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MAPPING OF RISKS AND DANGERS OF MASS MOVEMENTS IN HILLS OF THECITY OF RECIFE, PERNAMBUCO, BRAZIL

[1]Eduardo Antonio Maia Lins, [2]Edwagner Silva de Oliveira, [3]Pedro Eugenio Silva de Oliveira and [4]Joaquim Teodoro Romão de Oliveira

[1]Civil Engineer, Master and Doctor in Civil Engineering, Professor at the Federal Institute of Pernambuco and Catholic University of Pernambuco, Recife - PE, Brazil; [2]Chemical Engineer, graduated from the Catholic Universityof Pernambuco, Recife - PE, Brazil; [3]Civil Engineer, Master's in CIVIL Engineering, Professor at the Catholic University of Pernambuco, Recife - PE, Brazil; [4]Civil Engineer, Master and Doctor in Civil Engineering, Professor at the Catholic University of Pernambuco, Recife - PE, Brazil

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****Corresponding author:***
Eduardo Antonio Maia Lins

ABSTRACT

Landslides are among the most common natural disasters in mountainous areas, where they are enhanced by inadequate occupation of these areas, especially by the poorest people, who are unaware of the basic and safe concepts for housing construction. In the city of Recife, capital of Pernambuco, Brazil, these accidents occur more intensely during periods of rain, causing socioeconomic and environmental damage. The present study aimed to analyze and map the degree of risk and danger in two hills located in the city of Recife. For risk analysis, the qualitative method proposed by Gusmão Filho et al. (1992), while for the risk analysis the semi-qualitative method developed by Faria (2011) was used. From these results, thematic maps of these areas were generated, concluding that the studied areas present a considerable degree of risk and danger, requiring effective mitigating actions.

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INTRODUCTION

According to Monteiro and Veras (2017), in Brazil, in recent years, there has been a significant increase in the occupation of areas inappropriate for the occupation and establishment of housing, especially for low-income people, due to the low cost of these areas. Unfortunately, these people, who in the great majority are more needy, have not received more effective attention from the government, with regard to the use and occupation of land in an appropriate and safe way, since these areas have a great risk of slipping. These landslides occur every year and across the country, causing social, environmental, and economic damage. The risk areas tend to have great declivity, height, and extension, in addition to the presence of soils from the Barreiras Formation, which are characterized by a high susceptibility In addition, there are few areas that have an efficient mitigation work in the region. For Pfaltzgraff (2007) under the geological aspect, the Metropolitan Region of Recife (RMR) has, in its large percentage, two types of geological units: the plains and the hills. The plains, due to their low slope, do not participate as much in the landslide processes, however, the hills because they have high heights and declivities, are the major percussion of the landslides. Therefore, it is of great importance to adopt an efficient risk and hazard prevention and management policy, to reduce geotechnical accidents. There are many methods used to assess and determine the degree of risk and danger in an area. Such methods are characterized by presenting only a qualitative view, due to the type of analysis used. In this work, we used the qualitative method proposed by Gusmão Filho et al. (2012), a qualitative method, which takes into as: the topographic; geological and Environmental, where each factor presented is correlated with its attributes. To reduce the subjectivity existing in these qualitative methods, Faria (2011) proposed using the AHP (Hierarchical Analysis Process). This tool aims to assist in decision making, giving a qualitative character. This model assists in decision-making, as it favors a comprehensive and rational procedure to model problems involving subjective judgments, as well as the valuation and hierarchization of factors through the evaluation of a set of criteria explained by relative weights. Due to the large number of slopes, occupied or not, the need arises to assess the richness / dangers of landslides, especially in areas where recent accidents have already occurred. Through this work it is expected to evaluate, in a qualitative way the current risk and semi-qualitative the degree of danger of two areas located in the city of Recife, Pernambuco, Brazil. This study had as main objective the evaluation and elaboration of a mapping of risk and danger in the occurrence of landslides on two slopes located in the capital of Pernambuco, Brazil.

MATERIALS AND METHODS

Risk areas are areas prone to physical geological-geotechnical and hydraulic events, which can lead to loss of life and / or economic losses. Usually these places are houses located at the bottom of valleys that are subject to flooding and undermining, or are located on slopes with high slopes, which can present landslides and / or landslides (Cunha Filho, 2012).

