

GEOPROCESSING TECHNIQUES AND MODELLING APPLIED TO MONITOR EROSION OF TROPICAL SOILS

Mario Valerio Filho
Geraldo José Lucatelli Araujo Junior

Instituto Nacional de Pesquisas Espaciais - INPE,
P.O Box 515, 12.227-010 - São José dos Campos - SP-Brazil

Comission VII, Working Group 6

KEY WORDS: Remote Sensing, Modelling, Geoprocessing, Soil Erosion.

ABSTRACT:

This work presents a study that was made in an agricultural watershed (eastern São Paulo State, Brazil) and its purpose was to monitor soil erosion susceptibility areas and to provide information for rural planning. A Geographic Information System - GIS (SGI/INPE) was used to integrate physical parameters of the Universal Soil Loss Equation - USLE model adjusted. Erosivity, Erodibility, Slope Length, Slope Steepness, Land Use and Management and Conservationist Practices USLE factors were integrated in a GIS environment to obtain the soil loss estimation and characterization of areas under erosion process during 1988 and 1994. The erosion susceptibility maps provide an estimate and spatial distribution of areas with erosion risk as well as the monitoring of critical areas and provided further information for soil conservation planning.

1. INTRODUCTION

The great demand for food production for the growing population, has consequently caused the occupation of all agricultural lands without considering the capability potential of these areas. The results of this occupation is the loss of natural soil fertility, changes of water quality and silting of rivers and reservoirs.

For a rational land occupation and agricultural production it is important to establish agricultural policies which consider the food production needs and environmental conservation issues, specially considering soil and water conditions.

Geoprocessing techniques involving remote sensing and geographic information systems are important tools which allow the acquisition and integration of thematic data (Bocco and Valenzuela, 1988; Zhou, 1989; Castro, 1992; Olson et al., 1994) and also provide inputs for the spatial/temporal characterization of areas under erosion process at the watershed level, and characterization of soil erosion susceptibility.

In this context several works have been developed using loss estimate model Universal Soil Loss Equation-USLE (Wischmeier and Smith, 1978). There are several studies using USLE model such as: Ventura et al. (1988); Pinto (1991); Donzeli et al. (1992); Valerio Filho et al. (1993); and Mellerowicz et al. (1994).

This study presents a methodology of modelling and geoprocessing techniques for the characterization and

monitoring of areas submitted to soil erosion in 1988 and 1994.

2. METHODOLOGICAL PROCEDURES

The area under study is the watershed of Ribeirão Bonito, located around the lake of Barra Bonita, in the centre of São Paulo State, Brazil, located at S 22° 38' 11", to S 22° 27' 15" and W 42° 11' 52" to W 42° 06' 16".

The Ribeirão Bonito watershed is a natural landscape unit insert among the boundary of two larger geologic-geomorphologic units: Peripheral Depression, made up mainly by sandstones and the Front of Cuestas, a structure of sandstones and basaltic rocks. The escarpment, where this river is born, defines different runoff conditions, mainly at the medium and lower course at the Periferic Depression, characterizing wide and smooth interfluves and low relief energy.

The soil map is represented by six large groups with variations in physical and chemical characteristics. Agricultural production is concentrated at the lower and middle portion of the watershed, represented mainly by sugar cane plantations, summer crops, pastures and reforestation.

To perform this study, the USLE - Universal Soil Loss Equation, (Wischmeier and Smith, 1978) was used as an analytical guide to process and integrate the environmental data available. The USLE model is a function of six environmental and anthropic variables:

$$A = f (R \cdot K \cdot L \cdot S \cdot C \cdot P)$$

where A is the soil loss suitability index, R- erosivity, K- erodibility, L · S- topographic factor, C- land use and management and P- conservationist practices, were obtained from maps and available data (erosivity and erodibility), topographic charts (topographic factor - LS), L= slope length and S= Slope steepness. Finally an analysis and interpretation of digital TM/Landsat products was made as well as field work to obtain information about land use and management (factor C) and conservationists practices (factor P). The data sets were submitted to USLE model that was adapted to the Brazilian conditions (Bertoni & Lombardi Neto, 1985), and using a GIS system, the Natural Erosion Potential (NEP) was obtained by the equation:

$$NEP = R \cdot K (0.00984 \cdot L^{0.63} \cdot S^{1.18})$$

This represents the physical parameters (Erosivity, Erodibility and Topographic Factor). The characterization of areas under erosion processes (EP) was obtained by the ratio :

$$EP = A / At$$

where A = the soil loss suitability according to the USLE model and At = the tolerable index (Bertoni & Lombardi Neto, 1985). Values lower than 1 (EP < 1) indicate non-critical areas, and higher than 1 (EP > 1) points of critical areas.

3. RESULTS

The factors referring to the physical environment for USLE were obtained as follows: Erosivity (R - rainfall factor) was obtained from the Erosivity map of São Paulo State . Due to the small size of the watershed studied, a single value of the R factor was assumed. The Erodibility (K = soil erosion susceptibility) that varies basically according to soil physical characteristics, was determined from a soil survey at semi-detailed level of the area under study. The K factor value was obtained using the mapped soil types correlated with the Erodibility values according to Bertoni & Lombardi Neto (1985).

The Topographic Factor represented by slope length (L) and slope steepness (S) was defined from topographic maps at 1: 50,000 scale. The L factor was obtained by measuring the distance of each point up slope, until the beginning of runoff, and taking into consideration the arrangement of the contour lines. The S factor was obtained by using an analogic abacus directly over the topographic base, considering the distance between the contour lines and the defined six steepness classes.

