WATER BALANCE AND RUNOFF / WATER QUALITY GENERATION IN TILE-DRAINED AGRICULTURAL CATCHMENTS

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BOOK OF ABSTRACTS

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Water storage in snow cover and runoff in the CHMI experimental basins in the Jizerské hory Mts.

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The climatic stations Desná - Souš and Bedřichov - dam, which belong to the Czech Hydrometeorological Institute (CHMI) basic observation network, are situated in the Jizerské hory Mountains at the elevation 772 m and 777 m a.s.l. Measurements of snow depth and snow water equivalent in these stations are not quite representative for the upper part of the Jizerské hory Mountains which reach up to 1126 m a.s.l. Data from these two stations were insufficient for evaluation of water storage in snow cover for forecasting the volume of water inflow during the snow melting period into the dams in the Jizerské hory Mts. On this account, the regular measuring network of snow cover was established by the end of 1970´s in the basin of the Josefův Důl dam. The snow cover measuring network was also extended into seven experimental basins, which were established in the Jizerské hory Mts. in the 1980´s.

Since 1991 a stable measuring network with twenty-eight snow profiles has been used. The elevation ranges from 756 m to 997 m a.s.l. Paired profiles, one under the canopy and the other one on the clearing, are observed in eight locations. The measurement is practised regularly in weekly time steps. The GIS method is also applied in weekly intervals to create maps of snow depth and snow water equivalent.

The main aim of this work is to compare the results of water storages obtained in experimental basins before the time of snow melt with the total outflow measured in the hydrological stations during the snow melt period, for two winter seasons with extraordinary high snow depth. Differences between the water storage obtained by direct measurement and the total outflow could describe the specific character of each of seven experimental basins, which could be useful for the hydrological forecasting in this region.

The measured data also serve as a check and for possible adjustments of snow water equivalent values generated by the model SNOW 17, which is a part of the forecasting modeling system Aqualog. This system is in everyday use for the Elbe river forecasts in the Forecasting center of CHMI. Usefulness of this procedure was proved especially during the last years' floods from snow melting.

The model SNOW 17 has been calibrated for the catchment of the Černá Desná river with the closing profile Jezdecká (one of the experimental basins in the Jizerské hory Mountains). The results obtained demonstrate a very good capability of the model to simulate the dynamics of snow cover accumulation and thaw, if high quality input data are available.

Land drainage runoff components

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The runoff from tile-drainage on agricultural lands (drainage runoff) is a specific, directly measurable component of catchment runoff. It is not a hydrologically homogeneous runoff constituent but is itself composed of several components, differing from one another in their speed of reaction to rainfall or snowmelt events, their flow paths (underwent before they reach the drainage outlet) and their chemical composition. While the direct access of overland flow to tile drains is very limited (even though not entirely impossible), we can still separate different components of drainage runoff that can be referred to as "direct runoff", "interflow" and "baseflow", in a way very similar to that used when separating the stream runoff components.

We have developed and repeatedly used a semi-empirical separation procedure based on a combination of two techniques – a digital filter and a simple conceptual model GROUND. While we admit that more sophisticated and physically sound separation techniques should be preferred, we can demonstrate that even our semi-empirical procedure is capable of characterising, in an objective and reproducible manner, the runoff pattern of a particular catchment and, as a special case of it, the runoff pattern of a particular tile-drainage system. On the other hand the pattern of nitrate leaching from agricultural lands, certainly reflected in some way by the variation of drain and stream water quality, cannot be reproducibly identified using our semi-empirical runoff separation procedure.

The drainage runoff can also be characterised statistically. The probability-of-exceedance curves of average daily drainage runoff rates usually reveal three different parts. The first part, a low-discharge domain, reflects the local hydrogeology. The second part represents the cases when the soil profile itself is being drained, while the third part, when the flow rates are largest, reflects the situations when large amounts of water enter the drainage system via infiltration from soil surface and via shallow subsurface flow in the permeable topsoil. The flow rates in the large-discharge domain are frequently limited from above by the hydraulic capacity of the drainage pipes. Different shapes of the probability-of-exceedance curves for different drainage systems may also be used to characterise their particular runoff patterns.

Different hydrogeologic and geomorphologic situations induce different behaviour of particular tile drainage systems. It is difficult to find a universal modelling tool to describe all practically important cases. We tried to use DRAINMOD model for simulating the tile-drainage runoff pattern in a narrow alluvial strip within a highland catchment, including the modelling of inflow of foreign water from the adjacent slopes. The accordance between the model results and the measurements was satisfactory, even though not perfect.

We conclude that the drainage runoff pattern and separation of drainage runoff components are worth further studying, because they reveal objective facts about the catchment and the drainage system studied, including their bioeochemistry. All this, however, pertains to the catchments and drainage systems regularly monitored, while the ungauged systems can only be assessed by analogy with the gauged ones.

Water-balance based estimates of tile drainage contribution to flood flows

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When a part of the catchment has been tile-drained, it yields more runoff than before, due to the acceleration of autochthonous runoff from the tile-drained area, but also due to the abstraction of water from surrounding areas. The resulting (quasi-steady) flood flow enhancement factor depends on the autochthonous runoff enhancement factor and on areal extent of tile drainage. The factors can be derived by processing flow rates exceeding a threshold. The theory was applied to two experimental catchments in central Bohemia. The situations which could not be measured were simulated, using DRAINMOD model. The enhancement factor for the total runoff from tile-drained areas due to the presence of tile-drainage comes out about 1.7 for the Černičí catchment and about 3.2 for the Cerhovický potok catchment. Flow rates in small streams during less extreme floods with short return periods may be augmented, due to tile-drainage systems, by about 6 to 19 %.

Evaluation of actual evapotranspiration influenced by different soil types and crops

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The objective of this paper is to compare the actual evapotranspiration (ETA) values of different crops in relation to soil types and tile drainage. The daily and vegetation-season sums of ETA were calculated for the Dehtáře catchment by the methods of energy balance and Bowen ratio (β). β is the ratio of sensible heat flux to latent heat flux. The Bowen ratio method was derived from the theory of turbulent diffusion. If some conditions are fulfilled, it can be shown that the distribution of main components of the energy balance (sensible and latent heat flux) can be determined by simply measuring the difference in air temperatures and humidity between two heights above the plant cover (0.5 and 2.0 m). The basic condition is the equality of transport coefficients for vertical turbulent transport of heat and water vapour under conditions of neutral atmosphere stratification, and a sufficiently extensive plant cover. The Bowen ratio values measured during the periods when the conditions of validity of the energy balance and of the Bowen ratio method usage were fulfilled (i.e. from 10.00 to17.00 CET, at global radiation intensity > 200 $W.m^{-2}$, β between 0 and 4, in the peak of growing season, i.e. late March or early May to late August) were used. The ETA values were determined by means of four weather stations A to D (A above permanent grassland, B,C and D above arable land: 2004-winter wheat, 2005-spring barley, 2006-winter rape). Every weather station was equipped with a datalogger storing ten-minute averages of data, two sensors measuring soil temperature, two sensors measuring air temperature and relative air humidity at two heights, one soil heat flux sensor and one net radiometer. The station above permanent grassland was further equipped with a pyranometer, measuring the global radiation, an anemometer measuring wind speed and a wind vane measuring wind direction.

Differentiation of catchment territory into recharge and discharge zones allowed us to demonstrate that the tile-drained locations and the areas downstream of the drainage systems can always be considered as discharge zones (A,B). Location lying uphill from the drainage systems are recharge zones (C, D). Although the stations B, C and D were placed over the same crop, different ETA values were obtained in them. It is obvious ETA is related to the soil type. Stations A and B are located on Stagnosols, which are little permeable and ,before the construction of the tile drainage, were waterlogged by springs. On the contrary, Cambisols under the stations C and D, which only differed in their grittiness, are quite permeable and they have a lower retention capacity than the Stagnosols. Apart from the crops, higher ETA values and lower groundwater recharge were found in Stagnosols, although they were tile drained. Higher amounts of water infiltrates into Cambisols (without tile drainage) in comparison with Stagnosols, hence there had to be lower ETA sums over Cambisols. Considering the crop effect, the highest ETA values were reached on the permanent grassland located on Stagnosols. This resulted from the permanent canopy, its high water requirements, shallow roots, canopy density etc. The lowest sums of ETA were found in more permeable soils with a middle grittiness on Cambisols (C). Cambisols having poor or no grittiness (D) showed higher sums of ETA. Although Stagnosols are tile drained, they have a higher refrigerant effect in the landscape than Cambisols without tile drainage. It was proved by low Bowen ratio values on Stagnosols (A - 0,49, B - 0,6) in comparison with Cambisols (C-0,92, D – 0,83). The lowest ETA (C) on the soil with middle grittiness responded to the highest Bowen ratio, indicating the lowest refrigerant ability.

Phosphorus concentration in agricultural streams and adjacent tile-drainage all over Czech Republic

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Eutrophication, a phenomenon causing economic losses, health risk and aesthetic impediment, is a well-recognized problem worldwide. Phosphorus is believed to be limiting element of freshwater phytoplankton, namely for harmful cyanobacterial blooms, most serious manifestation of eutrophication. Because thr point sources of phosphorus pollution are expected to be clear up until 2010 (according to EC Directive 91/271, all cities over 2000 equivalent inhabitants (EI) are required to operate wastewater treatment plants and cities over 10 000 EI have to ensure tertiary level of treatment, e.g. phosphorus precipitation), non-point sources, especially from agriculture, will grow up in importance. From this perspective, our project is generally aimed to evaluate phosphorus load originating from non-point sources of totally agricultural catchments. To be specific, we intend to relate the extra-erosive P-load to the erosive one in the condition of the Czech Republic. For the purpose of this workshop we compare five creeks vs. their adjacent tile-drainage in terms of water quality.

On the basis of maps and aircraft photos, the catchments to be evaluated should fulfil the following conditions: land-use (major area of arable land, minor of forest, no residences, no permanent buildings), soil type (uniformity, total counts representing the percentage cover of CR), hydrology (headwater, the stream as long as possible, no standing water or wetland) and even distribution over the country area. The search resulted in a set of catchments among which the largest has 3 km^2 in area and the shortest stream is 200 m long (detailed GIS analyses are not yet finished).

