied; also, the emission of the surface and the heat generated by the human activities. The formation of Urban Heat Islands (UHI) and Urban Cool Islands (UCI), as well as the human environmental comfort, are also objects of study in the scope of this subsystem, focused in the present study.
The climate of the city consists in a composition of energy originated from natural and anthropogenic flows (OKE, 1978; HUNTER, 1976). In many urban areas of the planet, particular moments of energy excess occur and as a consequence, there is the formation of UHI, or the opposite, a reduction and the formation of UCI. In the Brazilian cities, these two situations can occur in different seasons or, simultaneously, at the same time during the day.
UHI or UCI can form themselves over the entire city when compared with the contiguous agricultural zone (urban boundary layer), or as an archipelago of intra-urbans islands (urban canopy layer), alternating between heat and coolness of different magnitudes. The occurrence of bigger diversity of internal thermal islands in the city shows, mainly, the biggest heterogeneity of land use, the functions and the urban morphology, and dominant atmospheric situation (MENDONÇA, 1995; MONTEIRO and MENDONÇA, 2003).
Regarding the localization of urban area, in relation to the surrounding rural area, the formation of UHIs and UCIs can be better defined or not. Thermal inertia of the ground shows an important factor in the definition of these islands (IMAMURA BORNSTEIN, 1991; MENDONÇA, 1995). The role played by the land use and occupation, when compared to the urban and agricultural surfaces, as well as the control of the intra-urban green masses (parks) in the SCU formation in Londrina and Maringa cities (Brazil), are analyzed in this study. Ground data and satellite images where applied to develop the analysis.

2. URBANIZATION AND CLIMATE IN LONDRINA AND MARINGÁ / BRASIL: General Aspects.

Londrina and Maringa are two cities (approximately 500,000 and 350,000 inhabitants, respectively) located in the South region of Brazil (Fig. 1). These cities are very new (established in 1934 and 1944, respectively) and display an American and modern model of urbanization, with high density of buildings and urban functions in the central area (CBD - Central Business District).
Following the logic of the reproduction of the agrarian and financial capital, these two cities have been created to concentrate and coordinate the activities of the entire North of Paraná. During approximately 50 years, the settling directed for the CTNP (Land Company North of the Paraná) substituted around 90% of the native forest (Atlantic Rainforest) for extensive coffee cultivation; later, the soy-wheat cultivation replaced the coffee.
In a short time, the regional urbanization evidenced the consolidation of an urban net whose materiality is sufficiently visible. Therefore, the cities outstand in the homogeneous landscape of extended cultivations (plantations). The formation of the urban and intra-urban climates of these cities evidences, directly, the characteristics of this type of landscape.

Fig. 1
LONDRINA AND MARINGÁ (Brazil) – Geographical localization



The North of Paraná region climate is the Cfa with hot and humid summer (thermal annual mean around 21°C; absolute temperatures can arrive at 41°C); cool and dry winter. The year mean rainfall of the region is around 1400mm to 1600mm, controlled by intertropical atmospheric systems (MEc and MTa) and extratropical (MPa) - Mendonça and Danni-Oliveira, 2007.
The regional deforestation and the agricultural activities constitute the main climatic factors of the human action in the area. These are much more expressive in the scope of the regional and local climate; therefore, the intensification of the radioactive flow of agricultural ground is accentuated in the two periods of the year harvests. The clay composition, the compacting and the dark coloration of the soil (*terra-roxa estruturada*), with weak albedo, generate high thermal inertia when the surface is humid (notably under clean sky conditions); thus, the agricultural surface influences strongly in the climatic characterization of the area (MENDONÇA, 1995).
The different surfaces react differently to the radioactive process and possess, consequently, albedo distinction (BONN et ROCHON, 1992); this, in turn, influences directly in the formation of the temperature of the next air layer. Agricultural surfaces, covered or naked and dry or humid, possess differences of emission and influence directly in the characterization; its coloration and porosity/compacting also has an important influence (MENDONÇA, 1995).
The *terra-roxa estruturada*, main regional type of ground, possess high thermal inertia in relation to the urban areas when it's humid and covered by cultivations. The regional agricultural calendar registers two harvests per year; so, the ground of the agricultural area is, at least, twice per year, naked. This happens in the preparation of the land for the summer cultivations (soy and corn mainly, between August and September) and the winter cultivations (wheat mainly, between March and July).
Notably, during these periods, when the agricultural surfaces of the region carry intense radioactive process, with low albedo, they show the most important influence on the climatic characterization of the area. The influence of the ground covering in the formation of the urban climate (boundary and canopy layer) of the cities of Londrina and Maringa can be observed in two situations, as it will be seen below.

