Vulnerability associated with precipitation and anthropogenic factors on Guarujá City (São Paulo, Brazil) from 1965 to 2001

Ricardo Araki
ricardo.araki@ige.unicamp.br
Geographer MsD., Department of Geography, The Geosciences Institute-UNICAMP, Brazil
Luci Hidalgo Nunes
Geographer, Lecturer, Department of Geography, The Geosciences Institute-UNICAMP, Brazil (lecturer, supervisor)

Landslides on slopes with urban occupation have been intensifying in many regions of the world, exposing the need for studies focused on the evaluation of their causes, in view of preventing and/or mitigating the associated losses.

Specific combinations of rainfall volumes, lithology, topography, sparse vegetation, impervious ground, past soil moisture conditions and land use accompany these events, but their impacts depend upon the vulnerability social groups. They are particularly common and severe in tropical regions, where the impoverishment of significant population segments, their inability to demand essential rights, the lack of alternatives for living in safer areas, and the inadequacy of basic infrastructure and organizational systems in the prevention or limitation of impacts, contribute to the continuous growth of society's vulnerability to these episodes.

Figure 1 illustrates the deaths caused by natural disasters in Brazil, showing that 7804 people died from 1948 to 2007; it is worth mentioning that landslides alone caused 1640 deaths in the period. However, it is possible that these figures are underestimated for some periods due to the lack of accurate statistics for natural disasters in Brazil.

In the last decades, Guarujá city (Figures 2 and 3) became a resort for the higher classes of

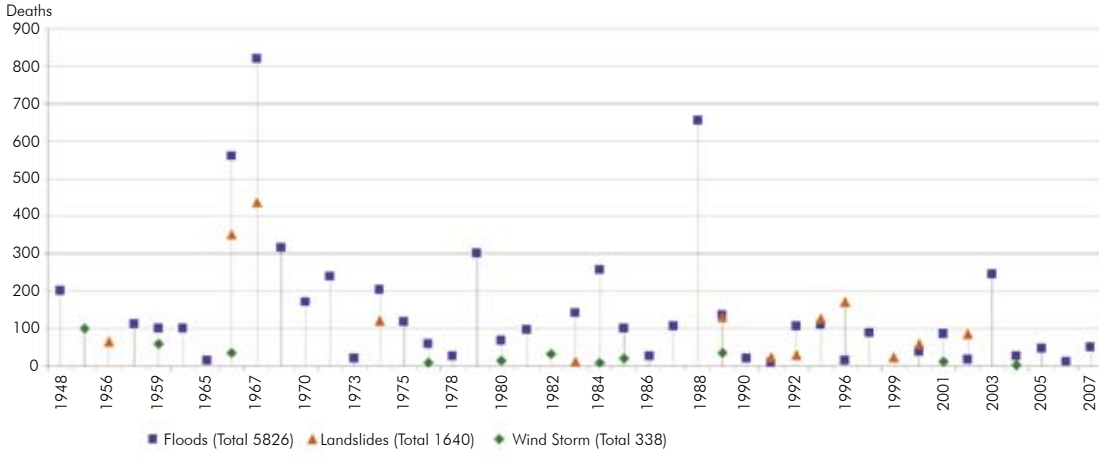

Figure 1 – Deaths caused by natural disasters in Brazil (1948 - 2007)
Source: EM-DAT – Figure elaborated by Ricardo Araki

São Paulo city and surrounding areas. Guarujá has easy access by fast and modern highways, paradisiacal beaches and constant good weather conditions. Meanwhile Guarujá and surrounding cities witnessed impressive growth, which brought in turn large contingents of workers that occupied the unstable slopes of Serra do Mar Escarpment, despite the fact that the city has been experiencing an increase in the number of landslides areas. Table 1 illustrates that the number of events in Guarujá is higher than in neighboring cities that are also part of the Metropolitan Region of Baixada Santista. In addition, the population of Guarujá increases up to 40% during summer vacation, bringing problems such as lack of appropriate waste treatment and sanitation. It is noteworthy that summer time coincides with the period of more intense and frequent rainfall, which can bring landslides, floods and their associated victims.

