Landslides inventory in the Angra dos Reis and Itaguaí region of the state of Rio de Janeiro, Brazil

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Abstract: The coastal zone of Angra dos Reis and Itaguaí region, in the state of Rio de Janeiro, has been frequently affected by gravitational mass movements caused by natural processes related to landform evolution. Human intervention has negatively affected areas, increasing the frequency of the gravitational mass movements. This work presents the results from a landslide inventory, developed from aerial photograph interpretation, satellite data and fieldwork, including historical data surveying. The landslide lnventory represents the record of the geographical distribution of the phenomena, relating the lithological, geomorphological, pedological and terrain factors. The methodology used for development of the landslides inventory followed the proposals of international scientific associations.

The gravitational mass movement features were identified, mapped and characterized based on attributes such as location, dimensions, orientation, position on the slope, geomorphological aspects related to the main drainage channel and aspects related to the human interference. The gravitational mass movements were classified as: translational landslides, rotational landslides, rockfalls and creep, and are shown in maps and tables.

Résumé: La zone côtière de Angra dos Reis et de région d'Itaguaí, dans l'état de Rio de Janeiro, a été fréquemment affectée par les mouvements de masse de la gravité provoqués par des processus normaux liés à l'évolution de forme de relief. L'intervention humaine a négativement affecté des secteurs, augmentant la fréquence des mouvements de masse de la gravité. Ce travail présente les résultats d'un inventaire d'éboulement, développé à partir de l'interprétation aérienne de photographie, des données satellites et des travaux sur le terrain, y compris l'enquête historique de données. L'éboulement lnventory représente le disque de la répartition géographique des phénomènes, reliant les facteurs lithologiques, géomorphologiques, pédologiques et de terrain. La méthodologie utilisée pour le développement des éboulements inventorient a suivi les propositions des associations scientifiques internationales.

Les dispositifs de masse de la gravité de mouvement ont été identifiés, tracés et caractérisés basé sur des attributs tels que l'endroit, les dimensions, l'orientation, la position sur la pente, les aspects géomorphologiques liés au conduit d'évacuation principal et les aspects liés à l'interférence humaine. Les mouvements de masse de la gravité ont été classifiés comme : des éboulements de translation, les éboulements de rotation, les rockfalls et le fluage, et sont montrés dans les cartes et les tables.

Keywords: geological hazards, geotechnical maps, landslides, slope stability, terrain analysis.

INTRODUCTION

Landslides represent a set of geological and geomorphological processes of great importance. Although these processes are of natural relief evolution, they can cause accidents, material injuries, and, many times, cause the death of people. The socio-economic losses caused by landslides can be significant and are likely to become more frequent as a consequence of the occupation of unstable slope areas. Continued urban development of land already undermined by slope instability is prevalent in the Angra dos Reis and Itaguaí regions of Rio de Janeiro, Brazil (Figure 1). This paper reviews a landslide inventory of these regions.

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Figure 1. Study area location

A *landslide inventory map* may be considered as a map representing the spatial distribution of mass movements. It includes information on location of the slope movement, typology and state of activity. In some cases the landslide inventory maps can simply represent the distribution of landslide scars and deposits without a subdivision into different types of slope failure (Parise 2001). Landslide inventory maps are the necessary base for the production of additional maps, such as landslide activity maps or landslide hazard maps.

Inventory creation to study the processes of mass movements is considered fundamental to the understanding of the development of these phenomena. A landslide inventory is essential before any analysis of the occurrence of landslides and their relationship to environmental conditions and to the application of preventive and mitigating measures to preserve and protect human life and urban structures (Soeters & Van Westen 1996).

Inventory maps are available in only a few countries and mostly for limited areas (Brabb 1993, Duman et al. 2005). Despite the ease with which they are prepared and their immediateness, however, landslide inventories are not yet very common (Guzzetti et al., 2000).

