IRSTI 39.12.27 https://doi.org/10.26577/JGEM.2023.v68.i1.03

Alyson Bueno Francisco*

Sao Paulo State University, Presidente Prudente, Brazil, Sao Paulo
*e-mail: alysonbueno@gmail.com

CHANGES IN LAND COVER AND RELATIONS WITH THE EQUATION UNIVERSAL SOIL LOSSES IN BASIN OF THE WESTERN PLATEAU OF SAO PAULO IN BRAZIL

The soil loss has become a problem of environmental degradation in Southeastern Brazil. In a region of tropical climate, with precipitations concentrated in summer and sandy soils, the substitution of native vegetation by pasture and cultivation of sugarcane caused changes in the hydrological regime of the hydrographic basins. Soil degradation conditions, with marks present in the landscape, need to be quantified by empirical methods. In the estimates of water erosion, the most used method is the Universal Equation of Soil Losses. The method of estimating soil losses by generating geographic information and spatial data. The Confusion Stream's basin is located in a region with replacement of pasture areas planted by sugarcane crop for fuel production. This research aims to estimate soil losses in a basin from comparative data from 2009 and 2018, derived from analysis of CBERS satellite images, with spatial resolution of 20 meters, in the mapping of land cover, through the classification of images in the IDRISI geographic information system. Rainfall erosivity factors and soil erodibility were obtained from secondary sources. The topographic factor was obtained from the processing of data from the Shuttle Radar Topography Mission. The areas of the land cover classes were related to factor C of the USLE and data estimates of secondary sources of erosivity factor (R), erodibility factor (K) and topographic factor with the data of slope (LS). From these parameters, an estimate of soil loss was presented for the basin of Confusion's Stream. The soil loss in the basin of Confusion's Stream was estimated by 2018 data at 2,484 t/ha/y.

Key words: erosion; basin Confusion's stream; agricultural crop.

Элисон Буэно Франциско*

Сан-Пауло мемлекеттік университеті, Президенти-Пруденти, Бразилия, Сан-Паула қ.
* e-mail: alysonbueno@gmail.com

Бразилиядағы Сан-Паулу Батыс үстірті бассейніндегі жер жамылғысының өзгеруі және әмбебап топырақ жоғалту теңдеуімен байланысы

Топырақтың деградациясы Бразилияның оңтүстік-шығысында экологиялық проблемаға айналды. Жазғы және құмды топырақтарда жауын-шашын шоғырланған тропиктік климат жағдайында жергілікті өсімдіктердің жайылымдық және қант қамысы өсірумен алмастырылуы гидрографиялық бассейндердің гидрологиялық режимінің өзгеруіне себеп болды. Ландшафттағы ерекшеліктері бар топырақтың деградация жағдайлары эмпирикалық әдістермен сандық түрде анықталуы керек. Су эрозиясын бағалау кезінде топырақ жоғалтудың универсалды теңдеу әдісі жиі қолданылады. Топырақтың жоғалуын бағалау әдісі географиялық ақпарат пен кеңістіктік мәліметтерді алу арқылы жүзеге асырылады. Конфуцион өзен бассейні отын өндіру үшін қант қамысы егілген жайылымдық алқапта орналасқан. Бұл зерттеу IDRISI географиялық ақпараттық жүйесіндегі кескіндерді классификациялау арқылы жер жамылғысының картасын жасауда 20 метрлік кеңістіктік тұнықтығы бар CBERS спутниктік суреттерін талдау нәтижесінде алынған 2009 және 2018 жылдардағы салыстырмалы деректер негізінде бассейндегі топырақтың жоғалуын бағалауға бағытталған. Екінші реттік көздерден шөгінділердің эрозиялық белсенділік коэффициенттері мен топырақтың эрозияға ұшырауы алынды. Топографиялық фактор Shuttle Radar Topography Mission деректерін өңдеуден алынды. Жер жамылғысы класының аудандары әмбебап топырақ тозу теңдеуімен (USLE) C коэффициентімен және эрозия коэффициентінің (R), эрозия коэффициентінің (K) және топографиялық фактордың еңіс деректерімен (LS) қайталама бастапқы деректер бағалауымен байланысты болды. Осы параметрлерге сүйене отырып, Конфуцион өзені бассейні үшін топырақтың жоғалуын бағалау ұсынылды. Конфусион өзені бассейніндегі топырақтың шайылуы 2018 жылғы мәліметтер бойынша 2484 т/га/жыл деңгейінде бағаланады.