From May to August 2006, the time of summer baseflow, we visited 195 catchments (234 profiles) all over the country and collected 162 one-shot water samples. Water was analyzed for 9 physicochemical and two bacteriological parameters, the discharge was roughly measured and rainfall and actual stage of crop was noted. The results show that 84 % of samples had suspended solids concentration under 20 mg/l, which indicate baseflow conditions and makes further comparison and statistical analyses possible. The dissolved phosphorus (PO_4-P) ratio was only rarely lower than 25% of the total phosphorus (TP), which is usually used as a marker of erosive P yield. In total, 90 % of profiles had TP concentration under the immission standard (0.15 mg/l), with a median of 0.047 mg/l. Most of the oustanding values were due to rainstorms during the last two days. PO_4-P concentration had a median of 0.026 mg/l and a mean of 0.046 mg/l, respectively. Similarly surprising are the results of bacteriological analyses. Only 6.6 % of samples exceed IS for intestinal enterococcus (20 CFU/ml) and 2,2 % exceed IS for faecal coliforms (40 CFU/ml), respectively. Most of the exceedances were related to apparent erosion.

Among various soil types, naturally, the creeks flowing on Dystric Cambisols are found as the poorest group and those on Eutric Fluvisols as the richest one, in terms of TP and PO_4-P concentrations. Haplic Chernozems have medium to low values of TP and PO_4-P in water, because of high calcium contents which fix phosphorus in complex compounds. Four of the five pairs of articially drained vs. undrained profiles show higher concentration of both phosphorus forms in the tile-drainage water. When taking into account that the discharge from tile drains is by an order of magnitude lower than the flow rates in small streams, it is hardly possible to pinpoint the drainage systems as a more impacting source of extra-erosive phosphorus pollution, even though many authors do so. From the dataset of 2006 we selected 23 best representing catchments (32 profiles) for seasonal monitoring in the next year. Results from two opposing cases of tile-drainage and adjacent stream behaviour will be described in detail.

Preliminary evaluation of non-point sources of phosphorus pollution originating from agricultural watersheds in terms of extra-erosion runoff (for now) confirm the other indices suggesting that the Czech Republic has generally a medium to low phosphorus concentration in running water. From the first results, it seems that the effect of tile drainage on water quality is significant. In future research,we intend to relate storm hydrographs to“phosphographs” in tile-drainage and adjacent streams and to continue in making the phosphorus balance in few selected watersheds more accurate.

Tile drainage water quality dynamics in connection with landuse in the Kopaninský stream catchment

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Steadily high nitrate concentrations in surface waters are the subject of actual research, especially in drinking water reservoir basins. Although the amount of nitrogen fertilisers used on agricultural land has rather decreased, the nitrate concentrations and their distribution during the year didn not react appropriately; there has not been a corresponding decrease. The research work made up to now showed that the tile-drainage water chemistry (especially the nitrate-nitrogen pattern) results from several mutually influenced factors, such as precipitation, soil type and its physical characteristics, the land use on the tile-drained areas and on the areas lying uphill from them, and the type and timing of agronomic operations. The technical parameters of drainage and the position of drains within the catchment are very important factors for runoff and water quality generation.

The Kopaninský stream catchment is situated within the drinking water reservoir basin Švihov (on the Želivka river) and represents a typical local small agricultural catchment with tile-drainage systems. "Kopaninský" means, in Czech, an area which had to be cultivated manually, using a hoe. The artificial drainage of these areas was built mainly during the 1970's and 1980´s, sometimes only to fulfil a set regional quota of land to be drained, in an elusive effort to reach the self-sufficiency of the country in agricultural produce. Drainage structures in these upland catchments were often of special types, designed to intercept shallow groundwater as well as deeper springs outflow. The drainage structures interconnected the recharge and discharge zones of the catchments, while the floodplain meadows and similar natural denitrification areas were bypassed.

The aim of this paper is to describe and discuss changes and trends and address the causes of the deteriorated drainage and small stream water quality in connection with some weather / hydrological parameters, soil and, especially, land use characteristic. Data from several drained and undrained subcatchments of the Kopanisnký stream and from the entire catchment closing profile were taken into acount. Relations between the stream and drainage water flow rates, and nitrate and ammonia concentrations were investigated. Statistical evalaution, including single and multiple correlations among all available data, was made. A strong dependence between the nitrate concentrations (especially the NO_3 C90 characteristic value, i.e., the concentraion with 90 % probability of non-exceedance) in both surface and drainage water and the ratio of arable land within each subcatchment was found.

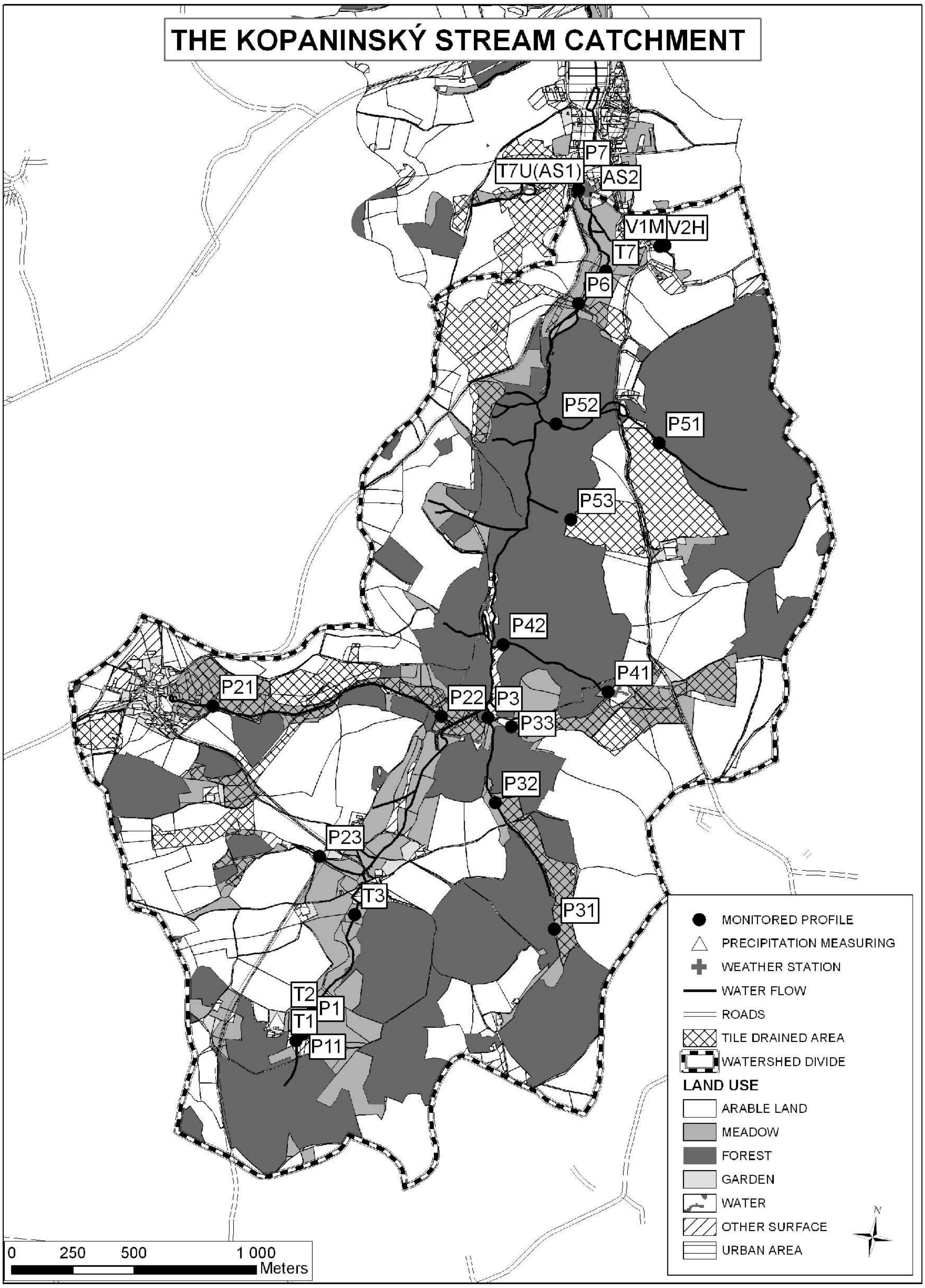

Fig. 1. Map of the Kopanisky stream catchment

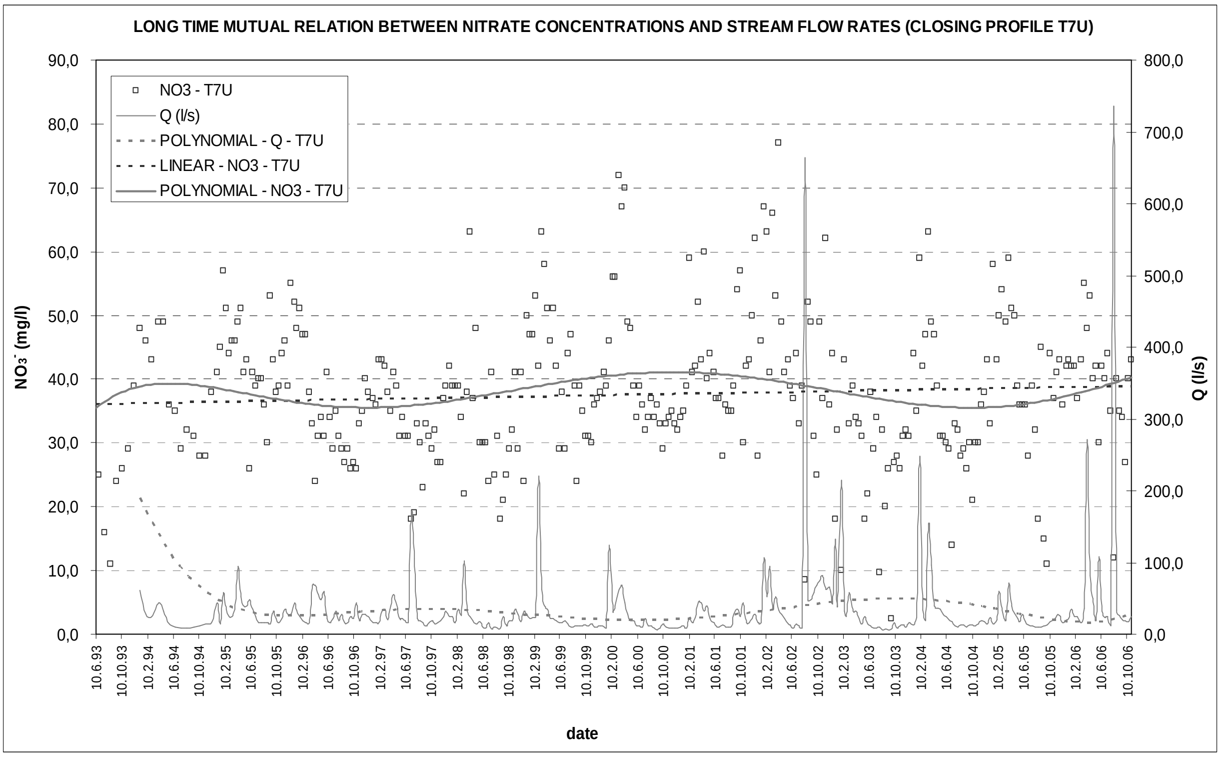

Fig. 2 Example of data evaluation – a process of nitrate concentration and stream flow

