
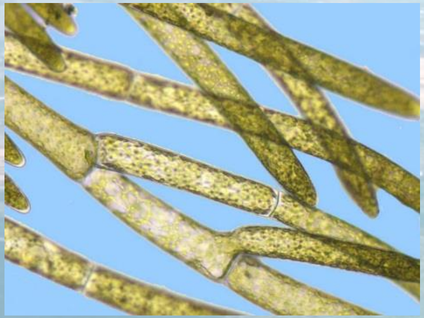

HydroEco´2015

The effect of soil erosion on ecosystem services

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Lake Balaton Catchment

- Lake Balaton Catchment, NW Hungary (6225 km^2)
- The lake with a total area of 577 km^2 is exposed to various kinds of environmental impacts including agricultural activity in the catchment.
- The influx of sediment and solutes into the lake deriving mainly from *non-point pollution sources* plays and important part from the aspects of the *eutrophication* and pollution of the lake.

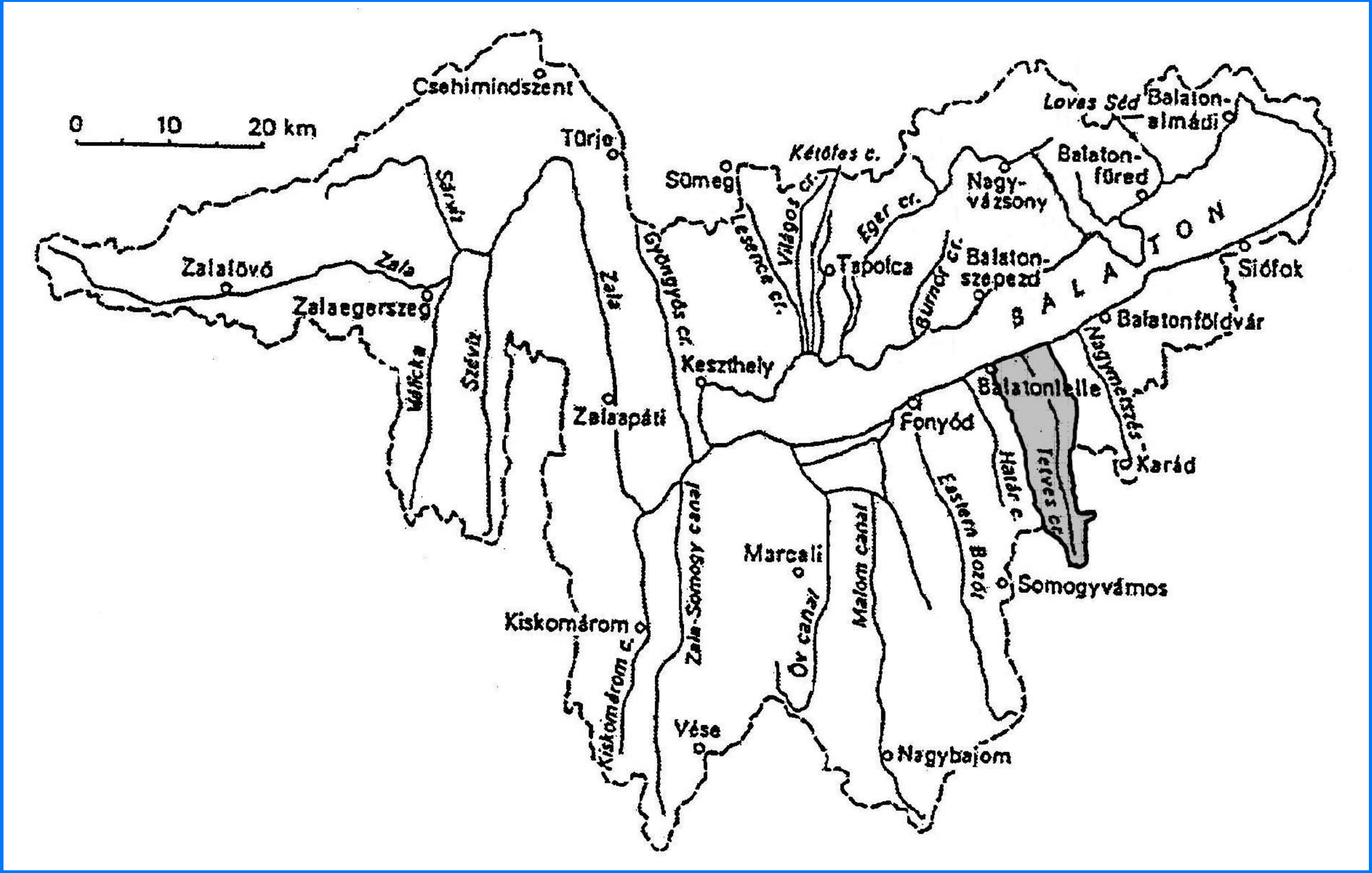
Soil erosion in Hungary

	Thousand hectares	% of the total area	% of the agricultural land	% of the eroded land
Area of the country	9 303	100	-	-
Area of agricultural land	6 484	69.7	100	-
Arable land	4 713	50.7	73.0	-
Total eroded land	2 297	24.7	35.3	100
strongly	554	6.0	8.5	24.1
moderately	885	9.5	13.6	38.5
weakly	852	9.2	13.2	37.4