Түйін сөздер: эрозия; Конфусион өзенінің бассейні; ауыл шаруашылығы дақылы.

Элисон Буэно Франциско*
Государственный университет Сан-Паулу, Президенти-Пруденти, Бразилия, г. Сан-Паулу
*e-mail: alysonbueno@gmail.com

Изменение земного покрова в бассейне Западного плато Сан-Паулу в Бразилии и его связь с универсальным уравнением потери почвы

Деградация почвы стала проблемой окружающей среды на юго-востоке Бразилии. В районе тропического климата с осадками, сосредоточенными в летних и песчаных почвах, замещение местной растительности пастбищами и возделыванием сахарного тростника вызвало изменение гидрологического режима гидрографических бассейнов. Условия деградации почвы с признаками, присутствующими в ландшафте, должны быть количественно оценены эмпирическими методами. При оценке водной эрозии наиболее часто используется метод универсального уравнения почвенных потерь. Метод оценки потерь почвы осуществляется путем получения географической информации и пространственных данных. Бассейн реки Конфусион расположен в районе замены пастбищных угодий, засеянных сахарным тростником для производства топлива. Это исследование направлено на оценку потерь почвы в бассейне на основе сравнительных данных за 2009 и 2018 годы, полученных в результате анализа спутниковых изображений CBERS с пространственным разрешением 20 метров при картографировании земного покрова посредством классификации изображений в географической информационной системе IDRISI. Коэффициенты эрозионной активности осадков и эродируемость почвы были получены из вторичных источников. Топографический фактор был получен в результате обработки данных Shuttle Radar Topography Mission. Площади классов земного покрова были связаны с коэффициентом C универсального уравнения деградации почвы (USLE) и оценками данных вторичных источников коэффициента эрозии (R), коэффициента эрозионности (K) и топографического фактора с данными уклона (LS). По этим параметрам была представлена оценка потери почвы для бассейна реки Конфусион. Смыв почвы в бассейне реки Конфусион оценивается по данным 2018 г. в 2484 т/га/год.

Ключевые слова: эрозия; бассейн реки Конфусион; сельскохозяйственная культура.

Introduction

The first estimates of soil losses in Brazil were analyzed in the 1940s using experimental plots at the Agronomic Institute of Campinas (Bertoni; Lombardi Neto, 1999).

The Universal Equation of Soil Losses was developed from the studies of Wischmeier and Smith (1961 Apud Laflen; Moldenhauer, 2003) from 10,000 data on soil loss rates in experimental plots in the United States of America.

Soil losses in Brazil are estimated at approximately 848 million tons per year (Merten; Minella, 2013). Fast-paced soil losses in the degraded areas of the Western Plateau of São Paulo represent environmental and economic damage.

The scale of watersheds has repercussions in recent years due to the details of the guaranteed by advances in geographic technologies. On the local scale, the particularities of each rural producer are found and mitigating measures are applied in the face of land degradation conditions. The dialogue with rural producers takes place through the technical knowledge of public agencies and researchers guide these agencies through extension projects. The definition of the concepts and principles of water management is essential to consolidate the necessary measures in river basins. Ideals based on rational water use are important to guide political decisions and favor of soil conservation measures and recovery of degraded areas.

The geoprocessing techniques used met the research needs, confirming that its use improves the processes and phases of spatial analysis. In addition, the created database can be replicated, corrected and updated at any time, which makes it dynamic and applicable to the most diverse spatial representation demands of the information contained therein (PIROLI, 2013).

The watershed is a territorial and physical unit present in nature bounded by drainage. Nature presents its diversity and researchers need to avoid generalizing small scales and seek to understand natural phenomena in field research.

In this sense, fieldwork is necessary, as the main methodology of the geographer, to investigate the nature of each hydrographic basin and present the diagnoses (inventories), to carry out environmental planning from the perspective of water resources management with adequate prognoses to ensure the future availability of drinking potable water (Guimarães, 1999).

