ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LX 18 Number 3, 2012

# THE INFLUENCE OF WATER EROSION PROCESSES ON SEDIMENT AND NUTRIET TRANSPORT FROM A SMALL AGRICULTURAL CATCHMENT AREA

F. Pavlík, M. Dumbrovský, J. Podhrázská, J. Konečná

**Received: December 8, 2011**

## Abstract

PAVLÍK, F., DUMBROVSKÝ, M., PODHRÁZSKÁ, J., KONEČNÁ, J.: *The influence of water erosion processes on sediment and nutriet transport from a small agricultural catchment area.* Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 3, pp. 155–164

Erosion processes in catchment areas cause serious ecologic and economic problems because of their negative consequences in terms of soil and water deterioration as well as for the environment as a whole. The soil particles washed down by water erosion are the biggest pollution factor due to their amount and volume. Sediments are the product of a selective process in which smaller and lighter particles are separated from eroded soil and taken away by water first. This means that the sediments contain a higher amount of organic, clay, and silt particles than the the original soils. Washed down sediments consist mainly of particles smaller than 0.05 mm (40–90% of the mixture). Other studies in the Czech Republic have focused on the assessment of soil erosion, based upon principles and parameters defined in the Universal Soil Loss Equation, but none of them has dealt with nutrient transport assessment as a consequence of water erosion. This paper presents a summary concerning the nutrient content in erosion sediment in a selected catchment area. Research work was conducted to identify and quantify the sediment load associated with nutrient transport especially from arable land on different soil types.

soil erosion, nutrient transport, catchment area, water quality

Soil and water are two important and closely related components of the environment. Permanent soil characteristics influence the amount of water retained in the soil profile, quantity and rate of runoff, infiltration, and evaporation. The presence and movement of water in the soil profile affects the stable characteristics of soil. The shift of these materials has an impact on environmental quality. In particular, water erosion removes topsoil and subsequently causes pollution of watercourses and water reservoirs with both suspended matter and dissolved and colloidal substances. It is therefore necessary to address the protection of soil and water simultaneously. Negative effects of water erosion on soil degradation and pollution of surface water have been studied at various scales by many authors (Bečvář, 2006; Kvítek & Doležal, 2003; Owens & Collins, 2006; Russell *et al.*, 2001). The advantage of studying very small basins (up to approximately 10 km$^2$) is the relative ease of making exact measurements of hydrological and meteorological characteristics in the real natural environment and the exact definability of the natural and anthropic conditions. The most intensive manifestations of water erosion in small agricultural catchments are caused by torrential rainfall or local melting of snow (Janeček *et al.*, 2007; Fulajtár & Jánský, 2001). Soil particles washed away by water erosion are the biggest polluting factors with regard to their amount and volume. Sediments are the product of a selective process. In this process of soil erosion initially the smaller and lighter particles are separated and carried by water. This means that the sediments contain more organic, clay, and dust particles than the soil from which they originate. According to Dub (1957) and Janeček *et al.* (2007) the drifting sediment particles consist mainly of particles smaller than 0.05 mm (40–90% mixture). Together with the downhill sediment runoff, mainly nutrients are transported, whose main sources are fertilizers and pesticides. Mostly phosphorus and nitrogen are taken away from agricultural land by water erosion.

## MATERIALS AND METHODS

Monitoring and quantification of sediment delivery from the catchment can be made by direct measurement of the quantity and concentrations in the output profile or by mathematical modelling. The article deals with the possibilities of direct measurements as well as the possibilities of model calculations (especially the possible ways to estimate the amount of soil washout and its nutrient content) and with a mutual comparison of different approaches. The experimental chapter contains basic information about chemicals and experimental and analytical equipment as well as experimental and mathematical techniques used to obtain the results presented. Detailed information about well-known facts or previously published techniques and illustrative figures, mainly the setup and equipment schemes, has been omitted.

### *Determination of sediment transport of undissolved substances and of nutrients from a catchment area by a model calculation*

Quantification of sediment transport of suspended solids in small agricultural catchment areas is based on the assumption that the loss of substances is caused by water erosion. The methods used to estimate soil erosion in the catchment areas are based on the RUSLE (Revised Universal Soil Loss Equation). The RUSLE is an empirical model that was developed using statistical techniques derived from analysis of runoff plot data by Wischemeier and Smith (1978). Hillslope erosion from sheet and rill erosion processes is estimated using RUSLE (Renard *et al.*, 1997). The RUSLE calculates mean annual soil loss ($Y$, tonnes ha$^{-1}$ y$^{-1}$) as a product of six factors: rainfall erosivity ($R$), soil erodibility ($K$), hillslope length ($L$), hillslope gradient ($S$), ground cover ($C$), and land use practice factor ($P$):

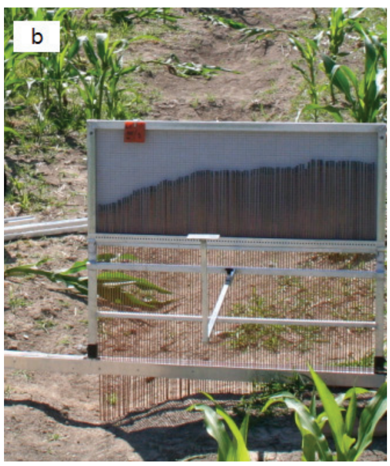
$$Y = R \times K \times L \times S \times C \times P. \quad (1)$$

It is designed for calculating the long-term average soil loss. This equation was used in the modification of the grid in an interface with a geographic information system (GIS) for the selected model agricultural catchment areas. The soil loss is determined according to the method on the basis of a digital elevation model (DEM) with the use of the USLE 2D program and the McCool LS algorithm (Govers, 2000). However calculation by this method does not indicate a significant soil loss from ephemeral gullies (Fig. 1). They are generated in the paths of concentrated surface runoff. Ephemeral gullies occur on arable land more frequently due to more intense precipitations. Loss of soil from the paths of concentrated surface runoff is an important component in the total balance of the soil loss in the catchment area.

