Analytical Hierarchy Process for Mass Moviments Susceptibility Mapping in Fernão Velho, Maceió, Northeast Brazil

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ABSTRACT

- The study was conducted using remote sensing data, field surveys, and Geographic Information System (GIS) tools, taking into account 10 primary variables: elevation, slope, land use and land cover, aspect, precipitation, soil class, lithology, density of geological faults, density of roads and buildings, and density of railway lines. The analysis and processing were carried out in conjunction with statistics, GIS, and remote sensing, which together opened up a new path in the evaluation of a large amount of geospatial data and mapping with different accuracies. The availability of various satellite data facilitated the study of baseline information on mass movements effectively and efficiently. The obtained results are cartographically spatialized, obtaining a map of zones susceptible to mass movement as a final result, in which the objective is to validate the results of the method through statistical cross-matching between zones susceptible to mass movement obtained by the AHP method and the existing mass movement data in the area provided by the municipal civil defense of Maceió. In addition, seeking a robust and reliable result, the accuracy of the model was confirmed through the Receiver Operating Characteristic (ROC) sensitivity test, aiming to create data and methods that can improve the management of the phenomenon and consequently of the risk in the study area. For the entire area in general, it was possible to accurately determine the degree of risk of mass movement in the Fernão Velho region through the model.

- **Keywords: AHP; RISK AREAS; REMOTE SENSING;**

1. INTRODUCTION

- ✓ Landslides are destructive natural phenomena that often lead to serious problems, resulting in loss of human life and property, and severe damage to nature;

- ✓ An area can be declared susceptible to mass movement if it has a slope greater than 25%, a plastic and semi-permeable lithology, or a geological structure that is more fragmented, allowing for greater water infiltration;

- ✓ Quantitative methods are based on numerical expressions of the relationship between controlling factors and recorded activities of mass movements.

- ✓ The study area, the Fernão Velho neighborhood, located on the banks of the Mundaú lagoon in the northwest sector of the city of Maceió, has historically been affected by various cracks and fissures, a situation monitored and analyzed by the Municipal Civil Defense of Maceió, which highlights a high potential for mass movements;

- ✓ The objective of this study was to produce an accurate survey of areas susceptible to mass movement. Fundamentally, this study aims to create a map of susceptibility to mass movement, using the statistical multicriteria evaluation technique previously mentioned AHP, which is a useful tool for reducing complex decisions;

