SUSCEPTIBILITY TO WATER EROSION OF SOILS FROM THE MUNICIPALITY SALTO DO CÉU, SW MATO GROSSO STATE, BRAZIL – BRASIL

Maria Cândida Moitinho NUNES[1]
Sandra Mara Alves da Silva NEVES[2]
Ronaldo José NEVES[2]
Jesã Pereira KREITLOW[2]
Antonio Marcos CHIMELLO[1]

Abstract

The evaluation of the potential for soil erosion may assist in the identification and recovery of degraded areas. The aim of this study was to evaluate the potential for soil erosion in the municipality of Salto do Céu, seeking proper planning of land use. In this area, a geomorphologic and soil type subdivision were made. A map on erosion potential was generated, associating the soil maps with erosion potential classes. These classes and the topographic factor originated a map of susceptibility to erosion. The erosion potential map was obtained matching the erosion susceptibility map with the capacity of land use from the area under study. Conflicts arose from the maps of potential erosion and usability. 59.57% of Salto do Céu area consists of Ultisols. In this municipality, 23.41% of its area has very high erosion potential, 67.80% medium erosion potential and 8.79% low erosion potential. Areas with high potential are composed of Entisols and Ultisols (Nitisols). The sites with high potential for water erosion are being used inadequately. In almost the entire municipality there are conflicts among the current land use and the real capacity to support the actual use.

Key words: Geo-Technology. Geographic Information Systems. Degradation. Land use.

Resumo

Susceptibilidade à erosão hídrica dos solos do município de Salto do Céu, região sudoeste Matogrossense – Brasil

A avaliação do potencial do solo à erosão hídrica pode auxiliar na identificação e recuperação de áreas degradadas. O objetivo desse trabalho foi avaliar o potencial à erosão dos solos do município de Salto do Céu, visando o planejamento adequado do uso da terra. Foi realizada a compartimentação morfopedológica da área. O mapa de erodibilidade foi gerado pela associação do mapa de solos com classes de erodibilidade. O mapa de erodibilidade e o do fator topográfico originaram o mapa de susceptibilidade à erosão. O mapa do potencial à erosão foi obtido pela compatibilização do mapa de susceptibilidade à erosão com o de capacidade de uso. Os conflitos foram obtidos a partir dos mapas de potencial à erosão e da capacidade de uso. Salto do Céu apresenta 59,57% de sua área composta por Argissolos. No município, 23,41% da área apresentam erodibilidade muito alta, 67,80% erodibilidade média e 8,79% erodibilidade baixa. As áreas com alta erodibilidade são compostas por Neossolos e Nitossolos. Os locais de alto potencial à erosão hídrica apresentam solos de erodibilidade muito alta, submetidos a atividades antrópicas inadequadas. A maior parte do município apresenta conflitos entre o uso atual e a capacidade de uso da terra.

Palavras-chave: Geotecnologias. Sistemas de Informação Geográfica. Degradação. Uso da terra.

[1] Universidade do Estado de Mato Grosso – UNEMAT/ Campus Cáceres. Departamento de Agronomia. Laboratório de Erosão e Conservação Ambiental. Av. Santos Dumont, s/n. Bairro: Santos Dumont. CEP: 78200-000, Cáceres/MT, Brasil – E-mails: nunes.candida@gmail.com; antoniokimelo@hotmail.com

[2] Universidade do Estado de Mato Grosso – UNEMAT/ Campus Cáceres. Curso de Geografia Laboratório de Geotecnologias Unemat. Av. Santos Dumont, s/n. Bairro: Santos Dumont. CEP: 78200-000, Cáceres/MT, Brasil – E-mails: ssneves@unemat.br; jesapk1@hotmail.com; rjneves@terra.com.br

INTRODUCTION

The economy of the municipality of Salto do Céu, located in SW Mato Grosso State, on the Upper Paraguai (BAP) river basin, is based on cattle raising, with a large number of settlements and small rural properties. Until the end of the 1990s, 78.08% of its area was deforested. In 2002 the deforestation reached 79.67% and this municipality was classified as the one with the fourth largest deforested area in the hydrographic basin of Rio Cabaçal (AVELINO, 2007).

Soil erosion by water is a disaggregation process and transportation of its particles by erosive agents (ELLISON, 1947) whereas erodibility is an intrinsic attribute of each soil and depends on its physical, chemical and mineralogical characteristics (ALBUQUERQUE et al., 2000; NUNES; CASSOL, 2008). Erosion can impoverish the soil productive capacity and consequently increase costs for health and food, besides polluting and silting watercourses (NUNES; CASSOL, 2008). The increase of land occupation in SW Mato Grosso State caused the deforestation of the original vegetation for the installation of pastures and cultures without adequate soil management, originating areas with a high degree of degradation. The susceptibility and the process of water erosion from the soil can be considered as the main factors for the identification of degraded areas. According to Peixoto *et al.* (1997), the increase of the degradation level of natural resources required urgent measures from science and society aiming at its recovery, management and conservation.

