ECONOMICAL EVALUATION OF SOIL AND NUTRIENT LOSS ON ARABLE LAND COMPARED WITH OTHER LAND USE FORMS

EVOLUŢIA ECONOMICĂ A PIERDERILOR NUTRIENŢILOR SOLULUI ÎN TERENUL ARABIL COMPARATIV CU ALTE MODURI DE UTILIZARE A TERENULUI

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Our measurements, calculations proved that there is a high amount of soil and nutrients loss in the Sósi Creek watershed. Eroded soil material carries humus and important fertilizers from the arable lands. It causes problems in the soils, surface and underground waters of remote areas and it causes financial loss for the farmers. Pedological researches can help farmers to optimize their land and fertilizer use. Based on the results of our research, it was possible to prepare a guide for farmers to help them measuring soil, nutrient and financial loss. Fertilizing with only the necessary amount of fertilizer, it is possible to reduce the pollution of surface and subsurface waters and the inputs of arable farming and to improve life quality.

INTRODUCTION

Soil is one of the most important, non-renewable natural resource. Its protection is obligatory for sustaining the agricultural environment as well as for the protection of the landscape and the nature (Centeri and Császár 2005, Gournellos et al. 2004).

The examined Sósi Creek is surrounded by arable lands, orchards and small forests where new owners of the former cooperative cope with shrinking market's need. There is no chance to construct a soil protection crop rotation because the market does not buy any products, that we consider soil protective (e.g. alfalfa). The cash crops are corn and sunflower that farmers usually combine with winter wheat or other cereals. This is the reason of big amount of soil loss on the slopes facing the Galga River. The humic layer on two arable foothills reaches 2.6 and 3.0 meters in depth. Soil management is down the slope. According to the soil examinations, P_2O_5-

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content of the soil is above 1000 ppm, no matter on which part are we measuring it on the slope. This high amount of nutrient is moving down and washes into the Galga river meaning serious fertilizer loads. We work on investigations to show trends in nutrient movements to offer economically viable soil protection measures for local farmers.

MATERIALS AND METHODS

The examined area is the Sósi Watershed, it lies approx. 50km southeast of Budapest, at the area of Hevizgyork and Galgaheviz village.

Soils were examined in situ by the Pürckhauer type soil core sampler (Finnern 1994) and by full soil profile descriptions (Stefanovits 1992). The core sampling gave possibility to take several samples and examine the following parameters: depth of layers, pH, color, soil physical type, carbonate content and soil type.

The laboratory experiments were done based on the Hungarian regulations in the Institute of Environment and Landscape Management, Dept. of Nature Conservation and Landscape Management.

We used the USLE model of Wischmeier and Smith (1972) to calculate the potential soil loss. Its well known equation is:

$$A = R \times K \times L \times S \times C \times P,$$

where

A = Soil Loss ($t \times ha^{-1} \times y^{-1}$),
R = Rainfall Erosion Index ($MJ \times mm \times ha^{-1} \times h^{-1} \times y^{-1}$),
K = Soil Erodibility Factor ($t \times ha \times h \times ha^{-1} \times MJ^{-1} \times mm^{-1}$),
L = Slope Length (dimensionless),
S = Slope Gradient Factor (dimensionless),
C = Cropping Cover Management Factor (dimensionless),

In Hungary Centeri (2002a, b, c) used and validated the model. USLE uses physical factors to quantify the amount of soil lost per hectare per year.

RESULTS

Results of pedological research

Based on the pedological investigations on the Sósi Creek watershed we can conclude that there are brown forest soils on the hillsides (mainly under forests), Chernozems and Regosols on the farmlands. Erosion and arable land use produced Colluviums and Regosols. The soils of the peaty meadow are having varying soil types and textures even in the parent material. The typical soil type of the area is the peaty meadow soil and fluvic meadow soils.

The Sósi Creek watershed is situated at the township of Hevizgyork and Galgaheviz, its total area is 5665 ha.

