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AquaTerra

Integrated Modelling of the river-sediment-soil-groundwater system; advanced tools for the management of catchment areas and river basins in the context of global change

Integrated Project

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SUMMARY

The establishment of tools for trends analysis in groundwater is essential for the prediction and evaluation of measures taken within context of the Water Framework Directive and the draft Groundwater Directive. This report describes the historic development of contaminant inputs into the groundwater system for the TREND 2 subcatchments. The historic input data are essential to interprete and understand time trends in groundwater, which is the focus of coming deliverables. The emphasis is on diffuse contaminants and includes figures of 1950-present nitrogen inputs fot the Wallonian and Dutch Meuse catchments and the German Schleswig-Holstein catchments. For the Dutch Meuse basin also historical inputs of P, K, S, Ca, Mg, Na, Zn and Cd were estimated. Inputs of the pesticide atrazine were estimated for the small French Brévilles catchment, using interviews with farmers.

On a regional scale, all of these cases show increasing inputs up to about 1985 and a decrease afterwards due to regulations from that time on. Trends in inputs of other diffuse pollutants (cations, heavy metals, pesticides) seem to be correlated to the well established nitrogen inputs. The effects of this increase and subsequent decrease on concentrations in the groundwater system will be analysed in further work within TREND2.

MILESTONES REACHED

T2.1: Reconstruction of former land use and climate at test locations

Results of this work should be interesting for the INTEGRATOR 2, EUPOL, BASIN R1, R3 AND R4 and FLUX workpackages of AquaTerra.

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1. Introduction to TREND 2 (TNO)

1.1 Background and objectives

The implementation of the EU Water Framework Directive (2000/60/EU) and the draft Groundwater Directive asks for specific methods to detect the presence of long-term anthropogenically induced upward trends in the concentration of pollutants in groundwater. Specific goals for trend detection have been under discussion during the preparation of the recent draft of the Groundwater Directive. The draft Directive defines criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversal. Figure 1.1 illustrates the trend reversal concept, as communicated by EU Commission Officer Mr. Ph. Quevauviller. The figure shows how the significance of trends is related to threshold concentrations which should be defined by the member states.

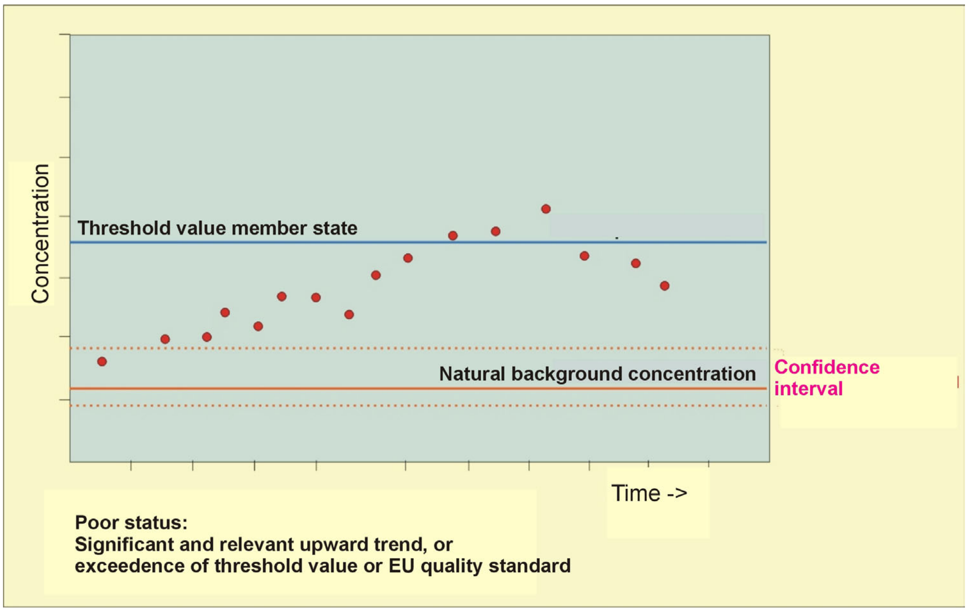

Figure 1.1: Trend reversal concept of the draft EU Groundwater Directive.

Trends should be reversed when concentrations increase up to 75% of the threshold concentration. Member states should reverse trends which present a significant risk of harm to associated aquatic ecosystems, directly dependent terrestrial ecosystems, human health, whether actual or potential, of the water environment, through the program of measures referred to in Article 11 of the Water Framework Directive, in order to progressively reduce pollution of groundwater. Thus, there is a direct link between trends in groundwater and the status and trends in related surface waters. This notion is central to the overall objectives of the AQUATERRA research project.

Working hypothesis 1:
Groundwater quality is of utmost importance to the quality of surface waters. Establishment of trends in groundwater is essential for prediction and evaluation of measures taken within the Framework Directive and the draft Groundwater Directive.

Accordingly, the work package TREND-2 of Aquaterra is dedicated to the following overall objectives.

1 Development of operational methods to assess, quantify and extrapolate trends in groundwater systems. The methods will be applied and tested at various

scales and in various hydrogeological situations. The methods applied should be related to the trend objectives of the Water Framework Directive and draft Groundwater Directive. In addition to the DOW, it is our ambition to link changes in groundwater quality to changes in surface water quality.

2 Linking changes in land use, climate and contamination history to changes in groundwater chemistry. We define a temporal trend as '*a change in groundwater quality over a specific period in time, over a given region, which is related to land use or water quality management',* according to Loftis 1991, 1996.

It should be noted that trends in groundwater quality time series are difficult to detect because of (1) the long travel times involved, (2) possible obscuring or attenuating effect of physical and chemical processes, (3) spatial variability of the subsurface, inputs and hydrological conditions and (4) short-term natural variability of groundwater quality time series. The TREND 2 package is dedicated to the development and validation of methods which overcome many of these problems.

Working hypothesis 2:
Detection of trends in groundwater is complicated by spatial variations in pressures, in flow paths and groundwater age, in chemical reactivity of groundwater bodies, and by temporal variations due to climatological factors. Methods for trend detection should be robust in dealing with this inherent variability.