Study Area: The selected areas are in the city of Recife, state of Pernambuco, Brazil (Figure 1). Two slopes were chosen, one located in the district of Bomba do Hemetério and the other slope located in the district Alto José Bonifácio for presenting the ideal conditions for applying the methods, as well as for having recently suffered landslides. Field visits were carried out over a week in May 2019.

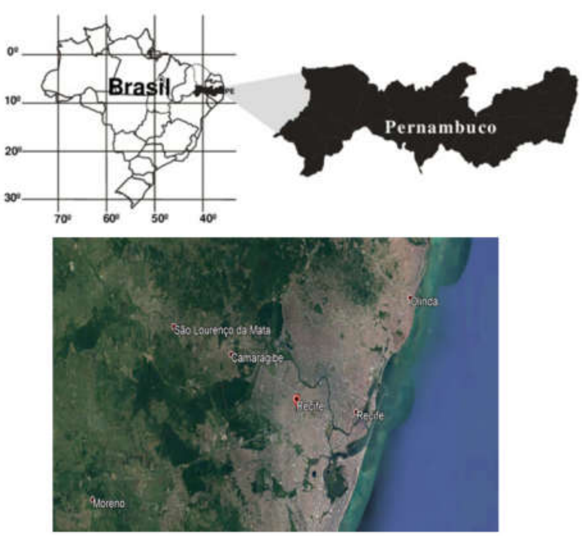

Figure 1. Location of the city of Recife. Source: Google Earth (2020)

With the use of Geoprocessing software Qgis (2019) and Google Maps (2019), the sections that will serve as a study

mentioned above, some data for the evaluated slopes were obtained and generated. QGIS is a program that operates in a GIS environment. The GIS is a system of both hardware and software, spatial information, computational procedures, and human resources, designed to capture, store, manipulate, and present all types of geographic data (Sherman, 2008).

District: Bomba do Hemetério: Located in the city of Recife, the neighborhood belongs to Microregion 2.2 of RPA 2. It has a population of 8,472 inhabitants and 2350 inhabited households spread over an area of 43 ha (hectares) according to the Demographic Census carried out in 2010 (IBGE, 2010). Figure 2 shows the boundary points for later definition of the chosen sectors. These points were obtained using the program GIS and later introduced into the program Google Maps.

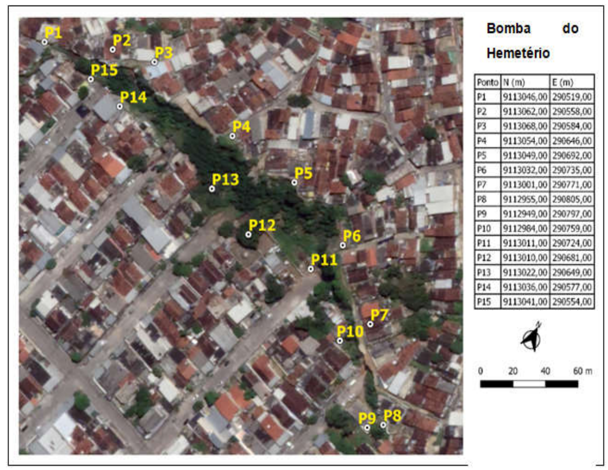

Fig. 2. Hillside belonging to the district of Bomba do Hemetério. Source: The authors (2020).

The sectors were delimited as follows:

Sector A1: P1, P2 and P15.
Sector B1: P2, P3, P14 and P15.
Sector C1: P3, P4, P13 and P14.
Sector D1: P4, P5, P12 and P13.
Sector E1: P5, P6, P11 and P12.
Sector F1: P6, P7, P10 and P11.
Sector G1: P7, P8, P9 and P10.

District: Alto José Bonifácio: Located in the city of Recife, the neighborhood belongs to microregion 3.2 of RPA 3. It has a population of 12,462 inhabitants and 3,570 inhabitants distributed over an area of 57 ha (hectares) according to the Demographic Census carried out in 2010 (IBGE, 2010). Figure 3 shows the bounding points for later definition of the chosen sections, these points were obtained using the programs GIS and Google Maps.

