ESTIMATE SOIL LOSS THROUGH SURFACE EROSION USING GEOGRAPHICAL INFORMATION SYSTEMS AND SATELLITE IMAGES

Loredana COPĂCEAN, Silvica ONCIA

University of Agricultural Sciences and Veterinary Medicine of Banat „Regele Mihai I al României", Timisoara
Calea Aradului, nr. 119, Timişoara, e-mail: lorecopacean@yahoo.com

Abstract. *Quantitative estimation of surface erosion of the soil, is not a current topic, the approach a working methodology for this purpose is temporal "localized" in 1950, when some researchers from the National Runoff and Soil Loss Data Center and Purdue University have made an empirical equation for the quantitative determination of eroded soil. In 1978, Wischmeier and Smith, gives Universal Soil Loss Equation (USLE), an equation designed to calculate the annual mean soil loss from agricultural lands. This study aims is to estimate the amount of annually soil lost by surface erosion, using specific methods and Geographyc Information Sistems data, in the administrative territory Traian Vuia, Timis County. The values of the equation coefficients were taken from the literature, under specific environmental conditions of the study area. For the calculation of some of the factors they were used satellite images. For the said territory, the average annual of soil loss through erosion ranges from 0 to 72.46 t/ha/year, these values having territorial distribution depending on the environmental conditions of each subunits. Given that data and maps were used to average scale, in the micro-regions, surface erosion can occur with greater intensity. The large number of methods of determination, but also, large differences in coefficient values used, can be detected by quantitative differences in the estimations.*

Key words: *estimation, erosion, informatics, soil*

INTRODUCTION

Quantitative estimation of surface erosion of the soil is not considered as a current topic, approach a working methodology is "localized" temporal in 1950, when some researchers from the National Runoff and Soil Loss Data Center and Purdue University should be formulated an equation for determining the quantitative loss of soil (PELTON J., et al, 2012). In 1978, Wischmeier and Smith, published *Universal Soil Loss Equation* (USLE), an empirical formula designed to calculate the annual mean of soil loss from agricultural lands (ZISU I., 2014). In 1997, Renard et al, make *Revised Universal Soil Loss Equation* (RUSLE), an equation which target specific climatic and topographical review on factor of USLE equation. To be applied to the environmental conditions specific to Romania, romanian researchers, coordinated by M. Motoc (2002), amended and adapted USLE as *Romanian Soil Erosion Model* – ROMSEM.

In recent decades, the development of Geographic Information Systems (GIS) allow the application and spatial representation of the USLE (DE ROO A.P.J., 1996), each factor of the equation is materialized through a map.

.

MATERIALS AND METHODS

This study aims to determine the annually amount of soil lost by surface erosion using methods and data specific to Geographical Information Systems.

The study area overlaps administrative territorial unit (ATU) Traian Vuia, located in the east of the Timis county.

In this study were used:

- soil map of ATU Traian Vuia (ONCIA SILVICA, et al, 2013)
- Digital Elevation Model of ATU Traian Vuia

- Map of land use - by extracting data from the database *Corinne Land Cover* [22]
- Climate map based on the information available free on http://www.worldclim.org, according to the methodology proposed by HIJMANS *et al.* (2005)
- a Landsat TM satellite image acquired in August 2011, taken from *Earth Explorer* database and downloaded free from website http://earthexplorer.usgs.gov.

Existing maps and maps resulting from this study were processed with ArcGIS 10.0 software.

To determine the average annual quantity of soil removed by erosion in the area was use equation (1), which represents *Universal Soil Loss Equation* (USLE), formulated by researchers WISCHMEIER and SMITH in 1978:

$$A = R \cdot K \cdot LS \cdot C \cdot P \quad (1)$$

where: A - average annual eroded soil (t/ha/year); R - rainfall aggressiveness coefficient (MJ mm/hha/year); K - erodability soil factor (thah/MJmm); LS - topographical factor, namely the length and angle of inclination (dimensionless); C - coefficient expressing cultural influence on the amount of eroded soil (dimensionless); P - coefficient expressing anti-erosion measures influence (dimensionless).

Rainfall aggressiveness coefficient values (R) were determined based on Modified Fournier index (ARNOLDUS. 1980, citat de ZISU I, 2014), according to relation:

$$F_M = \sum_{i=1}^{12} \frac{Pi^2}{P} \quad (2)$$

where: FM - Modified Fournier index; Pi - the average amount of rainfall for the month i (mm); P - average annual precipitation.