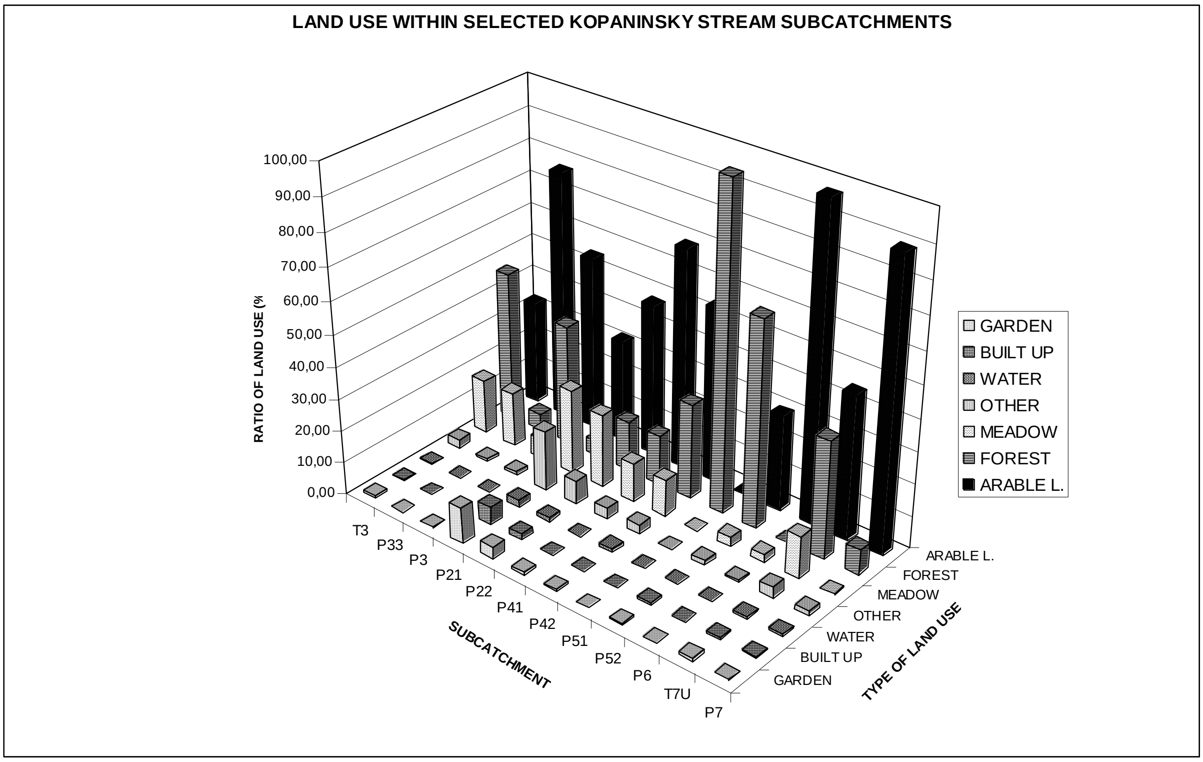

Fig. 3 Land use characteristic within studied subcatchments

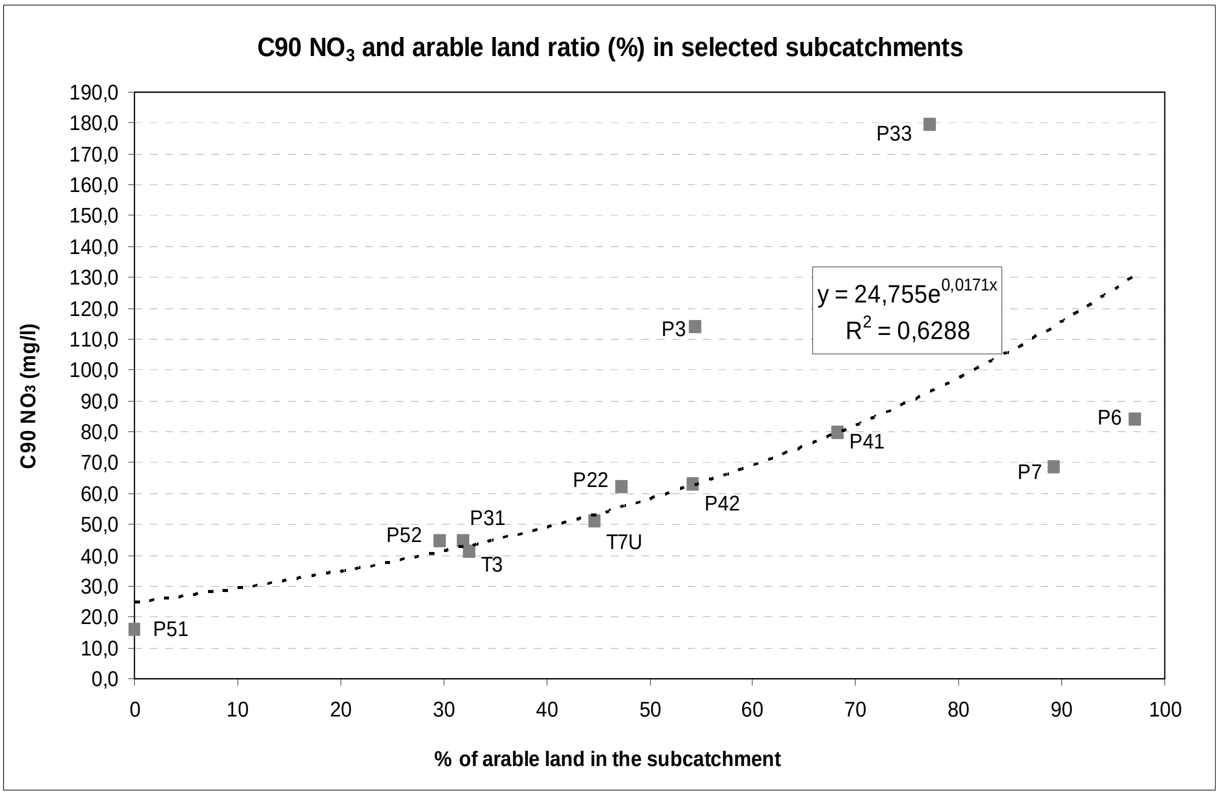

Fig. 4 Relation between the ratio of arable land and C90 (90 % probability of non-exceeding, NO_3)

Identification of P and N sources in a mixed rural catchment

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Typical rural landscape in the Czech Republic is composed of a mosaic of arable land, cropped meadows or pastures, cultural forests, fishponds, and villages. Export of phosphorus and nitrogen from land into surface runoff is often high and induces eutrophication of water bodies and slow flowing rivers. Distinguishing among nutrient sources in these mixed rural catchments is not an easy task and yet there is going on a debate about the principal causes of high nutrient concentrations in streams and about the methods of source revelation. This paper describes an apportionment method of P and N sources in the catchment that is based on (i) continuous monitoring of flow and flow-proportional sampling for water chemistry of stream water in the closing profile of catchment, (ii) grab sampling of surface waters in carefully selected sub-catchments and nutrient source areas, (iv) nutrient retention estimates in the stream network, and (iv) information on farming and aquaculture practices. The method was tested on the catchment of Radimovický brook in South Bohemia, a medium-size (8 km^2) catchment situated in the upland countryside (mean slope, 2°; population density, 13 inhabitants per km^2; livestock, 0.2 LU per ha; tile-drained area, 64%; arable land, 78%; permanent grassland, 6%; forest, 5%; urban areas 9%; water, 2%). A three-year monitoring of this catchment showed a high intra- and inter-seasonal variability of P and N export from drained or not drained arable land and fishponds that was mainly brought about by different precipitation and runoff patterns in each of the monitored years. The source separation was facilitated by the evaluation of P fractions (i.e., particulate P, dissolved reactive P, and dissolved non-reactive P), inorganic N compounds (nitrate, ammonium.), and other supportive indices (e.g., P and/or chlorophyll-a concentrations in suspended solids) in the runoff.

Runoff formation in a tile-drained agricultural basin of the Harz Mountains foreland, Northern Germany

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As compared to forested hard rock basins, runoff formation under tile-drained agricultural conditions is very special and still not well investigated in Germany. However, as a matter of fact, related turnover processes of water and dissolved matter transport cannot be understood by considering soil water movement alone. This was one result of a most comprehensive collaborative agro-ecological research centre in Bavaria (FAM Munich; http://fam.weihenstephan.de/indexalt.html) that ended in 2003. Another important but much earlier interdisciplinary collaborative project was under TUBS in the 80ies of the last century. One of its study basins is Krummbach (P1; 0.90 km²) which is located in the Harz Mountains foreland at about 30 km south of Braunschweig, with Ohebach sub-basin (P4; 0.32 km²) having dominant orthic to gleyic luvisols and cultivation of sugar beet and wheat. The two basins are till present monitored by the TUBS Dept. of Hydrology and Landscape Ecology.

For Ohebach, time series of air temperature, precipitation, river water level and discharge, drain discharge at two weirs, and groundwater tables of the unconfined porous aquifer are available. It will be shown that groundwater heads increase rapidly by up to decimetres within several hours as a response to actual basin input once the infiltration process has started. Groundwater flow mechanisms will be discussed with the respective hydraulic conditions. Hence storm hydrographs are mainly generated by increased groundwater fluxes exfiltrating into river channels, whereas surface flow is most frequently negligible. Similar but even more pronounced phenomenon can be observed for semi-confined conditions in hard rock basins of the adjacent Harz Mts. with dominant flood generating groundwater fluxes from the fissured rock aquifers.

