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Predicting Nutrient Loads in Chosen Catchment

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In recent years, the impact of water erosion coming mainly from agricultural land on surface water quality has attracted a large amount of attention in Europe.
The eroded soil itself and the adsorbed chemicals in it are regarded as non-point source pollution that leads to water quality degradation. The major source of chemicals is the result of increasing application of chemical nutrients and pesticides in excess amounts in order to maximize crop production. Increased levels of nitrogen and phosphorus, along with higher sediment loads, are the leading contributors to reduced water quality. Nitrogen and phosphorus move from fields to surface water when sediment is transported through runoff and soil erosion. As a result of the nitrogen- and phosphorus-enriched sediments, eutrophication - the growth of algae and other aquatic plants - occurs, decreasing dissolved oxygen levels.
The valuable tools for assessment of the behavior of chemicals in the environment are simulation models. Soil erosion models can simulate erosion processes in the watershed and may be able to take into account many of the complex interactions that affect rates of erosion.
This contribution is focused on the suggestion of the model for predicting the total nitrogen and phosphorus content in the Tisovec river catchment, which is situated in the east of Slovakia.

1. Introduction

Excess amounts of nutrients are the most extensive pollution problem affecting the water bodies throughout the world. Increased nutrient loading to water reservoirs leads to degraded water quality and ecosystem health, because a high degree of nitrogen and phosphorus enrichment cause eutrophication of inland waters, what tends towards detrimental effects including degradation of fisheries habitats. Nutrient inputs to water bodies are dominated by non-point sources (e.g. surface runoff, groundwater, atmospheric deposition). The amount of nutrients coming from an area, mainly adsorbed to the sediments, is largely dependent on the predominant land use (Wazniak et al., 2009; Hardy, 2011).
Nowadays, water quality protection programs require comparative nutrient export information for land management alternatives to prevent excess nutrient loading and the resulting impacts of accelerated eutrophication and degraded aquatic habitat in downstream water bodies. Estimated values from watershed models can provide this information but also measured field scale data are necessary to substantiate and/or improve these estimates.

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2. Material and methods

2.1 Tisovec catchment

The study of the predicting nutrient loads (nitrogen and phosphorus) in reservoir bottom sediments was conducted in the Tisovec river catchment, located in the east of Slovakia, in Bardejov district. The area of this watershed is about 6.0 km^2 and it falls in the Topla partial river basin. The annual average discharge is 0.045 m^3/s. About 1.5 km eastward from Hervartov village, the Klusov-Hervartov reservoir is located at an altitude of 343 m above sea level. The average depth of the Klusov-Hervartov reservoir is 3.5 m, surface area 2.2 ha and its total capacity is about 72,000 m^3. It was built for fishing, irrigations, recreation and for retention of high water.

The climate is continental with the mean maximum annual temperature varying from –3 °C in January to 20 °C in July. The mean annual precipitation is about 670 mm, with maximum in summer months.

Majority of land has slope more than 8 %. Soil types of the watershed are, in general, planosols, cambisols and albic luvisols. From the soil texture point of view, medium heavy soils (sandy loam) occur in this area, and according to the content of skeleton in the soil, slightly stony soils lead.

The land use of the catchment was found to be mixed type. The upstream part and middle part of the Tisovec catchment is an area mainly covered with forest (39.2 %) and pastures (21.7 %), while the lower part is an arable land (21.4 %) mainly used for cereals (spring barley, winter wheat), corn silage and winter oilseed rape growing. The rest of the land area is for other uses.

2.2 Predicting nutrient loads

The model for predicting nutrient loads in the Tisovec catchment has been suggested on the basis of the study realized in the vicinity of the Klusov-Hervartov reservoir, situated in this catchment (Junakova et al., 2009). The methodology works on the determination of total nitrogen (N) and phosphorus (P) concentrations in eroded sediments in dissolved and adsorbed form of followed elements. Based on our previous researches (Kovalikova and Balintova, 2008; Junakova et al., 2009), nutrient losses by surface runoff (dissolved form) weren't considered.