1.1 DATASETS

GEOLOGICAL SURVEY OF BRAZIL - CPRM

Google Earth Engine

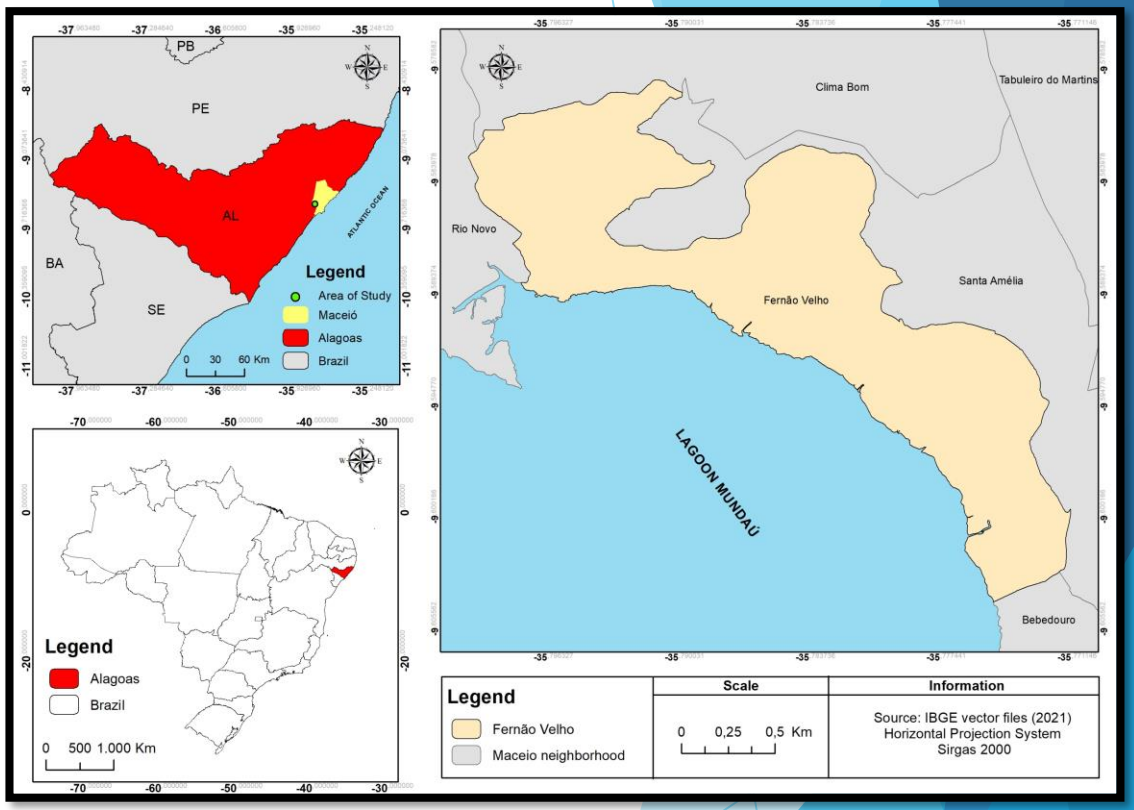
Embrapa

IBGE

DEFESA CIVIL MACEIÓ

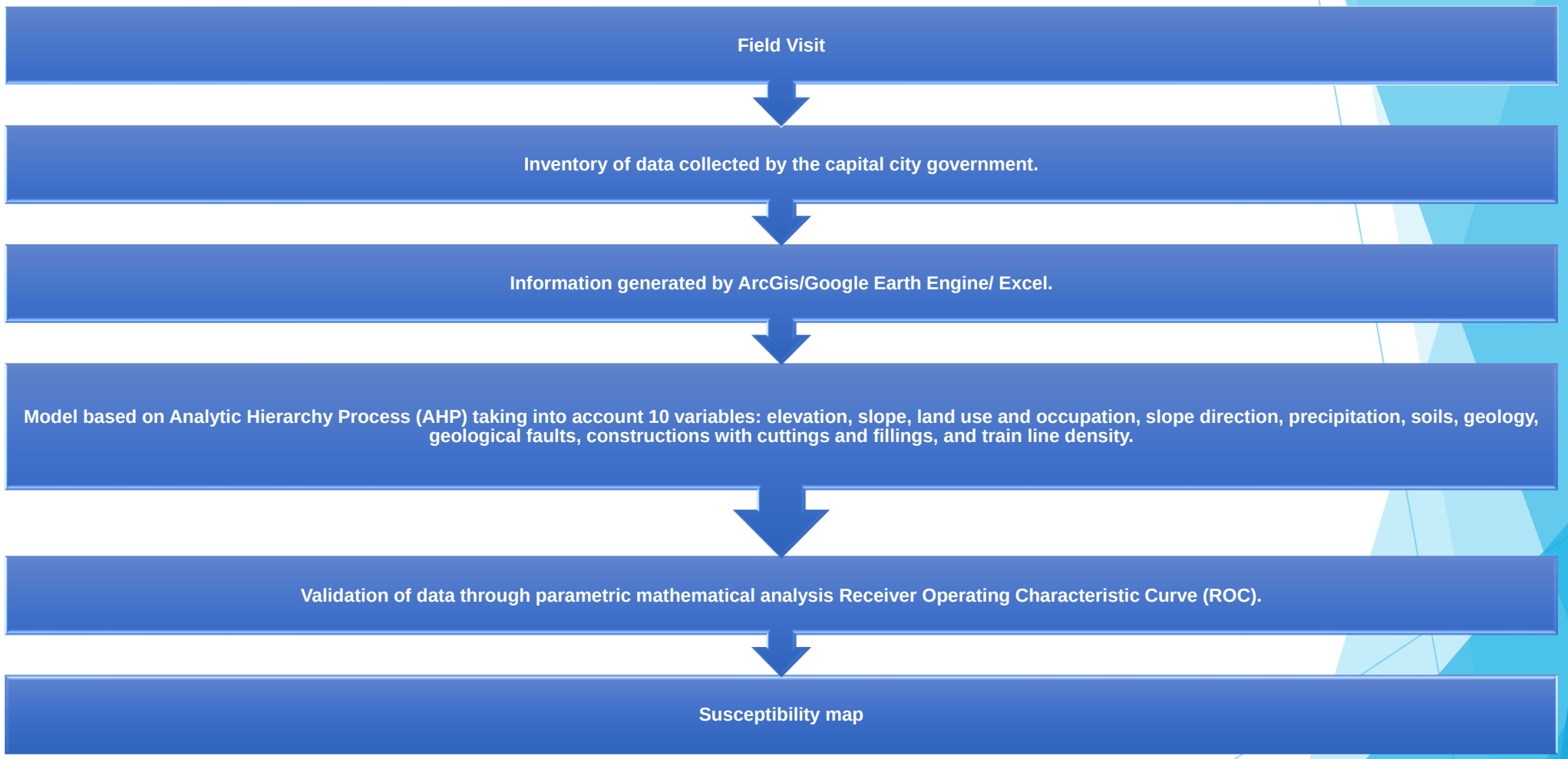
- The study was conducted in the Fernão Velho neighborhood located in the northwest sector of the city of Maceió, on the banks of the Mundaú Lagoon, bordered by remnants of Atlantic Forest to the east and the Mundaú Lagoon to the west. Its geographic coordinates are latitude -9.5892 and longitude -35.78157, occupying an area of 2.66 km² with a Cartesian perimeter of 13957.283 m and a population of 5,752 inhabitants (IBGE, 2010).
- Geologically, Fernão Velho is located in the Alagoas Sedimentary Basin, in the sub-region of the Alagoas Mata zone, and has predominantly Barreira Formation lithotypes, formed by unconsolidated sediments such as thick sand deposits, fine sand and clay layers, and is also characterized by soil classes such as Argisols and Latosols.