Groundwater pollution is caused by both point and diffuse sources. Large scale groundwater quality, however, is mainly connected to diffuse sources, so that the TREND 2 project will concentrate on trends in groundwater quality connected to diffuse inputs, notably nutrients, metals and pesticides. We will consider a number of large basins in Europe and try to devise a trend monitoring method and network. Although trends in groundwater quality can occur at large scales, linking groundwater quality to land use and contamination history requires analysis at smaller scale, i.e. groundwater subsystems. Thus, the approach zooms in on groundwater system analysis around observation locations. Results will be extended to large scale monitoring.

1.2 General methods used in TREND 2

Research activities within TREND 2 focus on the following issues:

1 *Inventory of monitoring data of different basins and sub-catchments*. The inventory focuses on observation points with existing long time series. The wells should preferably be located in agricultural areas, because pesticides and nutrients are the main concern in trend detection for the Water Framework Directive. Additional information will be collected about historical land use changes and related changes in the input of solutes into the groundwater system.

2 *Development of suitable trend detection concepts.* Trend detection concepts include both statistical approaches (classical parametrical and non-parametrical methods, hybrid techniques) and conceptual approaches (time-depth transformation, age dating)

3 *Methods for trend aggregation for groundwater bodies.* The Water Framework Directive demands that trends for individual points are aggregated on the

spatial scale of the groundwater bodies. The project will focus on robust methods for trend aggregation.

4 *Trend extrapolation.* Trend extrapolation will be based on statistical extrapolation methods and on deterministic modelling. Both 1D and 3D model may be applied to predict future changes and to compare these with measured data from time series.

5 *Recommendations for monitoring.* Results from the various case studies will be used to outline recommendations for optimizing monitoring networks for trend analysis

1.3 TREND 2 case studies

The following case studies have been selected for testing the methodologies:

Basin	Contaminants	Institutes
Meuse		
Dommel upper tributaries	Nitrate, sulfate, Ni, Cu, Zn, Cd	TNO/UU
Noord-Brabant region	Nitrate, sulfate, Ni, Cu, Zn, Cd	TNO/UU
Wallonian catchments:	Nitrate	Ulg
• Néblon		
• Pays Herve		
• Hesbaye		
• Floodplain Meuse		
Brévilles		
Brévilles catchment	Pesticides	BRGM
Elbe		IETU
• Schleswig-Holstein	Nitrate	

These cases have different spatial scales and different hydrogeological situations. Details on the various cases are provided in the subsequent chapters of this report.

1.4 Contents of the current report

This report describes the reconstruction of former land use within the subcatchments which were selected as test basins within Aquaterra (see also deliverable T2.1 for a description of the spatial datasets). Given the trend definition given above, an inventory of historical changes in land use and corresponding contaminant inputs is essential to understand and interprete trend analysis results.

1.5 Structure of the report

This report describes relevant land use changes for the various cases of TREND 2. Chapters 2 to 5 describe the land use changes in the Dutch Meuse, the Wallonian Meuse, the Brévilles and the selected Elbe sub-basins, respectively. Chapter 6 gives a brief overview of the results of the various cases, focusing on opportunities and limitations on the integration of methods for trend analysis.

1.6 Glossary

RIVM	National Institute for Public Health and the Environment (The Netherlands)
Bulk deposition	Total atmospheric deposition, both “wet” (dissolved in precipitation) and “dry” (aerosol deposition)
CBS	Statistics Netherlands

Denitrification	(Bio)chemical process reducing nitrate to dinitrogen gas
SPREAD	Solute Prediction from Regional distributed Agricultural Deposition, Kiwa Research and Consulting, The Netherlands
LEI	Agricultural Economics Research Institute (The Netherlands)
PET	Potential Evapotranspiration
MONERIS	Modelling Nutrient Emissions in River Systems
CORINE	« Coordination of information on the environment » programme of the European Commision
LU/LC	Land Use/Land Cover
PIRENE project	Integrated Research Programme on Environment – Water (Wallonia, Belgium)
EPICgrid	Catchment modelisations of soils and the vadose zone in the PIRENE model
CARHY project	Cartographie et modelisation hydrologique, Walloon Ministery of Public Works
CEA	Agricultural Center of Economics, Wallonia
SPGE	Société Publique de Gestion de l'Eau'

2. Land use history and the chemical load of recharging groundwater in agricultural recharge areas of the Dutch Meuse basin (TNO/UU)

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2.1 Introduction

The EU Water Framework Directive (EU, 2000) distinguishes two types of monitoring objectives for groundwater quality: (1) 'to present an overview of groundwater chemical status' and (2) 'to detect the presence of long-term anthropogenically induced upward trends in the concentration of pollutants'.

The province of Noord-Brabant, in which most of the Dutch Meuse basin is located, has a sandy subsurface which is quite vulnerable to agricultural pollution. In recent history, large amounts of manure were applied and the transport and fate of this diffuse agricultural pollution front is of concern to those responsible for groundwater quality.

To relate trends in groundwater quality to input, detailed knowledge of the input pattern is essential. This chapter describes the procedures for calculating the historical quality of recharging groundwater based on available measurements of dry deposition, rain quality, production figures of manure and fertilizer, and knowledge of agricultural practices of fertilizer application. Before discussing the method of fertilizer and manure distribution, a land use history is given.

Most studies towards input history of agricultural pollution are limited to the deposition of nitrogen and phosphorous. In contrast, this chapter describes the complete major chemical components found in groundwater: nutrients (N, K, P, S), inorganic cations (Na, Ca, Mg) and heavy metals (Cd, Zn). The two sources of chemicals in recharging groundwater – atmospheric deposition and fertilizing/manuring practices – are described separately. Data sources are listed in the subsequent sections.

2.2 Atmospheric deposition

When discussing the total atmospheric deposition, a distinction has to be made between "wet" and "dry" deposition: rainwater composition and aerosol deposition, the latter being dependent on vegetation type.
Three classes substances are discerned here: potential acidifying deposition (N+S), cations and heavy metals. This division is largely based on the fields of research from which data is derived.

