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# THE ROLE OF VEGETATION COVER IN THE CONTROL OF SOIL EROSION ON THE TIHANY PENINSULA

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Land cover has a basic role in soil protection. Soil erosion prediction of the hilly areas in Hungary is limited to arable lands and is not estimated under natural vegetation. Even soil mapping activity of cooperatives is limited to arable lands and soil maps under forests are prepared by forestry. In the present work soil erosion prediction is modelled by Universal Soil Loss Equation on the Tihany Peninsula. Crop management factors for natural vegetation are identified and local soil erodibility measurements are used to prepare an up-to-date and proper soil loss prediction map on the peninsula.

Key words: erodibility, erosion model, land cover, prediction, soil erosion

## INTRODUCTION

Because soil is formed slowly, it is essentially a finite resource. As a result of this relatively recent realisation, the severity of the global erosion problem is gradually becoming widely appreciated. The rate of soil degradation is greatly accentuated by using land for whatever purposes it is not capable of and by unsuitable methods of soil and crop management. Land cover has a basic role in soil protection. However agricultural production is usually not the best management practice for applying the best land cover. In the recent work I wish to analyse the effect of land cover in a national park where there has always been and still is present some agriculture, viticulture and the use of pastures.

Effects of plant cover on soil were investigated from many aspects. Researches on arable lands showed good effects of land cover on soil quality. Cover crops have the potential to improve soil health, to control erosion and weeds, and to maintain soil organic matter (Wagger 1989).

Natural soil variability in erosional landscapes accounts for yield differences that are not considered in erosion-productivity comparisons. Baseline data from virgin soils are lacking in most cases but the variability conclusion seems valid. Native vegetation differences in virgin soil in different landscape position (convex, concave slopes) support belief in soil differences. Differences in soils are because of differences in erosion potentials during soil development. Plant communities differ from place to place with the same general area (Daniels *et al.* 1987, Penksza *et al.* 1995).

Most researchers have found that forest clearing and soil erosion are in tight relationship (Paskett and Charles-Emile 1990). Between 1878 and 1988, aleppo pine area increased from 35,000 ha to 161,000 ha and sylvester pine from 30,000 ha to 230,000 ha in the department of Provence, alone. The explosion of conifers and the very combustible underbush increased incidence of fires. There will be continuing abandonment of cropland for the next 20 years, at least. In Provence, that will end cultivation on about 357,000 ha (Barbero *et al.* 1989).

In China, nearly all reduction in soil erosion were due to gully dams but still planted trees and shrubs on gully slopes, more crop rotation and bench terracing on more level farm land had their role in soil protection (Jiang *et al.* 1981).

Soó (1928) carried out research on the vegetation mapping of the Tihany Peninsula. He examined 60 plant associations. According to his work *Orno-Quercetum*, *Orno-Quercetum pubescenti-cerris*, *Quercetum petraeae-cerris*, *Querco-Carpinetum*, *Cotino-Quercetum*, *Chrysopogono-Caricetum* and *Querco pubescenti-Cotinetum balatonicum* are the most typical plant communities of the peninsula. At the end of the 19th century, human impacts caused an almost total deforestation of the peninsula. It provided good habitat for *Chrysopogono-Caricetum humilis, Caricetum humilis balatonicum*, *Diplachno-Festucetum sulcatae balatonicum*. Dry pastures were examined by Kárpáti *et al.* (1965) and Kárpáti *et al.* (1987). Barczi *et al.* (1996) has examined the relationship between relative ecological characteristics of typical associations of the Tihany Peninsula and measured soil characteristics. Penksza *et al.* (1994) report about new data on the flora and vegetation of the Tihany Peninsula. In their work they describe the area of lavender plantations as a separate association.

Ballenegger (1942) prepared the first detailed soil map of the Tihany area at the scale of 1 : 25,000. Teöreök and Sarkadi (1949) prepared a soil map of the peninsula at the scale of 1 : 50,000. Góczán (1970) examined the soil cover of the peninsula and concluded his experiences in a soil map at the scale 1 : 10,000. Barczi *et al.* (1997) prepared the digital version of the soil map of Tihany at the scale of 1 : 10,000.

## MATERIALS AND METHODS

*Estimating soil loss with USLE model*

Soil erosion researches started in the 1950s in Hungary. Later Wischmeier–Smith's Universal Soil Loss Equation (USLE) has been translated to Hungarian and related soil protection plans and works has been started. The standard reference for erosion modelling is the Wischmeier–Smith's Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978). New models were developed since 1978 but their hunger for input is too high and the database is not available or is very expensive to prepare. This is the reason why I chose USLE for my present work.

