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Geoprocessing techniques in the study of the soil erosion potential on agricultural lands

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RESUMEN

Sistemas de Información Geográfica (SIG) y técnicas de Sensoriamento Remoto han sido utilizados en el monitoreamiento de suelos en la región Sudeste brasileña. En el presente estudio, estas tecnologías fueron aplicadas en la caracterización del potencial de erosión de suelos (EP), utilizándose el modelo MUSLE (Modified USLE). El potencial de erosión de suelos de una cuenca hidrográfica de pequeño tamaño fue evaluado en dos escenarios diferentes (1980 y 2000), siendo adoptadas cuatro clases de EP: EP bajo, EP medio, EP alto y EP muy alto. Los resultados demostraron que la erosión potencial de suelos presentó alta correlación con las características del relieve, especialmente declividad y dissecación. Un análisis temporal indicó un aumento significativo en las clases EP medio y EP alto entre 1980 y 2000, explicado por las mudanzas en el uso y ocupación de tierras; éstos con significativa influencia en la determinación del factor Runoff. La metodología empleada se reveló importante para el estudio, garantizada por su gran flexibilidad en términos de entrada de datos, procesamiento y recuperación selectiva.

PALABRAS CLAVE: erosión de suelos, variable runoff, modelo de pérdida de suelos.

ABSTRACT

Geographic Information Systems (GIS) and Remote Sensing technologies have been used for land resources monitoring in the southeastern of Brazil. In the study those technologies were applied to characterize the soil erosion potential (EP) using the MUSLE model (Modified-USLE). The soil erosion potential were evaluated for the 1980 and 2000 scenarios in a small watershed, and four classes were adopted: EP low, EP medium, EP high and EP very high. The results showed that the soil erosion potential has a high correlation with the relief characteristics. The temporal analysis indicated the significant increase of EP medium and high classes between 1980 and 2000 scenarios. The utilizaation of the GIS approach was very important in this study providing the necessary flexibility in terms of data entry, data processing and data retrieval.

KEY WORDS: soil erosion, runoff factor, soil loss model.

INTRODUCCIÓN

Areas of different soil erosion potentials can be analysed based on the runoff, through statistical models which represent the use of variables of the physical and anthropic environment.

The characterization and spatialization of the potential and erosional risks on soils, due to rainfall can be studied using remote sensing techniques and GIS. The data integration through GIS can be done, for example, using predictive models as the Universal Soil Loss Equation - USLE (Wischmeier and Smith, 1978) and its modified version MUSLE (Modified USLE), according to Williams (1975). In Brazil some studies were developed applying the MUSLE model by Donzeli et al (1994) and Pinto (1996). They are used in this study as methodological support.

The main goal of this study was to provide the characterization of the soil erosion potential by rainfall process in a small watershed using geoprocessing techniques and the MUSLE model for two scenarios (1980 and 2000).

METHODOLOGICAL APPROACH

The area studied is part of the Jacaré-Pepira river basin (180 km^2) and is located at the northeast of the São Paulo State, Brazil (22°12'35" – 22°21'30"

