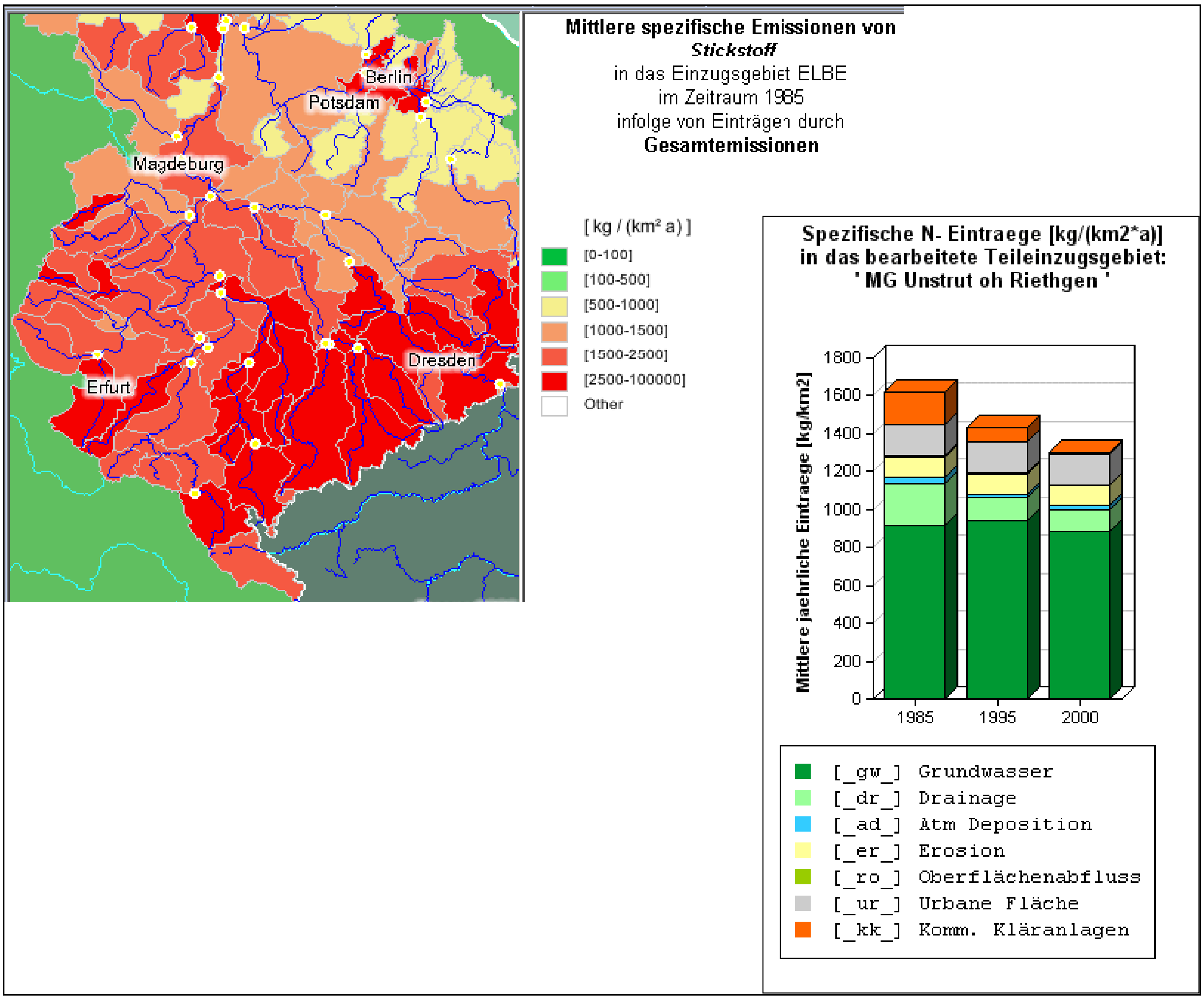
## AquaSAGE Central Europe

### Products / Services Delivered Today

The AquaSage service for Central Europe consists of maps and statistics qualifying and quantifying nutrient inputs into river basins. Basis of the service is the model MONERIS (MOdelling Nutrient Emissions in RIver Systems). The catchment based analysis allows either summary and differentiated catchment quantification of the main nutrient pathways. This analysis serves for identifying of regional focal points of nutrient pollution, which are prominently to be considered for the installation of measures for reducing inputs.