For setting the erodability coefficient (K), data were used to the texture, structure, content of organic material [21], for each unit of soil in the territory, according to those characteristics are assigned values between 0 - 0.0513, according to the methodology described in literature (PANAGOS *et al.* 2014, MOŢOC M., 1975, CONSTANTIN ELENA, 2011, ICPA, 1986).

Topographical factor (LS) - length and inclination of the slope - was computed in ArcGIS based on the Digital Elevation Model (DEM) with 30 m spatial resolution, using the algorithm proposed by PELTON J., et al (2012):

Power(“flowacc”*[cell resolution]/22.1,0.4)*Power(Sin(“sloperasterdeg”*0.01745))/0.09, 1.4)*1.4 (3)

Where: "flowlac" - accumulation due to water erosion; "Sloperasterdeg" - the slope in degrees.

Coefficient values that express the cultural influence of the quantity of eroded soil (C) were determined in two ways: in the first case, these values were adjusted for the area analyzed based on the data from the literature (CONSTANTIN ELENA 2011, CHISIS IRINA, 2013) with the values of 0 - 0.7 and in the latter case, they were determined using the *Normaalizat Difference Vegetation Index* (NDVI) according to the equation (KARABURUN A, 2010):

$$C = 1,02 - 1,21 \cdot NDVI \quad (4)$$

Regarding the influence of measures and anti-erosion work (P factor) was used in all cases a constant value equal to 1 which signifies the absence of such works.

For automatic calculation of surfaces, maps in raster format have been reclassified and converted into vector format (HERBEI M., 2013) using ArcGIS software.

RESULTS AND DISCUSSION

The study area is geographically situated in Bega river basin, in the eastern part of Timis county and overlapping administrative territory Traian Vuia. This area falls within altitude between 120 - 494 m (Figure 1).

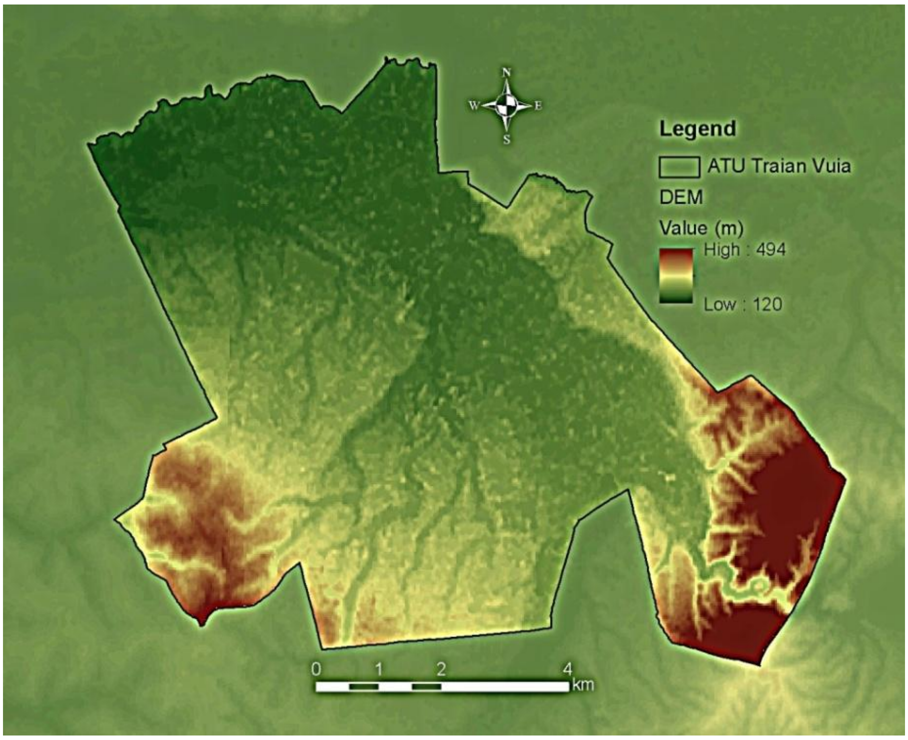

Figure 1 ATU Traian Vuia – Digital Elevation Model

Next we analyze separately each component factor of the USLE, then, based on the results will be made average annual soil loss situation at ATU Traian Vuia.

R factor can be determined by several methods (ROȘCA B., et al, 2012, CASTRAVEȚ T., 2012, MOȚOC M, et al, 1975), but in this study we applied equation (2) being used climate data available free on http://www.worldclim.org. For the study area, R factor has a value between 49.28 - 53.84, depending on the specific physic-geographical conditions.

K factor was determined from the map of types and subtypes of soil (ONCIA SILVICA et al, 2013), each of them, depending on the characteristics of the soil, being assign a coefficient between 0 - 0.0513 (Figure 2), according to the methodology taken from literature (PANAGOS et al, 2014, citat de ZISU I, 2014).

