Climate Extremes and Water Balance in the City of Sao Paulo - SP, Brazil: Subsidy for Public Policies

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I. INTRODUCTION

In recent years evidence has been presented that climate change is affecting the planet significantly (Trenberthet al., 2007; Meehl et al., 2007). Surveys show with confidence that global warming over the past fifty years has caused mainly human activities (IPCC AR4). Among the many consequences of climate change are increasing occurrences of intense precipitation. In Brazil, the types of disasters are most frequently associated with atmospheric instabilities, which are responsible for triggering floods, windstorms, tornadoes, hail and landslides. These types of disasters affect thousands of people annually, as these facts leads us to think about the importance of further studies related to hydrological events.

When it comes to urban climate, significant changes occur at how these areas expand, through interventions unconnected with intense compaction, soil sealing and vertical, suppression of vegetation and waterways. Considering the accelerated urban expansion and the delay in deployment of adequate infrastructure at the pace of growth of cities in the metropolitan region of São Paulo (RMSP- Região Metropolitana de São Paulo), we can say that these are not prepared for the effects of climate change. The RMSP has been the subject of several studies, because understanding the Brazilian urbanization without going through the experience of RMSP is almost impossible. It is the privileged site of numerous and simultaneous challenges: attraction and expulsion population, economic growth and poverty, social movements precursors; vulnerabilities social, economic and environmental (Bógus; Pasternak, 2009).

Two sources of climate change converge on the RMSP. On the one hand, the proper use and occupation of land which intensifies the effect of heat islands, accounting, for example, the increase of more than 2 ° C over the last 50 years in downtown São Paulo and higher incidences of the phenomenon of rain intense episodes that contribute to natural disasters. Thus, there is an intensification of the temperature increase and patterns of regional atmospheric circulation, resulting in increased frequency of heavy rainfall events, especially in the summer.

Regarding land use, if keep current patterns of use and occupation without effective control, several authors point out that there will be a significant increase in soil sealing, the disappearance of floodplains and watershed areas of occupation, as well as the process of silting of rivers, with the intensification of occurrences associated with floods and landslides.

Besides the higher increase in precipitation, another aggravating factor is drainage which has always been linked to the occupation of the valley and the poor environmental quality of urban spaces, agonized by the elimination of green areas, soil sealing, slums in lowland discarded by speculation, occupying permanent protection areas (APPs- Áreas de Proteção Permanente) along watercourses, etc. (Ross, 2004; DAEE, 2009).

The tragedies that have occurred in recent decades in Brazil produced images that still impress. According to the records of the Center for Emergency Management, raised by the newspaper O Estado de S. Paulo, in São Paulo, there was record flooding in 2009, with 1,422 occurrences in 111 days, and 124 in December 8, Extreme events asociedade more alarming concern those related to heavy precipitation (Marengo et al 2009) showed that since 1950 to 2003, the frequency and intensity of heavy rainfall have increased in the Southeast and South of Brazil, including the RMSP.

Given this problematic, this paper aims to contribute to an analysis in Subprefeitura Se, in the central region of São Paulo city – Brazil, in identifying points flood, terms of use and occupation of land and the main risk areas. Thus, possible adaptations to the city, contributing to an improvement in the condition of the population due. Moreover, it is expected to constitute subsidies methodology for planning actions in municipalities in the context of public policy.

II. PRESENTATION OF RESEARCH

The study area is located in the Metropolitan Region of São Paulo (RMSP) - Brazil. The RMSP is an integral part of the State of São Paulo (Figure 1). The São Paulo occupies an area of 522.986 km ² 1, between latitude 23 º 32 '52 "S and longitude 46 ° 38' 9" W, its location in the State of São Paulo is the South East. The climate is characterized by the Tropical Atlantic coast and altitude tropical inside.

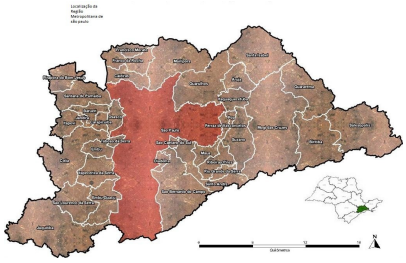


Figure 1: Localization of the study area. The large brown area represents the RMSP and the red area represents the city of São Paulo. (Source IBGE)

The city of São Paulo consists of 31 subprefectures and districts, this research focused on the Subprefecture Sé, because it is a central region and a major economic

importance, this region attracts a considerable number of people every day . The subprefecture Sé is a public organization, established from Law 13,399 of 2002. It is responsible for the administration of the following districts: Bom Retiro, Santa Cecilia, Consolação, Bela Vista, Republublica, Liberdade, Cambuci and Sé, located in the central region of São Paulo (Figure2), in an area of 26.2 km ² with a resident population of approximately 374,000 inhabitants.