Localization from the study area



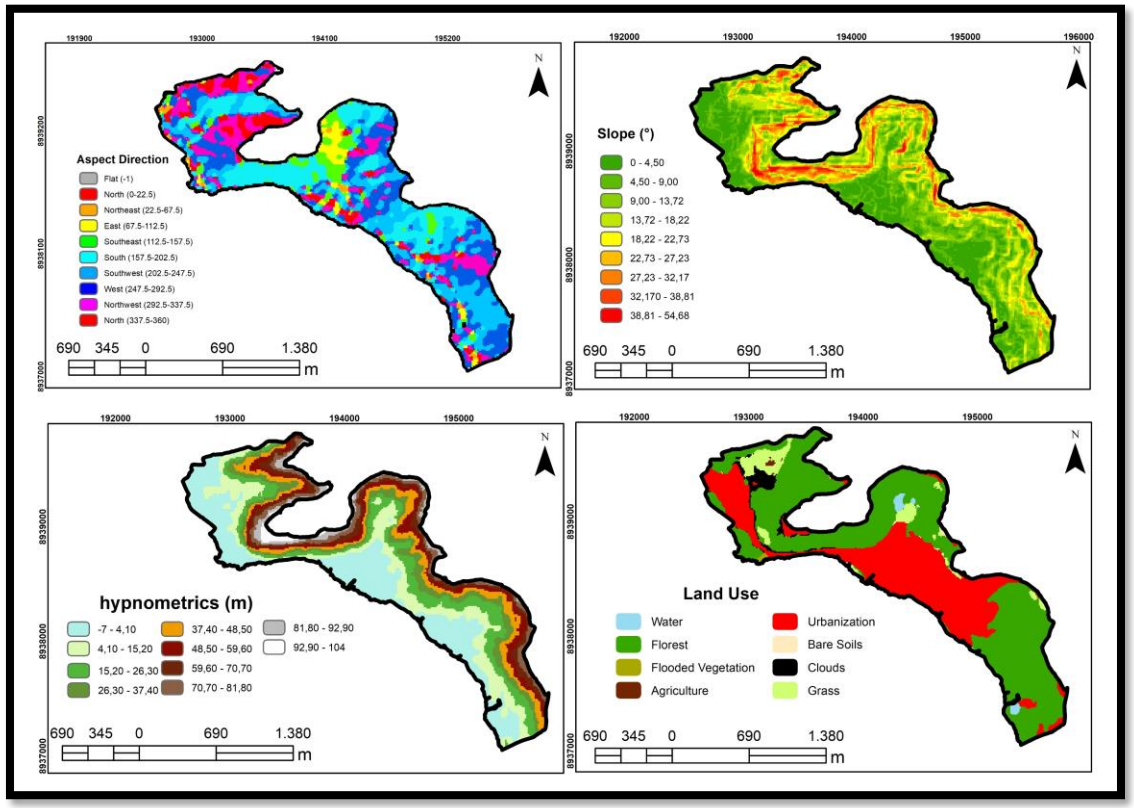
- The neighborhood is located in an area with a diversity of reliefs with slope ranging from 0° to 54°, and altitude variation from -7 - 104 meters.
- The climate of Maceió according to the Koppen As' classification is tropical rainy, with minimum temperatures above 20°C throughout the year. The neighborhood has an average annual precipitation ranging from 1200 to 2200 mm, according to the Clima bom rain gauge (number 270430215), belonging to CEMADEN, with rainfall concentration during the winter (April to September) and the hydrography of Fernão Velho is formed by the Mundaú Lagoon and small drainages that flow into the Mundaú Lagoon.