The sections were delimited as follows:

Sector A2: P1, P2 and P14.
Sector B2: P2, P3, P13 and P14.
Sector C2: P3, P4, P12 and P13.
Sector D2: P4, P5, P11 and P12.
Sector E2: P5, P6, P7, P10 and P11.
Sector F2: P7, P8, P9 and P10.

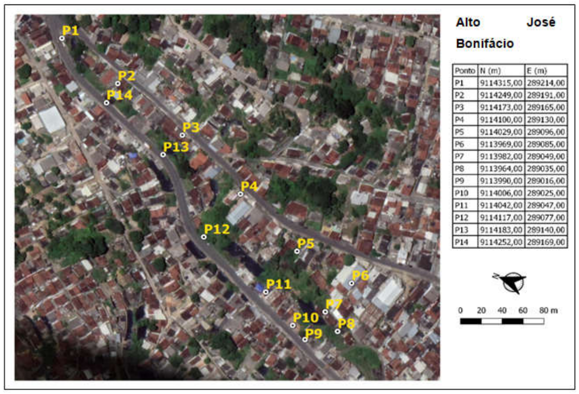

Figure 3. Hillside belonging to the district of Alto José Bonifácio. Source: The authors (2020).

Characterization of Study Areas

This section presents the characteristics of the study areas.

Height and extent of sectors: The heights were obtained using the level curves that are available in Recife (2019). Such level curves have an equidistance of 1 (one) meter, and through them the subtraction was carried out between the dimensions of the previously defined points, according to example 1.

Example 1:

Slope 1: Height of sector B1 is equal to the P2 point coordinate minus the P15 point coordinate (quota.P2 - quota.P15), and the P3 point coordinate minus the P14 point coordinate (quota.P3 - quota.P14) , and so on for the other sectors on both slopes. The L1 and L2 extensions of the sectors were obtained using the Pythagorean Theorem, presented in the equation 1, using the coordinates of the points as data. L1 represents the extension at the top and L2 represents the extension at the bottom of the slopes. These values are approximate to the reals. The information obtained is shown in Tables 1 and 2.

$$Dab = \sqrt{(Na - Nb)^2 + (Ea - Eb)^2} \qquad \text{Eq. (1)}$$

Declivity: To calculate the decline, the mean height of the sectors (Hm) was used, as well as the average horizontal length between the points of the sectors (Lm). The mean height (Hm) was used by the arithmetic mean of two heights that make up each sector. The average length (Lm) was also achieved by the arithmetic mean of the two components that make up each sector. In possession of this information, a trigonometric relationship was used. To facilitate understanding, compile the data for each section in Tables 3 and 4. It is important to emphasize, again, what data are shown in the approximate data of the actual values.

Morphology and Profile of the Sectors: This item will address the slope morphology both in profile and in plan. Such characteristics were described in Charts 1 and 2 and obtained from field visits and using the Google Earth. For each sector it was analyzed individually, observing its characteristics.

Lithology: The geological and soil maps of the areas under study were prepared using GIS and data acquired from CPRM (2019) was used.

Vegetation, drainage, cuts, and landfills: Charts 03 and 04, present the conditions of the slopes regarding the presence of vegetation, drainage, cuts, and treatments, and were obtained by visiting the field and using the Google Earth.

Analysis of Slope Risk and Danger Situations: Geological and geomorphological factors, physical causes related to water, tropic action and vegetation cover are factors considered fundamental for the stability of the slopes (Mantovani, 2016). The most notable features are the presence of soils from the Barreiras Formation, the high slopes, and the great heights and extensions of the slopes. These aspects, added to the high rainfall and human actions, provoke the countless cases of landslides observed every year in the city of Recife. Therefore, human actions represent a major destabilizing agent on the slopes. According to Coutinho and Silva (2006), the main mechanisms of performance of waters in triggering mass movements, are: reduction of cohesion apparent, variation of the piezometric level in homogeneous masses, rapid lowering of the level water (reservoirs), dynamic loading, elevation of the water column in discontinuities and retrograde underground erosion (“pipping”). The vegetation plays a major role in the dynamics of the slopes as shown in Figure 4. Both slopes showed a very variable density, ranging from small shrubs to large trees. Gray and Laiser (1982) highlight that vegetation can have a leverage effect, which corresponds to the shear force transferred by tree trunks to the ground when the canopy is reached by the wind; can also cause a wedge effect that corresponds to the lateral pressure caused by the roots when penetrating cracks, fissures and channels in the soil or rock; and can assist in movements due to vertical overload, caused by the weight of the trees, acting mainly when there are dense forests and instability processes with surface shallow rupture. This overload may have a beneficial effect or not on stability, depending on slope and soil characteristics (Wolle, 1980).