The service is delivered to the German Environmental Agency (UBA) and the Thuringian Institute for Environment and Geology (TLUG), both in charge for the reporting on water status and the installation of measures to conserve good water quality.

Examples of spatial and statistic results are shown in the following example.




*Examples of spatial & statistic results from MONERIS model [© GIA, Dr. Pagenkopf; UBA]*

## Methodology

The model MONERIS was developed and applied to estimate the nutrient inputs into river basins of Germany by point sources and various diffuse pathways. The model is based on data of river flow and water quality as well as a geographical information system (GIS), which includes digital maps and extensive statistical information.

Whereas point emissions from waste water treatment plants and industrial sources are directly discharged into the rivers, diffuse emissions into surface waters are caused by the sum of different pathways, which are realised by separate flow components. This separation of the components of diffuse sources is necessary, because nutrient concentrations and relevant processes for the pathways are mostly very different.

Consequently seven pathways are considered:

- point sources
- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

Most important input parameters are especially LC/LU information detailed to agricultural crop types which are provided by the SAGE core service.

## Today's Constraints

Besides availability of EO data in terms of large scale mapping of important LC/LU classes in reasonable time periods, another critical issue is the availability of harmonized additional data sets like statistics and thematic maps. A lot of work has to be done in preparation of input data while the modelling approach itself is settled. This is especially true for international approaches.

## Major Benefits

The MONERIS model approach can easily be transferred to other regions and river catchments and delivers standardized outputs important for reporting on the WFD. Thus, a standardized reporting approach with comparable outputs could be established through using this service on a regional scale and aggregating to national or international scale. The usage of catchment areas as the regional entities instead of legislative borders leads to easy integration into WFD reporting schemes required from the European Commission. Also the integration of all important pathways into the modelling approach guarantees a holistic consideration of all possible nutrient inputs into river systems.

## More Details

MONERIS model (BEHRENDT et al., 2000) estimates the different pathways using existing approaches as well as new conceptual approaches developed especially for modelling at medium and large spatial scales. It also considers retention of nutrients in rivers basins. Due to the limited and often inconsistent data available for large-scale modelling, MONERIS was designed to work with information collated from standard monitoring programs or available from federal bureaus.

MONERIS has been applied extensively to river basins in the Baltic catchment and in all of Germany, and is being used in several European projects today (BUFFER, DANUBS, STREAMES, EUROHARP), including EUROCAT.

The model is **based on**:

- data of river flow (from gauging stations)
- water quality (nutrient concentrations from monitoring stations)
- statistical data about nutrient inputs into the catchment
- geographical data (stored and analysed in a Geographic Information System (GIS)

The model is composed of a series of equations that allow the estimation of point sources and diffuse sources into the stream.
For the catchment defined for a particular application of the model, MONERIS will estimate the loads emitted through each of the **point sources** (direct discharges, waste water treatment plant effluents), and through a series of **diffuse pathways** (see Fig. 1: MONERIS diagram), including:

- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

Along each of these pathways from the source of the emission to the river, substances experience processes of transport, transformation, retention and loss. Knowledge of these processes is necessary to quantify and predict nutrient emissions into the river. MONERIS encapsulate knowledge of those processes.
**MONERIS produces** estimates of annual load through each of the defined point and diffuse pathways. It estimates nutrient retention and loss within the river system itself (i.e., the stream's self-purification processes).
The **final output** is an estimate of annual nutrient load in the river at the outlet of the study catchment, which is equal to the emissions into the river via point and diffuse sources *minus* the estimated nutrient retention and loss within the river system.
Thus MONERIS can help managers identify pathways that contribute significantly to nutrient loads and should be targeted for **management** practices aimed at nutrient emission reduction. Combined with geographic information in a GIS, it can help identify **hot spots** within the catchment -- particular areas that, due to a combination of high potential emission and a susceptibility to efficient transport, contribute nutrients significantly more that other areas.
Once MONERIS has been calibrated for a particular catchment, it can be used to develop management **scenarios**. For example, a manager can ask by how much nutrient emissions into the river would be reduced under a scenario of erosion control.