The USLE is an empirical model that uses physical factors to quantify the amount of soil loss per hectare per year. Its well-known equation is:
$A = R * K * L * S * C * P$

A = soil loss ($t\ ha^{-1}\ y^{-1}$);

R = rainfall erosion index ($MJ\ mm\ ha^{-1}\ h^{-1}\ y^{-1}$);

K = soil erodibility factor ($t\ ha\ h\ ha^{-1}\ MJ^{-1}\ mm^{-1}$);

L = slope length (dimensionless);

S = slope gradient factor (dimensionless); (L and S factors are combined to give one topographic factor: the LS factor. I used the modified version of slope length calculation of Hickey *et al.* (1994));

C = cropping cover management factor (dimensionless);

P = agricultural practice factor (dimensionless); (It is the ratio of soil loss with a specific support practice to the corresponding loss with upslope-downslope cultivation (Wischmeier and Smith 1978)).

*Database for USLE*

I was working at the scale of 1 : 10,000. The database for R and P factor were not available at our scale. R factor was constant according to local measurements. P factor was 1, since upslope-downslope cultivation was widespread. Other factors of USLE were based mainly on maps prepared by the team I am working in.

I used the digital version of the vegetation map of Zsembery (1999) to prepare the C factor map for the peninsula. Zsembery's vegetation mapping was based on areal photo interpretation on the former vegetation map of Soó (1928) and on fieldwork. With the help of the infrared photos and the fieldwork the association types could be separated.

The K factor map was based on the digital version of the soil map of Barczi (1996). I used the method of Hickey *et al.* (1994) and Desmet and Govers (1996) for calculating LS factor with GIS Arc/Info.

*Technical support*

I used ESRI (Environmental Systems Research Institute, Inc), NT Arc/Info 7.2 under Unix operation system for digital works and calculations, ESRI Arc/View 3.1 under Win98 operation system for presentation.

## RESULTS

*Rainfall erosivity (R factor) map for the Tihany Peninsula*

Since there are no detailed map for R factor at this scale, the R factor was constant = 162 MJ mm $ha^{-1}$ $h^{-1}$ $y^{-1}$.

*Soil erodibility (K factor) map for the Tihany Peninsula*

The second factor of USLE is K factor. I had rainfall simulations in the Balaton watershed to have a better calibration of K factors in the region. Our K factors varied from 0.008924 to 0.03806 t * ha* h * $ha^{-1}$ * $MJ^{-1}$ * $mm^{-1}$. I used these data to obtain the K factor map of the peninsula. Since K factor map is a basis for all soil erosion prediction models and in this manner it serves as basis for more sophisticated modeling, I include this in the list of results.

USLE is not able to calculate sedimentation, wherever the soil types' properties suggested (Cambisols, Fluvisols (FAO classification)), water or salt effected soils I gave zero K factor to show these soil types as potential sedimentation areas (Fig. 1).

*Cropping cover management factor (C factor, dimensionless) map for the Tihany Peninsula*

The vegetation map and its digital version were prepared at our university (Szent István University) and at the Purdue University (USA, Indiana State). Vegetation mapping was the basis for C factor map of the USLE model (Fig. 2). I used the USLE manual (Wischmeier and Smith 1978) for C factor classification. The result can be found in Table 2.

Different vegetation has different leaf area index (LAI) and it covers soil for different period of time during the year. The land cover of Tihany can be separated to four main types:

– settlements and lakes (C = 0),
– arable lands (0.5),
– vineyards and orchards (C = 0.55),
– natural cover (forests, meadow, etc.) with varying C factors (0.0005 to 0.11).

It is well-known that there are hundreds of land owners in Tihany, so it is hard to find out what kind of crop will be planted. On arable lands I chose the C factor of corn to predict effects of this – from the soil protection point of view – bad plant.

*Slope length (L, dimensionless) and slope gradient (S, dimensionless) factors for the Tihany Peninsula*

LS factor map was prepared by Pataki (2000) as described in "Materials and methods". These two factors play very important role in erosion modelling.