The cuts made on the slopes represent a major problem, as they were carried out inappropriately, compromising their stability. On the slope located in the Bomba do Hemetério neighborhood, none of the sectors has cuts capable of compromising stability. However, on the slope belonging to Alto José Bonifácio, all sectors show cuts, ranging from isolated cuts to disordered cuts. Although mass gravitational movements are part of the natural dynamics of areas with steep slopes, the action of man through its varied forms of use and occupation of the soil, interferes in the natural evolution of these processes, sometimes inducing, sometimes reducing its effects (Araújo, 2004). As for the buildings, they are present on both slopes. On the chosen slopes, the buildings are located at the top and at the foot of the slopes, increasing the overhead on the slopes causing an increase in their instability. Inadequate buildings cause other adverse situations. In some sectors, the lack of an adequate and / or efficient drainage system was observed, in addition to the discharge of wastewater directly on the slopes, and the presence of black pits and sinks. The absence of an efficient management of these waters, rain and / or sewage, reduces the stability of the slope, as it causes erosions and

Another very undesirable situation is the deposit of garbage and debris on the slope, especially on the slope located in the district of Bomba do Hemetério. These materials are heterogeneous, lack cohesion, retain water, and overload the slopes, generating numerous points of instability, being a trigger in the occurrence of landslides. The instability features are the major indicators of the occurrence of land instability processes. The main ones observed were posts and / or inclined trees; cracks and / or cracks in the structures and / or the surface; recent landslides. For the risk analysis of the chosen slopes, the method proposed by Gusmão et al. (2012) was used. This method is characterized by being a form of qualitative analysis, as previously mentioned. To facilitate the study, a follow-up form was applied to the field visit. It presents the risk factors, as well as their attributes. In possession of the values obtained for each sector of the slopes and using Excel, the calculation of the arithmetic mean was made for each attribute, and then for each factor Important to note that the weights proposed by Alheiros (1998) were not used to obtain the final risk degree sectors.

For the risk analysis of the chosen slopes, the method proposed byGusmão et al. (2012) was used. This method is characterized by being a form of qualitative analysis, as previously mentioned. To facilitate the study, a follow-up form was applied to the field visit. It presents the risk factors, as well as their attributes. In possession of the values obtained for each sector of the slopes and using Excel, the calculation of the arithmetic mean was made for each attribute, and then for each factor Important to note that the weights proposed by Alheiros (1998) were not used to obtain the final risk degree sectors. The Hazard assessment for the chosen slopes was made using the method proposed by Faria (2011) which is based on the Hierarchical Analysis Process Method (AHP). The plasticity indexes (PI) of each sector of the slopes were obtained using the slip hazard analysis worksheet and their respective tables also prepared by the author.

RESULTS AND DISCUSSION

In this item, the results obtained over the studies carried out using the methods of Gusmão Filho et al. (2012) and Faria (2011) are presented. Comparisons between the results obtained by the two methods are also presented.

Classification of Slope Risk Grade Using the Method Proposed by Gusmão Filho et al. (2012): In this section, the results obtained by the method proposed by Gusmão Filho et al. (2012) are presented. The results presented in Table 5, refer to the slope belonging to the district of Bomba do Hemetério. The sectors chosen had slightly different degrees of risk. It is possible to observe that 28.57% had a very high-risk level and 71.43% of the slope had a high-risk level. And for the whole slope, the degree of risk obtained was high. As for the slope present in the District of Alto José Bonifácio, the following degrees of risk were obtained, the results are shown in Table 6. It is possible to notice that 33.34% of the slope had a very high-risk level, 50% of the slope had a high-risk level, and 16.66% of the slope had a medium risk level. And for the whole slope, the degree of risk obtained was high.