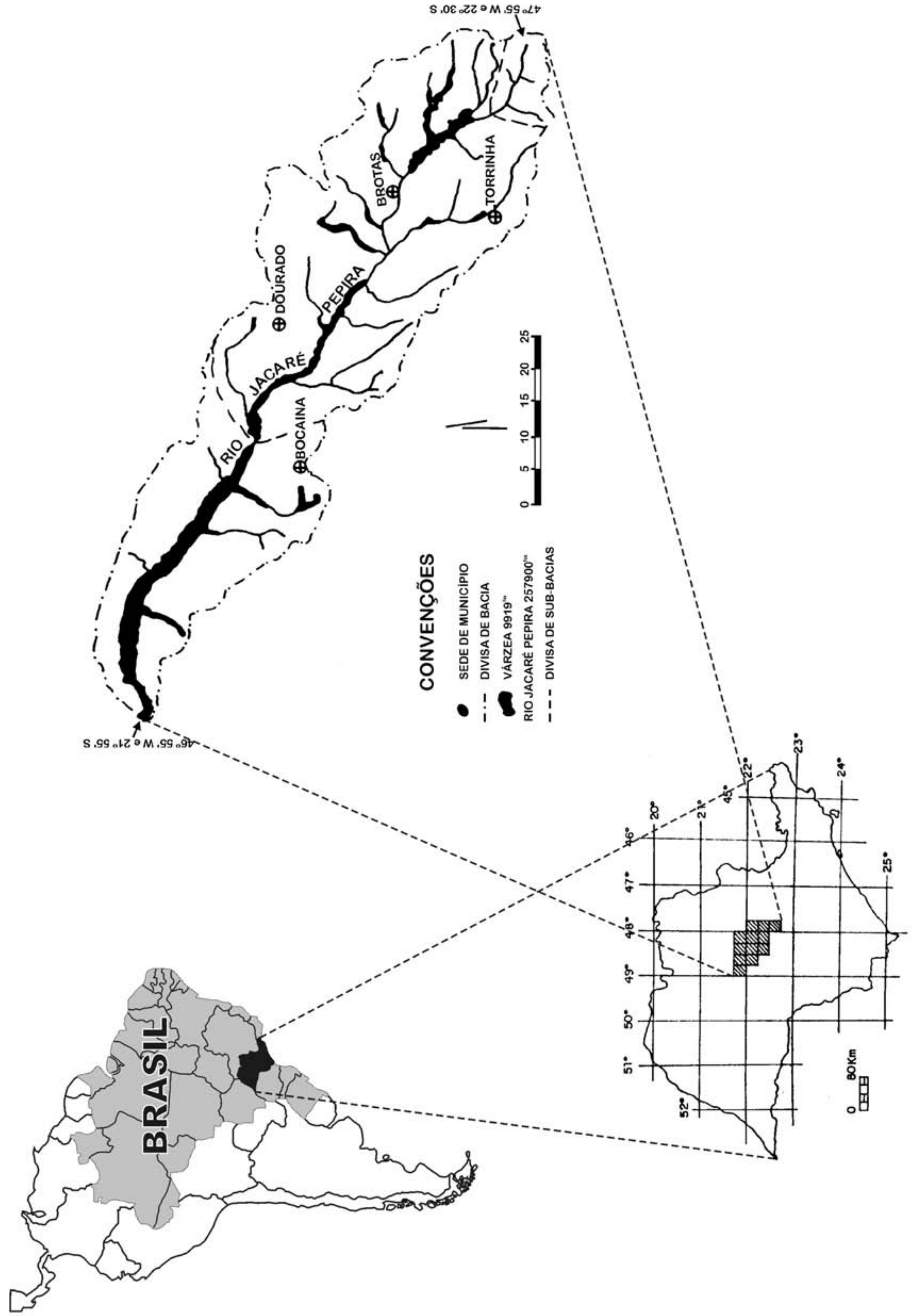

Figura 1. Localization of the study area.

Lat S; 48°08'50" Long W) (Figure 1). The relief is gently undulated. The climate is subtropical humid type CWa according to the Köppen system. The highest temperature is in December ($\overline{m} \cong 25.1°C$) and the lowest in June ($\overline{m} \cong 6.8°C$). Annual average precipitation is 1517 mm and the average precipitation in August is 34 mm and in December 259 mm. The most important soils are: Quartzipsammentic Haphortox (Red Yellow Latosols) 80% of the total area, Typic Quartzipsamment (Regosols) 10%, Typic Eutrorthox (Dark Red Latosols) 5%, Hydromorphic soils 3%, Typic Palendult (Red Yellow Podzols) 2%, (Giometti, 1993).

The cartographic base was prepared by using 1:50,000 topo sheets. Soils and geology thematic maps were also available (1:100,000) as well as LANDSAT digital data (1978 and 1998). These data were processed in a GIS system –SPRING– developed by INPE (Brazilian National Institute for Space Research).

The land use maps were produced considering the following classes: annual crops, sugar cane, citrus, pasture, forestry, dense savannah (cerrado), open savannah (campo cerrado), residual areas of tropical forest, swamp vegetation and urban areas. For the two scenarios the Landsat data were processed using contrast enhancement and IHS transformation techniques as shown in Garcia and Pinto (1998). The land use/land cover overlays were adjusted to the cartographic base for the scale 1:50,000 and the input in the GIS system environment was done through a digitazing table.

To characterize the soil erosion potential (EP) was used the MUSLE model (Williams, 1975), adapted by Donzelli et al (1994).

