THE ASSESSMENT OF SOIL EROSION PROCESS IN A TEST AREA AT NUTS4 LEVEL

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Abstract: *Soil erosion forms a major threat to European soil resources, soil being a vital and largely non-renewable resource. Therefore, there is a concern about this issue at European level. Assessing and monitoring soil erosion is needed to evaluate the impact of, inter alia, agricultural and land use policies in Europe. A case-study at a commune (NUTS4) level has been developed in order to compare two ways of applying the USLE equation (a model adjusted by Motoc, and also PESERA model). The input data are the soil map at the scale 1:200,000, a soil map for Adamclisi at the scale 1:10,000, as well as the grid 1 x 1km with the soil loss from running the European PESERA Model. Firstly, the areas affected by the soil erosion process are designed based on the soil maps at the two scales. The second step was to assess the water erosion risk, based on the information from 1:200,000 soil map. Thirdly, a model of computing the potential soil loss using USLE equation, adapted by Motoc, in two cases – land with and without canopy – have been run. The erosivity and erodability coefficient are assessed using expert judgment; the slope and the aspect have been calculated using ArcView modules. The topographic factor has been computed in two ways using both Motoc approach, and WEPP model. Finally, the PESERA model has been run, and the outputs have been compared with the outputs from the previous model. It can be noticed that there is a similitude between the soil loss from PESERA with that from soil map at the scale 1: 200,000, but there is a difference in the magnitude for the two models, the area affected by erosion process being approximately the same.*

Key words: *soil erosion, USLE equation, PESERA model*

INTRODUCTION

Soil erosion is a long-term natural process that has been largely responsible for shaping the physical landscape through distribution of the weathered materials produced by geomorphic processes (HUBER et al, 2008). A number of definitions of soil erosion exist (JONES et al, 2006). The ENVASSO Glossary of Key Terms defines soil erosion as: "The wearing away of the land surface by physical forces such as rainfall, flowing water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface to be deposited elsewhere" (based on Soil Science Society of America, 2001). When the term 'soil erosion' is used in the context of being a threat to soil, it refers to 'accelerated soil erosion', i.e. "Soil erosion, as a result of anthropogenic activity, in excess of accepted rates of natural soil formation, causing a deterioration or loss of one or more soil functions" (ENVASSO GLOSSARY OF KEY TERMS).

Soil erosion has been exacerbated by human activities, leading to one of the major and most widespread forms of land degradation (GOBIN et al, 2002). About 17 % of the total land area in Europe is affected to some degree (OLDEMAN et al, 1990, EEA, 2003). Major causes are unsustainable agricultural practices, large-scale farming and overgrazing in Western Europe and Central and Eastern Europe, and poor water and irrigation management especially in the Eastern Europe (UNECE, 2001). Soil erosion in Europe is due mainly to water (about 92 % of the total affected area) and less to wind (GOBIN et al, 2002). Wind erosion is localized in north-west Europe and Central and Eastern Europe (EEA, 2003).

There is an increasing awareness that erosion, which is primarily responsible for the severe degradation occurring in topographically complex landscapes, is caused not only by wind and water, but also by tillage, mainly due to the use of heavy powerful tillage machinery (GOBIN et al, 2002). The rate of soil formation being slow, any soil loss of more than 1 tone/ha/yr can be considered as irreversible within a time span of 50-100 years (EEA, 1999).

In Romania, there is a intensive concern about the assessment, the inventory and prognosis of erosion degradation process. The risk assessment involves the existence of a difference between the hazard (risk, threat) and the probability of its occurrence. There is a need of a stepping evaluation process, beginning with the identification and description of the risk and ending with the risk assessment.

The paper aims to describe several ways to evaluate the soil erosion process at commune (NUTS4) level, using different input data available at proper scales. As a study case, the Adamclisi commune, Constanța county, has been chosen. For this commune, different data regarding soil and land use have been available at different scales.

MATERIAL AND METHODS

The main data used in this analysis are: a) the soil map of Romania, 1:200,000 scale; b) the LCCS map, at the scale 1:100,000; c) the soil map for Adamclisi at the scale 1:10,000; d) its associated database (describing the main physical, chemical and morphological parameters); and e) the associated land use map at the scale 1:10,000.