Classification of the Slope Risk Level Using the Method Proposed by Faria (2011): Using the method developed by Faria (2011), the slopes studied presented different degrees of danger. For the slope located in the district of Bomba do Hemetério, the results obtained are described in Chart 5 and the classification criteria are shown in Table 6. Observing the results obtained in Table 8, it is possible to observe that 42.85% of the area presented a Very High degree of danger; 14.30% of the studied area had a high degree of danger; 42.85% of the area had a low degree of danger. Analyzing the slope, the degree of danger obtained was Very High. The results obtained for the slope located in the district of Alto José Bonifácio are shown in Table 7, and the classification parameters in Table 8. Looking at Chart 6, it is possible to notice that 33.33% of the slope presented a very high degree of danger; 16.67% of the slope had a high degree of danger; 33.33% of the slope had a medium degree of danger and 16.67% of the area had a low degree of danger. And for all areas, the degree of danger obtained was extremely high. It is important to note that for this method the presence of instabilities is an important indicator, therefore, some of the sectors of the slopes studied presented features of instabilities, as is the case of sectors: C1, D1 and E1; and D2 and F2. For this reason, some sectors had their degrees of danger changed to Very High, as shown in Table 7.

Comparison of Methods Gusmão Filho et al. (2012) and Faria (2011): For the slope number 1 (one), located in the Bomba do Hemetério, the results obtained a compatibility of 42.85%; and for the second slope, located in the Alto José Bonifácio, the compatibility achieved was 50.0% between the methods. Although these values are low, some sectors were only down one degree on the risk and danger scale. And these results were only achieved due to the method proposed by Faria (2011) considering the presence of instabilities. The results achieved by the method proposed by Gusmão Filho et al. (2012), was the one that presented a greater degree for the sectors. However, the presence of instability features is a great indicator of mass gravitational motion events, making the second method closer to reality. The maps presented in Figures 5 and 6, show the results achieved for the methods used in the analysis, as well as Charts 7 and 8. No mapping carried out by Mineral Resources Research Company (CPRM), 2019, for a susceptibility to landslides in the municipality of Recife, the values captured for embassies as variables studied of grade 1, low, and grade 2, average. Presenting a small compatibility with the method proposed by Faria (2011), in low grade areas. Figure 7 shows the susceptibility map produced by CPRM (2019). The method used to produce the map, elaborated by CPRM (2019) was not specified. However, it is possible to note that it does not take environmental factors into account. For this reason, the results presented for the chosen areas were below those obtained in this work. To Mantovani (2016), in general, among the 104 subsectors studied in Camaragibe, Pernambuco, Brazil, concentrated in the south-central portion of the municipality, 28 were classified as very high risk (27%), 62 with high risk (60%), 13 with medium risk (12%) and 1 with low risk (1%). The risk subsectors below refer to areas that have been expanded to cover all levels of risk, validating the methodology for the least critical scenarios.

FINAL CONSIDERATIONS

The results obtained using the risk assessment method proposed by Gusmão Filho et al. (2012), point out that the area located in Bomba do Hemetério 28.57% of the

Table 1. Data from the slope of Bomba do Hemetério.

District: Bomba do Hemetério				
Sector	Height	L1 (m)	L2 (m)	Average Length
A1	1,0 a 15,0 m	42,15	35,36	38,75
B1	15,0 a 20,0 m	26,68	23,54	25,11
C1	20,0 a 24,0 m	63,56	73,35	68,46
D1	24,0 a 25,0 m	46,27	34,18	40,23
E1	23,0 a 25,0 m	46,24	43,01	44,63
F1	18,0 a 23,0 m	47,51	44,20	45,86
G1	18,0 a 10,0 m	57,20	51,66	54,43

Source: The authors.

