

# GEOTECHNICAL RISKS AND SOCIAL VULNERABILITY IN COASTAL AREAS: INEQUALITIES AND CLIMATE CHANGE\*

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## Introduction

In the context of rising average sea levels and the frequency and intensity of extreme weather events, coastal regions are those at greatest risk worldwide and will be the areas most affected by climate and environmental change (IPCC, 2007; 2012; KRON, 2008).

The Brazilian coastal regions have large areas affected by urbanization, tourism or “second homes” (MORAES, 2007). In 2010, 45.6% of Brazil’s coastal municipalities were more than 80% urbanized, and almost a quarter (24.6%) of the Brazilian population was concentrated in coastal areas (IBGE, 2011). Moreover, the historical process of urbanization in Brazil has been characterized by unequal access to public services (CARMO, 2014), which over time has led to aspects that are indicative of the deficiencies and poor distribution of services and infrastructure in the urban environment (MORAES, 2007; CARMO and SILVA, 2009; CARMO, 2014). Carmo (2014) stresses that when a certain social group takes ownership of the results of economic development, another group (the larger part of society) is excluded from the benefits of this development. It is within this section of society that we recurrently see the problems associated with illegal settlement on hillsides, on the edges of water bodies or located in areas of recognized geological risk or environmental degradation. In a broader context of urban planning and policies, Maricato (2011) argues that as there is no across-the-board control of land use and occupation and, more significantly, very little provision (by the State) of legal housing alternatives, illegal settlements or *favelas* (according to the author) are the rule for urbanization and land occupation processes in Brazil.

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The context of the urbanization *status quo* in Brazilian cities and the increased intensity and frequency of extreme weather events (IPCC, 2012; WMO, 2013) accelerate the trend towards a substantive increase in situations of vulnerability (both social and environmental) in coastal areas (HOGAN *et al.*, 2001; CARMO and SILVA, 2009; MELLO *et al.*, 2010; 2012).

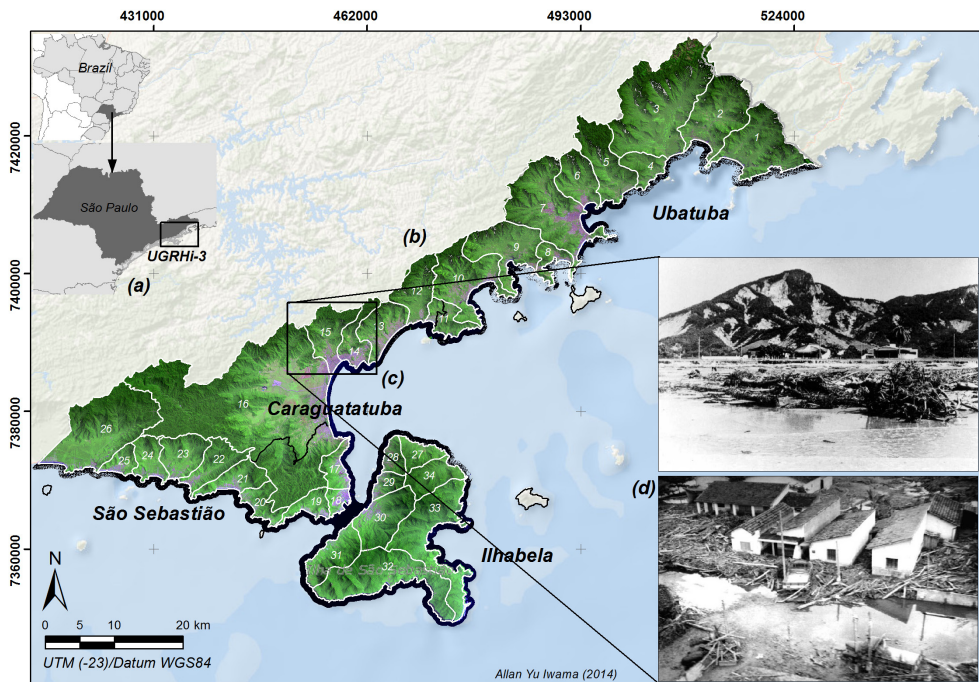
This work offers an analytical approach to situations of geodynamic risk and social vulnerability, studying the river basins [UGRHi-3 – which includes the municipalities of the Litoral Norte (northern coastal area) of the state of São Paulo and its thirty-four sub-basins - as analytical units. As the notion of vulnerability is polysemic – in addition to representing a complex and multidimensional phenomenon and, especially, one which requires temporal and contextual analysis, we have decided to adopt a broader concept: operationally, socio-environmental vulnerability can be described as “the coexistence, the accumulation or the spatial overlapping of situations of poverty and social privation and situations of exposure to environmental risk” (ALVES, 2006; 2013). Nevertheless, from an analytical perspective, vulnerability should not just be reduced to overlapping environmental and social situations, as there are contexts and specificities that require a contextual or historical analysis. A number of works have highlighted this characteristic of vulnerability (ADGER, 2006; ADGER *et al.*, 2009; BLAIKIE *et al.*, 1994; CUTTER *et al.*, 2003; O'BRIEN *et al.*, 2004; 2007; MARANDOLA Jr. and HOGAN, 2004; 2006; 2009a; VALENCIO, 2010) and we have therefore sought not to limit ourselves to the spatial aspects of risk and vulnerability, but have tried to examine given local contexts and circumstances through multi-level analysis (UGRHI-3 and sub-basins) and to link this to the distribution of hazards, as called for by Marandola Jr. and D'Antona (2014).