Quantitatively less significant surface flow does exist in the agricultural basins as can be concluded from soil erosion and basin-wide older colluvial deposits. Minor contributions of surface or direct flow of event water has also been confirmed by use of ^{18}O isotopes which suggest direct peak flow in the order of 10-15% of total discharge during single events. Drain discharges grow with increasing groundwater potential provided that groundwater tables intersect with subsurface drain lines. This happened frequently in the past since farmers had only rough ideas about groundwater tables when they constructed a new tile-drain system. A dye tracer experiment with eosin, which was brought out on the field’s surface above a main drain collector has proved quick tracer transport with the groundwater flux through the drain pipes at high groundwater level and with no lateral spreading of the tracer in the saturated zone, and tracer absorption by the soil matrix at low level. Since groundwater is a major runoff component, the average nitrate concentrations of total discharge and nitrate export rates are relatively low.

Meanwhile groundwater tables are considerably declining in the region since the nineties of the last century, and therefore subsurface drains seem to operate less efficiently with respect to groundwater, or have even no measurable discharge in recent years. An open question is how the changing hydraulic conditions influence the nutrient budget of the basin.

The influence of landuse on hydrological regime of a mountain catchment

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We have studied the influence of varying natural characteristics and landuse on the hydrological regime in the small mountain catchment of the Jalovecky creek, the Western Tatra Mountains, Slovakia. The study was performed in two steps. First, the flood characteristics in two contrasting subcatchments (the mountain and the foothill) were analysed. Second, the effect of landuse change in the mountain part of the catchment simulated by the distributed hydrological model was analysed.

Mountain part of the catchment has different geological, topographical, landuse and climatic characteristics than the foothill part. Both parts of the catchment have approximately the same area. Analysis of the long-term water balance data from period 1989-2005 showed that both parts contribute to catchment runoff equally, taking into account different precipitation. Hourly discharge data from both parts were compared to analyse flood characteristics (times of the beginning and peakflow, discharges at both times, concentration time and time lags). End and volume of the floods were not studied to avoid uncertainties connected with the determination of the end of the flood and separation of runoff components. Totally, 125 flood events were analysed. Most of them occurred in April to August. Concentration time in the mountain part of the catchment was typically shorter than in the foothill part. Ratio of the discharge at the beginning of the event to peak discharge was higher in the foothill part of the catchment which is not forested. This was the only characteristic which could indicate the influence of vegetation (forest) on discharge. However, there could be also other reasons than the difference in vegetation cover which could explain the more extreme course of runoff events in the foothill part of the catchment (e.g. the density of stream network). The data also indicate that the events are more extreme in drier conditions. The overall conclusion of the analysis is that comparison of discharge data along the stream results in extended understanding of catchment response, but it is difficult to identify the reason of the differences in characteristics of flood events.

Influence of landuse change on hydrological regime of the mountain part of the catchment was studied by the distributed hydrological model WaSiM-ETH. Calibrated and validated model was run with changed vegetation characteristics which represented several scenarios (complete afforestation by different tree species and complete deforestation). Then we have analysed the change of the long term actual evapotranspiration and runoff compared to present vegetation. Depending on vegetation scenario, the change of actual evapotranspiration varied between -26% and +3%. The change of runoff varied between -5% and +19%.

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Phosphorus losses from an artificially drained lowland catchment

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Due to the reduction of phosphorus emissions from point sources, 80 % of the monitoring stations in the federal state Mecklenburg-Vorpommern (Germany) reach the water quality class II ($\leq$ 0,1 PO_4-P mg l^{-1}), which is the general goal for all surface water bodies in Germany. However, this value alone does not guarantee the prevention of eutrophication. The brook Zarnow (15.5 km² catchment) is a typical example of a small surface water body in the extensively artificially drained agricultural lowland landscape of North-Eastern Germany. In this brook, the average PO_4-P concentrations also decreased from 2.2 mg l^{-1} (1975) to 0.1 mg l^{-1} (2005). However, in 2006, high PO_4-P concentrations have been measured on several occasions. To evaluate the role of artificial drainage for these high values as well as for the phosphorus concentrations and diffuse immissions in general, a hierarchical measurement programme was set up in the Zarnow catchment comprising sampling stations at a collector drain (4.2 ha), two ditches draining arable land (179 ha) and grassland (85 ha), respectively, and at the brook. Besides the discharge and meteorological parameters, PO_4-P concentrations were determined for the discharge periods (November to April) 2004/05 and 2005/06. The soils in the study area are mainly mineral soils (sandy loams and loamy sands) under arable land use and peat soils under grassland and forests. The topsoils of the arable land are characterised by an optimum to high phosphorus supply and low balance surpluses.

Although the precipitation sums in 2004/05 (269 mm) and 2005/06 (289 mm) were comparable, the discharge sums varied between years and scales. At all sampling stations, higher discharges were measured in 2005/06 (112 to 190 mm) than in 2004/05 (86 to 149 mm) as, due to a wetter summer, the onset of tile drainage occurred earlier in the season. Discharge events were frequently triggered by snowmelt during the exceptionally cold winter in 2005/06. In 2004/05, phosphorus concentrations at all sampling stations met the requirements of water quality class II and were not coupled to the discharge dynamics. In 2005/06, the largest snowmelt event led to rising concentrations at rising discharge rates at all sampling stations. Both erosion due to surface runoff and preferential flow processes within the soil profile might have caused these concentration patterns, as nitrate and chloride concentrations showed a dilution pattern during the same event. Overall, higher concentrations were measured during this winter, and only the brook could be classified into water quality class II. During all years, the grassland ditch showed the highest concentrations of up to 0.45 mg l^{-1}. These high concentrations might be explained by the mineralisation of the organic soils, the low sorption capacity of peat and the re-mobilisation of Iron(III)- and Aluminiumphosphates during periods with a high groundwater table and concurring anaerobic conditions. Overall, tile drainage does only deliver small amounts of phosphorus to the surface water bodies, although preferential flow events might cause significant concentration peaks. Degraded peatlands may, however, be a more important source of phosphorus immissions.

Runoff and hydrological aspects of tile drainage in a small agricultural catchment in the Bohemo-Moravian Highland

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The objective of this paper is to characterise the tile drainage runoff and discuss its hydrological aspects. Statistical characteristics of runoff are described and compared to the runoff from tile drainage and from undrained subcatchments. Selected rainfall runoff situations were studied in the subcatchments and were described by their runoff coefficients.

The study area of the Kopaninský stream experimental catchment (7.1 km^2) - a part of the Vltava (Moldau) river basin - is located in the Bohemo-Moravian Highland, Pelhřimov district. The land use is prevailingly agricultural. Nearly 50 % of the catchment´s area is covered by arable land, 37 % by forest and 12 % by grassland. The tile systematic drainage were built in the catchment in the years 1960-1980, tile drained area occupies 10 %.

The monitoring network consists of rain gauges and ultrasound sensors for recording the discharges by V-notches; all equipment belongs to the Research Institute for Soil and Water Conservation.

Runoff changes in the selected water basins in Šumava Mountains

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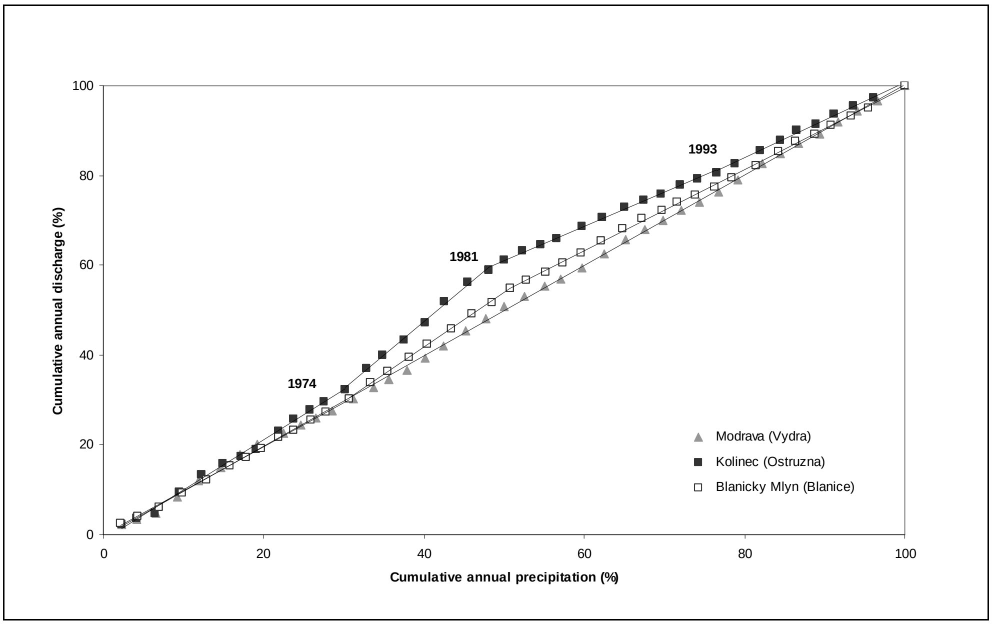
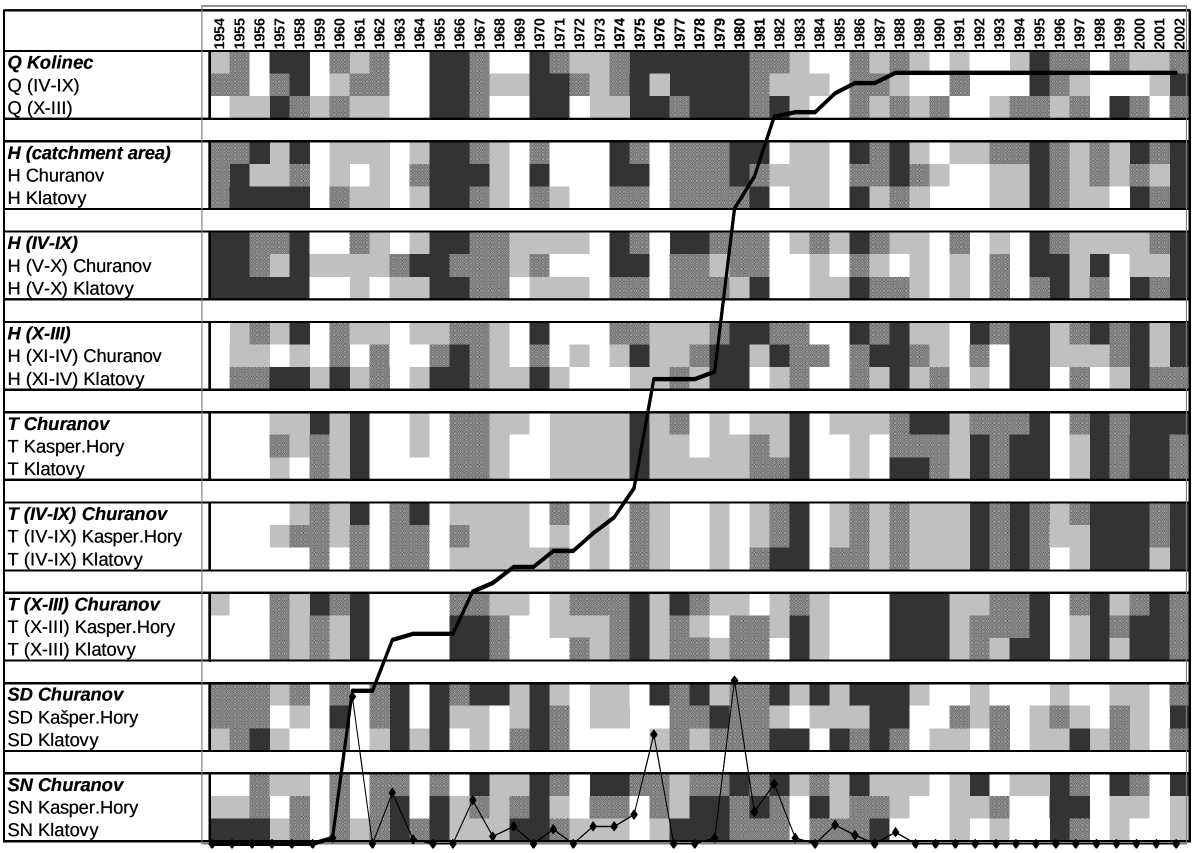
The main aim of our research was to monitor and try to explain changes in the development of the rainfall - runoff relationship of three small water basin in the Šumava Mountains and foothills: Ostružná, Blanice and Vydra basins. Selected water basins represent areas of diverse land use with different levels of anthropogenic intervention in the runoff regime and played an important role during the initial formation of catastrophic floods in Czech Republic in August 2002. The methodology of the research comprises analytical and synthetic procedures. The basic analytical procedure can be regarded as the analysis rainfall and runoff trend regime supplemented by an analysis of air temperature and snow parameters relationships. The basic source of input outflow and climate values was the Czech Hydrometeorological Institute (CHMI) database. The method of simple and double mass curves was used as the main method for the evaluation of the rainfall-runoff trend development. Analysis of changes in land use, river network training and land drainage were carried out also.