METHODOLOGY

The inventory was elaborated through fieldwork, satellite- and photo-interpretation. Landslides were manually mapped onto the 1:50,000 scale topographic maps. Accuracies of landslide locations obtained by this process are estimated to be better than 50 m.

According to Brardinoni, Slaymaker & Hassan (2003), fieldwork shows the relevant importance to the detection of features related to slope failures. Van Den Eeckhaut *et al.* (2005) said that, because most of the landslides are located under forest, aerial photo interpretation commonly used for the creation of landslide inventories is not a suitable tool to map all landslides.

SETTINGS OF THE AREA

Geological setting

The geology of the study area has metamorphic Proterozoic terrains, partially recovered by sediments of colluvial-alluvial origin in low areas and by sediments of the atlantic margin. Pre-Cambrian metamorphic rocks are represented by distinct tectono-magmatic domains, orientated ENE-WSW (Figure 2). These are lithological units related to Paraíba do Sul domains (kinzigitic gneisses, schists, quartzites and marbles), Juiz de Fora Complex (ortogranulites and tonalitic ortogneisses) and granitic ortogneisses to granodioritic rocks of Quirino Suite. It borders, at E, with Serra do Mar Domain, at the oriental sector. This domain presents an expressive number of orogenic granitoids and post-tectonic plutons, of Cambrian age.

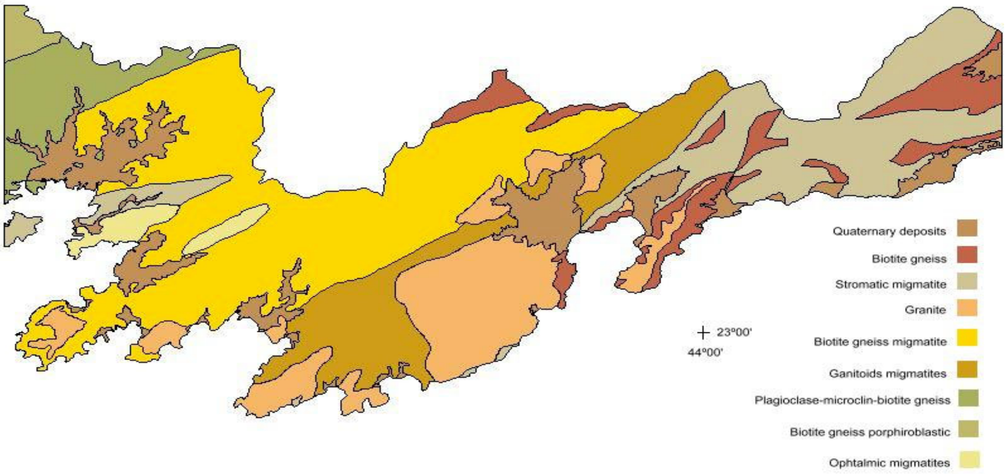

Figure 2. Geological setting.

Geomorphological setting

Regional morphology presents two extremely distinct areas: (i) Bocaina and (ii) Serra do Mar highlands, varyng from the sea level to near 1,700 meters above sea level (a. s. l.) (Figure 3). The Itaguaí-Angra dos Reis region is characterised by crustal movements, which have imposed a strong structural control to the morphology, not erased by climatic processes. It is possible to observe elongated valleys, straight segments of drainage, parallel ridges, great altimetric level differences and abrupt slopes.

Climatic influence is noted through observation of leveling and homogenization of forms in some areas and deep weathering of the rocks. Accumulation forms of marine, fluvial-marine and flow origin can be observed in the coastal areas. Relief evolution is represented by slope processes.