## Study area

The study area covers the Water Resources Management Unit (UGRHi-3), represented by the municipalities of the Litoral Norte of São Paulo – Caraguatatuba, Ilhabela, São Sebastião and Ubatuba. This region's population increased 25.4% between 2000 and 2010 (more than twofold the growth rate for the State of São Paulo, of 11.3%) - (SMA/CPLA, 2011a). Carmo *et al.* (2012) note that although growth rates are falling (analysis period between 1970 and 2010), nevertheless the population of Caraguatatuba increased from 88,000 to more than 100,000 inhabitants in just 3 years. The study area is set within a scenario of major environmental and social changes connected to the execution of major infrastructure projects (megaprojects) linked to the oil and gas industry in the region (CARMO *et al.*, 2012; TEIXEIRA, 2013). According to Teixeira (2013), while on the one hand these megaprojects may be relevant to the region's economic development, on the other, they highlight the region's role in conservation and tourism and may cause significant impacts that could compromise the integrity of the Atlantic Rainforest and trigger and/or increase the frequency and intensity of natural hazards, thus hindering the resolution of institutional issues (FILET *et al.*, 2001, SOUZA, 2004; TEIXEIRA, 2013). In addition to these important changes, the region is hemmed in by the sea on one side and the mountains on the mainland, with a large part of these mainland areas

lying close to hillside conservation areas – which are unsuitable for settlement (SMA/CPLA, 2011a) due to environmental restrictions and their status as areas of potential geological risk. The region has already witnessed events related to major landslides and flooding (the Caraguatatuba disaster in 1967) and these events could strike the region more often and with more intensity in the future. **Figure 1** shows the study area and photographic records of the 1967 event in Caraguatatuba, in which 436 people lost their lives and 3,000 residents were displaced.

**Figure 1.** (a) location of the Water Resources Management Unit – UGRHi-3 – Litoral Norte; (b) UGRHi-3 and its sub-basins, which encompasses the municipalities of Caraguatatuba, Ilhabela, São Sebastião and Ubatuba. Detail of Caraguatatuba in the (c) Santo Antônio river basin, affected by the 1967 “disaster” and (d) photographic records of the area affected by heavy rainfall (in 1967), causing damages for local residents.



## Materials and methods

Two groups of variables relating to (i) the physical environment and (ii) socio-demography were organized in a Geospatial Database in order to spatially plot the geotechnical risks and social vulnerability indices. Algebraic operations were applied to the digital maps, yielding potential areas of geotechnical risk and situations of social vulnerability (2000-2010).

(i) In the first group, digital maps of geotechnical risks for the physical environmental processes – the result of geological data, non-consolidated rock affected by human settlements (DINIZ, 1998; 2012), were obtained from IPT<sup>1</sup> (1994) on a 1:500,000 scale. Mapping of the geotechnical risks was organized using three main categories: landslides (and/or processes involving mass movements); floods, and soil settlement/instability related to tidal movement – according to Mendes (2009); soil settlement or subsidence is the term used in civil engineering to designate the phenomenon that takes place when a building subsides due to soil consolidation under its foundations.

In addition to the geotechnical risks, digital altimetry (Digital Elevation Model) and slope (1:50,000 scale) maps were drawn up to aid analysis in areas deemed to be at lower altitude, which are more densely populated or urbanized (McGRANAHAN *et al.*, 2007; UN, 2007) and are, directly or indirectly, susceptible to risk of flooding and tide-related soil settlement. These areas are also subject to extremes of climate, which can trigger the risks mentioned above.

In addition to these data, digital maps of landslide/slip and flood risk were obtained (IG-SP, 2006a, b, c; UNESP, 2006; IPT, 2010), on scales between 1:1,800 and 1:3,000, for a more detailed analysis in some sub-basins.

In the group of (ii) social variables, the São Paulo Social Vulnerability Index (IPVS) for the period 2000-2010 was analyzed, based on two premises: (1) aggregating income indicators with education and family life cycle indicators; (2) identifying areas according to the degree of vulnerability of the resident population (SEADE, 2000). The IPVS (2000) defines six vulnerability groups, ranging from *No Vulnerability* (Group 1) to *Very High Vulnerability* (Group 6). The IPVS (2010) retained some data to enable comparison of the 2000-2010 period, in addition to incorporating the per capita household indicator, as well as the situation of the census sectors as subnormal agglomerations (favelas) and their location (urban or rural). In practice, in the **high vulnerability** group, the 2010 IPVS was split into two groups: high vulnerability (urban sectors) and high vulnerability (rural sectors), making a total of seven social vulnerability groups (SEADE, 2013).

## Results and discussion

### *Geotechnical risks in the UGRHi-3 and sub-basins*

The geotechnical risks were analyzed differentiating the risk of landslide ( $R_L$ ), flood ( $R_F$ ) – associated with riverbanks and urbanized areas – and differential settlement/soil instability ( $R_P$ ) – related to tidal movement.

The examination of the extent of these risks in relation to the total distributed throughout UGRHi-3 (1,875 km<sup>2</sup> – the Anchieta islands, small islands around Ilhabela and São Sebastião were not included), indicate that the risks related to mass movements, in particular landslides, apply to 84.7% of UGRHi-3's area, with 13.5% relating to soil settlement (also linked to or influenced by tidal movement, and cutting and seepage of the land) and 1.8% corresponding to flooding (Figure 2a).

As roughly 70% of the area of UGRHi-3 overlaps with Strict-Use protected areas (Serra do Mar State Park and Ilhabela State Park), and bearing in mind that these protected areas restrict settlement, the total and the percentage of areas at risk of landslides ( $R_L$ ) in areas outside the Strict-Use protected areas were calculated, as these areas are subject to the process of land settlement (**Figure 2b**). Although the 84.7% percentage has fallen to 12.3% (of risks related to landslides), it can still be seen as significant in terms of the areas and in relation to the other types of geotechnical risk (**Table 1**).