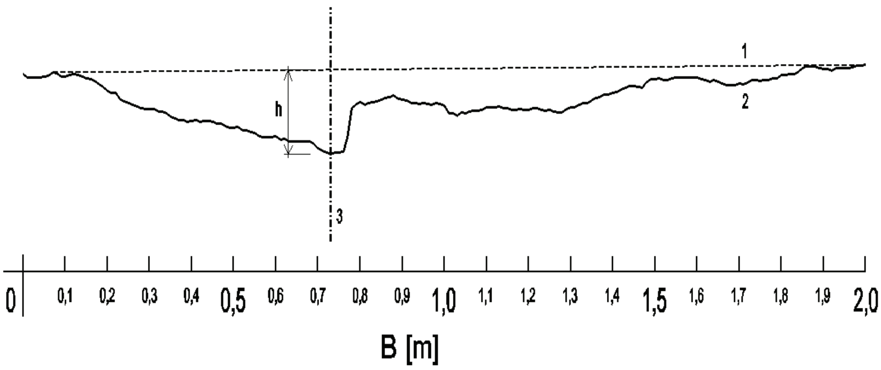
Several models (EGEM, AnnAGNPS, CREAMS) of the components of the total soil loss calculation exist, but these are not calibrated for conditions of the Czech Republic (CR). Consequently direct measurement of these ephemeral gullies was realized in the selected catchments. The Landscape Water Management Institute has developed a special device for this measurement called an erosion bridge, which works on a mechanical principle (Fig. 2). The cross profiles are measured along the ephemeral gully and subsequently the volume of the soil lost in the ephemeral gully is determined (Fig. 3).

When using this method, knowledge of the total balance of the soil loss in the catchment is necessary for the purpose of calculation of soil transported out of the river basin. The total soil loss in a catchment area had to be reduced by the soil delivery ratio


1: *Example of an ephemeral gully*




2: *Erosion bridge*




3: *Cross profile of terrain level of gully – measured by erosion bridge*

(SDR) to determine the amount of transported soil load in a catchment area outflow profile. Mostly in the water flow, the sediment delivery ratio (SDR) multiplied. The SDR depends on the size of the catchment area (Janeček *et al.*, 2007).

The nutrient load from hillslope erosion is calculated as the product of the hillslope sediment yield (hillslope erosion × SDR) multiplied by the nutrient concentration (NC) of this load. The nutrient concentration of the sediment load is determined from the proportion of clay and nutrient concentration of the bulk soil (BS). The model assumes that all nutrients are associated with the clay fraction. For internal catchment links when the percentage of clay is greater than the SDR, all sediment delivered to the channel is assumed to be clay. The nutrient concentration is then the bulk soil concentration enriched by the proportion of clay (Cp) in the hillslope soil:

$$NC = \frac{SC}{Cp} \times 0.5, \qquad (2)$$

for $Cp < SDR$.

In the few cases where the proportion of clay is less than the SDR, only a portion of the delivered sediment is clay and so the nutrient concentration is reduced by the ratio of the proportion of clay to the SDR. In previous projects (Brodie *et al.*, 2003) it was found that the nutrient enrichment ratio simulated by the above equation gave nutrient concentrations significantly higher than those observed in river sediments of the region. The enrichment ratios were also larger than those recorded in field experiments. Thus the effect of nutrient enrichment was reduced by half (the 0.5 factor in Equation 1). Data on soil clay proportions and nutrient concentrations for phosphorus and nitrogen were extracted from the Australian Soil Resource Information System (Henderson *et al.*, 2001). The nutrient loads from riverbank erosion were calculated as the product of their respective sediment yields multiplied by the soil nutrient concentration, which for phosphorous was taken to be 0.25 g $kg^{-1}$ and for nitrogen 1 g $kg^{-1}$.

To determine the total nutrient loss per year from a catchment the long term average concentrations of individual chemical elements in soils set by the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) were considered. The contents of phosphorus, potassium, magnesium, and calcium were measured in soils. Long term average concentrations for selected localities in the monitored periods 1999–2003 and 2004–2009 are listed in Table 1, where the final concentration for the period 1999–2009 was determined as the weighted mean throughout the area tested. Samples from each locality were taken from representative rectangular areas whose sides measured 25 × 40 m. Four samples were taken from each area. The samples from arable land were taken from the topsoil (according to the depth of the soil horizon, max. 30 cm). Then the content of total nitrogen and oxidizable carbon was determined according to the soil type. In Table I the average values for the years 1992 and 2001 are listed. The content of total nitrogen in soil is a quite constant value because it is formed of compounds that are difficult to decompose both chemically and microbiologically. Nitrogen is bound to aromatic cores of humic acids, fulvic acids, and humins. For that reason the content of total nitrogen in soil is often related to $C_{ox}$ and expressed by the C:N ratio. In CR soils the stated average value of C:N is 10–12:1. More limited ratios express higher humus quality and vice versa.