From the development of Geographic Information Systems, spatial data from watersheds served as parameters applying the Universal Equation of Soil Losses, mainly by the formation of numerical elevation models. The development of erosive processes in the large hydrographic basins of tropical environments made it propitious to apply this empirical model in river basins to generate databases in Geographic Information Systems (Parveen; Kumar, 2012).

In recent years, research on river basins and geoprocessing techniques has become more present in geographical studies. The spatiality of erosive processes involves the understanding of the aspects of hydrographic basins and the transformations that occur in rural landscapes of changes in agricultural activities. The use of conservation practices for the recovery of areas with degraded soils can contribute to the mappings performed by geographers with support in geographic information systems.

The Confusion Stream's basin has an area of 46,760 ha, located in the northwest part of the municipality of Rancharia. It is considered a sub-basin belonging to the River of Fish basin. The basin has an average width of 22 km and a maximum length of 34 km. The channel of Confusion stream of the main course is 35 km long, being the tributary Saltinho stream with an extension of 16 km. The Confusion stream has the maximum flows by the annual averages are 12 m³/s, with the highest occurrences in summer, where in region has tropical climate.

Figure 1 shows the location of the Confusion Stream's basin.

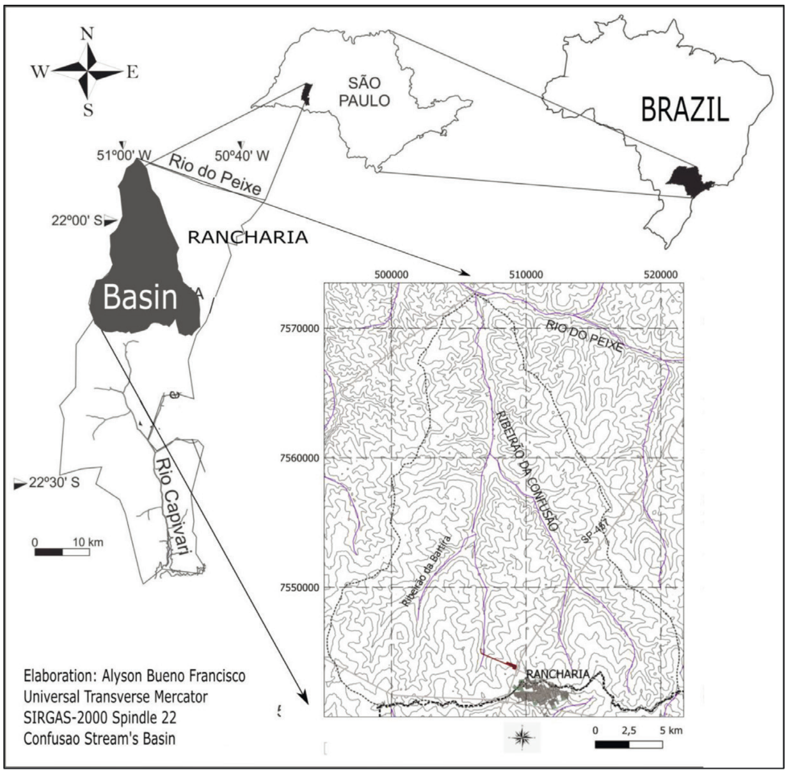

Figure 1 – Map of Confusion Stream's Basin

The quotas relief of the Confusion Stream's basin has between 380 and 540 meters. The relief consists of wide hills and wavy tops belonging to the Western Plateau of São Paulo. The slope is generally low between 5º and 15º in more than 80% of the area.

According to the Map of Soils in the State of São Paulo (Oliveira et al., 1999), the predominant soils in the Confusion Stream's basin are the Red Oxisols and the Red-Yellow Clay Sols. The erodibility values of the surface horizon of the Red Clay Sols of the Presidente Prudente region are estimated at 0.051 Mg/ha/year. For the Red Oxisols of the sandy phase, the estimated values were 0.016 Mg/ha/year (Freire; Godoy; Carvalho, 1992).

On the climatic conditions in the region affected by water erosion, Francisco (2017) presents the erosivity of rain for the municipality of Rancharia, considering precipitation data between 1945 and 2003, being in rainy years the R factor of 9,088 MJ.mm/ha.h.year; 7,129 MJ.mm/ha.h.year for regular years and 5,665 MJ.mm/ha.h.year for dry years.

