Realistic expectations for improving European waters

Final conference of COST Action 869

Mitigation Options for Nutrient Reduction in Surface Water and Groundwaters

Keszthely, Hungary, 12-14 October 2011

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CONTENT

Implementation of the Water Framework Directive in Denmark – a status.

Poul Nordemann Jensen
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The water planning process is in general delayed in Denmark. A public consultation was finalized in April 2011 with more than 4000 comments, proposals etc. At this moment the Danish water authorities are dealing with this huge number of protests etc. and making the necessary adjustments of the River Basin Management Plans (RBMP).

The necessary reduction in nutrient load and improvement in e.g. physical status of rivers was decided in a political agreement I 2009 – "Green Growth". One of the aims of this agreement was to ensure the fulfillment of the requirements in the WFD. The main environmental objectives of the this political agreement were

A reduction in the nitrogen load from agriculture to coastal areas of 19.000 ton N (app. 30 % of the actual total load and a bit more based on the actual load from agriculture).

A reduction of the phosphorus load from agriculture with 210 ton P

Improved physical status of 7.300 km. river (app. 25 % of the rivers included in the planning)

Nitrogen.

The calculated reduction in N-load is mainly based on one biological indicator – the depth limit of eelgrass (a marine flower plant).

The reduction in nitrogen load should be obtained in two ways (nearly equal in size) 1) by specific measures and 2) by a fixing of quotas and a free market for buying/selling of nitrogen. In a later political process, the question of how to implement a reduction via quotas was placed in a commission, which is still working!

So the first generation of draft RBMP only contains specific measures with an effect of app. 9.000 ton N.

The reduction of N from agriculture in the draft RBMPs were based on a fixed set of measures (a catalogue of measures) divided in general (i.e. valid for all farmers irrespective of the need for reduction in the coastal area) like

Buffer zones

Catch crops instead of winter crops

No soil preparation in the autumn

and targeted measures (only implemented in catchments where a need for reduction is documented) like

Wet lands

Targeted use of catch crops

General measures accounts for app. 2/3 of the total N-reduction – targeted measures for the remaining 1/3.

A calculated effect (in kgN/ha) of the particular general measure (and the cost) in the surface water (nearest river/lake) is presented in the catalogue of measures, so the same resulting effect in surface water is used in all 23 sub basin plans.

Phosphorus.

Only two measures are available for the water authorities to reduce the P-load from agriculture, buffer zones (general) and temporarily flooded riparian areas (targeted).

Public discussion of the draft RBMPs:

Many of the issues in the draft RBMPs has been subject to public (and to some degree among politicians) discussion like

The political decided reduction of 19.000 ton N (the impact on Danish/regional agriculture of a nearly 30 % reduction of the load = use of nutrients)

Use of ellgrass as an indicator – has not yet responded significantly on a 50 % reduction in N-load from 1990-2010.

Stop or change in river maintenance – risk of increased ground water level or even flooded valleys (especially triggered by a very rainy summer 2011)

Use of the term Heavily Modified Water Body for rivers – and the difference in number compared to the northern Germany.

The quality of the monitoring data used for calculation of load, status assessment etc. – especially the use of older data from e.g. 2005-06 to represent the situation in 2010-11.

The discussions have mainly been concentrated on the surface water area and not so much on ground water.

As the agricultural sector is in focus as a “source”, they have been very active in the debate during the last year.

Denmark had an election for the Parliament some weeks ago and a shift in political regime. What the impact from this change will be on the coming planning process (both in time and content) is not possible to assess at the time, when this abstract was produced.

European Union Strategy for Danube Region and the implementation of the Water Framework Directive

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The Danube River Basin (DRB) is the “most international” river basin in the world covering territories of 19 countries. With over 100 million people, and a fifth of EU surface, the area is vital for Europe. The DRB is not only characterised by its size and large number of countries but also by its diverse landscapes and the major socio-economic differences that exist between the upstream and downstream countries. The DRB has been the subject of many investigations and studies funded by the countries sharing the Basin and a wide range of organisations. The first part of the presentation will focus on the background information on the Danube Basin and Region, the EU Strategy for Danube Region (Danube Strategy), the Danube River Basin Management Plan (DRBMP) and the Water Framework Directive.

The DRBMP identified four significant, „basin-wide” transboundary issues that are a priority for the Danube Basin and the impact of the Danube River on the Black Sea: nutrient pollution, organic pollution, hazardous substances and hydromorphological alterations. The DRBMP identifies the most urgent, basin-wide management issues in detail, but it also identifies areas where more work is needed in the future , such as sediments and climate changes.

The Danube Strategy should have an important role in the management of those significant, basin-wide transboundary issues. The objectives, the scope and the structure and organisation of the Danube Strategy, the priority areas, the actions and projects will be discussed in the second part of the presentation.

There are eleven Priority Areas identified for the Danube Strategy, that represent the main areas where the macro-regional strategy can contribute to improvements. The objective of the 4th priority area is „to restore and maintain the quality of waters” and the objective of a few actions and projects of this priority area is control of nutrient loads.

The major criteria for the selection of the actions and example projects will be discussed: issues of basin-wide importance, issues based on the Danube River Basin Management Plan adopted by the Ministerial Meeting of the Danube River Basin countries, issues that requires a basin-wide perspective and cooperation between each or most of the countries sharing the whole basin, issues that requires inter-ministerial/inter-sectoral coordinating mechanisms and integration of different policies, issues that demonstrate immediate and visible benefits for the people of the Region, that have an impact on the macro-region (or a significant part of it), projects which promote sustainable development and cover several regions and countries;

– which are coherent and mutually supportive, creating win-win solutions and are realistic (technically feasible and with credible funding).

The organisation of the implementation of the Startegy, the international and national coordination, some of the frequently asked questions, the potential financial sources, the actions and potential projects dealing with nutrient control will be discussed in the third part of the presentation. The parallels of the water resources management aspects of the EU Strategies for the Baltic Sea Region and Danube Region, and what to learn from the Baltic Sea Strategy will be also discussed.

In the DRBMP plan for 2015 (and for the period lasting until 2027), the future visions of water-environmental problems in river basin level, and the chances of the efficient implementation of the mitigation measures, were laid down. The major Danube basin-wide vision for nutrient pollution of surface waters is „balanced management of nutrient emmissions via point and diffuse sources in the entire DRB that neither the waters of the Danube nor the Black Sea are threatened or impacted by eutrophication”. In the last part of the presentation the expected role of the Danube Strategy in the implementation of the mitigation measures of the Danube River Basin Management Plan regarding nutriens will be discussed.

The nutrient reduction function of the Külső-Béda oxbow (Danube-Drava National Park/Hungary)

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The role of wetlands along the river Danube in the reduction of nutrients have been described in several previous studies, but only a few data are available regarding to this function in the active floodplain area (23 000 ha) of the Danube Drava National Park at the Danube (rkm : 1497 - 1437). The aim of our study was to investigate the nutrient reduction function of the Külső-Béda oxbow situated in the active floodplain area of Béda-Karapancsa nature protection area (rkm 1442- .

According to our results the concentration of the total dissolved nitrogen and total dissolved phosphorus were lower, while the concentration of the dissolved organic carbon and dissolved total carbon were higher in the oxbow than in the main arm of the Danube. The dissolved total carbon and dissolved organic carbon concentrations increased in the oxbow water in the function of the distance from the main arm. The chlorophyll-a concentration was higher in the oxbow than in the main arm of the Danube and positively correlated with the concentration of the nutrients. The lower concentrations of the nutrients in the oxbow as comparing to the main arm, demonstrated the nutrient retention function of the Külső–Béda oxbow at Béda-Karapancsa floodplain area.

Integrated mitigation of diffuse phosphorus losses for improved water quality of lake Vansjø

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The western part of lake Vansjø in southeastern Norway has a very poor water quality due to algal growth and phosphorus has been identified as the limiting nutrient for growth.

Agriculture is one of the main contributors of nutrients to the lake and within this sector a comprehensive implementation of measures has been attained.

The objective of this paper is to evaluate the effect of the comprehensive integrated effort that has been put into reducing diffuse pollution (especially phosphorus losses) from agricultural areas around the lake western Vansjø.

The measures consisted of reduced tillage, reduced P fertilizer application, vegetated bufferzones and constructed wetlands. The strategy to implement measures consists of information campaigns, farmer meetings with discussions, field trips, environmental planning on individual farms including farms visits and least but not last contracts and economic incentives. Implementation of measures was registered and reported for each farm at the field scale.

Monitoring of the water quality in 9 small streams consisted of manual water sampling carried out weekly and during events starting 18. October 2004 and to d.d. Seven of the small streams represented runoff from agricultural and forested areas, one stream had only forested area within its catchment and one stream represented runoff from the housing areas in the city Moss.

Results show that from 2004 to 2009 the use of P fertilizer has been reduced by approx. 75%. The area of no-till in autumn has increased and for some of the stream catchments cover 100 % of the area. Vegetated buffer zones are established along most small streams and 11 constructed wetlands were built during the period 2004-2009.

The P concentrations of the seven agricultural streams show annual variation according to the weather conditions, but there is a decreasing trend in concentration though the statistical significance has not yet been proven.

The poster will evaluate trends in P concentrations and effects of the measures implemented in the small agricultural stream catchments around the lake western Vansjø.

Managing N,P,K excesses in soils, from applied fertilisers, using biochar; direct implications to tomato plant (Solanum lycopersicum L.) health and consequences to the mobility and uptake of trace elements

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In northern Italy, tomato plantations contribute a significant proportion of both economical prosperity and food capital. Multiple threats exist which are compromising production and safety of the outputs of these plantation, as well as soil quality. Managing applied N,P,K fertilisers, to reduce leaching and improve plant yields whilst, on a finer scale, preventing antagonisms between fertilisers and soil residual heavy metals, needs to be examined to determine whether co-mobilisation is influencing the chemical equilibrium in fertilised soils and hence reducing soil quality, plant health and food safety.

Organic soil amendments have been applied to manage soil nutrition and element mobility for many years. More recently biochars (biological residues combusted under low oxygen conditions, resulting in a porous, low density carbon rich material) have gained credence for soil applications because their large surface areas and cation exchange capacities have enabled enhanced sorption of both organic and inorganic contaminants to their surfaces, reducing pollutant mobility when amending contaminated soils, whilst providing improved soil aeration, water holding capacity and soil nutrition.

A short term scientific mission (STSM) has been granted by COST 869 to determine the efficacy of biochar for regulating N, P, K, from fertiliser applications, to soils in terms of reducing excess leaching. Potentially toxic elements, especially Cd and As in soil pore water and edible plant parts will be measured to establish whether any antagonisms exist between added nutrients and potentially toxic elements which could compromise the use of biochar in this system. Solanum lycopersicum L. cultivars, chosen from previous screening, will be transplanted to biochar amended soils and maintained in controlled conditions in the laboratory. In the following 2 months, pore water samples taken from each replicate will determine the effect that the biochar addition has to N, P, K leaching and Cd and As mobility. Plant growth parameters will be measured as well as foliar Cd and As concentrations at the end of the experiment to plant health and safety. The initial aims, set-up and results will be reported at the COST 869 final meeting in Hungary with the aim of informing the action 869 of steps that could be taken to increase fertiliser use efficiency and reduce N leaching to waters, from soils.

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Do a simple water dispersion test and soil properties allow to evaluate and prevent the risk of eutrophication deriving from soil particulate P losses?

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Under the requirements of the EU Water Framework Directive (WFD), surface waters must achieve good chemical and ecological status by 2015 (European Parliament, 2000). Levels of P are of particular concern, because P favours algal growth in surface waters and is the key limiting nutrient in freshwater rivers and lakes. Inputs from agriculture account for up to 20% of all P inputs to surface waters. Indeed, many European soils are overfertilized and, as a consequence, controlling the transfer of P from agricultural land to water has become a priority for catchment managers.
Many European regions have adopted mitigation measures to limit P transfer from soil to waters, most of them applied to a limited portion of the catchment, the so called ‘critical areas’. Thus simple tools able to identify the critical areas are needed.
According to the main process responsible for P transfer, different P forms are mobilized and thus the appropriate tool must be used. Where leaching is the prevalent process, soluble P (RP) is the main mobilized form while in runoffed subjected soils P is mobilized in particulate form attached to the suspended solids. On average particulate P (PP) represents up to 90% of the total P lost, and total P losses depend both on soil particle dispersion and on P solid enrichment.
To estimate P losses by leaching many Authors related RP to the soil P status through various equations, while by runoff potentially mobile PP can be predicted using dispersion tests, or as a function of soil properties affecting both soil dispersion and P enrichment.
Recently a simple test based on water dispersion with quite large soil to solution ratios has been proposed and validated through outdoor and indoor experiments (Withers et al., 2007). This test has been applied to various soil types in order (i) to obtain pedotransfer functions able to predict the risk of soil and P losses from soil properties (Withers et al., 2007, Borda et al., 2010), (ii) to evaluate whether the P suspended particles may act as sink or source of P as a function of soil P status (Hartikainen et al. 2010, Withers et al. 2009, Borda et al., 2011a, Borda et al., 2011b) and to individuate which is the size of more P enriched and potentially lost soil particles (Quinton et al. 2009).
Aim of this work is to review the results obtained with the water dispersion test:
a) to calculate pedotransfer functions for a larger number of soil types;
b) to evaluate the efficacy of the test to highlight modifications induced by applied mitigation options (minimum tillage, low input, increased aggregation, increased organic matter);
c) to estimate the effective availability of P bound to dispersed particles.