### *Detection of substance loss from the catchment by direct measurement*

In the experimental Kopaninský stream catchment, precipitation runoff events are monitored in the hydrometric profile and samples of water are taken for the analysis of undissolved substances contents and also nutrient contents. The Thomson's triangular spillway, ultrasound water level sensor, and precipitation gage are constructed in the hydrometric profile for measuring precipitation runoff events. The measured values of precipitation and discharge are saved in the data logger. For the purpose of sampling the hydrometric profile is equipped with an automated sampling device built in the bank above the overflow. Water from the rising part of the outflow wave gradually fills the bottles which are lined up vertically one above the other. The samples are taken immediately after

I: *Long term average nutrients concentration in selected localities*

| Locality | Period | $C_{ox}$ | $N_{tot}$ | Ratio C:N | Period | Area | P | K | Mg | Ca |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % | % | – | | ha | mg kg⁻¹ | | | |
| Šardice (Hodonín) | | | | | 1993–1998 | 45 168 | 78 | 255 | 281 | 5 228 |
| | 1992 | 1.30 | 0.142 | 9.2:1 | 1999–2003 | 39 922 | 79 | 273 | 278 | 5 724 |
| | 2001 | 1.21 | 0.134 | 9.0:1 | 2003–2008 | 46 953 | 76 | 274 | 285 | 5 880 |
| | 1992 and 2001 | 1.26 | 0.138 | 9.1:1 | 1993–2008 | 132 043 | 78 | 267 | 281 | 5 610 |
| Šlapanice (Brno) | | | | | 1993–1998 | 43 882 | 77 | 232 | 295 | 4 739 |
| | 1992 | 1.19 | 0.135 | 8.8:1 | 1999–2003 | 38 785 | 79 | 249 | 287 | 4 767 |
| | 2001 | 1.07 | 0.112 | 9.6:1 | 2003–2008 | 47 630 | 87 | 280 | 297 | 5 209 |
| | 1992 and 2001 | 1.13 | 0.124 | 9.1:1 | 1993–2008 | 130 297 | 81 | 255 | 293 | 4 919 |
| Nový Jičín | | | | | 1993–1998 | 35 532 | 98 | 254 | 136 | 2 243 |
| | 1992 | 1.19 | 0.135 | 8.8:1 | 1999–2003 | 33 765 | 84 | 229 | 155 | 2 251 |
| | 2001 | 1.07 | 0.112 | 9.6:1 | 2003–2008 | 34 022 | 94 | 251 | 165 | 2 259 |
| | 1992 and 2001 | 1.13 | 0.124 | 9.1:1 | 1993–2008 | 103 319 | 92 | 245 | 152 | 2 251 |
| Kop. potok (Pelhřimov) | | | | | 1993–1998 | 53 211 | 106 | 250 | 115 | 1 736 |
| | 1992 | 1.43 | 0.145 | 9.9:1 | 1999–2003 | 49 256 | 104 | 240 | 122 | 1 599 |
| | 2001 | 1.29 | 0.131 | 9.9:1 | 2003–2008 | 57 863 | 100 | 240 | 119 | 1 478 |
| | 1992 and 2001 | 1.36 | 0.138 | 9.9:1 | 1993–2008 | 160 330 | 103 | 243 | 119 | 1 601 |

Source: ÚKZÚZ

precipitation runoff events when at least one bottle of the automated sampling device has been filled up.

The condition of crops and agrotechnical interventions in the catchment are recorded for each precipitation runoff event. The transport of substances through the profile from the start to the culmination of flood flow is calculated from the known discharges, duration of flood wave rise, and concentration of undissolved substances and nutrients. The following substances were detected in the samples of water taken:

- Undissolved substances – gravimetrically (ČSN-EN 872)
- $NO_2^-$ – photometrically in the visible spectrum (ČSN-EN 26777)
- $NO_3^-$ – photometrically in the visible spectrum (ČSN iso 7890-3) (NaOH, salicylate)
- $PO_4^{3-}$ – photometrically in the visible spectrum (ČSN-EN 26777) (phosphomolybdenum blue method)
- $NH_4^+$ – photometrically in the visible spectrum (ČSN-EN iso 6878).

The samples of soils were taken and the following parameters were determined for the events when visible soil mass was transported and sedimented:

- $C_{ox}$ – oxidation by chrome-sulphuric acid and follows titration
- $N_{tot}$ – mineralization by $H_2SO_4$ photometrically
- available P, K, Mg and Ca – extracted in Mehlich III solution (= acetic acid, nitric acidfluoride and ammonium nitrate)
- physical properties (texture, bulk density).

## Methods of determination

### *Detection of available nutrients (P, K, Ca, Mg) according to Mehlich III*

Soil is extracted by acid solution which contains ammonium fluoride to increase the solubility of different forms of phosphorus bound with aluminium. Ammonium nitrate, which favourably influences the desorption of potassium, magnesium, and calcium, is also present in the solution. The acid reaction of the leaching solution is diluted with acetic acid and nitric acid. The presence of EDTA ensures good release of important nutrient elements. Calcium and magnesium contents are determined after solution dilution by the method of atomic absorption spectrophotometry in an acetylene-air flame. Interference is eliminated by the addition of lanthanum. Interpretation of the signal is done by the calibration curve method. Phosphorus in the soil extract is determined by means of spectrophotometry as phosphomolybdenum blue. Reduction by ascorbic acid proceeds in the environment of sulphuric acid in the presence of Sb (III). Intensity of blue colouring is measured on a spectrophotometer with a wavelength of passing light of 750 nm. After thermal excitation of potassium atoms in acetylene-air flame, the characteristic quantum is emitted. The intensity of characteristic radiation is proportionate to the potassium concentration in the foggy sample.