Despite deforestation for cotton planting until the 1970s and later the domain of pasture planting for cattle herd farming, the Confusion Stream's basin has preserved fragments of native forest (approximately 8% of the area), including a fragment of approximately 3,000 hectares.

In the last 15 years, installing a sugar-alcohol plant in the southwestern part of the basin favored the increase of sugarcane planting areas (23% to 34% of the area) with the existence of terraced plantations, replacing the degraded pasture areas.

Materials and Methods

The clinographic letter of slope was elaborated based on data from the digital elevation model from the SRTM mission, in the Slope routine of the TerrSet GIS. The slope data served as the basis for the elaboration of the estimation of the LS factor, ramp length (slopes) and unevenness (slopes).

The preparation of the land cover charts were carried out in the TerrSet Geographic Information System with orbital images of the CBERS satellite dated October 2009 and February 2018, through the supervised classification routine. The geographic referencing of the images was performed at GIS Idrisi. After geographic referencing, the false-color composition was applied with bands 2, 3 and 4.

Using the Digitize routine, reliable samples were selected with the vectorization of polygons, whose each class to be represented had a value. With the use of the Make-sig routine, signatures are created and then the classifier is defined with maximum likelihood with the use of the Max-like routine. Then, mode filtering was applied using a size 7x7. To cut out the area of the Confusion Stream's basin, the limits of the Shuttle Radar Topography Mission (SRTM) data were delimited using SRTM data in the GlobalMapper software. The vector that delimits the watershed was exported in Shapefile format, having as reference system the horizontal datum SIRGAS-2000.

Regarding the factors attributed to the Universal Equation of Soil Losses, the erodibility indexes presented by Freire et al. (1992). The rainfall erosivity (R) was estimated based on the reference of Francisco (2017) when presenting the values for an adjacent basin 15 km away from the Confusion Stream's basin. The types of soils identified in the hydrographic basin were adopted by the map presented by Oliveira et al. (1999). The C factor of soil management forms, by the land cover classes, followed the reference adopted by Pinto (1991). The factor conservation practices (P) was estimated based on the indices of calculations expressed by Bertoni and Lombardi Neto (1999).

Results and Discussion

Table 1 presents the land cover classes in 2009 and 2018 in the Confusion Stream's basin.

Table 1 – Areas and plots of land cover classes in Confusion Stream's basin

Land covers classes	Area in 2009(ha)	%	Area in 2018(ha)	%
Urban areas and roads	0.58	0.01	1.55	0.003
Native forest	3,610.00	7.72	3,913.28	8.37
Water channel	1.42	0.01	1.58	0.003
Agricultural crop	10,679.00	22.84	15,768.36	33.72
Pasture	23,085.00	49.75	22,571.32	48.27
Land wood	326.00	0.70	-	-
Bare soil	8,698.00	18.75	3,504.06	09.61

The Figure 2 presents the land cover map of the Confusion Stream's basin by 2009 data.