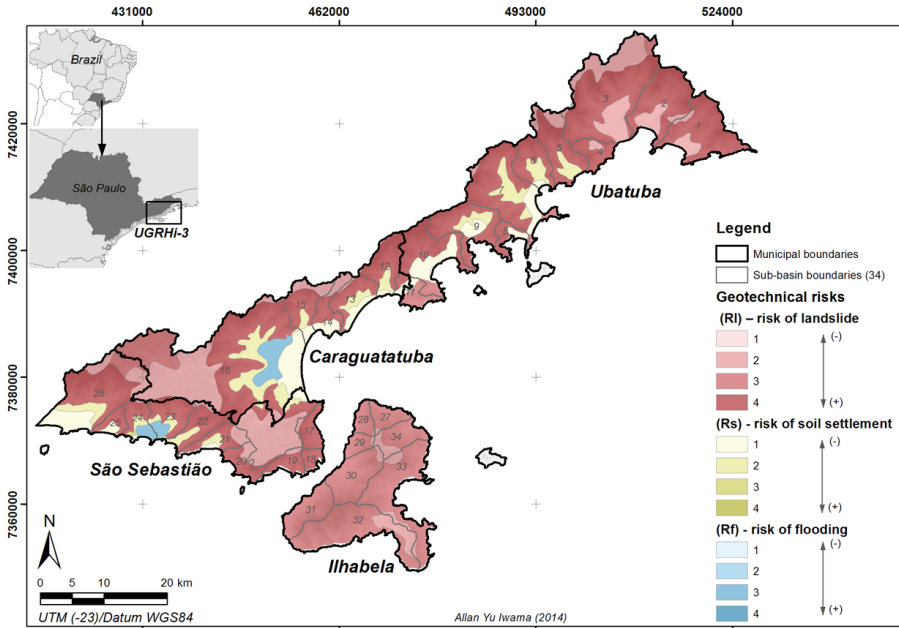
**Table 1. Risks of landslides (total and areas outside Strict-Use protected areas - the Serra do Mar and Ilhabela State Parks) –  $R_L$ , floods –  $R_f$  and soil settlement or subsidence –  $R_s$  in UGRHi-3 – Litoral Norte.**

Municipalities	Geotechnical risks – percentage and area (km <sup>2</sup> ) in relation to the total shared over the area (1:500,000 scale)				% of geotechnical risk, by municipality
	Landslides ( $R_L$ )		Floods ( $R_f$ )	Soil settlement ( $R_s$ ) – Land at low altitude < 10m	
	Total in each municipality	Portion outside State Parks (Strict-Use protected areas)			
Caraguatatuba	23.0 (431.8)	2.3 (42.5)	1.2 (23)	6 (113.4)	30.3
Ilhabela	17.3 (324.3)	2.7 (50.3)	-	-	17.3
São Sebastião	13.2 (247.1)	2.3 (43.9)	0.6 (10.9)	3.0 (55.9)	16.7
Ubatuba	31.2 (584.4)	4.9 (93.1)	-	4.5 (84.6)	35.7
<b>Distribution in UGRHI-3</b>	<b>84.7 (1.587)</b>	<b>12.3 (229.8)</b>	<b>1.8 (33.9)</b>	<b>13.5 (253.9)</b>	<b>100</b>

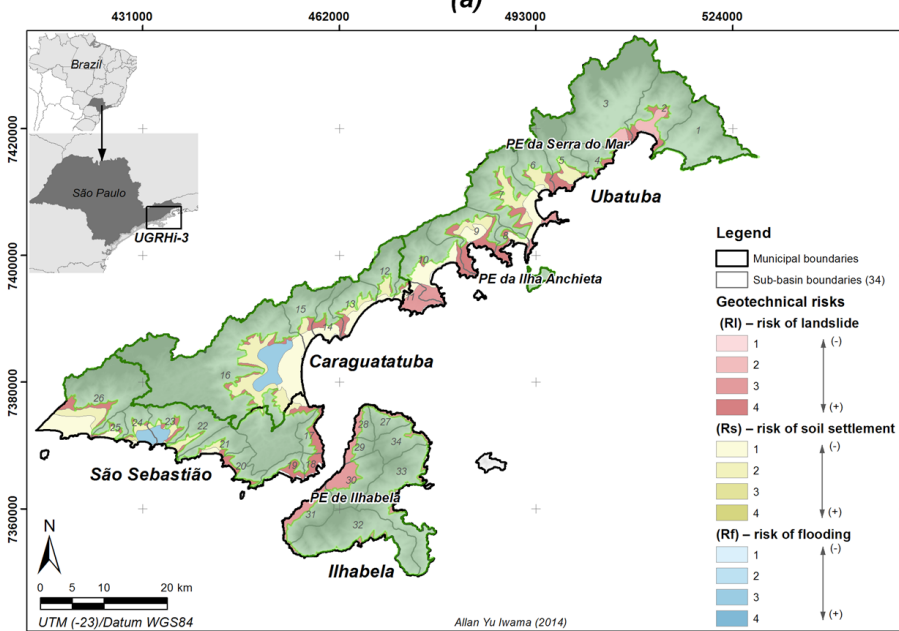
Within the geotechnical risks related to mass movement processes, in particular landslides, roughly 52% of the total of  $R_L$  is considered with *Very High Susceptibility* in the municipality of Ubatuba, 25% in São Sebastião and 22% in Caraguatatuba.