The largest deviations in runoff trend were seen in the Ostružná River basin, which is used for agriculture. The deviations were less significant in the Blanice River basin. No deviations were found in the naturally forested Vydra River basin. The changes were manifested by considerable increases in the runoff during the 1970s and 1980s, and by a gradual reduction in runoff during the following years. The analysis of runoff and precipitation distribution within a year identified certain links between increase in runoff and one of the periods rich in precipitation. The relatively continuous cold period was manifested by above-average snow cover depth. With regard to the specificity and non-repetition of the identified water runoff trend during the 50-year period, we can assume that, besides natural factors, anthropogenic interventions also played a role. This particularly includes the extensive amelioration measures, river network training and the construction of drainage systems. The period with the most intensive increase in drained areas corresponds with the increase in water runoff. Conversely, the significant reduction in arable land areas in the last ten years, together with the identified climatic trends, could contribute to the increase in the evapontranspiration and overall reduction in runoff. Determining the importance and influence of the factors affecting the water runoff seems to be very difficult.



Double mass curves of annual precipitation and discharge for gauging sites: Modrava, Kolinec, Blanický Mlýn (source: CHMI)



Climate development and increase of land drainage in the Ostružná River basin in period 1954-2002 (source: CHMI, AWMA).
Q: mean discharge, *H*: precipitation, *T*: mean air temperature, *SD*: snow cover depth, *SN*: number of days with snow cover. *Black colour areas*: values > upper quartil, *grey dark*: < upper quartil, median>, *grey light*: <median, lower quartil>, *white*: <lower quartil. Graph: *thin line*: development of land drainage, *thick line*: development of land drainage (cumulative).

Water quality of the agricultural catchment of Smržovský creek

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Continuous measurement of the water quality in the outflow is performed in the Jizera Mountains. Measurements are carried out by the Water Research Institute T.G.M., Prague since 2003 in the frame of Labe IV project. Depletion of various chemical compounds from the watershed influenced by rainfall runoff episodes and related to the seasonality is in the prime focus.Since 2004, water quality monitoring has been enhanced at the nearby agriculture watershed of Smržovský creek within the bounds of nature protected area Jizera Mountains. Watershed area is 2.6 km^2, altitude ranges from 645-836 m above the sea level. Watershed comprises an agriculture farm performing the production of hay and cattle grazing. The farm fullfills its activities under ecological regulation, thus inorganic fertilizers are prohibited. Major interest within the watershed is in the observation of mass outflow of nitrates and phosphates, aiming to describe the influence of the agricultural activities on the water quality in the outflow. Since the spring of 2005 variety of chemical indicators are analyzed on the weekly basis (COD_{Mn}, A_{254}, N-NO_3, SO_4, P-PO_4, Cl^-, Ca, Mg, Na, K, Fe, Al). Aiming to study the detailed variation of phosphates, automated water sampler was installed at the end of March 2006 at the outlet gauges station.

During the period of observation, several important rainfall runoff episodes were recorded. Major event was detected in the time of snowmelt, in the spring of 2006. During this time, continuous YSI probe recorded the highest concentration of chlorides, caused by the melting of snow and diluting the chlorides from the winter road maintenance materials. Simultaneously, lowest pH values (March 30^{th,} 2006 when the lowest value of 5.20, compared with the most often basic value of 6.50) was measured. During August 2006, highest rainfall totals were recorded influencing the drop of pH to 6.13 (21. 8. 2006 17:50) from previous 6.30, prior to detection of highest measured N-NO_3 6.28 mg.l^{-1} (22. 8. 2006 13:50). At the end of the outflow episode (30.8.06), highest concentration of Al 890 µg.l^{-1} was recorded. Sampling of the surface water by the automated sampler with the focus on nitrate and phosphate concentration was performed in April 2006, at the end of the snowmelt period and in August 2006 during the intensive rainfall period. In the water sampled, raised concentration of phosphates were not detected.

From the monitoring campaigns at the Smržovský creek, preliminary results show that, fluctuation of pH is minor during the rainfall-runoff episode, unlike observed effects of rapid pH decrease in the upper parts of Jizera Mountains where valleys are formed by peat, cambisols on granite and covered by spruce vegetation all enhancing acidic conditions. Concentration of aluminium in the outflow varies in wide range from the detectable threshold to clearly high concentration values. Peaks of the aluminium concentration is observed later than the flow maxima, clearly with the time shift. This phenomena can be explained by the effect of flushing of the soil profile by acidic water (solubility of Al is highly dependent on pH values). Due to findings showing very low values of nitrates and phosphates in Smržovský creek and negligible fluctuations of those during the storm events, it can be stated that agricultural activities, namely cattle grazing does not have negative influence on the water quality in this area. This is achieved most likely by the fact that industrial fertilizers are not used.

The regime of catchment discharge with respect to drainage system location

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This paper is aimed at quantification of the importance of drainage system location in the frame of the catchment geomorphology and at relating drainage flow rates to the stream flow rate over a longer period of time. Long term measurements in the experimental catchments of RISWC represent basic data, which are complemented by the results of monitoring of representative drainage systems. The quantification is achieved for the catchments of Dolský and Kotelský streams (Žejbro catchment) and is verified by means of drainage system examination in Černičí (Želivka catchment) and Rychnov nad Kněžnou (Orlice catchment).

The catchments are divided into three areas according to prevailing water cycle phases: the infiltration, transport and outlet areas. According to the geomorphology marks and on the basis of field measurements, the existing drainage systems are classified as belonging to one of these three areas. Continuous flow measurement is realized in one representative drainage system of the infiltration zone (profile Kladno), and in another drainage system in the outlet zone (profile Pokřikov). The experimental catchments are drained very intensively: 30 % of catchment area of the Dolský stream is tile-drained, this figure being even 56 % for the catchment area of Kotelský stream. Specific drainage runoff rates derived from measurement are ascribed to all drainage systems in the area of interest. Two-year time series are processed in order to express the drainage runoff rate in the context of stream flow rate.

The paper provides arguments in favour of the necessity to differentiate hydrological conditions of drainage systems and to assess the amount of drainage water contribution to medium and low stream flows.

Influence of artificial drainage on ecological stability of the landscape

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Ecological stability is defined as a resistance of the landscape towards disruption and recuperation of the landscape. Curves of variance describe changes of the landscape as a function of time. These curves of variance can be characterized by three independent parameters:

- general trend of the change (increase, decrease)
- relative amplitude of the oscillation round the general trend (small or big oscillation)
- rhythm of the oscillation (regular or irregular rhythm).

Construction of artificial drainage is an intervention into natural system and we can watch a response of nature to that intervention.

The Vočadlo agricultural micro-catchment has been monitoring since November 1975 by Czech Geological Survey. It is located in the Želivka (Švihov) drinking water reservoir basin in Bohemo-Moravian Highland in the crystalline complex. Area of the catchment is 59 ha. In the catchment there is neither urban area nor other point source of nitrogen pollution. In the year 1982 middle and lower parts of the catchment were artificially subdrained by tile-drainage. Subdrained area is 20.35 ha (about 1/3 of total catchment area).

The course of nitrate concentrations in the period before artificial drainage had been built (1975-1981) was balanced, the concentrations were mostly less than 50 mg NO3-/l. Soon after the artificial subdrainage had been built (1982-1987), the maximal nitrate concentrations grew up to 95 mg NO3-/l (it equals 21.5 mg N-NO3-/l). That steep increase of nitrate concentrations was caused by quick mineralization (oxidation) of soil organic matter which was not decomposed before. That quick mineralization followed after artificial decrease of groundwater table and aeration of the soil profile. Ploughing of 3.5 ha grasslands after the subdrainage construction contributed to higher nitrate leaching from soil, too.

After new balance stabilisation in the year 1990 nitrate concentrations oscillated around 65 mg NO3-/l (14,7 mg N-NO3-/l) over the period 1990-2001. The new balance is more than around 2/3 higher than before the artificial drainage construction. Reason of that fact is probably the destruction of denitrification barrier in the lower part of the valley (in the so-called riparian zone). Nitrate leached from soil in upper catchment part was reduced and it escaped as nitrogen gas into atmosphere in the waterlogged riparian zone before the artificial subdrainage construction. In the aerated soil profile nitrate cannot be reduced and it leaves into the stream.