Areas of risk for soil erosion by water are subject to imbalances or environmental instabilities which occur as a set of factors from a geo-system, affected by spontaneous natural changes or by human interventions (GÓES, 1994). It is necessary to know the geologic, geomorphologic, pedologic and climatic characteristics of the area under study, because the morphogenetic processes acting on the human environment today are aggravated by the introduction of inadequate technologies and associated practices to a destructive economy, which could drastically and catastrophically trigger these processes (BOIN, 2000). The human occupation of the soil is a decisive factor to accelerate erosive processes, which are led by the water volume falling on the terrain, and by its distribution in time and space, vegetation cover, type of soil/rock and topography (CUNHA, 1995).

Areas of slopes, whose soils suffer under inadequate human actions, present risks to soil erosion. Such risk varies according to environmental instability levels and to the degree of erosivity of the soil. The fast soil erosion process can be magnified by a series of factors (rainfall, flow, soil, slope, and vegetation cover and conservationist practices) (GÓES, 1994). This set of factors is a response to different actions or human impositions such as: deforestation of slopes to plant pastures or subsistence cultures, cattle trampling in medium and low slopes, or opening of access roads on hills and mining activities. Due to its physical attributes, the soils will be more or less vulnerable to erosion. Soil resistance to transport will depend on its natural protection and/or management of adequate use, and conservationist practices (FARIA et al., 2003).

The use of geo-technologies allows the acquisition, manipulation and integration of thematic data, serving as subsidies for the spatial/temporal characterization of areas with susceptibility to erosive processes (VALÉRIO FILHO; ARAÚJO JUNIOR, 1995). The use of GIS helps to conduct field survey, reducing the time to obtain results. Besides that, the combination of geo-referenced information, generated by the system, accelerates of areas of susceptibility to erosion (VALENTE, 1995). Remote Sensing is a tool capable of subsidizing the identification and evaluation of degraded areas, since it contributes to the discrimination of targets with different spectral behavior in the image, because the techniques for processing images are used to identify deforested areas and pastures under impact due to different types of use (SILVA et al., 2007).

The loss of soil due to water erosion, reduces the productive capacity of the land, and can cause the contamination of water flows, causing environmental, economical and social damage. The identification of those places with highest erodibility and erosion potential can help decision-making on land use and on the management system to be adopted, aiming at the conservation of natural resources and biodiversity. The identification of erosive processes in advanced condition, such as in the case of gully formation, can indicate the need of measures to their control or stabilization. In this context, the objective of this study is to evaluate the potential for water erosion of soils in the municipality Salto do Céu, aiming to improve planning of land use.

MATERIALS AND METHODS

Area under study

The municipality of Salto do Ceú is located at SW Mato Grosso State (Figure 1), with a population of 3,908 inhabitants, distributed on a territory of 1,752 km^2. Its population is distributed as follows: urban area 2,185 (55.9%) inhabitants and rural area 1,723 (44.1%) inhabitants (IBGE, 2010).

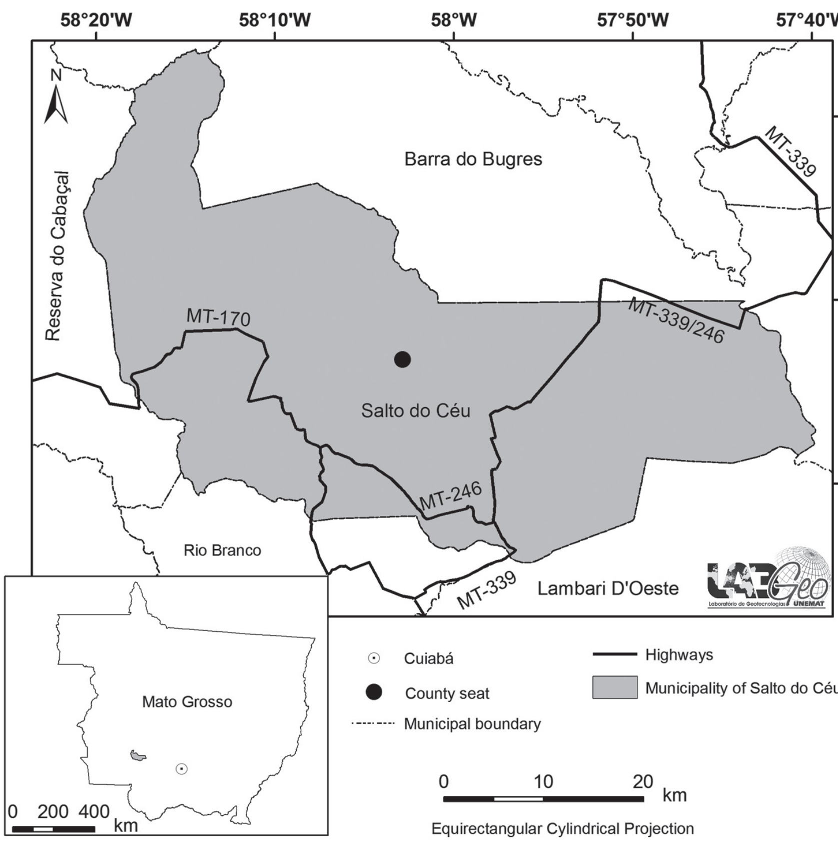

Figure 1 - Localization of the area under study.

