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The urban growth of the metropolitan area of Sao Paulo and its impact on the climate

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ABSTRACT

The Metropolitan Area of Sao Paulo (MASP) has undergone a rapid urban growth process over the years, and this has been reflected in major climate change. Thus, through the documentation of the urban evolution process of MASP associated with the analysis of historical series of meteorological data, this research tries to show that changes in land use, evidenced mainly by the loss of green areas in the process of urbanization growth over the years, may result in climatic changes characterized by different states of equilibrium. The climatic changes caused by urban growth are better observed in the temperatures, however, the variable precipitation, although with a high level of uncertainty, can also reflect these changes in particular episodes, which in the case of MASP occur mainly during the rainy season. The results of this research indicate that both precipitation and temperature data show a tendency to increase the frequency of days with extreme values, especially since the mid 70's. Knowing the results that intense changes in land use can generate, the population and urban planners should consider the possibility of applying actions to control and reduce this disturbance in addition to adapting to the changes that have already occurred.

1. Introduction

Of the developing countries, Brazil is one of the most urbanized in the world, where even small and medium-sized cities in the countryside are urbanizing without proper care of the orderly occupation of urban land. The climatic variations between urban and rural areas are high, having as main causes the replacement of natural vegetation by materials such as concrete and asphalt, the density of buildings among others (Lombardo, 1985).

This context fits with the Metropolitan Area of São Paulo (MASP), characterized by a strong urbanization and lack of proper planning, facing several challenges related to the environment and especially climate change as other parts of the world.

Nowadays, the MASP is characterized by a heterogeneous urban structure, which has been caused by the rapid growth of the city during the last century (Fig. 1). One of the effects of this growth is the social conflict and the contrast of high-rise office towers close to poor informal settlements (favelas).

The distribution of vegetated areas is non-uniform in the city. Only the wealthiest boroughs are characterized by a large amount of vegetation and tree-aligned streets, while the downtown and peripheral areas are almost devoid of vegetation (PMSP, 2015).

The denser vegetation areas of the MASP are mainly located on the outskirts of urban spot, characterized to be areas of environmental protection and preservation of water sources, and some important urban parks, such as the State Park of Fontes do Ipiranga (State Park), Ibirapuera Park and Olavo Egydio Setúbal Park (Carmo Park), that can provide indicators of the benefits and services provided by the vegetation like mitigating the effects of the urban climate.

Thus, through the documentation of the urban evolution process of MASP associated with the analysis of historical series of meteorological data, this research tries to show that changes in land use, evidenced mainly by the loss of green areas in the process of urbanization growth over the years, may result in climatic changes characterized by different states of equilibrium.

The climatic changes caused by urban growth are better observed in the temperatures, however, the variable precipitation, although with a high level of uncertainty, can also reflect these changes in particular episodes, which in the case of MASP occur mainly during the rainy season (summer).

It is known that the urban nuclei grow constantly, altering aspects such as the morphology of the terrain in which is inserted, besides their environmental and climatic conditions. However, urban expansion usually occurs in stages (historical, economic and social), which

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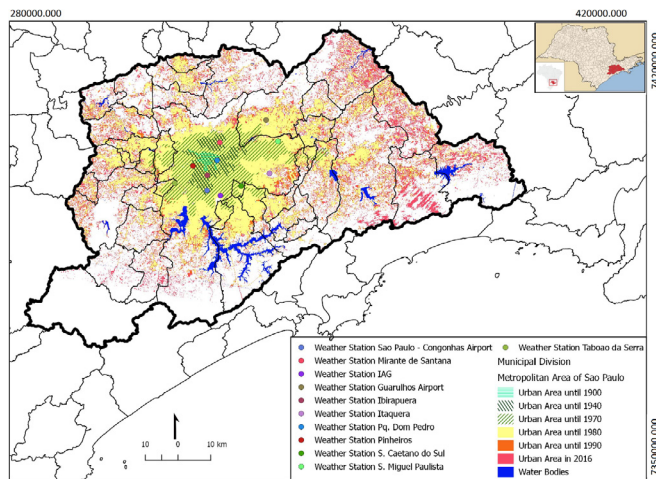


Fig. 1. Evolution of Metropolitan Area of Sao Paulo (1900–2016) with the location of the meteorological stations.

determine the proportions of growth and the different types of uses given to the land. The climatic changes observed in urban areas generally reflect each of these stages, and it is possible to note that in a context in which the land uses no longer change rapidly, the climatic parameters find a new state of equilibrium that lasts until a major change occurs.