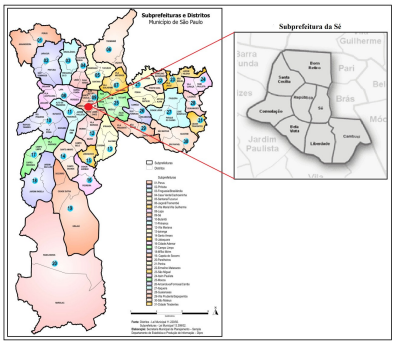


Figure 2: Delimitation the study area. The first map represents the Subprefectures and Districts of São Paulo and the second map is the delineation of the study area, the Subprefecture Sé. (Source: site city of São Paulo)

The central region was chosen as the study area because it has important characteristics of the city, serving as a reflection of the entire city, as high levels of speculation, lack of green areas, high degree of impermeability of the soil and disordered urban density.

Losses caused by flooding in Brazilian cities has increased exponentially, reducing quality of life and property values. This process is a result of consequent urbanization and sealing together with the channeling of stormwater (TUCCI, 2000).

To classify the use and occupation of the study area into two distinct periods (2002 and 2009) were used satellite imagery IKONOS and QuickBird. The GIS was obtained through MultiSpecApplication 3.3, which served as the general basis for the supervised classification, with the help of images was possible visual identification of targets in urban areas for the preparation of trainers and auditors of such classification. To statistically evaluate the accuracy of thematic mapping used the Kappa statistic (Landis & Koch, 1977 Moreira, 2003 apud Silva, 2004).

The rainfall data were obtained in BDMEP (Banco de Dados Meteorológicos para Ensino e Pesquisa - Meteorological Database for Education and Research), which hosts daily meteorological data in digital format, as a historical series of station network INMET (Instituto Nacional Meteorológico -National Institute of Meteorology). The period was acquired a decade (2001-2010). Data were tabulated in Excel, then calculated the average annual precipitation, analyzed and made into a graphic.

III. RESULTS AND CONCLUSIONS

From IKONOS satellite imagery (2002) and QuickBird (2009) of Subprefecture Sé (Figure 3), it was possible to extract several variables for the analysis of the use and occupation of the study area in two different periods through a program geoprocessing and subsequently crossing with precipitation data; through this thematic classification was possible to quantify different variables like: vegetation, asphalt, roofing among others, obtaining total amounts of each type of coverage.

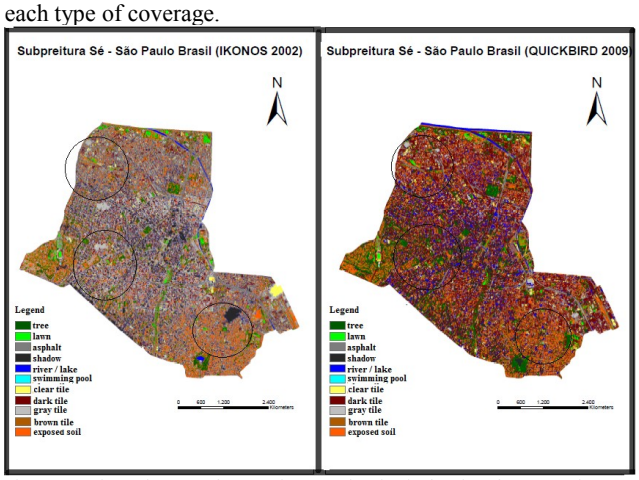


Figure 3 - Thematic map of use and occupation land of Subprefecture Sé in 2002 and 2009. (Source: Jesus, B.)

The relative proportions of the classes were organized in the classifications obtained in (Table 1) according to the image and the corresponding year. Note that there was a conflict in supervised classification with respect to differentiation of pixels of variable asphalt versus dark tile; a factor that made it difficult to distinguish both, was the fact that many buildings present coverage with materials similar to asphalt (color and composition). Another variable, the gray tile, show considered decreased percentage markedly during the period, which can be justified by the high level of pollution accumulated in the central region of São Paulo, where is located the area of study, as long, the trend of the tiles with lighter coloring, is getting dark. This fact can be observed comparing the variations of the percentages of the variable gray tile versus dark tile in different years.