The nitrate loss was very high in the years 1987 and 1988 but then the values decreased again. It is interesting that, soon after the subdrainage construction in the year 1982, the values of nitrate loss were more likely decreasing up to the year 1985 and expressive increase of nitrate loss was not observed again until the 5th year after the subdrainage construction. Despite differences in annual nitrate loss there is a clear increasing trend. High values of nitrate loss are not caused by high precipitation which could cause higher nitrate leaching from soil. Trend of annual precipitation is contrariwise decreasing. Higher nitrate loss is caused by artificial subdrainage.

After artificial drainage nitrate concentrations in drainage water increase expressively due to mineralization of soil organic matter in newly aerated soil. After eight years a new balance was stabilised there. Although concentrations of nitrate in drainage water are lower after the stabilisation of the new balance than within those eight years of mineralization, the concentrations are much higher than before the artificial drainage. The system has got a new level of metastability in the model of ”Russian hills” which was described by Godron & Forman (1983) (Landscape modification and changing ecological characteristics. In Mooney & Godron [Eds.] *Disturbance and Ecosystems: Components of Response*. Springer-Verlag, New York, pp.12-28.).

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Influence of tile drainage on nitrate concentrations in surface water

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Increasing nitrate concentrations in surface water in the second half of the 20th century is a well known fact. As the cause of this fact is considered especially high amount of fertilizers. Is it really the main reason? The available information about the Želivka river basin was collected, namely the average annual nitrate concentration and nitrate loss in the inflow of the Švihov drinking water reservoir (or in the Želivka river closing profile before the construction of the Švihov dam) and many relevant characteristics of the total Želivka River basin were included into this analysis:

- annual precipitation
- annual average flow rate
- land use
- portion of tile drained area in the basin
- mineral nitrogen fertilization
- amounts of diverse farm animals
- portion of inhabitants with sewerage in the basin
- portion of inhabitants with cleaning their sewerage in the waste water treatment plant in the basin
- total areas under diverse crops
- yields of these diverse crops

Unfortunately, not all these characteristics were found out for every year from the period 1945–2003.

The highest Pearson correlation coefficient between the nitrate concentrations and the other characteristics was at portion of tile drained area in the basin (0,94). At portion of permanent grasslands the Pearson correlation coefficient was –0,86 (negative correlation). At mineral nitrogen fertilization it was 0,79. With increasing yields of all the crops (which reflect amount of fertilization), with decreasing areas under crops which are unpretentious for nutrients (rye and oat), and with increasing areas under more fertilized crops (barley, maize, rape) the nitrate concentrations in streams increased, how it was shown in high correlation coefficients. The correlation coefficient between nitrate concentrations and portion of inhabitants with sewerage in the basin was also high (0,87). Correlation coefficients between nitrate loss and other factors were lower, but at the portion of tile drained area in the basin the correlation coefficient was the highest from them all again (0,74).

The annual course of nitrate nitrogen concentrations in the total inflow into the Švihov drinking water reservoir is compared with the annual amount of precipitation in the basin. We can explain the fluctuation of nitrate from the 1970’s (for which there is already enough data) by the fluctuation of annual amount of precipitation. It is difficult to see the coincidence from values of individual years, but after generalization of the trends by running averages the coincidence is clear.

The research was supported by the Research Institute for Soil and Water Conservation Prague - Research Programme No. 0002704901.

Concentrations of nitrate in small streams of the Švihov (Želivka) drinking water reservoir basin, CZ

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Although amount of fertilizers rapidly decreased in the 90's in Czech agriculture concentrations of nitrate increased. High concentrations of nitrate are a real trouble in management of drinking water reservoirs. Therefore there were monitored 36 brooks in Švihov drinking water reservoir (Želivka river) basin in the Bohemo-Moravian Highland (drinking water for the capital Prague). All this catchment is made of acid crystalline rocks. Aim of this research was to identify factors of basin leading to high values of nitrate.

36 profiles on small brooks of the Zelivka river basin were included into factor analysis. Monitoring was made by Agricultural Water Management Authority once per month. The period analyzed was from June 1993 to June 2002 (but not all the profiles were monitored all the time). Infiltration areas of the catchment were delimited according to valuated soil-ecological units data – all the characteristics of soil were taken into account.

The follwing 9 factors were taken into the factor analysis:

- Characteristic value C90 (concentration which will not be exceeded with probability 90% - from measured data)
- Amplitude of average month concentrations per year for all the period of monitoring
- Total area of the catchment
- Portion of arable land
- Portion of water areas
- Portion of infiltration areas covered by arable land
- Portion of artificially drained areas
- Number of inhabitants
- Number of large animal units

Results of the factor analysis: First two components displayed in the BiPlot explain together relative variance of the file from 66 %. Characteristic value C90 and also amplitude of concentrations are correlated to these factors: portion of arable land, portion of infiltration areas covered by arable land and less to portion of artificially drained areas. On the contrary, water areas have the positive effect.

Although in the year 1955 there lived more people and farm animals in the catchments, concentrations of nitrate in brooks were far lower. All artificial drainage systems in these catchments were made between 1960’s and 1980’s. This fact seems to be one of the most important reasons of this disproportion. For future decrease of nitrate concentrations it would be necessary to grass over infiltration areas of the catchment (shallow stony soils), infiltration areas of the drainage systems (or reduction of artificial drainage) and building and keeping of small ponds where are good conditions for eliminating of nitrate.

This work was supported by Czech Ministry of Agriculture project MZe-M07-99-01-09.

Delimitation of pollution source areas based on synthetic maps of soil vulnerability and bedrock environment and their validation

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Synthetic maps of soil vulnerability and bedrock environment for the Kopaninský stream catchment and Dehtáře catchment were compiled in cooperation with Geotest Brno, a.s., with the goal to validate this methodology on model catchments. Pressure infitrometers (VÚMOP) and geophysical methods (GEONIKA, s.r.o) were used for validation.

In scientific literature, the increase of nitrate concentration in surface water is unambiguously accredited to intensive fertilisation with inorganic nitrogen. There are, however, other factors that influence the movement of nitrogen substances and other related processes occurring in soils, above all:

- soil character, especially hydrophysical properties
- character of bedrock's unsaturated zone
- climate conditions
- character of land cover and land use

The synthetic vulnerability maps are compiled as an overlay of two maps – a map of soil vulnerability (categorized according to the soil infiltration capacity) and a map of the bedrock environment vulnerability. Various properties of soils and bedrock's unsaturated zones were evaluated from this point of view. To each property an assessed coefficient of significance was added, corresponding to its importance in terms of precipitation water infiltration to the groundwater table.

The map of soil vulnerability results from the analysis of BPEJ (valuated soil – ecological units). For the assessment of soil hydrological properties, the following set of criteria derivable from the BPEJ code was chosen: the main soil unit (soil type), terrain slope, exposition, soil depth and grittiness.

Each criterion was evaluated on a 1-5 scale (1 = maximum infiltration capacity, 5 = minimum infiltration capacity) and a coefficient of significance was ascribed to it. In the resulting map of soil vulnerability, the category 1 means the maximum capacity of the area to take in precipitation water and the category 5 represents the minimum such capacity.

The modules CREATE REGION and REGIONQUERY of ArcGIS were used when processing the maps. The methodology of compiling maps was developed in the Research Institute for Soil and Water Conservation (VÚMOP, v.v.i).

The bedrock environment vulnerability map was compiled from two input layers, namely the layer of bedrock environment character and the bedrock layer thickness. Again, both layers were categorized on a 1-5 scale. The category 1 means the maximally permeable bedrock environment and the category 5 an impermeable environment, the category 1 means a minimum layer thickness and the category 5 means a thickness over 25 m. The overall bedrock environment vulnerability were then derived as a linear combination of the twp categorization values multiplied by the corresponding coefficients of significance. The result was again categorized on a 1-5 scale, whereas the category 1 is most vulnerable and the category 5 is least vulnerable. The bedrock environment vulnerability map was created according to the methodology of the company GEOtest Brno, a.s.

The non-agricultural areas (urban areas and forest) were not assessed and are represented by white colour in the maps. The last step in creating the synthetic map of soil vulnerability and bedrock environment was the integration of the bedrock environment vulnerability layer with the soil infiltration capacity layer. For this synthesis, the following input data were used:
- the soil infiltration capacity layer according to BPEJ,
- the bedrock environment vulnerability layer.
The final map than represents 5 categories again, according to following table:

Categories of soil vulnerability and bedrock environment.

Categories	Definition
1.	very highly vulnerable
2.	highly vulnerable
3.	vulnerable
4.	little vulnerable
5.	very little vulnerable

Conclusion:
It was demonstrated that the final vulnerability maps of model areas, combining the soil infiltration capacity layer and the bedrock environment vulnerability layer, describe very well the degree of risk of groundwater vulnerability to pollution from agriculture, first of all to nitrates. From this point of view, it is possible to think about these maps as applicable in all instances where the quality of surface water and groundwater can be endangered by agriculture.

Research of soil and water conservation measures in small basins

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Land use adjustment process in the Czech Republic creates a space for realization of soil and water conservation measures. It includes water and wind erosion control measures, flood measures, soil degradation control measures, surface and underground water quality and quantity measures. According to specific conditions and risks, the measures designed are areal, like the overgrassing (or afforestation) of the agricultural land or linear ones (belts, insertion of a road with infiltration belt or interceptive ditch, hedges with ridges and accompanying greenery), polders and retention reservoirs in a command area (cadastre unit). Protective measures are polyfunctional, with reference to the requirements of nature conservation and improving of landscape aesthetics. Their parameters are dimensioned by the models of erosion soil loss and maximum outflows in a profile. Empiric data of efficiency of soil and water protective arrangements are rare. For this reason, measurement of rainfall and discharges and of suspended matter content was made at experimental catchments of our institute. The project is executed thanks to the support of the Ministry of Agriculture of the Czech Republic (MZE 00027049).

Research of efficiency of soil and water conservation measures takes place in 2 small basins, 1 drinking water basin and 2 other experimental sites. The Němčický stream is a small experimental basin (3.5 km^2) in Drahanská vysočina highlands, near Brno. In this basin the efficiency of overgrassind is explored in terms of stream discharges and insoluble matter transport reduction during extreme rainfall-runoff events. Within the frame of flood protection, a polder is designed in the downstream part of the basin. After its realization, the gauging of discharge transformation and sediment transport will be extended to this object. Second experimental basin, Kopaninský stream, represents different environmental conditions of Bohemian highlands. Its area is 7 km^2 and the research there is aimed at water erosion and its influence on water quality. Sub-basins are equipped with gauging profiles for discharge measurement. Automatic samplers collect water from rising limbs of flood waves and the samples are analysed for suspended sediment, nitrate and phosphate content. The results are interpreted in time and in the relations to the actual natural and anthropic conditions.