Although the percentage of the risks associated with *Very High Susceptibility* to landslides is relatively lower in the latter two municipalities, these risks are relevant as they are related to areas where large infrastructure projects are being carried out: the Tamoios road complex (in the Serra of Caraguatatuba tract and the mountainous area of São Sebastião, including the districts of Morro do Abrigo, Topolândia, Itatinga and Olaria). As regards the geotechnical risks related to landslides in the *High Susceptibility* category, more than 70% are concentrated in Ilhabela. However, some of these risks are associated with roughly 50 km<sup>2</sup> of areas subject to occupation in Ilhabela State Park, bordered by low altitude (< 10m) regions – **Figure 3a**. The geotechnical risks related to soil settlement and flooding, although insignificant in terms of their area, also apply to areas or regions with important infrastructure projects: the Caraguatatuba Gas Treatment Unit (UTGCA), in addition to tracts of the Tamoios road complex which cuts through some areas in the districts of Tinga and Morro do Algodão (Caraguatatuba) – **Figure 3b**.

Figure 2. Map of geotechnical risks: ( $R_l$ ) – risk of landslide; ( $R_f$ ) – risk of flooding; ( $R_s$ ) – risk of differentiated settlement or instability due to cut/fill/water seepage related to tidal movement (IPT, 1994). (a) in relation to the territory of UGRHi-3 and (b) in relation to areas subject to land occupation at low altitude and outside the limits of the Strict-Use protected areas in UGRHi-3 – Litoral Norte.

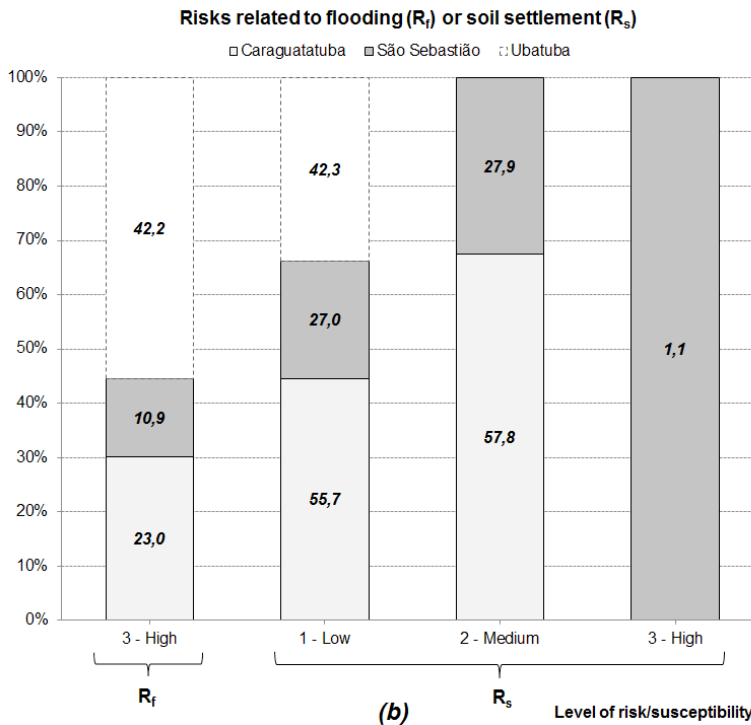
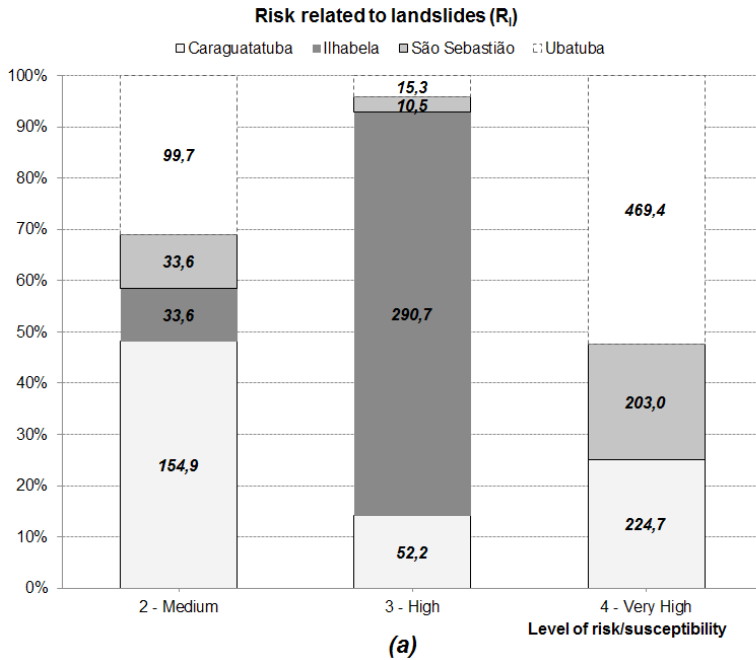


(a)



(b)

Figure 3. Geotechnical risks according to categories of level of susceptibility: (a) landslide-related processes; (b) processes related to flooding and soil settlement influenced by tidal movement.



### Potential geotechnical risks and social vulnerability (2000-2010)

In order to examine the potential risks to the population in UGRHi-3 – Litoral Norte, our analysis took the following into consideration: (1) *Very High Risk* and *High Susceptibility* to landslides, floods and/or soil settlement and instability related to tidal movement; (2) areas that do not overlap with Strict-Use protected areas (UCs), Serra do Mar State Park (PESM) and Ilhabela State Park (PEI) – as these are areas that limit human occupation (BRAZIL, 2000 - Law 9.985/2000, SNUC); (3) the location of risk areas mapped by the São Paulo Geological Institute (IG-SP, 2006a,b,c) and UNESP<sup>ii</sup>-Rio Claro (UNESP, 2006) and IPT (2010), on detailed scales ranging from 1:1,800 to 1:3,000. According to the risk mapping data on the detailed scales, approximately 745.9 km<sup>2</sup> (roughly 1.27% of the areas situated outside the Strict-Use protected areas) are at risk from landslides and flooding. This mapping is the technical product that the Civil Defence agencies use in the four municipalities and is the reference point for action in areas of eminent risk of deaths or damage to households. According to the technical risk reports for UGRHi-3 there are around 110 locations at risk of landslides or flooding throughout the area, with an estimate of 9,000 households exposed to geological-hydrological risks – **Table 2**.

