

The largest 24-hour rainfall event ever recorded in Brazil killed 65 people along the north coast of São Paulo state during the Carnival season.

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1. Introduction

Brazil is a vast country with a wide variety of climates. Although there exist some semi-arid areas, annual rainfall in the country is very high overall. Due to the frequent occurrence of hydrological disasters, hydrometeorological observations have been carried out at the national level for a long period of time. Until recently, the largest 24-hour rainfall ever recorded in the country was 404.8 mm measured in Florianópolis municipality, southern Brazil, on November 15th, 1991. This largest value was changed to 534.4 mm on March 20th, 2022 in Petrópolis municipality, Rio de Janeiro state.

However just under a year later, the maximum was changed again. A heavy rain event that reached 682 mm in 24 hours on February 5th-6th, 2023 caused a disaster with 65 dead, 1815 homeless, and 2251 temporarily-displaced people along the north coast region of São Paulo state (Figure 1).

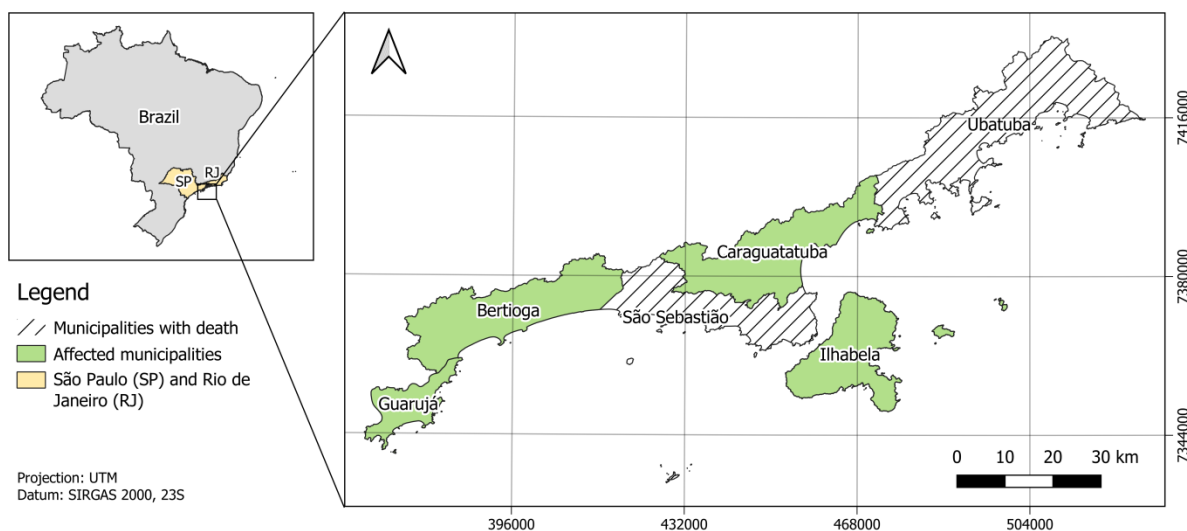


Figure 1 – Locality of the north coast region of São Paulo state and its constituent municipalities. Two municipalities drawn with diagonal lines are those that have lost human lives in the disaster. Note that normally Guarujá is not a part of this region.

2. Disaster area

The north coast region of São Paulo state is made up of the municipalities of Ubatuba, Caraguatatuba, Ilhabela, São Sebastião and Bertioga (Figure 1). It is the region that borders Rio de Janeiro state. And that is where the best beaches in the state are located: many are breathtaking. Figure 2 shows one typical scene of this place where there are few plane places between the sea and

the steep hillslopes covered by the Atlantic Forest. Some characteristics of the component municipalities are described in Table 1.