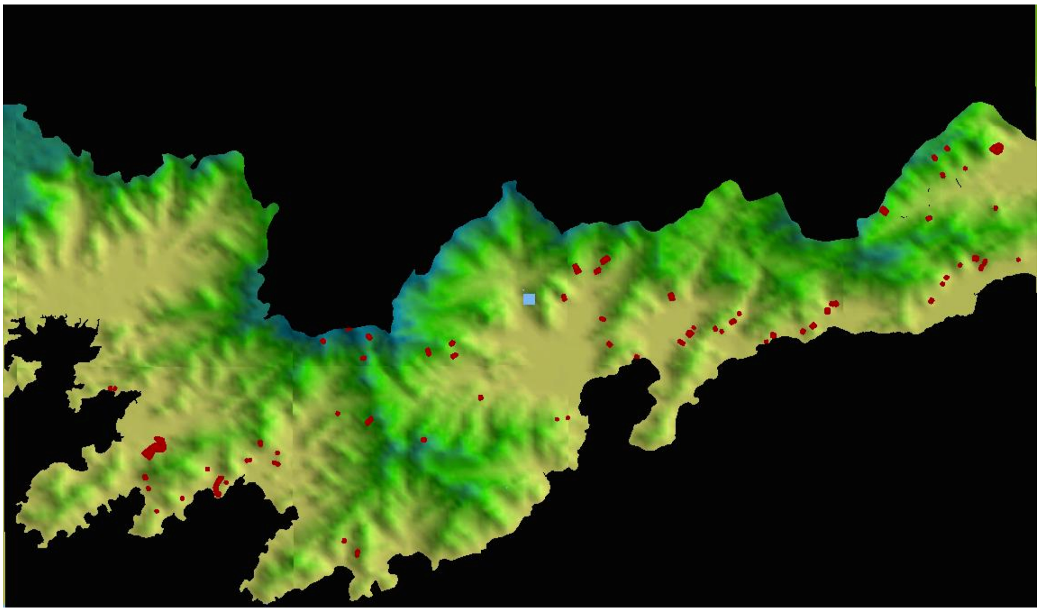

Figure 3. Shaded relief map of the area, showing the landslides locations.

Climate

The region is dominated by a hot climate (Nimer 1979). The major pluviometric indices vary from 2,000 to more than 2,500 mm/year, concentrated in the period of December to March. Temperatures are characterised by great amplitudes, varying from 12°C to 40ºC.

Luino (2005) comments that the quantity and typology of instability processes triggered by rainfall are related not only to an area's morphological and geological characteristics but also to intense rainfall distribution during meteorological disturbances. Moreover, critical rainfall thresholds can vary from place to place in relation to the climatic and geomorphological conditions of the area. Once the threshold has been exceeded, the instability processes are triggered.

The total duration of rainfall usually has a greater effect on mass movements than the number of short periods of very intensive precipitation.

Vegetation cover

The area is divided into two distinct regions of vegetal cover: forests, in the mountainous region, and bush, in the near coastal areas.

Anthropic characterization

Urban expansion and tourism, since the 1950s, have occupied the slopes and mangrove areas resulting in mass movement and environmental pollution (Souza, 2003). This region of Rio de Janeiro state has a population of about 250,000 people and an additional one million people come to the area through tourism from December to February each year. Poorly planned development in areas of slope instability, particularly around the BR101 Highway has resulted in deforestation, soil erosion and consequent landslides.

RESULTS

The mass movements were classified based on the systems proposed by Varnes (1978), IAEG (1990) and Cunha (1991) (slides, creep, erosion, rockfalls, complex movements). The landslides are also classified according to their geometry (planar (translational), circular (rotational), linear (gully), rockfalls, their position at the slope, lithology, vegetal cover, dimensions and slope inclination. Figure 4 shows the landslide classes frequency following the classification system of Varnes (1978).