### *Detection of $C_{ox}$*

Oxidizable organically bound carbon in soil is oxidized by chromic acid in the environment of the sulphuric acid surplus under the defined conditions.

The unconsumed chromic acid is determined by titration of Mohr salt solution with biamperometric indication of the titration end point.

***Detection of total nitrogen according to Kjeldahl***

The sample is decomposed by Kjeldahl's process of simmering together with sulphuric acid, ingredients, and formed $NH_4^+$ ions together with $NH_4^+$ ions originally present in the sample after alkalization distilled in the form of $NH_3$ into a certain volume of a volumetric solution of $H_2SO_4$ or HCl or into a solution of $H_3BO_3$. The captured $NH_3$ is then determined either indirectly by titration of the surplus of the volumetric solution of strong acid with a volumetric solution of NaOH, or, in the case of $H_3BO_3$, directly with a volumetric solution of acid ($H_2SO_4$ or HCl).

## Description of the localities studied

For the purposes of the article four localities were selected (described further in the text) for which model calculation of the transport of substances was carried out. One of the localities – the Kopaninský stream catchment – is in the same time experimental catchment from which the samples were taken and transport of substances was measured directly.

***Šlapanice location***

The area has been chosen in the area of the Dyje catchment in the Říčky catchment (HČP: 4-15-03-096), which is situated in the South Moravian region in the district of Brno-venkov (see Fig. 4). Two tracts of concentrated surface runoff (DSO) were identified, including the catchment areas situated in the southwestern part of the municipality of Bedřichovice cadastre and the northern part of the cadastral area of Šlapanice u Brna. Both areas are situated on arable land.

DSO1 had a catchment area of 5.6 ha and average slope of 12.6% and was identified on the soil block (SB) 1301 (according to LPIS – land parcel identification system). The average erosive wash of the DSO1 catchment is 17.4 t ha$^{-1}$ year$^{-1}$, according to Wischmeier and Smith's calculation. DSO2 had a catchment area of 13.4 ha and average slope of 9.5% and was identified on SB 0403 in the cadastre of Šlapanice u Brna. Average values of erosive wash in the catchment reach values of 12.0 t ha$^{-1}$ year$^{-1}$. The soil loss measured by the erosion bridge was 48.3 t year$^{-1}$ in DSO1 and 92.5 t year$^{-1}$ in DSO2. Corn was sown on the monitored area at the time of measurement. The results of loss and subsequent soil transport are listed in Tab. II.

***Šardice locality***

The area was chosen in the Šardický stream catchment (HČP: 4–17–01–094), situated in the South Moravian region in the district of Hodonín. The area is situated in the eastern part of the cadastral area of Šardice municipality, where there are two tracks of concentrated runoff including catchment areas in the soil block 1705 (according to LPIS) with southeast exposition (see Fig. 4). Both these areas are situated on arable land. The maximum and minimum altitudes of the area are 238.00 and 192.00 m above sea level, respectively. DSO1 has a catchment area of 10.8 ha and average slope of 10.4%. Average erosive wash of the DSO1 catchment is 14.8 t ha$^{-1}$ year$^{-1}$. DSO2 has a catchment area of 17.7 ha (see Fig. 4) and average slope of 8.8%. Average values of erosive wash in the catchment reach 11.0 t ha$^{-1}$ year$^{-1}$. The soil loss measured by the erosion bridge was 42.0 t year$^{-1}$ in DSO1 and 52.6 t year$^{-1}$ in DSO2. Corn was sown in the monitored area at the time of measurement. The results of loss and subsequent transport of soil are listed in Tab. II.

***Nový Jičín locality***

The area was chosen in the northern part of the Luha catchment (HČP: 2-01-01-051), situated in the Olomouc region in the district of Přerov. The area studied is situated in the central part of the cadastre Jindřichov u Hranic and on the border of the cadastres of Nejdek u Hranic and Střítež nad Ludinou. Two DSOs including catchment areas were identified in the localities (see Fig. 4). The DSO1 catchment area had a surface area of 7.3 ha on arable land of two SBs 0904/3 and 0903/1. The average slope of the area is 5.9% and the average erosive wash is 13.5 t ha$^{-1}$ year$^{-1}$. The DSO2 catchment area had a surface area of 33.6 ha and was located on arable land (27.1%) and a wooded area (72.9%). The catchment area is situated on four SBs, mainly on PB9301/1. The average slope of the area is 6.6% and average erosive wash is 9.6 t ha$^{-1}$ year$^{-1}$. The soil loss measured by the erosion bridge was 83.9 t year$^{-1}$ in DSO1 and 422.3 t year$^{-1}$ in DSO2. Corn was sown in the monitored area at the time of measurement. The results of loss and subsequent transport of soil are listed in Tab. II.