Figure 2 – Guarujá in São Paulo State and Brazil

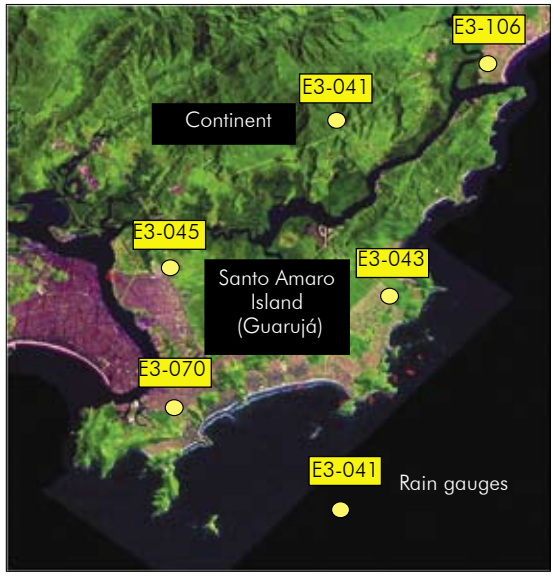

Figure 3 – Satellite image of Guarujá. (Source: EMBRAPA – Figure adapted by Ricardo Araki)

Table 1 – Risk areas in the RMBS – Metropolitan Region of Baixada Santista.
Source: PRIMAC – Table organized by Ricardo Araki

City	Floods Areas	Erosions Areas	Landslides Areas
Bertioga	18	1	1
Cubatão	11	0	8
Guarujá	31	12	**15**
Itanhaém	7	2	2
Mongaguá	10	0	3
Peruíbe	24	0	1
Praia Grande	37	0	0
Santos	31	0	10
São Vicente	90	1	8

Data from five rain gauges spread across the area were analyzed for two periods: 1965–1988 and 1991–2001 The landslide events were collected from local newspapers and the Guarujá Municipal Civil Defense.

Results revealed a substantial increase in landslides triggered by rainfall in the most recent period (1991-2001): 496 events against 81 in the previous period (1965-1988) as can be seen on Table 2; however, no appreciable annual change in the rainfall totals was found. Indeed, events took place with lower amounts of annual rainfall as shown in Figure 4, which compares the pluviometric totals of the more recent period in relation to the previous one. The fact that lower rainfall totals are triggering more landslides highlights the aggravation of environmental problems in the area, which are strongly correlated with inappropriate land use, such as deforestation of the Atlantic Rainforest and damage to mangroves as well as rapid and unplanned urbanization. These aspects brought in turn an increase in the vulnerability of the inhabitants of the at-risk areas.

A large number of landslides were registered on two dates: March 25th, 1991 (60 events) and

Table 2 – Areas that registered many landslides in Guarujá, in two periods
Sources: Governo do Estado, 1989 and COMDEC – Guarujá. Table organized by Ricardo Araki

Period	1965 to 1989			1991 to 2001		
Number of landslides	81 events			496 events		
Local of landslides	Morro da Glória	15 events	20%	Vila Baiana	171 events	34%
	Vila Sônia	10 events	12%	Morro da Cachoeira	62 events	12%
	Vila Júlia	10 events	12%	Morro do Engenho	55 events	11%
	Vila Baiana	9 events	11%	Vale da Morte	29 events	6%

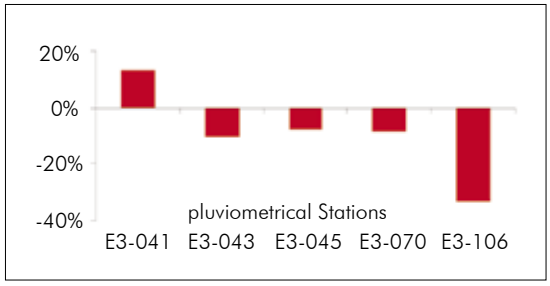

Figure 4 – Percent difference in rainfall between two periods (1965-1989 and 1991-2001). (Source: SIGRH. Figure elaborated by Ricardo Araki.)

