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Hazard areas land cover change between 1986 and 2010 in Sao Paulo City, Brazil

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ABSTRACT

Vegetation provides natural protection to soil, avoiding severe mass movements and regulating the flooding cycle of the drainage. The replacement of natural vegetation for urban areas takes population to risk situation. This hazard is increased in Megacities context, once the population density is very high and the low income population is exposed to slums and precarious settlements. Sao Paulo City is a great example for this process, where the prices of real estate nearby transportation system quickly increased in the last 5 years, accelerating the urban sprawl in risk areas. This work aims to assess the land cover changes at hazard areas in Sao Paulo city and relate this process with the expansion of the public transportation system. LANDSAT TM 5 scenes for the years 1986 and 2010 were classified using SVM algorithm. The hazard areas were defined based on the geotechnical map. The land cover change was evaluated for the whole study area, as well as focused on the hazardous areas such as flash flood and landslide. The results showed significant loss of vegetation in Sao Paulo City, and a large increase of the urban occupation at hazard areas. Findings from this study quantified loss of 43% for vegetation areas, 88% for bare soil areas, and 66% for pasture as consequences of uncontrolled urbanization process. Understanding land cover changes is important to subside urban planning, and avoid hazard areas occupation. Mainly considering the increasing projection for population, it is important to map and preview future occupation at hazard areas and also understand the factors that contribute to it. The subway system, rail system and roads expansion had a high contribution to this process. Therefore, this paper is relevant; because it points that transportation projects must consider the consequences over urban expansion and hazard areas occupation. This information, must be consider in relocation projects, once the hazard area population must not be relocated to places with lack of urban infrastructure.

Key-words: Remote Sensing, natural disasters, urban planning, GIS.

1. INTRODUCTION

Over the last decades the natural disasters and its damages had raised worldwide. According to EM-DAT (2009) since the 1970's the number of disasters increased from 50 per year to 350 in 2008, with a high score of 500 events in 2005. Also, the economic loss gone from 5 billion dollars in 1975 to 180 billion dollars in 2008, reaching 210 billion dollars in 2005 due to the Katrina Hurricane. The population living in hazard areas raises about 70 million people annually, and over 90% lives at developing countries (ALCÁNTARA-AYALA, 2002).

Between the years 2000 and 2008, 1,861 accidents related to several phenomena were registered, which: 944 (50%) floods, 367 (19%) landslides, 65 (4%) thunderstorms, and 485 (27%) various accidents (heavy rains, gales, house and wall collapses). These events caused 225 deaths and resulted in 50,347 homeless. São Paulo Metropolitan Region presented the highest number of events (567) and deaths (77) at São Paulo State for this period (BROLLO and FERREIRA, 2009). The high population density may be the responsible for the great recurrence of severe events at the Metropolitan Region of São Paulo.

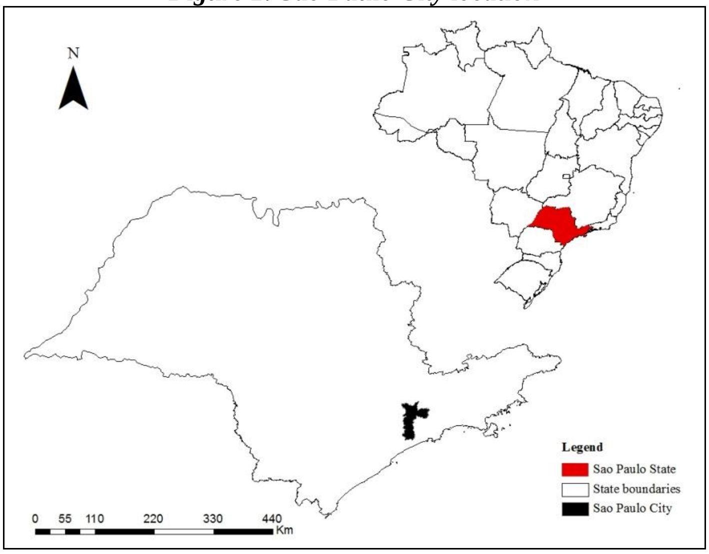
The importance of vegetation to avoid landslides and flood is evident, once it enhances soil cohesion and slope stability, and minimizes the runoff (COROMINAS, 2005). Although, considering the megacities, the urbanization has reached areas that should be conserved. Those areas are principally occupied by precarious settlements and expose many lives.

The objective of this work is assess the vegetation loss over areas with low physics aptitude to urban occupancy at São Paulo city, between the years 1986 and 2010, and evaluate its impacts on the occurrence of floods and landslides.