Most areas of the watershed are used as arable lands (70.1%). The risk of the erosion is the highest at these areas because of the intensive soil management. Cash crops are maize, sunflower and sometimes sugar beet. Farmers combine cash crops with cereals. Thanks to the structure of crop rotations and tillage practice, there is big amount of soil loss on the slopes facing the Galga Creek. Except having a crop rotation that give very little protection against soil loss, cultivation is down the slope.

Results of surface cover analyses

We prepared the updated digital version of the surface cover and analyzed the spatial distribution of the categories (**Table 1.**).

Table 1.

The types of the surface covers of the Sósi Creek watershed

	Area type	**Area (ha)**	**Area (%)**
1	Close-to-natural area	882.3	15.6
2	Vineyard, orchard, garden	522.9	9.2
3	Arable land	3965.3	70.1
4	Settlements	242.5	4.2
5	Surface water	51.9	0.9
	Total	5665.1	100

It was important to find out the distribution of close-to-natural areas since these serve as buffer zone against negative effects of intensive agriculture (pesticide and fertilizer loss). Analyses proved that only 15.6% of the watershed is close-to-natural area (forests and grasslands), while 4.2% is vineyard, orchard and garden and 4,2% of the area belongs to settlements. Most of the areas are arable farmlands (70.1%). This informs us how intensive is the land use on the examined area and how productive is the land. In the 1970s most of the inhabitants found a very good income from small scale farming, mainly from vegetable production.

Soil nutrient losses near the Sósi Creek

On the intensive arable lands the P_2O_5 contents were rather high with 700-3500 mg×kg^{-1}. This high P_2O_5 content originates in the high amount of fertilizers. The average amount of fertilizer is 250-350 kg to corn for one hectare. The type of the fertilizer is 3×15 which contains 15% N, 15% P_2O_5 and 15% K_2O. Despite the high amount of fertilizers, the pH values of the soils were neutral or only slightly alkaline (**Table 2.**).

Table 2.

Soil characteristics of the investigated sampling sites

Sample ID	**Depth of sampling (cm)**	**pH (H_2O)**	**pH (KCl)**	**AL-P_2O_5 (mg×kg^{-1})**	**AL-K_2O (mg×kg^{-1})**	**SOM (%)**	**$CaCO_3$ (%)**
1	0-30	8.2	7.7	3561.4	268.8	2.9	11.2
2	30-60	8.5	8.0	2456.8	155.2	1.9	10.3
3	0-30	8.0	7.5	1044.3	239.8	1.9	0.7
4	30-60	8.1	7.6	717.6	169.8	1.4	1.0
5	0-30	8.3	7.7	630.7	251.8	2.3	5.6
6	30-60	8.2	7.8	672.3	211.9	2.4	5.9
7	0-30	8.1	7.4	921.5	231.8	3.5	3.1
8	30-60	8.0	7.4	868.6	185.5	2.6	2.3
9	0-30	7.9	7.2	1000.8	299.6	4.0	0.9
10	30-60	7.9	7.2	827.1	256.1	3.8	1.6
11	0-30	7.9	7.3	921.5	246.1	2.9	1.5
12	30-60	8.0	7.4	755.3	168.4	2.1	1.3
13	0-30	8.2	7.5	1488.0	197.6	3.3	3.8
14	30-60	8.3	7.7	1284.1	127.0	2.1	4,2

SOM=Soil Organic Matter, AL = ammonium-lactate

It is important to remark that most of the times farmers haven't got enough financial support to cover the expenses of soil investigation so they mainly consider only the nutrient requirements of the required crops and they do not take into account the amount of the soil nutrients (and no other consideration is taken). The $CaCO_3$-content of the samples was small or medium. The samples were generally characterized by 1-3.5% humus content. These areas have been used as arable land for decades so the major part of the humus contents had already been used.

Based on the results it was possible to prepare a guide for farmers to help them measuring soil, nutrient and financial loss. First we measure the nutrient loss, than calculate soil loss (with USLE) and finally calculate the financial loss on different surface cover and slopes. **Table 3.** shows the results of the calculations done on an 8% slope.