**What MONERIS can't do**
MONERIS is **not a dynamic model**. It is balanced for a particular hydrologic period, and operates with annual average conditions.
MONERIS does not predict the influence of particular **storm events**. Storms are very important for nutrient loading into streams. Storms affect both point sources (e.g., via WWTP overflow) and diffuse sources (e.g., increasing surface runoff). MONERIS does not disregard storm events -- it simply incorporates them into

annual averages. They are part of the balance. As with computer programs, tough, GIGO (garbage in, garbage out) applies. Estimates produced by MONERIS will be only as good as the statistical data input to the model. A monitoring regime that is too infrequent to capture the influence of storm events on nutrient loads in rivers will probably provide understimates of total annual nutrient loads -- even if estimated and observed loads are in good agreement!
MONERIS cannot be operated in **near-real time** by feeding it hydrologic data as it arrives. By the same token, it cannot predict transient conditions (from one scenario to another): it will only estimate **equilibrium conditions** for a given, assumed set of hydrologic conditions.
To reiterate it, MONERIS is **not** a dynamic model. So why not use a dynamic model?
Dynamic models are much more demanding in terms of data. Also, they are based on a detailed knowledge of processes that more ofter that not simply isn't there. Dynamic models can be extremely useful for catchments that are well-studied and for which a wealth of data is available. If the purpose is the rapid assessment of problem areas (which pathways are contributing more to nutrient emissions in a stream), or if there is a need to estimate nutrient emissions in large areas (as in all of Germany), then a static model like MONERIS is the best bet.

**Diagram of point and diffuse pathways of nutrient emission estimated by MONERIS**
The complete description ca be downloaded from the official IGB website. For further information you can click on the components listed below.

Fig. 2: Nutrient balance in the agricultural area.

Fig. 3: Nutrient surplus in the soil.

Fig. 4: Nutrient input via surface runoff.

Fig. 5: Direct Nutrient inputs to the surface waters via atmospheric deposition

Fig 6:  Point sources

## References


BEHRENDT, H.; HUBER, P.; KORNMILCH, M.; OPITZ, D.; SCHMOLL, O.; SCHOLZ, G., UEBE, R. (2000) Nutrient emissions into river basins of Germany. UBA-Texte 23/00: 1-288, Umweltbundesamt Berlin, Berlin

