ENVIRONMENTAL VULNERABILITY INDICATORS TO THE COSTAL SLOPES OF SÃO PAULO, BRAZIL[*]

D'ANTONA, Álvaro de O. (FCA, NEPO-Unicamp, Brazil)
BUENO, Maria do Carmo D. (IBGE; IFCH-Unicamp, Brazil)
IWAMA, Allan Yu (NEPAM, IFCH-Unicamp, Brazil)

Abstract

In the context of current discussions regarding the human dimensions of climatic change, it is essential to locate and to characterize populations in situations of risk. It is necessary to adopt methods that allow differentiating these populations on an intra-municipal scale considering that extreme climatic events can affect population in different ways. We used a hybrid approach to distribute the population of São Paulo Coast in a grid. We performed an overlay operation of layers showing socio-demographic data and slope. Based on this procedure we were able to estimate and to characterize the population in areas at geological-hydrological risks in spatial units smaller than the census tracts. The methodology adopted shows to be adequate in studies of Population and Environment, creating a new analytical perspective and enabling a joint evaluation of the dimensions studied.

Keywords: climate change, Brazil, regular grid, risk

[*] This paper is part of the project *Aggregation of census data in a regular grid to analyze the distribution and characteristics of the population: the case of São Paulo, 2010* – grant #2012/50766-7, São Paulo Research Foundation (FAPESP).

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The climatic changes' impacts on populations depend on several aspects, including physical, environmental, social, economic, and cultural, besides the local infrastructure (JIANG & HARDEE, 2011). In the context of current discussions regarding the human dimensions of climatic change, it is essential to locate and to characterize vulnerable populations in situations of risk. It is necessary to adopt methods that allow accurately differentiating these populations on an intra-municipal scale considering that extreme climatic events can affect them in different ways and degrees.

The boundaries mismatches between statistical units that follow a political administrative structure and the social, environmental or artificial units are the major obstacle to the integration of socioeconomic and environmental data. Furthermore, the smallest spatial units commonly available for demographic data – the census tracts or enumeration areas – are inadequate for studies where more detail is required.

An approach to address these problems is to use a regular grid as the spatial unit for data from census surveys. This grid can be generated by geostatistical methods (GALLEGO, 2010), by dasymetric methods (MENNIS, 2003) or by the aggregation of microdata (GALLEGO, 2010). Given the smaller dimensions of the grid cells (compared to census tracts, for example), the grid also contributes to better distribute environmental variables such as the slope.

We used a hybrid approach to estimate the population in areas at risk of landslides and to characterize this population in spatial units smaller than the census tracts. We performed an overlay operation of layers showing socio-demographic data (2010 Population Census - IBGE) and slope. Based on this procedure we were able to estimate the population resident in areas geological-hydrological risks – based on geological data from environmental aspects (relief/unconsolidated material/rock) associated with human settlements (IPT, 1994; 1999), besides the slope greater than 30°, usually more susceptible to landslides (OGURA et al., 2004).

The statistical grid

The hybrid approach mixes bottom-up (aggregation) and top-down (disaggregation) techniques. This joint methodology is a novelty in Brazil, and it is suitable to many countries.

In Nordic countries, for example, the population grid is offered by statistical agencies since the 1970s. They have developed a building-code system that is the basis for aggregating the data into a statistical grid (UN 2007). In countries where it is not officially adopted the aggregation approach, it is necessary to use some method to reallocate census data from irregular units into a grid-based unit. Among the methods to perform the disaggregation without ancillary data, we can mention the areal weighting, the pycnophylactic interpolation (TOBLER 1979) and the kernel estimation (BRACKEN and MARTIN 1989). Among the methods that use ancillary data – such as land use classification derived from remote sense images (REIBEL and AGRAWAL 2007), a network vector layer (REIBEL and BUFALINO 2005) or point addresses (ZANDBERGEN 2011) –, the dasymetric mapping is the most usual (BUENO et al 2013).

In Brazil, two technological advances make possible to aggregate census data into small geographical units since the 2010 Census. A digital census mapping integrating the urban and rural areas has allowed the location of the dwellings in urban areas using

addresses. The *Address List for Statistical Purposes* (CNEFE), coupled to the use of handheld computers with GPS, has allowed capturing the coordinates of buildings in rural areas. However, we observed that the aggregation approach is not enough to put all collected census data aggregated in square grids because there is an amount of records without locational data. That limitation point to the hybrid approach used here to create a Brazilian statistical grid: the aggregation approach is used in regions where there is data that allow their geographic location and the disaggregation approach is used where these locational data don't exist (BUENO et al 2013).[1]

The grid used here has approximately square cells with sides around 1 km to rural areas and 250 m to urban areas, since the geographic projection has been used.

Study Area

The São Paulo state coastal area (around 400 km long; almost 2 million inhabitants) encompass 16 municipalities grouped into three sections: the Northern Coast, the Santos Metropolitan Region and the Southern Coast (FIGURE 1). The coast is characterized by extensive occupation of the *Serra do Mar* where is located most of the remaining Atlantic Forest in the state. These slopes have high steep inclines and, consequently, they are highly susceptible to landslides during periods of intense rainfall.