$EP = R_{unoff} \cdot K (0.00984 \cdot L^{0.63} \cdot S^{1.18})$, where:
EP = Soil Erosion Potential (t/ha);
R_{unoff} = Runoff ($m^3 \cdot m^3/sec$);
K = Soil erodibility factor;
L = Slope length factor;
S = Slope steepness factor

According to the MUSLE model the following data were acquired: Erodibility of soils, from the soil map by Almeida et al (1981) and adjusted by Bertoni & Lombardi Neto (1990) and Donzeli et al. (1992); Slope length and steepness from 1:50,000 topo sheets. The model is implement by two additional variables. The C factor which is derived from land use/cover maps and the P factor which represents the degree of conservation practices measurements. In this study the P factor was considered as 1.0 (without conservation practices).

The term R_{unoff} was used in the equation as adopted and specified by Donzeli et al (1994) and Pinto (1996), as follows:

$R_{unoff} = 89.6 (Q \cdot qp)^{0.56}$, where
Q = Surface flow volume (m^3)
qp - Maximum flow of discharge (m^3/sec)

To determine the equation, the following data were obtained:

- Surface flow volume (Q):
  - Determination of the hydrological classes of soils, considering their types, according to the USDA-SCS (1972) and Lombardi Neto et al (1993).
  - By overlaying the temporal land use (1980-2000) and the hydrological classes of soils were obtained the values of Curve Number (CN), as proposed by the USDA-SCS (1972) for both years. The CN values were transformed in surface flow estimation (Q) using a specific chart as shown in Figure 2. In this study the maximum rainfall intensity used was 115 mm/24 hs, for a return period of 10 years.
- To calculate qp was used the equation adopted and specified by Pinto (1996):

$Qp = 0.278 \cdot (Cx) \cdot I \cdot A^{0.9} \cdot K$, where
Cx = Runoff coefficient
I = Intensity of rainfall
A = Area of the study
K = Coefficient of the rainfall distribution

The values of R_{unoff} coefficient were spatialized for the 1980 and 2000 scenarios, considering the following classes of data: land use/land cover, hydrological classes of soils and relief classes (as defined through geomorphological and slope maps).

All information were integrated with the aid of the GIS system and maps of soil erosion potential classes (EP) were established for 1980 and 2000, according to the MUSLE model (Donzeli et al, 1994).

To characterize the dynamics of the erosion potential an overlaying of the EP80 and EP00 was performed in the GIS environment. The result was a layer of information showing changes on the classes in the context of the two selected scenarios. This overlaying was applied structuring a file of rules to cross the thematic classes.

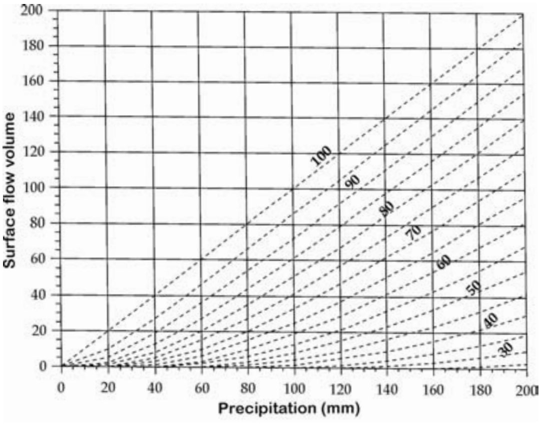

Figura 2. Graph for the estimative of runoff volume.

RESULTS

Using the proposed methodology, the following results were obtained:

1. Soil Erosion Potential (EP)

The soil erosion potential (EP) according to the MUSLE model was characterized for 1980 and 2000 as an indicator of the expectation of the erosion process which could result in a soil erosion by the rainfall over the slope surface.

The EP can be defined by the USLE model as well as by the MUSLE model (Pinto, 1996). The difference between the two models refers to the erosivity of rainfall (R) in the USLE model which is obtained through a rainfall average in a determined time series. In the MUSLE model the R variable is replaced by the runoff factor which is obtained considering a specific rainfall, hydrologic characteristics of soils, classes of slope and status of vegetation cover of the slope.

Using the GIS system, the data of the MUSLE model were integrated, using the methodological sequence discussed above. From the processed data were obtained matrices which were classified resulting in two thematic maps (2000-2002). The classes were defined using the automatic option of the GIS, considering the distribution of values and respectives frequencies. Four categorized classes were adopted: EP low, EP medium; EP high and EP very high (Table 1).