**Table 2. Areas at risk, sectors and estimated affected households and total households in 2010 (Demographic Census).**

Municipalities	Areas at risk (1:3000 scale)	Total risk sectors <sup>1</sup>	N. of households (risk areas) - 2006 <sup>2</sup>	N. of households (2010 census)
<b>Caraguatatuba</b>	18	49	250 (377 in 2010 <sup>3</sup> )	31,934
<b>Ilhabela</b>	12	27	451	9,015
<b>São Sebastião</b>	28	93	3,139	23,603
<b>Ubatuba</b>	54	149	5,126	25,075
<b>UGRHi-3 - Litoral Norte</b>	<b>112</b>	<b>318</b>	<b>8,966</b>	<b>89,627</b>

<sup>1</sup> A risk area may contain a number of risk sectors, which vary in their classification, ranging from low to very high risk (R1, R2, R3, R4). <sup>2</sup> Estimates based on technical reports by the IG (2006a, b, c); UNESP (2006).

<sup>3</sup> Estimate based on the IPT technical report (2010).

Analyzing social vulnerability, particularly the main changes in the patterns identified by the census sectors between 2000 and 2010, a change can be seen in the socio-economic profile and family structure of the population in individual permanent households. In general, the distribution of census sectors using social vulnerability indexes (IPVS 2000-2010) indicates that social vulnerability in the outskirts of municipalities – within the city limits though far from the central area – tends to increase, while the lower vulnerability sectors tend to be found in the central areas and those close to the coastline (MELLO *et al.*, 2012).



There are different reasons for this pattern, which can range from macroeconomic to local conditions. Fernandes (2006) cites some of them with regard to area legalization programmes in urban districts: political manipulation of informal settlement dwellers through clientelism practices; elitist urban planning that does not factor in the socio-economic realities of residents; and the obsolete nature of the legal processes which still predominate.

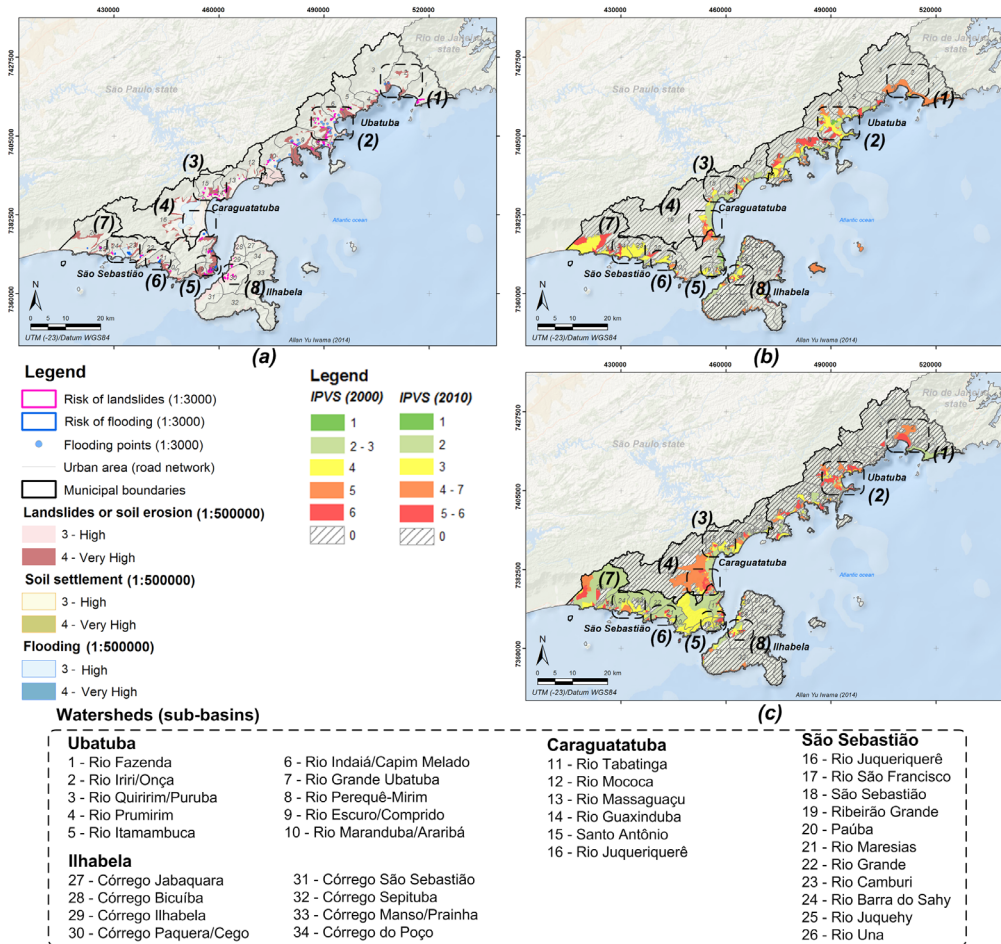
In order to further assess these changes, our analysis was split into the four municipalities in UGRHi-3. It aimed to contextualize the change in vulnerability patterns in specific sub-basins together with local circumstances when they were exposed to geotechnical risks.

The subset in **Figure 4** represent areas in the sub-basins with an increase in, or that remain with, high social vulnerability (**Figure 4b** – social vulnerability in 2000 and **Figure 4c** social vulnerability in 2010), especially those that went from low or medium social vulnerability to high or very high social vulnerability in areas of geotechnical risk (**Figure 4a**).