Source: Labgeo Unemat (2012)

The municipal area of Salto do Céu is distributed in the biomes Amazonia and *Cerrado* (Savanna) and the predominant soil type is Dystrophic Red Ultisol (SEPLAN, 2007). The climate is tropical warm and sub-humid and the dominant vegetation is Savanna. Its Human Development Index (IDH) is 0.702, below the average of the State (0.773) which, on the other hand, is below the average of Brazil (0.788) (Atlas of Human Development/PNUD, 2000).

METHODOLOGICAL PROCEDURES

For the execution of this work, a survey of mapping data available from public agencies was made (SEPLAN/MT, SEMA/MT, IBGE, MMA, INPE and ANA). The mappings of interest were compiled, matched and organized in a Geographic Databank (GDB) in ArcGIS, version 9.2 from ESRI. Hereafter the methodological steps followed are presented:

1st: The geomorphologic and pedologic subdivision of the area was made, associating data from geomorphologic and soils maps (PCBAB, 1997). Afterwards a refinement was made, inserting information referring to the relief phases (BRASIL, 2007).

2nd: The map on erodibility was generated by an association of the soil maps, whose nomenclature was updated according to EMBRAPA (2006) with the erodibility classes suggested by Salomão (2010).

The association of the erodibility map with the topographic factor (LS) originated the map of susceptibility to water erosion. The definition of classes of susceptibility to erosion, based on the percentage of slope, followed the criteria from IPT (1990).

The map with the topographic factor (LS) corresponds to the map of iso-declivity from the methodology proposed by Salomão (2010), and was obtained by a Digital Elevation Model (DEM), whose images were generated in 2004 by the interferometric SRTM radar (Shuttle Radar Topography Mission), band C, with spatial resolution of 90x90 m. These images were interpolated by Valeriano (2010), presenting afterwards a spatial resolution of 30x30 m. They are available free-of-charge on the site from INPE (http://www.dsr.inpe.br/topodata/). The digital processing of SRTM scenes included: generation of a mosaic, verification on the occurrence of altitude values and inexistence of values (holes) and conversion of the projection. From the radar images processed and the computer techniques used, maps on inclination (declivity) and direction of flow (slopes) were obtained. These maps were reclassified and combined to generate a map of homogeneous ramps, whence values of average declivity and ramp and height of ramp were extracted. Further details of this methodology are found in Fornelos & Neves (2007).

3rd : In order to obtain the map of actual potential to water erosion, matching of the susceptibility map to water erosion with the present land use was made, considering the following classes, as suggested by Salomão (2010):

Class I: high potential – the present land use is incompatible with the laminar water erosion;

Class II: medium potential – the present land use is incompatible with the laminar water erosion, but it may be controlled by adequate conservationist practices;

Class III: low potential – the present land use is compatible with the susceptibility to laminar water erosion.

For the evaluation of conflicts, the information derived from the maps of actual potential to water erosion was analyzed (SALOMÃO, 2010) and so was the land use capacity (LEPSCH, 1991).

The classification of conflict as well as the relation between susceptibility to water erosion and land use capacity was done, based on the methodology proposed by Hermuche et al. (2009).

For the validation of the maps generated, a field survey was made, observing the places of erosion in the municipality Salto do Céu. A GPS for the localization of points with water erosion was used, as well as photographic registration.

The maps generated were submitted to correction with information obtained during the field survey, and in the ArcGIS the layouts and quantification which subside the analysis were elaborated.

RESULTS AND DISCUSSION

The most representative compartment (29.1%) is the number 10 (Table 1) composed by the Dissection System + Distrophic Red Ultisol. The second most representative (20.25%) is compartment 3, representing the Regional Applanation System 2 + Entisol (Quartzipsamment).

Table 1 - Description and representativeness of compartments from the municipality Salto do Céu

Compartments	Geomorphology-Pedology	Area (ha)	Area (%)
1	Dissection system in mounds and hills + Haplic Inceptisol	3.474,351	2,420
2	Dissection system in hills and mounds + Entisol (Psamment)	941,377	0,656
3	Regional system of applanation 2 + Entisol (Quartzipsamment)	29.068,989	20,249
4	Regional system of applanation 2 + Distrophic Red Ultisol	12.013,409	8,368
5	System of floodplain + Distrophic Red Ultisol	2.136,959	1,489
6	Regional system of applanation 2 + Ultisol (Eutrophic Red Nitisol)	4.638,314	3,231
7	Dissection system in hills and mounds + Dystrophic Yellow Ultisol	18.228,561	12,698
8	Dissection system in hills and mounds + Eutrophic Red Ultisol	11.584,875	8,070
9	Dissection system in hills and mounds + Distrophic Red Oxisol	14.455,952	10,070
10	Dissection system + Distrophic Red Ultisol	41.908,170	29,193
11	Regional system of applanation 3 + Distrophic Red Ultisol	5.106,559	3,557
Total		143.557,516	100,000

Overall the municipality presents 59.57% of its area composed by Red Ultisols, which are composed of mineral material, with B textural horizon, immediately below A or E horizons, with low or high activity clay together with low base saturation and/or rich in Al in the major part of horizon B (EMBRAPA, 2006). Ultisols are susceptible to erosion due to the textural gradient and to the abrupt textural change because the sub-superficial horizon, with lower permeability, favors the surface runoff of water and consequently the erosion (CARVALHO et al., 2005).