Figures 3 and 4 show the spatial distribution of classes of erosion potential for 1980 and 2000. The data analysis show that the spatial arrangement of classes of erosion potential are closely related with the relief characteristics, mainly slope percent and degree of dissection. These areas are also mostly associated with soils presenting higher erodibility values.

Classes	EP	Qualitative Category
1	0 - 200	Low
2	200 - 1000	Medium
3	1000 - 2500	High
4	2500 - 32400* 35000**	Very High

* Maximum value for 1980
** Maximum value for 2000

Tabla 1. Classes of soil erosion potential (EP).

	SCENARIOS	
EP	1980 (%)	2000 (%)
Low	52.5	28.5
Medium	31.1	52.0
High	9.0	12.4
Very High	7.4	7.1

Tabla 2. Classes of soil erosion potential (EP), 1980 and 2000.

2. Temporal Analysis of the Soil Erosion Potential

Overlaying both maps of soil erosion potential the changes in the spatial distribution in the study area were obtained. Table 2 shows the percentage of classes distribution for both scenarios.

In 1980 the EP low is predominant, while in 2000 the predominance is for the EP medium. The EP high increased from 9.0 % to 12.4 %; the percentage of EP low was significantly reduced and the EP medium shows an important increase. These alterations are due to the changes on the land use and vegetative cover since they have great influence on the determination of the Runoff factor.

The overlaying of the erosion potential maps, in the GIS system allowed to establish seven classes (Figure 5), where areas in the original condition (1980) were remained in 2000 and the changes were toward a more favorable situation or toward a worst situation in terms of soil erosion risk.