2.2.1 N+S

For the period up to 1980, very few accurate measurements of acidifying deposition are available. Instead, the wet acidifying deposition is estimated from emission figures for this period. The deposition is assumed to be proportional to the emission, i.e. a 50% increase in emission will result in a 50% increase in deposition (Van der Grift and Van Beek, 1996) Stuyfzand (1991) has reported estimates of the emissions of acididifying substances since 1920. The emission-deposition relation was calibrated on the period 1983-1987 (5 year average for 1985), for which both emission and deposition figures are available.

The dry deposition is assumed to be proportional to the wet deposition. The ratio between dry and wet depends on both vegetation and substance. The ratios reported by Loman (1989), Heij (1991) and Jansen (1988) for several substances and vegetation types have been applied here to calculate the dry deposition for the period up to 1980.

From 1980 onward, national model estimates by the RIVM of wet and dry deposition of N (NO_x and NH_y) and S (SO_x) are available, with dry deposition as a function of vegetation/land use. In 1980, 1985, 1990-1995 and 2000, these estimates are on the regional scale of the province of Brabant. This creates a time dependent 'distribution key' of the national average deposition for downscaling towards the provincial scale. This key was interpolated and applied to the deposition data of whole period.

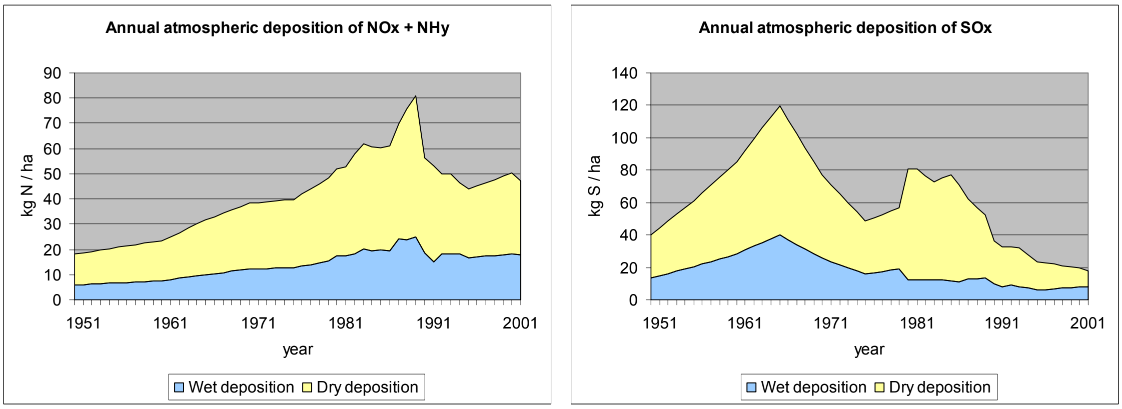

Figure 2.1 Annual atmospheric deposition of N (the sum of NO_x, NH_y) and S (SO_x).

The nitrogen deposition shows an increasing trend towards a peak in 1989, after which the trend is reversed. For sulphur, two peaks can be discerned. In the 1960s, the sulphur emissions from coal fuels were at the maximum. Limitations on sulphur emissions resulted in a downward trend. The second peak in the 1980s is caused the release of by aerosols from manure practices.

2.2.2 Cations

Cation deposition was based on the Dutch National Precipitation Chemistry Network for the period 1978 - 2000 (KNMI/RIVM, 1982-2001). For prior years, the 1978-1882 average was used. For the province of Brabant, station 231 at Gilze-Rijen, located at the center of Brabant, can be considered representative. Note that this network collects wet-only deposition since 1988. Up to 1988 the bulk deposition was measured, which is an overestimation of the concentrations in precipitation. Bulk deposition measurements were corrected to wet-only deposition using the estimated contribution of dry deposition in bulk deposition as reported by Heij et al.

To calculate dry deposition of cations for agricultural land, the ratios reported by Loman (1989), Heij (1991) and Jansen (1988) have been applied here to calculate the dry deposition for the period up to 1980.

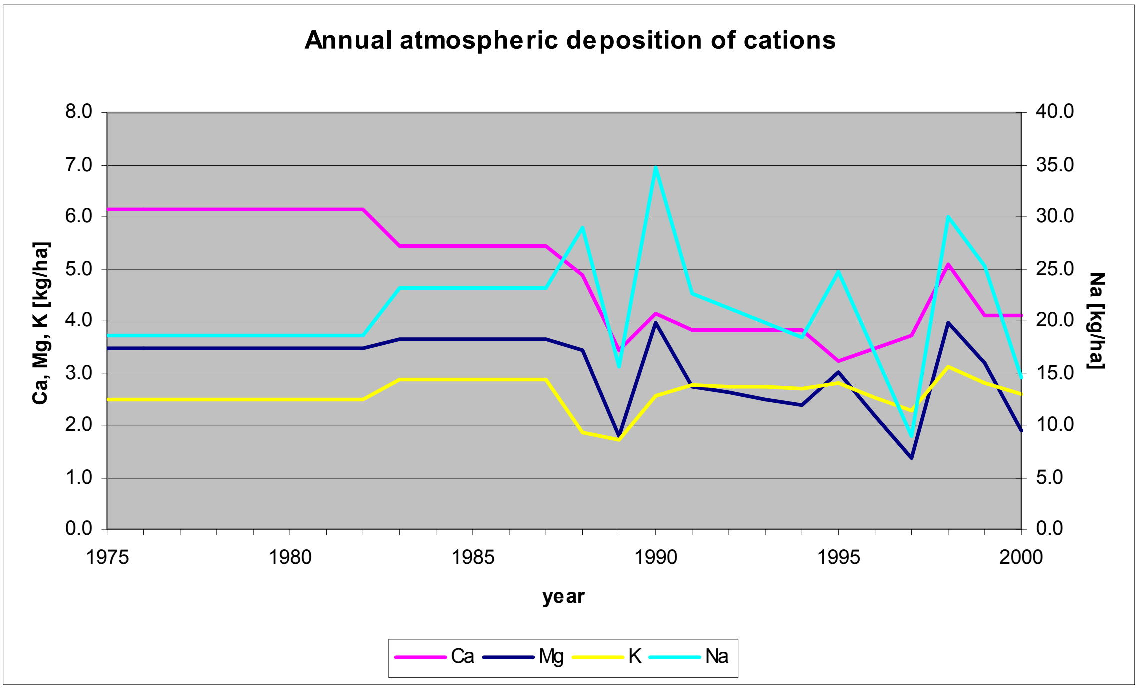

Figure 2.2 Annual atmospheric deposition of cations

2.2.3 Heavy metals

As with cations, the heavy metal deposition (Cd, Cu, Ni, Zn) was based on measurements of station 231 of the Dutch National Precipitation Chemistry Network. First measurements are dated from 1983, prior years are assigned the 1983-1987 average.