Table 2. Data from the slope of Alto José Bonifácio. Source: The authors

District: Alto José Bonifácio				
Sector	Height	L1(m)	L2 (m)	Average Length
A2	1,0 a 9,0 m	69,89	77,42	73,66
B2	9,0 a 12,0 m	80,32	74,85	77,59
C2	12,0 a 18,0 m	80,96	91,24	86,1
D2	18,0 a 23,0 m	78,72	80,78	79,75
E2	23,0 a 29,0 m	61,00	42,19	51,6
F2	16,0 a 19,0 m	22,8	18,36	20,58

Table 3. Calculation for obtaining the slope (Bomba do Hemetério)

Slope - Bomba do Hemetério						
Section	Points	L(m)	L average (m)	Height (m)	Average height (m)	D (%)
A1	P2-P15	21,38	21,38	1,0 a 15,0 m	8,0	37,4
B1	P3-P14	32,76	27,07	15,0 a 20,0 m	22,5	83,1
C1	P4-P13	32,14	32,45	20,0 a 24,0 m	22,0	67,8
D1	P5-P12	40,52	36,33	24,0 a 25,0 m	24,5	67,4
E1	P6-P11	23,71	32,11	23,0 a 25,0 m	24,0	74,7
F1	P7-P10	20,81	22,26	18,0 a 23,0 m	20,5	92,1
G1	P8-P9	10,00	15,40	18,0 a 10,0 m	14,0	90,9

Source: The authors (2020).

Table 4. Calculation to obtain the slope (Alto José Bonifácio)

Slope - Alto José Bonifácio						
Section	Points	L(m)	L average (m)	Height (m)	Average height (m)	D (%)
A2	P2-P14	22,204	22,204	1,0 a 9,0	5,00	22,5
B2	P3-P13	26,926	24,565	9,0 a 12,0	10,50	42,7
C2	P4-P12	55,660	41,293	12,0 a 18,0	15,00	36,3
D2	P5-P11	50,695	53,177	18,0 a 23,0	20,50	38,6
E2	P6-P10	70,491	60,593	23,0 a 29,0	26,00	42,9
F2	P8-P9	32,202	51,347	16,0 a 19,0	17,50	34,1

Source: The authors (2020).

Chart 1. Morphology of the Bomba do Hemetério slope

Slope - Bomba do Hemetério		
Sector	Morphology	
	Profile	Plan
A1	Convex	Line
B1	Concave - Convex	Winding
C1	Concave - Convex	Winding
D1	Concave - Convex	Winding
E1	Concave - Convex	Winding
F1	Concave - Convex	Winding
G1	Concave - Convex	Winding

Chart 2. Morphology of the Alto José Bonifácio slope.

Slope - Alto José Bonifácio		
Sector	Morphology	
	Profile	Plan
A2	Convex	Convex
B2	Convex	Line
C2	Convex	Concave
D2	Convex	Convex
E2	Concave - Convex	Concave
F2	Concave - Convex	Convex

Source: The authors (2020).

Chart 3. Environmental factors (Slope – Bomba do Hemetério).

Slope - Bomba do Hemetério				
Section	Vegetation (%)	Drainage	Terrain Cuts	Treatment Type
A1	100 a 70	Surface	Isolated	nonexistent
B1	100 a 70	Surface	Isolated	nonexistent
C1	100 a 70	Surface	Isolated	nonexistent
D1	100 a 70	nonexistent	Isolated	nonexistent
E1	100 a 70	nonexistent	Isolated	nonexistent
F1	100 a 70	Surface	Isolated	nonexistent
G1	100 a 70	Surface	Isolated	nonexistent

Source: The authors (2020).

Chart 4. Environmental factors (Slope - Alto José Bonifácio)

Slope – Alto José Bonifácio				
Section	Vegetation (%)	Drainage	Terrain Cuts	Treatment Type
A2	70 a 30	Insufficient	Isolated	nonexistent
B2	70 a 30	Surface	Disordered -	nonexistent
C2	30 a 0	Surface	Disordered +	nonexistent
D2	100 a 70	Surface	Disordered +	nonexistent
E2	30 a 0	Surface	Disordered +	nonexistent
F2	30 a 0	Surface	Disordered -	nonexistent

Source: The authors (2020).

Figure 4. Hillside located in Alto José Bonifácio, left sector D2, and the right sector E2. Source: The authors (2020).

Table 5. Final degree of risk for the slope located at the Bomba do Hemetério.