High Precision GNSS-GIS DEM to Improve Model Inputs in Catchment Studies

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The reduction of nutrient loss of surface and ground waters at a watershed level is an important issue. For this aim, the use of up to date GNSS-GIS (Global Navigation Satellite Systems – Geographic Information System) device systems is essential. In the present days, GIS systems in a wider sense give the background to applied research. Further devices connected to GIS systems, such as remote sensing, mobile communication, 3D modelling, geodesy and image processing, ensure further opportunities in research. Another important task is to create modern, relevant databases and spatial data systems with adequate structure for easy access and efficient use. Partly we can rely on the results of INSPIRE (Infrastructure for Spatial Information in Europe). An important base to count on throughout research is a high precision elevation or terrain model . Most of the cases, this does not exist with adequate precision for a certain area, so the generation of a model is unavoidable. For a big area, remote sensing gives an adequate solution. For smaller areas, parts of watersheds, however, a geodesic accuracy, RTK (Real Time Kinematic) topographic GNSS survey can give a more efficient and flexible solution. For all these modelling tasks, a useful device can be obtained using the terrain correction systems (GBAS) integrated into GNSS. It is important that the model should contain the terrain objects as well. Thus a high precision terrain model can be created in the most widely used formats.

The present article introduces the results of our GNSS survey and model generation carried out in Research Institute for Viticulture and Oenology, Badacsony, Hungary (~10 ha). The area is highly structured, and stripped, suitable for outflow modelling. The survey was carried out in the spring of 2010. using the GIS-GPS infrastructure of the Georgikon Faculty of the University of Pannonia, Keszthely, Hungary.

Examination of soil and water quality along the Koppány Valley Habitat Rehabilitation Experimental Area

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Landscape and land use change play an important role in the Koppány Creek Valley in Somogy County, Hungary. Once, the area was characterized by large extent of forestland, peaty and swampy areas but these were almost totally altered, made them suitable for arable farming. During our research we compared the maps of the first three military surveys, covering an era of 1770 to 1870 and in addition, the Unified National Map from the end of the 20th century.
Besides the analyses of the above mentioned maps, soil analyses were done on sloping and on flooded areas as well and water analyses on an experimental area, covering an approximately 2 km section of the Koppány Creek below Gerézdpuszta (Koppány Valley Habitat Rehabilitation Experimental Area).
In addition to the chemical analyses, biota was also examined. Macrozoobenton was analysed and Saprobity Index was determined.
This approach allowed us to give a detailed description of the experimental area, including water and soil quality analysis.
Comparison the soils of the forested and non-forested areas, we can state that overall water management capacity has suffered negative changes, including the change of infiltration and water holding capacity from good to bad. Brown forest soils disappeared on significantly large areas that are now covered by shallow, weakly humic soil types with a soil surface formed on loessy parent material or very close to and/or mixed with it. These changes in soil characteristics means more erosion, more runoff and soil loss, and at the bottom of the slope, more sediment accumulation. Shallow drillings proved the soils to be 160-240 cm, respectively. Concerning the original thickness of the original soils in the area it means 60-140cm sediment accumulation.
Chemical analyses of the water at the beginning, at the end of the experimental area and between the creek and a fishpond proved that – in average – the water quality after the fishpond is one class below the quality of the other two water sampling points.
Water quality class of the Koppány Creek at the Koppány Valley Habitat Rehabilitation Experimental Area was III. B. (less polluted) based on the analysis of the 298 individuals from 13 taxons, characterized by caddis-fly (Hydropsyche angustipennis).
Saprobity Index proved the water to be a Hungarian average: ß-mesosaprob (S=2.05), water quality = Class II (good).
Based on our results we call attention on the importance of reforestation and on the rehabilitation of the former wetlands. Covering the erosion hotspots could greatly improve infiltration capacity of the soils, resulting less runoff erosion, less sediments, better water management. Furthermore, wetlands filter pollution arriving from agricultural lands and as habitats provide refuge for rare and protected species, floodplains provide protection functions against flooding, and furthermore it is important as landscape value. The reintroduction, rehabilitation and protection of naturally flooded and swampy areas would equally serve the increase of water quality, biodiversity and decrease of negative flooding effects.

Removal of nitrate from drainage water using wood chips

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The nitrogen concentration in Dutch surface water is too high on many places. Leaching of nitrate from agricultural land is a major source of nitrogen in surface waters. With current fertilizer policy the water quality standards included in the Water Framework Directive cannot be met on short term. To meet these requirements, additional measures are therefore needed to reduce nitrate leaching from agricultural soils in the short term.
By denitrification nitrate can be converted into nitrogen: NO3-→NO2-→NO→N2O→N2 . For this process, organic matter is needed as an electron donor. On about 50% of Dutch farmland water is discharged to surface water via drainage pipes. By placing a filter with organic matter at the end of the drainage pipe the leached nitrate is converted to gaseous N2. For this purpose woodchips are often studied currently, since they are relatively stable on a longer term. In a column experiment we studied nitrate removal from a solution containing 100 mg/L NO3-. In the column we used woodchips from softwood and hardwood, either pure or mixed with sand (1:1 volume ratio). Residence time was either 3.6 days (slow) or 1.7 days (fast). The P concentration in the effluent and N2O-emission were determined frequently.

Experimental results show that 100% of the nitrate in the water could be removed in the columns. The extent of removal depends on the type of woodchips and on the residence time of water in the filter: hardwood removed more than softwood; mixing with sand decreased removal; increasing retention time of the water increased removal rate.

A practical problem is that a few days are needed to remove all nitrate from the water. Therefore, for drainage flows expected in practice, the filter must be too large for placing at the end of a drainpipe.

There is also a risk of 'pollution swapping': while nitrate is removed, there may be losses in the form of nitrous oxide (N2O) and phosphate. Emission of N2O differed between treatments: hardwood emitted much more than softwood; mixing with sand increased emission; increasing retention time of the water reduced emission. Concentrations of P-tot in the effluents were above the Dutch standard of 0.15 mg total P L-1 during 3 months. With hardwood P-tot started above 40 mg P-tot L-1, and decreased thereafter; softwood started low and increased to 0.6 mg P-tot L-1 thereafter.

We concluded that potential pollution swapping by N2O emission and phosphorus leaching should receive more attention when nitrate removal with organic matter is considered.

Removal of phosphorus from drainage water using an enveloped tile drain

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In Dutch surface waters, phosphorus (P) concentrations are often too high and eutrophication is a major problem. Leaching of P from agricultural land contributes largely to the total P load of surface waters. However, with source-oriented measures such as equilibrium fertilization, in certain parts of the rural areas the primary objective of the Water Framework Directive will not be met. Additional measures are, therefore, needed that can contribute to improving the chemical surface water quality.

We tested the effectiveness for reducing P leaching of enveloping a drainage pipe with iron-coated sand, a side product of drinking water production from anaerobic groundwater. We previously tested iron coated sand in the laboratory and found that it can bind P very well (Chardon et al., 2011). The field test was conducted on a dune sandy soil in the flower bulb-growing area in the western part of The Netherlands, where high concentrations of P can be found in surface and drainage waters. Concentrations of P in the effluent of the enveloped drainage pipe was compared with the quality of the effluent from two control drainage pipes. Preliminary results show that the average treatment efficiency is around 94%. The iron-coated sand did not lead to increased leaching of iron; on the contrary, less iron was found in the effluent from the enveloped drainage pipe when compared with the results of the control drainage pipes.

We conclude that surrounding drainage pipes with iron-coated sand seems to be a promising measure to reduce P leaching.

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Comparative analysis of phosphorus load reduction measures

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According to the water quality assessment carried out in Hungary approximately half of the surface water bodies (rivers and lakes) do not meet the criteria of good ecological status because of different types of water pollution (VKKI, 2010). Phytobenthos, phytoplankton and general physico-chemical parameters, which are supporting the biological elements, were used as indicators for nutrient pollution. Most of the cases (35% of water bodies) nutrients, principally phosphate (PO4-P) and total phosphorus (TP) concentrations exceed the WFD limit values corresponding good status. Typically, the status of smaller watercourses and ponds is significantly worse than that of the larger rivers and lakes. Discharge of treated waste waters contributes to almost half of the total P emissions to surface waters. Major diffuse P load in the hilly areas attributable to high erosion potential. The nutrient load is significant only in those flatland agricultural fields, from which excess water is drained off, while problems are caused rather by wastewater discharges in the lowland area of the country.

Emission and transport model (Kovács et al., 2008) was performed for the whole country in order to estimate P loads as well as river concentrations. Case study catchments were selected for model calibration and validation. Some of these served as the bases for cost assessment (Clement et al., 2010). Location of potential P source areas with exceeding annual soil loss of 1 mm/ha (approximately 15 kg/ha) and with total annual P load exceeding 2 kg/ha were designated for the application of BMP measures. Annual costs of the different management practices were collected from the "New Hungary Rural Development Plan" (Tar, 2006).

Highest cost-efficiency has the P removal applied at WWTPs, but its unique application is usually not sufficient for achieving good status where the diffuse pollution from agricultural origin is important as well. Among agricultural BMP's land use conversion of the arable land to grassland/pasture is significantly more cost effective (efficiency: 10-90€/kgP/a) than forestation (60-500€/kgP/a), however its application is rather preferable by landscape ecology and less the costs. In hilly arable lands load can be reduced by 50-80% with erosion control, cost-efficiency varies depending on the applied means (35-130€/kgP/a). Riparian buffer zones can reduce loads arriving from the direct catchment area (20-160€/kgP/a). On the other hand, widening of floodplains has positive impact on the total catchment load by increased river retention. In lowlands the most important one among measures is keeping of excess water within the area in wetlands (20-40€/kgP/a.). Nutrient balances calculated from the county fertilizer statistics do not indicate such nutrient excess so that it would be realistic to suppose the further reduction of nutrient input. Therefore controlling of mineral and organic fertilizers was excluded from the evaluation of potential BMP alternatives.

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NP turnover studies on European and on Danube basin levels

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According to Webster's Dictionary, the description of "Union" is: "A uniting into a coherent and harmonious whole". This paper deals with the question whether the plant nutrition practice within the EU 27 countries fits to this description of "Union", or not. The answer to this question is distressing. Instead of a trend towards equalization in surface NP balances and soil NP status in the EU27 countries, a further and accelerated polarization has happened in the last 15 to 20 years resulting in severe environmental threats in some of the former EU15 countries, especially in Belgium and the Netherlands, and causing severe agronomic, social, and rural development problems in most of the new EU 12 countries. The Nitrates Directive seems to be ineffective in stopping the disadvantageous trends and converting them into the right direction.

In the opinion of the authors, there is a need for a paradigm shift in the EU agro-environmental protection legislation. As a summary, according to the opinion of the authors, only through a major restructuring the livestock distribution in the EU, and only trough a major restructuring of the export-import policy of agricultural goods, and the price policy of the agricultural goods within the EU, the aims of the various directives, strategies, and policies, and the new SPS system can and will be fulfilled.

Another study was conducted on the Danube River Basin level to estimate the contribution of the various factors (Population, Industry, Agriculture, Background) to surface water NP loads. This research was done in the frames of the Integrated Danube Research Program, funded by PHARE. Due to the introduction of untreated sewage directly into surface waters, the NP load contributed by population waste was especially high in Central Europe in the early 90s. The steps taken by the EU to protect surface waters have thus led to a dramatic reduction in point-source pollution caused by the NP contained in sewage. The same strict regulations should be inaugurated in the Western European countries and NUTS-2 regions with the highest livestock densities in order to diminish excessive diffuse NP loads into surface and subsurface waters effectively.

Predicting phosphorus losses with the model PLEASE in the acid Sandy region of Flanders

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Intensification of agriculture, with concentration of intensive livestock breeding and intensive horticultural cropping systems in certain areas in Western Europe, has resulted in excessive fertilization both with mineral fertilizers and organic manures especially between the 1970's and 1990's. This has resulted also in excessive P build-up in specific areas, and especially acid sandy soils are prone to P leaching. According to Van der Zee et al. (1990), an acid sandy soil is considered P saturated when the phosphate saturation degree (PSD) is > 25% (or when the P concentration in the shallow groundwater is > 0.1 mg o-P l-1.

Between 1995 and 1997 and intensive sampling campaign was launched to make an inventory of the PSD of acid sandy soils in Flanders (De Smet et al., 1996). This was used as a basis for enforcing strict P fertilization rules on P saturated soils. In 2009 and 2010, we revisited a number of locations, part of which were P saturated fields with severe P fertilizer restrictions, and part of which were not P saturated at the time of the first survey.