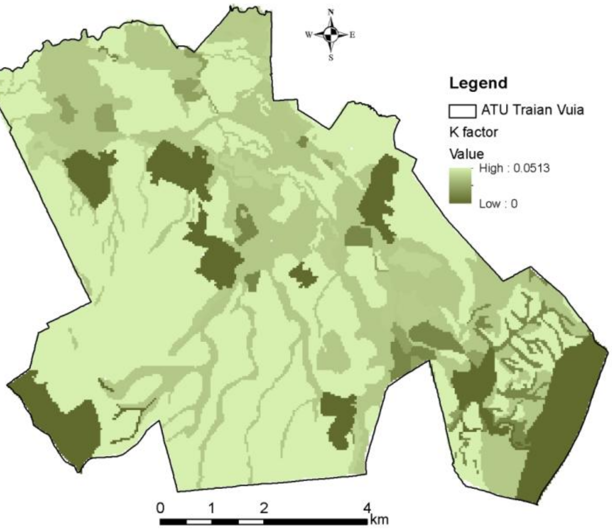

Figure 2 ATU Traian Vuia – K factor values

Areas with forests and construction areas have been assigned the value 0 (Figure 2).

Referring to the **topographical factor (LS),** PATRICHE C, et al. (2006) states that of all the USLE factors, it is most difficult to calculate (Figure 3).

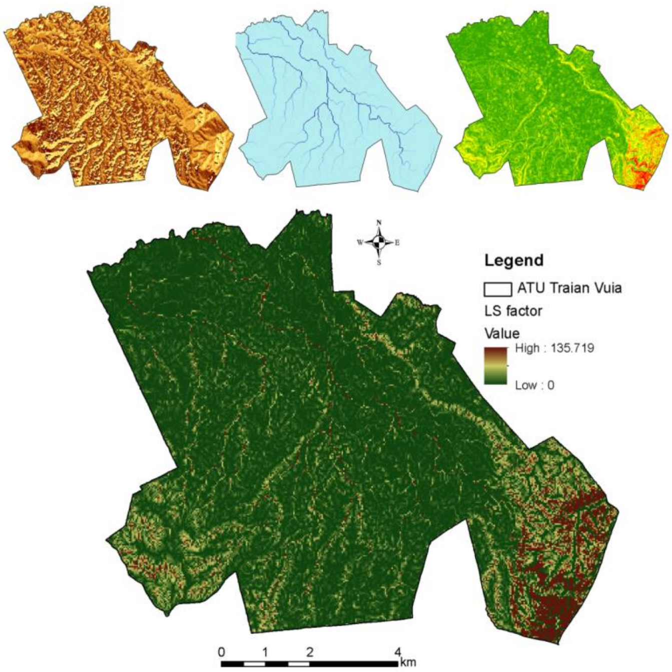

Figure 3 ATU Traian Vuia – topographical factor (LS), flow direction, flow accumulation, slope

Over time, they were created and tested a number of ways of determining who led the possibility of calculating it with GIS programs, using Digital Elevation Model. In this study, it was applied the algorithm set by PELTON J., et al (2012), which involves: determining the direction of flow, establish the possible accumulation, calculation of the slope (in degrees) and use the experimental coefficient, according to the equation (1).

C factor expresses the degree of protection of crops on the soil and can be determined by several methods. One way of determining is using the database Corine Land Cover (land use) and coefficients specified for each category, depending on the degree of protection against erosion processes (Figure 4), the coefficients drawn from research undertaken by YOUNG, (1989), CHIȘ IRINA (2013), MOȚOC M. (1975). In this case were used coefficients fixed by YOUNG (1989), citat de ZISU (2014).

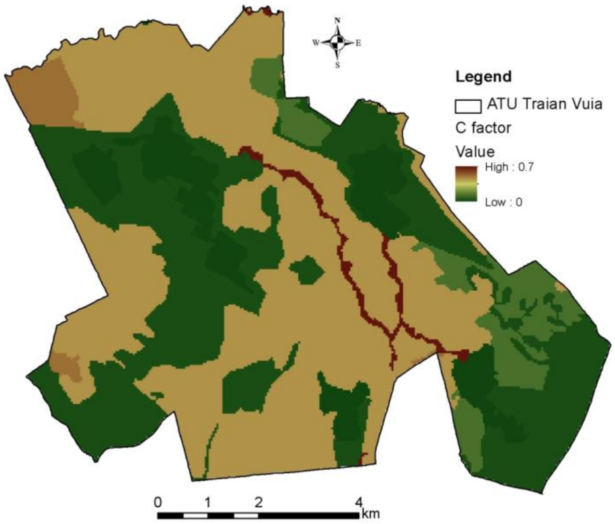

Figure 4 ATU Traian Vuia – C factor values

Another way of determining the C factor is based on satellite image processing (TERENTE M, 2008, KARABURUN A, 2010, CASTRAVEȚ, T,2012) (Figure 5).