2.3 Manure and fertilizer load

Production figures are used to derive the amount of fertilizer used, since no data is available of the actual use of manure and fertilizer. The distinction in manure and artificial fertilizer is very important in this. Because of the specific agricultural practices on these crops, this method distinguishes between three land use types: grassland, arable land and from 1970 onward maize. Available manure is distributed over these land use types in a specific way. The conversion of production figures into chemical load of recharging groundwater is described in this section. First the evolution of the land use in the province of Brabant is listed.

2.3.1 Agricultural area in Brabant

The most important aspect of the evolution of land use area is the introduction of maize in the Netherlands in 1970. Maize is the only crop on which an unlimited amount of manure and fertilizer can be applied. Also the introduction of maize incited the growth of intensive livestock farming in Brabant.

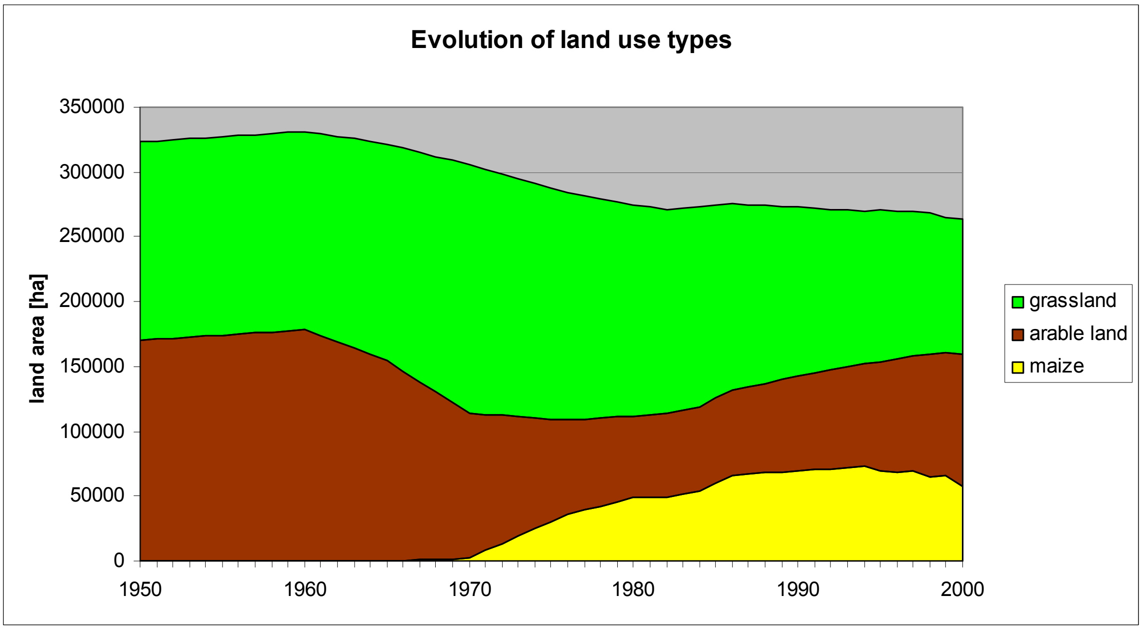

Figure 2.3 Evolution of land use types

2.3.2 Animal manure

Data on animal manure production are obtained from the Statistics Netherlands (CBS). Data is available for key years 1950, 1960, 1970, 1976, 1980, 1982, 1984, 1986 and 1988, and interpolated linearly for other years. For the period 1994 to present, Statline, the online database with annual data of the CBS was used (CBS, 2005).

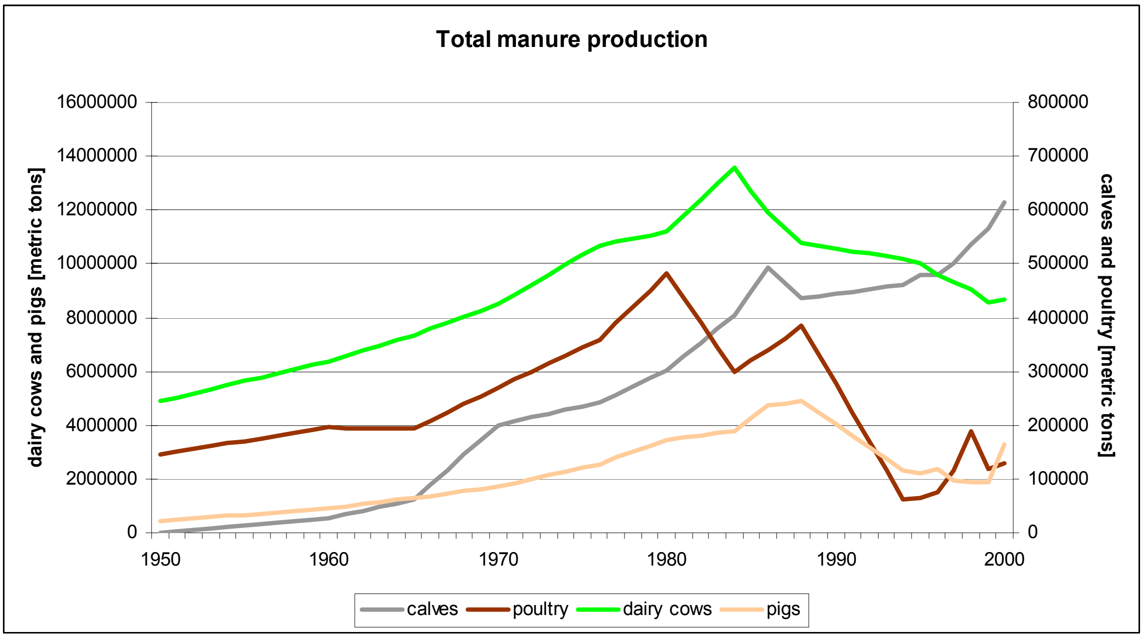

Figure 2.4 Total manure production in the province of Noord-Brabant

The data consists of the production of manure by dairy cows, calves, pigs for meat production, sows (with piglets) and poultry separately. Besides production figures, data on the chemical composition of the manure is required. These numbers were acquired from Evers and Pothoven (1995), assembled by Van der Grift and Van Beek (1996). The composition of animal manure is assumed to be constant in time, except for concentrations of N, P and K which are published annually by CBS since 1980 (N) or 1995 (P, K).