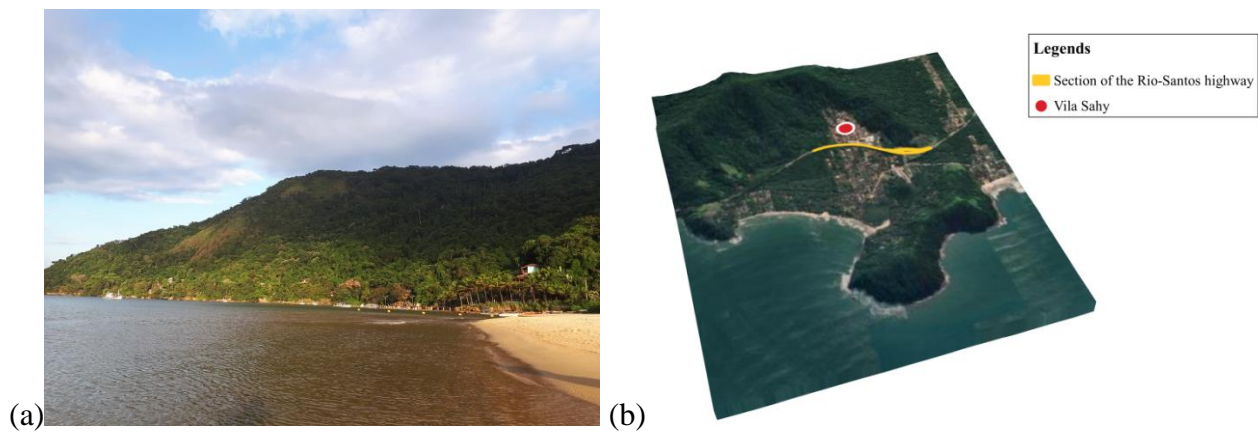


Figure 2 – Typical landscape of the north coast of São Paulo state: (a) Photo of steep hillslope with few beaches; and (b) 3D-image of São Sebastião municipality region with Vila do Sahy village.

Table 1 – Characteristics of the municipalities of the north coast region of São Paulo.

Municipality	Area (km ²)	Population (2021)	HDI (2013)
Ubatuba	708.105	92,819	0.751
Caraguatatuba	484.947	125,194	0.838
Ilhabela	346.389	36,194	0.756
São Sebastião	402.395	91,637	0.772
Bertioga	490.148	66,154	0.730
Guarujá*	142.589	320,459	0.751

Obs.: * The municipality of Guarujá is not considered a part of the north coast region.

Souza et al. (2018) demonstrated that a slope distribution of the north coast is 20.33% (< 2%), 3.29% (2-5%), 19.14% (5-15%), 42.57% (15-30%) and 14.68% (> 30%). Their report on a slope distribution of the region clearly indicates that there are very few flat or safe areas in this region. At such flat or safe areas, wealthy hotels and exclusive residential areas have been constructed. On the other hand, though many of the hillslopes that occupy most of the region are covered with Atlantic Forest which is legally protected, some of them are illegally occupied by a lot of houses.

The Atlantic forest is especially prone to landslides because the soil layer is not so deep and the rocks commonly have fractures. The region, at the same time, encompasses most of the larger Brazilian cities and tourist centers, where landslides disasters have been concentrated in recent years. Figure 3 shows municipalities with records of deaths due to landslides during the period 1988 to March 2011 and locations of large disasters with debris flows during the period 1900-2014. Most of them are located in the Atlantic Forest region (Brazilian coastal region).