Case study 1

- Study area - Tetves catchment (120 km^2)
- Sediment reservoir in lowermost part of the catchment, constructed in 1970 (13 ha), fishponds, both contain the deposited soil loss of the catchment
- Investigations based on 30 years sediment yield

Location of the study area: The Tetves catchment in Lake Balaton catchment



Stream Tetves

Stream Tetves was polluted by a bovine holding in 2010
source: www.alternativenergia.hu

Methods

- Caesium-137 isotope as a tracer of the surface soil. The Caesium-137 procedure demonstrates the dimension and spatial distribution of erosion and sedimentation
- The contamination under average Hungarian conditions and in undisturbed soil profiles does not exceed 25-30 cm depth
- In an undisturbed profile the total activity of the isotope decreases exponentially downwards from the surface

Methods

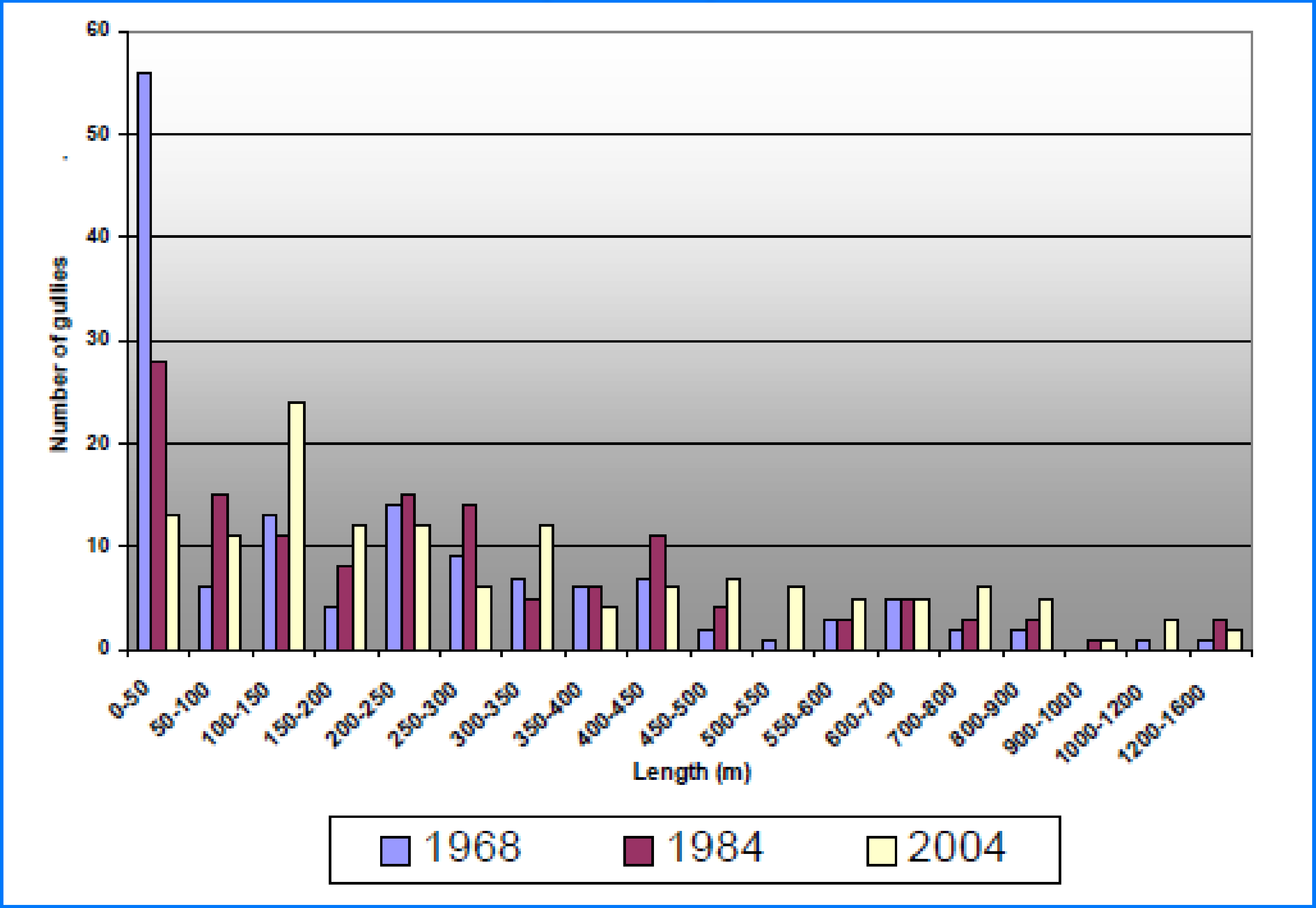
- If there is no activity concentration at the top of the soil profile, the profile is eroded. The presence of Cs-137 activity in deeper horizons refers to deposition of topsoil on the top of the original profile
- The volume of the fallout was determined by applying reference profiles
- Reservoir and fishpond sampled
- Gully Erosion Activity (1968, 1984, and 2004) studied by using maps, air photos and field survey (Jakab et al. 2006)

