METHODOLOGICAL PROPOSAL FOR THE DEVELOPMENT OF A MAP OF LANDSLIDE RISKS IN THE MUNICIPALITY OF PETROPOLIS

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INTRODUCTION

Urban settlement in Petrópolis began in the early 18^{th} Century and, until the present date, it has been happening in a disorganized and problematic way. Throughout all these years, the hillsides have been deforested, rivers have been polluted and silted up and, consequently, the number of landslides has increased.

Landslides in Petrópolis are historical events. They have been causing losses in human lives and considerable material damages, such as collapses of bridges, houses, barriers, besides other minor damages. In general, these losses and damages occur in needy areas where constructions are fragile and built in inadequate locations (environmental protection areas, fluid conversion areas, with loose blocks, in places with slopes angle higher than 45º, etc).

Landslide problems have been very scary, especially for the local population of Petrópolis. However, preventable measures of public interest, such as recovery of affected areas, use of prevention techniques, dislodgement of people from risk areas, and inspection of irregular settlements, among others, have not been implemented. This can be verified by observing in the data bank studied, the recurrence of landslides in the same area in previous years.

According to Gonçalves and Guerra (2001), the more urbanized part of the Municipality is located in the First and part of the Second District, mainly with irregular settlements on very steep hillsides. The great mass movements in Petrópolis, especially in the First District, are, among other factors, due to disorganized urban concentration in risk areas, concentrated rain fall, and hilly relief.

For this work, geocoding is characterized as a fundamental tool because it spreads these data in a very precise way. Through visualization of landslide concentration areas, it is possible to guess what the higher landslide risk areas are, since the landslide recurrence rate is very high. Local newspaper *Tribuna de Petrópolis* and IPT – Technology Research Institute landslide records from 1960 to 2004 were used as sources for developing the databank.

Therefore, due to the recurrence of tragedies resulting from landslides, it was necessary to develop a study aimed at preventing these tragedies from happening through the use of a Map of Landslide Risks in the Municipality of Petrópolis.

Location

The Municipality of Petrópolis is located North of the city of Rio de Janeiro, at Serra dos Órgãos Range, between the geographic coordinates 42º50' and 43º20' S - 22º10' and 22º36' W, as we can see in Figure 1. It has a hilly relief, steep slopes, small canyons, and a beautiful natural view. The climate is mild, with plenty of rain (2,000 to 3,000 mm per year), especially from October to May, with no dry season, with annual average temperature at a maximum of 23ºC (73.4F), varying from 10º C (50F) to 30º C (86F), which makes it one of the best climates in the world. The city (First District) is located at 809m (246') high, at Serra da Estrela Range (local name for Serra do Mar Range), with light tropical vegetation (tropical rainforests).

Petrópolis is a city that attracts people not only for its natural beauty, but especially for its history and architectural patrimony.

The First District (Petrópolis) has the higher population concentration, where the level of anthropic influence (disorganized settlement of hillsides, their deforestation, and garbage disposal), allied to physical factors (concentrated summer rains and hilly relief), was decisive for choosing the Municipality of Petrópolis as the pilot area for the development of the Map of Landslide Risks.

The Municipality is about 811 km^2 (313 sq. miles) large and encompasses five Districts. It gives its name its main District (Petrópolis – First District). The other ones are: Cascatinha, Second District; Itaipava, Third District; Pedro do Rio, Fourth District, and Posse, Fifth District.

According to the IBGE's Demographic Census (2000), the Municipality of Petrópolis has 286,537 inhabitants, with an increase of 38% during tourist seasons (O Globo, 01/25/2005).

