Background paper on recent methods, input data and modeled nutrient emissions and potential of measures to reduce these in the Danube catchment

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Introduction

The Water Framework Directive (2000/60/EC) requires Member States to regularly publish river basin management plans, which have to comprise a summary of significant anthropogenic pressures and impacts of human activity on the status of surface water and groundwater. One fraction of these anthropogenic pressures are waste water emissions from municipal sources.

Since 1997 the ICPDR has prepared inventories on point source emissions including emissions from municipal sources, with the existing waste water treatment plant being the core element of the inventory. In 2006 the ICPDR Municipal Emission Inventory was modified in a way to be consistent with the collection of data under the Urban Waste Water Treatment Directive (91/271/EEC).

Almost since the beginning of their activities in identifying anthropogenic pressures the ICDPR used MONERIS (Venohr et al. 211) to quantify nutrient emissions and loads and later also to estimate the effect of measures to reduce these.

Within the last years, more area covering spatially referenced data are available for the Danube river basin. Together with an extension of the calculation period until 2008 new input data have been considered and prepared for the use with MONERIS. Additionally to this MONERIS has been further developed.

With this background paper the effects of these changes in input data and methods are discussed and the recent model results are used to describe the possible effect and potential of measures to fulfill the WFD.

Updated input data for MONERIS applications for the years 2000 to 2008

The following list shows the most relevant input data used for the application of MONERIS to the Danube river basin.

Tab. 1: Input data for MONERIS run 2011.

Input data for MONERIS	**Description data source**
River system and lakes	• CCM River and Catchment Database - European Commission, JRC, 2007
Precipitation	• Global Precipitation Climatology Centre (GPCC)
Land use	• Corine Land Cover 2006 (Updated 2010) - EEA, European Topic Centre on Land Use and Spatial Information • Global Land Cover 2000 database (Hartley et al., 2006)
Drainage	• Artificially Drained Agricultural Areas - University of Frankfurt (2005)
Atmospheric deposition (NOx, NHy)	• EMEP/MSC-W model results - European Monitoring and Evaluation Programme (EMEP)
Evapo-transpiration	• Ahn & Tateishi (0,5*0,5° grid) - Ahn, C. H. and R. Tateishi, 1994. Development of global 30-minute grid potential evapotranspiration data set, Journal of the Japan Society Photogrammetry Remote Sensing, Vol. 33, No. 2, pp. 12 - 21.
Elevation	• Void-filled seamless SRTM data V1, 2004 - International Centre for Tropical Agriculture (CIAT) (90*90 m) • GTOPO30 - U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota (1000*1000m)
Population	• Gridded Population of the World version 3GPWv3, adjusted to match UN totals - Center for International Earth Science Information Network (CIESIN), Columbia University, SEDAC (NASA)
Hydrogeology	• digitised IHKE 1500 of Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) - RIVM Niederlande
Soil type	• Digital Soil Map of the World – FAO
Soil loss	• generation of soil loss map for different slope classes according to the Universal Soil Loss Equation
Discharge	• has been re-calibrated on basis of new monitoring data, evapo-transpiration and under consideration of the discharges according to WWTP inventory
Monitoring data	• was calculated as monthly values first, subsequently a flow-weighted mean annual concentration was calculated and multiplied with mean annual run-off
Water temperature	• mean annual water temperature was considered from all monitoring stations and transferred to un-monitored Aus
Connected	• EUROSTAT data on connection rates have been updated where

inhabitants	available • share of inhabitants connected to WWTP, sewer systems and DCTP have been applied to new population data
DCTP discharge type	• is calculated on basis of the geological conditions per AU (see Venohr et al., 2011)
WWTP	• inventory of agglomerations according to Urban Waste Water Treatment Directive (91/271/EEC)
P-accumulation N-surplus	• calculated as country specific data according to FAO and OECD data
Combined sewer system storage	• Estimated and discussed with countries

Model developments from Version 2 (used for the last ICPDR report) to the recent Version 3.0

MONERIS was recently reprogrammed in the programming language C# (earlier versions were programmed in Excel-VBA).

The new MONERIS 3.0 version has a more user-friendly interface with a better graphical presentation of results as well as a help function. It runs more stable and faster and has an extended measure catalogue. New calculation approaches, developed in the last years, were implemented in form of modules which facilitate further model developments.

The old MONERIS database can be easily imported in the MONERIS 3.0 version and the results exported to the old database. Due to this, users who are familiar with the old database can still use it for further statistical analyses.

Furthermore a preprocessing tool for the generation of the topology and other input data which uses GIS functions is provided.

Beyond the fixing of bug, which became obvious while re-programming MONERIS, a set of new developments have been implemented in the model.

- Atmospheric deposition
  The emissions of each pathway are calculated by the separate determination of the area, the runoff and the nutrient concentration.
  In the atmospheric deposition pathway the emissions on water surface areas are considered. The approach to determine the water surface area was recalibrated with an extended dataset which results in an increase of water surface area and thus in higher nutrient emissions. This approach delivers a better agreement with the observed river width.
- Urban systems
  a) In the urban system pathway the calculation of the water component was corrected, leading to a changed discharges but having no effect on the emissions from urban systems
  b) For inhabitants being connected to decentralized treatment plants (DCTP) MONERIS calculates (if not given as input data) the share of DCTP discharging directly via ditch or pipe to surface waters or via soil-groundwater-

passage. This share is calculated according to the geological underground, assuming that predominately pipe and ditches are used in unconsolidated undergrounds, where construction costs and efforts are comparatively low. In the old version the calculation of this share contained an error leading to exactly the opposite share of connection types.

- Erosion

  Not all areas are directly connected to surface waters and only a small fraction of eroded particles actually reaches the surface waters. Therefore, the share of areas that contribute to sediment input has to be defined, and is described by the Sediment Delivery Ratio (SDR). So far the SDR was only considered for arable land, all other land use classes contributed with 100 % of their areas to erosion. Now the SDR was also introduced for the land use class natural covered area. Thus only a certain portion of the eroded sediment of forest areas reaches the surface water anymore. Due to this, a reduction of nutrient emission will be the result.
- Surface runoff

  The water component in the surface runoff pathway was adapted in the runoff from snow and ice-covered areas according to Zessner et al. (2010). That results in higher specific surface runoff and thus in higher nutrient emissions from snow or ice covered areas.
- Consideration of negative water balances especially for monthly calculations

Comparison of input data and model versions

The use of new input data may not only improve but definitely change the model results to a various degree. This is overlaid by the effect of new model developments. We therefore compared the results using:

a) the older model version and the older data base (1996 -2004),

b) the new model and the older data base (1996-2004) and

c) the new model and the new data base (2000-2008) for overlapping time periods.