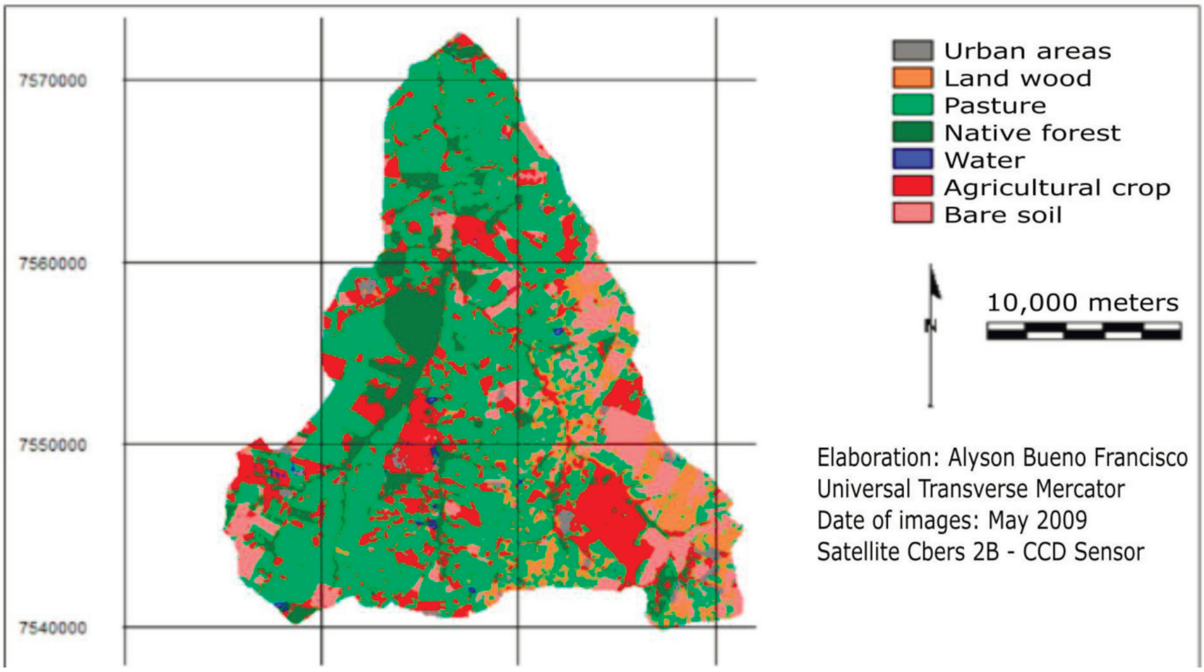

Figure 2 – Map of Land Cover of the Confusion Stream's Basin (2009)

Figure 3 presents the land cover map of the Confusion Stream's basin by 2018 data.

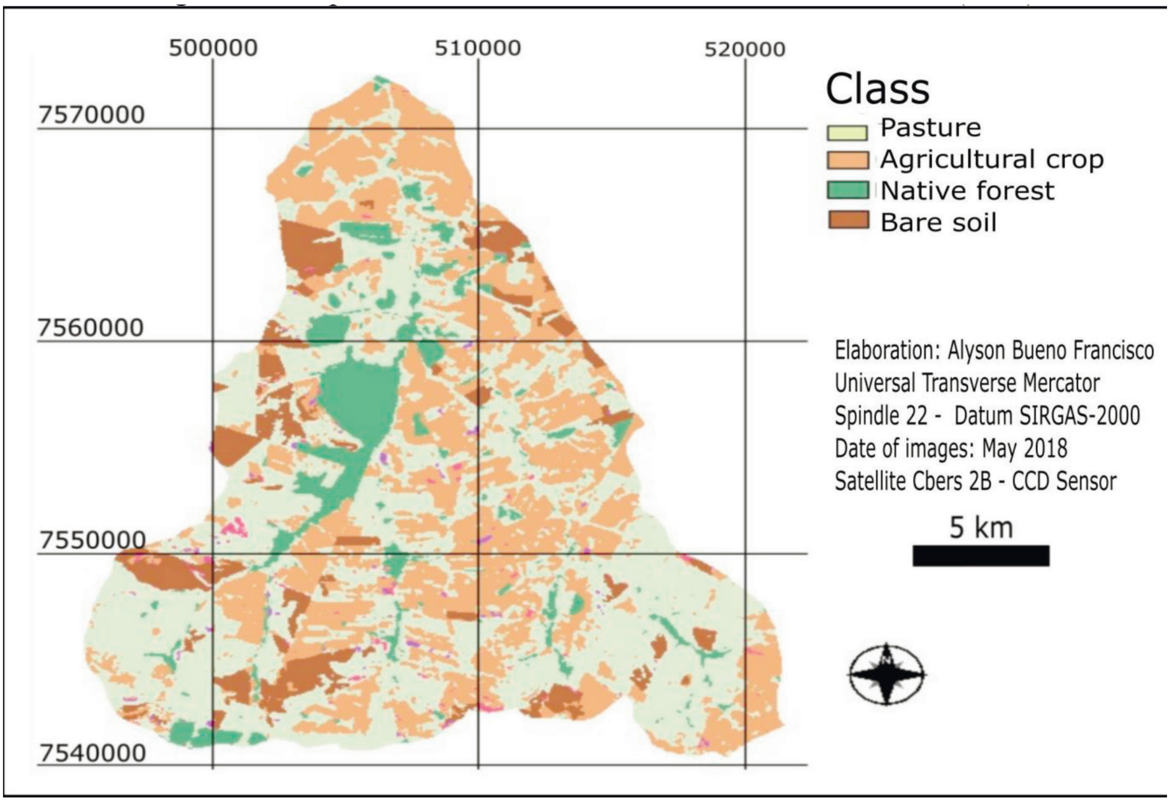

Figure 3 – Map of Land Cover of the Confusion Stream's Basin (2018)

The table 2 shows the relationship between the areas of the land cover classes and the C factor of land use applied in the Universal Equation of Soil Losses.