The case-by-case municipality analysis indicates that **(I) in Ubatuba**, the central region has seen the greatest share of social vulnerability changes, with census sectors varying from medium to high or very high social vulnerability during the 2000-2010 period. This area is depicted by subset **(2)** of **Figure 4**, in the Rio Grande de Ubatuba sub-basin. The districts at recurrent risk of landslides and sporadic flooding with increased social vulnerability were: Ipiranguinha, Mato Dentro, Horto, Estufa II, Sesmaria, Bela Vista and Marafunda. In the Rio Indaiá/Capim Melado sub-basin, in particular in the Sumidouro and Pedreira neighbourhoods, there is high level of social vulnerability due to a high risk of landslides. Olivato (2013) noted that some of the residents of the Sumidouro districts do not understand the hazards linked with landslides, although the area has been mapped and this type of hazard/risk is recurrent. This situation highlights the need to share the technical/scientific results with the community affected by disasters as it points to a lack of preparedness or adaptation to environmental or geotechnical hazards. Other similar situations also emerge in the far south of Ubatuba, in the rio Maranduba/Araribá sub-basin (risk of landslides in the Sertão de Araribá and Sertão da Quina districts) and in Rio Escuro/Comprido (covering the Corcovado and Rio Escuro districts).

In subset **(1)**, an area located in the Iriri/Onça sub-basin, over the 2000-2010 period social vulnerability rose in the Ubatumirim neighbourhood (high to very high) and in Sertão de Ubatumirim. This area stands out as being important because, although it is less densely populated, with characteristics verging on those of rural areas, it is a region at potential risk of landslides. There is one particular aspect about this sub-basin: it is populated by traditional inhabitants (caçaras), whose activities are based on the cultivation of manioc and bananas (SIMÕES, 2010; SILVA, 2010), and here one can see the ties of the caçara culture to the rainforest and the sea (SILVA, 2010; CALVIMONTES, 2013). Although some authors have argued that traditional groups or communities have a greater capacity to adapt – as they have closer ties to, and knowledge of, the locality and its environment –, research is still needed to understand to what extent they are prepared to face imminent hazards. While uncertainty remains as to the geotechnical risks, this

Figure 4. (a) Map of potential risks: ( $R_l$ ) – risk of landslide; ( $R_f$ ) – risk of flooding (IPT, 1994; 2010) and risk of landslides and flooding (IG-SP, 2006; UNESP, 2006). (b) IPVS map (2000) and (c) IPVS map (2010), both divided into census sectors.



population plays a key role in aspects of conservation (see SILVA, 2010; SIMÕES, 2010; CALVIMONTES, 2013).

(II) In Caraguatatuba, geotechnical risks are spread throughout the municipality, with two areas in two important sub-basins of note: the Rio Santo Antônio basin [subset (3)], where major landslides and heavy rainfall occurred in 1967 and which has now been virtually (re)occupied. The indicated area covers the Rio do Ouro, Caputera and Jaraguazinho neighbourhoods, which have witnessed increased social vulnerability in areas previously indicated as being subject to risk of landslides. In subset (4), the Rio Juqueriquerê basin, which covers an area of Porto Novo district and the Morro do Algodão neighbourhood, there is a recurrent risk of flooding (Figure 4). In addition to

the social vulnerability situation and the risk of flooding on the rio Juqueriquerê plain, of particular note is the location of the Caraguatatuba Gas Treatment Plant (UTGCA) on the plain, with gas pipelines linking offshore platforms to municipalities in the Paraíba Valley (such as Taubaté), crossing the Serra do Mar in its entirety. This situation tends to increase the extent of environmental and technological risks, because they are geographically interconnected.

**(III) In São Sebastião**, there have been considerable changes in social vulnerability throughout the entire municipal area. Of note are the subsets indicated in (5) the São Sebastião sub-basin, covering central districts like Vila Amélia, Porto Grande, Topolândia, Itatinga and Olaria. These districts are close to the buildings of the Almirante Barroso Maritime Terminal (TEBAR) and to oil pipelines, as well as lying close to the port of São Sebastião. There have already been technological accidents in this region involving projects linked to the oil and gas industry (POFFO *et al.*, 1996; POFFO, 2008), with negative impacts on the population and the environment. The port of São Sebastião is currently being expanded and, like the Caraguatatuba Gas Treatment Plant, this is likely to increase environmental and geological risks linked to technological risks. Although there are programmes to reduce the technological risks, such as APELL - Awareness and Preparedness for Emergencies at Local Level, it is well-known that its actions are only effective as a part of longer-term programmes.

The district (6), situated in the rio Maresias sub-basin, which covers the Maresias neighbourhood, expressly shows a clear division of houses or urban settlement into two strata: over the 2000-2010 period, one low social vulnerability stratum located on the plain and near to the coast line, with medium and high quality houses on Maresias beach; another stratum, highlighted as being of high social vulnerability - and classified as a sub-normal or precarious settlement, located in the area near to the Serra do Mar slopes ("sertão" of Maresias), of low construction quality houses or dwellings that are vulnerable to geotechnical risks or hazards. The "dividing line" between the two groups is the CESP (São Paulo Energy Company) road, where a transmission line passes, with this area suffering seasonal flooding.

Subset (7) indicates the sub-basins of the river Camburi, Barra do Sahy and Juquehy, which covers the districts of Camburi, Barra do Sahy, Juquehy and settlements or districts such as Lobo Guará, Areião, Rua da Rosa and Rua da Calçada in Camburi; and Vila Progresso, Morro do Esquimó and Vila Pernambuco in Juquehy. Similar situations of risk of flooding and landslides with damage to local communities are an ongoing occurrence in Barra do Una (far south of São Sebastião) and in the Boiçucanga district, located in the Rio Grande sub-basin.

The ongoing situation of high social vulnerability in areas of geotechnical risk can be found in almost all of UGRHi-3, often in the so-called "sertão" or hinterland areas, which are located close to the slopes of the Serra do Mar.

