Application of the SHALSTAB Model for Mapping Susceptible Landslide Areas in Mine Zone (Quadrilátero Ferrífero in Southeast Brazil)

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Abstract - Landslides is a common problem in the southeast of Brazil mainly after strong summer rainfalls. The understanding of this process has been awaking the interest of the scholars. Many methodologies have been developed in order to identify areas where landslide prone. A methodology named SHALSTAB has been used and/or refined in order to mapping instability areas in the hillslope. This methodology is a combination between a hydrological model and a slope stability model, based on a digital elevation model (DEM). Recently it was written in Avenue language and implemented for utilization in the ArcView Software. The methodology was applied in the mine region named Quadrilátero Ferrífero (BRAZIL). A DEM was made and also were determined their derivatives maps as slope and contributing area. The soil properties parameters values were obtained from references. The results demonstrated that the SHALSTAB model is also an effective tool to the identification of susceptible zones for the occurrence of shallow landslides at mine zones.

Keywords- SHALSTAB; Landslides; Quadrilátero Ferrífero

I. INTRODUCTION

The landslides are natural phenomena of external dynamics and, in tropical areas, are common especially during strong rainfall that took place frequently in the summer. This phenomenon has caused loss of lives and serious damage to roads, bridges, and properties.

In order to identify potentially unstable slopes, in this work was applied the model Shallow Stability - SHALSTAB [1], implemented in ArcView software [2], of predicting areas prone to shallow landsliding in mine zone (Quadrilátero Ferrífero (MG) in regional scale (1:50.000).

II. STUDY AREA

Located in the Southeastern portion of the Minas Gerais (MG) state, the study area correspond the Quadrilátero Ferrífero area enclosing approximately 7000 km² (Fig. 1).

Figure 1 - Location map for the Quadrilátero Ferrífero mine zone

III. METHOD

SHALSTAB comes being applied in diverse regions of the west of the United States since the decade of 90 [3, 4] Montgomery and recently was tested in Brazil, presenting resulted satisfactory [5, 6, 7].
This approach is based on combining a hydrological model with a slope stability model [3]. The hydrological model [8] determines relative soil saturation based on the analysis of upslope contributing areas, slope and soil transmissivity:

\[
W = \frac{Q_c}{T \cdot \tan \theta} \cdot \tan \phi
\]

where \( W \) represents the wetness index of the soil, \( a \) is the contributing area (m²), \( b \) is the length of the grid size (m), \( T \) is the soil transmissivity (m²/day), \( \theta \) is the local ground slope and \( q \) is the steady state rainfall intensity (mm/day). The (1) can be combined with the infinite-slope stability model to obtain a model of relative slope stability for cohesionless soils

\[
\frac{Q_c}{T} = \frac{\sin \theta}{(a/b)} \left[ \frac{\rho_w}{\rho_s} \left( \frac{1 - \tan \theta}{\tan \phi} \right) \right]
\]

where \( Q_c \) represents the critical steady-state rainfall required to trigger failure, \( \rho_w \) is the density for water, \( \rho_s \) is the saturated bulk density of the soil, \( \phi \) is the friction angle of the soil [3]. We calculated values of \( \log \left( \frac{Q_c}{T} \right) \) for each topographic grid element in the study area.

**IV. APPLICATION OF THE SHALSTAB MODEL IN THE QUADRILÁTERO FERRÍFERO REGION.**

A 20-m grid DEM was created from digital contour from a 1:50,000 scale topographic map and interpolated using the Topogrid module of ARC/INFO. Slope and contributing area values were obtained for the study area from the resulting DEM. Because that model dismisses cohesion, we use a higher value for the friction angle (45 degrees). We also adopted a density of 2.0 g/cm³ based on previous research.

**V. RESULTS**

The results demonstrate that shallow landslide initiation retains a strong topographic control. The \( \log \left( \frac{Q_c}{T} \right) \) classes in Fig.2 shows the levels of instability for the region.

The Fig.3 presents a detailed vision of the studied area, demonstrating that the places of highest instability is located in the east portion of the region, enclosing mainly the cities of Ouro Preto, Santa Bárbara, Itabirito and Mariana where happened many shallow landslide recently.

**VI CONCLUSION**

The results demonstrated that even using a small scale (1:50,000) the SHALSTAB model is a significant predictive tool to identify susceptible zones to the occurrence of shallow landslides. Is possible to infer that the good performance of the simple model (dismissing soil cohesion), reflects a strong topographic control on shallow landslide initiation in this area. The SHALSTAB in ArcView environment, consists in a viable and efficient tool that can be used for the municipal planning.

**REFERENCES**


Figure 3 - Map of susceptible zones of the shallow landslide in the Ouro Preto region, MG