Table 2 – Relation land cover classes with factor C of USLE

Land covers classes	Factor C	Area in 2009 (ha)	C (2009)	Area in 2018 (ha)	C (2018)
Native forest	0.0004	3,610	0.00003	3,913.28	0.00003
Agricultural crop	0.0500	10,679	0.11420	15,768.36	0.16860
Pasture	0.0075	23,085	0.37000	22,571.32	0.36200
Bare soil	0.1000	8,698	0.18601	3,504.06	0.00370

The data show factor C from 810.17 to 994.31, an increase of 18.5% in erosive potential according to land cover changes in 9 years.

The table 3 presents the relation of the areas of the land cover classes with the predominant types of soils by the K factor of erobility.

Table 3 – Factor of erodibility (K) in relation areas of land covers

Class of land cover	Soil type	Factor K	Área in 2009 (ha)	K (2009)	Área in 2018 (ha)	K (2018)
Native forest	Hydricsoil	0.003	3,610	0.00023	3,913.28	0.00025
Agricultural crop	Clay soil	0.051	10,679	0.01165	15,768.36	0.01719
Pasture	Oxissoil	0.016	23,085	0.00799	22,571.32	0.00772
Bare soil	Clay soil	0.051	8,698	0.00949	3,504.06	0.00382

The erodibility factor remained practically stable in 9 years, being present the addition of native forest areas present in hydromorphic soils of primary forests and a decrease in exposed soil areas, very conducive to the development of laminar erosion.

Based on the data of the factors of application of the Universal Equation of Soil Losses by erosivity presented to the municipality of Rancharia (Perusi et al., 2004) in 7,300 MJ.mm/ha.h.year, we have the estimated indices for the land cover classes in table 4.

Table 4 – Factor of erosivity rain (R) in relation áreas land covers

Class of land cover	Área in 2009 (ha)	R (2009)	Área in 2018 (ha)	R (2018)
Native forest	3,610	564.66	3,913.28	610.92
Agricultural crop	10,679	1,667.16	15,768.36	2,461.64
Pasture	23,085	3,603.94	22,571.32	3,523.7
Bare soil	9,024	1,408.8	3,504.06	547.03
∑	46,398	7,244.55	46,398	7,143.29

When considering the average length of 100 m of ramp in the basin and the mean slope of 5.67% or 10º, the topographic factor was estimated at 0.006.

The factor of conservation practices was calculated based on the mean slope of 10º, being obtained in 0.19342.

Considering the estimated factors of the USLE for the basin, the rates of soil losses were estimated in 2009 by the land cover classes in table 5.

Table 5 – Estimated factors of the USLE for the basin in 2009

Land covers	Factor R	Factor K	Factor LS	Factor C	Factor P	Ei	A (t/ha/year)
Native forest	564.66	0.00023	0.006	0.00003	0.19342	2.10^{-9}	0.0002
Agricultural crop	1,667.16	0.01165	0.006	0.11420	0.19342	0.0257	1,201.73
Pasture	3,603.94	0.00799	0.006	0.37000	0.19342	0.0123	577.51
Bare soil	1,357.9	0.00949	0.006	0.18601	0.19342	0.0027	130

The Confusion Stream's basin, with 46,760 ha, presents an estimate of soil losses at 1,909.24 t/ha/year in 2009. In the estimated soil loss in 2009, an erosion rate of 1,201 t/ha/year was found in the agricultural area, corresponding to 63% erosion rate in basin, whereas the agricultural area corresponds to 23% of the territorial area of the basin.

When considering the estimated factors of the USLE for the basin, the rates of soil losses were estimated in 2018 by the land cover classes in table 6.