The compartment 3 (Figures 2 and 3) is composed by soils of type Entisol (Quartzipsamment) which correspond to 16.60% of the municipality area. These soils don't present a stone contact within 50 cm depth, with horizon sequence A – C, but show a sand or frank sand texture in all horizons up to, at least, 150 cm depth (EMBRAPA, 2006).The Entisols (Quartzipsamments) have low resistance to water erosion, due to high sand content and low content of clay and organic material, resulting in low aggregation (BERTOL; ALMEIDA, 2000).

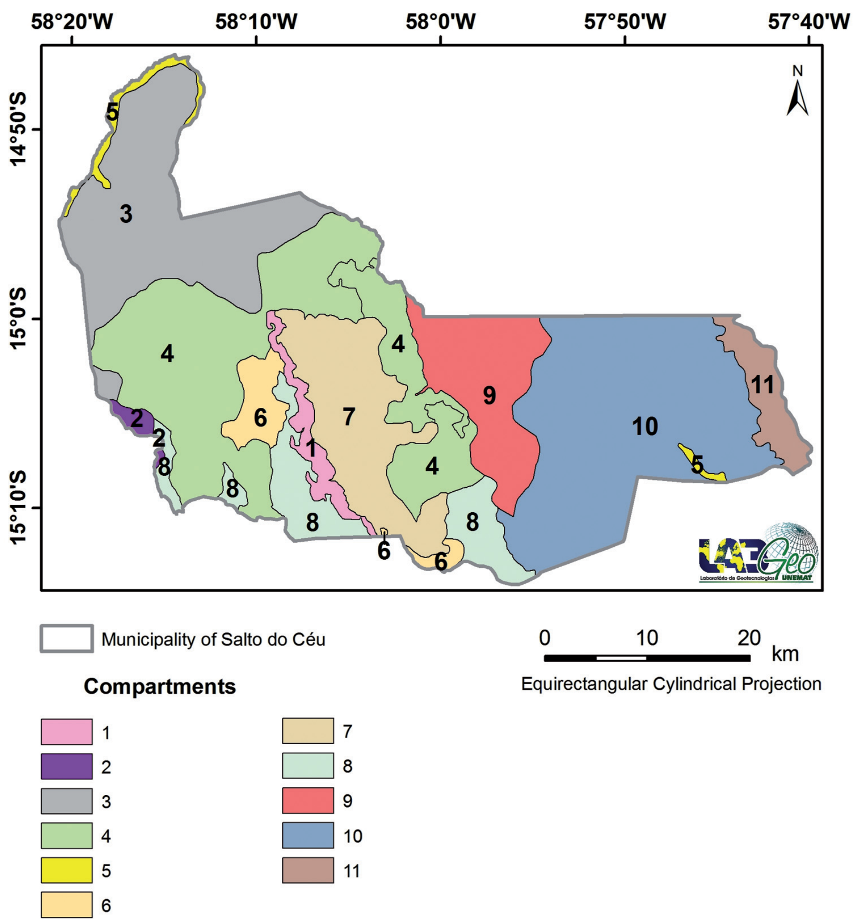

Figure 2 - Map of geomorphologic-pedologic compartments in the municipality Salto do Ceú