February 19th, 1993 (35 events). However, they presented distinguishing spatial-temporal patterns: on February 19th, 1993 there was an extraordinary amount of rainfall on this single day (Figure 5b), which suggests a convective episode; on March 25th, 1991 the temporal distribution of rainfall was higher (contribution of four rainy days) and the geographic distribution of rainfall was more similar among the rain gauges (i.e., higher spatial homogeneity), facts that indicate that rainfall might have been promoted by a front system in the region, possibly associated with a ZCAS (South Atlantic Convective Zone).

In addition, the data was re-analyzed for both days independently. Figure 6a shows a strong positive anomaly in the area on March 25th, 1991, but on February 19th, 1993 no significant anomaly is revealed (Figure 6b), which emphasizes the aspects addressed by Figures 5a and 5b.

Therefore, although on both days rainfall triggered numerous landslides in Guarujá, different types of precipitation (convective and a front system associated with ZCAS) accompanied

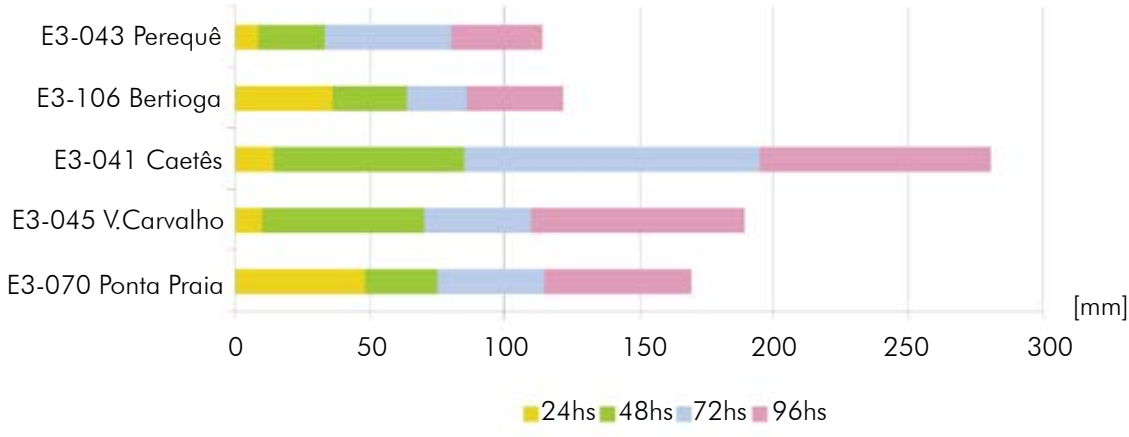

Figure 5a – Accumulated rainfall (a) March 25th, 1991. (Source: SIGRH. Figure organized by Ricardo Araki.)

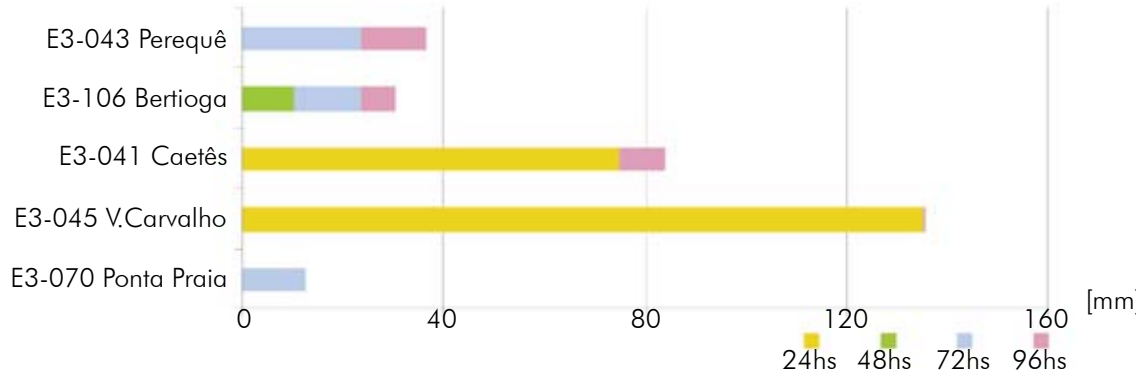

Figure 5b – February 19th, 1993. (Source: SIGRH. Figure organized by Ricardo Araki.)