2. STUDY AREA

São Paulo city (Fig. 1), capital of São Paulo State, has over 11 million people. The urbanization rate is 98.94%, and the geometric growth is 0.75% (SÃO PAULO STATE GOVERNMENT, 2012). The uncontrolled urban development in São Paulo city caused the occupancy over the lowland and valley bottom, river siltation, soil sealing, and incomplete drainage system (MARTINS, 2003). The combination of these characteristics resulted on the occurrence of floods that reach public roads and residential areas (OSTROWSKY and ZMITROWICZ, 1991). Also, the occupancy on slopes causes severe landslides and many human losses.

Figure 1: São Paulo City location



According to Peloggia (2005) São Paulo city geomorphology suffered drastic changes due to anthropic occupation. The floodplains and the strands covered by superficial hologenic formations no long exists, constituting high erosive potential areas.

3. METHODOLOGY

The land cover maps were generated using the Support Vector Machine (SVM) algorithm over LANDSAT TM5 images, of May of 1986 and April of 2010. The classes defined for the classification were vegetation, water, urban and roads, exposure soil and pasture. In short, the training areas were defined on the boundaries of the classes. The algorithm was applied over the bands 1, 2, 3, 4, 5 and 7 (FOODY and MATHER, 2006). The classification was evaluated by sampling truth points in high resolution images for the composition of the Kappa Index.
The geotechnical map of the study area (PMSP and EMPLASA, 1993) was used to define the landslide and flooding hazard areas. The landslide hazard points were located and 200 meter buffered, which encompasses the potential affected areas (GÓMES and KAVZOGLU, 2005). The flood areas were defined by the flooding susceptible zones. Then, the land cover change map was analyzed for the whole city and for the hazard areas.

4. RESULTS

The land cover maps for the year 1986 and year 2010 are shown at figures 2 and 3, respectively. The classification accuracy obtained by the Kappa Index was 0.798 and 0.812, for 1986 and 2010 maps, respectively.

Figure 2: São Paulo City land cover (1986)

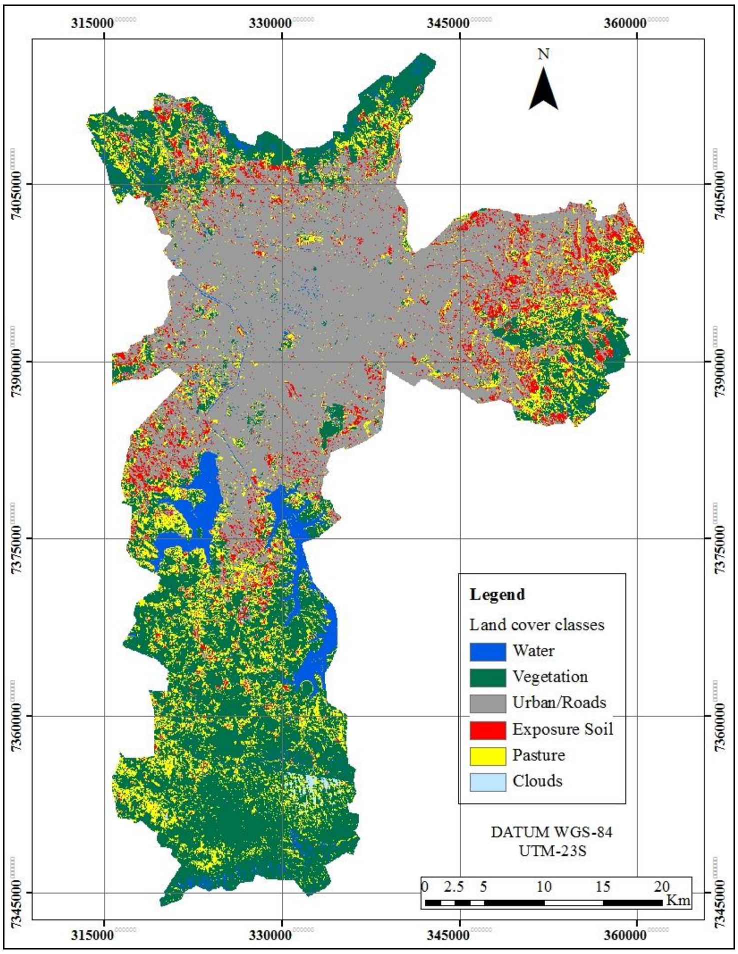
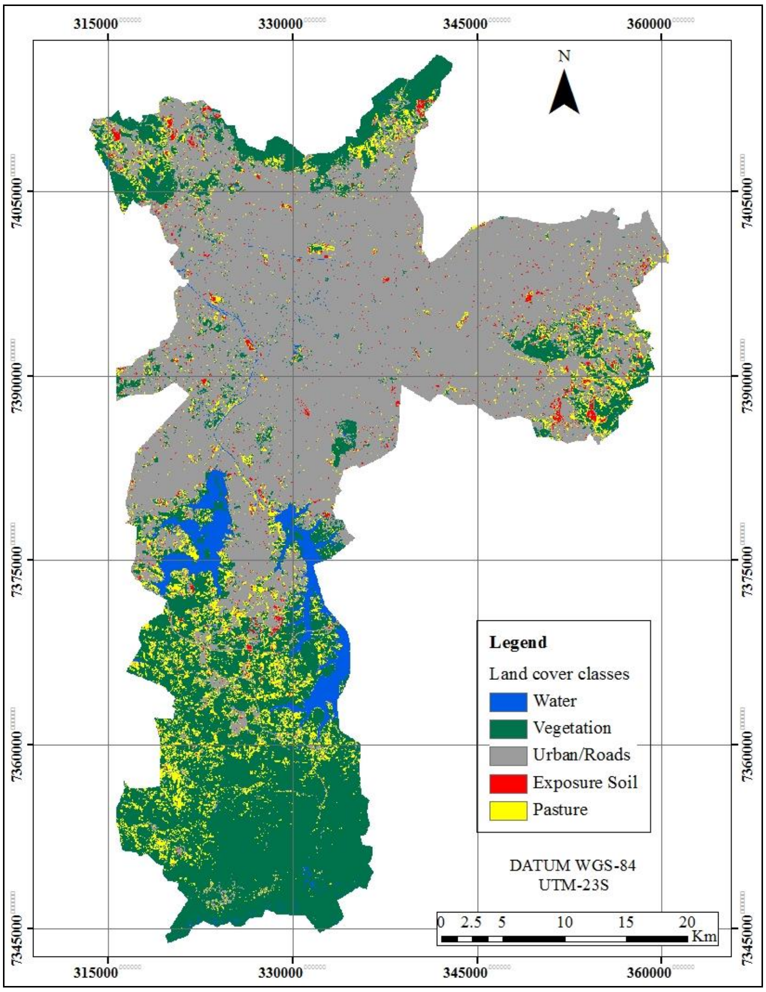