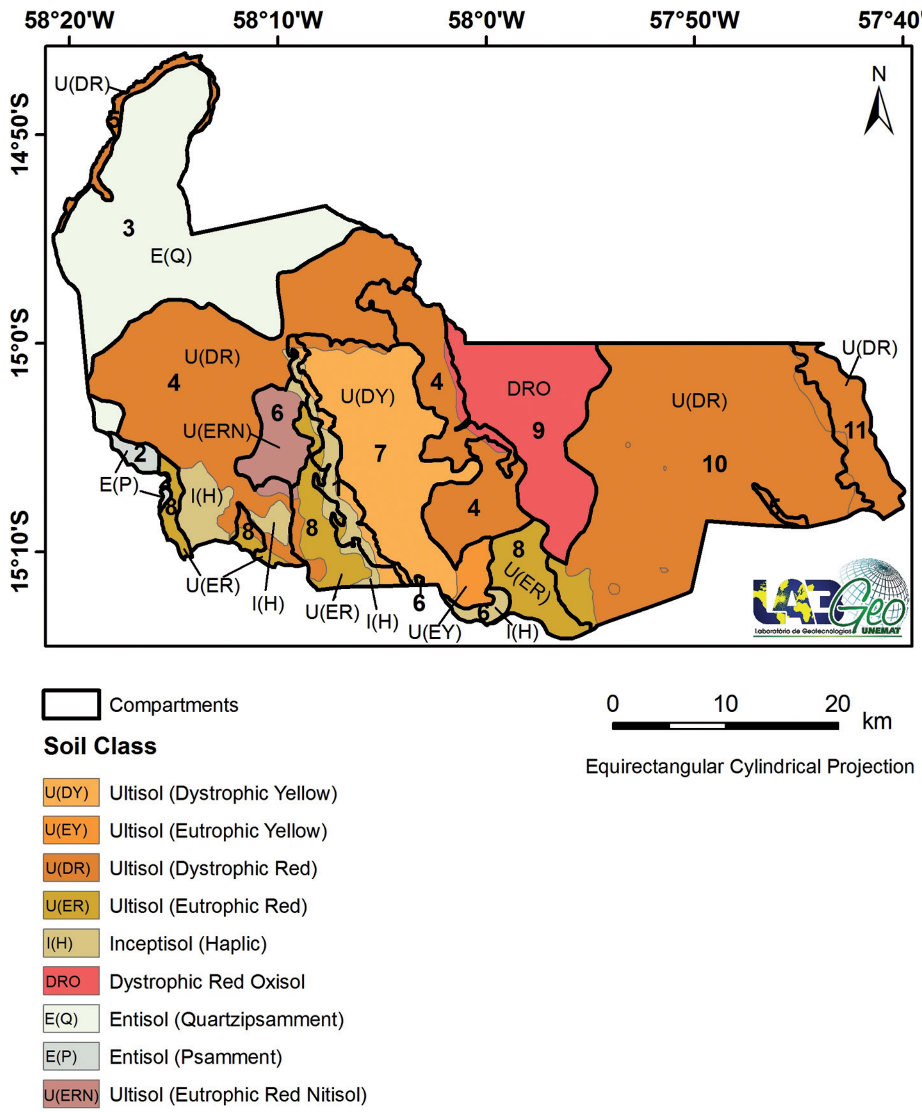

Figure 3 - Map of soils from municipality Salto do Céu

From the municipal area mapped, 23.41% present erodibility classified as very high and medium (67.80%) and low (8.79). Areas with high, low or nil degree of erodibility were not identified (Table 2).

Table 2 - Degrees of erodibility for pedologic units from municipality Salto do Ceú

Degrees of Erodibility	Pedologic Units mapped
Very high	Haplic Inceptisol, Ultisol (Eutrophic Red Nitisol), Entisol (Quartzipsamment), Entisol (Psamment)
High	-
Medium	Distrophic Red Ultisol, Dystrophic Yellow Ultisol, Eutrophic Red Ultisol, Argissolo Amarelo Eutrófico
Low	Distrophic Red Oxisol
Low to nil	-

Those areas with very high erodibility are composed by Entisol (Psamment), Entisol (Quartzipsamment) and Ultisol (Eutrophic Red Nitisol). The largest part of the municipality (91.75%) presents soils with high to medium erodibility. Only those areas with predominance of Distrophic Red Oxisol present a low erodibility degree (Figure 4).

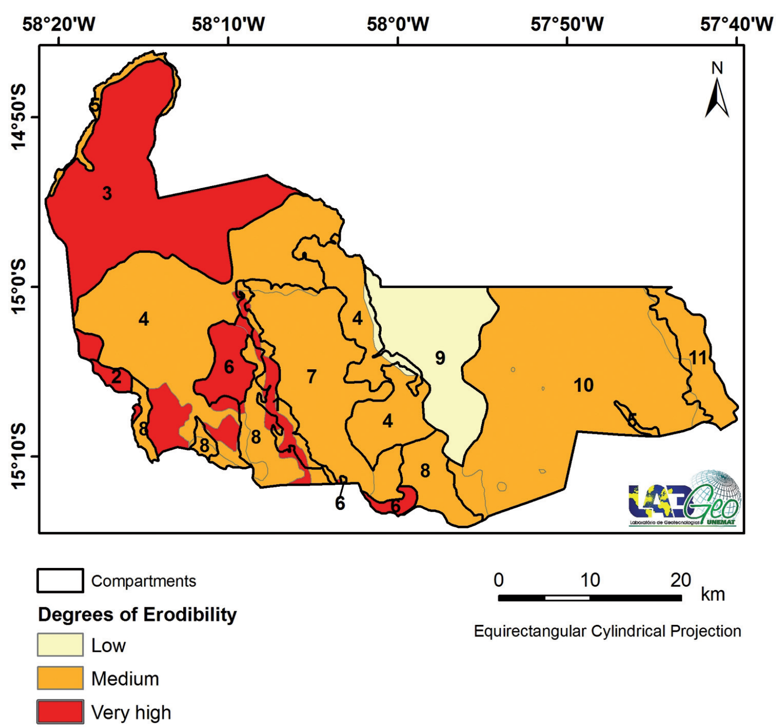

Figure 4 - Degrees of soil erodibility in the municipality Salto do Céu in different geomorphologic-pedologic compartments

The association of the erodibility map with the declivity map (Figure 5) allowed obtaining the map of susceptibility to water erosion (Figure 6), which shows that 98.88% of the municipal area are classified as moderately (18.27%), highly (58.07%) and extremely (22.54%) susceptible to water erosion.

