ΔΗΜΙΟΥΡΓΙΑ ΧΑΡΤΗ ΠΡΟΒΛΕΨΗΣ ΕΔΑΦΙΚΗΣ ΑΠΩΛΕΙΑΣ ΓΙΑ ΤΗΝ ΚΟΙΛΑΔΑ SARVIZ, ΟΥΓΓΑΡΙΑ

Ευελπίδου Ν.[1], Barczi A.[2], Vona M.[2], Penksza K [2], Centeri C.[2]

[1]Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών, Τμήμα Γεωλογίας και Γεωπεριβάλλοντος, Τομέας Γεωγραφίας και Κλιματολογίας
Πανεπιστημιούπολη, Ζωγράφου, 15784, Αθήνα, e-mail: evelpidou@geol.uoa.gr
[2] Πανεπιστήμιο Szent Istvan, Godollo,
Τομέας Συντήρησης Φυσικού Περιβάλλοντος και Οικολογίας Τοπίου
H-2103, Godollo, Pater K.u.1., Hungary, E-mail: Centeri.Csaba@kti.szie.hu

Περίληψη

Η κοιλάδα του Sárvíz βρίσκεται ΝΔ της πρωτεύουσας της Ουγγαρίας (Βουδαπέστη). Η συνολική έκταση της υπό μελέτη περιοχής είναι 60.561,85ha. Το εδαφικό κάλυμμα ποικίλει, σε μορφή μωσαϊκού, αλλά τα μεγαλύτερα τμήματα είναι μορφής Τσέρνοζεμ. Στα πλαίσια της εργασίας αυτής, δημιουργήθηκε ο εδαφικός χάρτης της κοιλάδας, με βάση παλαιότερους χάρτες, γεωτρήσεις και αεροφωτογραφίες. Βασιζόμενοι στον εδαφικό χάρτη, δημιουργήθηκε ο χάρτης διαβρωσιμότητας για την περιοχή της Sárvíz Valley Small Region Association. Η μοντελοποίηση της διεργασίας της διάβρωσης έγινε μέσω της χρήσης του μοντέλου USLE (παγκόσμια εξίσωση απώλειας εδάφους). Εντοπίστηκαν οι περιοχές στις οποίες χρειάζεται ιδιαίτερη προσοχή και πρέπει να ληφθούν μέτρα προστασίας. Ένας από τους στόχους της εργασίας αυτής, είναι η εφαρμογή των μεθόδων χαρτογράφησης και μοντελοποίησης, για τον υπολογισμό της διάβρωσης. Με τη χρήση των εργαλείων αυτών, είναι δυνατός ο καθορισμός των περιοχών που χρίζουν προστασίας σε θέματα διάβρωσης, καθώς επίσης και εντοπισμού των περιοχών μικρότερης σημασίας σε αγροτική εκμετάλλευση.

PREPARING THE SOIL LOSS PREDICTION MAP OF THE SARVIZ VALLEY, HUNGARY

Evelpidou N.[1], Barczi A.[2], Vona M.[2], Penksza K.,[2] Centeri C.[2]

[1]University of Athens, Faculty of Geology and Geoenvironment, Dept. of Geography and Climatology
Panepistimiopolis, Zografou, 15784, Athens, e-mail: evelpidou@geol.uoa.gr
[2]Szent Istvan University, Godollo, Dept. of Nature Conservation and Landscape Ecology
H-2103, Godollo, Pater K.u.1., Hungary, E-mail: Centeri.Csaba@kti.szie.hu

Abstract

Sárvíz Valley is approximately 100km long, situated SW from capital of Hungary (Budapest). The total examined area of the valley is 60561.85ha. The soil cover is very mosaic, but the larger spots belong to Chernozems. We prepared the soil map of the valley, based on former soil maps, core samplings and aerial photographs. Based on the soil map we prepared the erosion map on the territory of the Sárvíz Valley Small Region Association. Erosion modeling was done by the USLE (Universal Soil Loss Equation) model. We marked areas where different amount of special attention and soil protection measures are needed. One of the basic aims of this study is the application of soil mapping and modeling for the calculation of erosion. With the help of these tools we are able to outline the areas which, as far as erosion is concerned, are in need of protection, as well as the less useful areas for agricultural production.