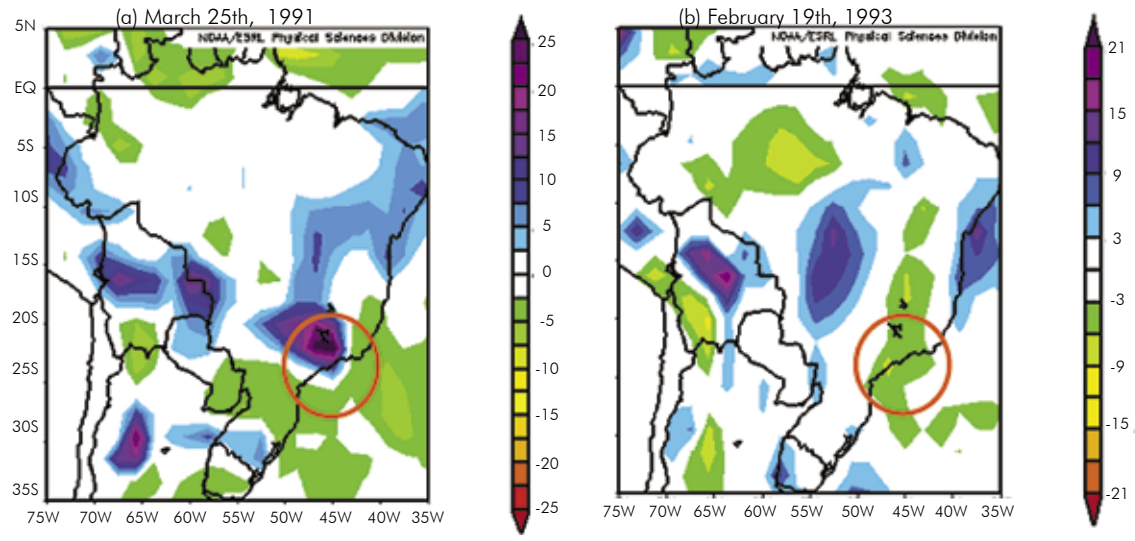

Figure 6a and 6b – Daily rainfall anomaly (a) March 25th, 1991 and (b) February 19th, 1993
Source: CDC / NOAA. Figure organized by Ricardo Araki

these calamitous events. It must be emphasized that convective storms, cold fronts and ZCAS are common atmospheric mechanisms in the area and play important roles in triggering landslides, terrain collapses and floods. Nevertheless, even though landslides are part of the natural evolution of humid tropics, the natural low stability threshold of the region is becoming lower due to the aggressive land use in this area, so that this sort of event may be registered continuously, causing economic losses and suffering to the population.

Sources

Governo do Estado de São Paulo 1989. Carta Geotécnica do Município de Guarujá. São Paulo: Instituto Geológico - Secretaria do Meio Ambiente - Instituto de Pesquisas Tecnológicas - Secretaria da Ciência, Tecnologia e Desenvolvimento Econômico. São Paulo.

CDC Climate Diagnostic Center.

COMDEC Comissão Municipal de Defesa Civil.

EM-DAT Emergency Disasters Data Base.

NOAA National Ocean & Atmospheric Administration.

PRIMACPrograma Regional de Identificação e Monitoramento de Áreas Críticas de Inundação, Erosões e Deslizamentos.

SIGRH Sistema Integrado de Gerenciamento de Recursos Hídricos de São Paulo.