To investigate if the restrictions were effective and to have an cost effective instrument to evaluate the PSD status of the acid sandy soils in Flanders, the PLEASE model was applied. The PLEASE model is developed in the Netherlands (Schoumans et al., in prep) and has proven to be a efficient instrument in identifying critical fields/areas for P leaching.

In this study, firstly the possibilities are investigated for using the PLEASE model in Flanders. Secondly the comparability with the currently used instruments in Flanders and the PLEASE model are investigated. Thereby evaluating the best technique to identify critical areas in terms of P leaching.

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Factors affecting the definition of critical source areas in Mediterranean areas

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There is little information available about P loss from agricultural watersheds in Mediterranean areas, particularly in Spain. During the last decade, some studies focus on the study of forms and quantities of P loss related to overland flow has been performed. Some studies were also focus on the evaluation of these losses in some tree crops without soil cover. The study and control of P losses in Mediterranean environments must be link to the study of the erosion. Erosion has been identified as one of the main factors constraining future agricultural productivity in soils and evidences reveal that significant amounts of P can be lost associated to this process. As an example, in a small catchment in SW Spain, more than 9 kg P ha–1 were lost in only one storm event.

Some considerations can be made in the definition of areas with high risk of P loss in agricultural catchments based on the evidences obtained during the last years. The concentration in P and Fe is increased in sediments when compared with original soils. The P fractions related to Fe increase and those related to insoluble Ca phosphate decrease in sediments when compared with original soils. The ratio of Fe bound to poorly crystalline oxides to that bound to crystalline oxides is four times higher in sediments than in soils. All these evidences reveal that sediments are much more sensitive to reductant conditions than soils.

Under the same storm conditions, sediment loss and P forms and concentration in sediments is different depending on the soil. In general, Fe and P concentrations in sediments decrease at increased soil loss. Also the poorly crystalline to crystalline Fe oxides decrease at increased soil loss, with a clear potential effect on P release under reductant conditions. At a watershed scale, Alfisols tend to loss less soil and P than Vertisols. However, sediments of Alfisols are much more enriched in P when compared with original soil, meanwhile the P concentration in sediments is similar to that in original soils in Vertisols. Beside this, adsorbed and soluble precipitated P are the forms with the larger increase in concentration in sediments when compared with soil in the Alfisols.

Soil cover by crop decrease the risk of P loss. Observed P losses with winter wheat are much lower (about 4 times) than that observed with sunflower (spring sown) in the same soil.

The role of Phragmites australis in the nutrient retention at Hungarian part of Lake Fertő/Neusiedler See

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The nutrient concentrations of the aboveground and belowground reed organs, surrounding water and sediment interstitial water were analysed in an inhomogen reed stand of Lake Fertő/Neusiedler See, situated near the Fertőrákos Bay, where a 7.5 ha reed area was used for subsequent cleaning of the pre-treated wastewater. A quantity of 250 m3 day-1 and in summer 300 m3 day-1 wastewater was let to this area, which developed a 5 respectively 25 cm water cover. However the soil surface of the stand was uneven, the natural inclination of the area, situated between the inflow and outflow, allowed the slow, non-uniform throughflow of the water. The investigations started in 2003 before the introduction of the wastewater and lasted until 2004. The reed was harvested in winter of 2003/2004. Before the introduction of the wastewater there was no water-cover on the reed parcel.
The nitrate, dissolved organic nitrogen concentration of the water was higher in the inlet than in the outlet, the phosphate concentration decreased in the function of the increasing distance from the inlet area. The nitrogen and phosphorus concentration of the aboveground parts (leaves, culms and flowers) and the phosphorus concentrations in the belowground parts (root and rhizome) of Phragmites australis were higher in 2004 than in 2003, which indicated that more nitrogen and phosphorus was taken up and stored in reed tissues. Our results demonstrate the nutrient retention capacity of Phragmites australis and give a concrete bases about the functioning of a root zone wetland, created by little modification of the natural conditions and they are also important in respect with the protection of the natural values of the Lake Fertő/Neusiedler See. However the use of an almost natural reed parcel for phytoremediation needs further investigations because the excess of nutrients can exert a negative effect on the reed metabolism and may affect the health condition of the reed stands.

Water quality in Jiu River basin

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The Jiu River basin is located in South – West part of Romania, at 430, 45` - 450, 30` northern latitude, 220, 34` - 240, 10` eastern longitude. The altitude is 1,649 m in the northern part and 24.1 m in the southern part, at Danube join.

It stretches on a 10,080 ha surface of which 4,935.16 ha is arable, with a length of 260 km, the width being of 60 Km in the upper part and 20 km in the down part, crossing 4 districts: Hunedoara, Gorj, Mehedinti and Dolj. The populace within this basin is 1,461,661 inhabitants (6.6% of Romanian population). The Jiu River has 54 tributaries.

The rocks of this basin are made of silica and lime the age of the deposits being Miocene, Pliocene and Quaternary.

The water resources are of 4,059 million m3/year of which 2,109.5 m3 are used. Within Jiu River basin there are 67 lakes with an useful volume of 147.61 million m3/year and 69 paddles.

The applied fertilizer quantities within this area have been, in 2010, of: 7.9 kg.N/ha, 2.11 kg.P/ha and 743 kg manure/ha.

The domestic animals number is 458,800, with an average of 0.4 animal/ha.

Seventy eight percent of the total number of villages and communes from the area are vulnerable to nitrate pollution because of random disposal of animal manure and lacking of special channels for eliminating animal wastes and purification stations.

The analysis of the quality indicators of Jiu River Waters taken from 3 points and five dates during the year emphasizes the following:

the dissolved oxygen overpass the C.M.A. value of 9 mg/liter in the upper part and it decreases downwards, at the last point being under the C.M.A, of 8.9-6.9 mg/liter and it decreases since first determination in January, to the last one in November 2010;

The ammonium nitrogen is under the limit with all determinations as points and time of sampling;

The nitric nitrogen overpass the limit (1 mg/liter) with all points and time of sampling, being between 1.17 – 2.35 mg/liter;

The nitrous nitrogen overpass the limit (0.01 mg/liter) with all determinations as points of sampling and time of sampling, reaching 0.016-0.036 mg/liter;

The phosphates content is under the limit (0.1 mg/liter) with all points and time of sampling;

The heavy metals contents overpass the limit due to the fact that the Jiu River crosses an area with open cut and underground mines.

Estimating N and P emissions to surface water at national scale: methodology and first results

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WFD article 5 report for analysis of agricultural pressures and impacts aims to identify those catchments where prioritized nonpoint-source control measures should be implemented in order to achieve good ecological status by 2015. In France 2004 WFD article 5 report, analysis of nutrients pressures was mostly based on monitoring data and N/P balance assessment, as no emission model was available for application at national scale. Yet, WFD requires member states to develop new methodologies for the assessment of nutrient emissions at catchment scale for 2013 article 5 reviewed reports. Therefore, the French National Agency for Water and Aquatic Environments (ONEMA, French acronym) and French National Institute for Agricultural Research (INRA) are currently developing a model able to estimate N nonpoint-source emissions to surface water, using readily available data.

This model is inspired from US model SPARROW (Smith, Schwarz et al. 1997) and European model GREEN (Grizzetti, Bouraoui et al. 2008), i.e. statistical approaches consisting of linking nitrogen sources and catchment's terrestrial and river system characteristics. As the model will be run with national databases, the quality of estimation is expected to be better than GREEN's. The first expected improvement is due to the fact that nitrogen diffuse sources consist of a nitrogen balance instead of nitrogen input in SPARROW and GREEN. In addition, land characteristics (soils parameters, climate and riparian wetlands distribution) and river system characteristics (rivers, lakes and reservoirs' residence time and depth) are expected to be more accurately described when using national databases than European-wide harmonized databases. Finally, deep aquifers discharge to streams will be described as a separate runoff component like in the RIVERSTRAHLER model (Billen, Garnier et al. 1994), because the associated N fluxes cannot be directly derived from N soil surface balance.

Model calibration and validation on 200 French catchments will be performed by the end of 2011, and model run at national scale by mid 2012. The results presented here were obtained in Brittany region, where the model was first tested.

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Potential phosphorus (P) and nitrogen (N) leaching from a clay soil with varied past levels of excessive P inputs

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On average, Swedish arable soils are currently close to phosphorus (P) balance, but widely varying excessive P accumulation has taken place in the past on animal farms. Manure overloading is a particular problem on fur farms rearing mink (Mustela vison) and foxes (Alopex lagopus and Vulpes vulpes), although the P in such manure is sometimes regarded as sparingly soluble and less prone to leaching. However, laboratory trials with simulated rain on lysimeters containing heavy clay (60%) topsoil from a former fur farm indicate that potential leaching of P in dissolved reactive form (PL-DRP) can be very high.

A series of soil analyses used in the EU to map the risk of P leaching has indicated that soil P extracted with acid ammonium lactate (P-AL) is a better indicator of PL-DRP (Pearson correlation coefficient 0.94) than the ratio of P-AL to phosphorus sorption index (P-AL/PSI) (Pearson correlation coefficient 0.88) or the degree of P saturation in the AL extract (DPS-AL) (Pearson correlation 0.72). The DPS-AL index was found to be less useful for the mink farm soil, since the former sites of the fur cages had an increased content of easily dissolved iron (Fe-AL) and aluminium (Al-AL) without a corresponding increase in P sorption capacity. In addition, both PL-DRP and P-AL were negatively correlated to the clay content (Pearson correlation coefficient -0.67 and -0.71 respectively), as a result of coarser soil texture around the site of the most intensive animal keeping. Potential leaching of DRP was also positively correlated to leaching of total organic carbon (TOC) (Pearson correlation coefficient 0.85) but not to leaching of total nitrogen (TotN). An additional clear correlation was found between concentrations of particulate-bound P (PP) and turbidity in the leachate during simulated rain events (Pearson correlation coefficient 0.92) and to P-AL in the soil (Pearson correlation coefficient 0.67).

The upper 5 cm soil layer proved to be the main source (mean 74%) of PL-DRP at this site, which had been under grass and thus undisturbed for the past 8 years. Similarly the upper 5 cm soil was indicated to be the main source (mean 80%) of PP. On average, addition of pig slurry corresponding to the Swedish maximum permissible animal density increased PL-DRP by 45%, potential TOC leaching by 33% and the risk of TotN leaching by more than 300%.

Seasonal variability of phosphorus concentration and yield: comparison of agricultural headwaters in the Czech Republic

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While assessing impacts of different phosphorus sources on eutrophication of different water bodies, we should be aware of basic ecological or rather limnological constraints and relations. Then we can avoid framework of simple accounting, which mostly ignores temporal dynamics of nutrient losses as well as temporal dynamics of actual or potential impacts. Thus, it is firstly important to know availability of emitted P for uptake by algal cell, either benthic or planktonic. Meaning, to distinguish between dissolved orthophosphates and unreactive particles, at least. Beyond this, we also need to know magnitude of phosphorus emission. Meaning, concentration (rather SRP) is utmost measure for any uptake, because both processes, either passive diffusion or active transport depends on concentration gradient. But we also recognise load or specific yield (rather TP) as a proper way of comparison among other sources. Thirdly, timing is crucial for any game in which living creatures play a key role. It´s obvious that P emitted during winter freeze will differ in fate from P emitted during summer storm. Thus, two aspects of time need to be considered: season and duration.

Three above mentioned P source´s properties (availability, magnitude and timing) we understand as relevant components of basic information required for further eutrophication impact assessment. And exactly these three characteristics are aim of our study evaluating seasonal variability of phosphorus emitted from agricultural land in Czech Republic or, generally said, from most important non-point source.

During three years from 2007 to 2009 we sampled twenty profiles of evenly distributed headwaters within Czech Republic. Each headwater had to be exclusively agricultural eliminating any habitation as it is able to mask P load from land upstream. All headwaters were selected to represent proportionally major soil groups of CZ, because soil group reflects factor of climate, geology, topography, organisms and time (Dokuchaev, 1883). Monthly grab samples were analysed for both fractions of P (among others) and spot discharge were directly measured. Peak events were sampled by passive samplers.

Obtained results clearly show spring as a season in which most of P loaded during baseflow condition is emitted. Nevertheless, concentrations at this part of year belong to lowest, while summer ones were confirmed as highest. Also streams in major soil groups like Cambisols (all subunits) and Dystric Planosols had higher concentration of SRP and TP during most of the year, compared to minor groups like Luvisols and Fluvisols. Samples captured during increased discharge events had concentration of TP by several orders higher than those of baseflow (within the same headwater). However, comprehensive conclusion of peaks is disabled by the lack of continuous discharge measurement during unattended periods.

Although, our results proved agricultural land as less important in acute eutrophication than “first village” at downstream reaches, any decision of water management must be aware of possible chronic stress which can be raised by P release from sediment, when it became anoxic. Final assessment of eutrophication impact of phosphorus emitted from agriculture land must be inevitably and tightly join to context of individual evaluated water body.

Catchment response to nitrogen input reduction: how to estimate it and what are the transfer time and the response time of headwater catchments?