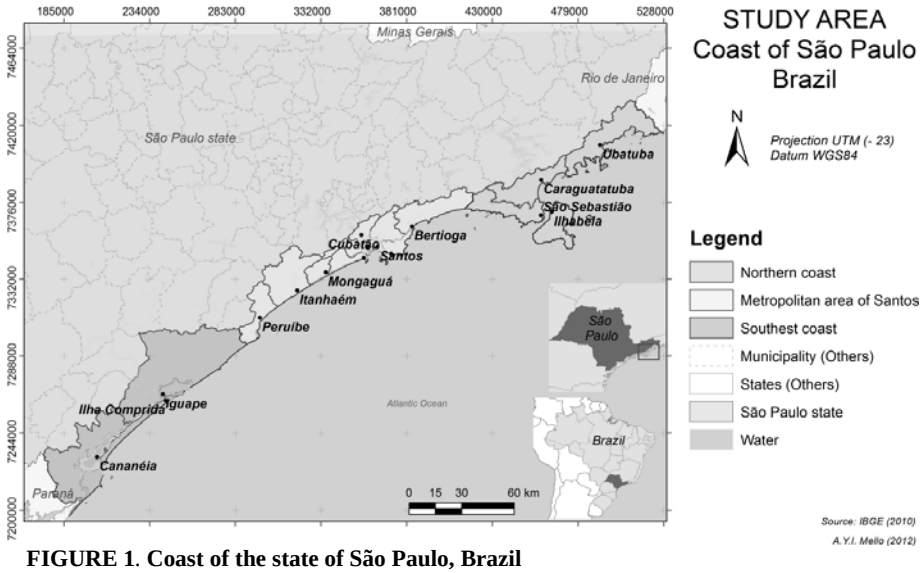

FIGURE 1. **Coast of the state of São Paulo, Brazil**
Source: Municipal Boundaries 2010 – IBGE.

[1] The grid is part of the BUENO PhD thesis in Demography, funded by the IBGE – Instituto Brasileiro de Geografia e Estatística and by CAPES (#17235-12-0). The 2010 Census microdata and mapping were provided by IBGE in an exceptional character for use in the mentioned PhD thesis.

Findings

FIGURE 2 shows the area susceptible to landslides and the population potentially vulnerable to geological hazards.[2]

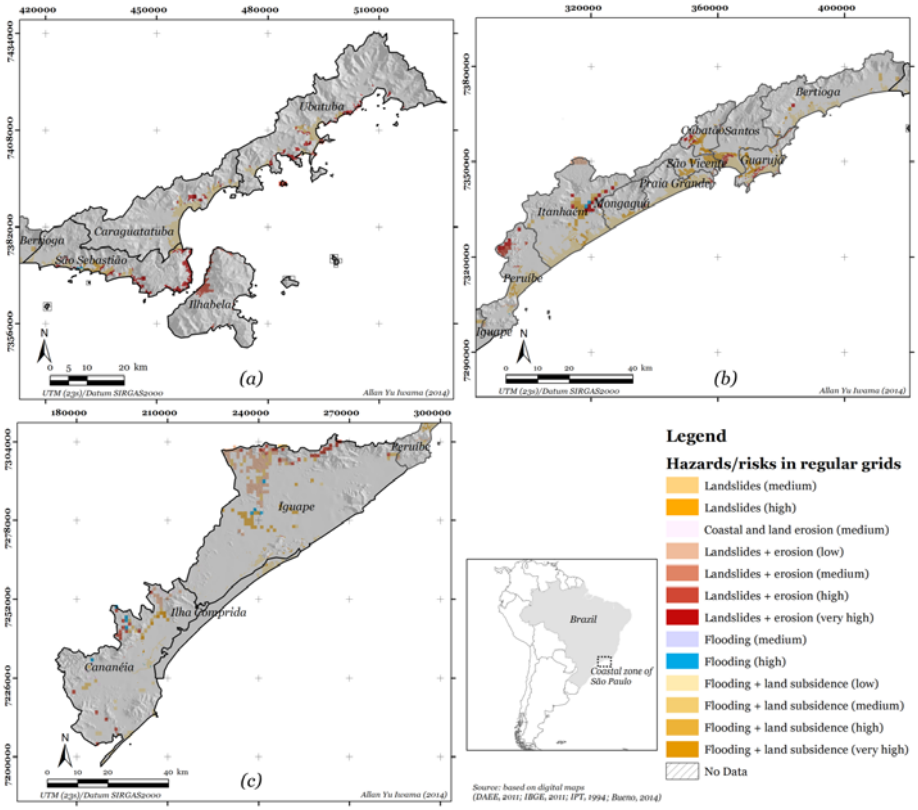

FIGURE 2. Spatial distribution of geodynamics risks and socio-demographic data - regions (a) Northern, (b) Santos Metropolitan Region, (c) Southern.

The grid accurately allows us to estimate and characterize the population affected by different hazards as the TABLE 1 exemplifies.

TABLE 1 - Estimated Population by hazards of landslides+flooding+land subsidence

Region	Pop. Affected	Indigenous	Illiterate population
Northern	246716	581	14097
Santos Metropolitan Region	1622689	2687	84075
Southern	33462	74	2238

[2] This result is part of the IWAMA's PhD thesis in Environmental and Society (FAPESP #2010/18501-8), in the scope of the project 'Urban Growth, Vulnerability and Adaptation: social and ecological dimensions of climate change on the Coast of São Paulo' (FAPESP #2008/58159-7).

The methodology adopted is adequate to Population and Environment studies, creating a new analytical perspective and enabling a joint evaluation of the dimensions studied. The statistical grid seems to offer an accurate representation: the cells are, generally, smaller than census tracts, what is better to distribute population and environmental variables; the hybrid approach is more consistent than the exclusive use of disaggregation or aggregation. As mentioned before, it is a technic only recently possible in Brazil, so it should be object of further studies.

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