SLOPE - BOMBA DO HEMETÉRIO					
SECTOR	RISK FACTORS			DEGREE OF RISK	CLASS
	TOPOGRAPHY	GEOLOGY	ENVIRONMENTAL		
A1	2,8	3,0	3,2	3,0	High
B1	3,2	3,0	3,2	3,2	High
C1	3,2	3,0	3,2	3,2	High
D1	3,2	3,5	3,4	3,4	Very High
E1	3,2	3,5	3,4	3,4	Very High
F1	3,2	3,3	3,2	3,2	High
G1	3,0	3,0	3,2	3,1	High
SLOPE	3,1	3,2	3,3	3,2	High

Source: The Authors (2020).

Table 6. Final grade of risk for the slope located in Alto José Bonifácio

SLOPE - ALTO JOSÉ BONIFÁCIO					
SECTOR	RISK FACTORS			DEGREE OF RISK	CLASS
	TOPOGRAPHY	GEOLOGY	ENVIRONMENTAL		
A2	2,00	2,75	3,20	2,65	Average
B2	2,80	3,00	3,00	2,93	High
C2	3,00	3,25	3,40	3,22	High
D2	2,60	4,00	3,60	3,40	Very High
E2	3,20	3,75	3,80	3,58	Very High
F2	2,20	3,50	2,60	2,77	High
SLOPE	2,63	3,38	3,27	3,09	High

Source: The Authors (2020).

Chart 5. Final degree of danger for the slope located at the Bomba do Hemetério

Slope - Bomba Do Hemetério				
Sector		Danger index		
	Ip	Degree of Danger	Fections of Instability	Final degree of Danger
A1	29,95	Low	Not	Low
B1	30,55	Low	Not	Low
C1	35,44	High	Yes	Very High
D1	36,02	High	Yes	Very High
E1	36,02	High	Yes	Very High
F1	35,44	High	Not	High
G1	30,55	Low	Not	Low
SLOPE	33,42	Average	Yes	Very High

Source: The Authors (2020).

Table 6. Hazard Index for the slope located at Bomba do Hemetério

DANGER INDEX	DEGREE OF DANGER
IP < 32,084	Low
32,084 ≤ IP ≤ 34,764	Average
IP > 34,764	High
Presence of Features Instability	Very High

Source: The Authors (2020).

Chart 6. Final degree of danger for the slope located in Alto José Bonifácio

SLOPE - ALTO JOSÉ BONIFÁCIO				
SECTOR		DANGER INDEX		
	IP	DEGREE OF DANGER	FECTIONS OF INSTABILITY	FINAL DEGREE OF DANGER
A2	12,47	Low	Not	Low
B2	19,63	Average	Not	Average
C2	21,34	High	Not	High
D2	21,02	High	Yes	Very High
E2	21,34	High	Yes	Very High
F2	18,99	Average	Not	Average
SLOPE	19,13	Average	Yes	Very High

Source: The Authors (2020).

Table 7. Danger index for the slope located in Alto José Bonifácio

DANGER INDEX	DEGREE OF DANGER
IP < 17,578	Low
17,578 ≤ IP ≤ 20,688	Average
IP > 20,688	High
Presence of Features Instability	Very High

Source: The Authors (2020).