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Shallow groundwater that develops on hillslopes is the main compartment in headwater catchments for flow and solute transport to rivers, and therefore mainly determines the response time of the catchment to a reduction in nitrogen input (Molenat et al., 2008). As internal observations are not easy, a mean resident time (MRT) based on isotopic composition of stream water and determined by using lumped mixing models is often the only one indicator of the response time of the catchment. Many examples of such estimations are reported in the literature. Different approaches have been experimented on two intensive farming and subsurface dominant catchments located in Oceanic Western Europe (Kerbernez, Naizin, Brittany, France), headwater catchments included in the Observatory for Research on Environment AgrHyS (Agro-Hydro-System) and a part of the French Network of catchments for environmental research (SOERE RBV focused on the Critical Zone). These systems are strongly constrained by anthropogenic pressures (agriculture) and are characterized by a clear non-equilibrium status, i.e. a N concentrations in leaching different from those in groundwater. A network of 42 nested piezometers was installed along a 200 m hillslope allowing water sampling along two transects in the permanent water table as well as in what we call the “fluctuating zone”, characterized by seasonal alternance of saturated and unsaturated conditions. Water composition was monitored at high frequency (weekly).

Five approaches have been developed on these sites: i) the spectral analysis of natural tracer concentration times series (Molénat et al., 1999), ii) the groundwater dating with the CFC SF6 and other dissolved atmospheric gases (Ayraud et al., 2009), iii) the numerical modelling of water and nitrate in the shallow groundwater (Molénat et al., 2002; Martin et al., 2006; Gascuel-Odoux et al., 2010), iiii) the numerical modeling of agricultural practices, nitrogen soil transformation and transfer over the catchment with different scenario of agricultural practices and climatic conditions (Gascuel-Odoux et al., 2010), v) observations of the variations in nitrate concentration in the shallow groundwater during the recharge processes (Legout et al., 2009; Rouxel et al., 2011). The spectral analysis consists in identifying the transfer function from the cross-analysis of time series of natural tracer concentrations in soil water drainage (or rainfall) and in stream water. The transfer function can be considered as the transit time distribution of the tracer. The spectral analysis requires time series two to three times longer than the mean transit time in the catchment. The principle of groundwater age dating with CFCs (chlorofluorocarbons), organic man-made compound, is to calculate the CFC atmospheric mixing ratio from the CFC concentration in groundwater in order to deduce the year the water was for the last time in equilibrium with atmosphere. Numerical modeling consists in building an aquifer flow model and in deriving flowpath and velocity from the flow model. Theoretically, numerical modeling allows estimating transit times as well as residence times within the catchment. It requires a fine characterization of the aquifer hydraulic properties, as well as of boundary conditions, which is absolutely difficult due to their high spatial variations. Numerical coupled models consist in aggregating information and models on climatic conditions, agricultural practices, soil and aquifer characteristics and processes, to study their potential effect on nitrate output. It requires holistic information on agro-hydrosystems. Observation of the variations in nitrate concentrations in the fluctuating zone and in the shallow groundwater, allow us to study the mixing processes, particularly important in non-equilibrium status catchment, and the delay these processes imply on the response time of the catchment.

These different approaches will be compared and their limit discussed. All approaches lead to the same conclusion: the transit time in small headwater catchments can be very long, exceeding one year. However the estimations of catchment residence and transit times are different depending on the approaches. The four first methods under-estimate the solute transit time, because under-estimating the solute mixing processes in groundwater. Instrumented observatories including spatial and temporal monitoring of the hillslope groundwater are required to understand the anthropogenic and environmental processes and their interactions, to model and predict the effect and the response time of such systems under different constraints. Such methods do not take into account the social time required to modify the agricultural systems which only could be estimated by using observations on a large network of stream waters and agricultural systems.

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Phosphorus transport in the Fonte Espiño-Rego de Abellas watershed (Galicia, NW Spain)

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With the aim of estimating the dynamics of P loss from soil to water, eight different sampling points were selected in a sub-basin (Fonte Espiño – Rego de Abellas, ---Ha) within the Xallas river basin (Galicia, NW Spain), in which the soils are mainly dedicated to forest and grassland use (with high inputs of organic fertilizers). The water flow and concentrations of P (total phosphorus, TP; particulate phosphorus, PP, and molybdate reactive phosphorus, MRP) were measured fortnightly at these sampling points, over a period of 12 months.

The results showed that the flow rates were very variable and depended on the climate conditions, with an important reduction in the summer period, during which some sources of both rivers dried up. The concentrations of P were also very variable throughout the year; the TP values reached close to 0.30 mg L-1, so that the waters would be classified as category B (under Spanish legislation). The predominant form of P in the waters was PP, and the concentration of MRP was only higher than 0.03 mg L-1 (one of the limiting values considered for the start of eutrophication) on very few occasions at some sampling points. The highest concentrations of PP were obtained after intense periods of precipitation, which suggests that they are mainly derived from soil erosion.

Despite the high levels of precipitation, the intense agricultural management and the concentrations of TP observed at certain times and points in the watershed, which indicate transfer of large amounts of P from the soil to the water, the amount of TP lost annually in the watershed under study was not excessively high. The relatively low amounts of P exported suggest the action of a buffering mechanism within the rivers. Thus, it was found that some stretches of both rivers within the watershed act as sinks of PP as a result of sedimentation of fine particles transported by the water.

In summary, although the climate (characterized by a intense rainy periods) and soil management (addition of large amounts of organic fertilizers such as cattle manure and slurry) may have favoured P losses, the water flow processes, which favour sedimentation of fine particles, tended to minimize the environmental impact of these losses, so that the sub-basin did not appear to be an important source of P for the main river basin (Xallas).

IDENTIFICATION OF THE PHOSPHORUS SOURCES AND THE CRITICAL SOURCE AREAS: YENİÇAĞA WATERSHED CASE STUDY (BOLU, TURKEY)

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Objectives of our project are to determine (a) the source contributions to the P load exerted on a shallow eutrophic lake (Lake Yeniçağa), (b) the critical source areas causing the terrestrial diffuse P load in the lake watershed.

Phosphorus budget of the lake is established via mass balance method using the internal and external P loads, P content of the lake water, and the lake's P load output. External P load is determined by monitoring the P influx from the lake tributaries, atmospheric deposition, and the sewage pumping station discharges. Atmospheric P deposition is measured using wet-dry deposition sampling. Downstream creek is monitored to determine the P export from the lake. The lake water is analyzed for its P content. Automatic water sampling and flow rate measurement stations are installed on two major tributaries. The stations have flow-based schemes enabling more frequent water sampling during wet periods. All water samples are analyzed for orthophosphate, total dissolved P and total P using ion chromatography and inductively coupled plasma-mass spectrometry. The monitoring scheme is planned to span 24 months and the P budget is quantified on a monthly basis.

A P index, based on the Pennsylvania index (USA), will be developed to identify the critical source areas in Lake Yeniçağa watershed. An extensive soil sampling campaign is currently underway to assess the plant available P status of the cropland in the watershed. Geographical location of each sample is recorded using a handheld global positioning device. Since Olsen (0.5 M NaHCO3 extractable) P is typically used as soil test P in Turkey, the samples are analyzed for their Olsen P content using the spectroscopic molybdate-blue method. More than 40 composite samples have been collected and analyzed so far. Target sample size is 200. The results will be used to identify the potential source areas where detailed P index application will be performed.

The presentation will mainly include the digitally mapped Olsen P results. Preliminary P budget results based on September 2011 data will also be presented.

Spatial Validation of a Rainfall-Runoff-Phosphorus (RRP) model

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In many regions, diffuse Phosphorus (P) losses from agriculture are the main cause for eutrophication of surface waters. Studies in different countries indicate that these losses originate from a small portion of a given catchment only. The localisation of such critical source areas (CSA) is a prerequisite for the evaluation of efficient and cost-effective mitigation options and catchment models are a valuable tool to identify them. However, models are often validated only at the catchment outlet. Furthermore, an increasing number of studies suggest that different runoff types (infiltration excess and saturation excess runoff) need to be distinguished when modelling phosphorus losses. Artificial rainfall experiments that we carried out in 2008 showed for example that SER has the potential to mobilise P more strongly than IER.

Here, we report on a comparison of field measurements with predictions of critical source areas obtained by means of the Rainfall-Runoff-Phosphorus (RRP) model of Lazzarotto (2005). The RRP model is a parsimonious semi-distributed model that was in particular designed to account for fast transport of dissolved P from intensively used grassland soils by surface runoff and preferential flow to tile-drains. The model was calibrated using runoff data from 4 different sub-catchments of Lake Sempach, Switzerland. At the catchment outlet, measured and modelled runoff and P concentrations matched well. The calibrated model was then used to assess the quality of the spatial predictions within a different catchment.

For this purpose, we performed soil moisture and runoff measurements within a sub-catchment of Lake Baldegg, which is located in the vicinity of Lake Sempach on the Swiss Plateau and, like the latter, is characterised by intensive agriculture. Four permanent measurement stations were set up at different locations in the catchment. Each station is equipped with 12 TDR probes, 2 temperature sensors, one runoff sensor and a piezometer. Soil moisture is measured at 10 and 30 cm depth. These stations provide continuous data which show whether the model is able to catch the temporal behaviour at these locations. Further data are obtained from piezometers, runoff sensors and mobile soil moisture measurements, as well as from P analysis of water samples collected at the catchment outlet and further upstream. Based on the topographical distribution of the measurement points, we expect that the setup will allow us to assess the relevance of infiltration excess and saturation excess runoff in P export from the catchment.

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Quantification of nutrient sources and setting up the strategy against eutrophication in the upper Vltava River basin (Czech Republic)

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High concentrations of nutrients and concomitant eutrophication problems have been the primary cause of non-compliance of many water bodies in the Czech Republic with the ecological quality standards required by the Water Framework Directive. The current river basin management plans have stated at many localities that the good ecological status cannot be reached by 2015 due to "unknown" sources of nutrients and that more detailed investigations are needed to reveal the origin of pollution. Hence, we developed a simple steady-state model of water quality for the water quality managers that is based on the apportionment of measured export of pollution at monitored stream/river profiles among major types of sources in the catchment (diffuse sources, e.g., runoff from land use categories like forest, grassland, arable land, and urban areas; point sources, e.g., municipal and industrial wastewater discharges and aquacultures). The model is set up and calibrated within an interconnected network of medium size (usually <50 km2) sub-catchments that correspond to the monitoring profiles at streams and rivers where flow and water quality data are available. The calibration means mainly evaluation and checkout of input data, information about the diffuse and point pollution sources, and setting correct retention functions at the specific sub-catchments. This model was used to evaluate sources and transport of phosphorus and nitrogen in the upper part of the Vltava basin with the closing profile at the dam of the eutrophicated Orlík Reservoir (12,100 km2; 220 monitored profiles; 320 sub-catchments). The study demonstrated that the model has an ability to elucidate and quantify also previously unrecognised or neglected nutrient sources, which included in the Vltava basin mainly non-evidenced discharges of wastewaters, fishpond aquacultures, and high-density livestock facilities. Model scenarios of water quality under different intensities of pollution from the most important source types helped to set the strategy for the cost-effective abatement of eutrophication in the Orlík Reservoir. On the other hand, the ongoing feasibility study on the needed mitigation measures to reduce nutrient loads into the Orlík Reservoir to a non-eutrophying level indicates that many important changes of the national water management will be necessary, especially in the fishery management of fishponds, efficiency of nutrient removal in wastewater treatment plants, and control of farming practices (mainly to regulate erosion and livestock density and/or manure application). Also large and costly investments into the infrastructure of urban areas (sewerage, new treatment plants) and restoration of streams and wetlands to increase the retention capacity of landscape seem to be unavoidable.

A farm scale sustainable nutrient management decision support system that estimates fertilizer replacement value of livestock manure using weather and soil moisture status

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With the uncertainty of chemical fertilizer markets and stringent environmental policies to adhere to such as the Nitrates Action Plan implemented under the terms of the EU Nitrates Directive, farmers are looking for support to maximise the nutrient value of livestock manure. The Sustainable Nutrient Management Decision Support System (SNM-DSS) uses current and forecast weather, in conjunction with three defined soil drainage classes (well, moderate and poor) to calculate the soil moisture deficit (SMD) values for 10 x 11 km grid cells across Ireland. These data can be used to calculate recent and forecast N, P & K fertilizer replacement values using the ALFAM model. The model accounts for 3, 5, 7 and 9% DM slurry, application by either splash plate or trailing shoe and high or low grass height. Depending on the input from the farmer (or other users) the system will return graphic output for (i) the entire country if no site-specific data are provided (ii) generalised farm data if the local grid cell is specified or (iii) field specific data if field drainage class, slurry composition, slurry storage status and recent management history are provided. The system components, their integration and fundamental heuristics are described using the Unified Modeling Language (UML).