2. METHODOLOGY

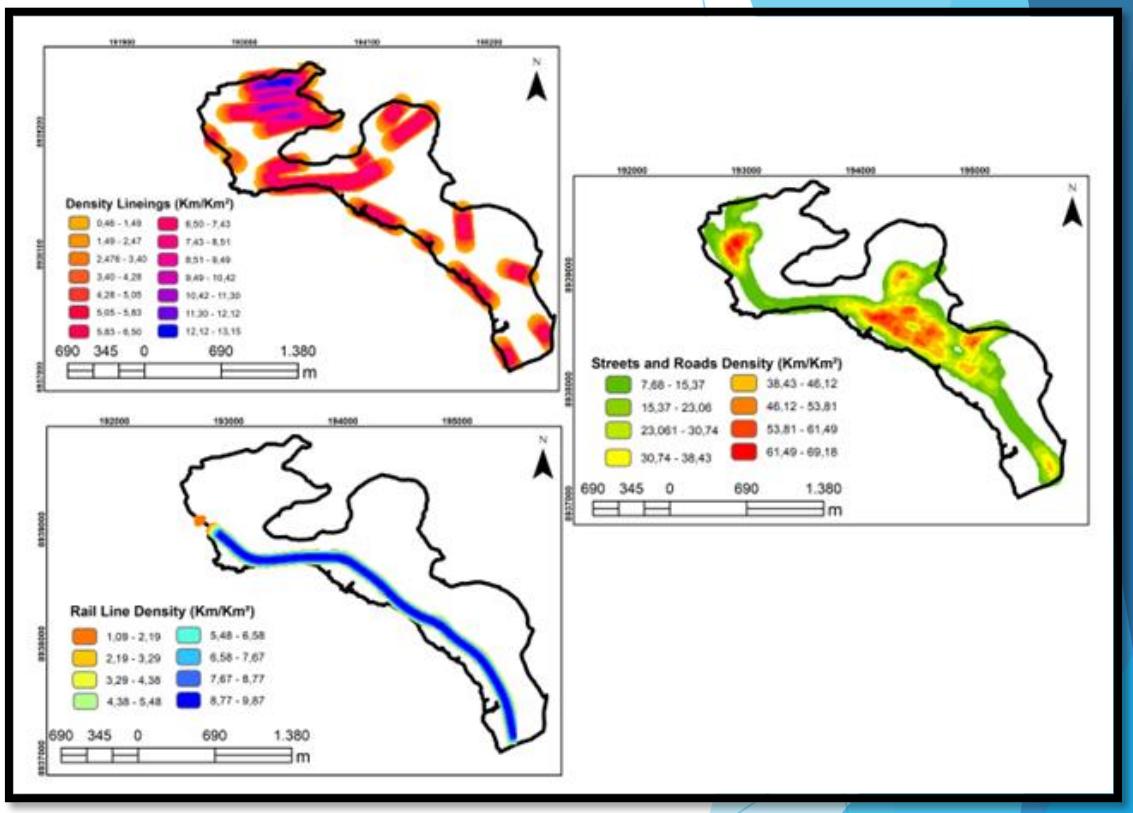


3. RESULTS

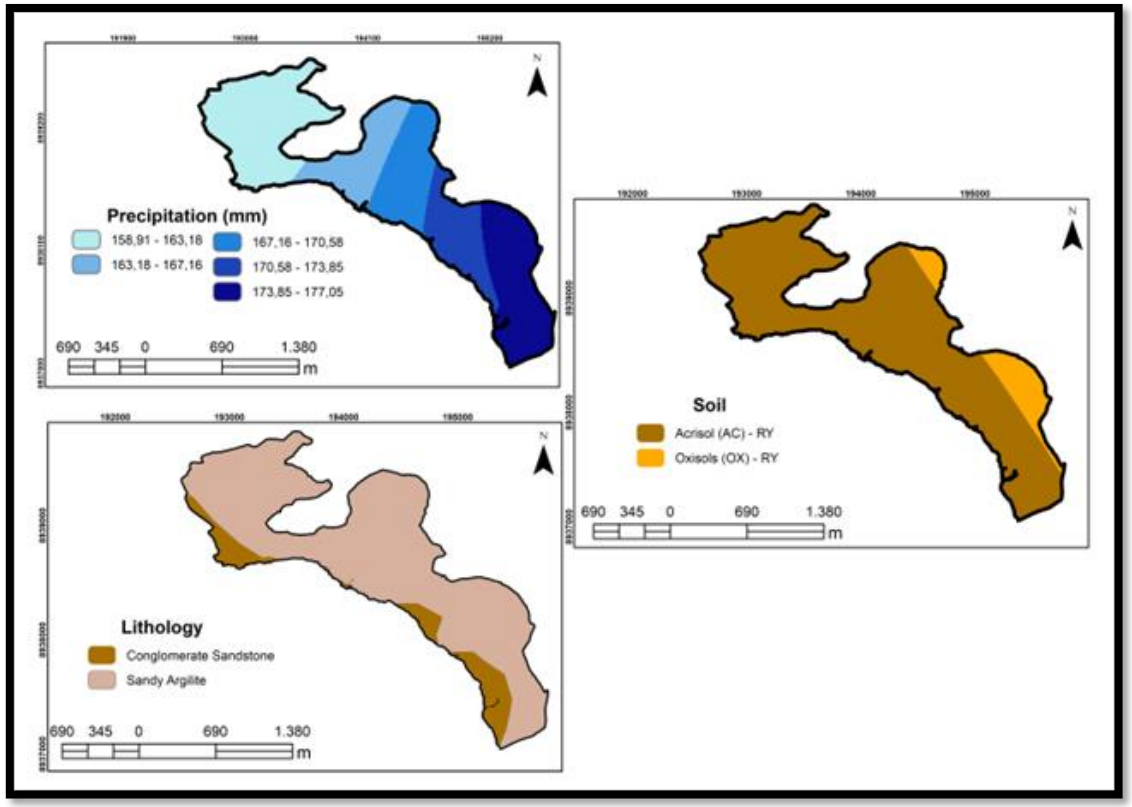
Aspect