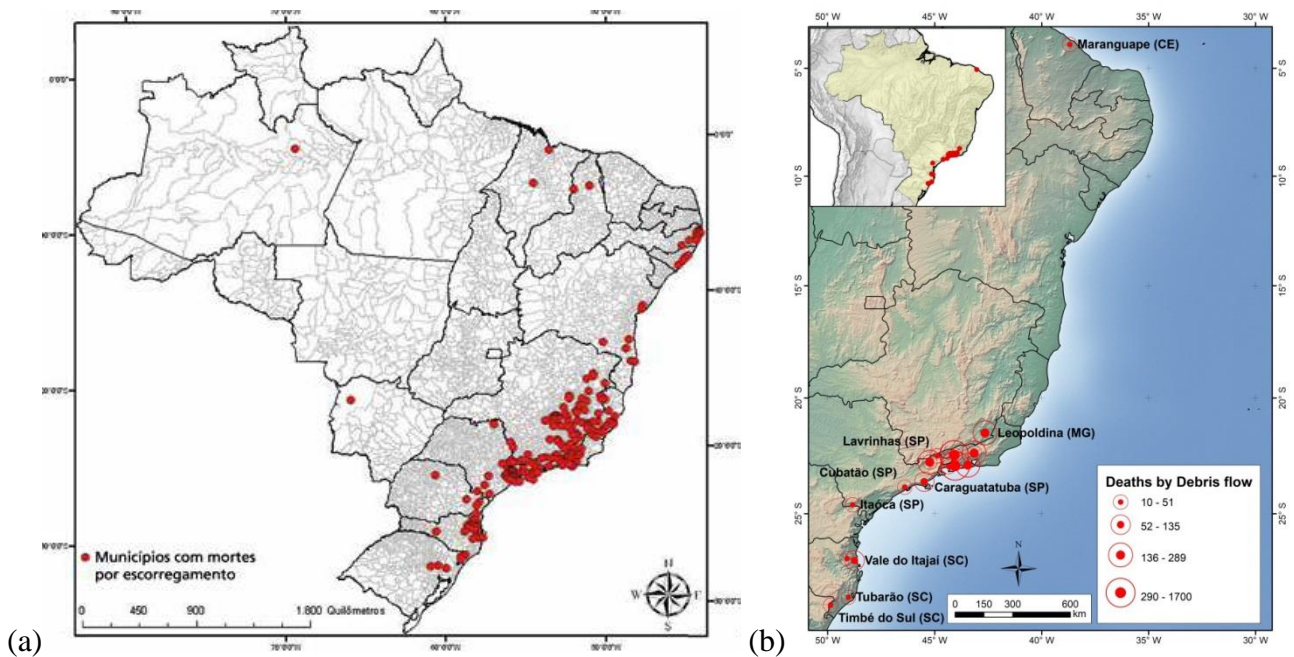


Figure 3 – Sediment-related disasters’ distribution in Brazil: (a) Municipalities with records of deaths due to landslides during the period 1988 to March 2011 (Source: Carvalho and Galvão, 2016); (b) Locations of large disasters with debris flows in Brazil during the period 1900-2014 (Source: Kobiyama et al., 2019)

On the coast of São Paulo, the Serra do Mar is predominantly characterized by an escarpment, a kind of huge step between the coastal plain and the plateau, clearly demonstrating a mountain environment. Especially on the north coast, as the case of São Sebastião, the Serra do Mar practically collapses onto the seafront, which makes the coastal area very narrow. This characteristic could be decisive for this tragedy. There is nowhere to run for evacuation. The lower region easily receives the sediments that violently descend from the steep hillslopes (Figure 4).



Figure 4 – Mud and debris covering residents’ area in São Sebastião municipality in February 2023 (Source: São Sebastião City Hall)

With the construction of the Brazil's Route BR-101 between Bertioga and São Sebastião municipalities (Figure 1), the local communities living just near the sea were displaced by force, and the beaches were occupied by closed subdivisions (an illegal urban plan at that time) aimed at the implementation of summer houses for the very high-income population. The poor population, whether former local communities or those who came to work for construction, had to occupy the foothills of the mountains, the areas geologically formed by the accumulation of soil and rocks caused by landslides. Therefore, such areas could be affected by landslides again (Figure 5).



Figure 5 – Typical locality of simple houses just beside hillslopes in São Sebastião in February 2023 (Source: Amanda Perobelli/Reuters)

Here it is necessary to say that above-mentioned constructions are not about demonizing tourists or high-income businesses. Cities are made up of this diverse ecosystem, and the resources derived from this economy are crucial, including in supporting public policy.