Table 3.

Soil loss calculation data with 8% slope angle

Surface cover	**Return possibility of the rainfall events**	**Yearly rainfall amount* (mm)**	**R (**)**	**C**	**A (t)**	**P_2O_5 loss (kg)**	**K_2O loss (kg)**
Forest	2 year	550	775	0.06	0.27	0.07	0.03
		600	800		0.28	0.07	0.03
	20 year	550	1740		0.60	0.15	0.06
		600	1840		0.64	0.16	0.06
Arable land (maize)	2 year	550	775	0.5	2.23	0.56	0.22
		600	800		2.30	0.58	0.23
	20 year	550	1740		5.01	1.25	0.50
		600	1840		5.30	1.33	0.53
Arable land (winter wheat)	2 year	550	775	0.25	1.12	0.28	0.11
		600	800		1.15	0.29	0.12
	20 year	550	1740		2.51	0.63	0.25
		600	1840		2.65	0.66	0.27

(Slope angle = 8%, K=0.009, LS=0.64, P=1), *average, **$MJ\times mm\times ha^{-1}\times h^{-1}\times y^{-1}$

Analyzes show two extremities in rainfall events. 2 year return possibility is very low while 20 year is very high. With the present climate sensitivity, 20 year return possibility of a rainfall event can be more often. K_2O loss per hectare varies from 0.03–0.53kg, while P_2O_5 loss per hectare varies between 0.28–1.33kg.

We calculated the loss of the farmers with erosion in Euro for different scenarios: no fertilization, 250-300-350 $kg\times ha^{-1}$ fertilizer use that was characteristic in the examined area (**Table 4.**).

Table 4.

Soil nutrient loss expressed in Euro on an 8% slope

P_2O_5*	K_2O*	P loss	K loss	Amount of P fertilizer used (kg×ha^{-1})			Amount of K fertilizer used (kg×ha^{-1})		
(kg×ha^{-1})		No fertilizing		250	300	350	250	300	350
				P loss in Euro			K loss in Euro		
0.07	0.03	0.04	0.02	9.8	11.8	13.7	4.2	5.0	5.9
0.07	0.03	0.04	0.02	9.8	11.8	13.7	4.2	5.0	5.9
0.15	0.06	0.08	0.03	21.0	25.2	29.4	8.4	10.1	11.8
0.16	0.06	0.09	0.03	22.4	26.9	31.4	8.4	10.1	11.8
0.56	0.22	0.31	0.12	78.4	94.1	109.8	30.8	37.0	43.1
0.58	0.23	0.32	0.13	81.2	97.4	113.7	32.2	38.6	45.1
1.25	0.5	0.70	0.28	175.0	210.0	245.0	70.0	84.0	98.0
1.33	0.53	0.74	0.30	186.2	223.4	260.7	74.2	89.0	103.9
0.28	0.11	0.16	0.06	39.2	47.0	54.9	15.4	18.5	21.6
0.29	0.12	0.16	0.07	40.6	48.7	56.8	16.8	20.2	23.5
0.63	0.25	0.35	0.14	88.2	105.8	123.5	35.0	42.0	49.0
0.66	0.27	0.37	0.15	92.4	110.9	129.4	37.8	45.4	52.9

(Slope angle = 8%, *average loss)

Calculations (**Table 4.**) proved that lower slope angle does not cause a high amount of fertilizer loss if there were no extreme rainfall event expected and there were no ferilizre used. However in case there is an extreme rainfall event after fertilization, soil and nutrient loss can reach high level. In case of the most extreme rainfall event, nutrient loss can reach €186 with 250kg P, €223 with 300kg and €260 with 350kg P fertilizer used. These figures are lower with the K loss: €74.2 with 250kg K, €89 with 300kg K and €103.9 with 350kg K fertilizer used. These figures are very low, can only be expressed in Euro cent.