Firstly, the soils affected by erosion degradation process have been designed, using the attributes of the polygons from both soil maps.

Secondly, for the assessment of water erosion process, a qualitative, as well as a quantitative approach, has been used.

The map of risk for water erosion process has been obtained directly from the attributes of the soil map at 1:200,000 scale.

The quantitative approaches meant the evaluation of soil loss (t/ha/yr), using both the adjusted USLE method (MOTOC et al, 1975), and the PESERA European model (KIRKBY et al, 2003).

In order to apply Motoc adjusted method, the following input data have been used: a) the Adamclisi soil map at the scale 1:10,000, containing attribute data refering to the soil type and subtype, surface and subsoil texture, parental material, slope, erosion intensity and area affected by erosion, land use, land evaluation marks for different crops and land uses; b) the Digital Terrain Model SRTM-30; c) the land use map 1: 10,000 scale, for Adamclisi commune.

The adjusted method developed by MOȚOC is based on USLE equation (Universal Soil Loss Equation), computing the soil loss (E) in t/ha/yr, with different computation methods:

$$E = K \cdot L^m \cdot I^n \cdot S \cdot C \cdot C_S$$

K – rainfall erosivity index has values between 0.09 and 0.14, the values being settled by expert judgment. For Adamclisi, a mean value of 0.096 have been considered.

S – soil erodibility coefficient has values between 0.7 and 0.9. The areas affected by surface erosion, erosion intensity degrees, as well as the dominant soil types, have been taken into consideration, according to the ICPA methodology (MESP, 1987). The outputs have been joined with the soil map and then converted in a grid coverage.

L and I – topographic factors. For computing these factors, the Digital Terrain Model SRTM-30 have been used an input coverage.

L – slope length was considered as having 2 values: 30 m when flow direction is the same with pixel's sides (the aspect is N-S or E-V), and $30\sqrt{2}$ for the flow direction diagonally to pixel (the aspect is NV-SE for example) (PATRICHE et al, 2006).

I – slope gradient. In this paper, the simple method of slope gradient and flow direction (Sammons, 2004) and an improved equation from WEPP model (USDA, 1995) have been used, and the results have been compared.

C – the canopy factor is a simple relation between erosion on bare soil and erosion observed under a cropping system. The C factor combines plant cover (canopy), the yield and the associated cropping techniques, ranging from 0.02 for forest areas to 1 for bare soils.

Cs – a factor that takes into account specific erosion control practices such as contour tilling or mounding, or contour ridging. It varies from 1 on soil with no erosion control to about 1/10 with tied ridging on a gentle slope (ROOSE, 1996). For Adamclisi, the value is 1.

The soil loss was computed both for bare soil, and for soil covered by vegetation (with canopy).

The PESERA project produced a regional model with a physical basis that can be applied to larger areas and can be used for scenario analysis and impact assessment. The data taken into account are as follows (KIRKBY et al, 2004): a) Climate data – The MARS database, assembled for Monitoring Agriculture with Remote Sensing (MARS Project), providing daily time series of rainfall, temperature and potential evapotranspiration, interpolated to a 50 km grid for Europe; b) Soils data – The European Soil Database, compiled by the European Soil Bureau Network (KING et al, 1995; HEINEKE et al, 1998), under the coordination of the JRC-Ispra, has been used to provide a consistent level of soils data at 1 km resolution across Europe; c) Land cover – Land use for PESERA is based on CORINE land cover at 250 m resolution for 1989; and d) Topography – A 30 second (1 km) DEM has been available from EROS for some years. Recently the SRTM 3 second (90m) DEM has been released for Europe, and this is being used to refine the data layer for local relief.

RESULTS AND DISCUSSIONS

At the beginning, the soils affected by erosion degradation process have been designed, using the polygons' attributes from the soil maps at the scales: 1:10,000 (fig. 1a) and 1:200,000 (fig. 1b).