Sampling points in the reservoir

Results

- Field survey - 140 gullies were mapped in 2004
- Only 85 were present in 1968 and 115 in 1984
- Before 1984 the increase in gully length was slow, after 1984 gully length grow quickly
- In 34 years the total length of the gullies increased by almost 60%
- Before 1984 the increase of the shortest (<50 m) gullies, after 1984 gullies longer than 450 m increased mostly

Gully distribution according to their length in 1968, 1984, and 2004



Changes in gully length in time

	1970	**1984***	**2004**
Total lenght (m)	29 942	36 688	47 064
Total lenght (%)	64	78	100
Average increase (m year^{-1})	-	173	519

*Air photos of 1984 do not cover the whole catchment area, there is a lack of data on 15 gullies. For these gullies data of the year 2004 were applied.

- Reservoir filling up (1970-2000) 95 300 m^3
- 7 800 m^3 organic matter was accumulated during 30 years
- The remaining 87 500 m^3 sediment comes from the catchment
- Net soil loss 113 750 t during 30 years
- Specific annual erosion rate is 0.8 t ha^{-1}
- The samples consist of layers - subsequent sedimentation events
- Below a threshold value of precipitation amount and/or intensity gullies deliver only sediments from sheet erosion
- Above threshold value – gully parent material is transported

A sediment sample from S2 point

- The total activity value of the 130 cm is 6.5 times higher than that of the fallout (51 350 Bq m^{-2}). Smaller volumes mean that the sediment contains subsoil without Cs-137 activity, as a consequence of gully erosion
- Minimum 50% of the sediment comes from layers below 20 cm of the soil profiles of the catchment, eroded by gully erosion
- Former investigations: 1 198 268 m^3 material was moved in the catchment by gully erosion

- Based on gully length measurements in 34 years 435 086 m^3 soil was eroded by gully erosion
- 10% of the soil eroded by gullies reached the sediment reservoir
- 1 287 m^3 $year^{-1}$ from a catchment of 120 km^2 - potential danger for Lake Balaton