One of the first Brazilian researchers to raise the idea that the urban climate has an adaptive character was Monteiro, who in 1976 proposed the methodology of the Urban Climate System (UCS) based on the General Theory of Systems, created by Ludwig Von Bertalanffy, associated with Arthur Koestler's holism principle. Monteiro's choice was due to the fact that this basis would help to reveal the essence of the urban climate since this is a phenomenon of high complexity. In this way, Monteiro established the UCS as a complex, open, adaptive and self-regulating system.

The methodology of UCS is projected on the city and its problems, having as a premise the three elements that are the base of the climatology in general: temperature, humidity, and atmospheric pressure. This approach was also innovative in the sense of analyzing the generation of the urban climate through the idea of co-participation between humans and nature and not of the antagonism between them.

In this paper the climatic changes observed in the MASP will be treated as the response of a system to the changes in one of its elements in the search for a new state of equilibrium, and the main motivation for carrying out this study is that the small and medium-sized cities tend to follow the same patterns of growth of large urban centers, so understanding how this process affects the climate can provide elements for a better long-term urban planning.

2. MASP - main features

Created by the Complementary Law No. 14 of July 8, 1973, the MASP is composed of 39 municipalities, including the city of São Paulo (the state capital). According to the latest census (IBGE, 2011), the total population is 19,672,582 inhabitants.

The population growth in the MASP accompanied its economic performance. In the nineteenth century, during the coffee cycle, São Paulo took command of the enrichment and developing process that exceeded the rest of the country and extends to the present days. In the mid-twentieth century, began the heavy industrialization process, which came as a result of the already deployed infrastructure and the accumulated capital.

The city of São Paulo has always been the main scenario of this development, alongside their neighboring São Bernardo, Diadema, São Caetano do Sul, Santo André, Mogi das Cruzes, Guarulhos and Osasco,

who already had a previous industrialization.

According to Custodio (2012), in the most recent decades, the lack of effective opportunities in the urban labor market, coupled with the low salaries paid to less qualified people, led to the beginning of a growing process of irregular occupations.

There are forecasts of a tendency to relative stabilization in the occupation process of the metropolitan area, despite the growth of commercial activities and services. But the general trend of stabilization is not uniformly distributed in the metropolitan territory; the peripheral areas continue to grow, as well as “favelization” process.

The urban area of the metropolitan region is located in the Paulistano Plateau, which has divided into two compartments: the Crystalline Edge and the Sedimentary Basin of São Paulo. The Crystalline Edge involves Sedimentary Basin to the East, West, and South and is formed by crystalline rocks susceptible to heavy erosion. It has altitudes between 850 m and 1,100 m, strong declivity, intense set of rivers, including important water sources. The urban occupation in this region is inappropriate because, without vegetation, erosion processes are favored. However, due to the high price of urban land in the more central areas, this is the region where it has recorded the highest population growth in recent decades.

The São Paulo Sedimentary Basin is 40 km wide in the North-South direction and approximately 70 km in the East-West direction. Inserted in the Paulistano Plateau, it presents altitudes varying from 718 m to just over 800 m, forming plains, terraces, hills, ramps, and spikes sculpted by climatic processes and by the erosive work and depository of the Tietê River and its tributaries. The topographic differences of the Sedimentary Basin do not exceed much the 100 m, and this strongly favored the human occupation, constituting the area of greater urbanization.

The urban area of São Paulo extended throughout the Sedimentary Basin. Today the MASP occupies an area of approximately 8,000 km², with an estimated density of 2465 inhabitants/km² (IBGE, 2011), presents intense waterproofing and serious problems of flooding and urban water supply.

The MASP is located along a climatic transition range (23°21'S and 46°44'W) between the climates Cwa, with a defined dry period, and the Af, permanently humid in southern Brazil (according to the Koeppen climate classification).

To the North is defined, with varied intensity, the existence of a dry period, coincident with the Autumn-Winter, although this is softened in the coast. The lower penetration of polar air in the northern sector reduces the amount of frontal rainfall from South to North and generally leads to good weather.

According to Tarifa and Armani (2001), one of the main climatic characteristics of this zonal transition is the alternation of seasons (hot and humid/cold and relatively drier) along with abrupt variations of the rhythm and succession of the types of weather. It is observed meteorological conditions of intense heating as well as intense cooling in short periods. This alternation explains, regionally, both the occurrence of strong pluviometric impacts and the existence, in certain years, of long sequences of dry periods.

3. Materials and methods

The development of this work was carried out in three stages that consisted in documenting how the evolution of the urban spot in the MASP occurred over time, how this evolution generated changes in the land uses of the region and, finally, how these changes caused impacts on the climate.

In order to document how the evolution of the urban spot occurred, an extensive bibliographical review was conducted, using historical archives, theses and articles that deal with the theme, as well as maps produced by the Empresa Paulista de Planejamento Metropolitano S.A (EMPLASA) (Paulista Metropolitan Planning Company).

This information was compiled in the map “Evolution of

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