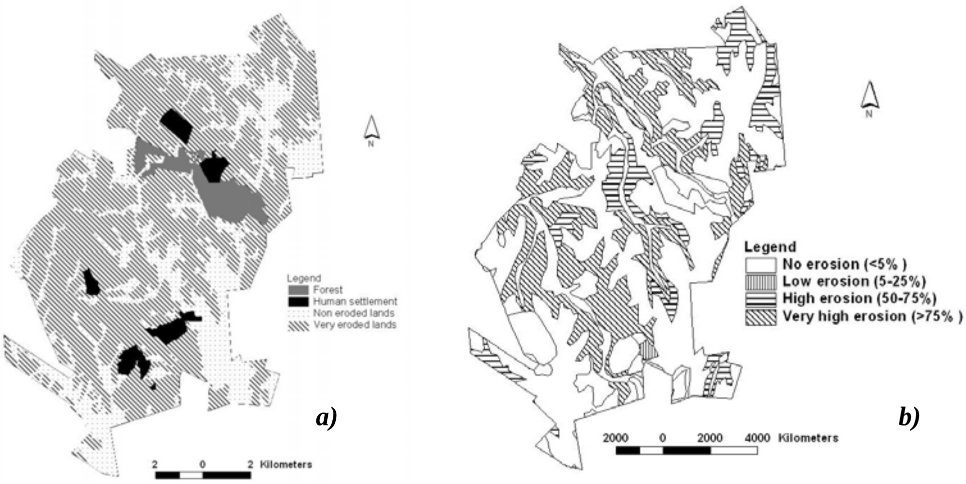

Figure 1. Adamclisi – Soil erosion maps using input data from soil map at the scales: a) 1:10,000 and b) 1:200,000

The results of this comparison are very different due to the different scales of the input soil maps (at the scale 1:10,000, the areas affected by erosion could be larger due to the more detailed soil data), as well as to different moments when these maps have been developed (nearly 30 years between gathering the data for the two maps, the erosion process being in progress all this time).

The map of erosion risk is shown in fig. 2, and it is similar to the map of the actual state of eroded soils at the scale 1:200,000. It could be noticed a similitude between the areas affected by soil erosion and the areas with risk to soil erosion.

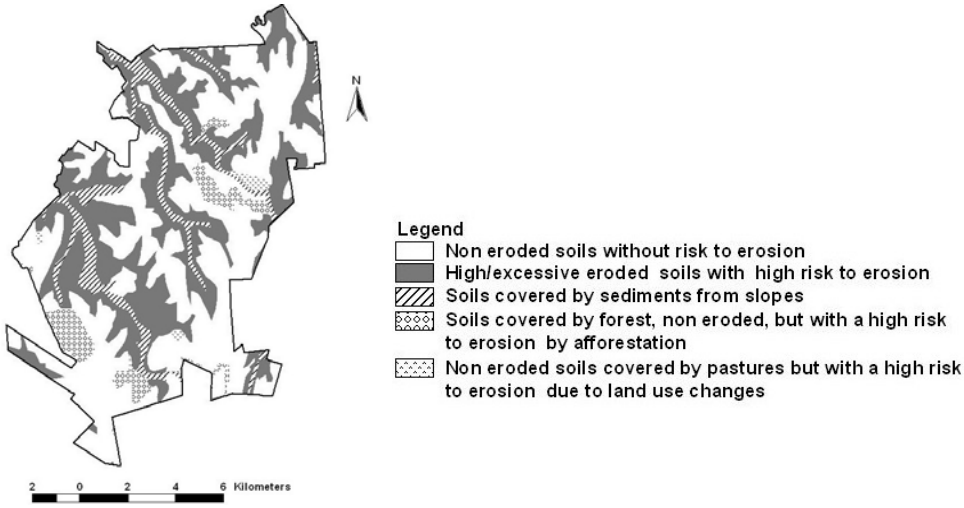

Figure 2. Adamclisi – The map of water erosion risk, using information from soil map at the scale 1:200,000

The soil loss has been computed in three different ways (MOTOC adjusted method and WEPP equation, as well as running PESERA model). The first two methods have been taken into consideration on bare soil and on soil covered by vegetation, and the results are shown in fig. 3 and 4. The maps of soil loss are similar to the map of the actual state of eroded soils at the scale 1:200,000. It could be noticed a similitude between the areas affected by soil erosion and the areas with risk to soil erosion.