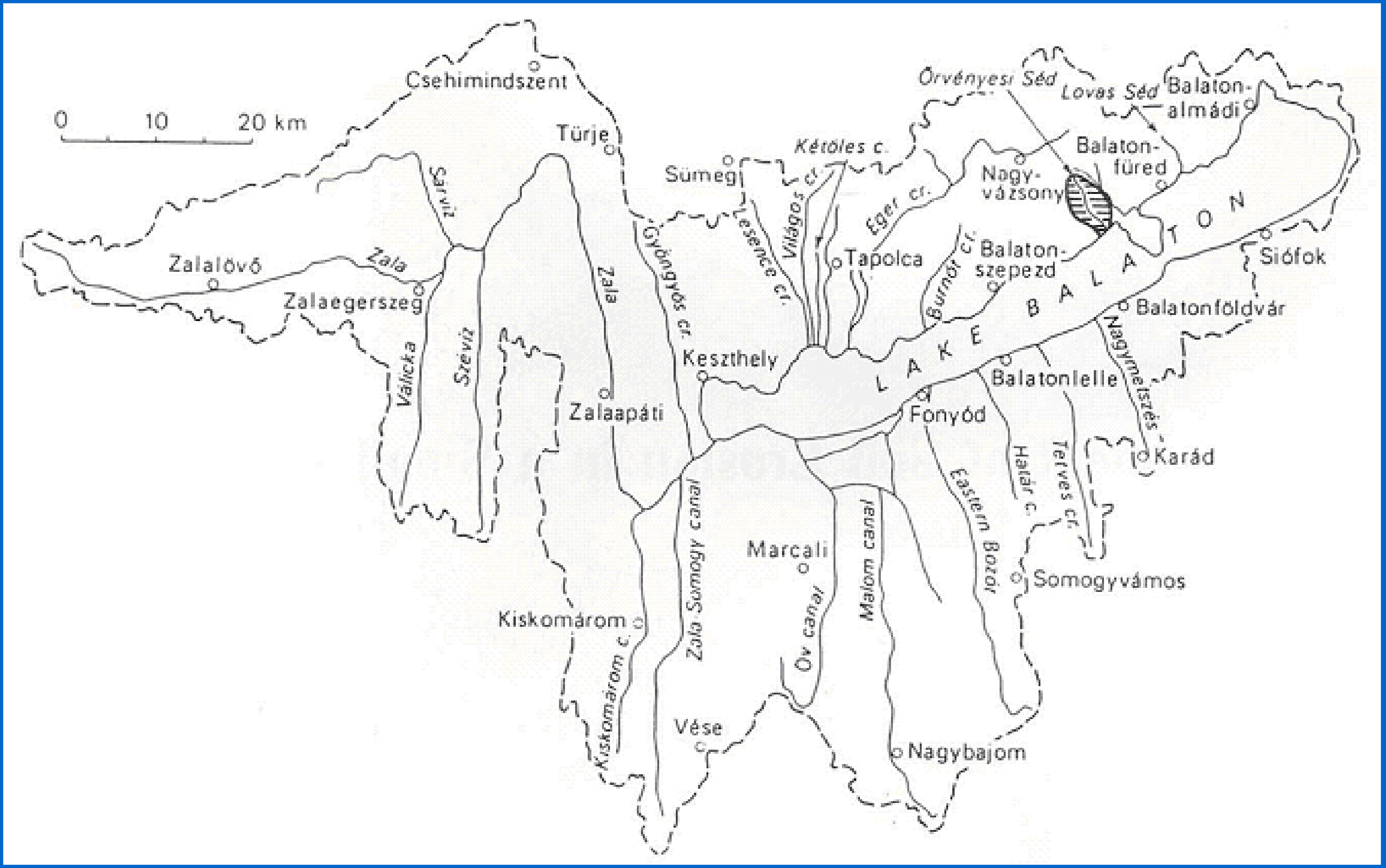
Conclusions

- Conditions of gully erosion and development are given in most of the hilly countries of Hungary.
- Results of the case study show that the majority of soil loss in the Tetves catchment is eroded by sheet erosion, however, in most cases the eroded soil remains in the catchment itself and doesn't leave it.
- The sediments which leave the basin contain more subsoil, approximately 50%. Gully erosion is sediment source and not only as transport channel in the catchment. The most active period of gully erosion was between 1984-1995.

Case study 2

- Study area – Örvényesi-Séd Catchment, Northern subcatchment
- Small catchments (24 km^2)
- Relative relief = 416 m a.s.l. – 104 m a.s.l. = 312 m
- Örvényesi-Séd creek is 8.1 km long
- Cambisols, rendzinas and vertisols are the main soil types

Örvényesi-Séd Catchment



Stream Örvényesi Séd

www.panoramio.com

The flooding stream in September 2014
Source: iho.hu

Methods

- Soil loss assessment by the Universal Soil Loss Equation (USLE)
- Soil loss (t/ha) calculated as

  A = RKLSCP

  A is the predicted soil loss (t/ha),

  R is the rainfall and runoff factor,

  K is the soil erodibility factor,

  LS is the factor of slope length and steepness,

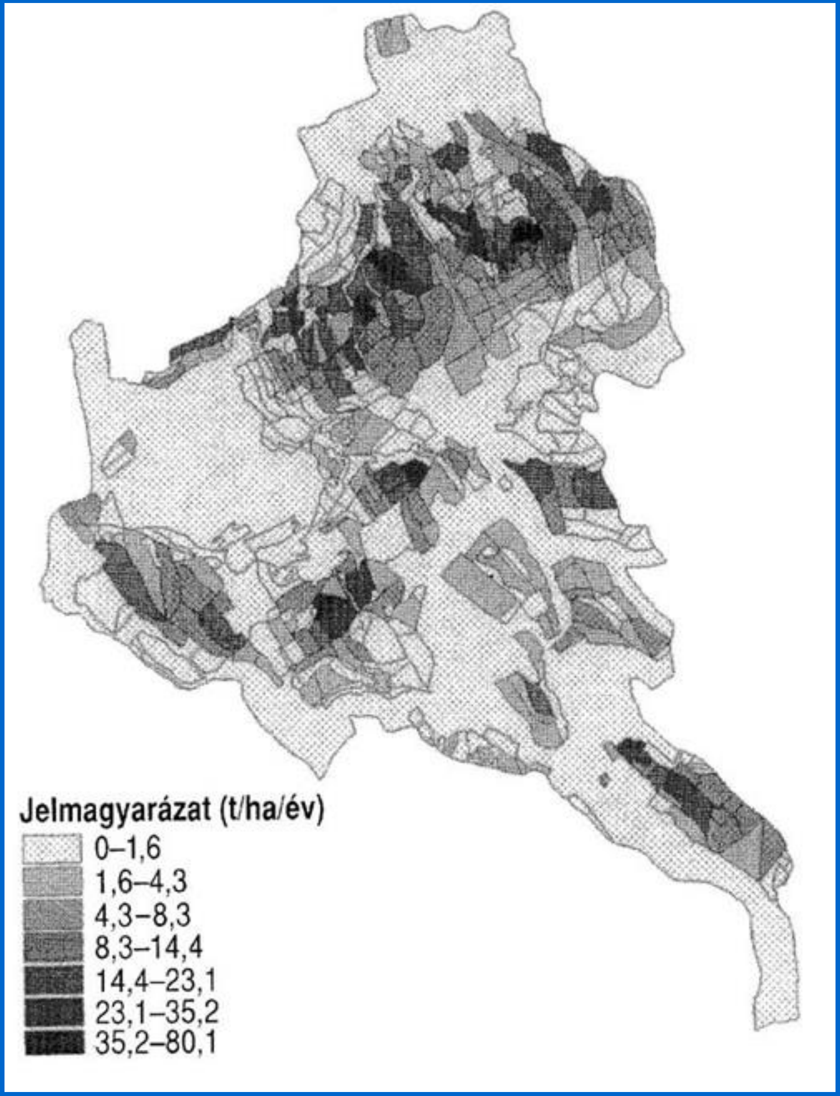
  C is the cover and management factor and

  P is the support practice factor.

