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Delimitation of Flood Areas with HAND Algorithm in the Camanducaia River Watershed, São Paulo, Brazil

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Abstract: The planning and management of water resources, calls for a discussion of the environmental, physical and technological sciences as well as public policies and social issues. Therefore, the management of water resources is exercised in order to have a working environment or to do the same, minimizing the frequency of adverse effects of extreme events as a flood. Likewise, it aims to minimize the frequency of adverse effects resulting from extreme occurrence such as flooding. To do so, it is necessary to map studies of susceptible areas to such event since, taking into account that the numerical modeling stands out as a tool in order to understand the hydrological processes. The Height Above the Nearest Drainage (HAND), a quantitative topographic algorithm, presents itself as a simplified conceptual model, used as a predictive way to delimit flood areas in river basins and is an alternative in the absence of detailed hydrological data for management. The objective of this work is to define more accurately the areas susceptible to flooding from the correlation between the algorithms that determine the HAND model and the surface slope plus the soil map, having as area of study the river basin Camanducaia, located in the state of Sao Paulo. It was found that by inserting in the delimitation of the susceptibility classes data referring to slope and soil map, the definition of the classes of susceptibility to flooding gains greater precision.

Key words: HAND, flood, digital elevation model

1. Introduction

The planning and management of water resources, calls for a discussion of the environmental, physical and technological sciences as well as public policies and social issues [1]. Therefore, the management of water resources is exercised in order to acquire environmental or economic benefits, in the same way, minimizing the frequency of adverse effects resulting from extreme events such as flooding. For this purpose, it is necessary to map studies of susceptible areas for such event, as the numerical modeling stands out as a tool in order to understand the hydrological processes.

An approach to estimating the extent of areas susceptible to flooding in a static manner involves correlating the numerical topographic surface with a water surface corresponding to the interpolation of the interpolation observed flood levels [2].

There are also complex methods that involve numerical modelling to estimate the extent of flooding and describe the continuity and movement of water, these models are termed as hydrodynamic [3, 4].

However, these approaches involve a complex input of the user's knowledge and also a quantity of available hydrological data. In another perspective, there is the simplified conceptual model [5] to delimit the areas susceptible to flooding. This model involves the use of topographic data acquired by remote sensing or the vectorization of topographical maps. The Height Above the Nearest Drainage (HAND), is a quantitative topographic numerical model [6-8], used as a predictive way to delineate flood areas in hydrographic

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basins and is an alternative in the absence of detailed hydrological data for management [5, 9]. This model has already been applied to map the hydrological risks in the metropolitan region of São Paulo and in the Itajaí's river basin in the state of Santa Catarina [9-11].

The objective of this work is to delineate more accurately the areas susceptible to flooding from the correlation between the algorithms that determine the HAND model and the surface slope plus the soil map, having as area of study the river basin Camanducaia, located in the state of São Paulo.

2. Material and Methods

For the mapping of areas susceptible to flooding, a Digital Elevation Model (DEM) was used in this work with the spatial resolution of thirty meters from the planialtimetric charts on the scale of 1:50,000 of the Instituto Brasileiro de Geografia e Estatística (IBGE). In addition, the HAND model, the slope values and the soil map [12] of the Camanducaia river basin in the state of São Paulo.

For the processing of the slope algorithm and the construction of the DEM, the ArcGIS Geographic Information System (GIS) [13] was used. and the elaboration of the HAND was through the model available on the website of the National Institute of Space Research (INPE)[1].

2.1 Study Area

The study area is understood as the watershed of the Camanducaia river, which integrates the hydrographic basins of the Piracicaba, Capivari and Jundiaí rivers (PCJ). The studied basin has approximately a total area of 110,463 hectares distributed by the municipalities of the states of Minas Gerais and São Paulo (Fig. 1A). However, the analysis of areas susceptible to flooding with the HAND model comprises the portion of the watershed of the state of São Paulo.

2.2 Digital Elevation Model

The development of the MDE was developed by the algorithm presented by Hutchinson [14]. The algorithm interpolates elevation data into a regular grid minimizing roughness and removing spurious depressions from the terrain. The interpolator uses the multi-grid method to soften the grid, using the Gauss — Seidel iterative mode by the succesive over — relaxation (SOR) process. The process transforms grids with coarse resolutions in fine resolutions with algorithm respecting constraints attributed by drainage lines, depressions and lakes based on georeferenced files indicated by the user. When the algorithm is processed with the drainage data, the accuracy of the model increases as the interaction process removes the anomalies that automatic drainage does not identify.