NITROGEN

Figure 1 shows a comparison of the emissions calculated with the different input data and model versions. The differences between the two model versions using the old database vary slightly within a range of 1 % to 3 %. The difference between the old and the new data base using the latest MONERIS Version vary between -5 % and 5 %. The total differences between to old database with the old model and the new data base with the latest model account to -5% to 8%. Although these difference are fairly small the differences for single analytical units and also as sum for the countries is partly much higher.

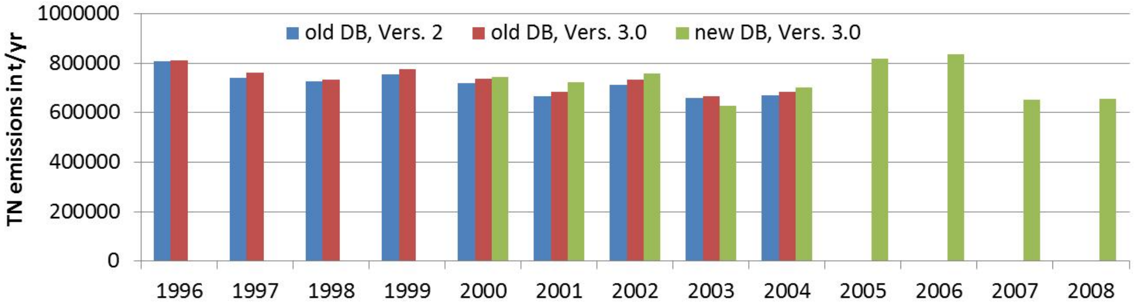


Figure 1: Comparison of the sum of TN emissions for the Danube river basin calculated with the old DB (Version of the Danube report (2009), the new generated database calculated with the old MONERIS versions used for the last management plan and the new developed MONERIS 3.0 version.

Having a look at the pathways, especially the TN emissions via tile drainages show a remarkable increase by 143 % (Table 1). This can be explained by the new map on tile drained areas. For the results of the Danube report (2009) information on tile drained areas were missing for most of countries, here no tile drained areas were assumed.

Also strong increase for discharges from WWTP was found. After comparing the input data a mistake in the data base of the first model run was found. Due to this the discharges from WWTP were underestimated. This error therefore has to be attributed to correction of the input data.

The rise in emissions via the atmospheric deposition pathway (6 %) is due to the new modeling approach delivering larger water surface areas. The strongest changes were identified for Germany, Slovenia, Austria and Romania (Table 2).

The strongest reduction TN emissions can be found for the pathway surface runoff, due to changes in the approach of the water component for snow and ice-covered areas. This improved approach in the surface runoff pathway affects the emissions especially in mountainous regions with a high ratio of snow and ice covered areas, e.g. Austria.

The change in TN emissions via erosion by -9 % (Table 1) comes from the new implementation of the sediment delivery ratio (SDR) for natural covered land. Due to the fact that natural covered land is the 2nd most important land use class in the Danube river basin, this remarkable reduction of TN emissions via erosion can be detected.

Table 1: Pathway separated TN emissions in t/a in the Danube river basin shown in Danube report (2009) and calculated with the new database and MONERIS Version 3.0.

	Danube report	new data base, Vers.	Change
	2000-2004	Long term, 2005	
	t/yr	t/yr	%
Atmos. Depo	13000	13830	6,4
Overland flow	67600	57595	-14,8
Tile drainage	27000	65531	142,7
Erosion	16900	15435	-8,7
Groundwater	373000	369990	-0,8
WWTP	105700	130743	23,7
Urban systems	82700	80405	-2,8
Total	686100	733530	6,9

Urban systems show an decrease of TN emissions by -3 %, which are mostly due to the corrected share of DCTP discharging via pipe/ditch or via groundwater passage and to a minor share due to the corrected water balance for combined sewer overflows.

Although the groundwater component calculated as residual (as difference of the total runoff and the sum of the runoff of all other diffuse pathways) no large differences can be found on a river basin scale. A detailed analysis of changes for the different countries will follow in a separate report.

Table 2: TN emissions and deviation between the last Danube report (2009) and the new database using MONERIS Version 3.0.

	Danube report (2009)	new data base, Vers. 3.00	Changes
	2000-2004		
	t/yr	t/yr	%
DE	115639	122080	5,6
AT	88598	116268	31,2
CZ	22322	19265	-13,7
HU	50156	54271	8,2
SI	23591	27694	17,4
HR	34816	38052	9,3
SK	42215	39378	-6,7
RS	56277	59813	6,3
BG	33512	31922	-4,7
BA	35246	33699	-4,4
MD	2201	5396	145,2
UA	26207	25587	-2,4
RO	146592	129136	-11,9
Other	8746	8708	-0,4
Total	686117	711270	3,7

Recent Nitrogen emissions at mean hydrological conditions

Total nitrogen emissions (TN) in the Danube river basin are 733,000 t/a for long term conditions calculated with the MONERIS 3.0 version. In Table 1 pathway separated TN emissions are presented. The groundwater pathway is responsible for 50 % of all TN emissions in the Danube river basin and thus the most important pathway. Emissions via point sources contribute with 18 % to total nitrogen emissions, via urban systems with 11 %, via surface runoff with 8 %, via tile drainages with 9 % and via atmospheric deposition and erosion with 2 % each.