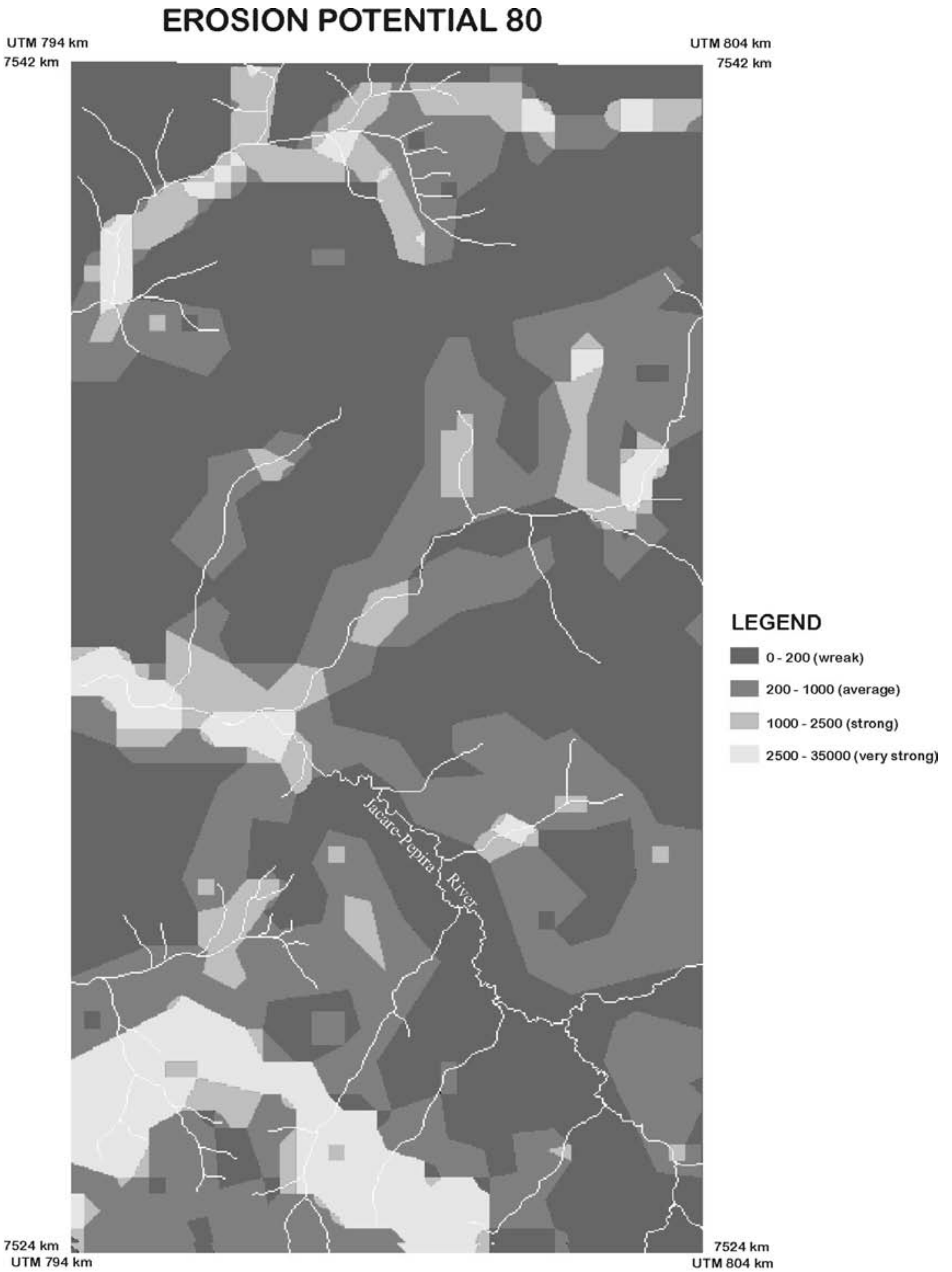

Figura 3. Classes of erosion potential of soils (EP) - 1980.