3. Rainfall characteristics triggering the tragedy

There was a forecast of a rainfall quantity of around 200 mm between February 18th (Saturday) and 19th (Sunday), 2023. Though the rainfall of 200 mm per 24 hours was already high, the actual one was even much higher. On February 18th, the most intense cold front during the last 54 years arrived from the south of the continent. There was a transport of heat and humidity coming from the Amazon region. These two dynamics met in the low atmospheric pressure zone. This low pressure caused the increase of wind coming from the sea. Thus, this event dragged moisture and raised sea levels. Rising sea levels hampered surface runoff into the sea. All these factors led to the highest 24-hour rainfall recorded in Brazil.

Table 2 presents the rainfall in 24 hours in several municipalities on the north coast of São Paulo. Since the mean monthly rainfall for February is 225 mm in this region, it can be said that the rainfall quantity of this event was extremely high.

Table 2 – Rainfall during 24 hours in the north coast region of São Paulo state

Municipality	24-hour rainfall (mm)	Death
Bertioga	682	0
São Sebastião	626	64
Guarujá	388	0
Ilha Bela	337	0
Ubatuba	335	1
Caraguatatuba	234	0

The 24-hour rainfall distribution can be seen in Figure 6. The extreme rainfall was very concentrated in Bertioga and São Sebastião municipalities. Here it should be noted that in Caraguatatuba a heavy rainfall event in March 1967 (584.8 mm in 48 hours) caused flash floods and debris flows, and killed 487 people.

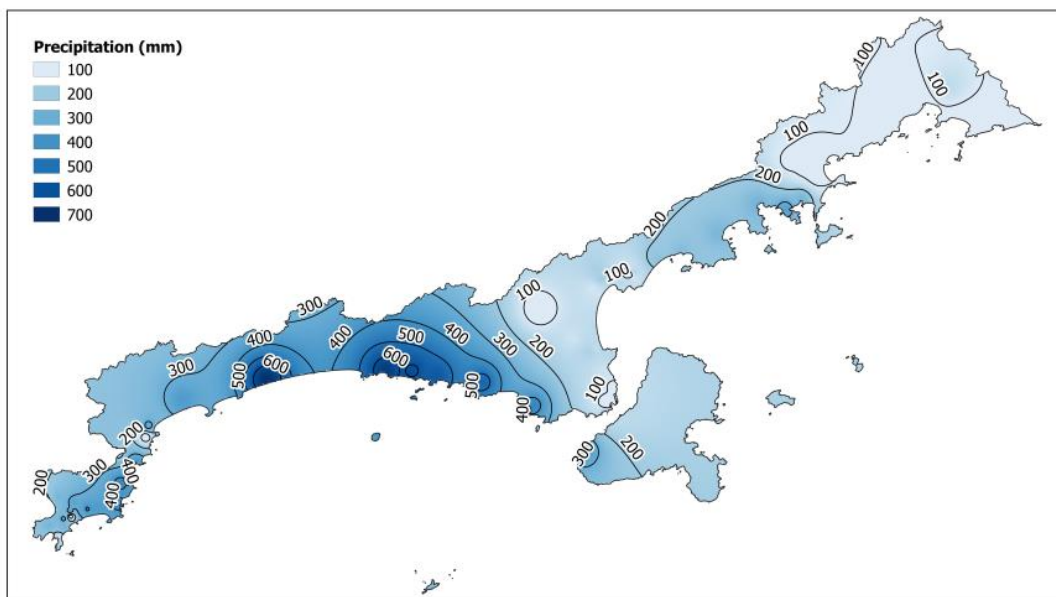


Figure 6 – Spatial distribution of 24-hours rainfall in the north coast of São Paulo during the period February 18th to 19th, 2023.

4. Principal factors causing disaster

As with any natural disaster, there are many factors involved in this disaster. However, here are three key points that seem decisive, being that one is related to natural phenomena and the other two are social issues.

4.1. Rainfall amount and intensity

Figure 7 demonstrates hyetographs obtained at two rainfall gauge stations: Praia de Guartuba (Bertioga municipality) and Barra do Una (São Sebastião municipality) which are both maintained by the Brazilian Center for Monitoring and Early Warnings of Natural Disasters (*Centro Nacional de Monitoramento e Alertas de Desastres Naturais – CEMADEN*). It was observed that in Bertioga, an extremely intense rainfall event occurred with 273 mm in 2 hours and 25 mm in 10 minutes on February 18th at night. On the same day overnight, Bertioga received more than 400 mm of rain for 6 hours.