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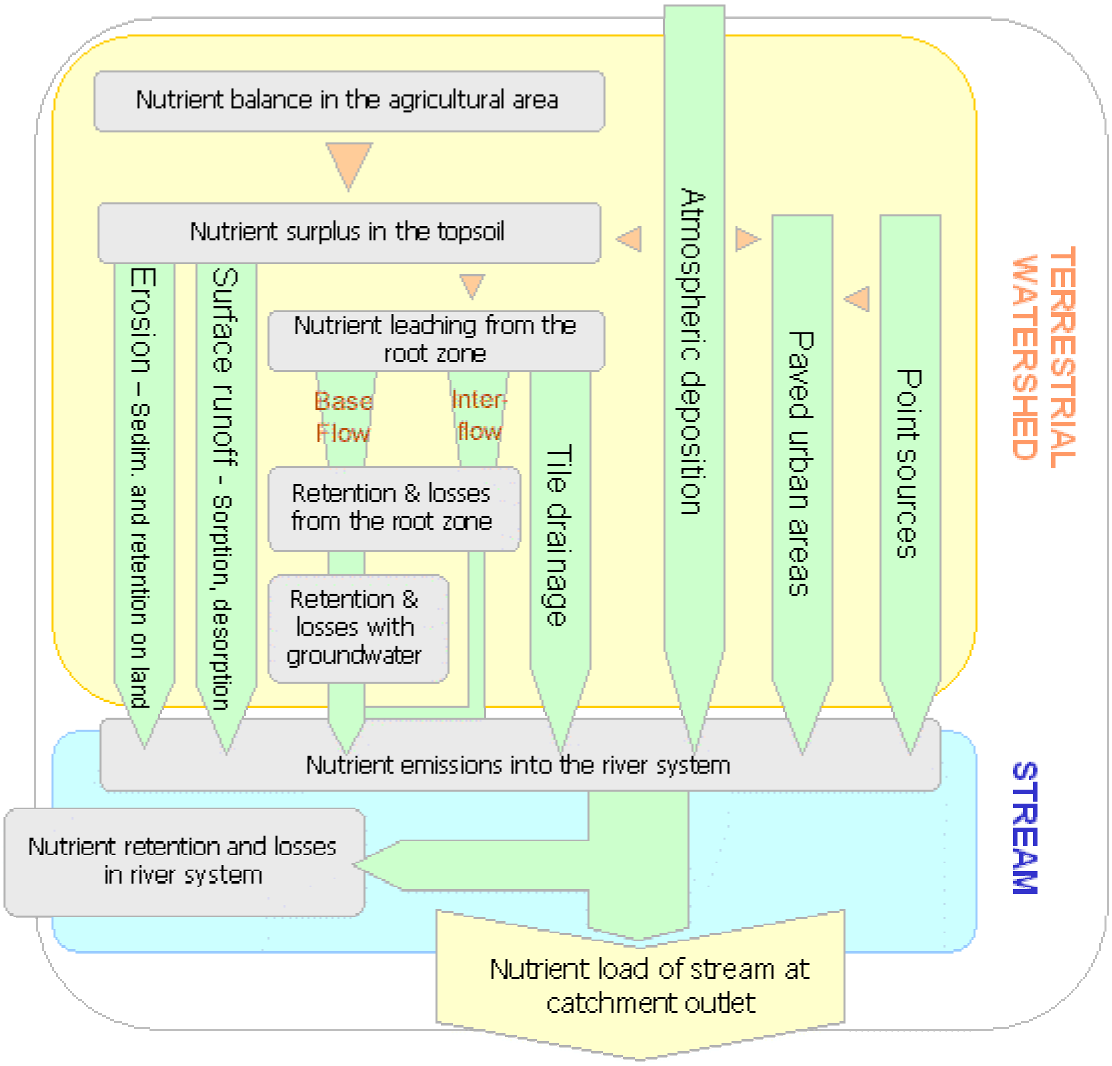
WERNER, W. & WODSAK, H.-P. (1994): Stickstoff- und Phosphoreintrag in Fließgewässer Deutschlands unter besonderer Berücksichtigung des Eintragsgeschehens im Lockergesteinsbereich der ehemaligen DDR, Agrarspektrum 22, Frankfurt am Main.


## Figure captions

Fig. 1: MONERIS: Schematic overview on the model system.
Fig. 2: MONERIS: Nutrient balance in the agricultural area.
Fig. 3: MONERIS: Nutrient surplus in the soil.
Fig. 4: MONERIS: Nutrient input via surface runoff.
Fig. 5: MONERIS: Direct Nutrient inputs to the surface waters via atmospheric deposition
Fig  6: MONERIS: Point sources



Nutrient balance in the agricultural area
Nutrient surplus in the topsoil
Erosion – Sedim. and retention on land
Surface runoff - Sorption, desorption
Nutrient leaching from the root zone
Base Flow
Inter-flow
Retention & losses from the root zone
Retention & losses with groundwater
Tile drainage
Atmospheric deposition
Paved urban areas
Point sources
TERRESTRIAL WATERSHED
Nutrient emissions into the river system
STREAM
Nutrient retention and losses in river system
Nutrient load of stream at catchment outlet


Fig. 1

Fig. 2

MONERIS

CLOSE WINDOW

**Nutrient Balance in the agricultural area**

Most diffuse nutrient emission from the watershed originates in agricultural practices. Nutrients reach the fields through natural deposition, manure additions, and fertilizer applications. Nutrients are removed through harvesting.