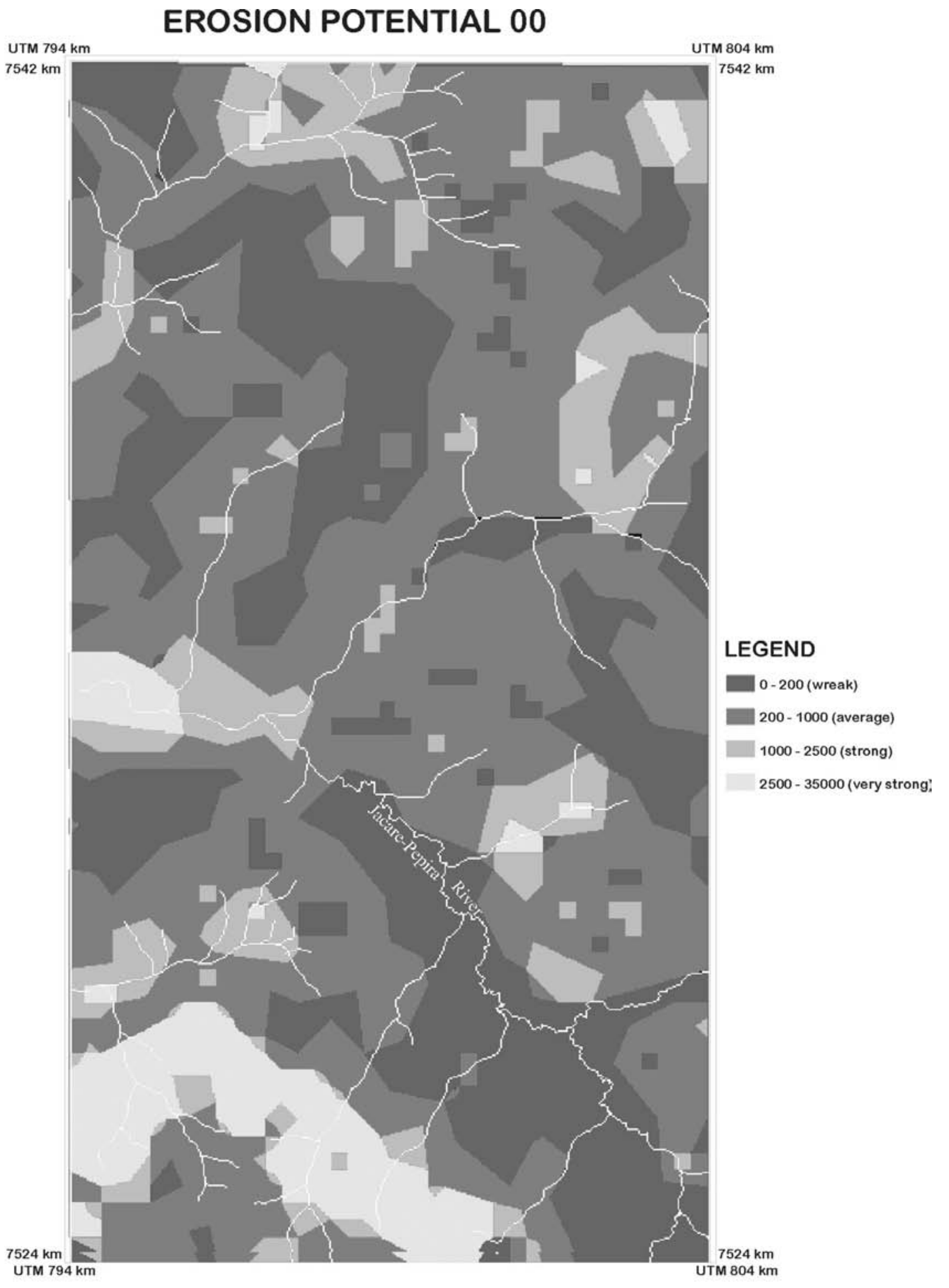

Figura 4. Classes of erosion potential of soils (EP) - 2000.

Table 3 shows the overlayed classes of the soil erosion potential for the two scenarios and the areas in percentage.

Table 3 shows that the area of first class of intersection remained stable for the two conditions of analysis, i.e., there were no alteration of land use cover for this class. Classes 2, 4 and 6 changed toward more restrictions classes, while for the classes 3, 5 and 7 the change were in the direction of less restrictions.

As erodibility of soils, length of slope and slope percent in the MUSLE model are constants for both scenarios, the differences in the classes of erosion potential are explained by the Runoff factor of the model which aggregates land use data, highly dynamic in time and space.

Classes	EP80 x EP00 Classes	Área (%)
1	1 - 1	27.1
2	1 - 2 / 3/ 4	25.2
3	2 - 1 / 2	25.6
4	2 - 3 / 4	5.3
5	3 - 1 / 2 / 3	8.2
6	3 - 4	1.1
7	4 - 1 / 2 / 3 / 4	7.5

Tabla 3. Overlay of the erosion potential classes in 1980 and 2000 (EP80 x EP00) - Percentage of existing classes.

FINAL CONSIDERATIONS

The methodological approach in this study considered geoprocessing techniques (remote sensing and GIS) and a predictive model (MUSLE) to characterize the erosion potential, for two different periods, in an agricultural watershed. The data integration in the MUSLE model through a GIS allowed the characterization of the erosion potential in the same scenario spaced by 20 years.

On the context of these two scenarios, significant changes were observed in the classes of soil erosion potential with an increase on the restrictions for 2000 mainly due to the development of the agriculture areas.

BIBLIOGRAPHY

ALMEIDA, C.F.F., OLIVEIRA, J.B. and PRADO, H. 1981. *Levantamento pedológico semidetalhado do Estado de São Paulo - Quadrícula de Brotas*. Campinas, IAC.

BERTONI, J. and LOMBARDI NETO, F. 1990. *Conservação do solo*. São Paulo, Editora Icone .

DONZELI, P.L., VALÉRIO 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, *Documentos IAC*. 29: 91-119.

DONZELI, P.L., PINTO, S.A.F., LOMBARDI NETO, F., VALÉRIO FILHO, M., VALERIANO, M.M. 1994. Modelo MUSLE e Sistemas de Informações Geográficas aplicados no estudo de pequenas bacias hidrográficas. *Proc. X Reunião Brasileira de Manejo e Conservação do Solo e da Água*. Florianópolis (SC). pp. 141-143.

GARCIA, G.J. and PINTO, S.A.F. 1998. Processamento de imagens TM - Landsat 5 como suporte aos estudos de erosão de solos. *Proc. XVII Congresso Brasileiro de Engenharia Agrícola*. Poços de Caldas - MG. (em CD-ROM) pp. 350-354.

GIOMETTI, A.B.R. 1993. *Contribuição ao Diagnóstico e Macrozoneamento da Bacia Hidrográfica do Rio Jacaré-Pepira (SP)*. Master's Thesis, Rio Claro, São Paulo State University (UNESP).

LOMBARDI NETO, F., LEPSH, I.F., OLIVEIRA, J.B., DRUGOWICH, M.I. 1993. *Terraceamento Agrícola*. Campinas, Boletim CATI nº 206.

PINTO, S.A.F. 1996. *Contribuição metodológica para análise de indicadores da erosão do solo utilizando técnicas de sensoriamento remoto, geoprocessamento e modelo preditivo*. Associate Prof. Thesis, Rio Claro, São Paulo State University (UNESP).

U.S.D.A. 1972. Soil Conservation Service. *National Engineering Handbook: Hydrology*. Washington, DC.