Λέξεις κλειδιά: USLE, διάβρωση, χαρτογράφηση, μοντελλοποίηση.

Key words: USLE, erosion, mapping, modeling.

1. Introduction

Inappropriate land use is one of the main reasons for soil erosion and land degradation (Hacisalihoglu, 2007; Evelpidou, 2006). Soil loss prediction is a perfect tool to outline areas where soil protection measures should take place. Various soil erosion models have been developed (Giordano, 1986; Kirkby, 1995; Thornes et al., 1996; Baturst et al., 1996) and other models have been proposed (Elwell, 1978; Morgan et al., 1984; Knisel, 1980; Nearing et al., 1989). Gournelos et al. (2004) proposed a model with the use of soft computing methods. It is possible to use soil erosion models to find the most appropriate crops to stop soil loss and unexpected runoff. The most widely used model for soil loss prediction is the USLE - Universal Soil Loss Equation (Wischmeier and Smith, 1978). USLE predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning (Stone and Hilborn, 2000).

Authors emphasize the importance of local measurements in order to use the USLE outside the USA (Hall *et al.*, 1985). Numerous measurements were made to use the model in other countries. The USLE was applied to the Rio Lempa Basin (El Salvador and Honduras) using GIS and remote sensing technolinogies, and the estimated erosion rates were compared with sediment delivery ratios. Spatial analysis indicated that agriculture on very steep slopes contributes only a small fraction to the total estimated soil erosion, whereas agriculture on gentle and moderately steep slopes played a more important role (Kim *et al.*, 2005). Onyando *et al.* (2005) were using USLE to calculate the potential amount of erosion in order to find out the source of the sediment in Lake Baringo that was filled up rapidly by sediment, decreasing its depth from 8 to 2,5m from 1972 to 2003. Fistikoglu and Harmancioglu (2002) used the USLE integrated with GIS to identify the gross erosion, sediment loads, and organic N loads within a small region of the Gediz River, Turkey. USLE model, have been used to estimate soil erosion in a Himalayan watershed (Jain *et al.*, 2001). Tattari *et al.* (2001) found that USLE highly overestimated erosion for Finnish agricultural clayey soils with relatively steep slopes (i.e. 7%-8%). Sparovek *et al.* (2000) compared three water erosion prediction methods (Cs-137, WEPP, USLE) in south-east Brazilian sugarcane production. USLE predicted the highest erosion values and spread out over the widest range.

Numerous attempts were made to make input data more accurate. Wilkes and Sawada (2005) generated annual and monthly R factor maps using geostatistical interpolation. Their annual and seasonal maps can help in land use planning within the regions of intense agriculture surrounding Lakes Huron, Erie, and Ontario. R factor map was prepared by da Silva (2004) for Brasil.

Rodriguez et al. (2006) were investigating the K factor of the USLE on the Canary Island to find out the role of soil organic matter (SOM) in the aggregate stability and in the resistance of Andosols to water erosion. The soil erodibility factor according to the USLE method was calculated for selected Polish soils by Wawer *et al.* (2005). Lang *et al.* (1984), Centeri (2002), Centeri and Császár (2005) and Kertész *et al.* (1997) measured soil erodibility under artificial rainfall. Stein *et al.* (1997) examined erodibility of reclaimed surface mined areas. Loch *et al.* (1998) had soil erodibility measurements on Australian soils. In Hungary, calibrations are made for calculating K factor based on measurements under natural rainfall (Kertész *et al.*, 1997). However Kertész *et al.* (1997) have not published results in Hungarian and soil types were not classified in the Hungarian Soil Classification System.

Soil erosion was examined with rainfall simulation from various aspects. Lang *et al.* (1984), Harmon *et al.* (1978), Lattanzi (1973) and Kerényi (1981) examined splash erosion under artificial rainfall on small erosion plots. Inter rill erosion required wider and longer plots (Neal 1938, Zingg 1940 and Lattanzi 1973). Van Liew and Saxton (1983), Meyer and Harmon (1989) and Quansah (1985) had researches on rill erosion. Rainfall simulators were used to describe larger areas Gilley *et al.* (1977), Hahn *et al.* (1985), Hart (1984), Mitchell *et al.* (1983) and Kertész *et al.* (1997). Finally rainfall simulators were under investigations (Auerswald and Eicher, 1992; Auerswald *et al.*, 1992a; Auerswald *et al.*, 1992a).