***Kopaninský stream locality***

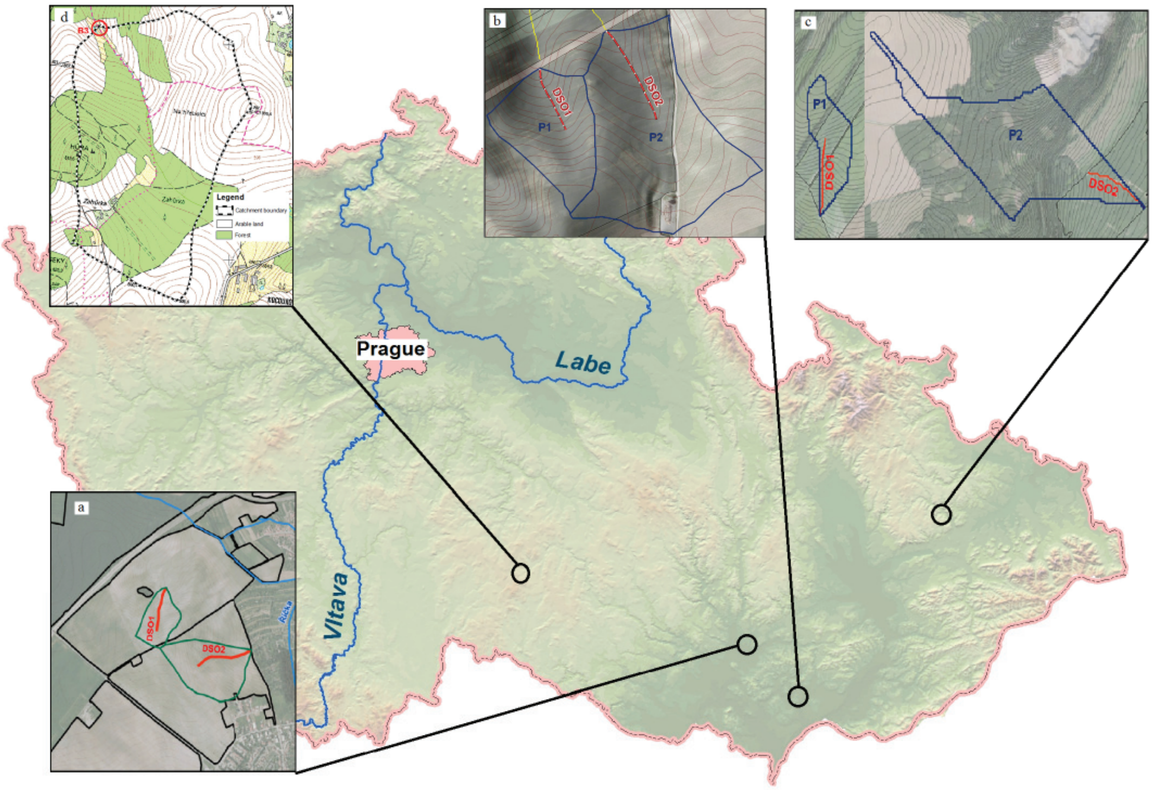
In 1985, the experimental catchment area of Kopaninský stream was established in the Bohemian-Moravian Highlands, where discharges, meteorological data, and water quality (focusing on the nitrogen content) are observed over the long term (Kvítek & Doležal, 2003). The relief of the basin is hilly with an average elevation of 550 m a.s.l. The basin of the Kopaninský stream is classified as a gently warm and damp climatic area characterized by an average annual temperature of 6.5 °C and average annual total rainfall of 700 mm.

The geologic substrate is formed of gneiss and locally quartzite. Medium-heavy or medium textured Cambisols on gneiss are characteristic for the experimental basin. Stagno-gleyic Cambisols and Stagnosols on gneiss are further significantly extended.

In 2004, the gauging profile B3 was established in the Kopaninský stream catchment area (Fig. 4) for the purposes of research on the erosive processes influencing the transport of undissolved substances and nutrients in the small agricultural catchment

II: *Total soil loss in the localities studied*

| Locality | Total soil loss | | Sediment delivery ratio | | Total sediment delivery | |
|---|---|---|---|---|---|---|
| | **DSO1** | **DSO2** | **DSO1 (SDR)** | **DSO2 (SDR)** | **DSO1** | **DSO2** |
| | **t rok$^{-1}$** | **t rok$^{-1}$** | **%** | **%** | **t rok$^{-1}$** | **t rok$^{-1}$** |
| Šardice (Hodonín) | 201.1 | 247.3 | 53.0 | 50.0 | **106.6** | **123.7** |
| Šlapanice (Brno) | 145.7 | 253.3 | 55.0 | 52.0 | **80.1** | **131.7** |
| Nový Jičín | 182.5 | 744.9 | 54.0 | 46.0 | **98.6** | **342.7** |
| Kop. potok (Pelhřimov) | 2005 | 2006 | 2005 (SDR) | 2006 (SDR) | 2005 | 2006 |
| | t rok$^{-1}$ | t rok$^{-1}$ | % | % | t rok$^{-1}$ | t rok$^{-1}$ |
| | 339.3 | 267.5 | 37.0 | 37.0 | **125.5** | **99.0** |




4: *General map of chosen localities, Šlapanice locality (a), Šardice locality (b), Nový Jičín locality (c), Kopaninský stream locality (d)*

areas. The profile was fitted with an automatic sampler of undissolved substances in order to more fully explore the possibility of erosion control on agricultural land and protection of surface water against accelerated sheet runoff and infiltration of nutrients and hazardous substances in the basin. Continuous measurement of this profile has been running since 2005. The collecting basin of the profile B3 has an area of 78 ha. Arable land covers 53% of the territory, while forests and permanent grassland cover 47%. The average gradient of this area is 7.4%. The most significant rainfall-discharge events occurred in the catchment area in 2005 and 2006. In those years no ephemeral gullies were identified in the catchment area. So erosion wash is considered only at the surface. In 2005, the average erosion wash was 4.4 t ha$^{-1}$ year$^{-1}$ with predominantly corn growing on 21.4% of the catchment area. In 2006, the average erosion wash was 3.4 t ha$^{-1}$ year$^{-1}$ with predominantly spring barley growing on 21.4% of the catchment area.