3. URBAN HEAT AND URBAN COOL ISLANDS IN LONDRINA AND MARINGÁ / BRASIL

The mineral composition, the compacting and the ground color of the region, accentuate its thermal variation, therefore showing low albedo when naked and dry. On these conditions and with direct sun flow, the thermal inertia of the agricultural surfaces is low when compared with the urban green areas. In situations as these, the cities of Londrina and Maringa form UCIs in the regional scope (urban boundary layer), so the urban vegetation (parks, squares, streets, yards, etc.) induce the formation of a space less warm than those of surroundings. The satellite images of the two cities, taken in different situations (2004 and 2006 - Fig. 2), evidences the formation of UHI (agricultural ground covered by cultivations) just as of UCI (naked agricultural ground).
The urban thermal profile of these two cities is similar to that proposed by OKE (1978); the air temperature tends to rise as the constructions and the urban functions are more intense. In general, this association is more important in the CBD zone (Central Business District), place of higher temperatures, as it can observed in the example of Londrina city (Fig. 3). Negative alterations of the *plateau* due to the *park effect* and *oasis effect* were also observed, even if the peak coincided with the most urbanized area of the city. On the parts influenced by the *park effect* and, simultaneously, *oases effect,* it was formed UCI; and UHI on the mineralized surfaces and under the concentration of urban activities.
The UCIs on the cities of Londrina and Maringa are formed, over all, during the daylight, with greater evidences between 09:00h and 16:00h during summer's harvest, when the agricultural ground is naked and dry; there has been observation of UCIs with intensities up until -4,5°C, contrary to the observed one by IMAMURA-BORNSTEIN (1991), to whom such occurrence is typical of the winter situation.

Fig. 2
LONDRINA/PR AND MARINGÁ (Brazil)
Colored Composition (6,5,2) Landsat Image/2004 and 2006