The catchment of the drinking water basin in Hubenov (Bohemian highlands) is studied in cooperation with the Water authority Povodí Moravy. Various erosion control measures (grassing, hedges, intercepting ponds) were realized thanks to comprehensive land use adjustment projects in several cadastre units. Longer data series evaluation shows a slight and slow trend of water quality improving. Experimental fields in Studená were chosen for observation of influence of the classic and regardful agrotechologies on soil properties, in particular the soil erodibility and infiltration capacity. With the aim of evaluation of different crops influence on erosive washoff, a cooperation with the Mendel University Brno proceeds at experimental plots in Vatín.

The project includes research of actual soil and water conservation measures and appropriate technologies under conditions of agricultural basins and experimental plots. Synthetic results should enable us to evaluate the efficiency of measures explores and to create a methodology for erosion and flood control measures design in the process of comprehensive land adjustments.

Land-use as a factor determining stream-water chemistry dynamics in small Carpathian Foothills' catchments

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The aim of the research was to assess the influence of land-use and land-management in the Carpathian Foothills' small drainage basins onto the dynamics of river-water chemical composition in different timescales: multiyear, seasonal and diurnal, taking into consideration flood periods as well as low-flow periods. The research was conducted in the catchment of Stara Rzeka (22.2 km2, mixed land-use: agricultural and forested) and two of its sub-catchments: Kubaleniec (1.03 km2, agricultural) and Lesny Potok (0.48 km2, forested).

The assessment of multiyear and seasonal changes of chemical composition was based on weekly (main ions) and biweekly sampling (nutrients). During the flood periods the sampling was more frequent: from several-minute to several-hour intervals. During low-flow periods the two-hour sampling intervals were applied. The following parameters were studied: pH, electrical conductivity, main ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}) and nutrients (NH_4^{+}, NO_2^{-}, NO_3^{-}, PO_4^{3-}).

During the several-year period of study the substantial rise of nutrients concentration was detected in the agricultural catchment, which was the result of the river flow reduction with simultaneous rise of untreated domestic sewage release into the streams. That was not the case for the forested catchment.

Seasonal fluctuations of water composition correlated with the river flow during a year. In agricultural catchment with domestic sewage supply the highest level of nutrients was detected during summer and autumn low-flows (ion concentration effect), while the lowest – during snow-melt in spring (dilution effect). Unexpected was the PO4 behaviour in the forested catchment: instead of the expected drop in summer growing season, the substantial rise of ion concentration was observed.

During the high flows caused by intensive (storm) rainfalls the land-use influence onto the chemical composition of water was well visible. It was manifested in different directions of hysteretic loops of ion content in agricultural and forested catchments. The difference between the catchments disappeared during long lasting low-intensity rainfall floods as well as during the floods caused by snowmelt. This resulted from different water circulation pattern in the agricultural and forested catchments during the storm floods, and similar circulation pattern during the low intensity rains and snowmelt.

Main factor controlling short-term (hourly) fluctuations of chemical composition of low-flow water during the day in summer season was river flow changeability due to the changes in evapotranspiration intensity. There were however differences between forested and agricultural catchments. In the forested one the main factor was evapotranspiration causing higher concentration of ions during the day and lower – in the night. In the agricultural catchment the driving factor was changing intensity of alluvial and spring-water discharge to the stream. Alluvial and spring waters were the medium transporting the domestic sewage released from the village households to the streams.

The Dragonja experimental watershed

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Abstract

The Dragonja river basin is situated on the border between Slovenia and Croatia. Due to political and social circumstances and poorly managed agriculture in the past, the catchment area has been depopulated in the past decades, leaving the forests to develop in the abandoned agricultural fields. The Dragonja watershed was chosen as an experimental watershed, since it is interesting because of the intensive natural reforestation in the last decades, which has caused a decrease in minimal and maximal flows. At the same time no noticeable climate (precipitation and temperature) changes have been perceived. The main intention of the project (experimental watershed) is to figure out the impact of changed land use on the water balance of the entire watershed and to determine the hydromorfological changes of the river basin.

Measurements in the last few years were the basis for cooperative scientific work between the Vrije Universiteit from Amsterdam and the University of Ljubljana, which resulted in several PhD Theses, Master Theses and scientific articles. At the same time the experimental watershed provided support to the teaching and studying process. Until now, many students from Amsterdam (VUA), Ljubljana (UL) and Freiburg (UF) have performed their field work and organized workshops on the subject of the catchment. Measurements included rainfall measurements (ONSET Rain gauge) in several locations (Labor (2x), Marezige, Kocjančiči, Sirči, Rokava, Boršt, Kubed and Stara Vala). We also established research plots in the forest where we analysed the forest hydrological cycle. Precipitation above the canopy, throughfall and stemflow on each plot were measured. Rainfall above the canopy was measured with a tipping bucket rain gauges and with totalisators (manual gauges) for control. Throughfall was measured with two steel gutters in combination with ten manual gauges in each plot, which were emptied and moved randomly every time. Stemflow was measured on two most typical species in each plot. Litter was collected regularly in 10 baskets for LAI (Leaf Area Index) estimation. For the same purpose and at the same points, hemispherical photographs of canopies were taken and three series of measurements of photosynthetically active radiation (PAR) were made.

For the needs of studying the processes of soil erosion and sediment transport in the Dragonja experimental catchment we measured discharge of the Dragonja river and took sediment samples (ISCO) in the Rokava catchment (the biggest tributary in the upper part of the Dragonja catchment). Part of the research in the Dragonja experimental watershed deals with the development of a new synthesis method of assessing the hydromorphological status of river corridors based on state analysis of the Dragonja river. The bases of the new method were time effectiveness of data gathering and accuracy of the method. Prior to the practical research implementation, a concept of a rapid transect data gathering was designed. Additionally, an extensive hydromorphological record sheet was elaborated, including a combined list of hydromorphological variables.
The conclusions of this project will improve the current understanding of hydrological processes, conditions and interaction between water, soil, deciduous forest and climate in the representative watershed of the Dragonja river.

Revitalization of sub-mountain headwater area Senotín

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European landscapes have been affected by human existence for thousands years. Agriculture and other activities changed extensive forest areas into steppes. Most serious negative influence on the landscape has the large-scale drainage of headwater regions in highlands. The network of natural terrestrial, aquatic and wetland communities has been significantly reduced. Drainage and unsuitable agricultural practices damaged physical, chemical and biological soil properties, which led to the reduction of water retention capacity and to the increase of surface runoff and soil erosion. Drying of vast areas, extreme oscillations of groundwater table and elution of nutrients are manifestations of ecological instability of the landscape.

Large-scale change of fully transpiring forest into inefficiently transpiring arable land negatively affects transformation of solar energy into the latent and sensible heat. Significant reduction of closed water cycle for the benefit of open one is caused by the insufficient transpiration on the landscape scale. Therefore, the present global changes of climate, as well as the frequent extreme weather situations in the Czech Republic, may be considered as a consequence of landscape use changes.

Renewal of fundamental ecological functions of landscapes which had been deforested, drained and unsuitably managed in the past, is one of the crucial conditions of future sustainable development. In the framework of the pilot project of revitalization of submountain headwater area Senotín (district Jindřichův Hradec, Czech Republic), which ahd been damaged by systematic tile drainage and unsuitable agricultural practices, methods and perspectives of landscape renewal are studied.

Technical and biotechnical adaptations of the revitalized area in Senotín have reduced the water runoff for the benefit of retention and evapotranspiration. Seven underground clay shields stopped the function of the drainage system. The adaptations of terrain and microrelief effectively slowed down the surface runoff and significantly increased the variability of microhabitats. The adaptations of the experimental area improved its water retention capacity and created basic conditions for the renewal of soil communities and biodiversity.

The aims of this paper are: (i) to demonstrate the runoff formation in the revitalized area, (ii) to show the influence of plant transpiration on the air tempertaure, (iii) to offer precise and relatively simple method of biomonitoring of the quality of terrestrial biotopes.

Long-term nitrogen losses from tile-drained arable land

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Tile drainage shortens the residence time of water in the soil and might therefore not only cause a pollution of surface waters with nutrients and pesticides, but also a change of the hydrological dynamics and responses of the catchment. Furthermore, preferential flow processes may result in an unexpected fast response of the tile drains. Although the catchment scale is the scale of interest to evaluate the environmental impacts of agricultural land use, hierarchical measurement approaches – in contrast to plot studies focussing on one collector drain – are scarce. Furthermore, tile drainage has rarely been explicitly included into distributed hydrological models. Therefore, the spatially distributed modelling approach MHYDAS-DRAIN was developed to account for anthropogenic impacts and a possible fast flow component in small catchments dominated by agriculture. The model is based on hydrological units derived from tile drainage and land use maps and connected to the drainage network. The basic assumption underlying model development is that the tile drain discharge is composed of preferential and matrix flow and that an additional baseflow component is present in the ditches. The slow drainage component is calculated with the Hooghoudt-equation, while the fast flow component is modelled with a transfer function approach. Flow routing is realised with an analytical solution of the diffusive wave equation.

The model was applied to a small lowland catchment in North-Eastern Germany, where a hierarchical monitoring programme for hydrology and hydrochemistry has been installed in 2003. Measured and modelled discharge rates at a collector drain outlet (4.2 ha catchment) and in a ditch (179 ha) as well as groundwater levels agreed reasonably well. As expected, tile drainage was dominating the hydrological response of the catchment. Using long-term meteorological data disaggregated to hourly values, estimates of discharge rates and nitrate-nitrogen losses could be derived. As only winter half-years with a precipitation sum around or even below the long-term average could be monitored so far, modelled nitrate-nitrogen losses during the winter of up to 37.6 kg ha^{-1} (collector drain) and 31.2 kg ha^{-1} (ditch) exceeded the losses measured until 2005/06 (collector drain: 20.1 kg ha^{-1}; ditch: 21.8 kg ha^{-1}). According to a regression analysis, the fast low component reduced nitrate-nitrogen losses, but this is not necessarily the case for other substances such as phosphorus. Overall, tile drained fields will have to be addressed if a reduction of the diffuse nutrient pollution in lowland catchments is intended. Therefore, management approaches for tile-drained areas need to be developed.