**(IV) In Ilhabela**, risks associated with landslides and falling blocks predominate (IG/SP, 2006a). In relation to other municipalities, it is noteworthy that the variation in the social vulnerability index did not present any sectors with significant changes over the 2000-2010 period. On the one hand, while some areas had increased social vulnerability

(in the São Sebastião and Ilhabela stream sub-basins, for example), on the other, there were areas that remained highly or very highly vulnerable between 2000-2010. In the subset indicated as (8) in **Figure 4**, which is part of the Paquera/Cego stream sub-basin, the main access to Ilhabela, the areas at high risk of landslides are located in census sectors that retained the characteristic of high social vulnerability (they include districts such as Reino, Barra Velha and Itaquanduba, in places like Buraco do Morcego, Green Park and Morro dos Mineiros).

### *Social and environmental vulnerability: issues of unequal development*

Different authors have proposed the need to reduce situations of vulnerability in the region. These include concerns about the geological-geomorphological characteristics of an area which is prone to landslides or flooding (BITAR, 2009), and relates to the increased occupation and concentration of urbanized areas in a scenario of infrastructure development for oil and gas production (SOUZA; LUNA, 2008; BITAR, 2009; CARMO et al., 2012).

There are considerable macroeconomic influences linked to the completion of these major undertakings in the region. Job offers have ended up influencing population growth in certain areas. Added to this factor is the lack of choice in terms of formal or legal land where housing, urban or agricultural policies are enforced, from which historically vulnerable residents or those living in precarious housing have been excluded.

In practice, this state of affairs causes “informal” occupation in areas of recognized geological risk or in protected environmental areas - as environmentally sensitive areas are generally disregarded by the formal real estate market, according to Fernandes (2006).

The problem does not necessarily stem from population increase, but rather from the lack of access to public facilities, infrastructure and sanitation, which has not kept up with rapid growth.

In all the municipalities analyzed in UGRHi-3, areas can be observed that maintained or increased situations of vulnerability over the 2000-2010 period, especially geotechnical risk areas. The situation is therefore important and of concern: over a ten-year period at the very least, we are still “mapping” areas in a constant situation – areas of recognized geotechnical risk, with some precarious settlements and conditions of high social vulnerability. This situation is also characterized by the geographic location, recurrent in so-called “sertão” regions – which are far from the coastline and situated in areas of steep slopes and/or close to watercourses.

In contrast, some population groups seem to have better access to basic urban infrastructure services. These groups have taken advantage of the benefits of economic development, often in regions closer to the coastline (and central regions of municipalities).

This situation of contrasts and accentuated socio-spatial segregation in the municipalities in the study area (and also in Brazilian coastal municipalities) can, in general, be summed up as one of socio-economic groups (basically income and education): higher socio-economic groups occupying coastal regions and those with a lower socio-economic level occupying the very steep slopes or areas close to watercourses at risk of flooding

(for example, the districts of Juquehy, Barra do Sahy, Maresias, on the south coast of São Sebastião; or Barra Velha, in Ilhabela). This contrast is not just seen with regard to the different hazards: for example, in the districts of Vila and Santa Teresa, in Ilhabela, there are situations involving households that are subject to the same level of risk of landslides, yet with differing states of social vulnerability.

In the broader scope of the land occupation process, informal urban development and illegal occupation have become the norm in terms of accessing urban land and housing (FERNANDES, 2006; CARVALHO, 2007; MARICATO, 2011), generating not just social problems, but also degrading the environment. This rule should not simply be seen as a model of socioeconomic “development”, but rather as a model that has perpetuated social inequalities over time, a model of “development for its own sake”, as Fernandes argues (2006). According to Valencio and Valencio (2011) there is a corporate ethical culture among public officials which endorses asymmetrical relations and displaces concerns about the common good, ratifying a model of development that is simultaneously concentrated and excluding.

### *Social and environmental vulnerability in the context of climate change*

The results show that there are areas of geotechnical risk that overlap areas that are already socially disadvantaged or in states of high social vulnerability (situations already observed in other areas in Brazil and the world – TOMINAGA *et al.*, 2009; UNISDR, 2004; 2009). Although this process (extensive or cumulative risks – UNISDR, 2004; 2009; 2011) is initially separate from the effects of climate change, as the impacts of extreme weather events become more visible and frequent, they tend to highlight or accentuate existing inequalities (BECK, 2010) or the “old” problems (poverty, inequality, inadequate access to public services, among others).

Although uncertainty still surrounds the issue of climate change, perhaps it may be more prudent to consider preventive or forward-looking measures in order to avoid the negative effects of these changes (HOGAN, 2009; GIDDENS, 2010), rather than to wait for the impacts or effects to become “visible and frequent”.

One of the actions that could be taken (by government and society) would be to target reducing the inequalities or social segregation and geotechnical or environmental risks by setting up management actions in an integrated way. In terms of public policies to manage risks and disasters in the context of climate change, Brazil has made considerable progress at the federal level through the National Policy on Climate Change (PNMC – Law 12.187/2009, BRAZIL, 2009) and by establishing the National Policy for Civil Protection and Defence (PNPDC – Law 12.608/2012, BRAZIL, 2012), which covers prevention, mitigation, preparedness, response and recovery, linking up civil protection and defining in an integrated manner policies on land use planning, urban development, health, the environment, climate change, water resources management, geology, infrastructure, education, and science and technology, among other sectorial policies.

At the state level, the São Paulo legislation on climate – the PEMC (Law 13.798/2009 – SÃO PAULO, 2009) together with State Decree 57.512/2011 (SÃO

PAULO, 2011), which set up the State Programme for Natural Disaster Prevention and Geological Risk Reduction Programme (PDN), also present guidance regarding the different bodies and institutions in the State, as well as highlighting the need to join up and optimize existing actions.