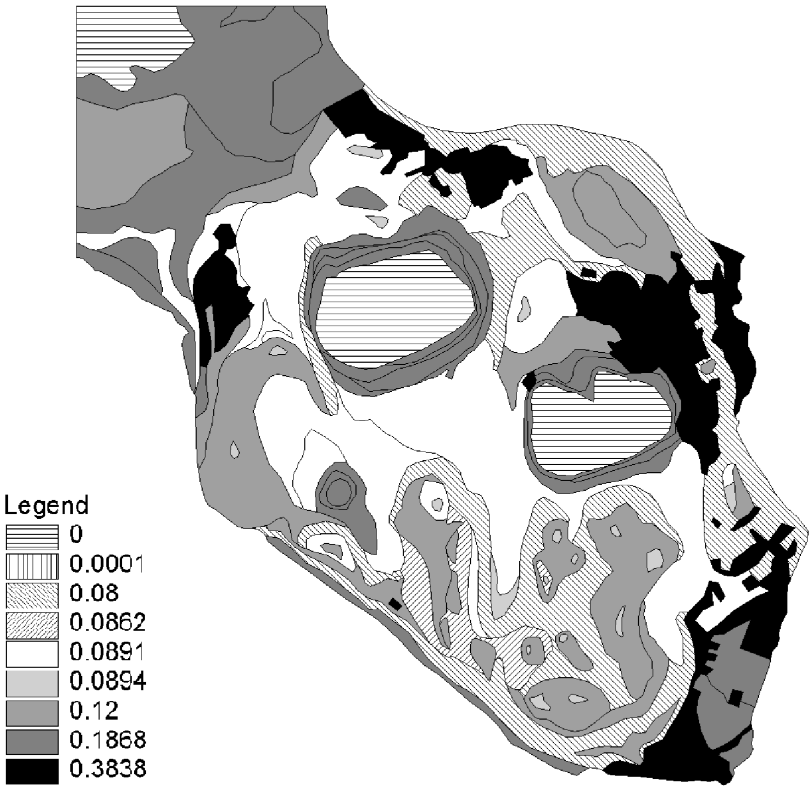


*Fig. 1.* K factor map at the scale of 1 : 10,000 for the Tihany Peninsula (for dimension of "t*ha*h*ha$^{-1}$*MJ$^{-1}$*mm$^{-1}$", values must be divided by 10)

*Table 1*
K factor distribution on the Tihany Peninsula

| Soil types | K factor |
|---|---|
| Leptosol with rocks in the A horizon | 0.03838 |
| Regosol | 0.03838 |
| Rendzina | 0.012 |
| Leptosol on basalt | 0.012 |
| Calcic Cambisol | 0.00891 |
| Cambisol on sand | 0.00894 |
| Luvisols | 0.00862 |
| Calcic Cambisol | 0.01868 |
| Phaeozem 1. | 0.01868 |
| Fluvisol | 0.0001 |

*Soil erosion prediction map for the Tihany Peninsula*

I have collected or prepared all maps of the USLE factors in digital forms for calculating soil erosion. The result can be seen on Fig. 3.

The white patches show areas where erosion means no threat or there are water bodies or settlements. Sustainable areas are in light