The determination of the total nutrient concentrations in detached eroded soil particles in adsorbed form is based on the soil loss calculation, which is supplemented with the determination of the average soil nutrient concentration in top soils (Figure 1).

Soil loss from the arable land was computed using well-known empirical equation USLE (Wischmeier and Smith, 1978; Ministry of Environment of the Slovak Republic, 2004), where the basic inputs consist of topography (Table 1) and land use data (Table 2).

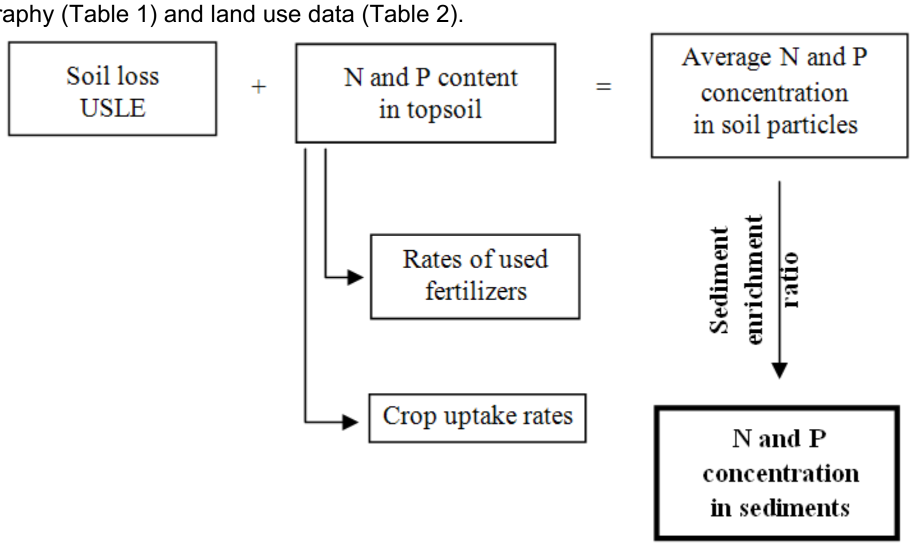

Figure 1: The scheme of the suggested model for prediction the content of total nitrogen and phosphorus in eroded soil particles and reservoir bottom sediments

Table 1: Basic characteristics of arable land units in the catchment

Plot number	Unit area [ha]	Slope [%]	Length [m]
1004/1	15.63	8.8	388
2001/1	18.46	10.49	980
3003/1	3.53	10.17	180
3005/1	3.06	8.87	200
2003/1	16.84	10.97	708
3101/1	35.36	10.37	786
2203/2	35.58	13.54	900
Total area	128.46	-	-

Table 2: Crop rotation for plots 1004/1 and 2001/1 during 10 years

Year	Crop	
	Plot 1004/1	Plot 2001/1
1998	winter oilseed rape	corn silage
1999	triticale	spring barley
2000	corn silage	triticale
2001	winter wheat	winter oilseed rape
2002	winter oilseed rape	triticale
2003	winter wheat	pea
2004	potatoes	winter wheat
2005	winter wheat	spring barley
2006	spring barley	winter rye
2007	winter oilseed rape	winter oilseed rape

The crop/vegetation and management factor resulting from the USLE calculation is a generalized C factor value for a specific crop that does not account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country. Because erosion varies according to the height of plant cover from the ground, also the C factor changes as the plants grow and the state of the soil surface alters.

In our experiments, the determination of the C factor was calculated by dividing this generalized C factor into five periods for each of the main periods of the cropping cycle (rough fallow, seedling, establishment, growing and maturing crop, residue or stubble field) (Junakova and Balintova, 2011a).

The average soil nutrient concentration in top soils was computed on the basis of subtraction the nutrient input from fertilizer use (data provided by the agricultural cooperative in followed area) and plant nutrient uptake (determined by the average yield in the Tisovec catchment's area).

