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Modelling of soil erosion and nutrient transport to serve watershedmanagement: case study in a subwatershed of Lake Velence in Hungary

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Introduction

The thesis 'the destiny of lakes depends on their watersheds' is more valid in the case of Lake Velence (Hungary, Transdanubia). The characteristics of the agricultural activity, the quantity of nutrient supply, the enforcement of water and soil protection attitudes in cultivation and nutrient management play serious role in the changes of water quality and the processes of eutrophication.

The alteration in the types of cultivation, the turn of former cooperative owned arable lands to mono-cultivated vineyards (in the 1990's) as well as privatization of lands or changes in field sizes and their occasional cultivation parallel to slopes reinforce erosion processes and the outwash of nutrients. One more serious fact is the fallow and use of wetlands along water flows for intense cultivation in the 1970's. The nutrients bound to soil particles similarly to the water and deposits from subwatersheds can reach the streams unhindered, finally, these 50-70-meter-wide wetlands became nutrient traps. The shelter-belts were also terminated using high-performance machines to widen the size of parcels; they were employed to trap soil particles on the slopes serving soil protection goals and furthermore the water quality of Lake Velence.

Recognizing these facts, we have proposed to observe the spatial and temporal variations of the nutrients in soils in the 14-km^2-area watershed of the Cibulka stream. The research project has been performed in two orders of magnitude:

- on *micro-scale*, along two 300-meter-long slope segments, we placed sediment traps at every 25 meters to collect downwashed sediment. It was for the comparison of the sediment's and the ambient soil (average) samples‘ macro- and microelement content and physical composition, and to calculate the Enrichment Factor (EF).

- on *meso-scale*, the temporal and spatial changes of nutrient transport in the subwatershed (14 km^2) of each precipitation events.

The study site

The whole watershed is petrographically and pedologically diversified as well as in terms of land use. The partially eroded loess-covered surfaces can be characrerised by mid-eroded chernozems and phaeozems. While granite and andesite bedrock areas are covered partly by natural oak forests and partly by acacia forest with poor grazing lands, the chernozem soils are cultivated as arable lands with wheat, corn and sunflower and as vineyards or orchards **(Bódis, Dormány, 2000)**; meadow chernozems and slope sediment soils exist only in small patches. The topsoil chemical reaction is neutral with pH 7.21–8.50. The climate of the study site is moderately cool and dry, the annual average temperature is 9.5–9.8 ^{o}C, the amount of precipitation is 550–600 mm with half of it in summer (**in: Marosi, Somogyi 1990**) often in wild tempests.

Sampling, measurement methods

The detailed sampling and laboratory analysis of the subwatershed and the study parcel was performed four times: twice in 2001 (May and June) and once more in May 2003 we measured the nutrient content of the topsoil. Sampling points were in the nodes of a 25-by-25-meter grid; their locations were positioned by theodolite. The 2001 sampling of the subwatershed was performed in 32 sites from the upper 10 cm layer, generating average sample. In 2004, along two 300-meter-long slope segments, we placed sediment traps at every 25 meters to collect downwashed sediment. It was for the comparison of the sediment's and the ambient soil (average) samples‘ macro- and microelement content and physical composition, and to calculate the so-called Enrichment Factor (EF). The analyzed properties and elements have been the following **(Kádár, 1998):** pH(KCl), K_A (Arany-type texture index), $CaCo_3$ and humus content (%) as well as the macro- and microelement content (NO_2-NO_3-N, P_2O_5, K_2O, Na, Mg, Ca, Mn, Zn, Cu, Fe, Mo, B, Al, As, Cd, Co, Cr, Hg, Ni, Pb). Nutrients' analysis has been about the available parts and the measurement of macroelements has been performed by the acetous-acid solution of ammonium-lactate while the measurement of the microelements has been digested by Laken Erviö method and analysed by ICP Thermo Jarell Ash ICAP 61E device (**Búzás, 1988**). For the analysis of Enrichment Factor (EF), the total element content has been specified utilizing aqua regia digestion and Perkin Elmer AAS device.

To quantify soil erosion (for 10-by-10 pixels: accumulation, loss and net erosion), '*Erosion2D/3D*' erosion assessment model (developed in Germany) has been employed (**Schmidt, 1996, Michael, 2000**), while the DEM and the maps of land use and soil parameters (particle compounds, soil type, humus content) have been created with ArcView(3.3) and ArcGIS(8) software **(Schob et al, 2004., Thiel, 2004).** For the statistical analyzes, the SPSS(11.0) for Windows software package has been utilized.

Temporal and spatial trends in nutrient transport

The parcel, chosen with special regard to the characteristic soil types, land use and slope conditions of the Cibulka stream watershed, has been observed for a 1-month-long period with special attention to temporal and spatial changes of the available nutrient content influenced by 60 mm precipitation in the study period. Paying attention to the relief of the study site, the formation of a NW-SE directed gully appears, and it has influenced both the physical and chemical characteristics of the soil, for instance the distribution of nutrients **(Déri, 1986, Kerényi, Szabó 1997)).** In this part of the parcel, mechanical composition is mostly sandy loam or loam; the erosional processes have already removed the finer fractions, and a similar decrease was determined in humus content. Owing to these changes, the adsorption capacity of the soil diminishes because the amount of colloid-surface particles that can adsorb has decreased. These properties of the soil (hardness, organic matter content) and the measured values of each element content show strong correlation (usually r=0.7-0.8).