2.3 Declivity

Acquisition of declivity values occurred by the Horn Method [15] which proposes a slope map by the weighted average of the maximum values in relation to the central point of a 3X3 regular grid using the eight nearby neighbours, causing the errors of DEM do not contribute intensively to the slope estimation errors. Then the slope map was classified according to the norms of EMBRAPA [16], plus the classification for areas below 2% slope that are susceptible to flooded [17] (Fig. 1C).

2.4 Height Above the Nearest Drainage (HAND)

The HAND quantitative topographic algorithm [6-8] presents itself as a simplified conceptual model, used as a predictive way to delimit areas of flooding in river basins and is an alternative in the absence of hydrological data detailed for management [5, 9].

The model normalizes the topography by measuring the altimetric difference between any point in the grid of a DEM and its drainage point in the drain network. It is directly related to the gravitational potential of draining each point of the DEM [7].

[1] http://www.handmodel.ccst.inpe.br.

The HAND does not involve any simulation of the physical processes of flooding as in the case of hydrodynamic models. The surface of the water is considered horizontal due to the lateral hydrostatic equilibrium, which leads to an estimate limited to the maximum extent of a stationary flood [10]. In general, the lateral hydrostatic balance implies that if a pixel value is less than the height of the water level, that pixel is considered as a flooded level [5, 9] (Fig. 1B).