Testing Htbrid Soil Moisture Defficit model data as a key component for a decision support tool for sustainable nutrient management

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Agriculture is believed to have caused major water pollution in Ireland through the 1980s and 1990s. While the level of water pollution has stabilised with annual variations in water quality most readily explained by annual weather variations (McGarrigle et al., 2010), water bodies are still under pressure (Schulte et al., 2006; McGarrigle et al., 2010). In response to these issues, the concept of a Sustainable Nutrient Management Decision Support System (SNM-DSS) was presented during the COST869 WG4 meeting at Nottwil, Switzerland (Holden, 2009). The proposed decision support tool uses the Hybrid Soil Moisture Deficit (SMD) Model (Schulte et al., 2005) as its key component. It is a water balance model that predicts soil water status in terms of millimetres of rainfall required to restore the soil to field capacity. As part of the testing and validation of the SNM-DSS, spatial and temporal variations of the SMD model predictions and its relationship with farmer opinion of slurry spreading opportunities were investigated. Point SMD predictions calculated from meteorological data measured on farm were compared with continuous time series point volumetric water content (θp) and periodic observations of variation in field volumetric water content (θf) both measured by time domain reflectometery on a number of sites. In situ daily SMD were then related to the percentage of farmers "yes" answers to the question "Can slurry be spread today?". Linear regression of θ and SMD was significant for both point θp (R2 = 0.69 to 0.78), and periodic averages derived from θf (R2 = 0.67 to 0.86). Likewise farmer opinion of slurry spreading opportunities was correlated to SMD values. In general Farmers would not have allowed slurry spreading when the soil was wetter than field capacity and farmers would have agreed to spread liquid manure when SMD was greater than 10 mm, but large uncertainties were observed between field capacity (SMD =0 mm) and SMD = 10 mm. The trends indicate that the SMD model simulated temporal and spatial variations of soil moisture status at the farm field scale. Furthermore farmers seem to have acquired a mental picure for a soil moisture status threshold for slurry spreading between SMD = 2 mm and SMD = 6 mm. The results showed that the SMD model has great potential for use in a nutrient management tool, permitting a forecast of when gravity moveable water will occur in a field

Keywords: slurry spreading opportunities, SMD model, farmer opinion

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Contribution of drainage areas to P input of a small watershed in Upper Austria

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In Austria, phosphorus input of agriculturally used land into surface waters is frequently attributed to soil erosion. However, due to the high intensity of drained land in various regions, approaches in detecting hot spots of nutrient leaching into surface waters may also be needed. At present nutrient input via drainage and leaching is an unknown variable in Austria and it is difficult to extrapolate results of other European areas because of the different management intensities, and soil- climate conditions.

Testing all water influents of a headwater catchment within an intensively used farmland in Upper Austria, we estimated the contribution of drained areas to the total P loads of the area. The watershed was chosen because it is known to be a criticaI area for the 2015 WFD period due to high phosphorus contents. The tested catchment (260 ha) is partly drained and mainly used for maize, barley, wheat and rape. All incoming flow from tile-drainages and subcatchments were mapped (7 subcatchments, 25 inlets – tile-drains, wells). At two different discharge conditions snap shot sampling runs were done. During normal discharge conditions snap shot sampling was done in summer, the second campaign was run within a snow melt event in January. For all mapped inlets discharge was measured and water samples were taken to calculate loads and concentrations of phosphorus. Discharge was measured either using a salt dilution method or cylinders (when no upstream access was possible).

The two sampling campaigns from January and July were compared for total phosphorus loads at the catchment outlet, for the subcatchments and for percentage of tile-drain contribution. Discharge at the catchment outlet in summer was 43 l.s-1 , with a total phosphorus load of 19 mg P.s-1. During the snow melt event discharge of 186 l.s-1 was measured with P loads of 240 mg P.s-1. For the normal discharge conditions (summer sampling) 10% of the total phosphorus load could be attributed to tile-drains, this represents a percentage of discharge of 8.0% from total discharge. During snow melt (winter sampling) about 16% of the P load was leached from tile-drains which represents a percentage of discharge of 13.5% from total discharge at the catchment outlet.

So far, no clear conclusion can be made for detecting hot spots at this catchment, partly due to non-identified tile-drained areas, partly due to the totally different sampling conditions. A simpler answer might be that the area as such does not contain particular hot spots of P input, but P input is homogeneously distributed. Another sampling run in summer, with comparable discharge conditions is planned to obtain more information about spatially distributed P input.

Estimation of emission of nitrogen and phosphorus compounds from polish agriculture to the Baltic Sea

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Poland is a typical lowland country with the prevailing share of agricultural territory (61%) and agricultural land (51%), including arable area and smaller share of forests and grassland in comparison to other countries in Baltic Sea. Almost the whole area of Poland lies in Baltic Sea basin and is drained by two big rivers Vistula and Oder, from which one is flowing exclusively along the country territory and by 10 small rivers discharging directly to the sea. The area of the country cover of 18% in the whole Baltic Sea basin and population density determine about 45% of total population located in Baltic Sea basin. Polish agriculture is very dispersed and not satisfactorily provided with the sanitary infrastructure.

Among 7 the biggest rivers discharging water to Baltic Sea (Newa, Wisła, Niemen, Dźwina, Oder, Gota and Kemi) two of them – Vistula and Oder flow along the Polish territory. Taking into consideration the outflow of water, in the last 18 years two dry periods - 1990-1993 and 2003-2007, one period of moderate outflow, 1994-1997 and one wet period characterized by the highest water outflow, 1998-2002 can be distinguished. The total amount of water flowing into Baltic Sea from Polish territory was in the range 38 – 70 km3 · year-1.

The amounts of biogenic substances discharged yearly with river's water is extremely variable and correlate closely with the outflow of water. Correlation coefficient is much higher for nitrogen compounds (total N), R=0,81, than for phosphorus compounds (total P), R=0,56. There is also a significant correlation between amounts of both elements (N total and P total), R=0,67. Higher regression coefficient for nitrogen compounds and lower for phosphorus compounds justify the hypothesis that most of nitrogen compounds originate from dispersed sources and most of the phosphorus compounds from point sources.

The model of valuation of the share of biogenic substances losses, originating from different sources to Baltic Sea were used to the estimation of nutrient emission from agriculture (Fotyma and Igras 2009). The retention from natural and point sources both of nitrogen and phosphorus compounds is 40%, and from disperse sources 60% of nitrogen and 80% of phosphorus compounds. Using this figures the most probable contribution of different sources of biogenic substances in the total amount discharged to Baltic Sea is as follows: 20% of nitrogen and phosphorus compounds from natural sources, 65% of nitrogen and 56% of phosphorus compounds from disperse sources (practically from agriculture) and 15% of nitrogen and 23% of phosphorus compounds from point sources. Therefore the share of agriculture in pollution of Baltic Sea with biogenic substances is quite considerable.

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Lysimeter cooperation to lowering nitrogen input into surface and groundwater

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With the aim to implement the EU - Water Framework Directive, six German Federal States founded a cooperation to use long term lysimeter trials regarding the influence of different land management practices on nitrogen (N)-leaching. A further goal of this cooperation is the determination of the water demand for agricultural plants with simultaneous consideration of climate change effects.

Currently the main task is to find out soil-dependent measures and threshold values of N- balance to minimize water pollution with this nutrient. An other important part of this cooperation is the description of the leaching risk potential of the different soils and to implement these knowledge into agricultural practice.

The different lysimeter treatments vary depending on the leaching risk of soils and the site specific agricultural managements (e.g., arable and live stock farming, crop rotation, organic farming etc.). The lysimeter soils originated from loess and sediments from the geological Trias formation in middle Germany as well as from sandy and loamy deposits of the ice age in northeastern Germany. The lysimeter trials in the different states are focussing on the following treatments:

different agricultural management systems, which vary in plant rotation, mineral or organic
fertilizer application, with or without legumes
mineral or organic fertilization according to scientific based recommendations
plough and conservation tillage
deep ploughing of soils followed by stabilization with legumes
conventional farming
organic farming
crop rotations with and without catch-crops.

The poster will inform about the structure of the cooperation as well as present first summarized results regarding the influence of different agricultural management practices on N-leaching. Furthermore, the poster will give an answer to the following question: Where are the potentials and the limits of agricultural use to reduce the N-leaching into water resources?

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Using GIS to locate critical resources of water reservoir pollution from agriculture

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Soil erosion is the most important form of physical destruction of soils in Slovakia. Under the action of erosion factors it comes to topsoil layer eroding, the loose soil particles are further transported and accumulated in other positions down slope or they reach water streams. But the damage does not occur only in agriculture but also in other economy sectors, particularly in water management. Transported eroded soil particles can negatively influence the place of their accumulation not only by their volume (clogging of water reservoirs), but also by their physical, chemical and biological properties which differ significantly from the original soil (by means of nutrient concentration, heavy metals, pesticide residues, etc.). This is one of the reasons why the protection of soil and water should be integrated (Antal, 2005).

The aim of this paper was to propose a methodical process of determining the major sources of water streams and water reservoirs pollution coming from agriculture in the Širočina basin (Western Slovakia) using GIS. By means of GIS analysis tools, the average annual soil loss in the basin was calculated according to USLE (Wishmeier-Smith, 1978), which was reduced by sediment delivery ratio (Williams, 1977, in Janeček et al., 1992). We determined the estimated amount of loosened soil particles transported into water streams and 3 small water reservoirs in the basin (Kondrlová, 2009). The amount of nitrogen applied to arable land was estimated based on the data of crop rotations in 2004 and 2005. By the combination of input layers it was possible to determine the parcels within the basin with the highest application of nitrogen fertilizers and soil loss in the both years. This approach allows to locate and to focus our attention to the potential sites of sources of surface waters nonpoint pollution. It should be noted that even with high quality input data available, a modeled situation provides only a general idea about response of river basin management on the soil loss due to water erosion and sediment quality and quantity.

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The influence of eco-tourism and farming co-existence on the quality of East Mediterranean altered wetland soils and waterways

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Agmon Hula in Northern Israel is a small (1.1 km2) artificial lake that was constructed in 1994 in the formally swampy area that was drained for farming in the 1950s. Following the establishment of this new aquatic system huge flocks of Grus grus (> 50,000) and other avian have adapted this area for wintering or seeking temporary shelter on their seasonal migratory route to East Africa. To minimize the crop damage the Agmon & farming authorities have began a planned feeding in an area of 70 ha adjacent to the Agmon that may have added up to1.0 ton P annually to the system. The objective of this study was to evaluate the influence of this massive feeding operation on the P status of these altered wetland soils and waterways. We installed a series of shallow wells across the feeding area at two depths (40- & 90 cm) between two major waterways and monitored the hydraulic heads and collected groundwater samples for elemental analyses. We also collected sediments from the waterways and conducted sequential P extraction. We found significant increase in groundwater SRP (> 0.5 mg l-1) in 2010 compared with the period prior to the feeding (SRP ~ 0.05 mg l-1). On the other hand, we found significant decrease in Fe(II), Ca, and SO4 concentrations in the shallow groundwater in 2010 (15-, 100-, and 20 mg l-1 respectively) compared with the period prior to the feeding (60, 700, 200 mg l-1 respectively). The sequential extraction experiment showed a shift in P fractionation from mostly inorganic P in the period before the feeding to organic P and NaOH extracted P as well as significant increase in total P (~ 4000 mg P kg-1 sediment) in 2010. On the basis of hydraulic head monitoring, sediment analysis, and periodic grass harvesting of the feeding area we concluded that about 0.3 to 0.8 ton of P has been removed by the harvesting practice. The significant decrease of Fe(II), Ca, and SO4 suggest that the geochemistry of the feeding area has shifted from Fe-P sorption sink and Ca-P precipitation sink into P source that has been removed by harvesting with little impact on waterways.

Potential of phosphorus (P) release from eight catch crops

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Growing catch crops (cover crops) is an important option to mitigate nitrogen (N) leaching losses in the late autumn and in winter after harvest of the main crop. However, their efficiency in leaching losses of dissolved reactive phosphorus (DRP) and dissolved organic phosphorus (DOP) is uncertain and may vary between crop species and varieties. The crop and root may act as sources of P when the plant cells are burst by frost which is of special concern for countries with cold winter climate and many freezing-thawing cycles. A green house experiment was carried out to study the potential of P release from 8 catch crops: English ryegrass (Lolium perenne L.), cocks foot (Dactylis glomerata L.), chicory (Cichorium intybus L.), red clover (Trifolium pretense L.), white mustard (Sinapis alba L.), phacelia (Phacelia tanacetifolia L.), oilseed radish (Raphanus sativus L. var. Oleiformis), and a variety of the latter specie, structurator (Raphanus sativus L. var. Longipinnatus). The root and shoot parts of the catch crops were separated at harvest. The roots were scanned for the morphology parameters: total length, total surface area, and specific surface area. Dissolved reactive P (DRP) and total P (TP) were extracted with water from root and shoot samples which had undergone different freezing (-thawing) cycle modes. Extractions (including control) were made after 4 continuous freezing-thawing cycles, after each of the 4 continuous freezing-thawing cycles, and after 3 continuous freezing days and l thawing day. The results were evaluated together with a laboratory leaching experiment with topsoil lysimeters and natural grown catch crops.