Simonides (2005) modified the gradient and slope length factor in order to compare the modified version of the USLE with the original model. Slope length and gradient is the most investigated area because it is the core of the digital version of the model. Water erosion is greatly affected by these two factors, thus make the calculation of the LS factor more appropriate highly increase the correctness of the model (Warren *et al.*, 2005; Wu *et al.*, 2005).

USLE C-factors (cover-management) for 40 crop rotation systems was investigated on arable farms in the Kemmelbeek watershed, Belgium (Gabriels *et al.*, 2003).

The major weakness of the USLE model is that it is unable to measure sedimentation. The sediment delivery ratio (SDR) is the usual tool to calculate the amount of the sediment (Krasa *et al.*, 2005).

The USLE was used for various purposes around the world. Haileslassie *et al.* (2005) used the model for the assessment of nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Moehansyah *et al.* (2004) used three soil erosion models for Riam Kanan catchment in South Kalimantan province of Indonesia. While ANSWERS (Areal Non-point Source Watershed Environment Response Simulation) was evaluated for its accuracy to predict both runoff and soil loss, USLE and AUSLE (Adapted USLE) were evaluated for soil loss only. Auerswald *et al.* (2003) examined soil erosion potential of organic versus conventional farming by USLE in Bavaria. They predicted an average 15% less erosion on arable land for organic agriculture than for conventional agriculture. Sparovek *et al.* (2000) compared three water erosion prediction methods (Cs-137, WEPP, USLE) in south-east Brazilian sugarcane production. USLE predicted the highest erosion values and spread out over the widest range.

Soil loss tolerance must be mentioned in order to set the categories on the soil loss map. In agricultural production permissible soil loss means that agricultural activity gives chance for soil formation and does not reduce soil fertility (Holý, 1982). Hall *et. al.* (1985) concluded, "An upper limit (to allowable soil loss) of 11 t/ha/year is generally accepted since it approximates the maximum rate of A horizon development under optimum condition". Larson (1981) proposed a two-level approach to setting T values: a T1 value reflecting on site soil productivity maintenance objectives, T2 value reflecting broader social purposes and off-site concerns, such as water pollution and reservoir sedimentation. The T1 values would be set by scientific experts in soils and agriculture, T2 values would be set by economists, environmental scientists and planners, and public policymakers. This way T2 temporarily might be set higher than T1.

The aim of this study is to show the soil loss map prepared by the USLE for the Sárvíz Small Region Association. USLE was the only possible solution to prepare this map because we had all the input data for this model only. The Sárvíz Small Region Association asked our research group to prepare a complex study of the area, including the planning of greenways. This project is a part of the complex study. On the field of erosion there is a strong cooperation between Greece and Hungary.

2. Data and methodology

2.1. Sárvíz Valley is approximately 100km long, situated SW from capital of Hungary (Budapest).

The total examined area of the valley is 60561.85ha. The valley is situated 89-161m a.s.l. The lower floodplains are 1km wide, followed by a second terrace of the river, 6-12m above the recent plain. The parent materials of the soils are mainly from the Pleistocene (dominantly loess, loessy sand). The soil cover is very mosaic, the larger spots belong to Chernozems, but there are water and salt affected soils, too. The examined Small Region Association involved ten settlements (Aba, Tác, Csősz, Soponya, Sárkeresztúr, Kisláng, Sárszentágota, Káloz, Sárbogárd, Sáregres).

2.2. Methodology – Soil loss calculation with the USLE model

The USLE is the most comprehensive technique available for estimating erosion on cropland but it is performing well under forests and meadows, too. It involves six major factors that affect upland soil erosion in terms of water: rainfall erosivity, soil erodibility, slope length, slope steepness, crop management techniques and surface cover (on close to natural areas), and conservation techniques. The USLE was created by Wischmeier and Smith (1978) to provide a convenient working tool for conservationists and it is used by scientists, students, farmers and decision makers. The well known equation is the following:

$$A = R * K * L * S * C * P$$

A = Soil loss $[t \cdot ha^{-1} \cdot y^{-1}]$,
R = Rainfall erosivity factor $[MJ\ mm\ ha^{-1} \cdot h^{-1} \cdot y^{-1}]$,
K = Soil erodibility factor $[t \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}]$,
L = Slope length factor [dimensionless],
S = Slope steepness factor [dimensionless],
C = Crop management and surface cover factor [dimensionless],
P = Conservation techniques [dimensionless].