Methods

- EROTOPs, territorial units of soil erosion assessment determines by ARC-INFO
- Runoff directions and slope angles were calculated from the DEM
- An *erotop* is a unit with approximatively the same runoff direction and without water collecting linear elements. They are bordered by the lines of diffluent or confluent runoff direction and by linear structures such as ditches, brooks, road field paths and terraces.
- Forested areas, settlements and flat valley bottoms are not taken into consideration. Soil loss was calculated for each erotop and the erotop map of the catchment was created by GIS aided method.

Estimated soil loss in Örvényesi-Séd Catchment



Results

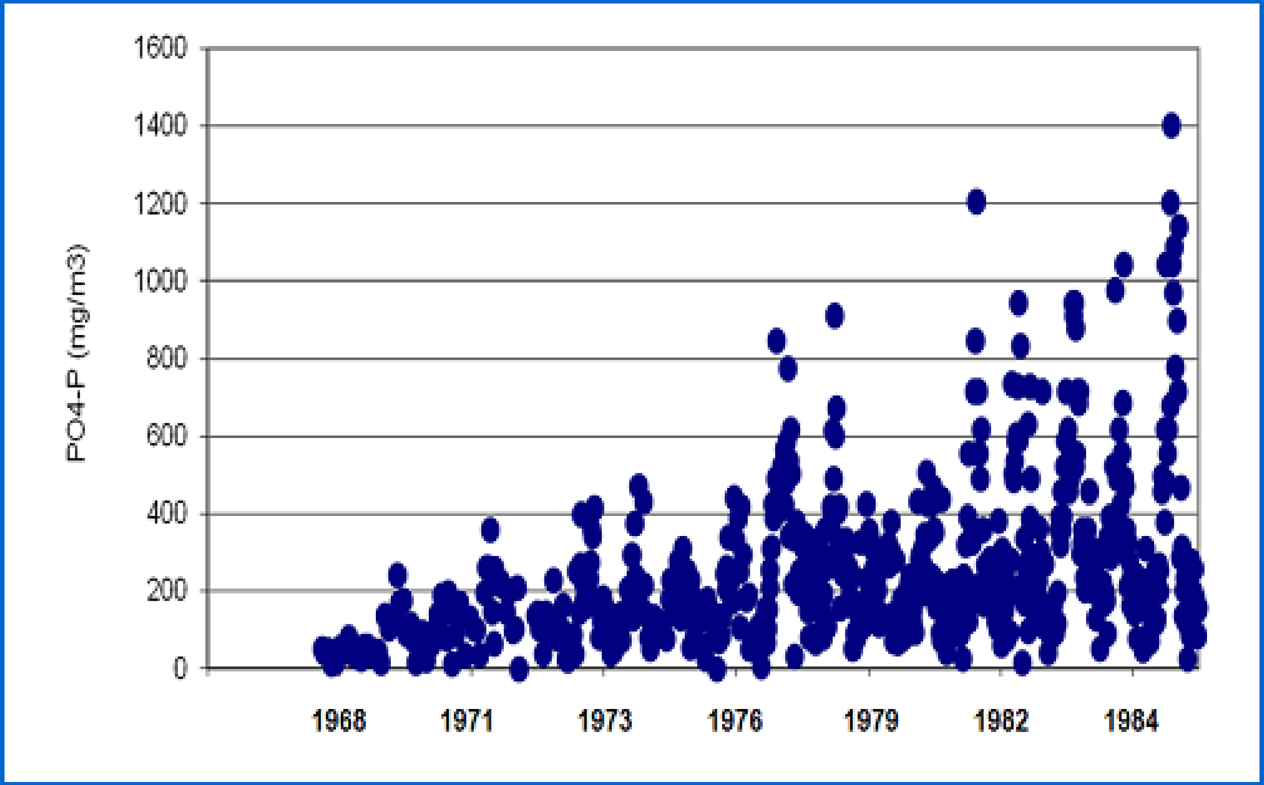
- The total estimated soil loss is 6400 t year^{-1} from 1220 ha of agricultural and abandoned land.
- The average value is 5.25 tha^{-1}year^{-1}
- Comparing the measured amount of sediment leaving the catchment with that of calculated soil loss we come to the conclusion that only 2% of the calculated value leaves the catchment.
- Most of the eroded material remains in the catchment itself, accumulated on the hillslopes, i.e. almost no contribution to eutrophication.

Case study 3

- Study area - Zala catchment (2622 km^2)
- The Zala river transports 45 % of the nutrient and sediment load
- Main polluting agents leading to water deterioration:
  - intensive agriculture, application of chemicals
  - industry
  - settlement development
  - tourism, recreation
  - flood control
  - fishing