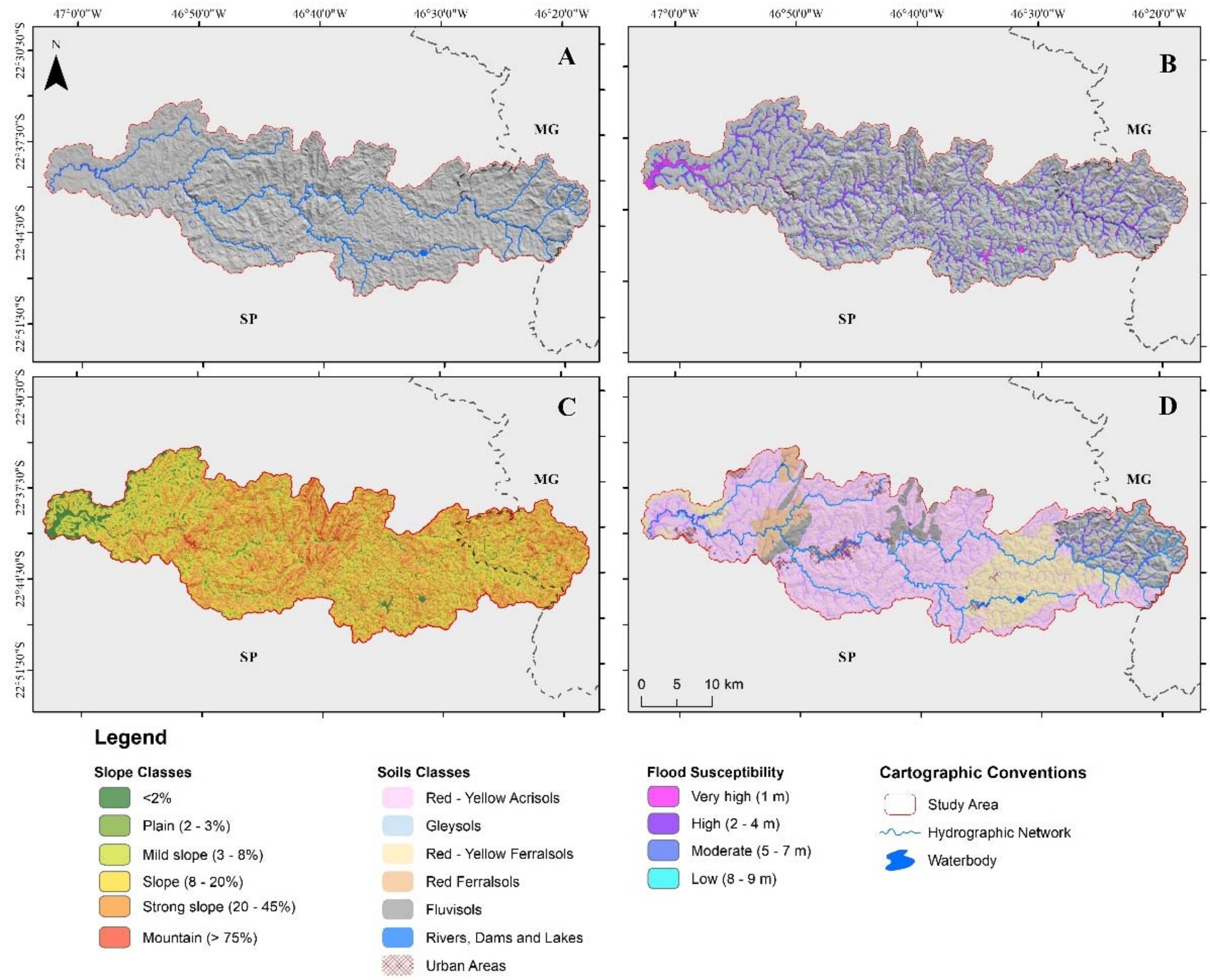

Fig. 1 A: Map of the location of the catchment area of the Camanducaia river. B: HAND: Distribution of areas susceptible to flooding. C: Classes of slope (%) of the study area. D: Distribution of soil types (1:250,000) in the catchment area of the Camanducaia river in the state of São Paulo.

2.5 Areas Susceptible to Flooding

The junction of the HAND with the soil map [12] (Fig. 1D) and the slope values allows the classification of the watershed in environments considering the canal-channel connectivity [7], with a smoother spatial scale, in which normalizes the ground for the analysis of water and soil interaction, resulting in the delimitation of environments susceptible to flooding with a higher accuracy (Fig. 2).

3. Results and Discussion

Overall, the results showed that the highest concentration of flood-prone areas in the Camanducaia river basin are found in the Red-Yellow Acrisols soils with an average of 8 km² when considering the slope