WILLIAMS, J.R. 1975. Sediment yield prediction with universal equation using runoff energy factor. In: *Present and perspective technology for predicting sediment yields and sources*. United States Department of Agriculture - ARS Handbook, S-40.

WISCHMEIER, W.H. and SMITH, D.D. 1978. *Predicting rainfall erosion losses*. United States Department of Agriculture Handbook nº 537.

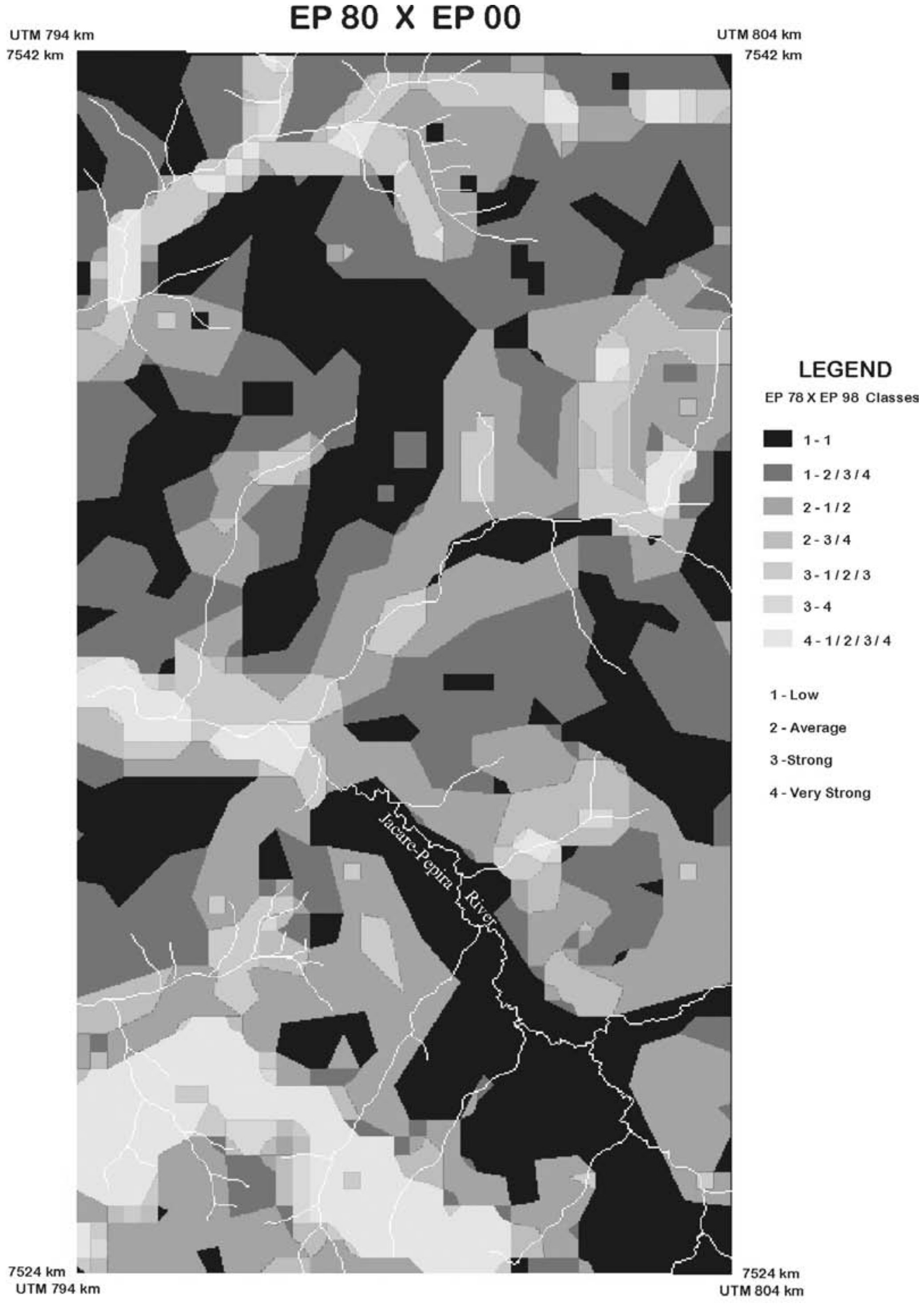

Figura 5. Intersection of EP 80 x EP 00.