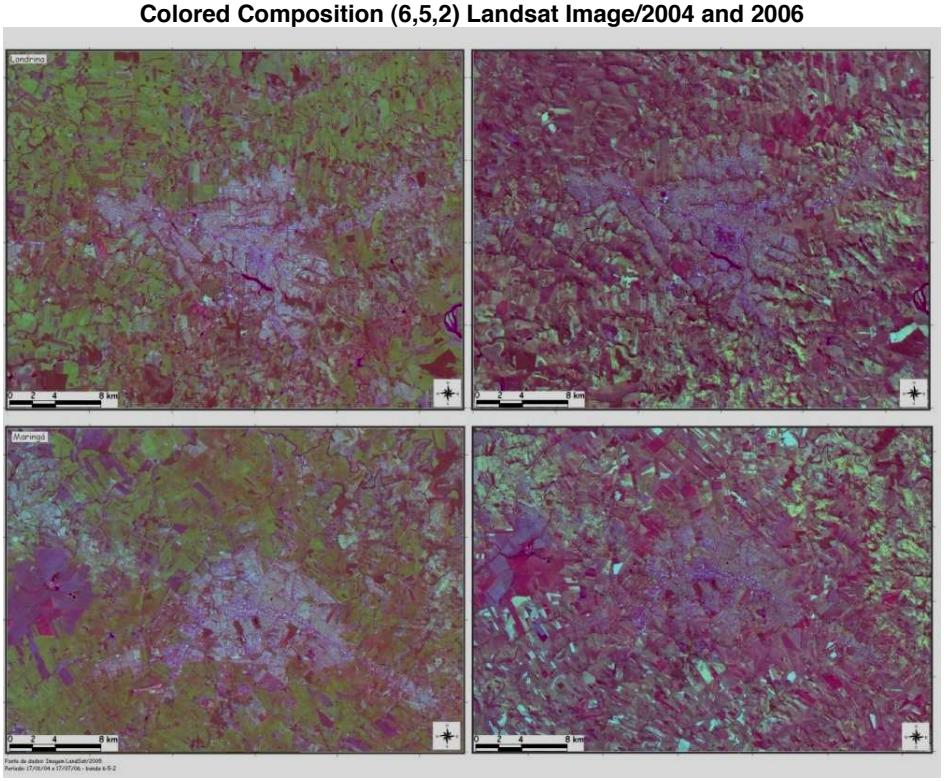


Fig. 3
LONDRINA/PR (Brazil)
Colored Composition (6,5,1) Landsat Image/1993

In regard to the formation of UHIs in these two cities, the meteorological data and satellite images have allowed to observe that it occurs at the end of the day, with more evidences around 22:00h. At Londrina city, the biggest observed intensity of UHI in the year of 1991 was of approximately 12ºC, when the agricultural ground was covered by cultivations. This fact accentuates the emission of the surfaces and of the urban activities that, under low wind, intensify the urban heat, producing air temperatures higher than rural surroundings.
In the scope of the different intra-urban landscapes of the two cities, it was possible to evidence the simultaneously formation of UHIs and UCIs of smaller scale. This scale of analysis (canopy layer) revealed the different roles played by the mineralized surfaces and the areas in which urbanism placed the urban parks. In the first ones, an intense variation was shown daily thermal-hygrometrical and seasonal, aspect far less evident when the second are observed; also, the meteorological data the urban surface termography indicated the role of these distinct environments in the formation of the urban climate.
The urban climate of Londrina in the 1993 summer, for example, at two different times, pointed the great influence of the mixture of surrounding agricultural ground in its formation, as IMAMURA-BORNSTEIN (Op Cit) observed. The formation of some UCIs, at the same time to the UHIs, when the area was dominated by the intertropical systems confirmed the importance of the intra-urban green spaces (*oasis effect*, *park effect*), originating ruptures in the continuity of the urban thermal *plateau* (OKE, 1978), even if the *peak* not always coinciding with the most urbanized area.
A difference of approximately 15℃ was also observed (23,4ºC - 41,4℃) in the urban area of Londrina (n otably over the urban green spaces) and the surrounding agricultural surfaces (with naked ground). The analysis of the variation of the thermal inertia is a factor of basic importance for the understanding of the city's climate (MENDONÇA, 1995).

4. CONCLUSIONS.

Londrina and Maringa, two cities situated in a region of intense agricultural production in the south of Brazil, have shown particular and interesting aspects about the formation of the urban climate. The study shows some results, according to the urban climate configuration proposed by OKE (1978) and MONTEIRO (1976).
The analysis of the local dimension of the cities in the regional scope (urban boundary layer) confirms, in general, that the formation of UHIs and UCIs is strongly controlled by the agricultural calendar (thermal inertia of ground); UCIs when the ground are naked (years harvests) and UHIs when covered by cultivation.
On the other hand, when analyzed under the perspective of the intra-urbans landscapes (canopy layer), the cities have shown the formation of simultaneous UHIs and UCIs, particularly in situations of low winds. The role of the ground cover was remarked. UHCs were associated to the mineralized areas and intense urban functionality; the UCIs have been associated to the *park effect* and *oasis effect* of the urban vegetation.

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