Table 2.1: Composition of animal manure in 2000.

	dry matter	nutrients				Minerals				
		org matter	N	P2O5	K2O	CaO	MgO	Na2O	Cl	S
	(g/kg)	(g\kg)				(g\kg)				
cows	95	60	4.9	1.8	6.8	2.1	1.3	0.7	3.0	0.7
calves	20	15	3.0	1.4	2.4	1.0	-	-	2.0	0.7
pigs	80	50	7.2	4.2	7.2	5.0	1.8	1.1	1.5	0.6
sows	60	40	4.2	3.0	4.3	0.8	1.1	0.5	1.5	0.4
poultry	322	230	15.2	18.7	13.0	23.5	2.5	2.0	3.5	1.6

An annual manure balance was constructed such that the produced amounts of manure are distributed over the area of grassland, arable land and maize, considering the manure requirements and limitations of these crops. These requirements and limitations are given by the National Reference Center for Agriculture, Nature and Food Quality. Basically, all animal manure is applied first, and nutrient deficiencies after application of animal manure are compensated by application of artificial fertilizer.

Grassland

First step is the application of 4/10 of the total dairy cow manure production on grassland, equaling the natural deposition during the grazing season. Additional manure is applied during the rest of the year up to an equivalent of 180 kg K2O/ha/yr. The amount of K2O in applied manure may not exceed 180 kg/ha/yr because higher loads can cause diseases in cattle. This sums the total annual animal manure load for grassland.

Arable land

The rest of the manure is applied to arable land to a maximum of 250 kg N/ha/yr, from the different sources in the following order: the remainder of the dairy cow, calves, pigs, sows and poultry.

The application of manure to arable land is limited to a maximum load of 250 kg N/ha/yr from animal manure because most crops – except for maize, which is treated seperately – do not tolerate higher loads.

Maize

The manure surplus which is left after applying manure to the grassland and arable land is applied to maize land. No limit applies to the amount of manure on maize. This has lead to han excessive high load of manure to maize land from the high production of manure in the 1980s.

2.3.3 Artificial fertilizer

Figures on national artificial fertilizer production since 1950 are obtained from the Agricultural Economical Insitute (LEI) (Pronk, 1983; LEI, 2005). These data describe the production of nitrogen, phosphor, potassium and chalk fertilizers. Each of these types contains not only the targeted chemical element, but a whole range of elements. Application of nitrogen fertilizer may also imply application of sodium, potassium, calcium, magnesium and/or sulphur. Thus detailed data on production of specific fertilizers and it's composition is required and available. (Evers, 1995) For example, the composition of various nitrogen fertilizers is given in table. Only with this data the accounting of fertilizers is possible.

Table 2.2: Composition of various nitrogen fertilizers

Dutch name	chemical formula	targeted component (%)	other components CaO	 MgO	(%) SOx	 Na2O
Zwavelzure Ammoniak	(NH4)2SO4	21			60.0	
Kalkammonsalpeter	NH4NO3 + CaCO3	27	12.0			
Stikstofmagnesium Meststof	NH4NO3 + CaCO3·MgCO3	21	6.0	4.0		
Kalksalpeter	Ca(NO3)2·NH4NO3·10H2O	15.5	26.3			
Chilisalpeter	NaNO3 + Na3BO3	16				35.0
Kalkstikstof	CaNCN + CaO + CO(NH2)2	21	60.0			
Ureum	CO(NH2)2	40 - 46				
Watervrije Ammoniak	NH3	83				
Kalisalpeter	KNO3	13				

The nationally produced amounts of artificial fertilizers are distributed over the total national area of grassland, arable land and maize as with animal manure. Distributing the artificial fertilizers, the following key table published by the CBS (1987) was applied.
This yields a nationally averaged application of each element in kg/ha/yr.

Table 2.3: Distribution of artificial fertilizers over natural area of grassland, arable land and maize

	Distribution of artificial fertilizers over national area of:		
Fertilizer type:	grassland	arable land	maize
Nitrogen	75%	25%	
Phosphor	30%	70%	
Potassium	20%	80%	

The application to arable land and maize is the weighted average of their area, i.e. 25% of the total nitrogen fertilizer production is divided by the total area of arable land and maize to obtain the load in kg/ha/yr of nitrogen fertilizers. This load is then broken down in the chemical elements which the nitrogen fertilizers are composed of.

This national average of fertilizer application per unit area is converted to the amount of fertilizer applied in Brabant, by comparing with a study of regional fertilizer application by Menke (1992). In this study, artificial fertilizer application is stated per agricultural area for the years 1985 and 1990. From these data, a correction factor for Brabant from the national average can be calculated. This is then used to scale the national estimates, using the Menke data for 1985 and 1990. In the Menke study, it appeared that in the region of Brabant only negligible amounts of artificial N or P fertilizers were applied to maize.

2.4 Crop uptake

The total nutrient load is largely used for crop growth. To calculate the composition of the water leaching from the root zone, crop uptake is subtracted from deposited loads. Historical crop yield figures were obtained from the CBS and from Van der Grift and Van Beek (1996).

Yield (in kg/ha) was multiplied by concentrations of nutrients in the harvested crops. These (averaged) concentrations were obtained from the Praktijkgids bemesting (Fertilizing practice guide) by the Nutrienten Management Instituut (NMI, 2000). Crop uptake was calculated for grass, arable land and maize, assuming a fixed equal share of potatoes, sugar beets and wheat on arable land.