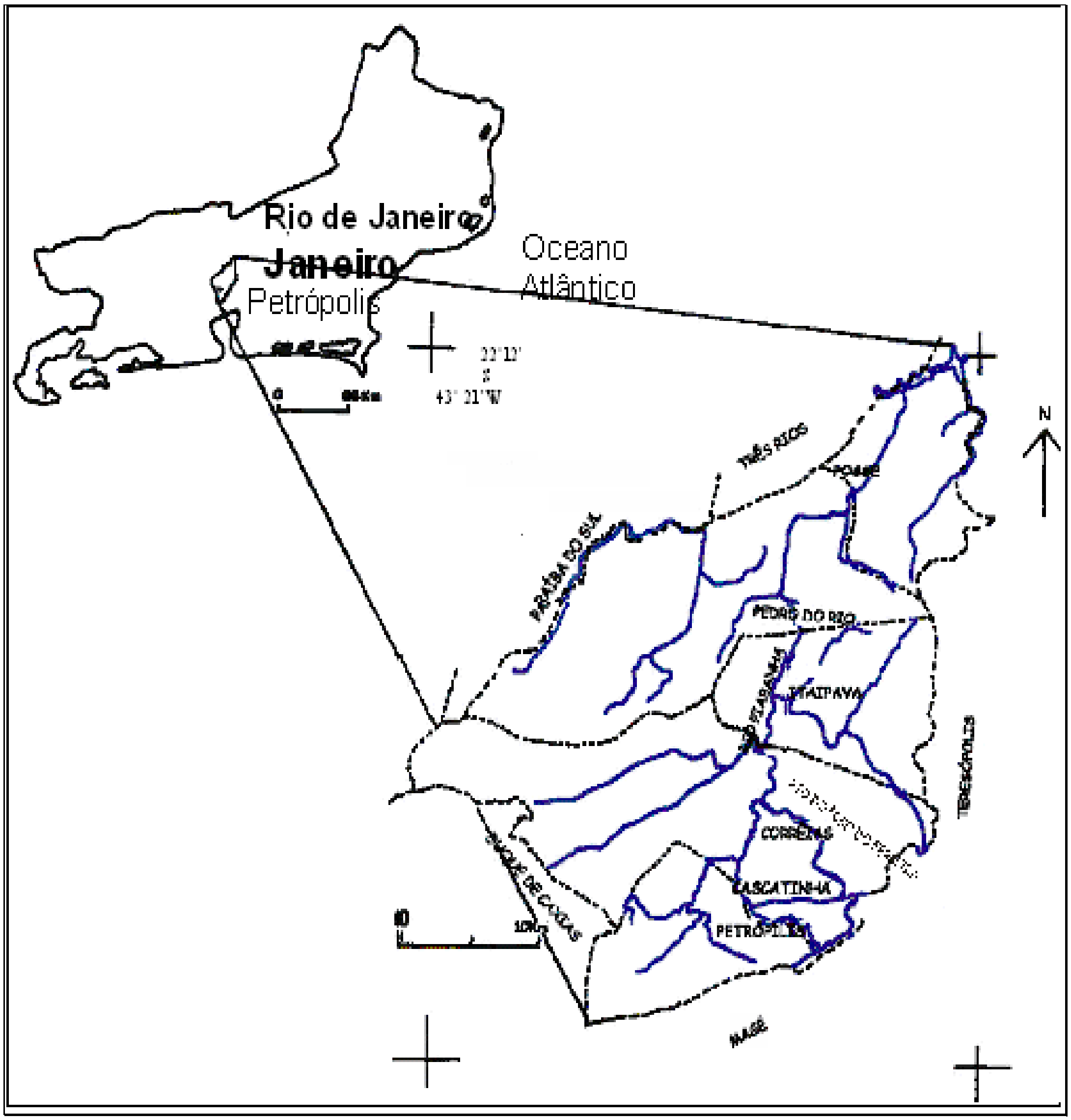

Figure 1: Localization map of studied area.

OBJECT

This work aims at relating landslide recurrence to the application of the Table containing the conditioning factors for the vulnerability of landslide events. The intention is also to qualify landslides using smaller and higher risk grades in levels from one to five, where the closest to one means smaller landslide risk, and the closest to five means higher landslide risk.

Some variables of the table have been considered, in order to exemplify the methodology used on the the Alert System, as we can note on Table 1.

Vulnerability factors for Landslides

A - Slope Angle
B - Vegetation cover
C - Gargabe/rubble
D - Strucutural quality of the houses

Level 1

A - 1º - 10º
B - Dense and stabilized forest
C - No debris
D - Good quality houses and foundation on solid material, far from the talus base.