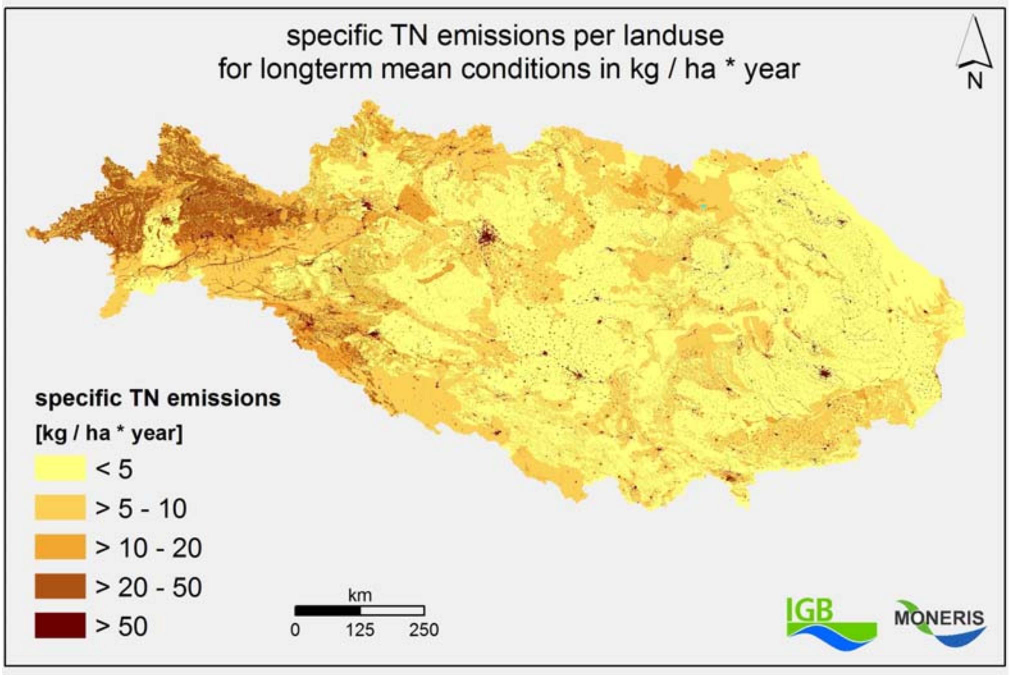


Figure 2: Spatial distribution of land use specific nitrogen emissions in the Danube river basin for mean hydrological conditions.

PHOSPHORUS

Figure 3 shows a comparison of the emissions calculated with the different input data and model versions. The differences between the two model versions using the old database vary within a range of -12 % to 3 %. The difference between the old and the new data base using the latest MONERIS Version vary between -6 % and 2 %. The total differences between to old database with the old model and the new data base with the latest model account to -3 % to -3 %. Although these difference are fairly small the differences for single analytical units and also as sum for the countries is partly much higher.

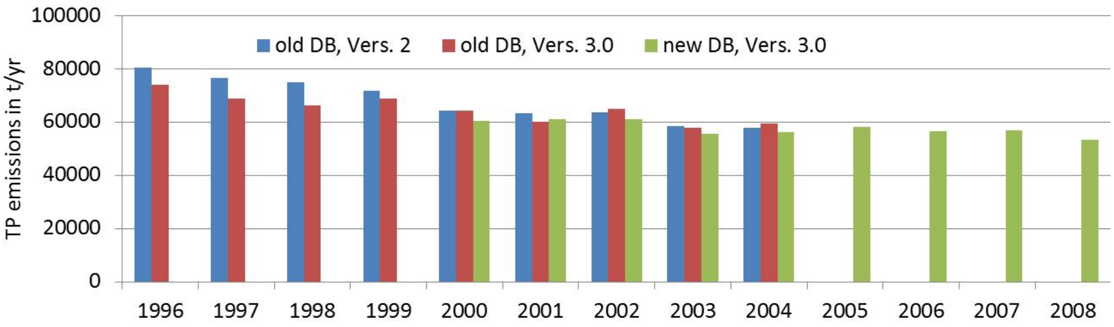


Figure 3: Comparison of the sum of TP emissions for the Danube river basin calculated with the old DB (Version of the Danube report (2009), the new generated database calculated with the old MONERIS versions used for the last management plan and the new developed MONERIS 3.0 version.

Total phosphorus emissions (TP) in the Danube river basin are 55,000 t/a for long term conditions calculated with the MONERIS 3.0 version. In **Error! Not a valid bookmark self-reference.** TP emissions via the different pathways are presented. The most important pathways in the Danube river basin are the urban system and the point sources pathway, which are responsible for 35 % and 32 % of all TP emissions, respectively. Emissions via erosion contribute with 21 % to total phosphorus emissions, via groundwater with 9 %, emissions via surface runoff, atmospheric deposition and tile drainages contribute each less than 1 % to the total phosphorus emissions.

Table 3: Pathway separated TP emissions in t/a in the Danube river basin shown in Danube report (2009) and calculated with the new database and MONERIS Version 3.0.

	Danube report (2009)	new data base, Vers. 3.00	Changes
	2000-2004	Long term, 2005	
	t/yr	t/yr	%
Atmos. Depo	340	329	-3,2
Overland flow	2370	377	-84,1
Tile drainage	160	462	188,8
Erosion	12330	11975	-2,9
Groundwater	4410	4768	8,1
WWTP	17070	17823	4,4
Urban systems	24920	19253	-22,7
Total	61590	54987	-10,7

Table 4: TP emissions and deviation in TP emissions between the last Danube report (2009) and the new database using MONERIS Version 3.0.

	Danube report (2009)	new data base, Vers. 3.00	Changes
	2000-2004		
	t/yr	t/yr	%
DE	4611	3455	-25,1
AT	4455	5283	18,6
CZ	1509	1170	-22,5
HU	8138	5246	-35,5
SI	1717	1926	12,1
HR	3294	3924	19,1
SK	3397	2607	-23,3
RS	6838	7593	11,0
BG	4468	3989	-10,7
BA	3299	3095	-6,2
MD	633	933	47,4
UA	2634	2365	-10,2
RO	15949	16942	6,2
Other	650	418	-35,7
Total	61592	58945	-4,3

In Table 3 it is recognizable that despite of the only small deviation in TP emissions the emissions via the different pathways alter substantially. On the one hand there is an decrease in emissions via urban systems, overland flow and erosion, on the other one there is an increase of emissions tile drainages, groundwater and WWTP. The reasons for these changes can be explained by the changes in methods, input data and the error found in the WWTP inventory.

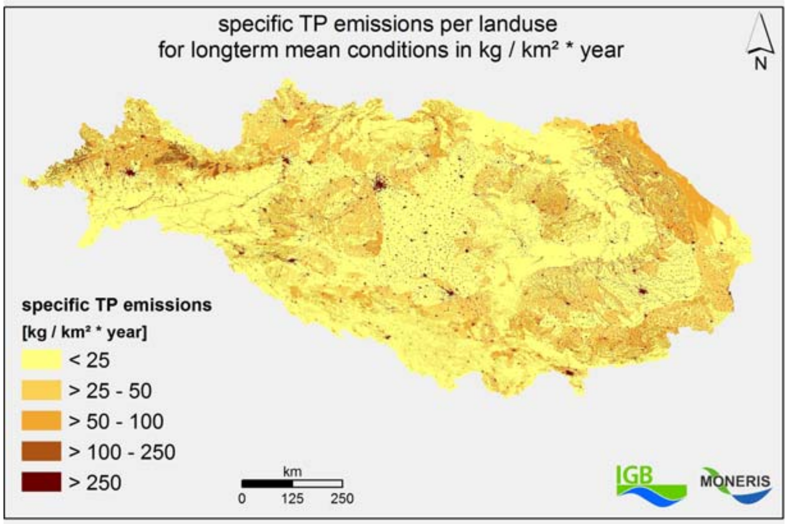


Figure 4: Spatial distribution of land use specific phosphorus emissions in the Danube river basin for mean hydrological conditions.