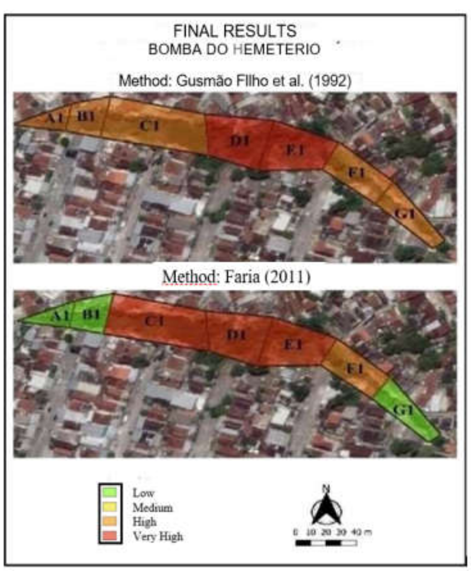

Figure 5. Results for the hillside located in the Bomba do

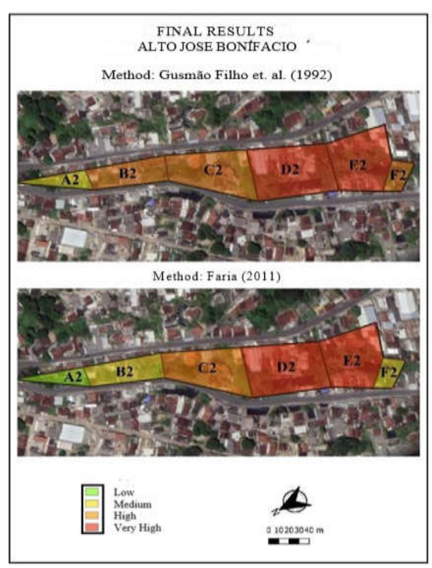

Figure 6. Results for the Hillside Located in Bairro Alto

Chart 8. Results achieved hillside located in Alto José Bonifácio

Slope – Alto J. Bonifácio		
Sector	Risk	Danger
A2	Average	Low
B2	High	Average
C2	High	High
D2	Very High	Very High
E2	Very High	Very High
F2	High	Average

Source: The Authors (2020).

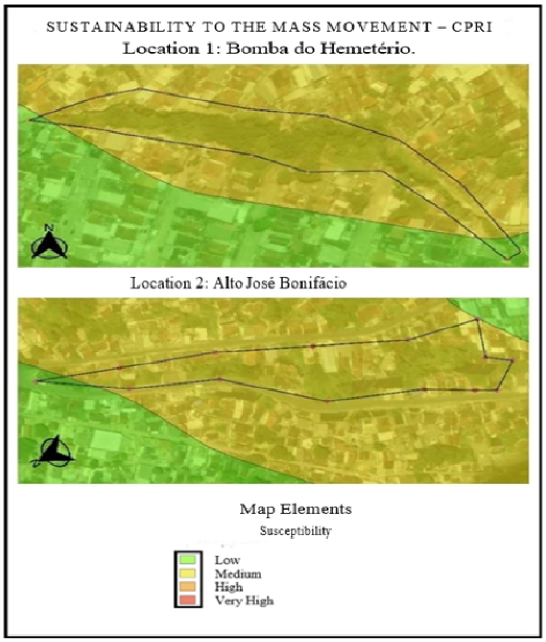

Figure 7. Susceptibility map. Source: The authors (2020)

area had a very high degree of risk and 71.43% of the area had a degree of high risk. As for the slope belonging to the Alto José Bonifácio neighborhood; 33.34% of the area had an extremely high degree of risk; 50.0% of the area had a high-risk level and 16.66% of the area had a medium risk level. Using the method proposed by Faria (2011), the area located at Bomba do Hemetério, obtained the following results: 42.85% extremely high degree of danger; 14.30% high degree of danger and 42.85% low degree of danger. For the second area, located in Alto José Bonifácio, the following results were obtained: 33.33% very high degree of danger; 16.67% high degree of danger; 33.33% of the area had a medium degree of danger and 16.67% a low degree of danger. By observing and comparing the results obtained. The results showed a compatibility of 42.85% for the slope located at Bomba do Hemetério; and 50.0% for the slope located in Alto José Bonifácio. In some sectors, there is a difference of 1 (one) degree in the scale. These results were only possible because the method proposed by Faria (2011) considers the presence of features of instabilities. When comparing these results with those obtained by CPRM (2019), it was noted that the degree of compatibility was extremely low, showing only some similarity when compared to areas that present a low degree of danger. Probably the comparative work did not use the environmental factor in the calculations. In general, the environmental factor is largely responsible for the degree of risk obtained for the slope located in the community of For the second slope located in Alto José Bonifácio, the geological factor is largely responsible for the degree of risk, followed by the environmental factor. The results obtained using the risk assessment method proposed by Gusmão Filho et al. (2012) and the hazard assessment method proposed by Faria (2011), are close to the reality observed on the slopes.

The slopes studied need treatments capable of providing adequate stability to prevent future landslides, avoiding loss of life and economic damage.

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