Table 6 – Estimated factors of the USLE for the basin in 2018

Land covers	Factor R	Factor K	Factor LS	Factor C	Factor P	Ei	A (t/ha/year)
Native forest	610.92	0.00023	0.006	0.00003	0.19342	2.10^{-9}	0.0002
Agricultural crop	2,461.64	0.01165	0.006	0.11420	0.19342	0.038	1,777.23
Pasture	3,523.7	0.00799	0.006	0.37000	0.19342	0.012	566
Bare soil	547.03	0.00949	0.006	0.18601	0.19342	0.003	140.85

The Confusion Stream's basin, with 46,760 hectares, presents an estimate of soil losses at 2,484.08 t/ha/year in 2018. In the estimate of soil loss in 2018, an erosion rate of 1,777 t/ha/year was found in the agricultural area, corresponding to 71.5% erosion rate in basin, whereas the agricultural area corresponds to 34% of the territorial area of the basin.

The Confusion Stream's basin, with 46,760 ha, presents an estimate of soil losses at 1,909.24 t/ha/year in 2009. The Confusion Stream's basin, with 46,760 hectares, presents an estimate of soil losses at 2,484.08 t/ha/year in 2018. The data show factor C from 810.17 to 994.31, an increase of 18.5% in erosive potential according to land cover changes in 9 years.

Conclusion

The Universal Equation of Soil Loss (USLE) is a method applicable to the studies of land cover changes in watersheds. In this article, erosion rates were estimated in a basin located on the plateau of a tropical region where in the last 9 years (2009-2018) there have been changes in land cover.

In the basin of Confusion stream there was a change from 23 to 34% of the agricultural crop area in 9 years, and the rate of erosion in the segment of the agricultural crop area was also increased from 63 to 71.5%. The largest geographical distribution of agricultural crop areas in this basin are where with clay soils with high susceptibility to erosion, erodibility of 0.051 (K factor).

Although conservation practices are applied in planting in level curves in sugarcane areas, erosion rates may be evident in this study. Despite few areas, the cover with bare soil needs attention in the face of rain action in the tropical climate during the summer.

References

Bertoni, J., Lombardi, F. (1999) Conservação do solo. São Paulo, Icone.

Freire, O., Godoy, M. C. T. F., Carvalho, W. A. (1992) Erodibilidade de alguns solos do oeste do estado de São Paulo. Revista de Geografia, São Paulo, n.11, pp. 77-87.

Guimarães, E. M. A. (1999) Trabalhos de campo em bacias hidrográficas: os caminhos de uma experiência em Educação Ambiental. Dissertação, Mestrado em Geografia, Universidade Estadual de Campinas, 184p.

Laflen, J. M., Moldenhauer, W. C. (2003) The Story USLE: pioneering soil erosion prediction. Beijing, China, World Association of Soil and Water Conservation.

Merten, G. H., Minella, J. P. G. (2013) The expansion of Brazilian agriculture: soil erosion scenarios. International Soil and Water Conservation Research, v. 1(3), pp. 37-48, 2013.

Oliveira, J.B., Camargo, M. N., Rossi, M., Calderano, B. (1999) Map of Soils in the State of São Paulo. Scale: 1: 500.000, Agronomic Institute of Campinas, 1999.

Parveen, R., Kumar, U. (2012) Integrated Approach of Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Loss Risk Assessment in Upper South Koel Basin, Jharkhand. Journal of Geographic Information System. v.4 (6), pp 67-79.

Perusi, M.C., Zero, V., Tommaselli, J.T.G., Brigatti, N. (2004) Erosividade das chuvas no extremo oeste do Estado de São Paulo nos anos de 1998 e 1999. Caderno Prudentino de Geografia, v. 26, pp. 25-36.

Pinto, S.A.F. (1991) Sensoriamento Remoto e integração de dados aplicados no estudo da erosão dos solos: contribuição metodológica. Thesis (Physical Geography), University of São Paulo, 185p.

Piroli, E.L. (2013) Geoprocessamento aplicado ao estudo do uso da terra das áreas de preservação permanente dos corpos d'água da Bacia Hidrográfica do Rio Pardo. Tese (Livre Docência em Geoprocessamento e Sensoriamento Remoto), Universidade Estadual Paulista, 150p.