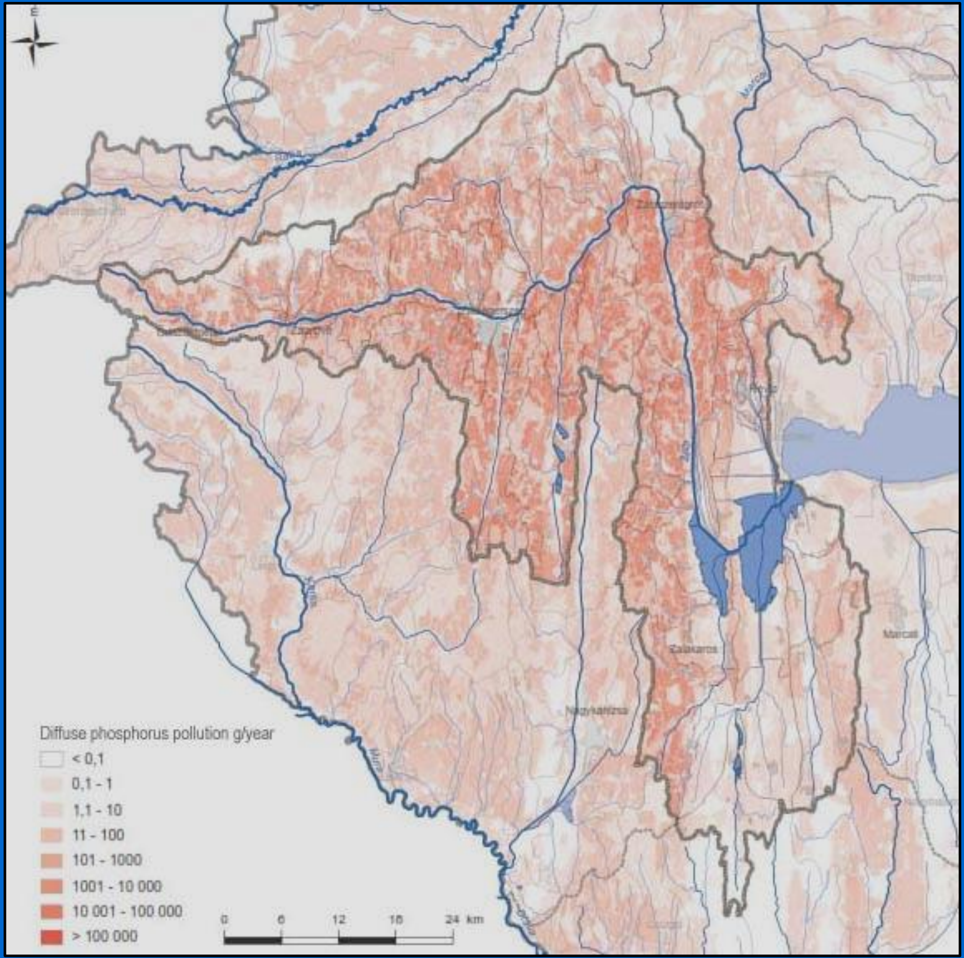
Location of Zala catchment

Changes in phosphorus level in Zala river (1968-1984)



source: http://www.okologia.mta.hu

Diffuse phosphorus pollution in Zala catchment (2010)