The following concentrations were used for these calculations:

Table 2.3: Concentrations of chemicals in crops that used to derive crop uptake.

crop	N	P	K	Ca	S
grass	3.2 %	0.5 %	2.1 %	0.5 %	0.3 %
potatoes	0.3 %	0.03%	0.02%	0.02%	0.03%
sugar beets	0.5 %	0.04%	0.03%	0.1 %	0.05%
wheat	2.3 %	0.2 %	0.2 %	0.2 %	0.3 %
maize	1.2 %	0.2 %	1.0 %	0.1 %	0.1 %

For example, in 1995, 11.500 kg of maize (dry matter) was harvested on average per acre. Harvesting the maize, 138 kg of N (=1.2% * 11.500 kg), 23 kg of P (=0.2% * 11.500 kg), 115 kg of K (=1.0% * 11.500 kg), 11.5 kg of Ca (=0.1% * 11.500 kg) and 11.5 kg of S (=0.1% * 11.500 kg) was removed from the system. These amounts are substracted from the total deposition in 1995 to produce the net load of agricultural chemicals to the groundwater system under maize production.

2.5 Net load

The result is the annual surplus of nutrients, cations and heavy metals deposited on the land surface since 1950, for every land use class distinguished in this document. This annual surplus is represented graphically in the figures below. The excess load – subtracting the crop uptake from the sum of deposition, manure and fertilizer – is leached out of the root zone. This is especially important for our purpose and is indicated with the red line in the figures below. The figure for N does not include denitrification in the unsaturated zone, which will be discussed in section 6.

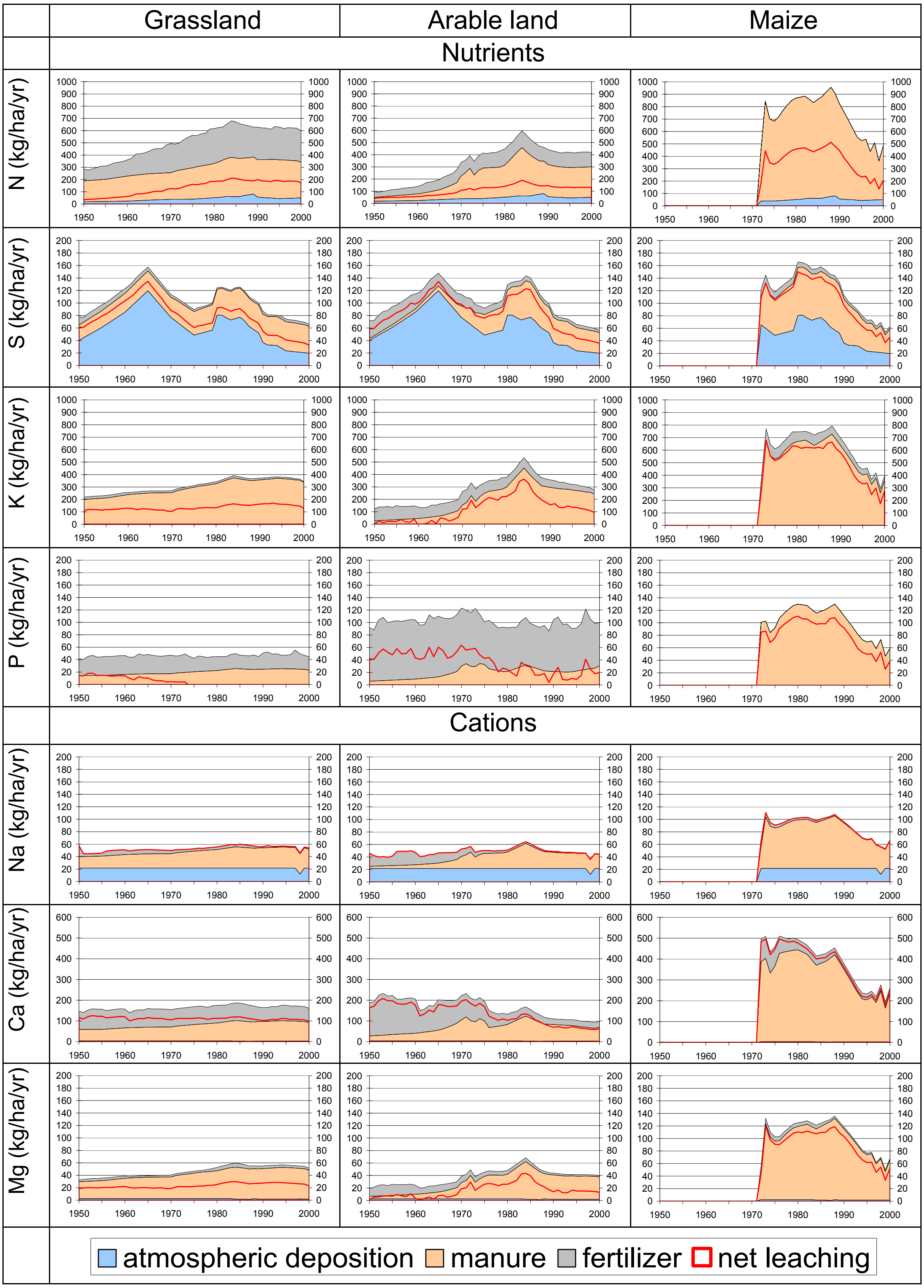

Figure 2.5: Historical inputs by atmospheric depostion, manure and fertilizer and excess loads for grassland, arable land and maize for N, S, K, Na, Ca and Mg