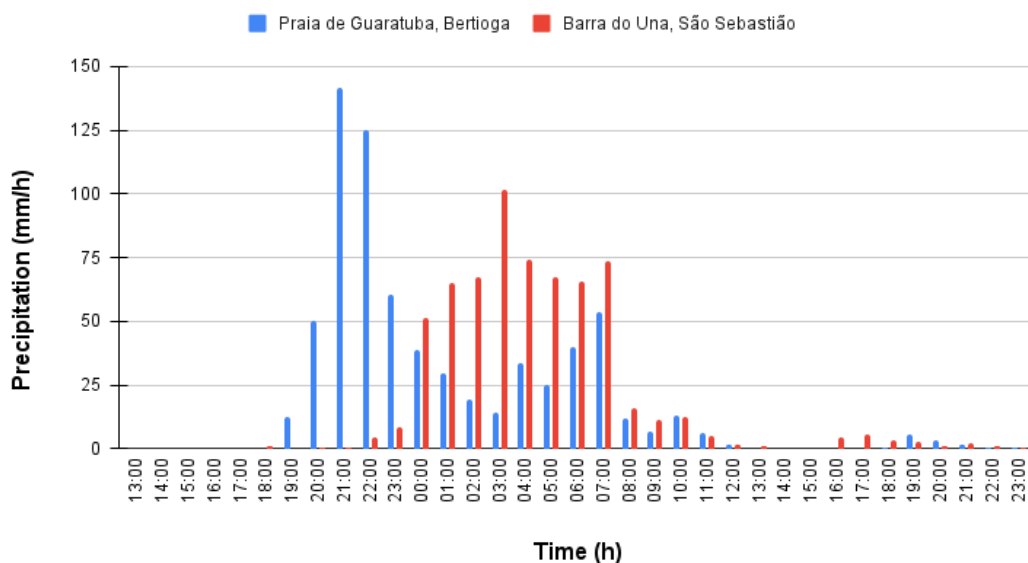


Figure 7 – Hyetographs obtained at two rainfall gauge stations: Praia de Guartuba (Bertioga municipality) and Barra do Una (São Sebastião municipality) from February 18th 13:00 to 19th 23:00.

If only this rainfall factor is observed, the present disaster can be easily considered “purely natural-hazard-induced disaster”, i.e., “natural disaster”. However, we need to see other factors which attributes to a local society.

4.2. Carnival season

Here base on the report of Casemiro and Matos (2023) and Xavier (2023), the actions of several organizations are chronologically presented.

- On February 13th, the CEMADEN started to issue bulletins describing the high risk of "hydrological events" in the region.