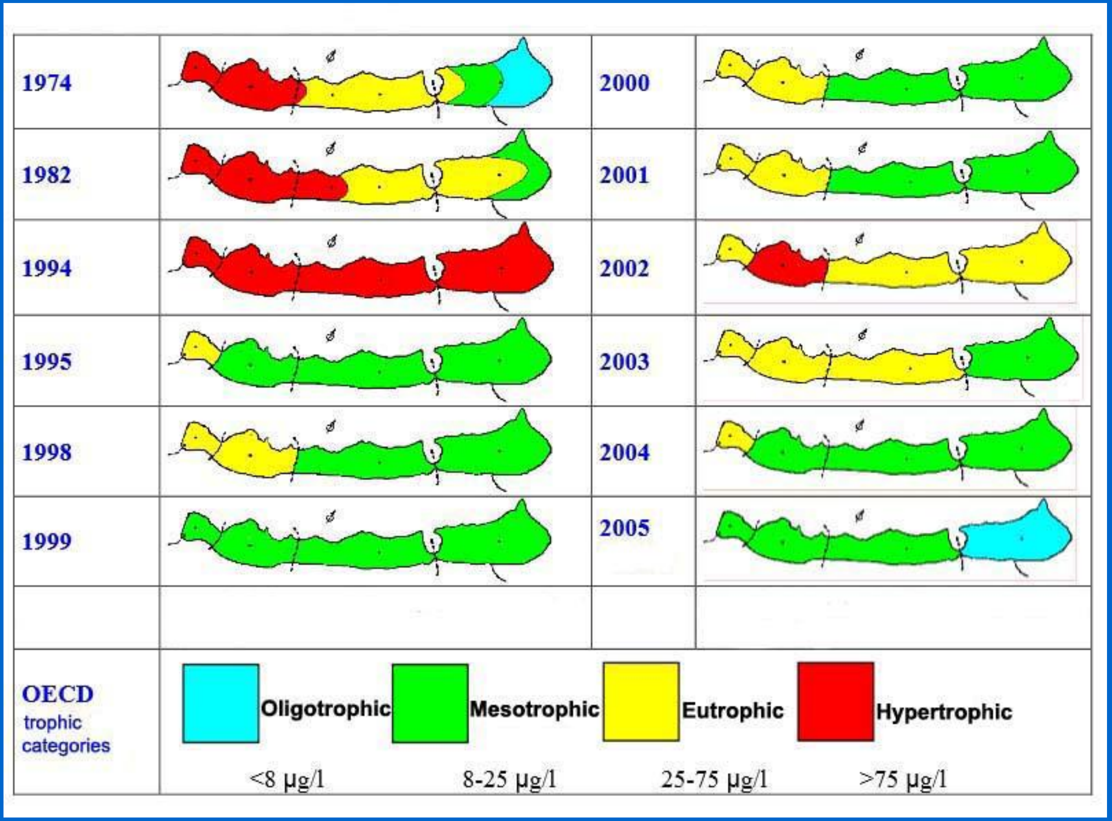


source: www.vizeink.hu

Pollution events in recent past

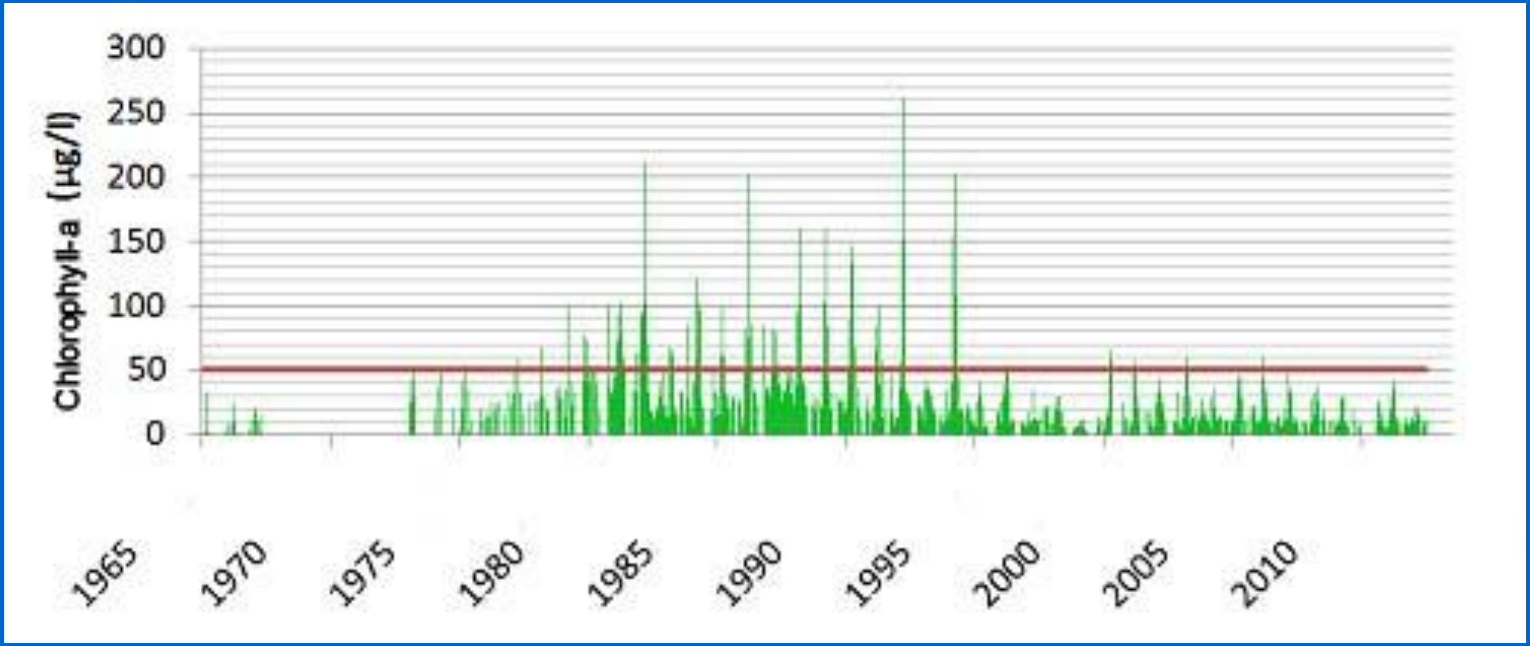
- 1966 in Keszthely bay accelerated eutriphication due to phytoplanktons
- 1974 and 1982 further decrease of water quality, fish dying
- 1994 hypertrophic state, plant nutrients feeding the algae

Changes in trophic levels in the basins of Lake Balaton (1974-2005)



source: http://kdtktvf.zoldhatosag.hu/

Changes in Chlorophyll-a level in the western basin of Lake Balaton (1965-2010)



source: http://www.okologia.mta.hu

Kis-Balaton Water Protection System I. (1985)

- Filtering the water flowing to Balaton
- The main task is to decrease of the nutrient burden of the Zala river by the help of a reservoir storing the water 60 - 90 days before letting it to flow to Lake Balaton
- Upper reservoir since 1985 with Lake Ingói-berek
- Measurements between 1995-2004 proved that the system is efficient only in case of high discharge

Ingói Berek (marsh)

Kányavár Island

Kis-Balaton Water Protection System II.