To obtain the C factor (Land use and soil management), the TM/Landsat scenes (TM 3,4, and 5 bands) were digitally processed at SITIM/INPE (Image Processing System) using contrast stretch, IHS tranformation and enhancement by Decorrelation. The color compositions obtained were visually analysed and the color composites (3B,4G,5R and 3B,5G,4R) were those which best contributed to characterize the land use and land cover classes. Nevertheless the products obtained from IHS transformation and enhancement by Decorrelation from TM bands 3, 4 and 5 were useful to identify some small areas occupied by summer and perennial crops. The analisys of different products and field verification allowed the elaboration of land use and land cover 1:50,000 maps related to 1988 and 1994.

Table 1 presents the quantitative results of land use / land cover classes for the period under study, showing for year 1994 the decrease of areas with perennial crops, sugar cane, natural vegetation and reforestation but one can see the increase mainly of areas with summer crops and pastures of the same date. The information of these maps allow to obtain the factor C for the USLE model. The scale and resolution of the satellite data used limited the characterization of the conservationists practices and so the P factor was defined based on ground information.

Land Use and Land Cover	1988		1994	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Urban areas	96.98	1.00	111.49	1.11
Perennial Crops	177.08	1.84	143.66	1.49
Summer Crops	521.36	5.44	1511.14	15.82
Sugar Cane	3010.79	31.36	2487.03	26.07
Natural vegetation	2375.52	24.80	1860.40	19.46
Reforestation	1149.41	11.97	209.01	2.18
Pasture	2242.33	23.48	3250.74	33.98
Total	9573.47	100.00	9573.47	100.00

Table 1 - Quantitative assessment of land use and land cover classes in 1988 and 1994.

USLE factors related to physical elements such as Erosivity (R), Erodibility (K), Slope Length (L) and

Slope Steepness (S) were integrated to form the Natural Erosion Potential (NEP) for the area under study and they were divided into three levels : low, medium and high.

The integration of A (soil loss suitability) and At (tolerable index) data, allowed the discrimination of areas under erosion process (EP) and areas without erosion and areas of high erosion risks on the timeframe 1988 - 1994. Table 2 presents the quantitative results of critical areas and non-critical areas and it is possible verify that for the year 1994 there is an increase of critical area (58.67% to 65.98).

Classes	1988		1994	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Critical Areas	5616.57	58.67	6316.56	65.98
Non- Critical Areas	3956.90	41.33	3256.91	34.02

Table 2 - Quantitative assessment of areas submitted to erosion processes in 1988 and 1994.

This fact is associated mainly to the reduction of reforestation and natural vegetation areas as well as to the increase of areas planted with summer crops and pasture that present lower soil erosion protection when compared to reforestation and natural vegetation areas.

The analysis of the NEP and EP maps for the two dates shows that the class with high NEP coincides with areas of high erosion risks, although there are areas that present high NEP but without erosion risks due to the presence of natural vegetation and reforestation. The EP maps allows the verification of the influence of land use changes on the erosion process and shows the importance of this kind of information as an input for environmental and agricultural planning of watersheds.

4. CONCLUSIONS

This study shows that, for small watersheds it is possible to monitor soil erosion processes using the USLE model and geoprocessing techniques. The temporal analysis of these areas submitted to erosion risks shows that the most critical areas are mainly associated with summer and perennial crops, growing in incompatible conditions to the land use capability of these areas.

5. REFERENCES

- Bertoni, J.; Lombardi Neto, F., 1985. Conservação do solo. Piracicaba, Livrocere, 285p.
- Bocco, G.; Valenzuela, C.R., 1988. Integration of GIS and image processing in soil erosion studies using ILWIS. ITC Journal, (4): 309-319.
- Castro, A.G., 1992. Técnicas de sensoriamento remoto e sistemas de informação geográfica no estudo integrado de bacias hidrográficas. Msc. Thesis, INPE, São José dos Campos, Brazil. 94p.
- Donzeli, P.L.; Valerio Filho, M.; Pinto, S.A.F.; Nogueira, F.P.; Rotta, C.L.; Lombardi Neto, F., 1992. Técnicas de sensoriamento remoto aplicadas ao diagnóstico básico para planejamento e monitoramento de microbacias hidrográficas. Campinas, Brazil, Instituto Agrônomo de Campinas. Documentos IAC (29), 91-119.
- Mellerowicz, K.T.; Rees, T.L.; Chow, T.L.; Ghanem, I., 1994. Soil conservation planning at the watershed level using the Universal Soil Loss Equation with GIS and microcomputer technologies: a case study. Journal of Soil Water Conservation, 49(2): 194-200.
- Olson, K.R.; Lal, R.; Norton, L.D., 1994. Evaluation of methods to study erosion-productivity relationships. Journal of Soil and Water Conservation, 49(6): 586-590.
- Pinto, S.A.F., 1991. Sensoriamento remoto e integração de dados aplicados no estudo da erosão dos solos: contribuição metodológica. Doctor Thesis, São Paulo. Universidade de São Paulo, Brazil 122p.
- Valerio Filho, M.; Donzeli, P.L.; Pinto, S.A.F., 1993. Remote sensing and data integration to evaluate the potential soil erosion and land capability. In: International Symposium on Remote Sensing and Global Environmental Change, Graz, Austria, (2) 678-685.
- Ventura, S.J.; Chrisman, N.R.; Connors, K.; Gurda, R.F.; Martin, R.W., 1988. A land information system for soil erosion control planning. Journal of Soil and Water Conservation, 43(3): 230-233.
- Wischmeier, W.H.; Smith, D.D., 1978. Predicting rainfall erosion losses - a guide to conservation planning. Agriculture Handbook, 537, U.S. Department of Agriculture, Washington, 58p.
- Zhou, Q., 1989. A method for integrating remote sensing and geographic information systems. Photogrammetric Engineering and Remote Sensing, Falls Church, 55(5):591-596.