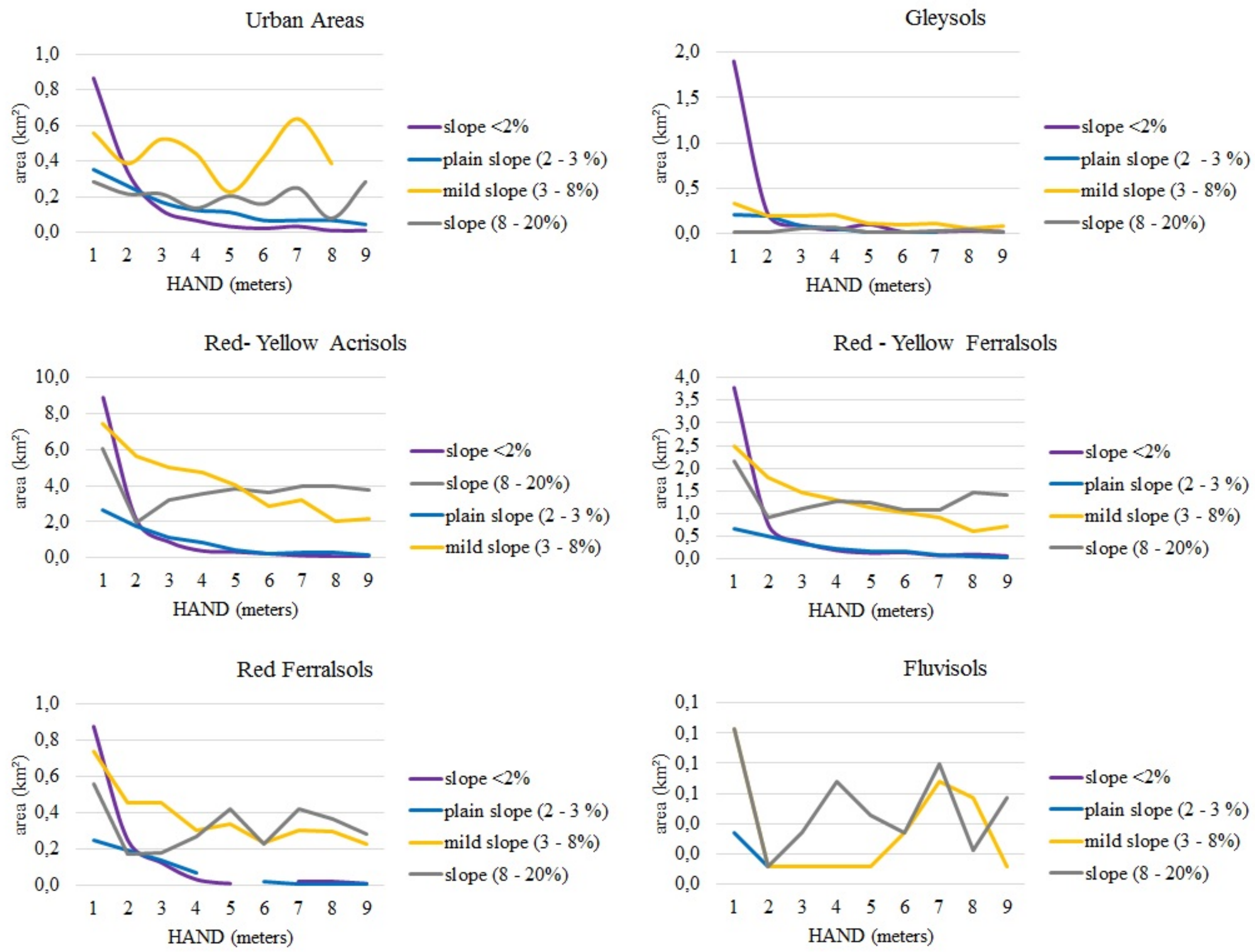

Fig. 2 Distribution of soils by areas susceptible to flooding considering slope classes.

below 2%. This result is consistent, since the areas of Acrisols have more restrictive characteristics to percolation of water, due to the more significant textural relation between one horizon and another. With the increase of clay the water finds resistance to infiltration in the profile, saturating the surfacial horizons and accelerating the process of surface runoff and erosion. In events of prolonged precipitation this can cause natural floods.

However, the areas considered Urban were more likely to flood. Despite the amount of areas susceptible to flooding with slope less than 2% point 900 m², the impact is greater since the soil is waterproofed with low vegetation cover. The result on a short time scale, in periods of precipitation, is a higher rate of surface runoff by altering the response time of the main channel flow to fast than in anthropomised environments with low drainage infrastructure, there is the extrapolation of water to the banks of the river, causing the flooding process.

The other soils presented low distribution in areas susceptible to flooding, but their hydrological characteristics may infer the intensity of the flooding process and the surface runoff. The Red-Yellow Ferralsols, soils with a high infiltration rate and high degree of resistance and erosion tolerance in addition to a high macroporosity are upstream of the Camanducaia river, where the slope is higher in relation to the hydrographic basin [18, 19]. Flooding in these areas is possible however, with low occurrence due to high infiltration rate and slope of the hydrographic basin.

The Red Ferralsols are distributed in the low-course areas of the Camanducaia river in the embedded valley region and the hydrological characteristics of these soils fall within the same group as the Red-Yellow Ferralsols [18]. Finally, the Gleysols soils and the Fluvisols present a lower concentration and close to the drainage network. The first type of soils are on flattened surfaces, in alluvial plains and valley bottoms, places favorable to water saturation. And the second type of soils are distributed in alluvial plains that are preferably located in the border range of the rivers [18]. These soils are favorable to the flooding process or are in flooded areas but their presence is smaller and punctual in the watershed.4. Conclusion

The use of the HAND model was proved simple and useful for the delimitation of possible flood areas. It is a method that can be used for environmental modelling, pedology, hydrology and other disciplines. The use of soil and slope maps plus the HAND values increased the accuracy and the characteristics of the flooding areas in the Camanducaia river basin and thus, this process is favorable for the planning and management of basins in the absence of hydrological data.

Overall, the methodological process used in this study showed that the Camanducaia river basin showed high susceptibility of flooding due to the low rate of infiltration caused by the distribution of Red-Yellow Acrisols, Urban area, Gleysols and Regosols.

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