Nat. Hazards Earth Syst. Sci. Discuss., 1, C2769–C2777, 2014
www.nat-hazards-earth-syst-sci-discuss.net/1/C2769/2014/

Natural Hazards
and Earth System
Sciences
Discussions

Interactive comment on "Shallow landslide prediction and analysis with risk assessment using a spatial model in the coastal region in the state of São Paulo, Brazil" *by* P. I. M. Camarinha et al.

P. I. M. Camarinha et al.

pedro.camarinha@inpe.br

Received and published: 28 February 2014

Anonymous Referee #2 "The paper "Shallow landslide prediction and analysis with risk assessment using a spatial model in the coastal region in the state of São Paulo, Brazil" cover interesting topics for NHESS but there are different critical points requiring major revisions (see annotated pdf for specific comments). "

1) "The choice of the factors and their weighting is not explained and some choices are debatable."

-This part is completely modified in the article, as described below. Each thematic class of all maps was assessed by landslides susceptibility standpoint, evaluating their particularities with regard to favor or mitigate the triggering of mass movements. In Brazil, a study reference with this type of weighting analysis was developed by Crepani et al. (2001). The authors evaluate some thematic maps (soils, geology, topography, land use) and their classes was weighted from assumptions made by experts in different scientific area, taking into account the specificities related to physical weathering Brazilian soils and destabilization of slopes. The same criteria was used in the present study, and some classes that was not evaluated by Crepani et al. (2001) were weighted after consenting different analyzes made by a geotechnical engineer, a forestry engineer and an expert on natural disasters (which are the authors of this study), and other related studies (Veloso, 2012; Ferandes and Amaral, 2003; Binda e Bertotti, 2007; Kannungo et al., 2006; Vieira et al., 2010).

Before producing the susceptibility maps, the thematic maps related to landslide susceptibility must be weighted for the use the Fuzzy Gamma technique. The weights vary from 0 to 1, where 0 indicates classes with no relationship to landslide occurrence and 1 indicates classes with a high relationship to landslides. This weighting transforms the thematic maps onto a numerical grid, in which each class of map receives a weight (from 0 to 1).

For the Land use and land cover map, the weights assigned to each vegetation class depend on the type of coverage. The volume of material removed and transported by rainwater is related to the density of vegetation cover and the slope declivity, and with vegetation removal, these processes become more intense, especially in areas with steep slopes (Vieira et. al, 2010). The land cover class ' forest' is the one that presents the lowest weight in that category (Table 3), because the forest cover, along with the understory, add to the soil good interception of rainwaters, preventing runoff and consequently the landslide processes. In Eucalyptus plantations, the soil is not fully protected as in the forests because there isn't always the presence of understory, which makes the soil more susceptible to landslide. And so were evaluated all classes of this theme. Note that our method considers the urban area as a strong contributing factor to the destabilization of slopes (weight equals 1.0), while forests and natural areas remains the most stable slopes. These relationships are inherent of the study area, because the urban areas that are on the slopes were occupied rapidly during the last decades and years without any planning, so that there are too many factors that increase the susceptibility of landslides, such as: urban system drainage is deficient, the houses have foundations supported on the shallow layers of soil (not on the rocks); and there are points with no sewage uptake and so the wastewater favor the erosion in the foothills of slopes.

Therefore, our methodology is likely to indicate critical places within urbanized areas and, exactly for this reason, we use the risk sectors as the unit of validation. The geological map shows various information including the lithological type layer 1, the layer closest to the earth's superficiel. The weights were based on rock types present in this layer and related study conducted in Brazil by Crepani et al. (2001), in which the relations between the different types of rock landslides were evaluated. Igneous rocks had lower probabilities of landslide, metamorphic and sedimentary intermediate probability were more likely to landslides, which was considered as the basis for weighting. The topography was addressed through horizontal and vertical curvatures and the slope. The horizontal curvature refers to the divergent/convergent character of flows of matter on the ground when analyzed on a horizontal projection. This curvature is related to the processes of migration and accumulation of water, minerals and organic matter in soil caused by gravity, and plays an important role in the resulting water balance and pedogenesis process (Veloso, 2002). Terrain with convergent profiles presents a higher risk of sliding incidents than divergent profiles (Fernandes and Amaral, 2003).

Several geomorphological studies have called attention to the role played by the concave portions of the relief (hollows) on the convergence of water streams, both surface and sub-surface, favoring the development of soil saturation conditions and ultimately the generation of landslides on the slopes (Tsukamoto et al., 1982; Reneau et al., 1984; Crozier and Vaughan, 1990; Dietrich and Dunne, 1993; Fernandes et al., 1994; Fernandes et al., 2004).