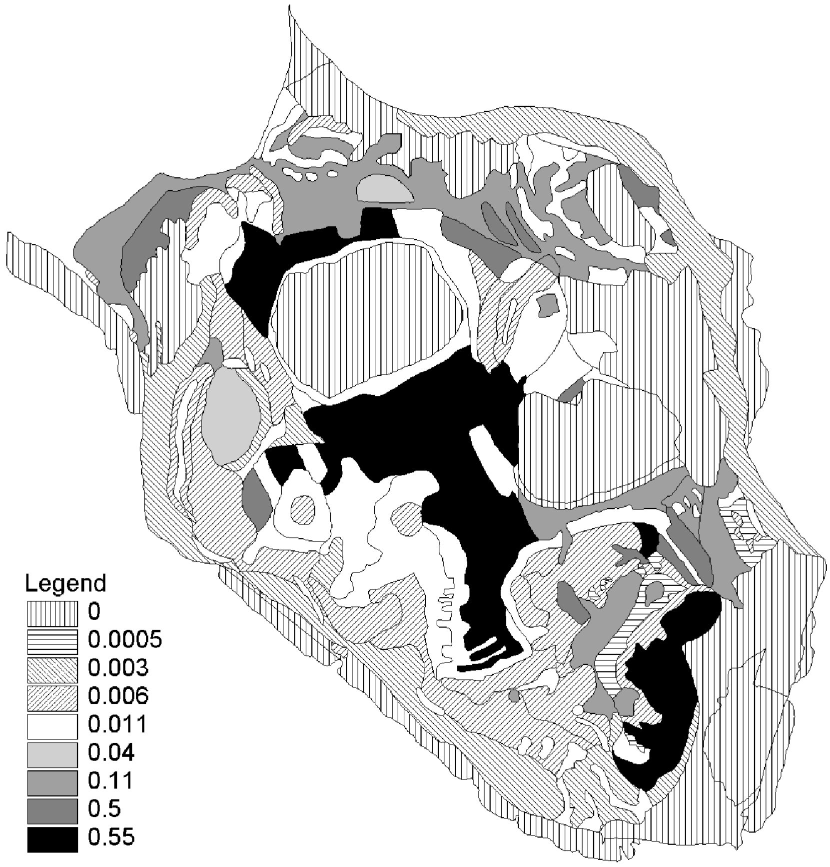


*Fig. 2.* C factor map at the scale of 1 : 10,000 for the Tihany Peninsula with corn on arable lands

gray. The category is zero to 2 t $ha^{-1}$ $y^{-1}$. The upper limit of this class reflects the maximum soil formation rate on intensive agricultural land. The maximum allowable soil loss is 2 t $ha^{-1}$ $y^{-1}$ since this is the possible soil formation rate in the worst circumstances like with corn on arable lands. This is the soil loss tolerance rate that I suggest for environmentally sensitive areas.

*Table 2*
C factor values for erosion mapping

| Vegetation | C factor |
|---|---|
| *Agrostio-Alopecuretum pratensis* | 0.011 |
| Agrosti Stoloniferae | 0.011 |
| *Bromo sterili-Robinietum* | 0.006 |
| *Arrhenatheretum elatioris* | 0.011 |
| Inner Lake Vegetation Complex 1 | 0 |
| Inner Lake Vegetation Complex 2 | 0 |
| *Festucetum rupicolae* with shrub | 0.006 |
| *Cotino-Quercetum pubescentis* | 0.006 |
| *Prunus spinosae-Crataegetum* | 0.011 |
| *Potentillo-Festucetum pseudovinae* | 0.011 |
| *Salico-Populetum albae* | 0.006 |
| *Pinus nigra* | 0.0005 |
| Mixed forest vegetation complex | 0.003 |
| *Lemnetum-Thyphaetum* complex | 0 |
| Settlements | 0 |
| *Cleistogeno-Festucetum rupicolae* | 0.011 |
| *Lavandulo-Festucetum pseudovinae* | 0.04 |
| *Molinietum coeruleae* | 0.011 |
| Phragmition communis | 0 |
| *Orno-Quercetum pubescenti cerris* | 0.006 |
| Fallow | 0.011 |
| *Orno-Quercetum* with *Pinus nigra* facies | 0.003 |
| *Quercetum petrae-cerris* | 0.006 |
| *Caricetum melanostachyae* | 0.006 |
| *Salicetum albae-fragilis* | 0.006 |
| Arable land with winter wheat/corn | 0.25/0.5 |
| *Festucetum rupicolae* | 0.011 |
| *Cleistogeno-Festucetum rupicolae festucetum valesiaceae* | 0.11 |
| *Cleistogeno-Festucetum rupicolae festucetum valesiaceae* with shrub | 0.11 |
| Vineyard | 0.55 |
| Lake | 0 |

However, there is another soil loss tolerance rate for farmers that is not so strict. This is 12.5 t $ha^{-1}$ $y^{-1}$ (middle gray in Fig. 3). USLE manual allows farmers to act on their land without protecting their soils if soil loss does not exceed 12.5 t $ha^{-1}$ $y^{-1}$. If we consider that maximum soil formation rate is about 2 t $ha^{-1}$ $y^{-1}$ than we can realise a real threat to soils.

Wherever the map shows black colour (Fig. 3), the predicted soil loss is above acceptable limits even for USLE. Still there is farming and farmers are using unsuitable methods of soil and crop management. In some countries ef-