Figure 3: São Paulo City land cover (2010)



Tab. 1 presents the percentage of land cover changes in the study area between the years 1986 and 2010. Similarly, Tab. 2 presents the percentage of land cover changes in the hazard areas between the years 1986 and 2010.

Table 1: Land cover changes for São Paulo City (1986-2010)

	Water [%]	Vegetation [%]	Urban/Roads [%]	Exposure Soil [%]	Pasture [%]	Clouds [%]
Water [%]	**98.99**	**0.93**	**0.50**	**0.07**	**0.42**	**0.31**
Vegetation [%]	**0.821**	**75.01**	**1.80**	**2.46**	**28.56**	**75.67**
Urban/Roads [%]	**0.169**	**14.88**	**95.65**	**82.62**	**41.16**	**17.87**
Exposure Soil [%]	**0.007**	**0.97**	**0.76**	**6.07**	**3.35**	**1.56**
Pasture [%]	**0.01**	**8.21**	**1.30**	**8.78**	**26.52**	**4.6**
Clouds [%]	**0**	**0**	**0**	**0**	**0**	**0**
Class Changes [%]	**1.01**	**24.99**	**4.35**	**93.93**	**73.48**	**100**

Table 2: Land cover changes in hazard areas at Sao Paulo City (1986-2010)

	Water [%]	Vegetation [%]	Urban/Roads [%]	Exposure Soil [%]	Pasture [%]	Clouds [%]
Water [%]	**78.69**	**0.66**	**0.20**	**0.02**	**0.03**	**0**
Vegetation [%]	**12.70**	**47.37**	**1.23**	**0.78**	**10.24**	**0**
Urban/Roads [%]	**7.74**	**42.98**	**97.25**	**87.62**	**66.12**	**95.70**
Exposure Soil [%]	**0.38**	**1.46**	**0.51**	**6.08**	**3.97**	**2.50**
Pasture [%]	**0.49**	**7.53**	**0.81**	**5.50**	**19.64**	**1.80**
Clouds [%]	**0**	**0**	**0**	**0**	**0**	**0**
Class Changes [%]	**21.31**	**52.63**	**2.75**	**93.92**	**80.36**	**100**

5. DISCUSSION

In comparison to 1986, Figure 3 clearly shows that urban growth mainly happened at North, West and East regions of the city. The North and Northwest areas of the city are characterized by high steep slopes and rugged terrain, which vegetation has been substituted by urbanization. Some isolated urban areas in the South are showed in Figure 3. In addition, the comparative analysis shows considerable growth near the two water reservoirs (Billings and Guarapiranga), which can explain the eutrophication process detected. Besides, it is evident the consolidation of the periphery urban areas.

Table 1 evidences that São Paulo City lost almost 25% (121 km² approximately) of the vegetated areas, most of them for urban/roads areas. Although, pasture and exposure soil had suffered the most severe change losing 73.48% and 93.93%, respectively. Both classes lost the greatest areas to urban/roads class.