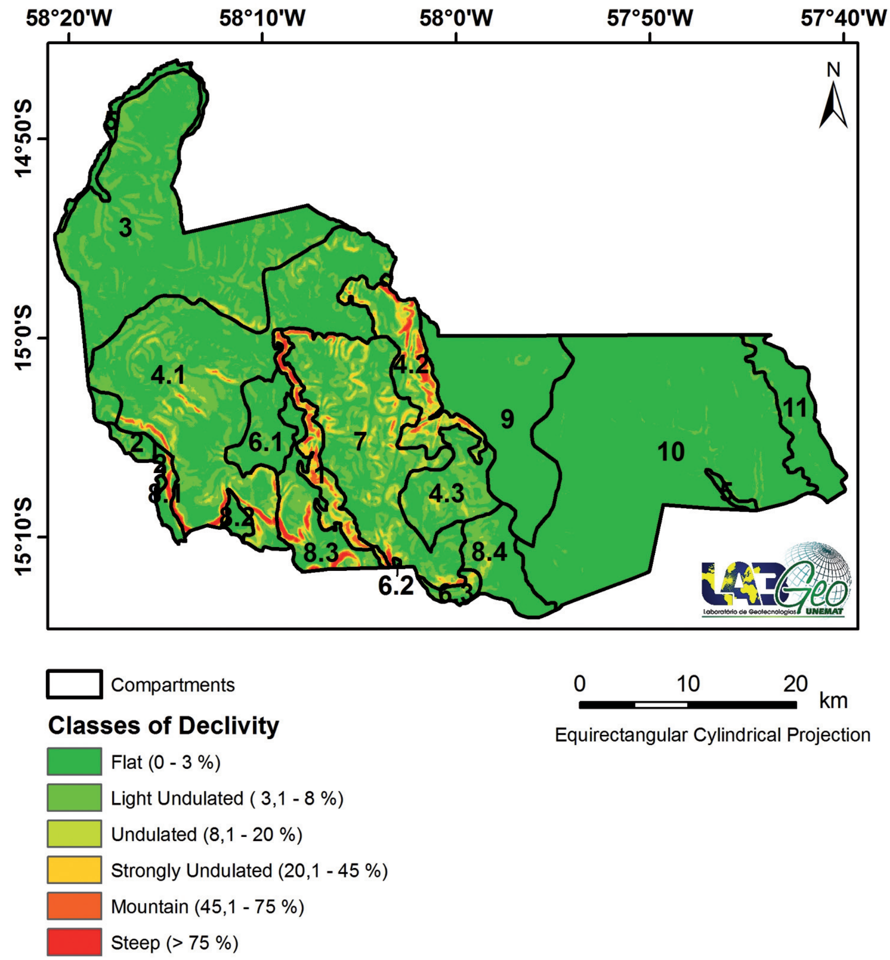

Figure 5 - Classes of declivity in the municipality of Salto do Céu in the different geomorphologic-pedologic compartments

The compartments 2, 3 and 6 are extremely susceptible to water erosion (Figure 6). This is due possibly to the type of soil in these sections (Figure 3), because the relief in these areas is predominantly flat (0 to 3% slope), with erodibility values varying between 82.94%; 92.33% and 94,67% respectively.

The classes of present potential to water erosion (Table 3) indicate that there is an intense human activity in extremely to very susceptible areas to erosion. According to Vitte & Guerra (2004), the inadequate use and management of soil result in accelerated erosive processes, which are generally irreversible.