The content of total nitrogen and phosphorus in transported sediments detached through water erosion was calculated using the proposed equation (Junakova et al, 2009; Junakova and Balintova, 2011b):

$$C_X = \frac{\sum_{i=1}^{5} X_i . G_i}{G_{r.i}} . e^{2-0,2ln(G_{r,i}.1000)} \qquad (1)$$

where C_X – the average annual concentration of total N, P in transported soil particles in $kg_{N,P}$/ha or $mg_{N,P}/kg_{soil}$,

X_i – residual concentration of total N, P in soil in *i*-period (estimated like X_i = background soil concentration + (fertilizer nutrient input – plant nutrient uptake) in $kg_{N,P}$/ha; background soil concentration was estimated like difference between total nutrient concentration in soil and plant available nutrients in soil,

G_i – soil loss in individual cropping periods by Wischmeier and Smith in t/ha,

$G_{r,i}$ – average soil loss in *i*-year on followed plot in t/ha/year.

Calculated nutrient concentrations in transported soil particles were verified with the chemical analysis results of samples collected from the reservoir. The composite sediment samples (24 samples) were taken from the selected localities near the dyke of the Klusov-Hervartov reservoir, especially due to deposition of finest particles (fractions below 63 μm) preferentially attaching the nutrients.

3. Results and discussion

Calculations were realized for two units (plots 1004/1 and 2001/1) of arable land situated in the neighbourhood of the reservoir in the Tisovec catchment. A cause of this hypothesis was the fact, that the Tisovec catchment falls from the farmed land point of view to Klusov agricultural cooperative, where all plots have similar soil characteristic, especially topographically characteristics (Table 1) and cover crops and management (Table 2).

For more accurate calculation in our study, the both calculations (soil loss and the average soil nutrient concentration in top soils) were divided into five periods for each of the main periods of the cropping cycle (rough fallow, seedling, establishment, growing and maturing crop, residue or stubble field). Based on the determining of "divided" results, partial soil loss G_i and partial residual concentration X_i of total N and P in soil in individual cropping periods for mentioned plots were calculated (Junakova and Balintova, 2011a).

According to the suggested prediction model the total nitrogen and phosphorus concentrations in transported soil particles from two followed plots were calculated (Table 3, 4). Then calculated nutrient concentration in bottom reservoir sediments were verified with determined concentrations by statistical assessment using t-test and F-test, at 0.05 significance level. Determined nitrogen concentrations in sediments varied from 0.15 to 0.26 % and phosphorus concentrations ranged from 0.048 to 0.113 % depending on sampling location and depth. On the basis of determining two-sided confidence intervals for the expected values of random variables with the confidence coefficient 0.95 it can be stated, that the expected values of calculated and determined concentration of total N and P are not statistical significantly different (Junakova et al., 2009).

Based on the calculated average annual concentrations of total N, P in transported soil particles from followed plots (C_X) to the Klusov reservoir, the final total nutrient load from the arable land of the Tisovec catchment area (128.46 ha of arable land) was estimated during 19 years as a weighted mean of yearly nutrient losses from two plots of arable land located in vicinity of reservoir (Table 5). Total nutrient load from the Tisovec catchment estimated during 19 years represents approximately 55.5 t of total nitrogen and 18.5 t of total phosphorus.

Table 3: Calculated nutrient concentrations in transported soil particles from plot 1004/1and total nutrient loss

Year	Plot 1004/1						
	$G_{r,i}$ [t/ha/year]	Unit area [ha]	$G_{r,i}$ [t/year]	N [%]	P [%]	ΣN [t/ha/year]	ΣP [t/ha/year]
1998	7.75	15.63	121.10	0.198	0.084	0.015	0.007
1999	8.16	15.63	127.47	0.196	0.083	0.016	0.007
2000	17.73	15.63	277.14	0.166	0.071	0.029	0.013
2001	1.91	15.63	29.87	0.254	0.109	0.005	0.002
2002	5.45	15.63	85.11	0.208	0.088	0.011	0.005
2003	7.71	15.63	120.45	0.193	0.082	0.015	0.006
2004	15.22	15.63	237.84	0.173	0.073	0.026	0.011
2005	2.44	15.63	38.13	0.246	0.104	0.006	0.003
2006	8.58	15.63	134.11	0.192	0.081	0.016	0.007
2007	8.06	15.63	125.92	0.194	0.081	0.016	0.007