Topographical, Slope, Land Use, hypnometrics (m)



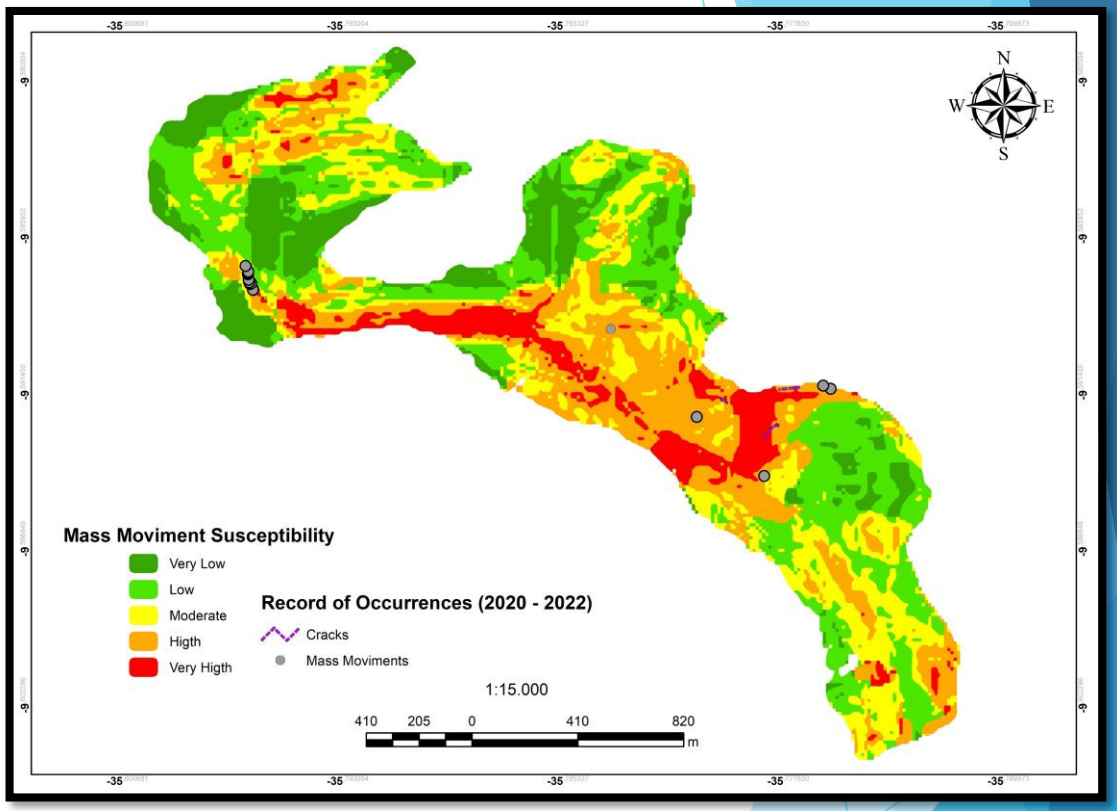
Lineament, drainage and streets and roads density