- On the 16th (Thursday), 48 hours in advance, the CEMADEN sent a disaster forecast warning about "very intense rainfalls with the potential to cause disasters" to the federal government and the State Civil Defense Agency (SCDA) of São Paulo, including the possible locations of the disaster. On the same day, the website of this Agency warned that heavy rain would be expected over the weekend: "Highlights and attention to the north coast where accumulations up to 250 mm can be recorded". This kind of warning is unusual. In this way, the coastal areas of São Paulo were attracting attention anyway. However, the SCDA gave no warning to the local city offices.
- On the 17th (Friday), at 00:52 am, the SCDA sent the first SMS alert to the cell phones of only 34,000 people registered in its system on the north coast. The bureaucratic message, however, spoke only of "isolated rain" in Ubatuba and nearby areas without reference to the disaster risk on the hillsides of Vila do Sahy village.
- On the 17th, even in the morning, the CEMADEN held a meeting with the Brazilian Center for Risk and Disaster Management (*Centro Nacional de Gerenciamento de Riscos e Desastres* – CENAD) and with the SCDA. Therefore, the incident was well anticipated and had been notified to the competent authorities and local authorities. The CEMADEN sent a list of all danger areas, including Vila do Sahy, but the disaster's magnitude was not well predicted.
- On the 18th (Saturday), the CEMADEN issued more than 60 alerts for Ubatuba, Ilhabela, Caraguatatuba and São Sebastião municipalities, etc. At noon, the SCDA sent an SMS to the population about heavy rain in the region. It should be noted that the state governor later admitted that the SMS messages sent to part of the population had no effect. Residents, however, reported that they were not alerted by the SCDA and were not asked to leave their houses even in the face of the danger of landslides. Here it should be noted that the entire state of São Paulo, including the north coast region, does not have siren's systems in hazard areas. As a result, all the population have been dependent upon the notifications of the state and municipal Civil Defense agencies.
- Around 11 pm, the storm was already quite intense, and the municipal Civil Defense of São Sebastião tried to reach Vila do Sahy, but there was no longer any access due to landslides. The SCDA sent an SMS saying that there was "persistent rain on the north coast" and warned the population to be aware of "the walls' inclination and cracks" and, if necessary, to leave the place. At this time, however, there was no shelter set up by the SCDA or any guidance as to where the population should go.
- On the 19th (Sunday), at 2:00 am, the rain was very intense, and many landslides began to take place in the north coast region. Several locations were already without electricity and internet or cell phone signal. At 3:00 am, the SCDA sent a new SMS to people registered by cell phone, advised the population to be aware of "the walls inclination and cracks", but did not mention anything about the risk of landslides. Here it should be noted that in the north coast region, only about 12% of 288,000 residents were registered in the SCDA's system.
- At 6 am, a new SMS from the SCDA, saying rain, wind and lightning, asked people to leave the place in case of "the walls' inclination and cracks". However, it did not mention landslides yet. At this moment, there were already dead and missing people buried alive.

Note that this tragedy occurred during the Carnival season, one of the busiest times for tourism in Brazil. This lack of communication may have happened by chance, or the announcement may have been made out of consideration for the risk of keeping tourists away from the city during the carnival season. In any case, the above-mentioned lack of information transmission increased the damage. According to the announcement of the São Sebastião city hall, 500 thousand people had been expected for the four days of the Carnival. Then the heaviest rainfall in history hit the north coast of Sao Paulo over the Carnival weekend. Therefore, many tourists who were not familiar with the local geography died in this tragedy.

Thousands of tourists went down to the beaches to enjoy the Carnival in the north coast. Only in São Sebastião municipality with less than 100 thousand inhabitants, there were almost 500 thousand people on Saturday. The SCDA did nothing to prevent or at least discourage this. City halls on the north coast did nothing, either. The radios, televisions and internet did not advise against moving this huge population towards the point where the flash flood and debris flow would occur. In fact, the alert was given, but nobody was interested. No one recognized the seriousness of the matter. Furthermore, it should be noted that nobody knew what to do after the alert. This is due to the lack of training each citizen.

Because of these disasters, on Sunday several municipalities canceled festivities that were planned and the rains kept tourists away from the beaches. However, landslide deposits on roads made it difficult for tourists to leave the north coast. This situation further increased the disaster magnitude.

If this historic downpour had occurred outside of the carnival season, the disaster might not have been so severe.

4.3. Remarkable and deep-rooted social problems in historical background

One of the major and most serious problems in Brazil is the irregular and illegal land-occupation of hazard areas. This problem requires the analyses of different factors, including the vulnerability of several types associated with the populations that occupy these spaces.

The area most affected by the disaster is the Vila do Sahy village which is typical of such land-occupations. This village emerged in the 1980s as an occupation by needy immigrants from the Brazilian Northeast region seeking job opportunities. The houses in Vila do Sahy are simple and located close to very steep slopes (Figure 8). Residents work mainly in condominiums, luxury houses, and high-end hotels in the region. The occupation is irregular because it is located within an environmental protection area. This village is a "frozen" area, i.e., where new land-occupations are prohibited. The freezing took place in 2009. However, expansion of the area (village) continues even today.