Table 4: Calculated nutrient concentrations in transported soil particles from plot 2001/1and total nutrient loss

Year	Plot 2001/1						
	$G_{r,i}$ [t/ha/year]	Unit area [ha]	$G_{r,i}$ [t/year]	N [%]	P [%]	ΣN [t/ha/year]	ΣP [t/ha/year]
1998	27.73	18.46	511.86	0.179	0.053	0.050	0.015
1999	5.34	18.46	98.57	0.249	0.074	0.013	0.004
2000	13.28	18.46	245.20	0.207	0.061	0.028	0.008
2001	15.93	18.46	294.00	0.201	0.059	0.032	0.009
2002	15.86	18.46	292.85	0.199	0.058	0.032	0.009
2003	17.81	18.46	328.77	0.194	0.056	0.034	0.010
2004	13.99	18.46	258.23	0.203	0.059	0.028	0.008
2005	8.02	18.46	147.97	0.228	0.066	0.018	0.005
2006	13.12	18.46	242.24	0.206	0.060	0.027	0.008
2007	12.28	18.46	226.70	0.208	0.060	0.026	0.007

Table 5: Total nutrient load from the arable land of the Tisovec catchment area during 19 years

Year	Plot 1004/1 + plot 2001/1	
	Mean average	
	ΣN [t/ha/year]	ΣP [t/ha/year]
1998	0.034	0.011
1999	0.015	0.005
2000	0.028	0.010
2001	0.020	0.006
2002	0.022	0.007
2003	0.025	0.008
2004	0.027	0.010
2005	0.013	0.004
2006	0.022	0.007
2007	0.021	0.007
average	0.023	0.008
Σ 19 years	55.50	18.52

4. Conclusion

This paper summarizes the main calculation steps and the obtained results of nutrient loads in the Tisovec catchment in Slovakia using the suggested model. The base of this model is to determine the total nutrient concentrations in detached eroded soil particles in adsorbed form, which consist of the soil loss calculation, supplemented with the determination of the average soil nutrient concentration in top soils.

According to the calculated average annual nutrient concentrations in transported soil particles from the Tisovec catchment to the Klusov reservoir, the final total nutrient load from the arable land of the Tisovec catchment area was estimated during 19 years and it represents approximately 55.5 t of total nitrogen and 18.5 t of total phosphorus.

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References

Hardy K., Guarnieri F., 2011, Modeling and Hazard Analysis for Contaminated Sediments Using Stamp Model, Chemical Engineering Transactions, 25, 737-742. DOI:10.3303/CET1125123

Junakova N., Balintova M., Vodicka R., 2009, Nutrient concentration in eroded sediments detached through water erosion, CEST 2009, Crete, B-400 – B-406.

Junakova N., Balintova M., 2011a, Model for predicting the nutrient content in reservoir bottom sediments, SGEM 2011, Vol. 3, Bulgaria-Sofia, 475-482.

Junakova N., Balintova M., 2011b, The modelling of total nitrogen, phosphorus and pottasium concentrations in eroded soil particles and reservoir bottom sediments, CEST 2011, Greece-Rhodes, Crete, B-452 - B-458.

Kovalikova N., Balintova M., 2008, Influence of water erosion processes on the bottom sediment quality, Chemické listy, 102, 397-398.

Ministry of Environment of the Slovak Republic, 2004, Act No. 220/2004 Coll. On Protection and Exploitation of Agricultural Land and Amending and Supplementing of Act No. 245/2003 Coll. on Integrated Prevention and Control of Pollution of the Environment and Amending and Supplementing of Certain Acts (in Slovak).

Wazniak C., Wells D., Hall M., 2004, The Maryland Coastal Bays ecosystem, Chapter 1.2, Maryland’s Coastal Bays: Ecosystem Health Assessment, Maryland Department of Natural Resources <www.dnr.state.md.us/coastalbays/publications/Chapter1.2.pdf> Accessed 20.03.2012

Wischmeier W. H., Smith D. D., 1978, Predicting Rainfall Erosion Losses. A Guide to Conservation Planning, Agriculture Handbook No. 537, U.S. Department of Agriculture.