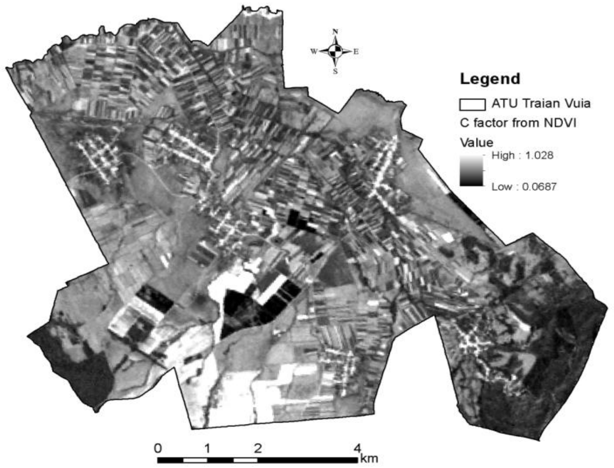

Figure 5 ATU Traian Vuia – C factor extracted from satellite images

For the calculation of the C factor is determined NDVI and apply equation (4), the acquired image is displayed in Figure 5.

P factor, which expresses the execution of anti-erosion works, was not considered, in the absence of data confirming the existence and type of such works.

On the basis of five parameters USLE, quantified and represented spatially, apply GIS technique calculation that involves multiplying the 4 layers (R, K, LS, C) and the value of constant factor P (*Raster Calculator* function) according to the equation (1). C factor was taken into account obtained on the basis of satellite images. The result of soil erosion is the map described above (Figure 6) in raster format.

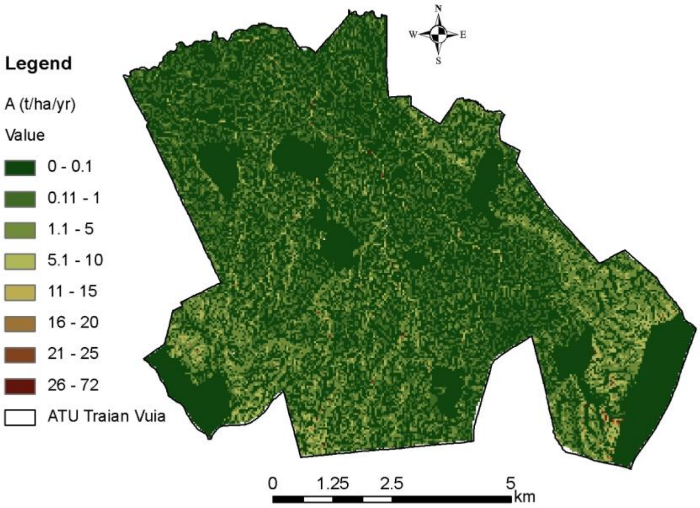

Fig. 6 ATU Traian Vuia – map of surface soil erosion susceptibility

According to the data presented in Figure 6, annual average amount of soil eroded ranges from 0 to 72.469 t/ha/year, with spatial variations in accordance with physical and geographical conditions. The lowest values are specific for areas of meadow and the largest quantities of soil are lost in steep slope areas in southeastern territory.

According to the classification made by ICPA (1987), from the total area of 6976 ha [20], approx. 65% fall in the "*very low susceptibility*", approx. 20% are soils with "*low susceptibility*", 0.7% in class "*moderate susceptibility*" and only 0.3% fall in the class "*high susceptibility*".

CONCLUSIONS

Administrative territory Traian Vuia is located in the low hills, with altitudes between 120 - 494 m and physical and geographical conditions specific to this altitudinal range.

According to the results obtained by applying USLE, having adapted to the specific conditions of the western part of Romania, the average annual eroded soil ranges from 0 to 72.46 t/ha/year. The lowest values are specific for areas of meadow and the largest quantities of soil are eroded in areas with altitudes and steeper slope. According to the classification made by ICPA (1987), from the total area of 6976 ha [18], approx. 65% fall in the "*very low susceptibility*", approx. 20% are soils with "*low susceptibility*", 0.7% in class "*moderate susceptibility*" and only 0.3% fall in the class "*high susceptibility*".

Given that data and maps were used to average scale, in the micro-regions surface erosion can occur with greater intensity.