## RESULTS AND DISCUSSION

### Model calculation

The final nutrients loss was calculated of the determinate values of total soil loss by water erosion (a combination of model calculation and direct

III: *Total substances loss in chosen localities*

| Locality | Place | Total substances loss | | | | | |
|---|---|---|---|---|---|---|---|
| | | $C_{ox}$ | $N_{tot}$ | P | K | Mg | Ca |
| | | Kg | | | | | |
| Šardice (Hodonín) | DSO 1 | 1.3 | 0.1 | 8.3 | 28.5 | 30.0 | 597.9 |
| | DSO2 | 1.6 | 0.2 | 9.6 | 33.0 | 34.8 | 693.7 |
| Šlapanice (Brno) | DSO 1 | 0.9 | 0.1 | 6.5 | 20.4 | 23.5 | 394.2 |
| | DSO2 | 1.5 | 0.2 | 10.7 | 33.5 | 38.7 | 647.9 |
| Nový Jičín | DSO1 | 1.1 | 0.1 | 9.1 | 24.1 | 15.0 | 221.8 |
| | DSO2 | 3.9 | 0.4 | 31.6 | 83.9 | 52.0 | 771.3 |
| Kopaninský stream (Pelhřimov) | 2005 | 1.7 | 0.2 | 12.9 | 30.5 | 14.9 | 201.0 |
| | 2006 | 1.3 | 0.1 | 10.2 | 24.1 | 11.8 | 158.4 |

measurement) and the average values in soil nutrient concentrations at selected locations (Tab. III).

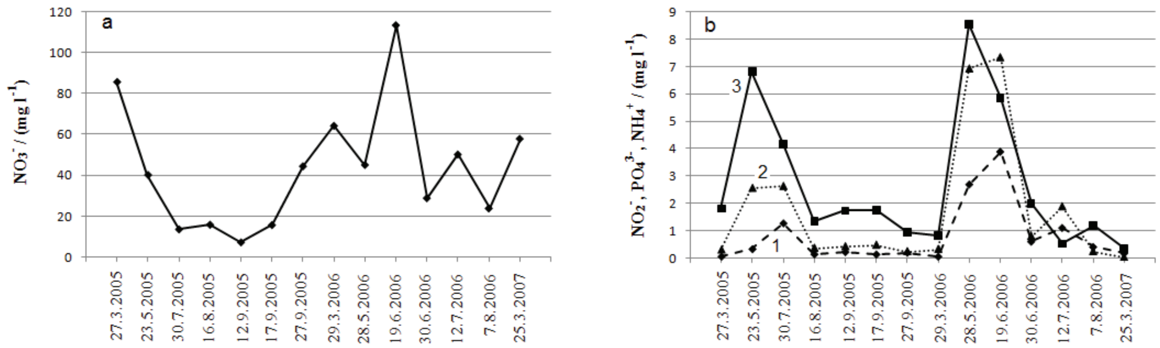
## Direct measurement – catchment area of the Kopaninský stream

The amount of transported nutrients and undissolved substance outside the Kopaniský stream area show Tab. IV. Nutrients were determined only in 2005–2007. Values of concentrations of nutrients in times of increased runoff events show Fig. 5.

The most intensive storm event in 2005 caused massive soil loss and subsequent deposition at the heel of a slope in a vegetative zone along a stream. Samples of the deposited material were taken from there. Results of analyses (Tab. V) were compared with apparently undamaged soil (reference samples) from the upper part of the slope.

IV: *Maximum discharges and transport of undissolved substances during extreme rainfall-discharge events in 2005 to 2010*