On the examined area there are more extreme slope angles. We show the results of soil, P_2O_5 and K_2O loss calculations on a 20% slope (**Table 5.**). Based on the calculation in Table 5., we give a calculation on losses of fertilizer in Euro (**Table 6.**). **Table 5** is similar to Table 3, except the slope angle is changed from 8 to 20%.

Table 5.

Soil loss calculation data with 20% slope angle

Surface cover	**Return possibility of the rainfall events**	**Yearly rainfall amount* (mm)**	**R (**)**	**C**	**A (t)**	**P_2O_5 loss (kg)**	**K_2O loss (kg)**
Forest	2 year	550	775	0.06	0.98	0.25	0.10
		600	800		1,02	0.25	0.10
	20 year	550	1740		2,21	0.55	0.22
		600	1840		2,34	0.58	0.23
Arable land (maize)	2 year	550	775	0.5	8.20	2.05	0.82
		600	800		8.46	2.12	0.85
	20 year	550	1740		18.40	4.60	1.84
		600	1840		19.46	4.87	1.95
Arable land (winter wheat)	2 year	550	775	0.25	4.10	1.02	0.41
		600	800		4.23	1.06	0.42
	20 year	550	1740		9.20	2.30	0.92
		600	1840		9.73	2.43	0.97

(Slope angle (20%), K=0.009, LS=2.35, P=1), *average, **$MJ \times mm \times ha^{-1} \times h^{-1} \times y^{-1}$

The ferilizer loss calculations for the 20% slope can be found in **Table 6.**

Table 6.

Soil nutrient loss expressed in Euro on a 20% slope

$P_2O_5^*$	**K_2O^***	**P loss**	**K loss**	**Amount of P fertilizer used ($kg \times ha^{-1}$)**			**Amount of K fertilizer used ($kg \times ha^{-1}$)**		
($kg \times ha^{-1}$)		**No fertilizing**		**250**	**300**	**350**	**250**	**300**	**350**
				P loss in Euro			**K loss in Euro**		
0.25	0.1	0.14	0.06	35.0	42.0	49.0	14.0	16.8	19.6
0.25	0.1	0.14	0.06	35.0	42.0	49.0	14.0	16.8	19.6
0.55	0.22	0.31	0.12	77.0	92.4	107.8	30.8	37.0	43.1
0.58	0.23	0.32	0.13	81.2	97.4	113.7	32.2	38.6	45.1
2.05	0.82	1.15	0.46	287.0	344.4	401.8	114.8	137.8	160.7
2.12	0.85	1.19	0.48	296.8	356.2	415.5	119.0	142.8	166.6
4.60	1.84	2.58	1.03	644.0	772.8	901.6	257.6	309.1	360.6
4.87	1.95	2.73	1.09	681.8	818.2	954.5	273.0	327.6	382.2
1.02	0.41	0.57	0.23	142.8	171.4	199.9	57.4	68.9	80.4
1.06	0.42	0.59	0.24	148.4	178.1	207.8	58.8	70.6	82.3
2.30	0.92	1.29	0.52	322.0	386.4	450.8	128.8	154.6	180.3
2.43	0.97	1.36	0.54	340.2	408.2	476.3	135.8	163.0	190.1

(Slope angle = 20%, *average loss)

It is obvious that the amount of soil loss is much higher when we calculate it on a 20% slope (max. 19.46t×ha^{-1}, **Table 5.**) compared with the calculations for the 8% slope (max. 5.3t×ha^{-1}, **Table 3.**).

The most extreme differences occure when we compare the situation of the lower examined slope angle (8%) and lowest possible rainfall erosivity of the 600mm yearly rainfall amount with the highest slope angle of 35% and the 650mm rainfall amount with the 20 year return possibility. In comparison of the best and worst case scenarios, the amount of the soil and fertilizer loss can be 185 times higher.

We can conclude that soil, nutrient and financial loss can reach unpredictable amount with extreme rainfall events, especially in case they return with higher possibility.

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