

Modeling shallow landslides susceptibility based on statistical analysis

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1.INTRODUCTION

Shallow landslides occur under different lithological, structural and morphological conditions. In Brazil (Figure 1) it is very common the occurrence of high magnitude events in areas with a morphological predisposition, besides favorable climatic conditions.

The susceptibility definition can be done by a **bivariate** statistics analysis through Informative Value (YIN and YAN, 1988). It is a quantitative manner to compare the spatial distribution of the process with parameters that contribute for its occurrence from the attribution of weights to each one.

The general aim of this research is to identify the shallow landslides susceptibility from a statiscal analysis of the morphological factors to Caraguatatuba county, in São Paulo state, Brazil.

3.METHODOLOGY



Figure 1 - Events of high magnitude occurred in Brazil in the Serra do Mar. A: Caraguatatuba, 1967; B: Serra do Mar paranaense, 2011; C: Mountain Region of Rio de Janeiro, 2011 and D: Itaóca, 2014.



Figure 7 - Inventory of shallow landslides of the 1967 event.

4.RESULTS

The morphological conditioning factors analysis to define shallow landslides suscetibility are essencial to understand the dynamic of the process. According to Lan et al. (2004); Vieira et al. (2010) and Dias et al. (2016), some morphological classes may be more process-prone than others. Slope angles above 30°, average altitudes and concave curvature, in general, are preferred areas for landslides.

The class that presented the highest index was in the "elevation" for the range of 201 to 400 m of altitude.

The susceptibility map generated (Figure 9) identified steep areas as more susceptible to shallow landslides occurrence. The results showed that some morphological caracteristics are associated to the occurrence of shallow landslides, with a 78% confidence in the map validation through the Area Under the Curve (AUC).

This result was expected, other authors appoint to the conditions that most significantly influence the occurrence of this kind of movement, such as the presence of high slope angles.



2.STUDY AREA

Caraguatatuba county (Figure 2), is located in Serra do Mar, a mountain range with top level in altitudes between 800 and 1800 m, in the coastline of the south and southeast regions of Brazil (ALMEIDA and CARNEIRO, 1998). It presents favorable structural and morphological conditions to shallow landslides occurrence, predominating the metamorphic and igneous rocks; faults and fractures (CRUZ, 1974), besides of high pluviometric volumes between 1,600 and 2,000 mm, specially in summer season (Dec to Mar).

In 1967 at Caraguatatuba county occured a high magnitude event, which was characterized by rainfall above average in a short period of time (584.8 mm / 48 h), triggering landslides and debris flow in the area, affecting the city's infrastructure and resulting in 120 deaths (Figures 3 to 6) (CRUZ, 1974; DE PLOYE and CRUZ, 1979).

(a) Morphological maps construction (Elevation, curvature, slope and aspect) based on SRTM (30 m); (b) Bivariate statistics aplication by Informative Value for each factor, using the inventory of scars from the 1967 event (Figure 7 and 8) and (c) Definition of susceptibility and validation.



Figure 8 - Scars of shallow landslides of the 1967 event in detail (Photo: Olga Cruz).

5.FINAL CONSIDERATIONS

The research allows to identify which are, initially, **the** most susceptible areas to shallow landslides, in order to trace morphological characteristics for their occurrence.

Thus, it allowed to **identify the need to incorporate** other conditining factor to the analysis, such as **lithology and structures**, in order to obtain a more complete analysis of the factors influencing the process in the area. This task will be carried out in the next stages of the research.





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Figure 2 - Location of study area. A: Brazil; B: São Paulo state and C: Caraguatatuba county and its lithological characteristics.

Acknowledgments:













1967 EVENT



Figure 3 - Shallow landslides on the hill of Caraguatatuba county (Source: Public Archive of Caraguatatuba).



Figure 4 - Material mobilized in the streets of the city (Source: Public Archive of Caraguatatuba).



Figure 5 - Generalized landslides in the region's hills (Source: Public Archive of Caraguatatuba).



Figure 6 - Material mobilized by debris flows (Source: Public Archive of Caraguatatuba).