It could be also noticed that all four maps are very similar, the greater values of soil losses being located on slopes. The difference is given by the maximum soil loss: for Motoc method 14.924 t/ha/yr on bare soil, and 14.924 t/ha/yr on soil covered with vegetation, and for WEPP model, 3.922 t/ha/yr on bare soil, and 3.39 t/ha/yr on soil covered with vegetation. The values are greater for bare soils in both methods, but less than usual values for Dobrogea (15-20 t/ha/yr), the canopy leading to a decrease of risk to erosion. The areas with such high values are small, the larger area being occupied by soils without risk to erosion. This is due to small values of coefficients related to soil and climate, while the LS factor focused the runoff on small areas, located on slopes. The threshold values being 2t/ha/yr for acceptable losses, only about 2% of the total area of Adamclisi shows risk to erosion. The losses have been classified using 7 classes, according to Indicator no. 187 (MESP, 1987) and are presented in table 1 for Motoc adjusted method.

By running PESERA model, the soil loss values are significantly smaller, highlighting no risk of erosion in Adamclisi (fig. 5). The estimated values are less than 0,4 t/ha/yr, meaning no risk of erosion according to Indicator no. 187 MESP. The higher values are on slopes, similar to the estimated values using Motoc adjusted method.

The small values obtained running PESERA model (table 2) are not usual for this region. The area is occupied mostly by eroded soils (regosols and erodisols) and some soils on slopes. Therefore, a risk to erosion is mostly expected.

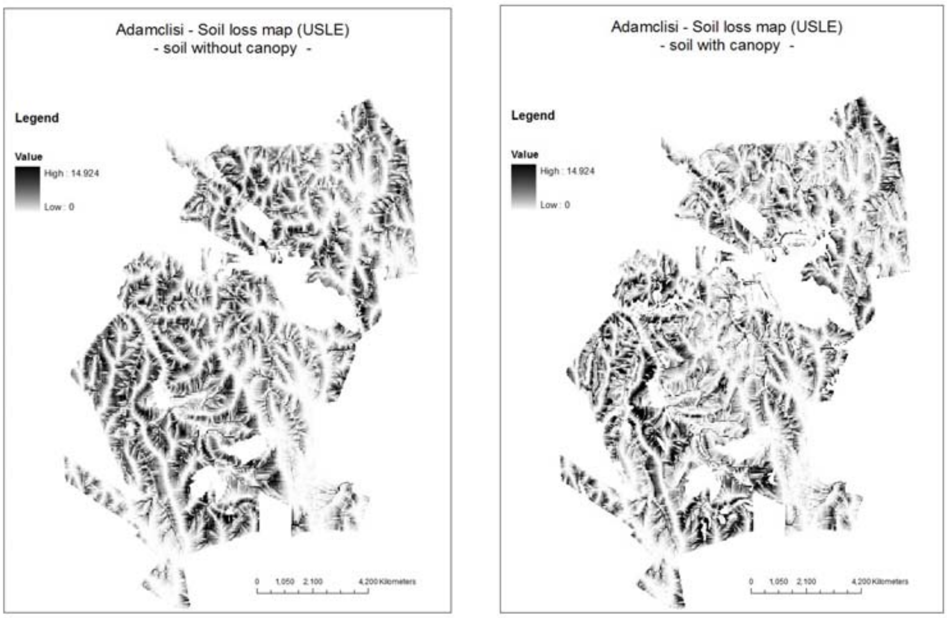

Figure 3. Adamclisi – Soil loss maps using Motoc adjusted method for: a) bare soil, b) soil covered by vegetation.