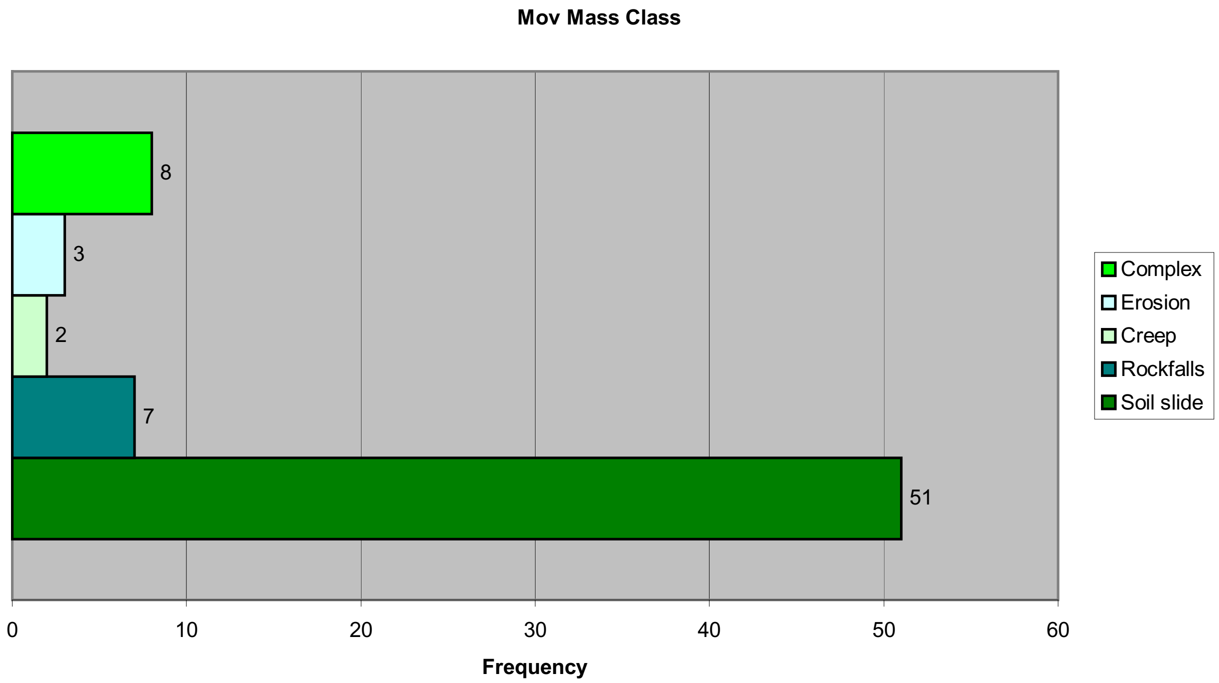

Figure 4. Landslide areas. Number of landslides is indicated in x-axis and the classes of landslide areas in the y-axis.

71 gravitational mass movements were identified in an area of 950 km² (Figure 4). We can observe that:

- Landslide types include slides, falls, flows, erosion and complex mass movements;
- 22% of the total landslides are complex landslides
- The main type of mass movement are simple slides.

Figure 5 exhibits the landslide areas frequency. The “very large” mass movements correspond to 65% of the total and the “large” corresponds to 25%. This can be attributed to the high relief amplitude of the region, varying from the sea level to near 2,000 m a.s.l. in a few kilometers.