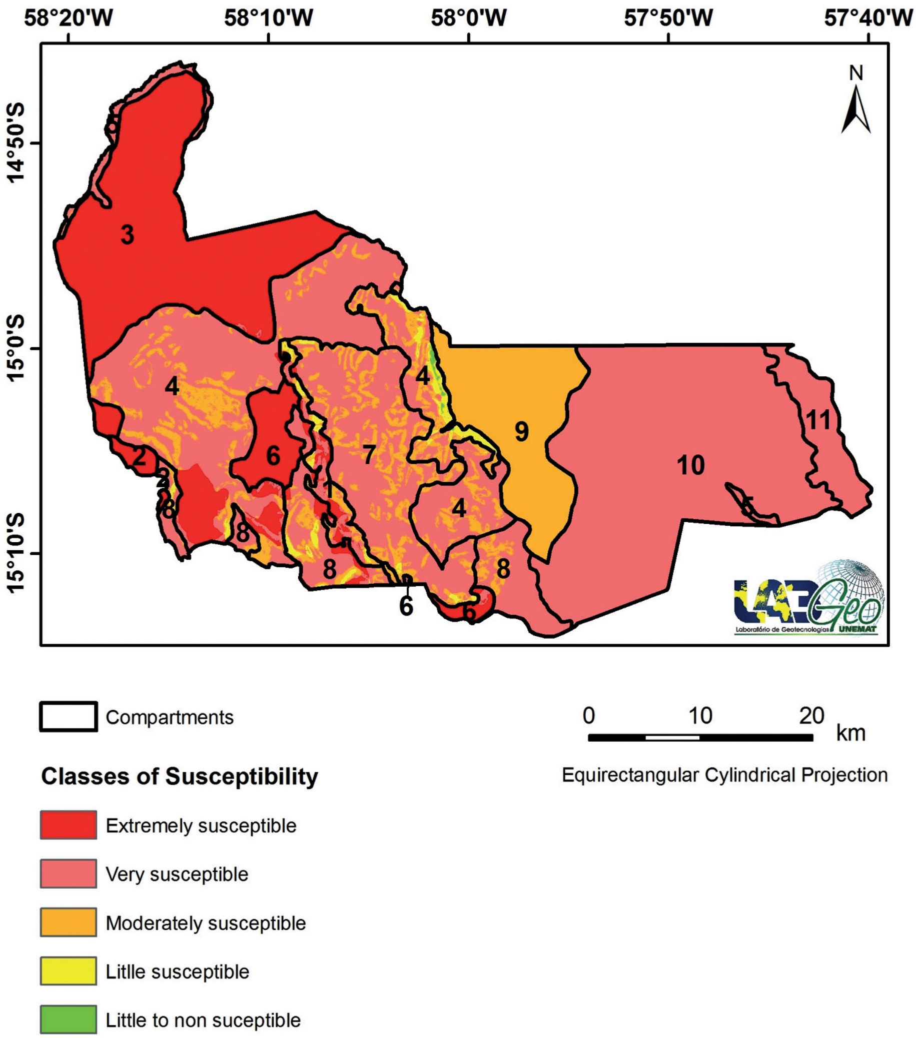

Figure 6 - Susceptibility to water erosion in the municipality of Salto do Céu in the different geomorphologic-pedologic compartments

Table 3 - Classes of potential to water erosion according to the susceptibility of soil to water erosion and actual land use classes

Susceptibility to Water erosion	Present land use classes				
	I Intense human activity	II Moderate human activity	III Very reduced human activity – Low to medium vegetation size	IV Very reduced human activity – High to medium vegetation size	V Water and floodplains
I (Extremely susceptible)	I	I	I	II	-
II (Very susceptible)	I	II	II	III	-
III (Moderately susceptible)	II	II	II	III	-
IV(Little susceptible)	II	III	III	III	-
V (Little to non susceptible)	III	III	III	III	III

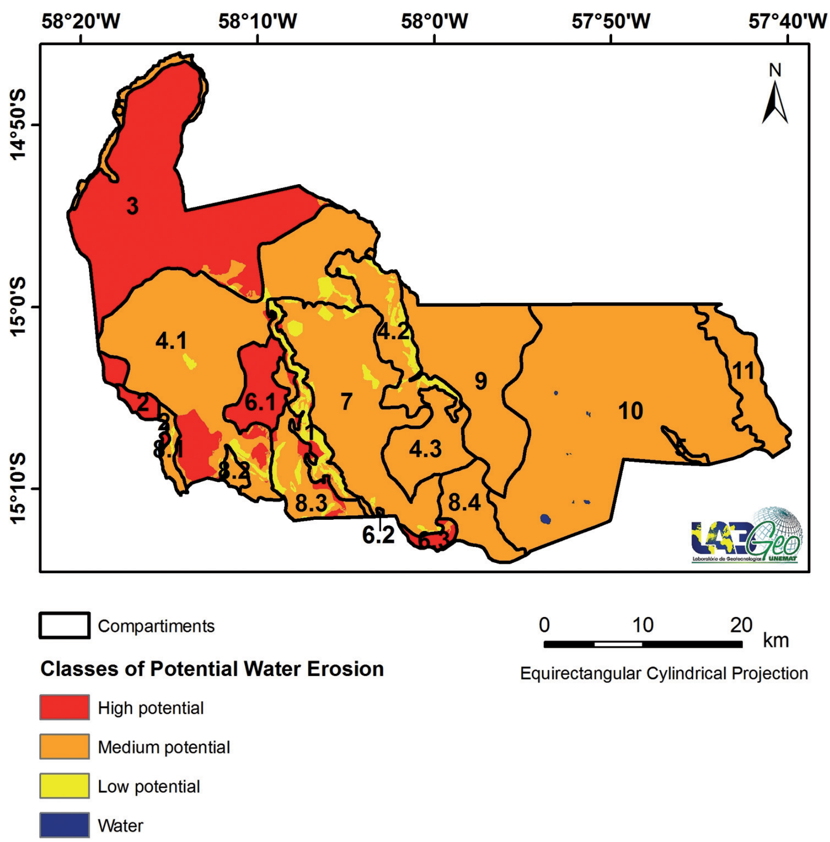

Figure 7 - Present potential to water erosion in the municipality of Salto do Céu in the different geomorphologic-pedologic compartments

In the municipality Salto do Céu, even in places of very reduced human activity and with low to medium size vegetation, if the soil is extremely susceptible to erosion, the potential to water erosion will be high (Figure 7). So the soils from the region under study need detailed evaluation of the erosive processes in the field, in parallel with a strategic monitoring plan, stabilization and/or recovery of degraded areas or with potential for degradation.