Waterflow and solute movement in the Hupselse Beek catchment, the Netherlands

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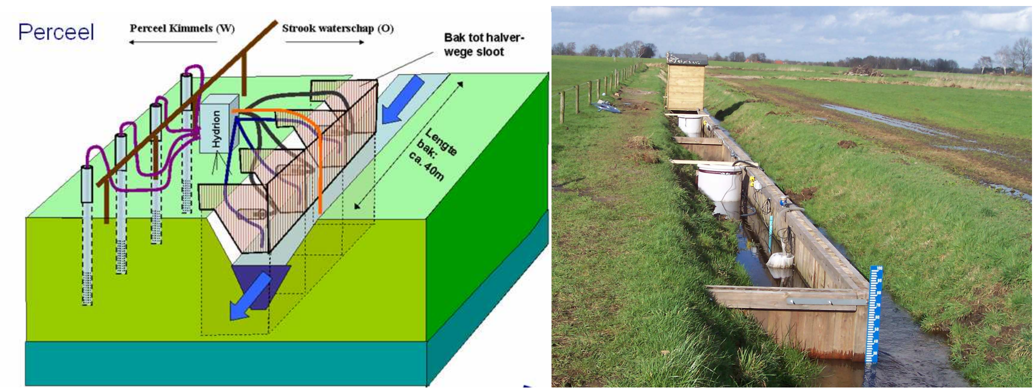
The main goal of this research project is to develop a strategy to monitor and predict ground and surface water quality in order to be able to quantify the effects of changing agricultural and industrial practices on the surface water quality. The European Water Framework Directive (EWD) poses strict guidelines for surface water quality, which have to be met in 2015. To reach the goals set in these guidelines we will have to structurally change our water management and our agricultural and industrial emissions. These changes will only get enough support when we can accurately describe and predict the local and regional implications of solute transport processes. Therefore, there is a need for models that can predict pollutant transport at a regional scale. These models can only be build, based on an accurate conceptual framework for water and solute transport on a regional scale, taking into account the non-linearity's of local transport processes and the heterogeneity of the groundwater system. This research project has an experimental setup that will focus on the dynamics in travel times and travel pathways of solutes in the hydrological top system of drained land in the Hupselse Beek catchment, The Netherlands.



The experimental setup for measuring water quality and water flow from 3 tile drains, from the groundwater flow of 3 small drained plots, surface water and 4 groundwater wells. Picture shows experimental setup (left), and a photo of field equipment (right). Hupselse Beek catchment. Hydrion: Selective electrodes for measurement ions Na, Ca, K, NO_3, NH_4, Cl, HCO_3

Runoff coefficient measurements in the Cerhovický stream experimental catchment

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The runoff coefficient is one of fundamental hydrological characteristics of a catchment. It indicates a share of the precipitation water that flows away in the stream. In the case of a higher runoff, the area in question should be considered as a more hilly and, hence, as a land with a low infiltration and retention capacity. The runoff coefficient helps to evaluate the appropriateness of the land in a given catchment for agricultural use.

We present results of runoff coefficient calculations based on the measurements, carried out continuously in the Cerhovický stream catchment over a substantial period of time from 1986 up to 2006. The relevant precipitation data were measured directly in the catchment. The average value of the runoff coefficient for the entire catchment, as well as runoff coefficients for the agricultural and the forest parts of the catchment, are presented. The total average runoff coefficient for the Cerhovický stream is 0.2153. The average runoff coefficient for the forest part is 0.1584 and for the agricultural part 0.0618. Differences between the years with high and low precipitation were identified; the runoff coefficient for relatively dry years seems to be lower than that for the years with the high volume of precipitation.

Changes of the land use and soil properties on the model submontane region in the Czech Republic

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For the research projects dealing with the changes of the properties of the soil cover of the Czech Republic we used - in order to check the results- selected model territories. One of them, situated in the sub-mountainous region of Český les in West Bohemia, was explored in detail. The model territory (area of about 360 hectares) is near to the state boundary to Germany and falls within the cadastral unit of the village Železná, district Domažlice. In the course of 1980's, it was drained by tile drainage.

The village Železná counted 1138 inhabitants at the beginning of the 1930's. After the 2nd World War the village almost perished; now it has no more than 40 permanent inhabitants. Even the land use has changed considerably: before the 2nd World War the people managed mostly small ploughed fields and pastures, whereas during the 1980's a considerable part of the area was left waste. After the drainage has been built in the 1980's, the territory was shortly used as arable land, but since the 1990's the whole area is covered by permanent grassland and is used for grazing cattle.

In the frame of the research project we compared the soil chemical and soil physical properties using samples taken up both during the detailed hydropedological survey before the draining and now. The new samples were taken up from the same sites, the same soil pits but thirty years later than the first set.

Nitrate concentration and nitrogen leaching out of the small tile drained catchment

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The nitrate concentration in tile drainage water is an important theme in Czech Republic, because of the fact that many drinking water reservoirs in Czech republic are situated in the areas where the tile drainage was built and where the wet meadows were changed into arable lands. The problem is not only high nitrate concentration in water but the leaching of nitrogen, as one of most important nutrient, out of the soil. For the purpose of monitoring of the nitrogen cycle the experimental catchment Dehtáře was chosen. It is located in the Bohemo–Moravian Highland. The area of this catchment is 57.9ha, it is tile drained and divided into a left (partly grassed) and a right (arable land) part. The systematic tile drainage was built in 1977 in the western (discharge) part of the catchment.

The NO_3^- concentration in drainage water of the experimental catchment is monitored in regular fortnight periods since September 2005. There are 10 measuring manholes in Dehtare catchment, in which the samples are taken. A special significance is attributed to the KL and KP measuring profiles, which are closing profiles of the left (KL) and the right (KP) part of the catchment. The nitrate concentrations in the two closing profiles are, in the long term, nearly permanently higher then 50 mg/l (the limit stipulated by the Czech standard for drinking water and by the 676/91EEC Nitrate Directive). Since spring 2005, the daily concentrations are mostly higher than 100 mg/l. The concentrations are otherwise very variable in time, oscilating from 25 mg/l (16.3.2004) to 204 mg/l (26.4.2005) in the KL manhole and from 33 mg/l (3.12.2003), to 191 mg/l (26.4.2005) in the KP manhole. The average concentrations over the entire period of monitoring are KL 109 mg/l in KL and 91 mg/l in KP. Because of the fact that the concentration is mostly higher in the left part of the catchment, we conclude that the grassland in the discharge zone has no significant influence on the nitrate concentration in drainage water. The lowest nitrate concentrations over the calendar year occur in winter, mostly from January to March, while the highest ones occur in late spring. This seasonal oscillation of nitrate concentration is typical for diffuse sources of pollution. The relation between the drain discharge and nitrate concentration is variable during the year, depending on the nitrate content in soil (the time that has passed since the fertilization), but the problem is that this relation is different on the left and the right part of the catchment. The right part reveals mostly a positive correlation (higher discharge means higher nitrate concentration), while in the left part of the Dehtáře catchment the relation is mostly negative (higher discharge means lower nitrate concentration), even though the time of application and the amount of fertilizer is very similar in the both parts of the catchment.

Another problem to solve is the nitrogen leaching out of the catchment. The dominant factor, which affects the quantity of nitrate leaching, is the volume of runoff, while the nitrate concentration has no significant influence on the amount of nitrogen leached. From the seasonal point of view, the period of snowmelt is critical for the annual amount of nitrogen leached out and can contribute 25 – 50% of to the total annual N loss. Less significant secondary maxima of N leaching can occur in summer due to high discharges after heavy rains. In accordance with different precipitation sums in individual years, the annual amount of N leached out of the catchment is very variable, from 4.45 $kg.ha^{-1}$ to 91.6 $kg.ha^{-1}$ (in 2006), what is not only an environmental problem but an economic problem, too.

Small agricultural tile drained catchment Dehtáře: equipment and monitoring

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The experimental catchment Dehtáře is a typical example of small agricultural catchment on crystallic and methamorphic (paragneiss, partly migmatised paragneiss and migmatite) rocks of Czech-Moravian Highlands, without permanent surface flow, which was tile drained. The systematic tile drainage was built in 1977 in the discharge part of the catchment. Spacing of the drains is 13 or 20 m, depth is 1.0-1.1 m. Area of this catchment is 57.9 ha. For the purpose of nitrate concentration monitoring in different types of landuse, the catchment is divided into a left part (29,6 ha), where there is, except arable land, well-used grassland overlying the discharge zone and a part of the recharge zone, and a right part (28,3 ha), which is covered mainly by arable land with a small portion of forest (1.7 ha) in the north and north – west part.

The Dehtáře catchment is presently very well equiped by automatical gauges. Continuous measuring started in September 2003. There are 10 V-notches placed in measuring manholes, providing information about the flow rate and drainage water temperature every ten minutes. Three of these gauges have a facility for data transmission by GSM. Furthermore, we are measuring groundwater table in 9 wells, of which three wells are equipped with automatic gauge with 10-min recording time, while the other are hand-measured every fortnight.

As to the soil characteristics, the soil moisture and temperature are monitored on three sites. These characteristics are measured at 0.3 m, 0.6 m and 0.9 m depths and the gauges have a facility for data transmission by GSM. Meteorological information is obtained by automatic weather station. Air temperature and air humidity at two levels, global radiation, soil heat flux and soil temperature at two depths are recorded. The station is also equipped with an anemometer and a pyranometer. An automatic raingauge, which is installed on one of measuring manholes, records the sum of precipitation every ten minutes, and every minute when rain occurs. During the growing season, another three meteorological stations are in operation for comparing the actual evapotranspiration values (ETA) of different crops, soil types and tile drained fields.

Very important is the field work, because the nitrate concentration and other pollution indicators are obtained by point sampling of drainage water in a manhole every fortnight. The measurement of discharge and water temperature are checked manually, which is very useful for calibration of measuring instruments and in the case of failure of the automatic gauge. Once a month, the data from all automatic gauges are downloaded into a notebook.

Evaluation of nutrient loss caused by extreme runoff events from spring snowmelt on tile drained subcatchments

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Extreme runoff events were evaluated in two tile-drained subcatchments of the Jenínský stream catchment. Spring snowmelt in March 2006 caused local floods with one of the highest runoff rates recorded during the whole research period. Discharge was measured continuously with ultrasonic probes. Water samples were collected and analysed in regular 24-hour intervals during the whole snowmelt. These data were examined to evaluate nutrient losses from both subcatchments, with a special focus on nitrogen losses. Despite considerable dilution which reduced the values of the water quality parameters monitored, the nutrient losses during the snowmelt period were very high and amounted to a significant portion of the whole annual losses. Our results illustrate the importance of extreme runoff events in the process of nutrient losses generation.