Thus, convergents (horizontal curvature) and concave (vertical curvature) relief forms received the highest weights in for susceptibility analysis (Neuhauser and Terhorst, 2007; Brenning, 2005; Talebi et al., 2008). The slope map was divided into 5 classes in accordance with those suggested by Binda and Bertotti (2007) and Kanungo et al. (2006), with weights attributed to each slope class. The steeper slopes are more disposed to landslides and is one of the key factors in inducing slope instability. As the slope angle increase, shear stress in soil or other unconsolidated material generally increases as well. Gentle slopes are expected to have a low frequency of landslides because of generally lower shear stress associated with low gradients (Anbalagan, 1992).

For the different soil types, the weights were also based on the study of Crepani et al. (2001). The higher or lower susceptibility of a soil to landslides depends on many factors and the most important are: soil structure, type and amount of clays, permeability, and soil depth and the presence of impermeable layers (Lee and Min, 2001). In the natural landscape units considered stable value assigned to the soils in the range of susceptibility is close to zero and are represented by the class of soil type Latosols. Latosols are well developed, with great depth and porosity and is therefore considered the land whose soil materials are the most decomposed. Are considered old or mature soils (Coelho-Neto et al., 2009).

In the natural landscape units considered intermediate, the value assigned to the soils in in relation to the susceptibility is close to 0.5, and are represented by the class of the Podzolic solis. The Podzolic soils compared to the Latosols, have smaller depth and are less stable and less weathered soils. Usually occur in reliefs with mountainous. The Podzolic soils presents a B horizon, where there is accumulation of clay, ie during the process of forming a good part of the clay is translocated by eluviation to the horizon

A to B horizon, where it accumulated. In these soils the difference in texture between the A and B horizons (caused by accumulation of clay in the B horizon) hinders water infiltration in profile, which favors mass movements.

In the natural landscape units considered susceptible occur soils to which is assigned the maximum value, ie, near to 1.0. These soils are young and undeveloped, with principal characteristics the small evolution in soil profiles. In these soils the horizon A establish directly on the C horizon or else occur directly on bedrock (lack the B horizon). Are considered to be young soils in the initial phase of formation because they are still developing from source materials recently deposited, or because they are located in places of high slope, where the rate of soil loss is equal to or greater than the speed transformation of rock into soil. (Coelho-Neto et al., 2009). In this group are also Gleisols, Spodosols, Cambisols and Urban soils.

2) "The fuzzy gamma operator is not explained: for example why a gamma of 0.8?"

-Due to the uncertainties arising from the materials and parameters used in the landslide assessments and nonlinear character of the landslide phenomena, utilization of the fuzzy gamma technique can be considered as an effective approach when insufficient data exist statistically or when it is difficult to evaluate the landslide susceptibility by mathematical models, especially for large areas (Ercanoglu and Gokceoglu, 2004), such as our study area and other municipalities that do not have any mapping and could use this methodology.

The Fuzzy Gamma Logic in the Equation 1 (see the manuscript); where μi is the fuzzy membership function for the i-th map (theme), and i=1, 2,.., n maps (themes) are to be combined, and γ (gamma) is a parameter within the range (0 to 1). Discerning choice of γ produces output values that ensure a flexible compromise between the ‘increase’ tendencies of the fuzzy algebraic sum and the ‘decrease’ effects of the fuzzy algebraic product.

For Bonham-Carter (1994), the values in the range from 0 to 0.35 show a “diminutive” character, i.e., they are always less than or equal to the smallest input fuzzy member; the values in the range from 0.8 to 1.0 have an “increasing” character, in which the output value will be equal to or greater than the value of the largest fuzzy member input values, and the range from 0.35 to 0.8 does not have an “increasing” or “diminutive” character.

Susceptibility maps were generated with values of gamma equal to 0.8. These input values do not have a diminutive or increasing character and were used in works from Lee (2007), Pradhan et al. (2009) and Pradhan (2010). Another justification for the choice of gamma equal to 0.8 are works developed by the same authors of this paper in other study areas (Canavesi et al., 2013; Alvalá et al., 2013), which found that 0.8 provides the best results for representing shallow landslide phenomena in the same region when compared with other values.

References:

CANAVESI, V., CAMARINHA, P. I. M., ALGARVE, V. R., CARNEIRO, R. L. C., ALVALA, R. C. S. Análise da susceptibilidade a deslizamentos de terra: estudo de caso de Paraibuna, SP In: XVI Simpósio Brasileiro de Sensoriamento Remoto, 2013, Foz do Iguaçu - PR. Anais do XVI Simpósio Brasileiro de Sensoriamento Remoto. São José dos Campos: INPE, 2013. v.1. p.5251 – 5258.

ALVALA, R. C. S., CAMARINHA, P. I. M., CANAVESI, V. Landslide susceptibility mapping in the coastal region in the State of São Paulo, Brazil In: AGU Meeting of the Americas, 2013, Cancun. Abstracts AGU, 2013.