Variables Precipitation, Soil and Lithology

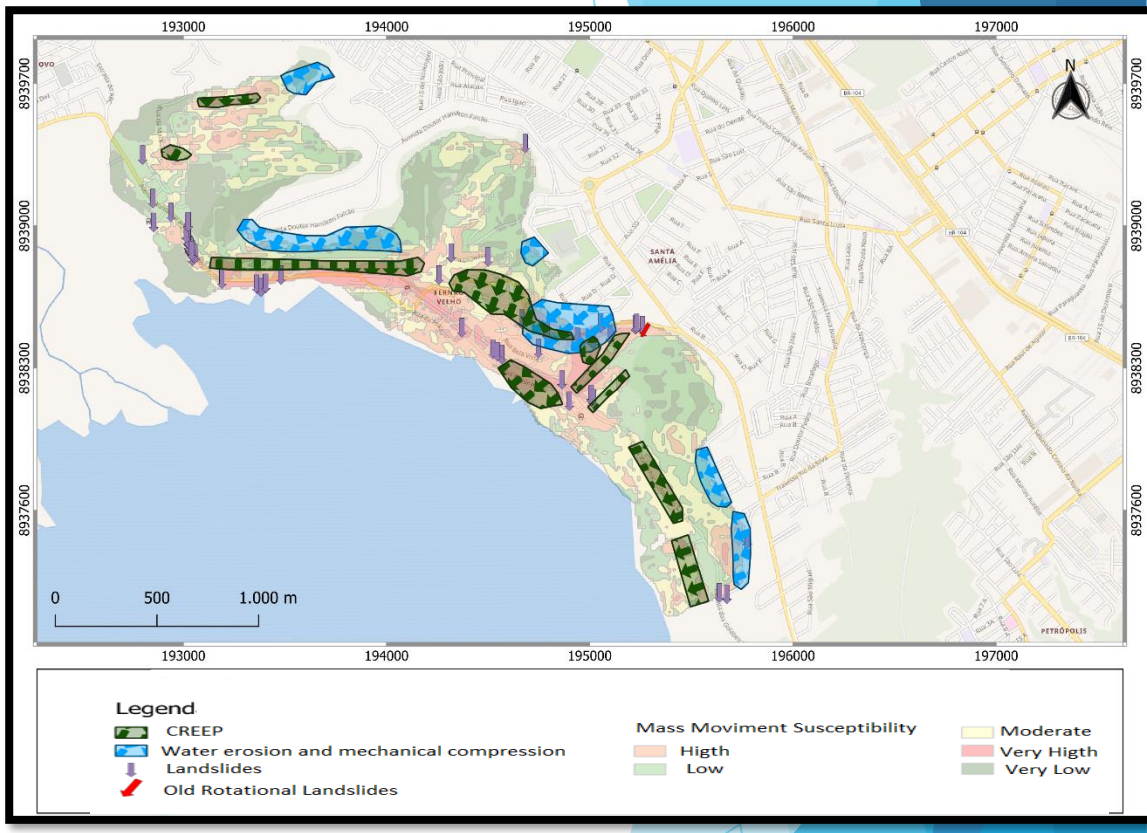


Mass movement Susceptibility



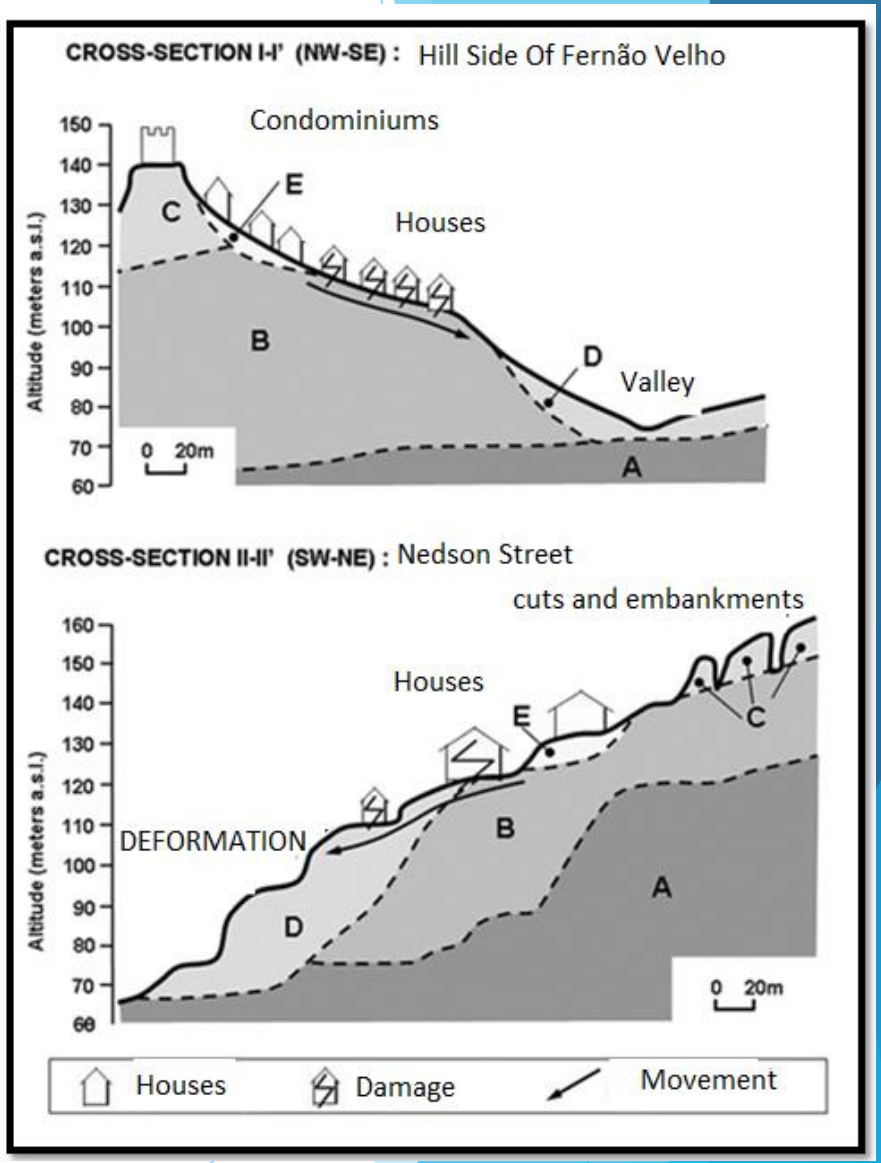
Movement in area

- The terrain instability affects the first 5 m of the zones identified as zones with very high susceptibility by the model and possibly also in zones of high susceptibility, at most. There is no historical and present evidence that the plateau, including the condominiums in Santa Amélia and surroundings, has suffered significant damage due to the instability of the slopes. However, since the slope is compressed by the condominiums, mainly the one on the main hillside, which is diagnosed as a very high-risk zone, in case of collapse, it may affect the condominium located above, namely Dela Reyna condominium, which is not part of Fernão Velho neighborhood but is situated in a high-risk zone



The evidence of instability is given by the influence of constructions in risk zones and the condominiums with drainage disposed on the slope or reuse of the neighborhood's drainage possibly being enhancers of cracks in the formation on the main slope. It is possible to perceive sand and clay, dipping 10° towards SW. The origin of the cracks can be attributed to a mechanism of planar sliding produced between the formations in zones A. The comparison of images from 2022 to 2023 shows that the distribution of the cracks has changed in this period. Therefore, this can be considered an active plane.

It is possible to understand the movement mechanism through the section on the main slope and on the section of Nedson street.