Figure 8 – Very simple houses destroyed by landslide in Vila do Sahy village, São Sebastião municipality in February 2023 (Source: Rovena Rosa/Agência Brasil)

Schmidt (2023) reported that the City Hall of São Sebastião has received at least four warnings about the risks of landslides and floods in the municipality since 2013. The first warning came in 2013 when the State University of Campinas (UNICAMP) investigated the expansion of risk areas in the São Sebastião municipality and detailed the landslides hazard areas.

The second took place in 2018 when the Institute of Technological Research (*Instituto de Pesquisas Tecnológicas* – IPT) conducted a survey and pointed out 52 areas that were at risk of landslides in São Sebastião. Their report showed that in São Sebastião there were 161 houses in areas of high risk for landslides and 2,043 houses in areas of medium or low risk for landslides. The mayor of São Sebastião commented: “People do not leave these areas, and stay. Talking is easy. When we start the demolition program, the popular commotion is enormous, the pressure is violent” (UOL, 2023). This mayor’s comment clearly implies that the whole society with each resident’s force has been increasing its vulnerability.

The third was associated to an inspection by the State Public Ministry of São Paulo which conducted on November 11th, 2020, evaluated a plan of the São Sebastião municipality to urbanize and legalize the situation of properties in the area, and identified works and areas at risk of landslides in Vila do Sahy. Then, the Public Prosecutor's Office filed a lawsuit against the City Hall to demand measures. In this way, the City Hall should fulfill its duty to urbanize several villages, to legalize the situation of the properties, and to increase the security of the properties, especially in Vila do Sahy. However, its actions are much smaller than what they are charged with. For example, the City Hall adopted measures to minimize risks to the population regarding possible floods; meanwhile, the biggest problem in hazard areas is surely landslides (Figure 9). In 2020, the State Public Ministry concluded that Vila do Sahy village would be an announced “true tragedy” (Schmidt, 2023).



Figure 9 –Landslides in Vila do Sahy village, São Sebastião municipality in February 2023 (Source: Tiago Queiroz/Estadão Conteúdo)

Finally, as the fourth warning, in 2022, the Housing and Urban Development Company of the State of São Paulo (*Companhia de Desenvolvimento Habitacional e Urbano do Estado de São Paulo* – CDHU) suggested that families occupying Vila do Sahy should be relocated to a neighboring area which is out of the landslides hazard areas.

It seems that there are problems not only on the administration's side, but also on the residents' side. In other words, disasters have become a more serious social problem in the study region, because disaster education has not been disseminated in both sides.

5. Final remarks

Many scientists have linked this historic rainfall event to climate change. While effect of climate change may be clear and undeniable, its consequence, i.e. disaster especially with 65 deaths could have resulted from mismanagement in society. In the north coast region of São Paulo, occupation of the steep hillside practically began due to the regional geography where there are very few flat and safe areas. In the case of São Sebastião, with the growth of residential subdivision and developments aimed at tourists, people, especially the less wealthy, are being expelled to more fragile places, with less infrastructure and larger steepness.

Any disasters have various causes. The larger the disasters' magnitude, the more complex the combination of causes that can occur. This unexpected combination makes it difficult to prevent larger disasters. In the tragedy of the north coast of São Paulo in 2023, such a combination could be: unstable local geology + increasingly frequent heavy rains + ignoring weather and civil defense warnings + lack of urban planning + inability to provide security to communities that have historically been displaced to unsafe areas. Thus this combination indicates urgent necessity to carry out huge quantity of actions for the Disaster Risk Reduction (DRR).

Since January 2019, 35% of Brazilian municipalities have faced emergency situations or public calamities due to storms, landslides, flash floods or floods (Unterstell and Margulis, 2023). This current situation naturally improve DRR at the nation's level. Indeed, the CEMANDEN has been showing its better execution in terms of institutional action (alert system performance in the country). This must result from a lot of experiences due to the frequent occurrences of disasters and their warnings' actions.