The redistribution and the decreasing tendency of the nutrient content can also be linked to the formation of the gully, it can be observed perfectly both in the changes of the amounts of macro- (**P, K**) and microelements (**Cd, Ni, Pb**). The amount decrease of (analyzed) available nutrient content could be indicated after a month, while the amount of **Ca** has increased in parts of the parcel most struck by erosion. It is caused by the resected genetic profiles of chernozem soils to the loess bedrock which contains a high amount of **Ca**.

The physical conditions, humus content and spatial changes in the distribution of macro- and microelements have been affected by the development of microrelief, as well as the usual direction of regular cultivation alongside of slopes, the broad distance and weeding of lines. All these facts help to modify the direction of material redeposition in the small valley from NW-SE to N-S. The lack of deep ploughing moderates the swallow capacity and also increases surface flow.

For the sake of further investigation of macro- and microelements moving by erosion, we have placed sediment traps every 25 meters along two 300-meter-long slope segments of the study-parcel; the downwashed sediment with the samples of the upper 0-5 cm topsoil from the surroundings was collected monthly. The homogenized average samples have been taken under siltable part ($<$0,002 mm) and total element content analysis. To specify the enriched clay+silt fraction, Corg and element content in sediment moving by erosion, Enrichment Factor (EF) has been calculated (**Duttmann, 1999; Boy, 2002**) by the followings:

$$EF_{element} = \textit{Conc. of elements}_{sediment} \,/\, \textit{Conc. of elements}_{soil}$$

$$EF_{clay} = \textit{Claycontent}_{sediment} \,/\, \textit{Claycontent}_{soil}$$

	Minimum	**Maximum**	**Mean**	**Std. Deviation**
Sed. Cu	16,85	61,34	29,85	8,46
Soil Cu	12,55	57,79	27,58	8,81
Sed. Ni	18,18	112,00	57,90	21,65
Soil Ni	9,58	59,85	31,94	11,51
Sed. Pb	10,56	56,33	31,52	13,21
Soil Pb	12,53	53,26	28,74	9,35
Sed. Zn	30,10	134,90	55,04	13,82
Soil Zn	16,17	65,22	46,02	9,06
Sed. Cr	91,94	196,50	136,35	23,11
Soil Cr	56,00	173,90	133,19	22,01
Sed. Clay	32,00	83,20	59,58	11,79
Soil Clay	25,38	78,50	52,39	16,51
Sed. C_{org}	0,40	3,99	1,75	,89
Soil C_{org}	0,20	4,83	1,05	,70
EF Cu	,43	3,02	1,15	,38
EF Ni	,37	6,86	2,18	1,37
EF Pb	,57	2,15	1,12	,41
EF Zn	,64	3,14	1,23	,41
EF Cr	,66	2,85	1,045	,27
EF Clay	,55	2,42	1,25	,45
EF C_{org}	-1,00	6,35	1,08	1,91

Table 1. Descriptive statistics

It can be ascertained by measurements that only **EF=1.25 enrichment of clay+silt** and **EF=1,08 enrichment of humus content** are characteristic by given slope conditions and soil type comparing the sediment moving by erosion to the local soil types. Principally, **Ni** (EF=2.1), **Zn** (EF=1.2) and **Cu** (EF=1.1) of microelements enrich in erosional moving sediment, while **Pb** (EF=1.08) and **Cr** (EF=1.02) are represented with the same concentration like in the surrounding topsoil layer in the sediment traps' material (Table 1.).

Running '*Erosion3D*' demanded digital data and map like DEM, land use, land cover, roughness, particle compounds, organic matter content, thickness of productive layer – they have been created employing ArcView and ArcGIS. Applying them, erosion, accumulation and their resultant, the net erosion, in kg/m^2 have been modelled pixel by pixel and by each precipitation event (recorded by field station). Regarding the watershed, two erosion-risk areas have been sketched up; one of them has appeared in the high-relief arable lands (with corn and winter wheat) of the NW segments, while the other one is located in the area under intensive viniculture where the sample study parcel lies; here the net erosion has resulted 1-2 kg/m^2.

Elements		**06/06/2004**			**24/06/2004**	
	max.	average	dispersion	max.	average	dispersion
Zn	784.39	14.26	49.35	1928	39.09	133.44
Cu	255.45	5.021	16.38	626.028	13.75	44.29
Pb	251.08	4.11	13.93	620.9	11.259	37.29

Table 2. Transport values of nutrients bond to topsoil particles after two precipitation events (mg/m^2) (Precipitation event paramaters:*06/06/2004*: duration: 3:40-4:40 PM, max. intensity: 16,8 mm/h, cumulated prec.: 8,9 mm; *24/06/2004*: duration: 2.40-5.40 AM, max.intensity:31,2 mm/h, cumulated prec.: 18 mm)

The calculated net erosion (kg/m^2) by precipitation events and the initial nutrient distribution maps (mg/kg), as well as the calculated EF values (%) of the study parcel, enabled the creation of the maps of nutrient transport value (mg/m^2) concerning each precipitation event. The average **Zn** transport value has been 14.26 mg/m^2 of the study site, but after a cumulated precipitation event, of 8.9 mm (3:40-4:40 PM, 25/11/2004) with maximum intensity of 16.8 mm/h, the value of **Zn** transport reached 200-400 mg/m^2 on the mostly eroded areas. Furthermore, the areas most struck by erosion have produced possible 900-1000 mg/m^2 **Zn** transport value (Table 2.).

This fact must definitely be considered in the environmental protection of agriculture, in sustainable development and in achieving environmental friendly nutrient management. The erosion model to the whole watershed and the exploration of the nutrient transport's necessaries are important form different considerations, such as

- help for regional planning (erosion-optimal land use and cultivation methods),
- the dynamic nutrient maps representing the topsoil's nutrient transport for precision agriculture to supply proper amount of nutrients.

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