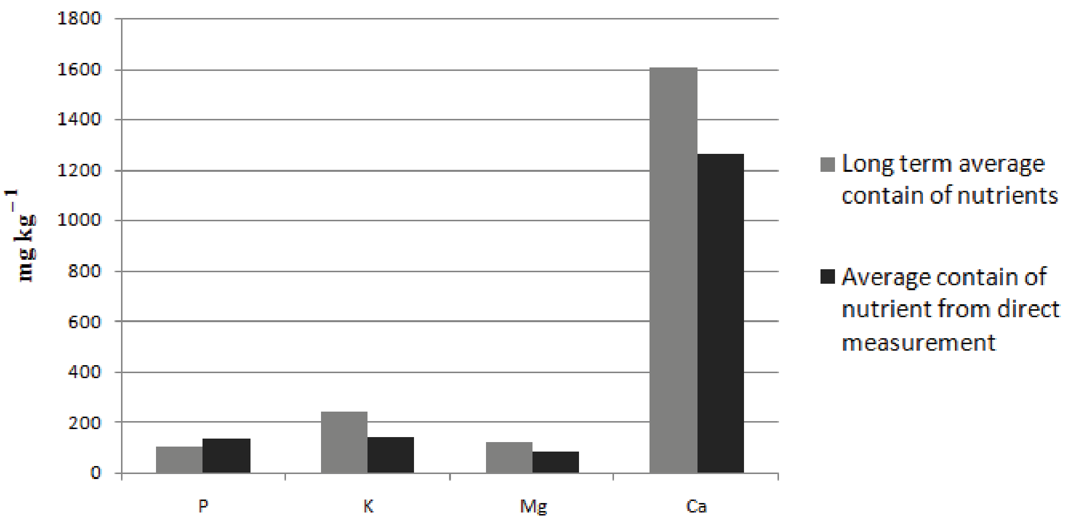
| Year | Date | Profile | Discharge | Precipitation | | Volume | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Q_{max}$ ($l\ s^{-1}$) | Causal rainfall total (mm) | Max. intensity ($mm\ min^{-1}$) | $NO_3^-$ (kg) | $NO_2^-$ (kg) | $PO_4^{3-}$ (kg) | $NH_4^+$ (kg) | Undissolved substance (kg) |
| 2005 | 27. 3. | B3 | 482.3 | 1.6 | snow melting | 208.00 | 0.14 | 4.41 | 0.74 | 4 760.9 |
| | 23. 5. | B3 | 690.0 | 89.8 | 2.0 | 55.05 | 0.45 | 9.30 | 3.50 | 366 747.0 |
| | 30. 7. | B3 | 602.0 | 29.8 | 1.3 | 16.68 | 1.54 | 5.04 | 3.20 | 105 401.3 |
| | 16. 8. | B3 | 115.6 | 34.2 | 0.1 | 3.90 | 0.22 | 2.44 | 1.85 | 5 448.9 |
| | 12. 9. | B3 | 690.0 | 57.2 | 1.4 | 5.98 | 0.18 | 1.41 | 0.35 | 33 830.7 |
| | 17. 9. | B3 | 390.1 | 11.4 | 0.2 | 39.72 | 0.34 | 4.39 | 1.21 | 19 732.5 |
| | 27. 9. | B3 | 94.1 | 15.8 | 0.3 | 3.85 | 0.07 | 0.08 | 0.02 | 325.8 |
| 2006 | 29. 3. | B3 | 611.2 | 11.2 | snow melting | 4722.90 | 4.05 | 60.93 | 24.28 | 58 167.5 |
| | 28. 5. | B3 | 340.5 | 35.8 | 0.3 | 75.50 | 4.47 | 14.26 | 11.59 | 27 169.9 |
| | 19. 6. | B3 | 425.0 | 14.2 | 1.0 | 27.90 | 0.95 | 1.44 | 1.81 | 8 943.5 |
| | 30. 6. | B3 | 82.9 | 41.6 | 0.2 | 11.54 | 0.24 | 0.80 | 0.32 | 2 228.4 |
| | 12. 7. | B3 | 125.6 | 29.6 | 2.0 | 9.10 | 0.20 | 0.10 | 0.34 | 303.4 |
| | 7. 8. | B3 | 190.4 | 71.0 | 0.2 | 37.90 | 0.65 | 1.88 | 0.39 | 1 621.1 |
| 2007 | 25. 3. | B3 | 22.1 | 0.4 | snow melting | 12.33 | 0.04 | 0.07 | 0.01 | 16.6 |
| 2009 | 5. 3. | B3 | 79.3 | – | snow melting | – | – | – | – | 3 520.6 |
| | 4. 8. | B3 | 59.8 | 20.4 | 1.5 | – | – | – | – | 110.7 |
| 2010 | 21. 3. | B3 | 57.8 | – | snow melting | – | – | – | – | 730.9 |
| | 2. 6. | B3 | 94.78 | 37.2 | 0.3 | – | – | – | – | 1 907.5 |
| | 7. 8. | B3 | 80.97 | 35.0 | 1.0 | – | – | – | – | 1 687.7 |
| | 23. 8. | B3 | 67.42 | 12.0 | 1.0 | – | – | – | – | 132.3 |




5: *The measured concentrations of nutrients in Kopaninský stream locality, (a) – nitrate and (b) – nitrite (line 1), ammonium (line 2), phosphate (line 3)*

V: *Physical and chemical characteristics of the sediment and original soil*

| Locality | Textural fraction (%) | | | $C_{ox}$ (%) | $N_{tot}$ (%) | Available nutrients (mg kg⁻¹) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <0.01 mm | 0.01–0.05 mm | 0.05–2.0 mm | | | P | K | Mg | Ca |
| Apparently undamaged field (refer. samples) | 25.1 | 18.7 | 56.3 | 1.24 | 0.102 | 136.0 | 140.5 | 80.5 | 1260.0 |
| Sediment on the field heel | 11.4 | 8.7 | 80.0 | 0.56 | 0.069 | 67.4 | 76.0 | 59.0 | 587.5 |
| Sediment on the meadow | 5.5 | 6.0 | 88.6 | 0.33 | 0.050 | 43.9 | 99.0 | 67.5 | 700.5 |




6: *Comparison of nutrients content in Kopaninský stream locality*

The results of the analyses of the original soil (reference soil) were also compared with long term average contents of available nutrients in soil (Fig. 6).