On the other hand, state and local governments have not practiced as often as CEMADEN in recent years. According to Unterstell and Margulis (2023), today, a gap exists in the inability to link state-of-the-art information generated by centers of excellence related to climate and disaster risk issues such as CEMADEN to actual action by state and local governments. These states and local governments often lack real-world experience and are unable to act appropriately in an emergency. This strongly underlines the urgent need for simulated behavioral training and risk management awareness rising at the local and state government level.

Similar to the tragedy of Petrópolis municipality in Rio de Janeiro state in 2022 (Kobiyama, 2022), many people did not know where to go at the moment of emergency in the north coast of São Paulo in 2023. Precisely for this reason, it is necessary to have regular awareness and training for residents.

Considering all of the above, it seems that there is no solution other than persistently continuing disaster education for the general public as well as state and local governments.

References

- Carvalho, C.S.; Galvão, T. (2016) Prevenção de riscos de deslizamentos em encostas em áreas urbanas. In: Moraes, M.P.; Krause, C.; Lima Neto, V.C. (eds.) **Caracterização e tipologia de assentamentos precários : estudos de caso brasileiros**. Brasília: IPEA, p.169-185.
- Casemiro, P.; Matos, T. (2023) **Governo de SP e Prefeitura de São Sebastião foram avisados de risco de desastre 2 dias antes, diz diretor de órgão nacional de monitoramento**. In: G1 São Paulo. São Paulo, 22 Feb. 2023. Available in <https://g1.globo.com/sp/sao-paulo/noticia/2023/02/22/governo-de-sp-e-prefeitura-de-sao-sebastiao-foram-avisados-de-risco-de-desastre-2-dias-antes-diz-diretor-de-orgao-nacional-de-monitoramento.ghtml> Access on April 1, 2023.
- Kobiyama, M. (2022) Unusual rainfall intensity and total amount causing more than 200 deaths in Petrópolis City, Rio de Janeiro State, Brazil, in February 2022. **GADRI Actions**, v.17, n.1, p.15-20.
- Kobiyama, M.; Michel, G.P.; Goerl, R.F. (2019) Proposal of debris flow disasters management in Brazil based on historical and legal aspects. **International Journal of Erosion Control Engineering**, v.11, n.3, p.85-93.
- Schmidt, T. (2023) **Em 10 anos, São Sebastião recebeu ao menos 4 alertas sobre risco de tragédia**. In: Brasil de Fato. São Paulo, 26 Feb. 2023. Available in <https://www.brasildefato.com.br/2023/02/26/em-10-anos-sao-sebastiao-recebeu-ao-menos-4-alertas-sobre-risco-de-tragedia> Access on April 1, 2023.
- Souza, S.O.; Oliveira, R.C.; Lupinacci, C.M. (2018) Mapeamento da declividade enquanto instrumento de planejamento do litoral norte paulista. In: **Proceedings** of XII National Symposium of Geomorphology (Crato, 2018). Available in <https://www.sinageo.org.br/2018/trabalhos/9/9-5-546.html> Access on March 1, 2023.

Unterstell, N.; Margulis, S. (2023) **A tragédia de São Sebastião é um ultimato.** In: Outras Palavras. Piauí, 27 Feb. 2023. Available in <https://outraspalavras.net/outrasmidias/a-tragedia-de-sao-sebastiao-e-um-ultimato/> Access on April 1, 2023.

UOL (2023) **Governo de SP e Prefeitura de São Sebastião foram avisados de risco de desastre 2 dias antes, diz diretor de órgão nacional de monitoramento.** In: UOL. São Paulo, 24 Feb. 2023. Available in <https://noticias.uol.com.br/cotidiano/ultimas-noticias/2023/02/24/o-que-poderia-ter-sido-feito-evitado-tragedia-litoral-sp.htm> Access on April 1, 2023.

Xavier, C. (2023) **Governos de SP e São Sebastião ignoram alertas de desastre.** In: Vermelho. Brasília, 22 Feb. 2023. Available in <https://vermelho.org.br/2023/02/22/governos-de-sp-e-sao-sebastiao-ignoram-alertas-de-desastre-2-dias-antes/> Access on April 1, 2023.