Morphometric Controls for the Characterization of Debris Flow in the Mountainous Region of the State of Rio de Janeiro, Southeast, Brazil

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INTRODUCTION

In the last thirty-five years, morphometric indicators (i.e. basin area, basin length, shape, slope, amplitude, among others) have been widely used to identify the basins susceptible to debris flows in different geomorphological environments in the world. The most recent studies on the analysis of morphometric indicators to characterize the zones of initiation, transport and deposition of debris flows have prioritized the use of objective methods, in order to facilitate and expedite the analysis. This work focuses on the Mountainous Region of Rio de Janeiro State, which is historically associated to landslides with high numbers of deaths and extensive economic costs, due to the presence of slopes with high gradients, expressive topographic amplitudes, talus deposits and residual soils arranged on rocks, always in conviviality with a dense and vulnerable urban occupation. Within this context, the objective is to use basin morphometric indicators to characterize five catchments, hit by debris flows related to the mega disaster event of January/2011.

METHODOLOGY

On January 11-12th, 2011, a number of landslides, but also debris flows affected the slopes of Mountainous Region of Rio de Janeiro State, associated with rainfall of 270 mm in 48 hours, with peaks of 80 mm/hour (Lima, 2013). The most destructive and deadly debris flows were those that affected the Cuiabá and Santo Antônio basins (Petrópolis), the Vieira and Príncipe basins (Teresópolis city) and the Córrego D'Antas basin (Nova Friburgo city).

The method used to study the influence of morphometric indices on the generation of debris flows in 5 watersheds involved the following tasks, in this order:

- The identification of landslides scars occurred immediately after disasters through satellite imagery analysis, helicopter overfly photography and field corrections;
- The field investigation sought to compartmentalize the phases of the debris flow through the role played by geology, by alteration profiles, by debris flows deposits, and by the distance of range, considering morphometric parameters of drainage basin;
- The morphometric indicators (Basin area; Watershed length; Circularity ratio and Melton Ratio) were extracted from Digital Elevation Models (DEM), with spatial resolution of 10m, through the interpolation of the level curves in the Geographic Information System for the selected drainage basins.

RESULTS AND DISCUSSION

The data acquired for the study basins are presented in **Table 1**. The area and the length of the basin are parameters that contribute to the sediment supply characteristics and the peak flow. Considering the mean (42.79 km^2) of the area of the basins affected in the past by debris flows,

greater than ≥10km^2, topographic controls such as knickpoints or natural dams can influence the propagation of these processes.

The circularity ratio (Area of circle having the same length of perimeter as the basin) tends toward unity as the basin approaches the circular shape and decreases as the shape becomes elongated. The Vieira river basin presented a high value for this variable; it can be inferred high discharge of runoff. Another parameter evaluated was the Melton Ratio, which establishes the relation between the amplitude and the area of the basin. The morphometric indices used are the basin length (WL) <2.7km and Melton Ratio (R) >0.6 (Wildford et al., 2004). According to **Table 1**, the study basins present Melton Ratio ≤0.20 and basin length ≥5km, classified as Flooding based on Wildford et al. (2004). These values differ substantially from those found in the literature, which attribute to occurrence of debris flow at prone locations in the Serra do Mar (Brazilian Southeastern escarpment): Melton Ratio > 0.3 or> 0.6 and Watershed Length <2.7 km (Corsi et al. 2015; Picanço et al. 2016).

Table 1 Morphometric parameters of studied basins

Basin	A (km^2)	WL (km)	RC	R
Cuiabá	36.1	9.9	0.43	0.18
D'Antas	53.1	14.2	0.34	0.16
Príncipe	11.9	5.9	0.39	0.26
S.Antônio	80.1	16.3	0.29	0.17
Vieira	32.5	7	0.53	0.21

A - drainage area (km^2); WL - watershed length (km); RC- Circularity ratio; R - Melton Ratio

However, it was possible to classify the typology through the study of deposits of debris flows found in drainage channel, sometimes exhibiting more than one cycle. The drainage basins chosen were classified according to the typology: (1) Príncipe basin such as debris flow; (2) Vieira basin classified as debris flow; (3) Cuiabá basin classified as earth flow; (4) Santo Antônio basin classified as debris flow; (5) D'Antas basin classified as mud flow.

CONCLUSIONS

The analysis of the morphometric indicators alone did not allow a reflection of the drainage channel zoning for geomorphological processes. Minimally expeditious field investigations are required for the recognition of debris deposits and the use of other factors related to the geological conditions combined with the digital analysis of the terrain of the basins under analysis. As future steps, to identify the influence of morphometric controls on the debris flow distribution, the partial results will be complemented with the analysis of the secondary attributes of the Digital Elevation Models: Index topographic wetness, Stream Power Index, and Topographic Factor (LS-Factor).

REFERENCES

CORSI, A.C.; GRAMANI, M.F.; OGURA, A.T. (2015). Método para delimitação de bacias de drenagem suscetíveis a corrida de massa e enxurrada em regiões serranas. In: 9º Simpósio Brasileiro de Cartografia Geotécnica e Geoambiental, Cuiabá-MT, 2015.

LIMA, I.F. (2013). O Fluxo de massa do Vieira, Teresópolis-RJ, Megadesastre de 2011: Análise das feições sedimentológicas e de sua fenomenologia. 75f. Dissertação (Mestrado em Geologia) – Programa de Pós-graduação em Análise de Bacias e Faixas Móveis, Faculdade de Geologia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro. 2013.

PICANÇO, J.L; TANAKA, H.S; MESQUITA, M. J.; COSTA, V.V.; LUIZ, E.F.O; LOPES, A.B.B.; AFONSO, F.K.; PIMENT, V. Debris flow hazard zonation in Serra da Prata Range, Paraná State, Brazil: Watershed morphometric Constrain. Landslide and Engineered Slopes. Experience, Theory and Practice. In: Proceedings of the 12th International Symposium on Landslides. 2016.

WILFORD, D.J.; SAKALS, M.E.; INNES, J.L.; SIDLE, R.C.; BERGERUD, W.A. Recognition of debris flow, debris flood and flood hazard through watershed morphometrics. Landslides. fls 6. 2004

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