## CONCLUSIONS

The loss of sediments and nutrients from a catchment can have impacts on agriculture in terms of loss of productive nutrient rich soil, as well as impacts on downstream water quality and river ecosystems. Sediment delivered to streams has several potential impacts downstream. High loads of suspended sediment and the silts and clays that are carried in the flow degrade water quality in streams, reservoirs, and aquatic ecosystems. This is a result of both the sediment itself and the nutrients that the sediment carries. High concentrations of suspended sediment reduce stream clarity, inhibit respiration and feeding of stream biota, diminish light needed for plant photosynthesis, make water unsuitable for irrigation, and require treatment of water for human use. The export of high suspended sediment volumes to river and stream areas affects aquatic environments by increasing turbidity through suspension of the sediment.

The protection and rational using of land especially in mentioned case study areas through the soil erosion control offers potential possibilities for the establishment of a flexible, environmental – friendly sustainable water management. It requires the following, so that the rational land use takes into consideration especially the environmental aspects and also adoption and implementation of scientific-based soil and water management technologies. The agroecological land use will positively affect not only the runoff parameters and associated sediment transport, but significantly also the quality of water ecosystems.

The general impacts of increased sediment and nutrients on stream systems have been well documented (e.g. Alexander & Hansen, 1986), as have their effects on aquatic environments such as the Great Barrier Reef (e.g. Williams, 2001; McCulloch *et al.*, 2003; Baker, 2003). It is also important to note that the suspended sediment loads in rivers in general are supply limited (Olive & Walker, 1982). That is, rivers have a very high capacity to transport suspended sediment, and sediment yields are limited only by the amount of sediment delivered to the streams, not discharge of the river itself. Consequently, if sediment delivery increases, sediment yield increases proportionally.

Sediments are derived from a number of processes which include: runoff on the land, termed surface wash and rill erosion or alternatively hillslope erosion; erosion of gullies formed as a result of land clearing or grazing; and erosion of the banks of streams and rivers. In many cases one process dominates in terms of delivering sediments and nutrients to streams, and the predominant process can vary from one part of a catchment to another.

The delivery of sediment to streams from sheet and rill erosion on hillslopes is modified by the hillslope sediment delivery ratio. SDR is a measure of the proportion of fine particles eroded from the hillslope which remain suspended long enough to reach a stream channel. For this project, SDR was set as a uniform 0.1 based on the methods and data presented in Lu *et al.* (2003) and Lu *et al.* (submitted). Sediment produced by sheet and rill erosion is assumed to contribute only to the suspended sediment (not coarse sediment) load of rivers.

Therefore understanding where the major sediment and nutrient sources are within a catchment is a crucial step to understanding how to manage these pollutants in the future.

## SUMMARY

This paper presents a summary concerning the nutrient content in erosion sediment in a selected catchment area. Research work was conducted to identify and quantify the sediment load associated with nutrient transport especially from arable land. The article deals with the possibilities of direct measurements as well as the possibilities of model calculations (especially the possible ways to estimate the amount of soil washout and its nutrient content) and with a mutual comparison of this two different approaches.

Determination of sediment transport of undissolved substances and of nutrients from a catchment area by a model calculation is based on knowledge of the average soil loss in the catchment and the average concentrations of substances. Quantification of sediment transport of suspended solids in small agricultural catchment areas is based on the assumption that the loss of substances is caused by water erosion. The methods used to estimate of soil erosion in the catchment areas are based on the RUSLE (Revised Universal Soil Loss Equation). This determination was used in the modification of the grid in an interface with a geographic information system (GIS) for the selected model agricultural catchment areas (Šlapanice, Šardice, Nový Jičín, Kopaninský stream). But calculation by this method does not indicate a significant soil loss from ephemeral gullies as an important component in the total balance of the soil loss in the catchment area. From this reason was determination of soil lost by RUSLE supplemented by direct measurement of soil lost in the paths of concentrated surface runoff by erosion bridge (special mechanical device). The total soil loss in a catchment area had to be reduced by the soil delivery ratio (SDR) to determine the amount of transported soil load in a catchment area outflow profile. To determine the total nutrient loss per year from a catchment the long term average concentrations of individual chemical elements in soils set by the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) were considered. The contents of phosphorus, potassium, magnesium, and calcium were measured in soils.

Determination of sediment transport of undissolved substances and of nutrients from a catchment area by a direct measurement is based on monitoring in the hydrometric profile which is equipped with Thomson's triangular spillway, ultrasound water level sensor, and precipitation gage. Water samples are taken by automatic sampling device built in the bank. To assess the nutrient content in the soil were also collected soil samples at various field positions.

Acknowledgement

The paper was elaborated in the frame of research projects MZE 0049002702 and QI91C200 thanks to the support of the Ministry of Agriculture of the Czech Republic.

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Address

Ing. František Pavlík, doc. Ing. Miroslav Dumbrovský, CSc., Ústav vodního hospodářství krajiny, Fakulta stavební, Vysoké učení technické v Brně, Veveří 95, 602 00 Brno, Česká republika, Ing. Jana Podhrázská, Ph.D., Ing. Jana Konečná, Výzkumný ústav meliorací a ochrany půdy, v. v. i., pracoviště Brno, Lidická 25/27, 602 00 Brno, Česká republika, e-mail: pavlik.f@fce.vutbr.cz, dumbrovsky.m@fce.vutbr.cz, podhrazska.jana@vumopbrno.cz, konecna.jana@vumopbrno.cz