The difference between inputs and outputs is the surplus, which can accumulate in the soil and eventually make its way to the surface waters via direct drainage (e.g., tile drainage), surface runoff, or subsurface runoff, or can infiltrate deeper into the groundwater flow system.

Fig. 3

**MONERIS** [CLOSE WINDOW]

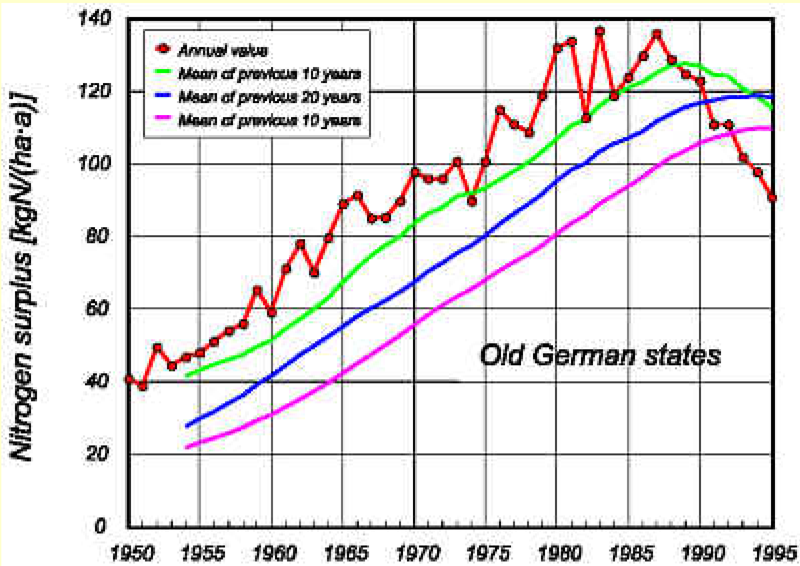
**Nutrient Surplus in the Soil**

The main source of diffuse nutrients comes from the excess phosphorus and nitrogen accumulating in the soil every year -- i.e., the difference between nutrient additions with deposition and fertilizer application, and nutrient extraction with harvest. The nutrient surplus is susceptible of being exported to the groundwater or surface waters.

Nutrient surplus is expressed as kg N (or P) / ha.year

In addition to the current year's nutrient surplus, it is also important to take into account the changes in nutrient surplus over the previous decades. This gives us an idea of the rate of accumulation of nutrients in the soil.

In the case of **nitrogen**, it allows us to estimate the average residence time in the unsaturated zone and in the groundwater. This is done through a comparison of long-term changes in DIN (dissolved inorganic nitrogen) in the river and time series of nutrient surplus moving averages for different time lags. Here's an example for the old German states:




**Phosphorus**, on the other hand, is accumulated in the upper soil layers until a saturation level is reached. From time series data and current soils concentration we can estimate changes in phosphorus content over time.

Fig. 4

**MONERIS** CLOSE WINDOW

**Nutrient Input via Surface Runoff**

When the precipitation rate exceeds the infiltration rate of a soil, the soil is said to be saturated and, after filling any small depressions in the ground, excess water will flow overland to the streams. This constitutes surface runoff.