Model validation MONERIS 3.0

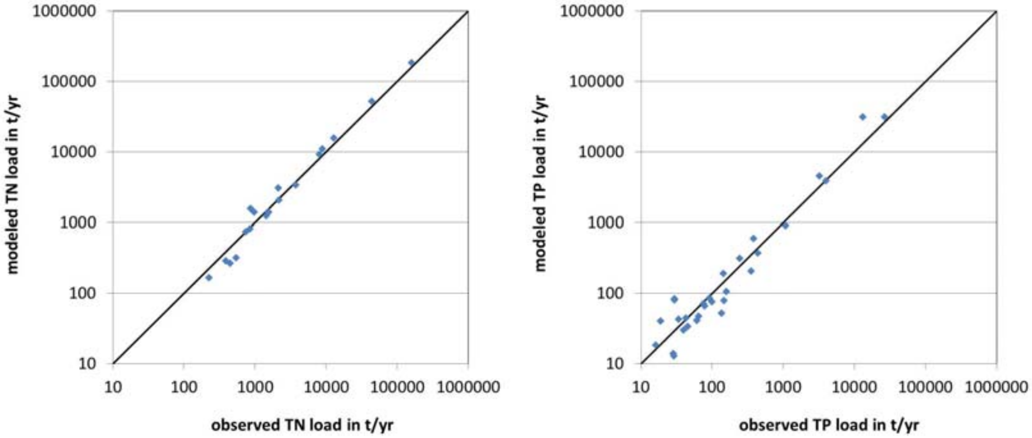


Figure 5: Comparison of observed and modeled TN and TP loads for long term conditions.

Tab. 2: statistical evaluation of modeled loads compared with observed loads for long term mean conditions. Only monitoring stations with more than 9 measurements per year where considered. The modeled loads are compared to a 5-year mean from 2004-2008. Here mean values were only considered if more than 3 years were available in this period.

		Dev	r²	EF	n
TN	t/yr	24.2	1.00	0.97	18
DIN	t/yr	46.0	0.91	0.43	67
TP	t/yr	43.5	0.95	0.51	31

Conclusion - new MONERIS version

Using the new MONERIS version in combination with the new data base let to a mean change in TN emissions by 4 % and TP emissions -4 % in the Danube river basin. Although, the overall changes a quite small, for some of the countries substantial changes in TN and TP emissions were found, but could all be explain by the new approaches or mistakes in the older data base. No further update of the input data on basis of expert knowledge have been added. The new data base with new model version in general showed a good agreement between observed and modeled loads.

Pressures and reduction potentials

The Danube River Basin Management Plan (2009) specifies that the way towards the nutrient pollution vision will be achieved through the implementation of the following management objectives by 2015:

EU Member States, Accession Countries and Non EU MS:

- ⇨ Reduction of the total amount of nutrients entering the Danube and its tributaries to levels consistent with the achievement of the good ecological/chemical status in the Danube River Basin District by 2015.
- ⇨ Reduction of discharged nutrient loads in the Black Sea Basin to such levels, which permit the Black Sea ecosystems to recover to conditions similar to those observed in the 1960s.
- ⇨ Reduction of phosphates in detergents preferably by eliminating phosphates in detergent products as it is already the case for some Danube countries.
- ⇨ Implementation of the management objectives described for organic pollution with additional focus on the reduction of nutrient point source emissions (see above).
- ⇨ Implementations of best environmental practices regarding agricultural practices (for EU Member States linked to EU Common Agricultural Policy (CAP)).
- ⇨ Create baseline scenarios of nutrient input by 2015 taking the respective preconditions and requirements of the Danube Countries (EU Member States, Accession Countries, Non EU Member States) into account.
- ⇨ Definition of basin-wide, sub-basin and/or national quantitative reduction targets (i.e. for point and diffuse sources) taking the respective preconditions and requirements of the Danube Countries (EU Member States, Accession Countries, Non EU Member States) into account.

In addition, for EU Member States:

- ⇨ Implementation of the UWWTD (91/271/EEC) as described for organic pollution (see above) taking into account the character of the receiving coastal waters as a sensitive area.

Implementation of the EU Nitrates Directive (91/676/EEC) taking vulnerable zones into account in case natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters of the DRBD are found to be eutrophic or in the near future may become eutrophic.

The recent targets for concentrations at the mouth of the Danube of TN ≤ 1.5 mg/l and of TP ≤ 0.09 mg/l agree with the state of the 1960ies. With calculated mean concentrations of 1,8 mg/l (TN, observed DIN concentration at Monitoring station (RENI, Lower Danube) plus organic share calculated by MONERIS) and 0.11 mg/l (TP, observed mean TP concentration 2008-2008 at Monitoring station Lower Danube) a further reduction of concentration by 17 % and 18 % would be needed. This reduction goals agrees with the state of the 1960ies.

To estimate the potential of measures the pathways and the source of nutrients have to be considered. The pathways have been described in Table 1 and Total phosphorus emissions (TP) in the Danube river basin are 55,000 t/a for long term conditions calculated with the MONERIS 3.0 version. In **Error! Not a valid bookmark self-reference.** TP emissions via the different pathways are presented. The most important pathways in the Danube river basin are the urban system and the point sources pathway, which are responsible for 35 % and 32 % of all

TP emissions, respectively. Emissions via erosion contribute with 21 % to total phosphorus emissions, via groundwater with 9 %, emissions via surface runoff, atmospheric deposition and tile drainages contribute each less than 1 % to the total phosphorus emissions.

Table 3, showing the dominance of groundwater as pathway for nitrogen and or WWTP and urban systems for phosphorus. The source apportionment (Table 5) shows about the same amount of TN emissions coming from urban systems and from agricultural areas. As shown for the pathways, urban systems are the dominant source for TP emissions. This suggests a limited potential of measures on agricultural areas to reduce the nutrient emissions.

A conflict could arise from the potential future development agricultural especially in the middle and lower parts of the Danube.

Table 5: Source 11apportionment of TN and TP emissions at long term mean conditions in the Danube river basin.

Sources	TN		TP	
	t/yr	%	t/a	%
natural background	46395	6	3997	7
urban sources	205975	28	37076	67
agricultural areas	199504	27	13435	24
from this	72118	10		
	58977	8		
other areas	79932	11	479	1
	68593	9		

Time lag between application of measures and reduced emissions

Many currently discussed measures to reduce nitrogen emissions result in a reduction of N-surplus on agricultural areas. Nitrogen is washed out of the soil quite fast and does not accumulate in soils as much as phosphorus does. Nevertheless, nitrogen is transported in groundwater over several years. Figure 6 shows the mean groundwater residence time modeled with MONERIS. Consequently, nitrogen fertilizer once apply to agricultural land may find its way to surface water after decades and will appear as a mixed signal of fertilizer applications during groundwater residence time. In order to fulfill the WFD measures have to be found which help to improve the water quality until 2027.