The urban/roads losses may be attributed to the classification accuracy. The changes from urban/roads to water may be attributed to building shadows that were classified as water at the 1986 scene. Also, the classification may have confused the spectral behavior of the exposure soil, which can be similar to some kind of roofs.

Using the information in Table 2 is possible to quantify changes from vegetation, pasture and bare soil to urban/roads within hazard areas. Also, 4.8 km² changed from exposure soil to urban/roads, 3.4 km² from pasture to urban/roads and 2.3 km² from vegetation to urban/roads.

In order to understand the key of this study, it is important to highlight that 6.04% of the urban growth in São Paulo occurred within hazard areas, and 69.45% of the actual hazard areas in São Paulo were not classified as urban in 1986. This fact evidences the uncontrolled urban growth process, and also unavailability of adequate areas for settlements.

Furthermore, these data show the serious delay in the municipal conservancy policies. In an opposite but ideal situation, areas located nearby rivers, flooding plain, or on high slope areas must be protected, and its natural vegetation must be preserved, as defined by federal laws.

Although, the results show that over 52% vegetation coverage present in 1986 was lost, and it was replaced by urban and pastures. Besides the instauration of hazard areas, these changes may have further impacts, as depreciation of water and soil quality, and deregulation of the hydrological cycle.

In general, the urban sprawl impacts directly over the real estate values. In this sense, a very interesting process happens in the new hazard areas during the observed period. Commonly, transportation infrastructure as subways, railways and roads has a positive impact over the real estate value. However, in megacities, mainly located in developing countries, public transportation system attracts the urban sprawl and precarious settlements. Most of the time, nearby transportation facilities there are limited available areas for housing. In this way, even dangerous areas have been occupied by the population and have become hazard places, depreciating the real estate value of these areas.

6. CONCLUSION

This work focuses on quantify the changes in cover changes between 1986 and 2010 in Sao Paulo City, as well as pre-defined hazard places located in the study area. The vegetation areas turned into urban/roads areas, which have exposed population to the risks associate with severe climatic events. The comprehension of the occupation process is important to support urban planning and help to control the urban occupancy. Besides, these disaster events and sprawl over the transportation spread sites have big impact on the real estate value.

The results present the land cover changes, the hazard areas, and evidences that the loss of vegetation contributed to the establishment of the actual scenario. Also, this work generated data that may contribute to the urban planning. Therefore, further works must be held to asses the process of urban occupation over the hazard areas through a larger period, trying to understand its dynamics.

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8. REFERENCES

ALCÁNTARA–AYALA I. 2002. Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries. *Geomorphology* 47:107-124.

BROLLO M J, C J FERREIRA. 2009. Indicadores de Desastres Naturais no Estado de São Paulo. *Anais do XI Simpósio de Geologia do Sudeste* 1:120-125.

COROMINAS J. 2005. *Impacto sobre los riesgos naturales de origen climático: inestabilidad de laderas*. In: Moreno, JM ed. Proyecto ECCE – Evaluación Preliminar de los impactos en España por efecto del Cambio Climático. Madrid, Spain. Ministerio de Medio Ambiente de España. p. 549-579.

EM-DAT *Emergency Database. 2009*. The Office of US Foreign Disaster Assistance/Centre for Research on the Epidemiology of Disasters. Consultado 20 jan. 2012. Disponible en http://www.emdat.be/ Database.

FOODY GM, A MATHER. 2006. The use of small sets of containing mixed pixels for accurate hard image classification: Training on mixed spectral responses for classification by SVM. *Remote Sensing of Environment* 103:179-189.

GÓMES H, T KAVZOGLU. 2005. Assessment of shallow landslide susceptibility using artificial neural networks in Jaboosa River Basin, Venezuela. *Engineering Geology* 78:11-27.

MARTINS MLR. 2003. São Paulo: além do plano diretor. *Estudos Avançados* 17(47).

OSTROWSKY MSB, W ZMITROWICZ. 1991. Urbanização e controle de enchentes: o Caso de São Paulo: seus conflitos e Inter-relações. *Boletim Técnico da Escola Politécnica da USP 50*.

PELOGGIA AUG. 2005. A cidade, as vertentes e as várzeas: A transformação do relevo pela ação do homem no município de São Paulo, *Revista do Departamento de Geografia/FFLCH-USP* 16:24-31.

PMSP and EMPLASA. 1993. *Carta Geotécnica do Município de São Paulo. São Paulo*. PMSP.
São Paulo State Government. 2012. Sistema Estadual de Análise de Dados (SEADE). Informação dos Municípios Paulistas (IMP). Accessed in Feb 08, 2012. Available online in: <http://www.seade.gov.br>.