GULLY EROSION RISK ZONING: PROPOSAL OF A METHODOLOGY AND CASE STUDY

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1. Introduction

Gullying is the most advanced, complex stage of erosion processes, with more local destructive power than other types of erosion (São Paulo, 1990). In this paper, we propose a method to generate gully erosion risk zoning in the far south plateau of Brazil, based on geological characteristics, soils and geomorphology.

2. Methodology

The methodology can be divided into three different stages: data acquisition, data integration using geoprocessing techniques and validation of results.

The data acquisition stage includes mapping the gullies and characterizing the variables that we suppose as they may control gully development. These variables include lithology, lineaments, terrain slope, curvature of the slope on the plane and in profile, catchment area and soils

The gullies were mapped on 1:25,000 scale based on the analysis of aerial photographs (1:60.000), taken in 1996, and field studies. This stage is very important since it indicates areas where the behaviors of variables involving geology, geomorphology and soils should be recognized, as well as the regions that will constitute the samples for two situations or classes: areas with erosion and areas without erosion.

The lithological characterization was based on the description of outcroppings, on geological profiling and petrographic analysis.

The lineaments were extracted from aerial photographs on the 1:110,000 and 1:60,000 scales and analyzed using a rosette diagram to identify the preferential directions.

The geomorphology variables were estimated based on the Numerical Model of the Terrain derived from the planialtimetric map on a 25,000 scale.

Soil distribution was based on surveys performed on a 50,000 scale (Carvalho *et al.,* 1990) and on the description of toposequences (Boulet *et al,*1993).

The data integration stage used geoprocessing procedures to integrate the gully map and the variables data. The result was a gully erosion risk zoning.

The spatial data integration model used was Bayesian (Eastman, 1999), which expresses the *a posterior*i probability that an hypothesis that is previously known will be true according to new evidence. The *a priori* probability, i.e., the probability that the hypothesis will turn out to be true despite the evidence, for *potential area for gullying*, was estimated to be 7% based on the sum of gullies catchment areas. Consequently, the probability for *potential area of the non-occurrence of gullying* was 93%.

Using *a posteriori* probability for *potential area for gullying,* we empirically determined five potential risk classes for gully erosion, ranging from very low to very high (Table 1).

Table 1. Risk of erosion considering the probability of gullying.

Probability (%)	Potential risk
0 – 30	Very low
30 – 50	Low
50 – 70	Moderate
70 – 90	High
90 – 100	Very High

3. Description of the Area

The methodology proposed was applied in the Taboão Creek Catchment, in the far south of Brazil, a part of the Prata Basin drainage system, with an area of approximately 100 km?.

The rocks in the area are mainly volcanic with basic composition intercalated by volcanogenic sedimentary horizons.

The relief is characterized by homogeneous dissection and consists of mild, well-rounded hills. Basin relief ranges from 330 to 495m. The mean slope in the basin is 8%, although in the valleys the slope varies from 10 to 20%.

The soils are predominantly clayey (mainly Oxisols). These soils have inherent resistance to erosion in their natural state due to the high degree of clay flocculation, high porosity, good permeability, and to the fact that they occur in areas with a mild relief. However, if badly managed, they tend to develop a dense surface layer which favors water runoff and consequently erosion.

The regional climate is temperate, without distinct wet and dry seasons (Nimer, 1989). Mean annual precipitation is 1,700 mm and the monthly distribution of precipitations is remarkably uniform, between 120 and 160 mm from 1945 to 1985. (Chevallier and Castro, 1991). However, major annual and monthly variations were recorded in 1992 and 1997, due to the El Niño effect (Castro *et al*., 1993).

Concerning to agriclutural landuse, 90% of the area is used for crop and cattle production, with soybean as the main crop. The planting technique used is no-till, where the number of times the machines pass over the soil has

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diminished compared with the practices used until the 1990s, which were greatly responsible for the onset of erosion. (Castro *et al.*, 1993, 1999).

4. Results

The zoning of potential risk areas for gully erosion in the Taboão Catchment indicates that most of the area (78%) presents a very low risk of erosion and only 12% of the area presents high and very high risk for gully erosion.

The characterization of five potential gully erosion risk classes based on the variables that describe the geology, geomorphology and soils, showed that the relationships between these variables and risk classes are not completely linear. An example would be the mean slope of the terrain in the areas occupied by different risk classes. Although erosion risk shows a tendency to rise as the mean slope of the terrain increases, the mean slope values found in the areas with low erosion risk does not follow this trend.

A clear linear relationship was found between gully catchment area and erosion risk. The values for the different classes show that the portions of the basin that are more susceptible to erosion are with larger contributing areas.

The behaviors of the slope curvatures in profile and on plane are different from expected. While the percentages of slopes with a convex profile are approximately constant in all risk classes, the concave and plane shapes vary greatly and irregularly from class to class. Despite this, the concave slope shows a tendency to increase as the erosion risk becomes higher, and reaches up to 54% of the area occupied by the very high risk class. On the other hand, the plane slope tends to occur less frequently, as the risk of erosion increases, it varies from 85% in the very low risk class to approximately 33% in the very high erosion risk class. Concerning to slope curvature on plane, the plane shapes become less frequent as the risk of erosion increases. This trend was also observed on concave slopes, although not so clearly. The convex shapes diminished as the risk of erosion increases, but from the moderate risk on they are more frequent.

There are very clear relationships between the geology in the Taboão Catchment and erosion risk. Sandstones are more frequent as the potential risk for gully erosion increases. This relationship is much clearer if the lineaments are considered since 82% of the areas at a very high risk of erosion are related to lineaments whereas these occur in only 3% of the very low risk areas. For the lineament direction, we found that the NE direction is linked to the very low and low erosion risk classes, and this association significantly diminishes as the risk increases. On the other hand, lineaments in the NW direction are more profound with the increased risk of erosion and they predominate in the high and very high erosion risk classes.

The most significant relationship between soil and erosion risk zoning is demonstrated by the soils of the mapping units related to higher terrain slope, which show a considerably increased surface as the potential erosion risk increases.

The validation of zoning of the potential gully erosion risk can be performed by identifying the potential risk in places where gullies have been mapped. It is observed that about 78% of the gullies are located in areas with *high and very high erosion risk*.

Lithology and soils are main factors responsible for gully development in areas where erosion risk is moderate, low and very low. Sandstones are the substrate of 70% of these gullies and the soils of mapping unit related to higher terrain slopes are much more frequent in these cases than in the others.

5. Conclusions

The methodology used to look at the risk of gully erosion as a function of geology, geomorphology and soil is proved appropriate for the study area. That was shown by the validation of zoning of the potential gully erosion risk.

The results obtained show that the variables control in different ways the development of gullies and that their characteristics which determine the classes of erosion risk indicate their interactive nature. However, the fact that there is no full agreement between the gullies and areas with *high* and *very high erosion risk* may indicate that the variables chosen are not the only ones that control the phenomenon of gully erosion in the study area.

The clear relationships between the gullies and the lithology, lineaments, and soils indicate that subsurface flow can be a very significant component in gully erosion and it should be further studied.

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