Taking into account that disasters are not just physical events, but, above all, social disasters, breaking apart the social dynamic (SIENA, 2011), public authorities need to make a commitment to vulnerable social groups (VARGAS, 2006; VALENCIO *et al.*, 2009; VARGAS, 2010), with input from technical-scientific research that supports effective intervention to reduce and mitigate risk.

These results, when taken as a whole for the UGRHi-3 region, reinforce the need for greater attention to reducing these risks, extending preventive measures and making the necessary changes for existing and planned infrastructure (BITAR, 2009), seeking appropriate land use planning through Master Plans and Ecological-Economic Zoning (ZEE) that take the risk of disasters into account. In this regard, an important step is being taken at present with the inclusion of the topic of risks and disasters in the current ZEE for the study area (FERREIRA, 2012).

## Final considerations

The results indicate that the areas of geotechnical risk in UGRHi-3 – Litoral Norte, that are classified as having High or Very High Susceptibility to landslides or floods are distributed primarily in areas where communities or houses have only access to the most basic public services, or in areas of precarious housing. Attention needs to be focused on situations of social vulnerability that have remained over a ten-year period, linked to a context of social contrasts and socio-spatial segregation, without effective intervention or action to reduce the impacts in the face of imminent hazard of disaster. Lastly, the risks associated with extreme weather events can affect everyone, regardless of their socioeconomic status, which makes preventive action and forward-looking planning all the more urgent as a basis for reducing the risks of climate-change-related disasters. In actual fact what we have observed is remedial action taken after the event, following “disasters”. The reasons for this situation range from insufficient staff for civil defence teams to cover the whole area of the municipalities, to institutional policy being more oriented towards reconstruction work than prevention. This reality is changing with public policies focused on integrating management instruments (such as rules for land use subdivision, master plans, zoning and risk mapping) while also taking into account aspects of climate change. Nevertheless, this change in reality is still incipient.

The importance of interdisciplinary studies is essential in this field, as understanding social aspects (their dynamic and timeframe) is required to an analysis of vulnerability, what must be understood as a process. Finally, this analysis will also have to include studies on multiple scales in order to identify the heterogeneous nature of situations of vulnerability.

## Notes

- i IPT – São Paulo State Institute for Technological Research.
- ii UNESP-Rio Claro – University of the State of São Paulo, Rio Claro Campus.

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# GEOTECHNICAL RISKS AND SOCIAL VULNERABILITY IN COASTAL AREAS: INEQUALITIES AND CLIMATE CHANGE

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**Abstract:** The coastal zones are potential areas of environmental risks, particularly in the context of extreme climate events. Moreover there is a significant portion of the population living in coastal zones, emphasizing the importance of characterizing situations of risk and vulnerability in these regions. A spatial and contextual analysis was elaborated in Northern coast of São Paulo (Water Resources Management Unit – UGRHI-3) and sub-basins, indicating the distribution of geotechnical risks associated with: landslides in potential areas to occupation (12.3%), flooding (1.8%) and land subsidence (13.5%). At least ten years was found situations under high social vulnerability in areas of high or very high susceptibility of geotechnical risks, besides the socio-spatial segregation of people at risk. Finally, although incipient, this work indicates a positive perspective for disaster risk reduction with the implementation of public policy based on integration territorial management instruments.

**Keywords:** Risk; Vulnerability; Multiscale; Climate change.

**Resumo:** As zonas costeiras são áreas de potenciais riscos ambientais, sobretudo no contexto de eventos climáticos extremos. Há uma importante parcela da população vivendo em zonas costeiras, enfatizando a importância de caracterizar as situações de riscos e vulnerabilidade nessa região. Este trabalho realizou uma análise na Unidade de Gerenciamento de Recursos Hídricos (UGRHi-3) – Litoral Norte de São Paulo e sub-bacias, indicando a distribuição de riscos geotécnicos associados a: escorregamentos em áreas potenciais de ocupação (12,3%), de inundação (1,8%) e recalques dos solo (13,5%). Os resultados apontam para uma situação de pelo menos dez anos de áreas que têm permanecido em condições de alta vulnerabilidade social, situadas em áreas de riscos geotécnicos considerados de alta/muito alta suscetibilidade, além de um contraste socioespacial das populações em risco. Por fim, apesar de incipiente, há uma perspectiva positiva para a redução de riscos e desastres, com a implementação de políticas públicas orientadas para uma integração de instrumentos de gestão territorial.

**Palavras-chave:** Riscos; Vulnerabilidade; Multiescalar; Mudanças climáticas.

**Resumen:** Las zonas costeras son las potenciales áreas del riesgos ambientales, especialmente en el contexto de cambios climáticos extremos. Además, hay una porción significativa de la población viviendo en la costa, dando énfasis y importancia para caracterizar las situaciones de riesgo y vulnerabilidad nestas regiones. El artículo ha analizado en la Unidad de Gestión de Recursos Hídricos - UGRHI-3, costa norte y sub-cuencas del São Paulo la distribución de los riesgos asociados con: deslizamientos de tierra en las zonas potenciales del ocupación (12,3%), inundación (1,8%) y los asentamientos del suelo (13,5%). Los resultados apuntan para una situación de al menos diez años en que algunas áreas tienes permanecido en condiciones de alta vulnerabilidad social en zonas de riesgos geotécnicos de alta/muy alta susceptibilidad, además de una segregación socio-espacial de las poblaciones en situación de riesgo. Por último, aunque incipiente, este trabajo indica una perspectiva positiva para la reducción del riesgo y desastres, con la implementación de políticas públicas para la integración de gestión territorial.

**Palabras-clave:** Riesgo; Vulnerabilidad; Multiescala; Cambios climáticos.

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