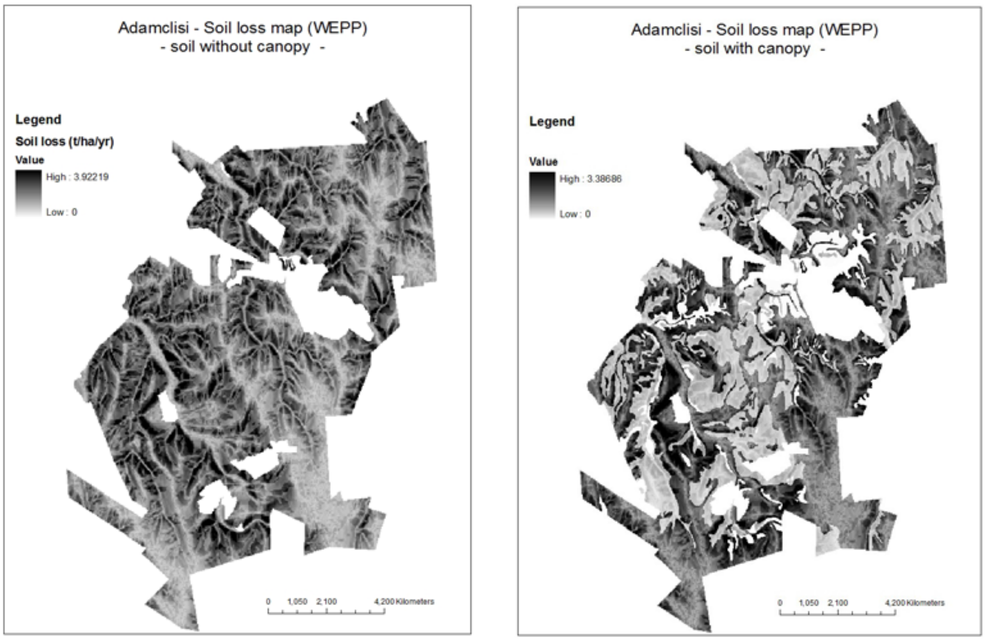

Figure 4. Adamclisi – Soil loss maps using WEPP equation for: a) bare soil, b) soil covered by vegetation.

Table 1

Soil loss estimated by using Motoc adjusted method

Class	Soil loss (t/ha/yr)	Area ha	%	ha	%
		Bare soil	Soil with canopy		
1	0 - 2	13509.50	98.14	13414.60	97.47
2	2 - 4	202.41	1.47	274.95	2.00
3	4 - 6	39.06	0.28	48.87	0.36
4	6 - 8	11.61	0.08	15.03	0.11
5	8 - 10	2.52	0.02	9.00	0.07
6	10 - 12	0.81	0.01	0.81	0.01
7	12 - 15	0,54	0,01	0.18	0.00
		13765.91	**100.00**	13763.44	100.00

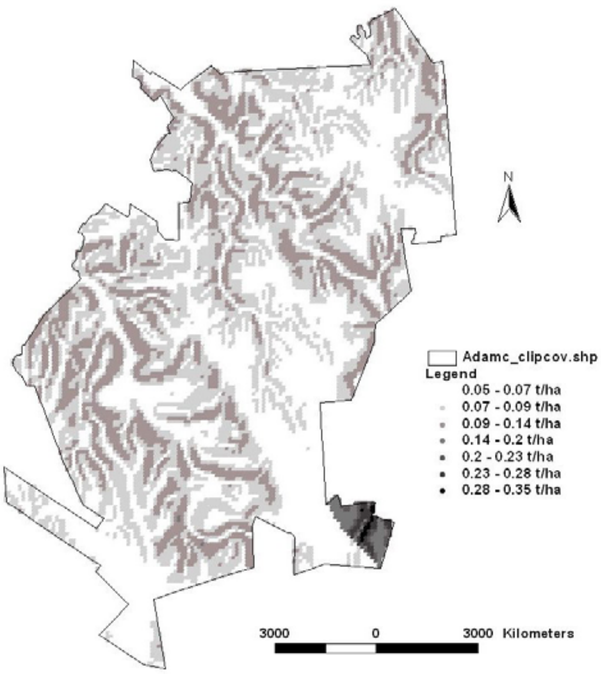

Figure 5. Adamclisi – Soil loss map using PESERA model and SRTM-100 m.