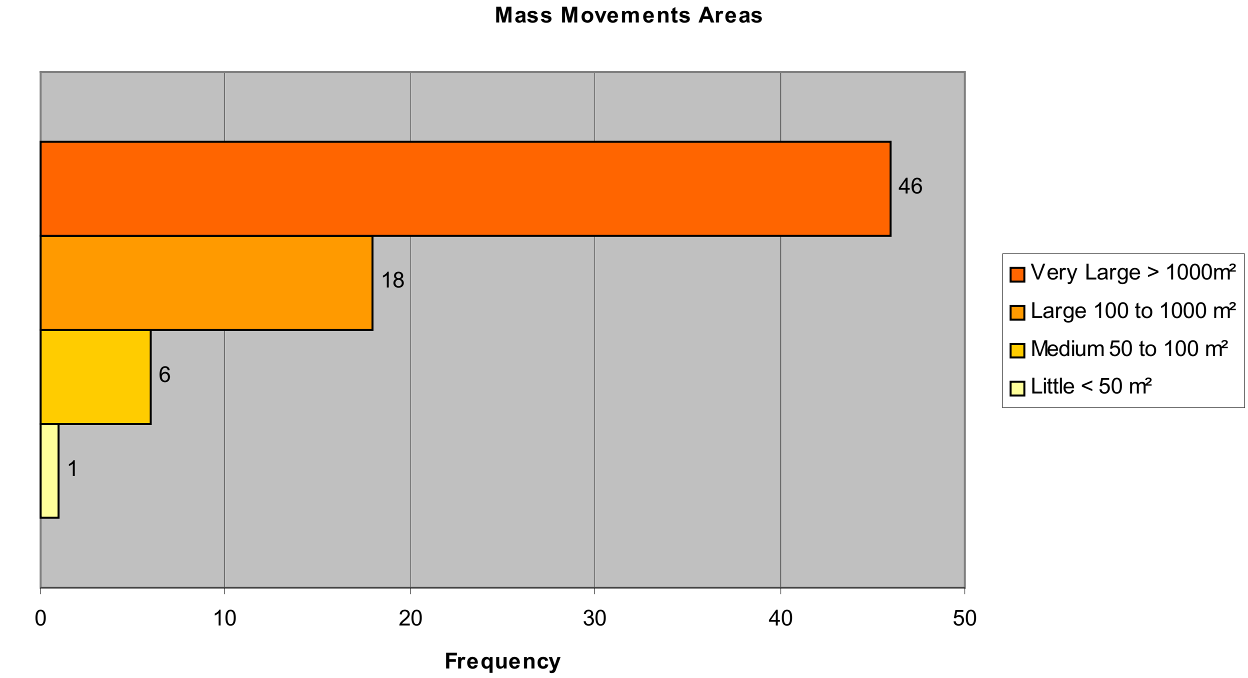

Figure 5. Landslide areas. Number of landslides is indicated in x-axis and the classes of landslide areas in the y-axis.

Figure 6 shows the gravitational mass movements distribution in the study area. From a total of 71 gravitational mass movements, 18 are in proximity to the BR101 Highway and 10 are located in urban areas.

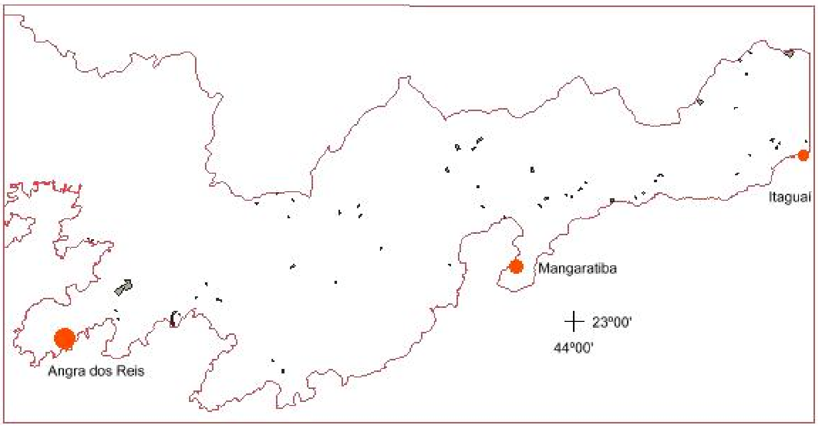

Figure 6. Landslides inventory map.

CONCLUSIONS

Because the random occupation of the area, the work of landslides inventory is of great importance, contributing to the terrain stability study and urbanization orientation.

The landslides inventory for the region allows the identification of dangerous areas with regard to slope stability, making easier the identification of geological risks and giving the possibility of planning the urban occupation.

From a total of 71 GMM, 18 are related to BR101 Highway and 10 are located in urban areas. These data show, on the one hand, the potential influence of human intervention for the deflagration of the Gravitational Mass Movements and, and on the other, the exposition of highway and urban structures to the extremely hazardous consequences of the landslides.

Landslides are frequent and widespread in the area. This landslide inventory first approach aims to play a significant role in the regional planning of the Itaguaí-Angra dos Reis region.

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