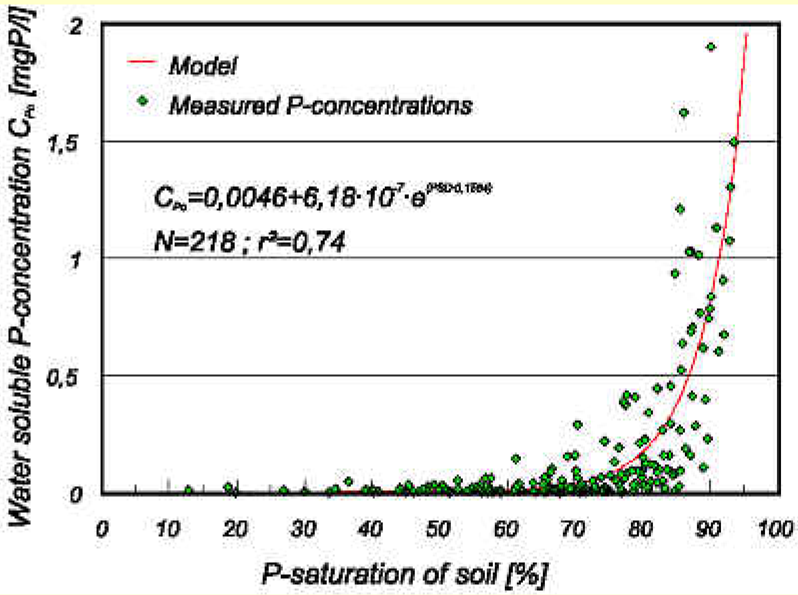
Specific surface runoff (surface runoff per unit area) is expressed as mm/m$^2$.yr). Total surface runoff is expressed as m$^3$/yr.

Surface runoff is assumed to be minimal in densely vegetated areas (such as forests). Conversely, overland flow is, in the absence of infiltration, the only component to be considered in impervious areas (mostly, paved urban areas). These are considered elsewhere (see flowchart of MONERIS).

The estimation of nutrient inputs to streams via surface runoff has two components. First, an estimate of surface runoff is needed. Second, the concentration of N and P in surface runoff needs to be estimated.

**Average yearly surface runoff** is a fraction of average annual precipitation, so this latter measurement is obviusly needed. Calculations of total runoff will use precipitation and the total area of surfaces contributing to surface runoff. The estimation is then effected using empirical equations. These equation may take into account seasonal differences in the proportion of precipitation that goes into surface runoff.

**Nutrient concentrations** in surface runoff depend on land use, especially for phosphorus, which binds strongly to soil particles.P binds very strongly to soil particles. This means that P concentration will increase rapidly as the soil approaches P saturation:




Nitrogen is more mobile. In either case, the average nutrient concentration in total runoff needs to be calculated as an average of concentrations in each land type weighed by land type area.

Fig. 5

**MONERIS** CLOSE WINDOW

**Direct Nutrient Inputs to the Surface Waters via Atmospheric Deposition**

This is the amount of phosphorus and nitrogen that fall directly on open waters (rivers and lakes) in drained areas of the catchment. Its estimation is based essentially on an estimate of the total area of open waters and an estimate of nutrient deposition.

The estimation of the total surface area of open waters is not trivial, because it depends on map scale, for example.

The estimation of nutrient deposition is considerably more difficult, however, because data are scarce. Nutrient deposition has two components: dry deposition (dust) and wet deposition (deposition with rain).

Phosphorus deposition is rarely measured. Nitrogen deposition is measured more frequently because of its involvement in acid rain. Still, European networks are based on a 50km x 50 km grid, which is coarse for small catchments:

EMEP 50-KM GRID

To complicate things even further, it would be advisable to add a time component to all this: changes in deposition over time and water residence time in the different open water bodies (a lake's memory is better that a stream's memory).

Fig. 6

MONERIS

CLOSE WINDOW

**Point sources**

Point sources of nitrogen and phosphorus are those that directly discharged into the river.

There are two main types of point sources:

- direct discharges into the streams (untreated sewage, direct industrial discharges)
- Municipal wastewater treatment plant (WWTP) effluents

At least in principle, it should be easy to measure flow and concentration in order to estimate load (usually expressed relative to catchment area as tonnes per unit area and year). Therefore, if the volume of water treated (or average flow) and the concentrations of nutrients in the **effluent** are known, the average annual load from a point source can be **estimated directly**. Sources of uncertainty arise from the frequency of measurements and variability of outflow, the chemical species measured (e.g., total inorganic N may be measured but not total N), and the occurrence of overflow events.
In cases where concentration and volume treated (or flow) are not available, load must be estimated indirectly (the **specific calculation** method), based on the approximate volume of water treated from municipal and from industrial sources, the average nutrient concentrations in those sources, and the estimated nutrient removal efficiency of WWTPs.