3)"The sections “Results and discussions” and “conclusions” are very difficult to follow, the reader (at least me), is not able to easily evaluate the performance of the method. Apart from the problem of using risk maps to validate susceptibility maps (that is not an optimal choice), what the reader would like to know are the % of correctly classified areas and % of misclassified areas. For example looking at figure 10 the results seem not so good: for example in R1, low risk, your model give high and moderate

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

susceptibility..."

-Although the use of "risk sectors" as the validation unit is not usual, it was verified that this type of data can be seamlessly applied to the presented methodology due to two aspects which should be highlighted:

i) The first aspect is due to the way in which the methodology was structured, which resulted in a map that not represents the pure and natural susceptibility. That is explained by inclusion of the land use map in the Fuzzy Gamma step and the highest weight given for urbanized areas class (weight = 1.0). This fact makes the methodology has a bias to represent the most susceptible areas inside urbanized locations, approaching the concept of "risk areas" (and not a pure and natural susceptibility). It is important to notice that it is not relevant for the scope of this paper to identify very high susceptibility in uninhabited areas. Also for this reason, the use of risk sectors makes sense in our standpoint because they could represent the intersection between high susceptibility and possible damages. It is also important to note that there is a necessary condition the existence of a "very high" susceptibility to characterize one risk sectors as "critical" (classes R3 and R4). However, not always one place with "very high" susceptibility will characterize exactly a risk area. Ie, locations with "very high" susceptibility should be understood as a strong indicative of risk, but that should be assessed and confirmed by in-situ evidences. Assuming these aspects, it is clear that it is not expected that the critical risk sectors (R3 and R4 classes) will be composed majority by "very high" susceptibility, but in the meantime, that they have a portion with it. Therefore, the presented results of Figure 10 are consistent with the expected as regarding for R3 and R4. On the other hand, the risk sectors classified as R1 and R2 must have an intermediate landslide susceptibility (predisposing factors), made as described in CPRM document (presented in Table 2): "R1 sectors - The geological and geotechnical predisposing factors (slope, terrain types, etc.) and the level of intervention in the sector are low potential for landslide processes development. There is no evidence of destructive process development on the slopes. Is the less critical condition. Maintained existing conditions, it is not expected the occurrence of landslide events in the rainy period." Thus, we expect that these risk sectors (R1 and R2) have a higher proportion of "moderate" and "high" classes and almost nothing for "very high" class.

ii) The second aspect is the possibility of using RC/RP indices analogous to the LC/LP indices which are widely used in the literature and, thus, allowing comparison of the quality of the results. In this regard, the presented methodology was able to achieve equivalent ratio to satisfying those found in studies of high resolution (LP> 5 %).

4") The fact that this model is limited to translational landslides reduces the significance of the method and makes difficult the comparison with CPRM zonation, which considers many types of landslides."

-The model presented specifically for this study examines the shallow landslides. However, the methodology allows it to be adapted to any other phenomenon that want to map, such as another type of mass movement (rotational landslides or creeps, for example) or even floods maps. For this to be done, the used themes must be revalued and weighting step should be remade under a new point of view that considers intrinsic characteristics to the studied phenomenon. Therefore , the model is not limited only to the shallows landslides. Regarding the validation was done using data from CPRM , it is important to note that shallow landslides are the predominant kind of slope failure mechanisms in the study area. It is rare to find, for example, deep rotational landslides. Thus, although the risk sectors are related to mass movements, it is known that specifically in this region it refers to shallow landslides.

Follows an important reference of the Technological Research Institute of São Paulo State (IPT), evidencing the occurrence of shallow landslides in the region.

Mass movement events in Serra do Mar are known to occur in intervals of 5 to 10 years during the rainy season (Nalon, 2000) and, since the 1920s, there have been records of these processes, mainly debris flows and shallow land-slides that caused

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

several casualties and destroyed some of the local industrial plants (Meis and Silva, 1968; Barata, 1969; Costa Nunes, 1969; Jones, 1973; Vargas Jr. et al., 1986; Wolle and Hachich, 1989; Lacerda, 1997; Fernandes et al., 2004; Lacerda, 2007). In 1929, many shallow landslides were triggered in the city of Santos, located on the foothills of Serra do Mar. Again, in 1956, the same region was affected as the accumulated rainfall reached the value of 373 mm in 24 h, triggering 60 shallow landslides almost simultaneously (IPT, 1986).

References:

IPT (Technology Research Institute of the Sãoo Paulo State): Indicação preliminar de áreas prioritárias para recomposição da cobertura vegetal na Serra do Mar na área de Cubatão, Report, São Paulo, 1986 (in Portuguese)

Costa Nunes, A. J.: Landslides in soils of decomposed rock due to intense rainstorms, 7th International Conference on Soil Me-chanics and Foundation Engineering, Mexico, 1969

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 5199, 2013.