Table 1-Total values with each type of coverage

	Ikonos 2002		Quick Bird 2009	
Class	Percent	Area (Hectares)	Percent	Area (Hectares)
Copa de árvore	5,42%	144,605	10,70%	285,469
relvado	3,09%	82,442	1,81%	48,222
asfalto	18,82%	502,048	6,04%	161,062
sombra	10,64%	283,766	8,55%	228,067
rio/lago	5,02%	134,005	8,33%	222,272
Piscina	0,23%	6,187	0,13%	3,36
telha clara	2,55%	68,015	4,43%	118,115
telha escura	9,88%	263,573	35,34%	942,737
Telha cinza	24,50%	653,543	4,38%	116,946
telha ceramica	1,45%	38,552	5,77%	154,027
solo exposto	18,40%	490,75	14,53%	387,61

The Kappa statistics and overall accuracy obtained from the error matrix of the supervised classifications are contained in (Table 2), which proves the accuracy of the mapping as excellent, 80-100% (LANDIS & KOCH, 1977).]

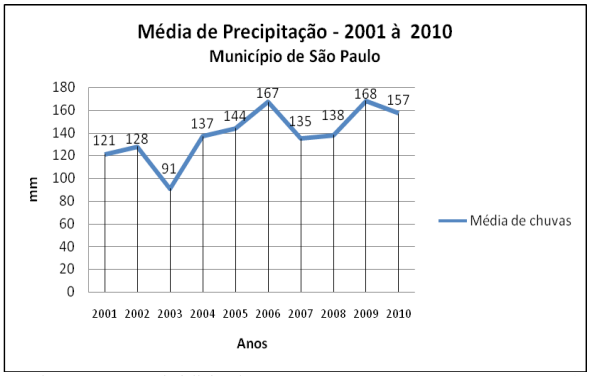
Table 2 - Overall Accuracy and Kappa values obtained for the automatic classifications supervised the subprefecture Sé - São Paulo, obtained by satellite images.

Imagem	Exatidão Geral (%)	Kappa (%)
Ikonos 2002	99	97,6
QuickBird 2009	99,7	92,2
+ (100 - percent omission error); also called producer's accuracy.		
* (100 - percent commission error); also called user's accuracy.		

The thematic maps of use and occupation land of Subprefecture Sé (Figure 3) for the years 2002 and 2009

clearly observe that the Subprefecture Sé it has displayed a continuous increase in the rate of soil impermeability, factors which influence the formation of islands heat in the central region of São Paulo.

The graph below was criated from the average annual rainfall of the last decade, obtained from the Meteorological Database for Education and Research (BDMEP-Banco de Dados Meteorológicos para Ensino e Pesquisa). The analysis of the graph enables us to realize that there has been a gradual increase in the level of rainfall in the years between 2001 and 2010. With the exception of 2003, which for some reason had a level of below normal rainfall. The years 2006 and 2009 were the years with the highest rainfall of the decade in question.



Graph 1 - Average rainfall for the years 2001 to 2010. (Source: Zanon, F. N.)

Relating the results from the analysis of thematic maps of use and occupation land of Subprefecture Sé in 2002 and 2009 (Figure 3) with the graph of precipitation observed that in 2002 the average rainfall was 128 mm, while in 2009 the average was 168 mm, an increase of 40mm. Coupled to this data we have the increase in impervious areas, in other words, the uncontrolled growth of urban centers, lack of planning and use and occupation land , among many problems tend to intensify the factors that result in flooding and points increasingly more frequent.

It was noted from the analysis of thematic maps of use and occupation land of Subprefecture Sé in 2002 and 2009 (Figure 3) the reduction of lawn area and exposed soil. This results in reducing permeable areas. In addition, the Subprefecture Sé has low vegetation density and a high density of built area, which reflects the formation of heat island. All disordered density in Subprefecture Sé tied to results of mean precipitation shown in Graph 1, demonstrate the trend of rising flood points in central Sao Paulo.

The path to change is intrinsically linked with new research and data about climate change along with effective adaptation strategies developed to São Paulo and the entire metropolitan region. Within this perspective, adaptation measures are an opportunity to rethink the ways of interaction between human activities and the environment.

Some suggestions for adaptations to MRSP (metropolitan region of São Paulo) relates primarily to changes in the urban climate, for example, do not let the urban plan of the city is governed exclusively by the real estate sector, but by environmental laws that prioritize the general welfare of the population.

Another important factor is to adaptation measure for the water balance, urban interventions resulting from sealing surface can alter the conditions of movement of water in the soil, causing uplift or lowering the water table (DAEE 2009).

This study demonstrated that the urban landscape presents a different configuration according to the dynamism of the use and occupation land, making it possible with the contribution of work such as identifying critical points and think about redesigning the area.

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