- Preparations started 2007-2009
- At smaller discharge values Ingói berek is set aside and the water is directed to Fenéki lake
- New water reservoir will be formed by involving Zimányi and Vörsi Berek wetlands
- Habitat reconstruction in Zalavár bay
- Water protection and nature protection
- The system may be put into operation by the end of 2015 which hopefully mitigate most of the problems

The values of ecosystem services in Hungary

Biome	Area (km^2)	Ecosystem services (10^6 EUR/year 2011)																	
		Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Water supply	Erosion control	Soil formulation	Nutrient cycling	Waste treatment	Pollination	Biological control	Habitat	Food production	Raw materials	Genetic resources	Recreation	Cultural	Total
Forest	23 020		2467.3					280.4		2439.4		112.1		1411.5	700.9		1009.3	56.2	8467.5
Grass	18 920	161.5			69.1		668.3	22.9		2005.3	576.3	530.1		1544.4			46.2		5624.1
Swamps	1 130	182.7		6236.9	30.4	5221.5				5739.4			417.6	351.7	145.8		788.7	1210.6	20315.5
Lakes/rivers	1 870				**12430.1**	**4832.6**				**1518.2**				**93.5**			**525.1**		**19399.4**
Cropland	44 050										751.4	1287.9		2897.8					4936.8
Urban	4 020																		
Total	93 012	344.2	2467.3	6236.9	12519.6	10054.1	668.3	303.4	0.00	11702.3	1327.7	1930.1	417.6	6289.2	846.7	0.00	2369.2	1266.8	**58744.3**
(%)		5.9	42.0	106.2	**213.1**	**171.2**	11.4	5.2	0.00	**199.2**	22.6	32.9	7.1	**107.1**	14.4	0.00	40.3	21.6	100

Source: Dombi 2012, based on Constanza et al. 1997

Empty cells indicate the lack of data, grey cells mean negligible values.

The total territory of lakes and rivers is insignificant (only 2 %) in Hungary, however, they provide approximately one third of the ecosystem services

Ecosystem services provided by Lake Balaton and the potential effects of soil erosion

Ecosystem service class	Ecosystem service	Notes and sub-class of ecosystem services	Main ecosystem services provided by Lake Balaton and the effects of soil erosion on them		
			Örvényes Catchment - Central lake basin	Tetves Catchment - Central lake basin	Zala Catchment – Western lake basin
Provisioning ecosystem services	Food	Fish stock (fish migration, river mouth opening)	!	!	!
	Fibre	Reeds	!	!	!
	Freshwater supply	Agricultural water supply (irrigation is negligible)			
		Municipal water supply (toxic **algae**, need of waste treatment)			
		Industrial water supply Negligible			
		Stock water supply (natural process - evaporation)	!	!	!
	Biological products	Not applicable			
	Abiotic products	No extractions			
Regulating ecosystem services	Climate regulation	Not applicable			
	Disease regulation	Parasite and toxic **algae** regulation	!	!	!
	Water regulation	Water storage potential			
	Water purification	Total phosphorus concentration, **algae,** small total area of reedbed habitat	!	!	!
	Erosion control	Presence of vegetation (e.g. willows) stabilizing lakeshores	!	!	!
	Pest regulation	Invasive, non-native species (e.g. **algae**, non-native fish)	!	!	!
	Natural hazard regulation	Providing space for flood water and drought protection	!	!	!
Cultural ecosystem services	Conservation values	Native biodiversity and habitat	!	!	!
		Endangered native species	!	!	!
		Ecological landscapes of significance (Ramsar sites)	!	!	!
	Educational values	Historical/archaeological values			
		Knowledge systems			
	Aesthetic values	Perceptive beauty (**algae**)	!	!	!
	Spiritual and religious values				
	Recreational values	Boating (e.g. sailing, rowing, kayaking)			
		Fishing			
		Hunting (e.g. duck hunting)			
		Picnicking			
		Swimming			
		Walking			

red color: negative impact (soil erosion) yellow color: negligible effect (soil erosion) !: negative tendencies (in general)

Conclusions

- Small catchments, northern shore (e.g. Örvényesi Séd Catchment): negligible or slight effect of sediment load on the ecosystem of Lake Balaton
- Large catchments, southern shore (Tetves Catchment): also slight effect, except high intensitiy rainfall events leading to gully erosion
- Zala catchment: Zala river contributes to the half of the sediment load; diffuse phosphorus pollution is still significant; NO_3 pollution has decreased after the decline of agriculture; there are no hypertrophic conditions any more, improving tendencies
- Several ecosystem services of Lake Balaton are suffering
- Soil erosion contributes to eutrophic conditions in the western and central basins of Lake Balaton


Thank you for your attention!

- According to the trophic classification provided by OECD, in both lake basins (Keszthely Basin and Szemes Basin) belonging to the study areas eutrophication can be observed indicated by the concentration of Chlorophyll-a of algae (above 25 µg/l). The high **concentration of algae** affects several ecosystem services (see table) therefore the concentration of Chlorophyll-a of algae as a biophysical indicator is of utmost importance. When soil erosion affects the lake, it changes the concentration of algae, since the sediments produced by soil erosion increase the volume of organic matters in the lake. Hence, soil erosion through the increased concentration of algae affects negatively the concerned ecosystem services. In case of Zala catchment, further anthropogenic impacts cause more intense algae proliferation.
- **Sedimentation**, another important biophysical indicator, affects mainly freshwater supply, water regulation, water purification, natural hazard regulation.