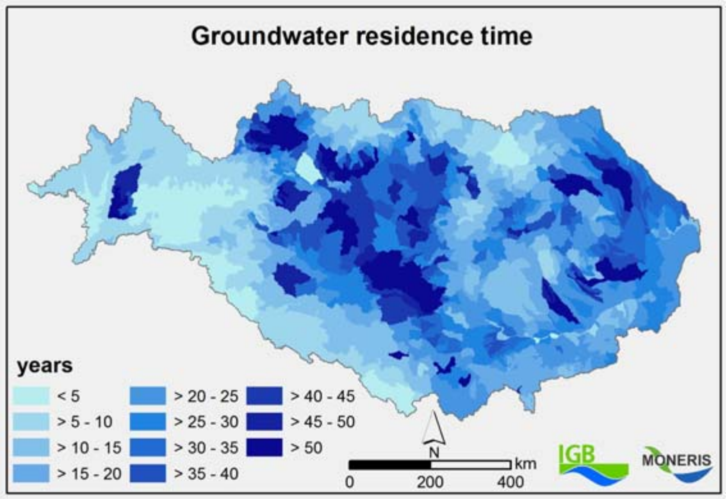


Figure 6: Mean groundwater residence time in the Danube river basin estimated with MONERIS (Venohr et al. 2011).

The following calculations show the temporal lag in changing N emissions to a reduction of N surplus on agricultural areas. For this scenario it was assumed that N surplus is linearly reduced from 2010 to 2020 to a level of 5 kg/(ha·yr). A final level of 5 kg/(ha·yr) was set to reflect a situation with very little human impact. It can be seen that emissions via tile drainage react very fast and already shows a reduction by 30 after 5 years. After 15 years no further reductions of emissions via tile drainages were calculated (Figure 7).

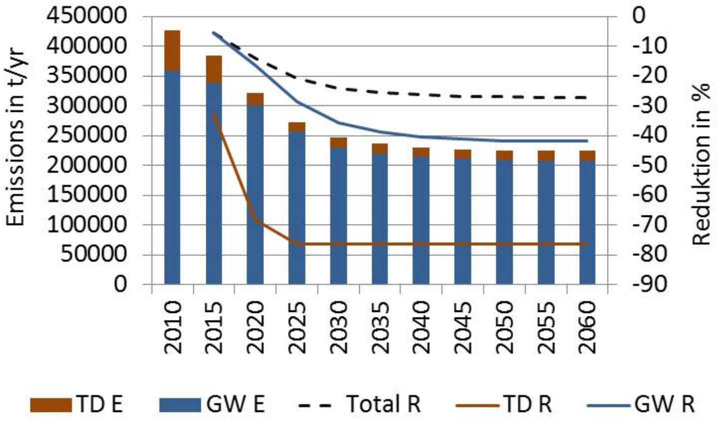


Figure 7: Decreasing N emissions via tile drainages and groundwater due to a reduction of N surplus reduction and the percentage reduction equivalent in the Danube river basin.

Groundwater emissions show a much longer time lag. Here it takes about 40 years until no further reductions of groundwater emissions are modeled. Consequently the time lag results from the combination of the share of tile drained areas (reacting fast) and the groundwater residence time.

A fast reduction of N emissions can therefore be found were you either have a short groundwater residence time or a high share of tile drained areas. Figure 8 shows the change in total N emissions 10, 20 or 30 years after reducing N surplus. It has to be mentioned that information on tile drained areas have a very high uncertainty, as they are very often not available as geo-referenced data and therefore in general have to be modeled.

For phosphorus the time lag might be much longer. Additionally to the residence time in groundwater (which is in general less import for P than for N), phosphor accumulated in soils but also in sediments of surface waters can, after re-suspension, compensate the effect of reduced P application and emissions. This effect was observed, when in 1990 after re-unification of the two German states, P emissions from phosphate in detergents, waste water treatment plants and from agriculture were reduced drastically within few years. In some lakes P concentration did not significantly drop for more than 15-20 years.