Procedure for using the USLE

1. Determine an average R factor for the area, setting the return possibility of the average yearly rainfall amounts.
2. Determine the K factors (based on nomograms of Wischmeier and Smith (1978), on equation based on soil characteristics and on measurements under artificial rain).
3. Calculate the LS values based on the Digital Elevation Model.
4. Choose the crop type factor for the crop to be grown.
5. Select the P factor based on the tillage practice to be used.
6. Multiply the 5 factors together to obtain the soil loss in (t·ha-1·y-1).
7. Erosion modeling was done by the ERDAS Arc/Info and Arc/View programs.

3. Results

3.1. Description of the settlements

Based on the renewed genetic soil map of the area, prepared by our research team, a more appropriate soil erodibility map was used for the soil loss map at the scale of 1:10000 (Figure 1.).

It was important for the Sárvíz Small Region Association to have a description for each settlement separately, so we described the erosion map by cutting out the areas settlement by settlement (Table 1).

Table 1. Soil erosion threat of the settlements in the Sárvíz Micro Region, Hungary

Settlements	**Dustribution of the different erosion categories (%)**		
	0-2 t ha^{-1} y^{-1}	**2-11 t ha^{-1} y^{-1}**	**11< t ha^{-1} y^{-1}**
Aba	86.9	11.9	1.2
Tác	92.9	7.1	0.0
Csősz	89.8	9.9	0.3
Soponya	88.4	11.6	0.0
Sárkeresztúr	91.1	8.7	0.3
Kisláng	96.1	3.9	0.0
Sárszentágota	96.0	3.8	0.1
Káloz	87.6	12.3	0.1
Sárbogárd	84.2	15.0	0.9
Sáregres	79.4	18.5	2.1
Average:	89.2	10.3	0.5

With the help of the GIS, we were able to produce statistical tables based on erosion modeling (Table 1). Table 1. shows data for the 10 settlements in the Sárvíz Small Region Association, for the three preset categories.

Most of the settlements' area belongs to the lowest erosion category (0.2 t ha-1 y-1). The range of this area coverage is 79.4–96.1%, standard deviation (SD) value is 4.9.

The medium erosion category (2-11 t ha^{-1} y^{-1}) has similar standard deviation (SD = 4.4) since values of percentage ranges from 3.8 to 18.5. Six out of 10 settlements has 9.9% or more areas with medium erosion category. This is the erosion rate where soil protection measures are usually not enforced but erosion is higher than soil formation, so we can count on continuous soil depletion. This medium erosion category might be more important for the farmers and decision makers than higher values since it is not connected to any obligatory measures against erosion!

The severe erosion category (11< t ha-1 y-1) cover only a small – an average 0,5% – proportion of the areas and it has a much lower, SD = 0,66. It means about 300 hectares inside the examined area and it can cause serious off-site effects locally, because 11< t ha-1 y-1 totals 3300 tons of sediments concentrated on a relatively small area. This huge amount of soil loss must be handled by local authorities.

It was important to calculate erosion by settlements. We prepared the statistics for each settlements and for each erosion categories. Figure 1. shows the order of the severe erosion category of the settlements. Figure 1. calls attention of the mayors of the settlements on the importance of soil loss.

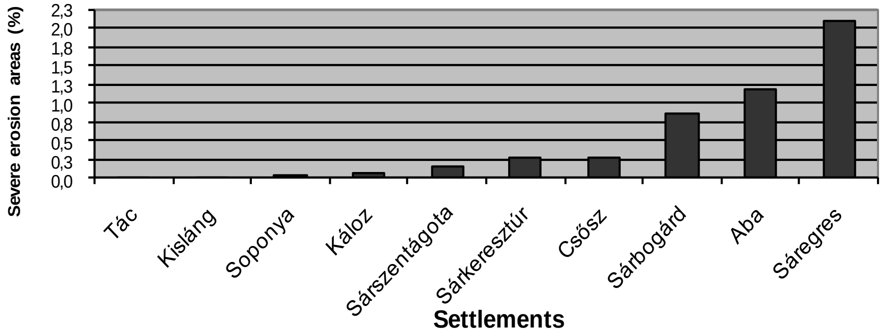

Figure 1. Order of the settlements and the proportion of severe erosion on their area, Sárvíz Valley Micro Region Association, Hungary