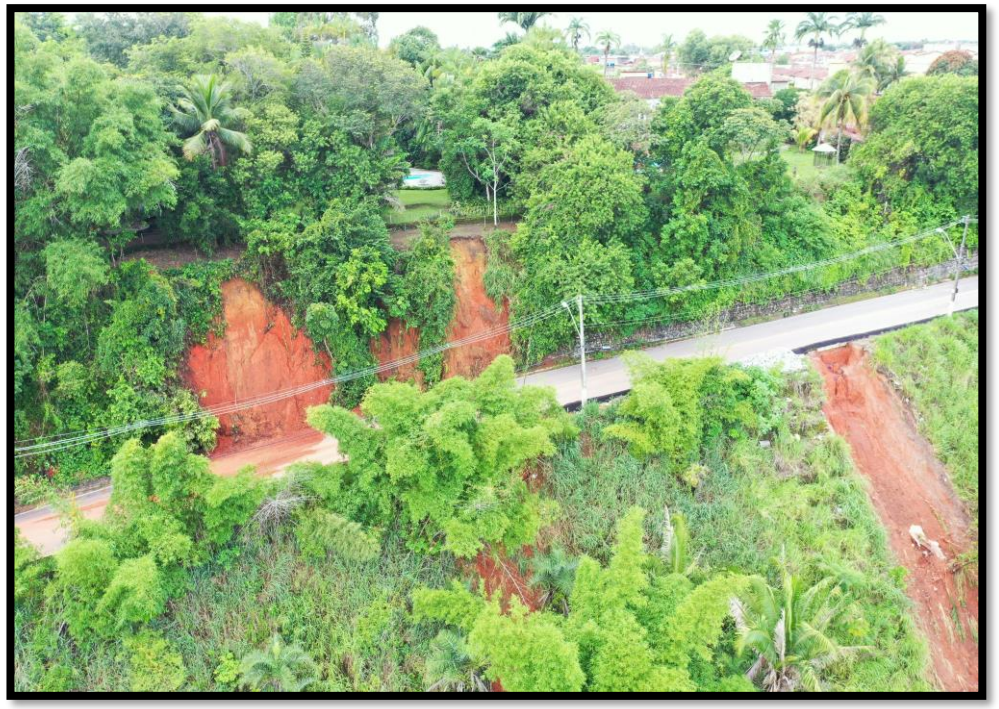


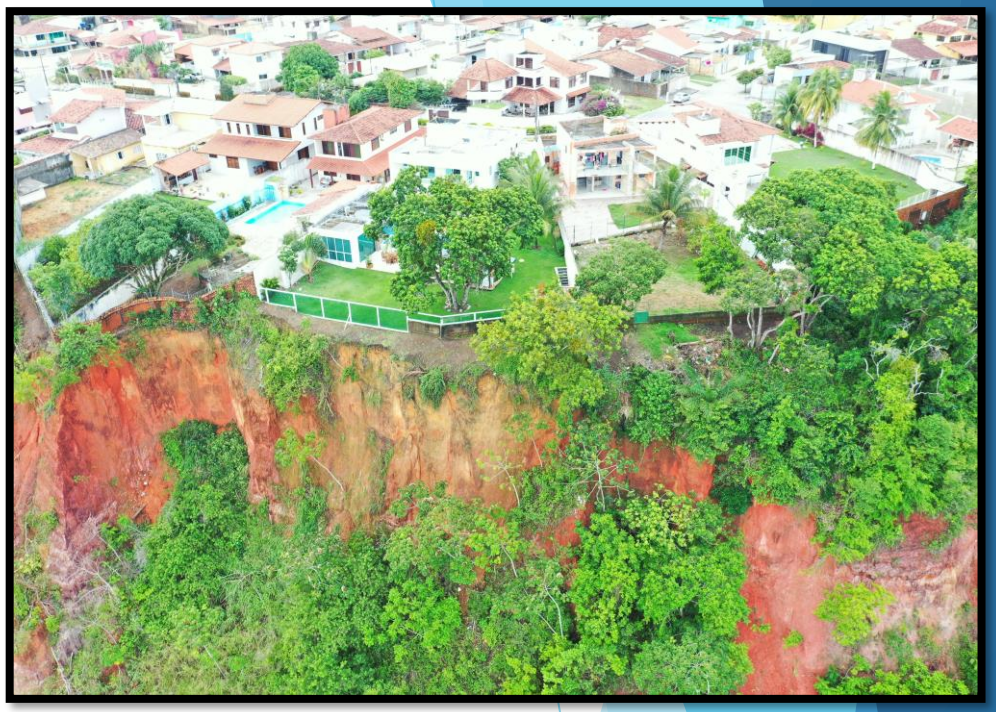
RED ZONE

FILED TRUE

RED ZONE

FILED TRUE





HILL SIDE DE FERNÃO VELHO - MACEIÓ

Pairwise Comparisons

Item Number	1	2	3	4	5	6	7	8	9	10
Item Description	Preciptation	Slope	Aspect	Hypnometric	Lithology	Soil	Land Use	Density of Lineings	Rail Line Density	Streets and Roads Density
Preciptation	1,00	1,00000	8,00000	8,00000	1,00000	2,00000	2,00000	0,20000	2,00000	2,00000
Slope	1,00	1,00	8,00000	8,00000	1,00000	2,00000	2,00000	0,11000	3,00000	3,00000
Aspect	0,13	0,13	1,00	1,00000	0,12000	0,14000	0,50000	0,50000	0,50000	0,50000
Hypnometric	0,13	0,13	1,00	1,00	0,12000	0,11000	0,20000	0,20000	0,50000	0,50000
Lithology	1,00	1,00	8,33	8,33	1,00	1,00000	0,20000	0,20000	1,00000	1,00000
Soil	1,00	0,50	7,14	9,09	1,00	1,00	0,20000	0,12000	1,00000	1,00000
Land Use	8,33	0,50	2,00	5,00	5,00	5,00	1,00	0,20000	0,25000	0,25000
Density of Lineings	8,33	9,09	2,00	5,00	5,00	8,33	5,00	1,00	0,10000	0,10000
Rail Line Density	1,00	0,33	2,00	2,00	1,00	1,00	4,00	10,00	1,00	1,00000
Streets and Roads Density	1,00	0,33	2,00	2,00	1,00	1,00	4,00	10,00	1,00	1,00
Sum	22,92	14,01	41,48	49,42	16,24	21,58	19,10	22,53	10,35	10,35