Development of hydrological adaptation strategies with consideration of climate change and increasingly globalised markets

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The German Ministry of Science and Education (BMBF) sponsores from September 2010 until August 2015 the interdisciplinary research project "Sustainable Land Management in the North German Lowland – NaLaMa-nT". The aim of the project is to develop a knowledge and decision basis for a sustainable land management concept. This strategy will be tested in four representative model regions in a west-east transect in the northern part of Germany (from the Dutch-German border administrative district Diepholz via Uelzen and Flaeming in the central part to the district Oder-Spree at the border to Poland). The scientific work is divided in 21 subprojects dealing with climatology, water management, agriculture, forestry and socio-economic aspects. The poster will inform about the structure of the project and will focus on water management activities in the sensitive area Flaeming. This area is important for the agricultural production as well as for the drinking water supply of the region. Thus, two stakeholder conflicts exists: (1) protection of raw water quantity and quality that is needed for a sustainable supply of drinking water to the region according the EU Water Framework Directive and (2) warranty of a sustainable agricultural production under the conditions of climate change and globalised markets. A bottom up strategy is displayed which focused on the measuring of hydro-pedological data at different agricultural and forest sites and the scaling up of these data to model realistic scenarios for sustainable land management strategies for the investigated region.

Spatiotemporal variation in groundwater nitrogen and phosphorus in two agricultural river catchments

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In agricultural river catchments with permeable soils there is evidence that sub-surface pathways need to be considered for both diffuse nitrogen (N) and phosphorus (P) transfer. Stream water chemistry is reflected by groundwater chemistry not only during baseflow conditions, but also during event flow when a major fraction of both N and P loads were interpreted to be delivered from sub-surface pathways. In order to minimize N and P transfer from groundwater to surface water we need to understand how sub-surface water may vary in time and space, as well as how it may be linked to sources, water recharge and temporal changes in land management. The Agricultural Catchments Programme (ACP) is providing scientific evidence needed to support Irish agriculture in meeting the requirements of the Water Framework Directive (WFD). A 'nutrient transfer continuum' from source, through pathways, to delivery and impact in a water body receptor is used as a framework for evaluation of the European Union Nitrates Directive regulations and the Surface and Groundwater regulations. In this study we present one and a half years of data of N and P concentrations in groundwater of different strata, monitored through multilevel monitoring wells on four hill-slopes within two c. 10 km2 agricultural catchments with permeable soils. One with arable land overlying slate bedrock and the other with intensively managed grassland on sandstone. We investigate possible links between sources, groundwater and surface water to support mitigation action. The grassland catchment was more hydrologically and chemically buffered than the arable catchment. The latter showed a relatively quick response and transfer to the stream via strata of weathered bedrock. Effects of temporary changes in management were observed in the groundwater quality but with a delay of c. five months. The grassland had elevated nitrate-N concentrations and showed more spatiotemporal variability. The nitrate-N was highest in the near-stream shallow strata and there were indications of denitrification with depth. One site was N buffered in the near-stream zone, but this zone was bypassed with high nitrate-N content water from the uplands via subsurface drains. Even though the soils were not P saturated the groundwater was elevated in orthophosphate concentrations in both catchments, and mostly so in the near-stream groundwater. The processes of P enrichment of groundwater needs further investigation however soil permeability and/or P saturation alone are insufficient indicators of the risk of P delivery to streams. Current monitoring patterns in Ireland have detected instances of elevated P in locally important aquifers. We stress the need to understand the integrated effects on groundwater quality caused by spatiotemporal variability in recharge and land management.

Mitigation options for reducing nitrate leaching from grazed dairy pastures in southern New Zealand.

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There are a number of mitigation practices ("Best Management Practices", or BMPs) currently available that can reduce the impacts of intensive farming on water quality. However, each mitigation measure differs in its effectiveness, cost and likely impact on those waters, depending on factors that include soil type, climate, topography and the regional sensitivity of water bodies. Consequently, it can be difficult for land managers to select a mitigation measure or combination of mitigation practices which are most appropriate to their farm. To address this problem, a Toolbox of Best Management Practices has been assembled with a suite of options, an assessment of their cost and effectiveness, and an indicative ranking of where expenditure should be prioritised to ensure that maximum benefit is obtained for each dollar invested. Here we describe how this tool has been used to guide farm management decisions aimed at reducing N leaching losses from dairy farms in southern New Zealand. Management strategies that target urine N deposited in autumn or winter appear to be the most cost-effective options for reducing N leaching. Such practices include applying the nitrification inhibitor dicyandiamide (DCD) to pastures, off-paddock wintering of cows, or restricting pasture grazing times during autumn. Wetlands are another cost-effective option for attenuating N in land drainage, although their efficiency depends on the degree to which drainage flows can be intercepted. In contrast, management strategies that involve changing land use to less intensive dry stock farming systems or reducing dairy cow stocking rates are strategies that incur large opportunity costs and thus have relatively low cost-effectiveness.

Managing cattle slurry application timings to mitigate diffuse water pollution

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Around 47 million tonnes of livestock slurry supplying c.210,000 tonnes of nitrogen (N) and c.50,000 tonnes of phosphorus (P) are applied to agricultural land in the UK each year. Efficient utilisation of manure nutrients is essential to reduce diffuse water pollution. Indeed, organic manures are considered to be one of the main causes of controllable nutrient pollution in UK farming systems.

This paper summarises results from a drained clay soil study site in Oxfordshire (England) where the impact of different slurry application timings (autumn, winter and spring) on losses of agricultural pollutants to water (nitrate, ammonium and phosphorus) were quantified over four drainage seasons. The autumn slurry applications to arable land presented the greatest risk of nitrate-N loss to drainage waters ($P<0.05$), with losses in the range 8-11% of total N applied compared with 2-6% of total N applied from the winter timings. However, ammonium and P losses in drainage waters following autumn slurry applications were low. In contrast, slurry applications in winter and spring resulted in elevated ammonium and P concentrations/losses in drainage waters, reflecting the rapid connectivity between the soil surface and field drains when slurry applications are made to 'wet' soils.

The results from this drained clay soil study site show that spring slurry application timings present the lowest risk and autumn timings the highest risk of nitrate leaching loss. However, slurry applications to 'wet' soils, particularly in winter, but also in spring, are likely to result in elevated ammonium and P concentrations in drainage waters (an example of 'pollution swapping'). In order to minimise the risks of diffuse water pollution, farmers will need to ensure that they have sufficient over-winter slurry storage capacity to provide the flexibility to spread slurry when soils have dried out sufficiently in spring (i.e. ideally when the soil moisture deficit is >20mm).

Measures, methodologies and tools for a sustainable agricultural management: Experience and preliminary results from Greek catchments

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Agriculture is by far the largest consumer of freshwater resources in Greece, accounting for nearly 90% of the total abstractions for irrigation purposes and at the same time the main responsible for setting water bodies at risk of not reaching targets set by environmental legislation due to high nutrient (Nitrogen (N) and Phosphorus (P)) concentrations. Water scarcity and drought, land desertification due to soil erosion and water shortages as well as sediment and nutrient water pollution are major environmental concerns in Greece, a country with typical geoclimatic conditions of the Mediterranean area with rough topography, erosive soils and uneven precipitation distribution with extreme rainfall and flush-flood events. These concerns become greater in areas where farming practices such as extensive irrigation, deep soil tillage, high chemical fertilization and manure application, high livestock stocking rates and over-grazing have been identified as potential pressures deteriorating the quantity and quality of water bodies. In order to address these pressures and reach a “good ecological status” of water bodies (ideally, although improbably, by 2015), it is essential that agricultural Best Management Practices (BMPs) be included in the Programs of Measures (PoMs) of the River Basin Management Plans (RBMPs). However, a key element of these plans is the cost-effective implementation of such practices at the river basin scale in order to meet the required multiple objectives related both to the good status of water and the maintenance of the high economic value of agricultural systems for farmers.

Working on this field of research, the authors have already developed and used novel tools and methodologies that promise to assist in the development of a sustainable agricultural management planning in Greek river basins, where there is urgent need for dealing with the problem of data scarcity in a consistent and efficient way, as well as for meeting the notable delays in the implementation of the environmental legislation. Distributed models have been developed for several basins, which have indicated the most suitable locations for BMPs implementation, based on comprehensive model validation approaches that face the problem of data limitations and provide a solid and reliable basis for testing the effectiveness of different measures. Great efforts have also been made to develop economic instruments for costing measures at the river basin scale, incorporating BMPs implementation cost and income reduction, thus enabling the calculation of the cost-effectiveness of measures and scenarios against multiple environmental objectives. Moreover, decision support systems have been developed by combining models, economic data and robust evolutionary algorithms in order to enable the identification of the most cost-effective BMP allocation schemes across the agricultural land of river basins. This study presents the most recent results produced from the implementation of these tools and methodologies in catchments of Central and Northwestern Greece and concludes that the combination of distributed physically-based models with socio-economic data, decision support tools and possibly with novel products of the satellite/remote sensing technology can be the next step in decision-making for quick and accurate environmental predictions and acceptable agricultural management solutions in river basins.

Spatial and temporal dynamics of nutrient fluxes in aquatic ecosystems of the Dambovnic catchment

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It is well documented that changes occurred in the development of the socio-economical systems lead to changes in the quality and quantity of water resources. One of most severe problems of aquatic ecosystems consists in the increase of nutrient loads and their evolution towards eutrophication. This process is strongly related to diffuse nutrient emissions and agriculture is the main contributor to this kind of pollution. Therefore, lot of effort is put to improve the knowledge on sources, fate, stocks and sinks of nutrients at catchment level in order to elaborate proper management plans for protection of the surface waters and groundwaters. An intensive study was carried out at the level of Dambovnic River, aiming to characterize the spatial and temporal dynamics of nutrient fluxes in correlation to the catchment hydrogeomorphological characteristics and to obtain an improved process-understanding of nutrients pathways. Dambovnic River is a third order tributary of Danube River, previously characterized by high specific nutrient emissions. The monitoring program was conducted over a two year period and revealed the influence of point and diffuse emission sources on nutrient loads as well as of local particularities of adjacent ecosystems. Although the nitrogen specific emissions were not high at the catchment level, increased concentrations of ammonium were identified upstream the river (up to 15 mg N-NH4+/l), being correlated with the industrial discharges of waste water. Total nitrogen showed a seasonal dynamics, especially downstream the river and its concentrations were below 20 mg TN/l. Phosphorous levels were often exceeding the limits for very good and good quality of surface waters and reached very high values during summer periods (up to 1 mg P-PO43-/l). Key factors influencing both nitrogen and phosphorous dynamics were investigated. Regional nutrient balance was developed and MONERIS model (MOdelling Nutrient Emissions in RIver Systems) has been applied in order to identify the main pathways of nutrients, the area specific emission and share of nutrient emissions by anthropic activities in the basin. The results of the mathematical modeling revealed the contribution of both point and diffuse sources to the nutrient load of the river. Waste water treatment plant is the main pathway for nitrogen, which is characterized by the highest area specific emission in the upper part of the Dambovnic catchment. The highest phosphorus emission stems from agriculture, which accounts for more than 50% of the total with the exception of sub-cathment located upstream the river (Suseni), characterized by equal contribution of agriculture and point sources (industry and population). Mathematical modeling proved to be an useful tool in the assessment of nutrient balances at catchment level and an important steps towards a comprehensive control of nutrient fluxes and development of sustainable management plans at the regional scale.

Effect of hydrological connectivity on nutrient availability and primary production patterns in Danube floodplains.

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Aquatic primary production is a key property for the ecological functioning of riverine wetlands. Autochtonous organic matter derived from local primary production is commonly more labile and easier to assimilate than allochthonous carbon from the catchment and is expected to be a crucial carbon source for riverine food webs. As a consequence aquatic primary production is of high importance in nutrient uptake and self-purification processes of the whole riverine landscape. In the Lobau, an urban riverine wetland within the city limits of Vienna, Austria, nutrient availability is determined by external and internal processes in relation to the hydrological connectivity pattern. The wetland is a back-flooded lake system where the hydrological connection with the main channel of the River Danube is limited due to flood levees and is established up to 137 days per year in the lower parts of the Lobau. It comes along with high nutrient input which, combined with still sufficient light availability, provides optimum conditions for algal primary production. As a consequence, phytoplankton is dominating aquatic production and the nutrient retention potential is high. In isolated or low connected parts of the wetland, macrophytes become more important, as connection with the river is established only during floods and nutrient inputs via the river are rare. Internal processes like anoxic phosphorus release by the sediments are of some importance for algal primary production.