3.1. Erosion threat scenarios with various C factors on arable land

There is no digital system that should follow the changes of crops on arable lands. The only solution to solve this problem is to prepare scenarios or to choose a farmer who is ready to provide us information for a certain territory. We should have needed information for the whole investigation area so we could only work with the scenarios. Table 2. shows the results of soil loss in percentage for the three erosion categories. The basis for this calculation is the erosion map (Figure 2.).

Table 2. Erosion threat under different plant covers in the Sárvíz Micro Region Association

Soil loss t/ha/y	C factor			
	C=0,1	C=0,2 5	C=0,5	C=0,6
	(in the percentage of the total area)			
0-2	99,04	95,47	87,87	84,09
2-11	0,96	4,40	11,34	14,78
11-	0,00	0,13	0,79	1,13

As we can see from Table 2., it is not necessary to plant trees on the arable lands, it is enough to choose the crops for the crop rotation carefully to reach 0.1 value for the C factor!

The overall geograpy of the examined area can be seen in Figure 1. We can see that the valley, characterized by lowlands is situated in the direction of North-East to the South-West and these areas bolong to the lowest soil loss category. Low erosion plains are followed by higher erosion hillsides on both sides of the valley.

Figure 2. outline areas with the various erosion categories. The map can be used to produce different scenarios for farmers not only by changing the C factor but with changing R factor and thus forecast the effects of climatic changes. If we remove the C factor from

the input parameters we get the soil erosion threat of the area.

4. Conclusions

Soil loss prediction is an increasingly developing scientific area. There are tens of models available for various purposes. In the present work USLE was the only available model for this huge area in order to calculate erosion rates for local authorities, as it was expected.

The soil loss map provides important information for farmers and decision makers. Figure 2. is a perfect tool to find areas where special attention is needed so this method provides economically viable way of land protection. If there is no protection measures taken, local population has to cope with hundreds of tons of sediment yearly (!) that could even cause more, unexpected problem besides piling up sediment in street dykes.

We offer the erosion map for further investigation of nature conservation, environmental protection and for the planning and construction of greenways and other ecological corridors.

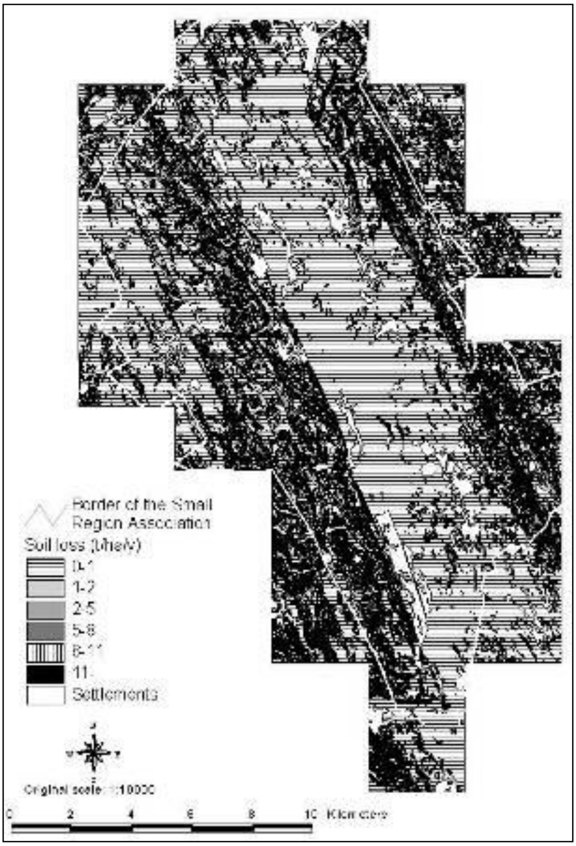

Figure 2. Erosion map of the Sárvíz Valley Micro Region Association, Hungary

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