Level 2

A - 11º - 20º
B - Concentrated trees.
C - Small amount of debris (up to 50 cm) on few places.
D - Brick houses, with or without coat, with foundation on solid and stable material and defficient structure.

Level 3

A - 21º a 30º
B - Short trees and well spaced.
C - Considerable amount of debris (over 50 cm thick) around the house.
D - Brick houses with deficient foundation and without trough, located near the crest and/or near the talus base.

Level 4

A - 31º a 41º
B – Grass.
C - Presence of a great amount of debris (over 1.0 m thick) disposed on regular intervals and on the same places.
D - Brick houses without foundation, without trough, deficient structure, with cracks.

Level 5

A - Over 41º
B - Bare soil.
C - Presence of great amount of debris (over 1.0 m thick) disposed all over the place.
D - Brick houses without foundation and without structure or made on wood, with cracks and sinking of the soil on some places near the house.

IPT – Technology Research Institute and Tribuna de Petrópolis were used as sources to help generate a data bank with over 800 landslide records, from 1960 to the present day.

By doing so, the intention is to list the landslide frequency to their qualification, which will result in the Map of Landslide Risks in the Municipality of Petrópolis.

METHODOLOGY

According to Marques (2001), Geomorphology is a fundamental tool for studying the environment due to the attention given to its study of plans and projects development needed to explain the possible environmental impacts, which will result from its implementation, such is the case of this work.

The methodology used included four main stages carried out in a sequence throughout the development of the research.

In the first stage of the work, a survey of texts and preliminary work about the area and the subject being discussed was made. This survey was carried out as a theoretical and conceptual contribution to the work, since it widens the general view of the subject and provides a better characterization of the area. Two maps of the municipality have been made with the main drainage, seen on Figure 2, and another map with the contour lines spaced every 200 metres, containing the main roads and highways, as seen on Figure 3.