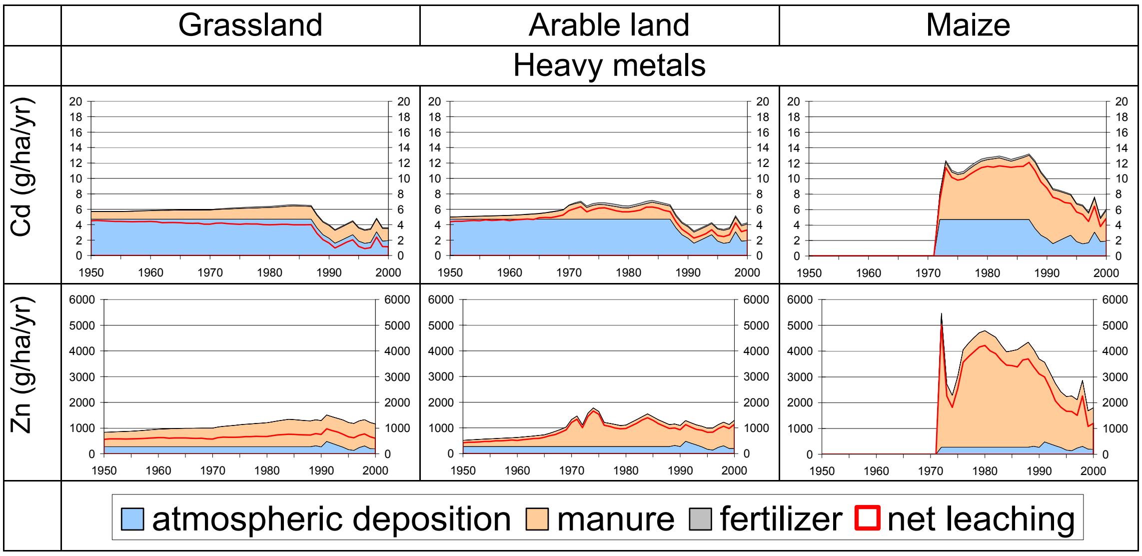

Figure 2.6: Historical inputs by atmospheric depostion, manure and fertilizer and excess loads for grassland, arable land and maize for Cd and Zn

These figures represent the average annual load of nutrients, cations and heavy metals for agricultural land in the province of Brabant, i.e. the lower Dutch Meuse basin. For other regions in the Netherlands, the accounting method presented here could well be applied, with regional input data of atmospheric deposition, manure production, and fertilizer sales. For other European regions (outside the Netherlands), regional knowledge of the agricultural practices are also needed to apply this method.

The figures 2.5 and 2.6 show large variations between the different elements and the different land use types. For all land use types, manure is the largest source of nitrogen and potassium. This is especially true for maize, where the manure input is by far the largest source for every element, except sulphur. Sulphur has a large contribution from atmospheric deposition and the net patterns are very similar for grassland, arable land and maize. The large contribution of manure load on maize, which has decreased strongly since 1990, results in very similar patterns for all elements in maize, decreasing strongly since 1990. This distinguishes maize from the other crops, where patterns are less pronounced. Patterns for heavy metals are less reliable, since atmospheric deposition has been estimated for the period up to 1983. For maize the figures are more reliable as a result of the large contribution of manure.

2.6 Aggregation to regional scale concentrations

A catchment to basin scale approach does not demand the detailed information of input curves of individual land use types but rather an averaged input curve for agricultural land in the area. In this case, we have constructed the aggregated input curve for the recharge areas with intensive livestock farming, to compare it to the measurements of groundwater quality measurements in these vulnerable areas.

The previous presented loads in mass per area were converted into concentrations in recharging groundwater by dividing by precipitation surplus. Here, an average precipitation surplus between 1970 and 2000 was used. Because of the nonlinear effects from interannual varation in precipitation surplus, annual surpluses are not a more valid estimation of the dilution of the load. In practice a wetter year will lead to higher concentrations and leaching of nutrients that have accumulated i.e. have not been leached during previous dryer years. The time-averaging that was introduced by sampling from the 1 or 2 m long screens will also dampen this effect.

Nitrogen uptake by crops and denitrification losses in the root zone was calculated according to SPREAD (Kiwa Research and Consultancy, 1998). SPREAD (Solute Prediction from Regional distributed Agricultural Deposition) was developed by Kiwa to be able reconstruct diffuse inputs relevant for drinking water companies.

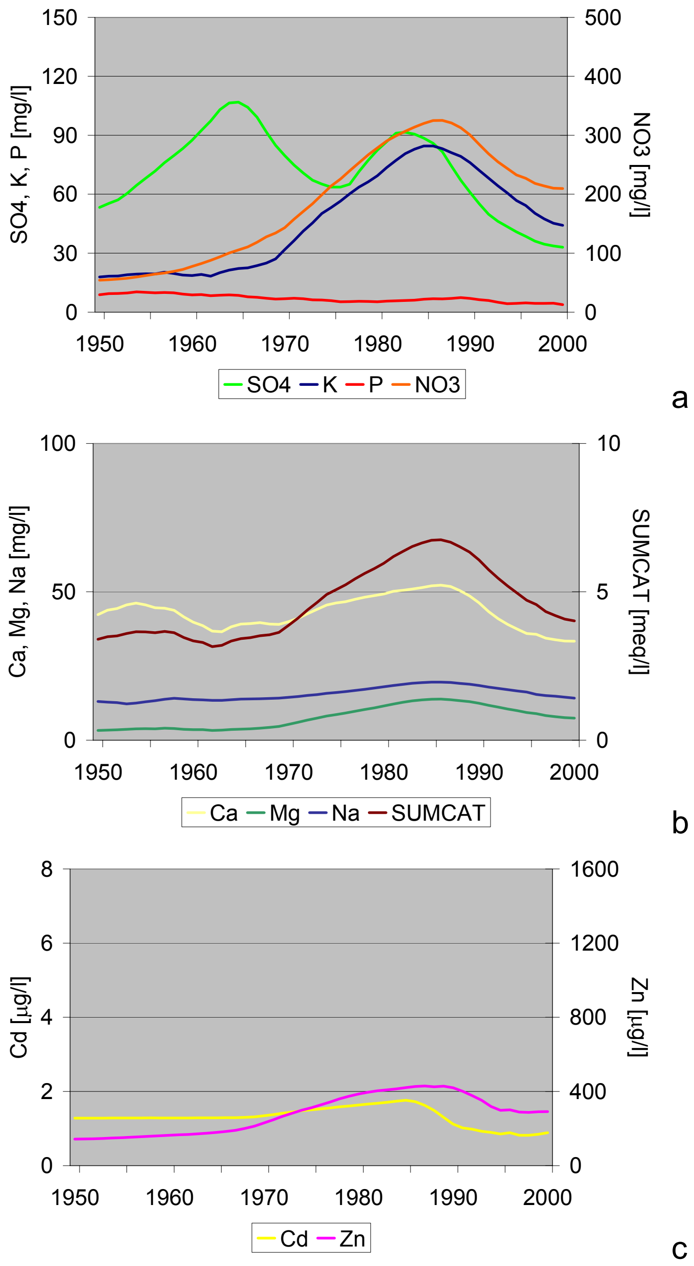

Figure 2.7: Estimate of the concentration of nutrients (a), cations (b) and heavy metals (c) in recharging groundwater. A 5 year moving average was applied to cancel out difficult to quantify variations in the precipitation record when considering data over several years. All substances show a peak in the mid 1980's when the use of manure was at it's high, except phosphor. Sulphur shows a peak in the 1960's as a result of atmospheric deposition from fossil fuel use.