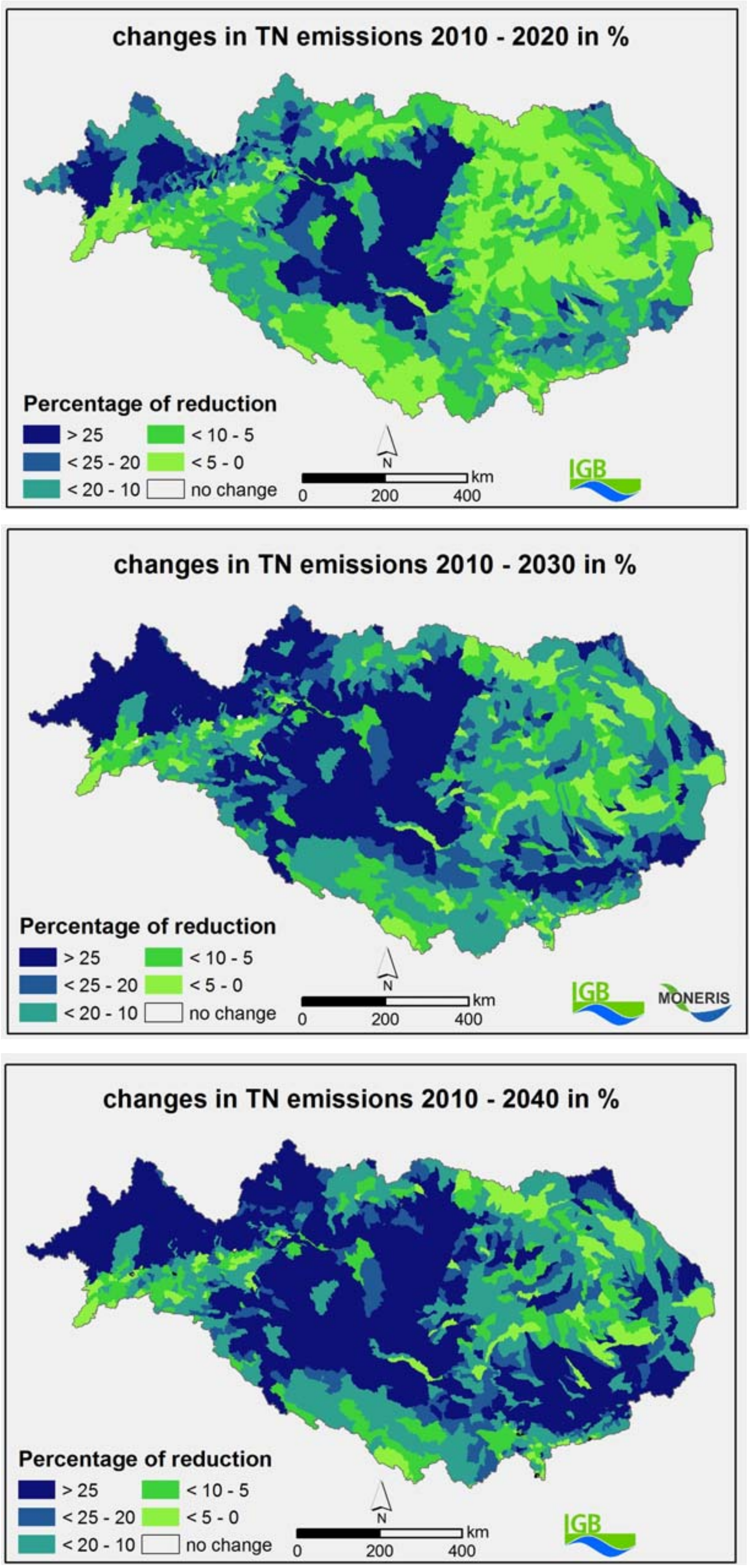


Figure 8: Changes in TN emissions after reducing N-surplus linearly from 2010 to 2020 to a level of 5 kg/(ha·yr)

Potential of development of N surplus

The Pressures and Measures Expert Group of the ICPDR agreed on three scenarios on the potential development of N surplus:

1) Baseline scenario: Based on the potential development of agriculture in the different countries but also on the different act already put in place the countries estimate the changes in fertilizer application, life stock and harvest yields. With these figures the resulting N surplus per country was calculated. This scenario represents the most realistic development for each of the countries. Within scenario for the up-stream countries a reduction of N surplus is assumed whereas for the most of the middle and lower Danube countries a moderate increase of N surplus is estimated (Table 6).
2) AgriNut-I scenario: assumes that the nitrogen surplus of the Danube countries will be the same as for the EU 15 in the year 2000.
3) AgriNut-II scenario: assumes that the Nitrogen balance for the Danube countries will be nearly constant for DE, AT and SI whereas a significant increase is calculated for CZ, BA, HR, SK, RS, BG, HU, RO and UA. The increase assumption is based on finding of the EU FP 5 project daNUbs.

Table 6: Recent values of N-surplus for the main countries in the Danube river basin, and assumed values for the baseline, AgriNut-I and AgriNut-II scenario.

	Baseline			AgriNut-I		AgriNut-II	
	2005	2015	change	2015	change		change
	kg/(ha·yr)	kg/(ha·yr)	%	kg/(ha·yr)	%	kg/(ha·yr)	%
DE	81.6	65.7	-23	57.1	-30.1	80.9	-0.9
AT	43.6	51.9	-18	57.1	30.8	43.4	-0.5
CZ	47.4	44.3	-12.8	57.1	20.4	97.3	105.4
SK	26.5	21.1	19.5	57.1	115.3	75	183.2
SI	73.8	52.2	-20.1	57.1	-22.7	75.7	2.5
HR	34.1	16.8	8.6	57.1	67.5	46.2	35.5
BA	17.5	19.6	14.2	57.1	226	38.9	122.5
RS	13.3	14.5	35.4	57.1	328.9	69.9	425.6
HU	22.5	20.9	14.9	57.1	153	61.7	173.7
RO	22.8	25	36.8	57.1	150.1	52.1	128.3
BG	15.5	14.2	18	57.1	267.5	54.4	250.4
UA	13.4	12.1	42.7	57.1	327.1	39.6	196.3
MD	20.0	18.6	18.2	57.1	185.5	47.6	138.5

How to identify hot spot areas

In order to derive a fast, effective and cost-effective reduction of emissions and loads suitable regions for the application of measures have to be found. Here a set of procedures can be considered:

- Regions with high emissions: Such areas contribute the highest share of emissions, but very often only identify urban areas, intensively used agricultural areas (Figure 2, Figure 4). As an area covering application of measures is in general not possible, and could also impact a productive agriculture, areas with an above average contribution to the loads have to be identified.
- One approach to identify these areas is the application of the impact ratio (Venohr et al, 2011). The impact ratio identifies AUs either having a high share on the total emissions

or on the resulting load at the mouth of the Danube, considering the natural nutrient retention in surface waters. Figure 9 and Figure 10 show the impact ratio calculated individually for the countries.

- Further increased groundwater concentration indicate nutrient rich leakage water, especially occurring for intensively used, sandy soils, with elevated precipitation. Figure 11 and Figure 12 show the mean groundwater N and P concentration in groundwater.
- As shown above groundwater residence time is an additional driver to identify areas where fast and cost-effective measures are possible (Figure 6).