The large number of methods of determination, but also large differences in coefficient values used can be detected by quantitative differences in the estimates made.

BIBLIOGRAPHY

1. CASTRAVEŢ T., *Estimating annual soil loss by water erosion in the middle Prut Plain, Republic of Moldova,* Geographia Napocensis, anul VI, nr. 2, 2012
2. CHIŞ IRINA, *Efectul precipitaţiilor asupra morfodinamicii spaţiului montan şi deluros din judeţul Cluj,* Cluj Napoca, 2013, Rezumatul Tezei de doctorat
3. CONSTANTIN ELENA, *Îmbunătăţiri funciare,* 2011, on-line at http://www.horticultura-bucuresti.ro/fisiere/file/ID/Manuale%20ID/Imbunatatiri%20funciare.pdf
4. DE ROO, A.P.J., *Soil erosion assessment using GIS, Geographical information systems in hydrology*, Kluwer Academic Publishers, Dordrecht, Boston, USA, 1996
5. HERBEI M., *Sisteme Informatice Geografice – Aplicaţii,* Editura Universitarias, Petroşani, 2013
6. HIJMANS ET AL., *Very high resolution interpolated climate surfaces for global land areas*, International Journal of Climatology, 25: 1965-1978, 2005
7. KARABURUN A, *Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershid,* Czean Journal of Applied Sciences (3)1, pag. 77 – 85, 2010
8. MITASOVA HELENA, ET AL., *Modelling topographic potential for erosion and deposition using GIS,* International Journal of Geographical Information Science, 10 (5), 1996
9. MOŢOC, M., ET AL, *Eroziunea solului şi metodele de combatere*, Editura Ceres, Bucureşti, 1975
10. MOŢOC, M., MIRCEA, S., *Evaluarea factorilor care determină riscul eroziunii hidrice în suprafaţă*, Editura Bren, Bucureşti, 2002
11. ONCIA SILVICA, ET AL, *Geographical dimension of land degradation and quantitative evaluation of surface erosion, for the territory of Traian Vuia municipality,using Geographic Information Systems,* 13th SGEM GeoConference on Informatics, Geoinformatics And Remote Sensing, www.sgem.org, SGEM 2013 Conference Proceedings, ISBN 978-954-91818-9-0/ ISSN 1314-2704, June 16-22, 2013, Vol. 1, pp 737–744, DOI: 10.5593/SGEM2013/BB2.V1/S11.016, 2013
12. PANAGOS, P., ET AL, *Soil erodibility in Europe: A high-resolution dataset based on LUCAS,* Science of the Total Environment, 479–480: 189–200, 2014
13. PATRICHE C., ET AL, *Aspects regarding soil erosion spatial modeling using the USLE/RUSLE equation within GIS*. Geographia Technica. Vol 2, 2006
14. PELTON J., ET AL, *Calculating Slope Length Factor (LS) in the Revised Universal Soil Loss Equation (RUSLE)*, 2012, on-line at: http://gis4geomorphology.com/wpcontent/uploads/2014/05/LS-Factor-in-RUSLE-with-ArcGIS 10.x_Pelton_Frazier_Pikcilingis_2014.docx
15. RENARD, K. G., ET AL, *Predicting soil erosion by water: a guide to conservation planning with the Revised Soil Loss Equation (RUSLE).* Agriculturae Handbook, No. 703, U.S. Department of Agriculture, Washington DC, 1997
16. ROŞCA B., ET AL, *Models for Estimating Soil Erosion in the Middle and Lower Vasluieţ Basin,* Bulletin UASVM Agriculture 69(1)/2012, Electronic ISSN 1843-5386, 2012
17. TERENTE M., *Modelarea şi analiza digitală a terenului. Cu aplicaţii în bazinul montan al Teleajenului,* 2008, on-line at: http://www.geo-spatial.org/download/modelarea-digitala-a-terenului
18. WISCHMEIER, W. H., SMITH, D. D., *Preadicting rainfall erosion losses. A guide to conservation planning,* Agriculture Handbook, No. 537, U.S. Department of Agriculture, Washington DC. 1978
19. ZISU I., *Studiu pedogeografic al dealurilor Lugojului cu privire speciala asupra calitatii terenurilor agricole,* 2014, Teză de doctorat
20. ••• Arhiva Oficiului de Cadastru şi Publicitate Imobiliară Timiş
21. ••• Arhiva Oficiului de Studii Pedologice şi Agrochimice Timişoara

22. ••• Corine Land Cover database
23. ••• http://www.worldclim.org,
24. ••• http://earthexplorer.usgs.gov