Compartment 9, with predominant Distrophic Red Oxisol, in spite of a natural low degree of erodibility (Figure 4) and predominantly almost entirely on flat terrain (99.75%) , presents a medium potential to erosion, probably due to inadequate land use.

The map for water erosion potential (Figure 7) indicates that the places of high potential to water erosion are composed by Entisols, Ultisols (Nitisols) and Inceptisols, which are extremely susceptible soils to water erosion (Figure 4), and were submitted to inadequate human activities.

From data presented in table 4, one verifies that only one of the geomorphologic-pedologic compartments (9.09%) does not present land use conflicts. In most compartments (55.55%) there are low conflicts, in 27.27% medium and in 9.09% high.

In the largest section of the municipality (81.82%) there are clear conflicts related to the actual land use and the capacity for its use. The results obtained indicate that special attention must be given to the soils of the municipality, with field evaluations directed to the identification of prior and strategic places for the recovery or stabilization of the water erosion process, especially when there is a formation of erosion rills.

Compartment/ Geomorphology and Pedology	Area (ha)	Vegetation cover and actual land use	Relief	Susceptibility to erosion	Present potential to erosion	Capacity of use	Conflict
1. Dissection system in hills and mounds + Haplic Inceptisol	3474.35	Cattle raising and secondary vegetation	Undulated	Strongly to extremely susceptible	Low	VI, VII and VIII	Low
2. Dissection system in hills and mounds + Entisol (Psamment)	941.38	Cattle raising	Flat	Moderately to extremely susceptible	High	IV, VI, VII and VIII	Medium
3. Regional applanation system 2 + Entisol (Quartzipsamment)	29060.99	Semi-deciduous sub-montane forest, Savanna Woodland with riparian Forest, Savanna with Forest, Cattle raising, Secondary vegetation.	Flat	Moderately to extremely susceptible	High	IV, VI, VII and VIII	Medium
4. Regional applanation system 2 + Distrophic Red Ultisol	43612.95	Semi-deciduous sub-montane forest, Savanna Woodland with riparian Forest, Savanna with Forest, Cattle raising, Secondary vegetation.	Light undulated	Moderately to very susceptible	Medium	IV and VI	Low
5. System of floodplain + Distrophic Red Ultisol	2136.96	Area of ecological tension with contact between Savanna (S) and Seasonal Forest (C or F) and Savanna with trees and Riparian Forest.	Flat	Very susceptible	High	VI	Nil
6. Regional applanation system 2 +Ultisol (Eutrophic Red Nitisol)	4638.31	Cattle raising and secondary vegetation	Light undulated	Extremely susceptible	Medium	VII e VIII	High
7. Dissection system in hills and mounds + Dystrophic Yellow Ultisol	18228.56	Semi-deciduous seasonal sub-montane Forest, cattle raising and secondary vegetation	Light undulated	Moderately to very susceptible	Medium	IV e VI	Low
8. Dissection system in hills and mounds + Eutrophic Red Ultisol	11584.89	Area of ecological tension with contact between Savanna (S) and Seasonal Forest (C or F) and Savanna with trees and Riparian Forest, Woodland Savanna, cattle raising and secondary vegetation.	Strongly undulated	Moderately to very susceptible	Medium	IV e VI	Medium
9. Dissection system in hills and mounds + Distrophic Red Oxisol	14455.96	Area of ecological tension with contact between Savanna (S) and Seasonal Forest (C or F) and Woodland Savanna with Riparian Forest and cattle raising.	Flat	Moderately susceptible	Medium	IV	Low
10. Dissection system + Distrophic Red Ultisol	41908.17	Area of ecological tension with contact between Savanna (S) and Seasonal Forest (C or F) and Woodland Savanna with Riparian Forest, water and cattle raising.	Flat	Very susceptible	Medium	VI	Low
11. Regional applanation system 3 + Distrophic Red Ultisol	5106.56	Area of ecological tension with contact between Savanna (S) and Seasonal Forest (C or F) and Woodland Savanna with Riparian Forest, water and cattle raising	Flat	Very susceptible	Medium	VI	Low
Total	175149.08						

Table 4 - Characterization of geomorphologic-pedologic compartments and classification of land use conflicts in the municipality Salto do Céu

CONCLUSIONS

The execution of this study allows the following conclusions: 59.57% of the area from the municipality is composed of Ultisols; 91,21% of the area mapped present medium to very high erodibility. The sections included in these classes are composed by Entisol (Psamment), Entisol (Quartzipsamment) and Ultisol (Eutrophic Red Nitisol);

The municipality presents 98.88% of its area classified as extremely to moderately susceptible to water erosion;

Those places with high potential to water erosion are composed by soils extremely susceptible to erosion, submitted to inadequate human activities;

The high erosive potential of soils from the municipality can damage the local agrarian and cattle raising productivity, besides contaminating and silting the river courses in the region and also environmentally damage the *Pantanal Matogrossense*;

Most part of the municipality presents clear conflicts in the comparison between present land use and land use capacity;

The geo-technologies (GIS, Geographic Databank, GPS and DEM) are indispensable to generate the information and conclusions presented, allowing both a qualitative and quantitative environmental evaluation.

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