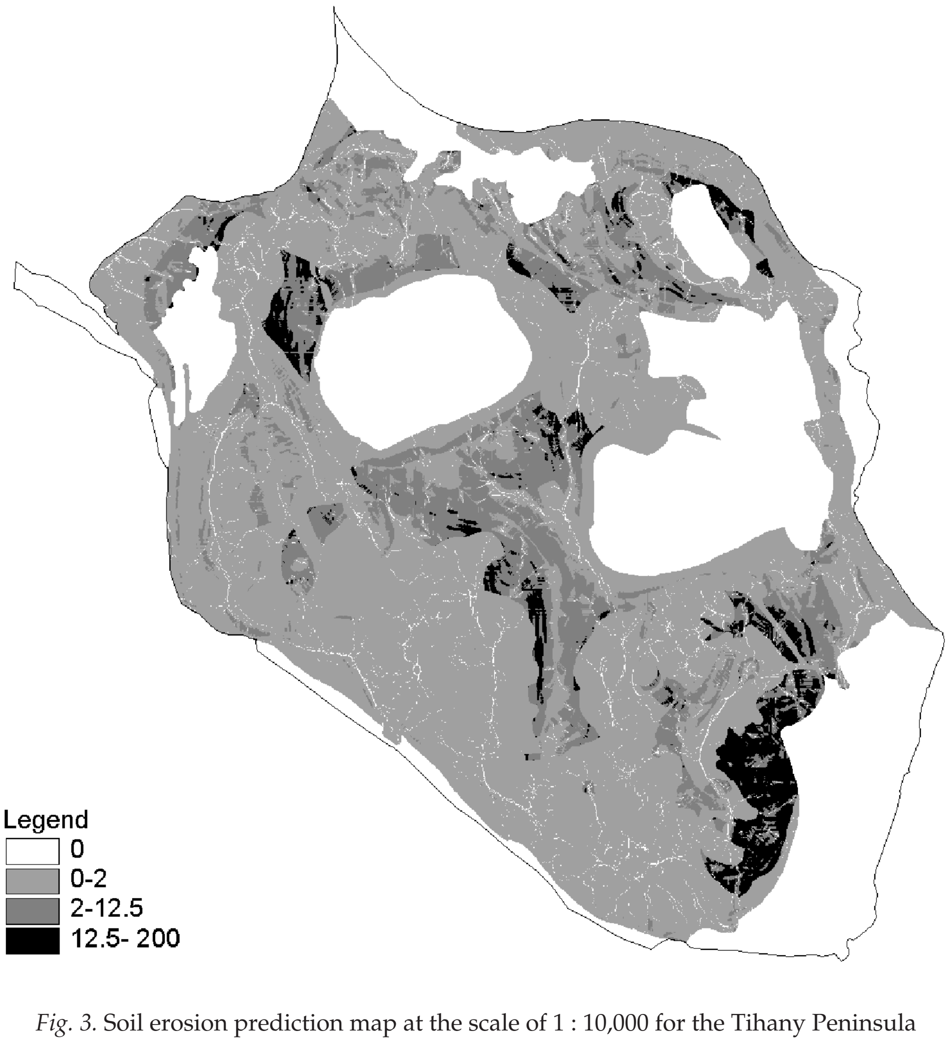


*Fig. 3.* Soil erosion prediction map at the scale of 1 : 10,000 for the Tihany Peninsula

forts are made to reduce soil erosion to sustainable limits and force land owners to use their lands in this manner.

The map can serve as a base for further calculations. C factor is available for all kinds of crop rotations, monocultures or single events. So farmers can choose their crop rotation and calculating soil loss for the given crop. If they care about their land they can change some crop in the rotation to reduce erosion to the tolerable rate.

*Importance of estimating soil loss on non-arable lands*

So far soil erosion prediction was limited to arable lands. However, in some cases soil erosion exceeds tolerable limits on non-arable lands. Very intensive rains can come with so high energy that even natural vegetation cover is unable to stop soil losses.

Soil erosion prediction is usually based on "in situ" observations or it predicts soil erosion risk based on geological, meteorological, soil and other information. Cooperatives prepared soil erosion cartograms along with genetic mapping on arable lands. In my prediction I used the freshest database about present vegetation cover, so where there is no change in vegetation since preparation of this map, soil erosion prediction is proper for the given cover. In most cases the steepest areas have best cover and less soil loss (like pine forests).

## CONCLUSIONS

I have estimated soil loss with the USLE method for the Tihany Peninsula. Under similar circumstances different vegetation has different effect on soil loss reflected through the C factor in the USLE model.

On arable land the estimated soil loss depends on the crop rotation and on the crop that covers the examined area for the given year. So it depends on the farmers but also on politics, since farmers are only the final decision makers.

On environmentally or naturally sensitive areas like the Tihany Peninsula we need more strict measures for soil conservation, disregarding which decision making party has made those.

There is a great lack of information on how the border of areas covered by natural vegetation and of arable lands behave. Researches in this area must start before the further erosion model had developed.

The map shows the high-risk areas. In Tihany there are two inner lakes that are very sensitive for any human activity. The Balaton Upland National Park could use this map to find out the size of the proper buffer strip around the lakes or to ask the farmers to switch crop rotation. However subsidies are needed, respectively.

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