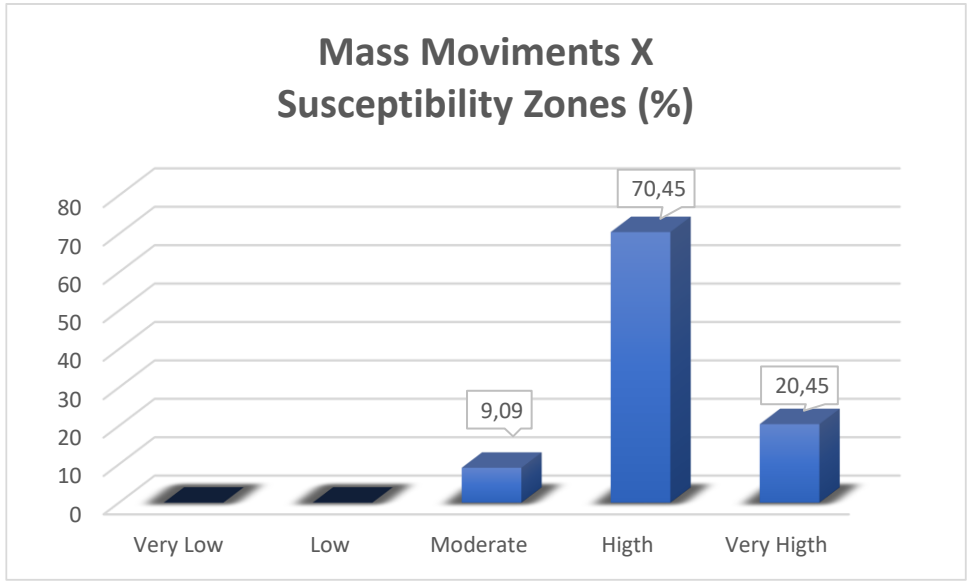
Standardized Matrix

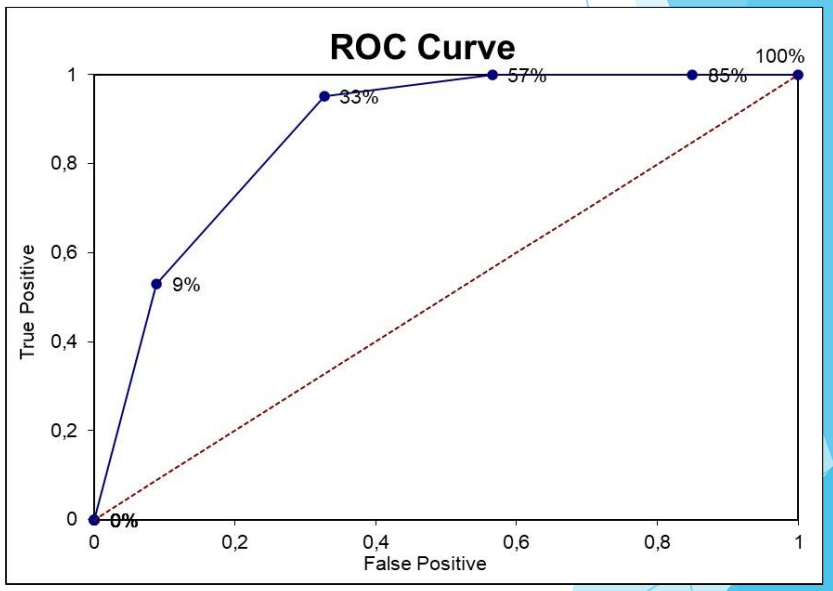
		Preciptation	Slope	Aspect	Hypnometric	Lithology	Soil	Land Use	Density of Lineings	Rail Line Density	Streets and Roads Density	**Weight**
1	Preciptation	0,04	0,07	0,19	0,16	0,06	0,09	0,10	0,01	0,19	0,19	**11,2%**
2	Slope	0,04	0,07	0,19	0,16	0,06	0,09	0,10	0,00	0,29	0,29	**13,1%**
3	Aspect	0,01	0,01	0,02	0,02	0,01	0,01	0,03	0,02	0,05	0,05	**2,2%**
4	Hypnometric	0,01	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,05	0,05	**1,9%**
5	Lithology	0,04	0,07	0,20	0,17	0,06	0,05	0,01	0,01	0,10	0,10	**8,1%**
6	Soil	0,04	0,04	0,17	0,18	0,06	0,05	0,01	0,01	0,10	0,10	**7,5%**
7	Land Use	0,36	0,04	0,05	0,10	0,31	0,23	0,05	0,01	0,02	0,02	**12,0%**
8	Density of Lineings	0,36	0,65	0,05	0,10	0,31	0,39	0,26	0,04	0,01	0,01	**21,8%**
9	Rail Line Density	0,04	0,02	0,05	0,04	0,06	0,05	0,21	0,44	0,10	0,10	**11,1%**
10	Streets and Roads Density	0,04	0,02	0,05	0,04	0,06	0,05	0,21	0,44	0,10	0,10	**11,1%**

CI and CR worksheet

		Preciptation	Slope	Aspect	Hypnometric	Lithology	Soil	Land Use	Density of Lineings	Rail Line Density	Streets and Roads Density	SUM	SUM/Weight
1	Preciptation	0,11	0,13	0,17	0,15	0,08	0,15	0,24	0,04	0,22	0,22	1,53	13,58
2	Slope	0,11	0,13	0,17	0,15	0,08	0,15	0,24	0,02	0,33	0,33	1,73	13,16
3	Aspect	0,01	0,02	0,02	0,02	0,01	0,01	0,06	0,11	0,06	0,06	0,37	17,06
4	Hypnometric	0,01	0,02	0,02	0,02	0,01	0,01	0,02	0,04	0,06	0,06	0,27	14,29
5	Lithology	0,11	0,13	0,18	0,16	0,08	0,08	0,02	0,04	0,11	0,11	1,03	12,75
6	Soil	0,11	0,07	0,16	0,17	0,08	0,08	0,02	0,03	0,11	1,53	0,50	6,69
7	Land Use	0,94	0,07	0,04	0,09	0,40	0,38	0,12	0,04	0,03	0,03	1,14	9,51
8	Density of Lineings	0,94	1,19	0,04	0,09	0,40	0,63	0,60	0,22	0,01	0,01	2,27	10,40
9	Rail Line Density	0,11	0,04	0,04	0,04	0,08	0,08	0,48	2,18	0,11	0,11	0,24	2,14
10	Streets and Roads Density	0,11	0,04	0,22	0,22	0,11	0,11	0,45	1,12	0,11	1,03	0,60	5,40

The analysis result was verified from existing mass movement occurrence locations, where an ROC index was obtained, with an AUC of 86% and a confidence interval of 82%, with an accuracy rate of 90%.





4. CONCLUSIONS

- It was possible to accurately determine the degree of mass movement risk for the entire area in the Fernão Velho region through the model.
- The obtained results are cartographically specialized, resulting in a map of zones susceptible to mass movement. The aim is to validate the method results by statistically cross-referencing the zones susceptible to mass movement obtained by the AHP method with the existing mass movement data in the area, provided by the municipal civil defense of Maceió. Additionally, in order to obtain a robust and reliable result, it was intended to confirm the accuracy of the model through the Receiver Operating Characteristic (ROC) sensitivity test.
- It is important to consider the possibility of relocating people living in high-risk areas if mitigating measures are not sufficient to ensure their safety.
- Finally, the generation of an accurate and validated landslide susceptibility map aims to create data and methods that may improve the management of the phenomenon and, consequently, the risk in the study area.

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