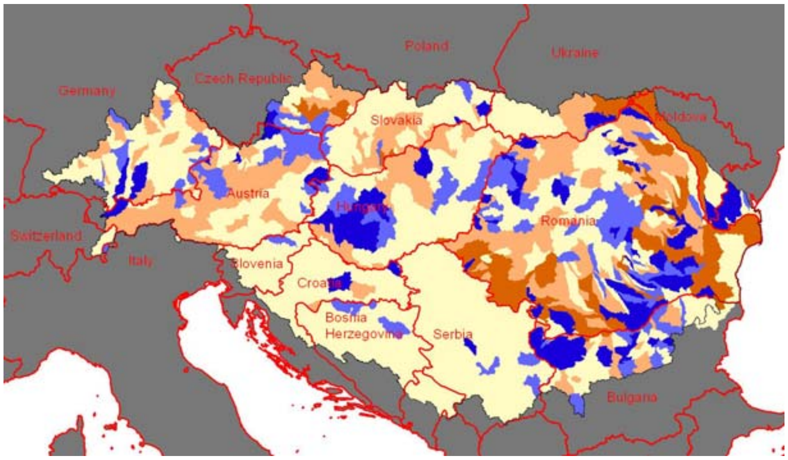


Figure 9: TN impact ratio per country

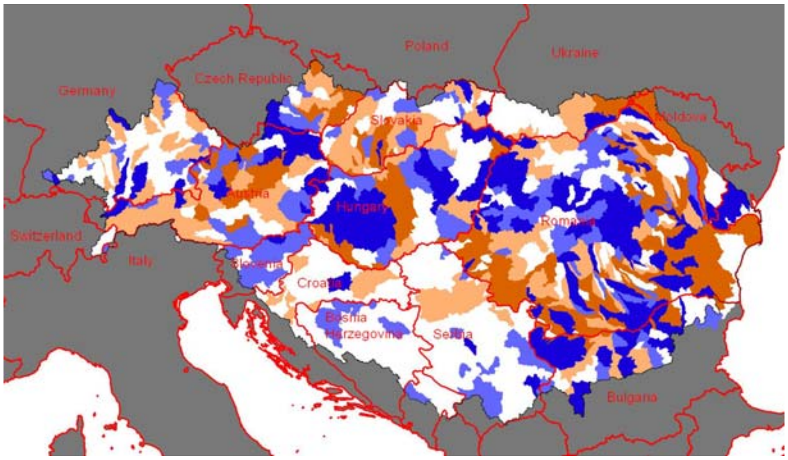


Figure 10: TP impact ratio per country

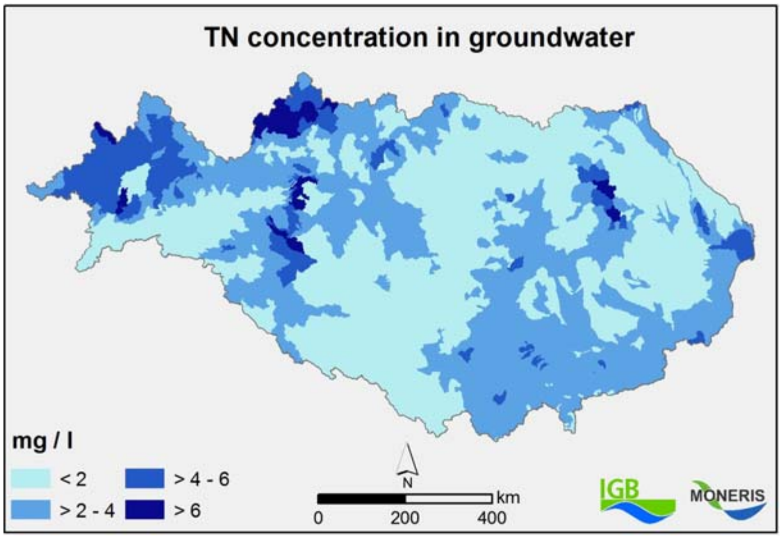


Figure 11: Mean TN groundwater concentration in the Danube river basin.

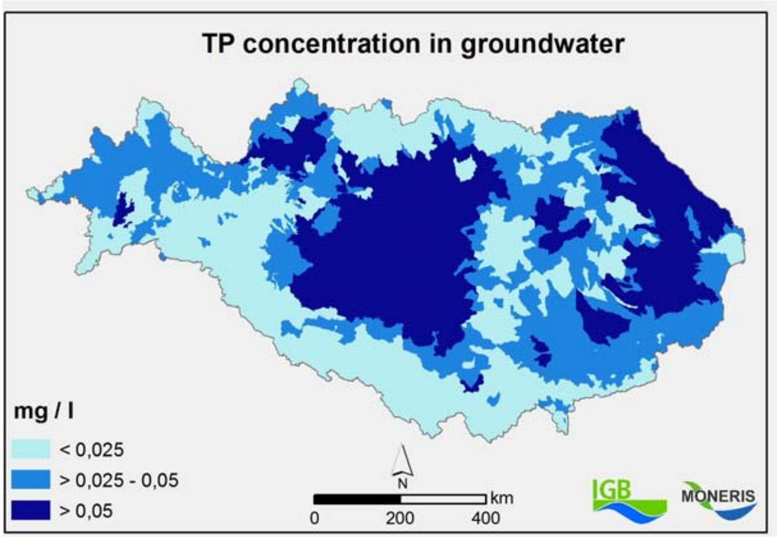
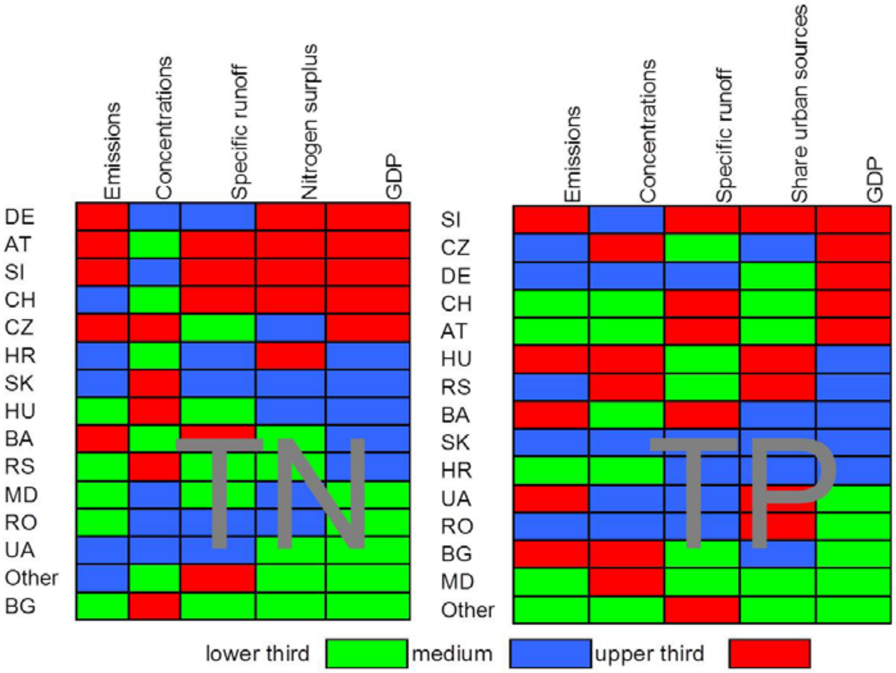


Figure 12: Mean TP groundwater concentration in the Danube river basin.

Figure 13: compares the above mentioned parameters on a country level. This colation shows high emissions, increased N surplus, high water availability and higher GDPs. On the other hand countries with lower GDPs have in general lower values for the mentioned parameters. This rises the question for the link between GDP and the intesities of agricultural land-use.