Table 2

Soil loss estimated by using PESERA model

Class	Soil loss (t/ha/yr)	Area ha	%
1	0.00 – 0.07	6081.00	44.06
2	0.07 – 0.09	2754.00	19.96
3	0.09 – 0.14	4772.00	34.58
4	0.14 – 0.20	92.00	0.67
5	0.20 – 0.23	39.00	0.28
6	0.23 – 0.28	50.00	0.36
7	0.28 – 0.35	13.00	0.09
		13801.00	**100.00**

The values of soil losses computed using Motoc adjusted method are in the same range of values with measurements from experimental fields. On another hand, PESERA model uses complex data, that could be more appropriate to the assessment of risk to erosion, but there are no measurements to support these results.

The harmonization of all methodologies is an important issue in risk assessment; therefore an analysis of them is necessary.

The concept of tolerable soil loss emerged from the need to highlight in a way more appropriate, the balance between the eroded soil loss and the new soil mass. Practically, the tolerable soil loss is the value corresponding to the annually mean rate for soil erosion that don’t lead to a significant long-term drop of yield capacity (therefore, being balanced by pedogenesis process). Another definition: ”maximum soil loss due to surface erosion, allowing a high level of soil productivity, for an undefined period” (STAMEY si SMITH, 1964, quoted by POPA, 2005). This concept is used to assess the vulnerability of agroecosystems to soil erosion process: Vulnerability = Erosion rate / Tolerable soil loss.

For values closed to 1, the agroecosystem works in equilibrium, for values less than 1, the soil pedogenesis is more important, while for values greater than 1, the accelerated soil erosion is in progress, leading to soil degradation (FLOREA, 1997).

As a consequence several authors tried to study the maximum tolerable soil loss for agricultural areas, as shown in table 3 (POPA et al, 2005).

Table 3

Maximum tolerable soil loss for arable soils

Author	Tolerable soil loss (t/ha/yr)
Thompson L. M.	1.2 – 14.4
Whatt si Miller	5.0 – 10.0
Whischmeyer W.H	7.0 – 11.0
Motoc M.	2.0 – 8.0
FAO-UNEP-UNESCO (1979)	0.0 – 10.0
Jambor et al (1998)	0.0 – 4.0
Stefanovits, 1966	2.0

MOȚOC and VINTILĂ (1995) proposed the value of 6-8 t/ha for tolerable soil loss on arable soils, and 9 t/ha/yr for orchards and vineyards (approximately 0.5-0.7 mm soil depth annually and, respectively, 0.8 mm). There is assumed that 1-2 m soil depth is replaced in 5000 years. This means a loss of 2.8-3 t/ha/yr for 1 m depth. As a consequence, table 4 shows the following classes for erosion risk, closed to that estimated by Motoc.

Table 4

Main classes for soil erosion risk

Class	Estimated soil loss (t/ha/yr)
Negligible	3 - 6 t/ha/yr
Weak erosion	7 - 15 t/ha/ yr
Moderate erosion	15 - 30 t/ha/ yr
Strong erosion	30 - 45 t/ha/an yr
Very strong erosion	45 - 60 t/ha/ yr
Excessively	>60 t/ha/yr

CONCLUSIONS

The soil erosion process has been evaluated at NUTS4 level (Adamclisi commune, Constanta county), using maps at different scales. There was noticed a similitude between the areas affected by erosion and those with risk to erosion.

Using Motoc adjusted method, 14.924 t/ha/yr have been obtained as maximum soil loss, less than estimated values for Dobrogea (15-20 t/ha/yr). The areas with maximum soil losses are small and situated on slopes, due to the LS factor. A smaller value was obtained using WEPP model (3.922 t/ha/yr). If soil losses less than 2t/ha/yr are tolerable, only an area of approximatively 2% from Adamclisi area has a risk to erosion. The results are in the range of values from measurements for experimental fields.

Using PESERA model, there is no risk to erosion for Adamclisi, the soil losses being less than 0,4 t/ha/yr, with a similar trend of an increasing erosion on slopes. There is not in concordance with soil inventories for that area, which include many eroded soils (regosols and erodisols).

The soil loss maps are similar as image, the area with the most pronounced risk being the same (about 2%), but the values computed in different ways are different. That means that is necessary a reassessment of the factors involved in USLE equation, as well as their weighting.

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