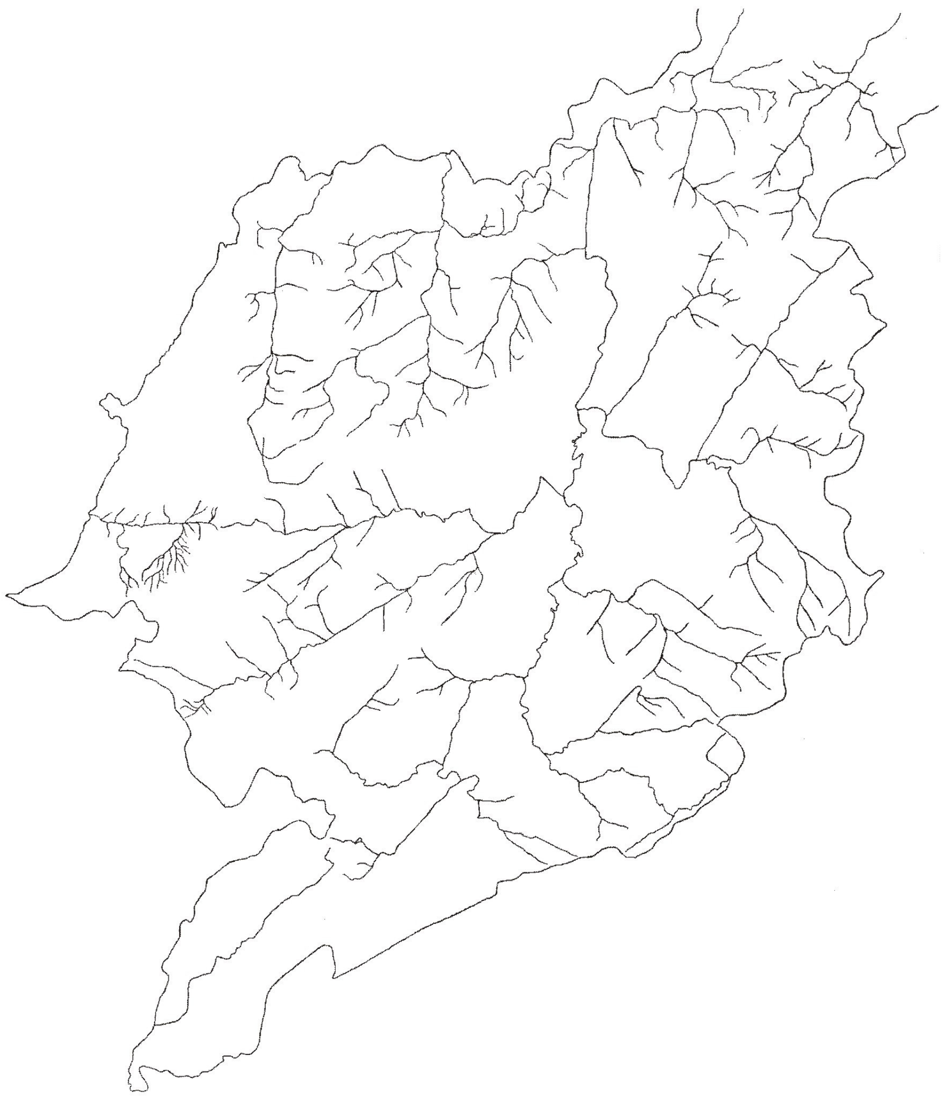

Figure 2: Map of the rain drainage system of Petropolis Municipality.

Figure 3: Contour lines map of Petropolis Municipality with 200 metres interval.

In the second stage, the records about mass movements in Petrópolis in the period ranging from 1960 to 2004 were updated using the data bank on landslides in Petrópolis (IPT, 1991) and from the local newspaper *Tribuna de Petrópolis*, also from 1960 to the present date.

In the third stage, landslide surveys were gereferenced and classified according to the Landslide Vulnerability Factors (Table 1), and computerized in data banks to better analyze them. This Table is aimed at classifying the variables in levels from one to five, where the closest to one means smaller risk of landslide, and the closest to five means higher risk of landslides. By doing so, we intend to classify the areas where landslides occur in different risk levels.

The Landslide Vulnerability Factors Table was developed with the following variables: declivity, natural drainage, sewage network, rain collectors, water system, garbage disposals, existing cuts and/or landfill, existing stabilization work, vegetation cover, existing apparent boulders, lithostructural aspects, structural quality of housing, hillside waterproofing, existing pedestrian access, many unpaved pedestrian accesses, hillside occupation density, and geotechnical aspects.

Along with all the stages, there were many field works for georeferencing 835 landslides that were catalogued with the goal of reducing landslides until the year 2004. These field works were fundamental for a better physical and anthropic characterization of the area, through walking on narrow roads and photos have been taken on the field, as well as to improve the understanding and analysis of mass movement data bank from 1960 to 2004. The figures 4, 5 and 6 illustrate the variables chosen, such as slope angle, vegetation cover, garbage and the structural quality of the houses.

Finally, for the fourth stage, there is the development of a final map, which will be made illustrating the relationship between the reduction of landslides and the classification of their risk level.

Figure 4: House built on a very unstable slope with slope angle over 70º, with a cut on the talus, characterizing a level 5 risk on the Table of Vulnerability Factors (Valparaiso, 2004).

Figure 5: House with deficient structure, presence of cracks and soil sinking, outlining level 5 risk on the Table of Landslides Vulnerability Risk (Valparaiso, 2004).

Figure 6: House with deficient structure, soil sinking and the presence of clandestine pipes with water leakage, outlining level 5 risk on the Table of Landslide Vulnerability (Valparaiso, 2004).

EXPECTED RESULTS

We intend to relate the localization and the number of landslides shown on the Landslide Map with the risk level presented in the area, which is generated through the application of the Landslide Vulnerability Factors Table previously selected (landslides in the year 2004).

The final product will be the Landslide Risk Map of the Municipality of Petrópolis.

Through this work, our conclusion is that the landslide reduction is extremely important for analyzing landslides, and it is fundamental for assessing their risks on the hillsides of the Municipality of Petrópolis. It is also important to consider and research the causes for these landslides, so that preventable measures are proposed and tragedies such as the ones that happened in the summer of 2001 do not occur again.

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Acknowledgements: the authors would like to thank SEMADUR (Environmental and Urban Development State Secretariat) do Rio de Janeiro and CNPq (National Council for Scientific and Technological Development) for their support to this research.