Integrated approach to improving water quality in Ireland

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Eutrophication is a key challenge in Ireland to achieving the objectives of both the EU Nitrates and Water Framework Directives with agriculture and industrial water discharges among the main pressures. Mitigation measures under the Nitrates Directive regulations are the mechanism for improving water quality from agricultural pressures. These constrain the magnitude and timing of nutrient management on agricultural land to minimise losses. The efficacy of these measures is being evaluated through the Agricultural Catchments Programme using the source-delivery-impact design in six benchmark agricultural catchments across a land use and soil type gradient (Fealy et al., 2010; Wall et al., 2011). It focuses on high spatiotemporal resolution monitoring of aspects of the nutrient transfer continuum, these data, in conjunction with other national inventories of pressures and water quality impacts, will guide expectations on the immediate and long term benefits accruing from the regulations. While these national inventories indicate a decline in agricultural nutrient source pressures the catchment studies highlight differential nutrient mobilisation potential, especially on low permeability soils. Even in agricultural catchments, the nutrient impact on river ecology may also be influenced by rural point sources and especially in ecologically sensitive summer periods during low flow and when diffuse pathways are disconnected. Concurrently, a decision support tool, for nutrient optimisation, is being developed using current and forecast weather across three defined soil drainage classes (well, moderate and poor) to calculate the soil moisture deficit (SMD) values for 10 x11 km grid cells. These data are used to forecast potential a transport vector and slurry N, P, K fertilizer replacement values. A farmer can evaluate whether a decision to spread is likely to (i) lead to unwanted nutrient loss due to runoff or leaching and (ii) maximize the fertilizer replacement value. While there is no plan for the tool to replace legislative restrictions, if used it should increase nutrient management efficiency and reduce environmental losses. The policy expectation of reductions in nutrient loadings as a result of the mitigation measures will also have to be considered in terms of physiographic variability including soil nutrient status, soil hydrology, hydrogeology, meteorology and current water quality status. These factors result in a time lag between nutrient reduction at source and water quality response. Nitrate (NO3) and phosphorus (P) are typically differentially transported by leaching and surface/near surface flow, respectively. Time lag for NO3 includes the times for leaching through the unsaturated zone, movement through the aquifer and aquifer dilution; time lags can range 7 to 16 years for unsaturated zones <3m (Fenton et al. 2011). Phosphorus time lags include depletion of soil test P (STP), transport to receiving water and reduction of in-stream P. Depletion of STP is related to the initial total soil P content, STP and soil P balance. Estimated average time lag for STP to decrease from high to agronomically recommended was 7-16 years but may take >20 years (Schulte et al 2010). WFD expectations need to recognise the potentially long time lags involved in mitigation measure effects.

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Using nitrification inhibitors to reduce nitrogen losses

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The steady increase in the cost of N fertiliser on farms has resulted in a renewed interest in methods to improve the utilisation efficiency of N sources such as fertiliser, manure and faeces/urine from grazing animals. Improving N efficiency reduces farm input costs and N losses to the environment. The main N losses with negative impacts on the environment are nitrate (NO3) leaching to surface and groundwater and gaseous losses of ammonia (NH3) and nitrous oxide (N2O). Losses of N through NO3 leaching and denitrification occur when NO3 is present in the soil. Nitrate is produced in the soil through nitrification, which is the enzymatic conversion of ammonium (NH4) to NO3 by soil microorganisms. The rate of NO3 formation in soil can be reduced by using a nitrification inhibitor to reduce the activity of specific soil microorganisms. There are a number of commercial sources of nitrification inhibitors, with dicyandiamide (DCD) being commonly used on grassland in New Zealand. Nitrification inhibitors are effective when applied directly to the soil or in combination with organic or ammoniacal N sources. Experiments examining the use of DCD with urine, fertiliser and manure N sources have been conducted at Johnstown Castle in collaboration with Lincoln University New Zealand, AFBI Northern Ireland and Teagasc Moorepark over the past 5 years. Recently our research has shown that DCD significantly reduces NO3 leaching from urine patches by approximately 40%. Current legislation for acceptable NO3 levels in waters is based on concentrations and thus the finding that DCD significantly reduces peak NO3 concentrations is important. Our research has shown that the use of the nitrification inhibitor DCD can reduce environmental emissions of NO3 and N2O. These N savings would be expected to result in increased herbage DM production, due to the higher N availability in the DCD treatments. Here our results have been conflicting. Although DCD consistently increased herbage N content, there was no consistent effect on herbage DM production. Lysimeter studies have shown that DCD increased herbage DM by up to 35% on a free draining soil under low fertiliser N inputs, but there was little response at high fertiliser N rates. Incorporation of DCD with band spread slurry significantly increased herbage DM production by 5.5% in one of the two year studies. At Moorepark, low herbage DM response to DCD has been reported. Variable responses to DCD on herbage DM production have been reported in New Zealand, from 1 to 21%. The effect of DCD on herbage production appears to be more pronounced at low N fertiliser inputs, due to lower soil N availability and thus a greater impact of N saved from loss. Nevertheless, it is under high N input situations that DCD can reduce the environmental impact of Irish agriculture. Inhibitors are a useful technology to reduce environmental N losses occurring within Irish agricultural systems. Reductions of NO3 leaching and N2O emissions of up to 70% are sizable but currently in Ireland there is no financial benefit associated with the reduction in environmental emissions. The agronomic benefits are less clear, but there appears to be increased agronomic responses at low N fertiliser rates.

Interactions between agricultural practice, mobility and retention of P in soils

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In Denmark 1400 kg P per ha have accumulated in agricultural soils during the last century. This P is an important resource for agricultural production, and agricultural management should aim at efficient utilization. This P has also raised the potential for P export to the aquatic environment – an export which should be reduced.

In a joint project under the research program "Animal Husbandry, the Neighbors and the Environment" under the Danish Ministry of Food, Agriculture and Fisheries, we have investigated: (1) how phosphorus leaching from the plough layer is affected by agricultural management practices such as manure application method, soil tillage and liming (2) how the accumulated P distributes in the soil profile, (3) the certainty of the Olsen soil P test, how it performs as a predictor for P leaching and how it develops over time under different P input scenarios on different soil types.

Our aims were: (1) to gain better understanding of the soil processes governing P leaching from the plough layer and P redistribution in the soil profile and (2) to gather information, which can be used for devising best management practices for mitigation of the P losses through tile drains to surface waters.

In leaching studies on intact soil columns (20 by 20 cm) we showed that P leaching generally increased with increasing soil P status, and that dissolved P forms dominate in the effluent at higher soil P status levels. Slurry application method and timing of soil tillage had pronounced effects on the soil leaching potential especially on structured soils. In the soils examined here P leaching was less in the limed treatment, even though lime had not been applied recently to the limed treatment.

We also examined further previous findings, which showed that ca. 50% of the accumulation of P in agricultural soils in Denmark seems to take place below the plough layer. We demonstrated that this subsoil P accumulation seem to be related to carbon content in the subsoil.

The model for prediction of Olsen soil P test values in yearly time steps from knowledge of net P input to the field, the soil type and the present Olsen P value is still ongoing, but preliminary results and ideas will be presented in the poster.

Application of the phosphorous leaching model PLEASE at the regional scale

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High soil phosphorus contents in agricultural soils in the Netherlands cause excessive losses of phosphorous to surface waters. Current national phosphorous reduction policies are insufficient to reach the water quality standards set by the European Water Framework Directive in all catchments by 2015. Accordingly, additional measures have to be considered at the regional scale to further reduce phosphorous loadings to surface waters. For a cost effective implementation of these measures an instrument to identify critical source areas for phosphorus leaching is indispensable. In the Netherlands phosphorus leaching at the national scale is simulated with a comprehensive mechanistic simulation model (STONE, Wolf et al., 2005) focusing on changes in phosphorous leaching with time. The identification of critical source areas requires simulations at a high spatial resolution (field scale or smaller). STONE is less suitable for this purpose, because of the large number of input parameters required by this complex model. For this reason, a simple model (PLEASE: Phosphorus LEAching from Soils to the Environment; Schoumans et al.,subm.) has been developed based on the same mechanistic process description for inorganic P as the complex model STONE and a simplified description of the lateral flow of water from soil to surface waters. With this model phosphorous leaching to surface waters can be calculated using readily available information of field characteristics like depth of the groundwater table, precipitation surplus, phosphorous status and phosphorus adsorption capacity of the soil (Schoumans et al., subm. Van der Salm et al, 2011).

The model was applied to four Dutch catchments with contrasting hydrology, soil types and degree of phosphorus saturation of the soils. A soil sampling program was carried out to obtain input data on P binding capacity and P status of the soils. In each catchment 70 sites have been sampled. The sites were selected based on spatial coverage sampling. To calculate the P discharge from the catchments two approaches were followed: (i) PLEASE was applied to each of the 70 sites and the results were averaged to obtain an estimated of the P leaching of the catchment and (ii) the soil input data were interpolated to 25*25 m grids, followed by modeling the P leaching for each grid. The results of both methods were compared with the measured discharge. For one of the catchments the implications of the manure policy of the last decade and the expected effect of the reduction in P surpluses on the discharge in the forthcoming decade is shown.

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Possibilities of regulation of surface outflow characteristics with change of soil surface roughness

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Erosion control or flood protection measures are frequently designed according to discharge or volume of surface outflow. To estimate these values, it is necessary to know the depth and velocity of surface outflow, which are functions of total precipitation, respectively of rain intensity, slope angle and slope length, soil characteristics and land use as well as of soil surface roughness. The roughness value is defined as rate of disturbance or irregularity of the soil surface at such a scale which is generally too small to be captured by conventional topographic maps. It is described predominately with table values as Manning, Bazin or Random Roughness index, which is calculated as standard deviation from surface irregularities by roughness clinometer. Recently, this method is replaced by photogrametric measurement resulting in point clouds (X,Y,Z), which describe given surface disturbances with very high resolution. Repeated screenings enable us to quantify the change of soil surface roughness during the vegetation period, which do not need to have always decreasing tendency. Significant influence of soil surface roughness on characteristics of surface outflow grounds in the fact, that roughness elements on the slope frequently exceed the depth of surface outflow which is then forced to flow off these elements. At the same time, surface roughness can be relatively easily and unassumingly changed by human activity.

Rills switch catchments into a higher P-load mode - a case study

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The water quality of Lake Balaton had improved after the various interventions to reduce external P load between the late 1970`s and early 1990`s. However, the improvement seems to have reversed in the recent years and hypertrophic conditions can be frequently observed during summer period in the shallow water near the shoreline. The bad water quality is also not uncommon in the open water in the Keszthely- a Szigliget-basin. Further reduction of the external P load must be pursued to achieve WFD targets.
The loess derived and eroded soils in the southern watershed of the lake are largely under agricultural cultivation. The Somogybabod study catchment (7 km2) belongs to the catchment of the Tetves stream that drains approximately 80 km2 into the lake. Only 35 % of the study catchment is arable land the rest is woodland, orchards and bushes along the ephemeral stream in the valley bottom. The rainfall and water level is continuously monitored at the outlet of the catchment, samples are automatically taken during runoff events and later, runoff, suspended sediment an phosphorus load are calculated. The arable land was monitored for basic soil properties and 61 surface soil samples were collected. We conducted laboratory experiments with them to simulate erosion processes and P load. We analysed the data from 2006 in this study. A short but heavy rainfall on 29th June 2006 resulted in excessive runoff and erosion and formed several rills on the arable land. The rills were monitored on the field for depth and cross section, and soil bulk density was measured beside the rills, the length was derived from satellite images and the calculation was partly controlled by GPS measurements. Aerial photos were used to digitize strongly eroded spots on arable land which are white from high calcium-carbonate content in dry condition.
The calculated soil loss from rills was comparable with the exactly measured sediment loss at the outlet. However, total P concentration of the sediment indicate that bulk soil en-masse was eroded only at the very beginning of the runoff event, and later on, P-enriched soil was delivered due to the partial settlement of the particles. We calculated that at least three times more soil eroded originally from the surface than we could measure at the outlet. Partial coincidence of strongly eroded spots and rill heads indicate that periodical rill formations significantly contribute to the erosion and P load from the catchment. Comparison of the runoff events before and after the rill forming event reinforces the existence of elevated P transport due to the improved connectivity. SWAT model runs confirm the observations that with rills, slight footslopes will produce much less runoff and erosion while steep slopes in shoulder position produce more.
Our conclusion is that prevention of rill formation must be a priority tool to reduce P load into Lake Balaton and to achieve WFD target.

Approximative P index calculation to predict total P in rivers of CEE countries

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Recent changes in agricultural practices and their impact on the trophic status of surface waters in CEE countries have been evaluated using a few selected pressure and state indicators (phosphorus balance, phosphorus status and erosion of agricultural land, tentative P index, chlorophyll-a, total and phosphate phosphorus content of water) by compiling and analysing data from the literature.