	Emissions	Concentrations	Specific runoff	Nitrogen surplus	GDP
DE	🟥	🟦	🟦	🟥	🟥
AT	🟥	🟩	🟥	🟥	🟥
SI	🟥	🟦	🟥	🟥	🟥
CH	🟦	🟩	🟥	🟥	🟥
CZ	🟥	🟥	🟩	🟦	🟥
HR	🟦	🟩	🟦	🟥	🟦
SK	🟦	🟥	🟦	🟦	🟦
HU	🟩	🟥	🟩	🟦	🟦
BA	🟥	🟩	🟥	🟩	🟦
RS	🟩	🟥	🟩	🟩	🟦
MD	🟩	🟦	🟩	🟦	🟩
RO	🟩	🟦	🟦	🟦	🟩
UA	🟦	🟦	🟦	🟩	🟩
Other	🟦	🟩	🟥	🟩	🟩
BG	🟩	🟥	🟩	🟩	🟩

	Emissions	Concentrations	Specific runoff	Share urban sources	GDP
SI	🟥	🟦	🟥	🟥	🟥
CZ	🟦	🟥	🟩	🟦	🟥
DE	🟦	🟦	🟦	🟩	🟥
CH	🟩	🟩	🟥	🟩	🟥
AT	🟩	🟩	🟥	🟩	🟥
HU	🟥	🟥	🟩	🟥	🟦
RS	🟦	🟥	🟩	🟥	🟦
BA	🟥	🟩	🟥	🟦	🟦
SK	🟦	🟦	🟦	🟦	🟦
HR	🟩	🟩	🟦	🟦	🟦
UA	🟥	🟦	🟦	🟥	🟩
RO	🟦	🟦	🟦	🟥	🟩
BG	🟥	🟥	🟩	🟦	🟩
MD	🟩	🟥	🟩	🟩	🟩
Other	🟩	🟩	🟥	🟩	🟩

lower third 🟩 medium 🟦 upper third 🟥

Figure 13: Comparison of nutrient emissions, nutrient concentrations in surface water, spezific run-off, N surplus, share of urban sources and GDP.

Figure 14 compares the N surplus and the harvest yield on a country level. Comparing the countries the figure suggests a strong correlation between these two parameters. Looking at the individual countries this correlation is often negative. This indicate, that within the country-specific agricultural-socio-economic and climatic conditions N surpluses reductions can be achieved without having a negative effect on the yields. Whereas, if the agricultural-socio-economic framework changes, this might also effect the yields. Considering the precipitation also a strong climatic driver becomes obvious. Figure 15: compares mean nitrogen emissions and GDP per country, showing high GDPs only for countries also having high emissions. These countries in general have a low share of emissions from urban sources. These to figures in combination raise the question, whether intensive agricultural land use has to come together with high emissions and welfare (high GDP).

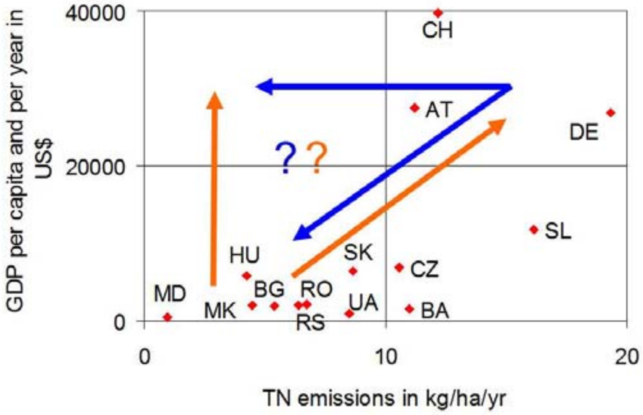


Figure 14: Comparison of N surplus and harvest yield for country based values for the years 1995-2005.

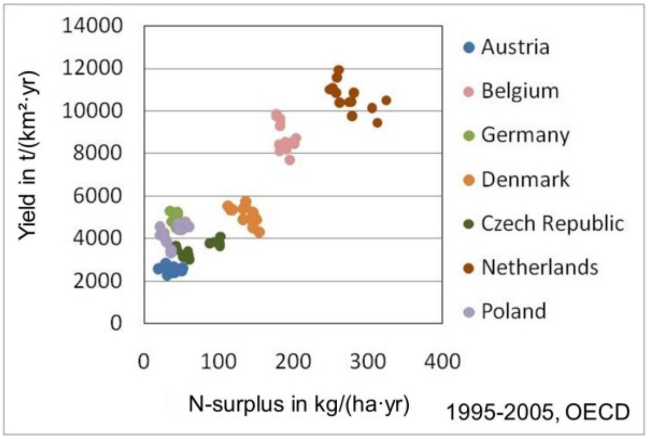
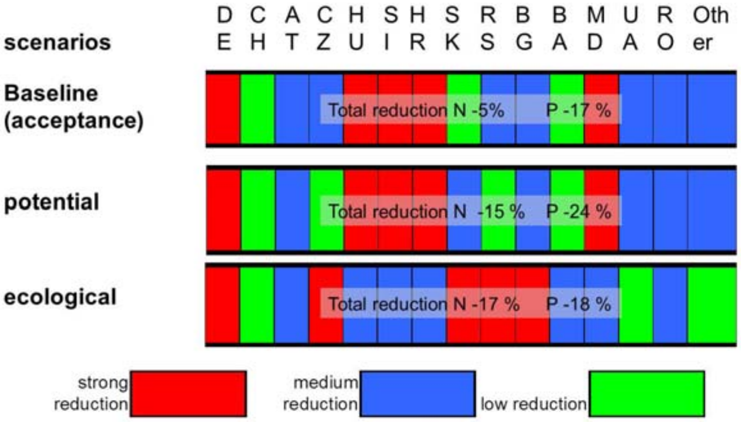


Figure 15: Comparison of mean TN emissions (2000-2004) modeled with MONERIS and mean GDPs on a country level (data from EUROSTAT).

Potential development and their impact on nutrient emissions

Based on the conditions and potential developments of N surplus a set of three scenarios have been calculated:

1) Baseline (acceptance) scenario: Fulfillment of the EU-Wastewater directive for waste water treatment plants, Change in N-surplus according to baseline scenario (see above)
2) Potential: additional to 1) a set of moderate measures have been applied equally to all AUs: reduction off soil loss by soil conservation, catch crops on arable land, improvement of sewer systems.
3) Ecological: assumes a reduction of emissions in AU to meet N concentrations at the outlet according to 1960ies (see above).



scenarios	DE	CH	AT	CZ	HU	SI	HR	SK	RS	BG	BA	MD	UA	RO	Other
Baseline (acceptance)	🟥	🟩	🟦	🟦	🟥	🟥	🟥	🟩	🟦	🟦	🟩	🟥	🟦	🟦	🟦
potential	🟥	🟩	🟦	🟩	🟥	🟥	🟥	🟦	🟩	🟦	🟩	🟥	🟦	🟦	🟦
ecological	🟥	🟩	🟦	🟥	🟦	🟦	🟦	🟥	🟥	🟥	🟦	🟦	🟩	🟦	🟩

strong reduction 🟥 medium reduction 🟦 low reduction 🟩

Figure 16: Reduction potential and needs to reach a good ecological status in the Danube river basin.