The P index method was developed in the USA for assessing the environmental effects of agriculture (Sharpley et al., 2003) and has also been tested in Europe (Hethwaite et al., 2005). The P index contains a small number of carefully selected source and transport factors. The dataset compiled in the our study for the CEE countries does not allow a precise calculation of the P-index, but ve had data on P balances and on the degree of erosion which make it possible to calculate approximative indices for P loads. We applied a: weighting factors of 1, 3 and 5 for light, moderate and strong erosion, respectively, and these were multiplied by the corresponding area percentages and summed up for each CEE country. The annual average P balances from the 1980s were considered as an indicator of the long-term P surplus in agricultural soils and this was multiplied by the calculated erosion index. The resulting tentative P index was plotted against the total P concentrations in the rivers. Although the compiled data are extremely diverse in space and time and were often calculated using different methods, a significant positive relationship was found. Only 11 percent of the variation in TP for the rivers should be attributed to the tentative P index, i.e. to the impact of differences in the agricultural non-point source P load, which increased in the order: Estonia, Romania, Poland, Latvia, Slovakia, Bulgaria, Czech Republic and Hungary. This is confirmed by the fact that, according to Vollenbroek (1994) the contribution of agricultural diffuse P loads to the total P loads entering surface waters in the Danube Basin countries (which are mostly CEE countries) ranges from 9-10% in Slovakia, Croatia and Hungary to 28-40% in Romania, Austria, Germany and Slovenia. Our conclusion was the even very approximate data and calculation may be used as relevant indicator for water quality if data consistency is ensured. Thus, environmental statistics must be steered toward harmonization and toward collection of more environmentally relevant data.

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INFLUENCE OF AGRICULTURAL PRACTICES ON GROUNDWATER QUALITY

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Groundwater chemical composition depends on natural factors mainly influenced by the soil type, geological profile, as well as very often it is influenced by loading from fertilizers, septic systems and livestock wastes because of the specific hydraulic and physical properties of the overlaying soils.
This study was made on the territory of a small watershed at the experimental station - Tsalapitsa in South Bulgaria on Fluvisol. Fluctuation of the shallow groundwater table was monitored at three permanently built piped drilling wells and samples for chemical analysis were taken monthly. The assessment of groundwater chemical composition is based on data for the period 2005 - 2010 years, when different types of agricultural crops were grown and also there was a change in the loading with fertilizers of the watershed.
Nitrate content in the groundwater was influenced by the reduced anthropogenic loading with fertilizers and it could be seen a trend in nitrate concentration decreasing during the last years from the monitoring period when nitrate concentrations are around and below MPCL. The highest nitrate concentrations were measured during spring-summer months. It was observed a correspondence between the dynamics of NO3- and K+ content and the same trend of temporal fluctuation of both elements i.e. variation in these elements under this particular soil have one and the same origin. Calcium concentrations in groundwater vary in considerably short limits, although the variation is not so significant, fluctuation corresponds with this of the nitrate content.

Key Words: chemical elements, groundwater, anthropogenic impact, nitrate pollution.

A river-load oriented model to evaluate the efficiency of environmental policy measures against phosphorus losses.

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Watersheds losses of phosphorus and suspended matters have large economic and environmental incidences. To evaluate environmental policies or ahead of the implementation of mitigation options, stakeholders concerned by surface water resources sustainability require analytical tools to evaluate the apportionment between point and diffuse sources of nutriments and pollutants. A number of empirical and mass balance modeling approaches have been developed in the recent years to answer to this operational demand (Cassel et al, 2002; Nemery, 2003). Point and diffuse sources were commonly evaluated from loading values or using power functions established between phosphorus concentration and water discharge measured under mid and long-term monitoring programs at watersheds outlets (Burher et Wagner 1982). These models do not explicitly account for the processes that control P concentrations and dynamics in the river system. Quantitative impact on mass balances of In-stream processes has been often neglected although they determine storage and speciation transformations of P inputs (Dorioz et al, 1998).

To differentiate the phosphorus sources, we developed a simple and loaded-oriented model –- that computes retention, settling, re-suspension rates of fine and coarse P fractions and their relation to P concentration of bed-sediments. The model is applied on a long-term database (25 years provided by the International Commission for Geneva lake Protection) of water discharge and chemical flows to evaluate the incidence of agricultural (Policy Measures for Integrated Production and Required Ecological Provisions) and sewage treatment policies (implementation of modern and efficient sewage treatment systems) implemented in the Venoge watershed (240 km²) for the control of Geneva lake pollution. The model predicts adequately observed values of dissolved and particulate phosphorus. It can detect changes occurring in the behavior of the river system, notably the P retention properties that vary with the organic pollution of the river, with two main patterns: retention properties limited by anoxia in conditions of excessive loads, and concentration-dependent properties after restoration of water quality. The model reflects the gradual decrease of point and diffuse inputs over the studied period.

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Biomass harvesting decreases phosphorus runoff from frozen and thawed grass fields

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Dense grass decreases erosion and particle bound nutrients in surface runoff from grassed fields. Surface application of phosphorus (P) fertilizers on grass, however, increases P losses to watercourses. High amounts of dissolved reactive P (DRP) may also be leached from perennial grass (e.g. cultivated grass, green fallows, buffer zone areas between fields and watercourses, and managed uncultivated fields) during spring runoff when P is liberated from frost-injured vegetation.

To estimate P loss potential through pathways describe above the losses of total P (TP) and DRP (<0.2 µm) from unfertilized grass were studied after freezing and thawing, typical phenomena in Finland. Samples of surface soil (0–2 cm), surface and subsurface runoff (0–30 cm), and above-ground biomass as well as undisturbed soil samples (0–7 cm) were taken from the Lintupaju buffer zones located at Jokioinen, SW Finland. Concentration of plant available P (PAc) was analysed from the soil samples using the Finnish method of ammonium acetate extractable P at pH 4.65. Surface runoff water was collected from the experimental field, and from previously frozen and thawed soil blocks which were placed under indoor rainfall simulation. Grass samples were also frozen and thawed and then leached with deionised water.

The concentration of plant available P increased in surface soil of perennial grass fields if the above-ground biomass was not annually harvested. The highest concentration of PAc was observed from unharvested natural grass (16 mg l-1) corresponding to good P status for cultivated soil. The equivalent value for soil where grass was harvested was 8 mg l-1 (fair or satisfactory P status). In the Lintupaju experimental field, up to 0.9 kg ha-1 DRP was observed in surface runoff from field plots with unharvested buffer zones in spring 2003. The equivalent values from the plots with harvested buffer zones were 0.4–0.7 kg ha-1.

The P concentrations in plant tissues varied along with growing season and plant species. The highest P concentrations (3.1–5.0 mg g-1) were measured in the beginning of growing season. Both the above-ground biomass and P amounts in the biomass were the greatest during blooming and in the beginning of ripening. The highest P concentrations were measured from dandelion and yarrow species and the smallest ones from timothy, meadow fescue, common bent, and white clover.

When leached with deionised water, the DRP concentration in surface runoff water from grass covered soil blocks increased after the first freeze-thaw cycle. The highest observed DRP concentration was up to 3.7 mg l-1.

In plant leachates, high DRP quantities representing 1.6–3.1 kg ha-1 were observed after four freeze-thaw cycles. The highest amounts were from unharvested grass areas and from grass grown above dung and urine patches.

The results indicate that the spring time load for DRP from perennial grass to water can be markedly decreased by annual harvesting of the grass biomass and by choosing suitable plant species to grassed fields. More research is needed to specify the optimum harvest time.

Linking scales in assessments of mitigation options for riverine nutrient reduction

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When analyzing impacts of mitigation measures for nutrient reduction in surface water and groundwater it is important to be able to compare different mitigation alternatives to assure that that the most efficient measures, to the best of knowledge, are taken. In such a complex system as the agricultural, different alternatives are not easily compared, especially if the conditions for the system change over time, e. g. climatic, demographic and technological changes. To ensure that the best decision is taken decision support is needed.

To meet needs like this the HYPE (Hydrological Predictions for the Environment) model was developed. The model is a dynamic, semi-distributed and process-based model based on well-known hydrological and nutrient transport concepts. It integrates soil, groundwater, surface water, lakes and rivers. The HYPE model can be applied with different resolution in time and space. In Sweden, it is used in the implementation of the EU water framework directive, providing daily time-series of water quantity and quality data with 10 km2 resolution for the whole country. The model is especially efficient in linking scales in an operational production system for large regions.

In its European set-up, called E-HYPE, the model covers nearly 9 million km2 divided into more than 36000 sub basins (average area 213 km2). Input data was taken from readily available, free data bases such as Corine and Globcover for land cover and European Soils Database and Digital Soil Map of the World.

Due to its flexibility HYPE can also be set up in smaller scales in order to link processes at local or even plot level to coarser resolutions in both time and space.

So far, the model has been used to assess source apportionment of nutrient load on the sea, reconstruction of historic discharge and nutrients at daily time-step (1971 to 2008), analysis of the implementation of the Baltic Sea Action Plan (BSAP) including climate change impact on water and nutrients for present emissions and diffuse sources in the basin and the combined effect of BSAP implementation and climate change on nutrient load to the Baltic Sea. In addition, the model is run in forecast mode with automatic delivery of 2-10 days water and nutrient forecasts to different oceanographic communities such as the Baltic Operational Oceanographic System, the North West European Shelf Operational Oceanographic System for direct input to several oceanographic forecast models.

Results from HYPE are readily available on the internet via web products. E-HypeWeb is a public web service where where you can easily download daily and monthly simulation results of discharge (m3/s) for one or several sub basins in Europe. Data for download can be chosen by either specifying a sub basin ID or selecting areas from a map. In addition, nutrient loads can be downloaded for the Baltic Sea basin.

Advanced computation of nutrients flows in river catchments as decision support for development of programs of measures in Austria

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Introduction

In Austria water pollution with organic carbon and nutrients from municipalities and industries has been reduced significantly during the last decades. This was mainly achieved by a best available technology (BAT) driven waste water treatment with enhanced nitrogen and phosphorus removal. Nevertheless, nutrient loadings (mainly phosphorus) are still relevant pressures for about 18 % of the Austrian surface water bodies. Additionally, nutrient discharges via River Danube are still seen as major pressure for the Black Sea ecosystem.

Any further measures to reduce nutrient pollution of surface waters have to focus on diffuse sources of pollution or have to go beyond the already implemented BAT–requirements in waste water treatment. The selection of efficient measures considering the protection of different types of water bodies (ambient surface waters and receiving seas) has to be based on reliable quantifications of pathways and sources of nutrient emissions and the effectiveness of measures for emission reduction.

Material and Methods

Emission modeling based on a lumped sum, empirical modeling approach has been performed to the Austrian territory subdivided into 367 sub-catchments of 50 to 400 km2 size for calculation of nitrogen and phosphorus emissions and retention and losses of nutrients in the river network. 102 of the considered sub-catchments have appropriate water quality measurements at their outlet in order to calibrate and validate model calculations. From the beginning it became clear that special attention had to be paid to the specific alpine character of many Austrian sub catchments.

Environmental quality standards (EQS) for nutrient parameters as part of the general physical-chemical description of a water body differ depending on reference conditions and are defined as 90 % percentiles for concentrations of PO4-P and NO3-N in Austria. Therefore, the model had to be enhanced for calculations of 90 % percentiles in stream concentrations in order to relate model calculations to EQS of ambient waters. After validation of model results against measurements, scenarios have been calculated and measures have been compared in respect to their effectiveness in respect to achievement of EQS in local rivers and in respect the reduction of transported loads towards the receiving sea.

Result and Discussion

Results of scenario calculations show that a set of measures with increased requirements for waste water treatment (effluent concentrations < 0,5 mgTP/l for all wwtp with more than 1000 p.e.) may still reduce the total P loads exported via river systems by about 18 %, while its effectiveness on improvement of local water quality in respect to PO4-P concentrations is relevant only in exceptional cases. In contrast, a set of measures with erosion abatement to reduce 90 % of soil loss form all arable areas contributing to erosion inputs into rivers, results in significantly less than 15 % reduction of total TP export via the Austrian river system, but it is effective in many of the local rivers with actual exceedance of the EQS. Implementation of both scenarios would reduce total exports of P by about 30 % and the percentage of rivers exceeding local EQS could be reduced from almost 20 % of all rivers to less than 10 %. While in the actually released Austrian program of measures for achieving good water quality status in all river bodies such quantitative assessments are not implemented yet, actually performed investigations will deliver an enhanced decision support for development of the next program of measures for implementation of EU water framework directive.

DETERMINATION OF FUZZY-RULES FOR MODIFYING PHOSPHORUS DELIVERY ESTIMATES WITH MITIGATION MEASURES

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To meet our environmental management responsibilities there is a need to estimate the likely effect of current and future land management policies on water quality under environmental and economic change. Where targeted mitigation measures are required to reduce pollution we need to choose the most effective strategies given catchment characteristics, climate and economic drivers. Efficient management of diffuse phosphorus (P) delivery to streams at national scale requires mitigation strategies to be modelled such that catchment mitigation strategies can be optimised. Owing to limited catchment scale experimental results on which a mitigation measure rule-base can be based, expert opinion was employed to make scale-dependent extrapolations from the information available. The expert opinion came from Department for Environment Food and Rural Affairs (Defra) funded research project team and from a focussed expert workshop. We discuss the challenges in the derivation and implementation of the fuzzy rules for the mitigation measures effectiveness. Although the derived scale-dependent rules include an element of expert opinion, they do provide hypotheses that can be tested and improved by experimentation at appropriate scales.
Keywords: mitigation strategy; phosphorus delivery; fuzzy modelling; constructed wetlands; riparian buffer; water quality

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