2.7 Discussion

In this chapter we have provided an estimate of the concentrations of nutrients, cations and heavy metals in recharging groundwater at the regional scale of the province of Brabant (i.e. the lower Dutch Meuse basin). This involves accounting of the three sources (atmospheric deposition, manure and fertilizer) and the uptake by crops and denitrification in the unsaturated zone. Various sources of uncertainty can be addressed here.

The 'dry' component of the atmospheric deposition has not been measured until 1988. Instead an approximation based the measured bulk deposition was used, based on a constant ratio of 'wet' vs. 'dry' deposition. The deposition of nitrogen and sulphur before 1980 was related to the emission figures that are available for this period. These assume a proportional relationship between emissions and deposition. Since sulphur has a large atmospheric component in the total deposition, this uncertainty plays a significant role in the estimate of the concentration in recharging groundwater. Data after 1980 are based on measurements and have a smaller uncertainty. For cations and heavy metals, the first measurement was dated 1983, and no data exists before that. Here it is assumed that no trend in the deposition of cations and heavy metals exist before 1983, but this remains open for discussion.

The method to estimate the use of manure on different crops is based on the production of several types of manure, the concentration of substances in the manure and the distribution between different land use types. Production figures of manure are relatively well known in the whole of Netherlands on a provincial scale. The concentrations of substances in manure is often based on a single estimate, except for nitrogen, phosphor and potassium which are variable in recent years. The distribution of manure over grassland, arable land and maize is according to the advice of the LEI. The actual practice may be different, and more variable. This introduces a source of uncertainty in the accounting method.

For the distribution of fertilizer between the crops fixed ratios were applied for the complete period. Again this may introduce an uncertainty in the contribution of fertilizer to the total load.

Crop uptake is based on annual crop yield and average fixed concentrations in harvested crops. Also a fixed ratio between rotating crops on arable land was assumed. In practice crop rotation will cause inter-annual variation in crop uptake, but this will cancel out on a larger time scale of 3-5 years or with a regional approach.

Denitrification was calculated by the SPREAD method developed by Kiwa Research and Consultancy. Since denitrification may be very variable even on a very small scale, this approach is again not suitable for field scale studies. Nevertheless, SPREAD is able to capture the overall relations between denitrification and nitrogen input for a regional scale study.

Variation in precipitation and evaporation is neglected in this document. Although this may be a large source of variation on intra and inter annual time scales, on the scale of decades this will not play a role. Up to date, no suitable protocol has been found to correct for meteorological variation on this scale. Methods applicable on the field scale require detailed and accurate knowledge of soil type and hydraulic properties, which is not available on a regional scale.

2.8 Conclusions

To relate trends in groundwater quality to input, detailed knowledge of the input pattern is essential. Actual measurements of atmospheric deposition or reports of actual manure application are not available for the whole area and the whole time span, so the estimated input pattern is based on indirect data, such as emission or production figures. The uncertainty introduced in this method should not be neglected Nevertheless, the purpose of this dataset is not to be compared with measurements on the field scale, but to regionally aggregated time series. This comparison will be described in Deliverable T2.4. First results indicate a good predictive capability of the method presented here, with correlation coefficients between predicted and observed concentrations in groundwater of 0.9 and higher.

Concluding, the presented input pattern is accurate in that the multi year average will agree well with the actual input. It will not be able to describe the inter-annual variability in concentrations in recharging groundwater. Also, and more importantly, the trends in this input patterns are robust. For most substances, there is an upward trend towards a peak in the concentration in recharging groundwater around the mid 1980's. Younger water will show a declining trend. Exceptions to this general rule are phosphor and sulphur. The first shows little or no trend and the latter shows two peaks: one in the mid 1960's caused by the combustion of fossil fuels, and one in the 1980's, related to agricultural practice, as with other substances. These patterns are expected to appear in trend analysis of young groundwater in areas vulnerable to agricultural pollution in the Dutch Meuse basin. Results of the trend analysis will be published in forthcoming TREND 2 deliverables.

3. Documentation of reconstructed land use changes around test sites for Meuse BE (ULg)

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3.1 Introduction

During period 13-18, HGULg has focused his work, for the TREND workpackage, on the finalisation of 'point-by-point' trend analysis for nitrate concentration in groundwater in the four selected sub-catchments (Deliverable T2.4, HGULg). In the next months, investigations will be performed with the aim of relating land-use practices to groundwater quality trends.

In the framework of the PIRENE Project funded by the Walloon Governement, UHAGx (Prof S. Dautrebande) has reconstructed land use and estimated fluxes of nitrates to the groundwater for the last 30 years for the Walloon part of the Meuse Basin. This deliverable, prepared and written by UHAGx shows the results of this study obtained for the studied sub-catchments.

3.2 Land use and quantitative evaluation of the risk of nitrate contamination for the Hesbaye aquifer, Pays of Herve, Néblon basin and the alluvial aquifer

The risk of surface water and groundwater nitrate pollution from environmental pressures on soil was evaluated for the most watersheds in the Walloon region by EPICgrid model (UHAGx-FUSAgx) (Figure 3.0.1), in the PIRENE Program application (
Figure 3.0.2), including different validations; the model simulate the hydrological processes of Meuse and Escaut Walloon catchments, including notably unsaturated and variably saturated flows of the vadose zone. The Interuniversitary PIRENE project was (18 teams, coordination Prof. J.Smitz , ULg) funded by Walloon Government, in the context of the EU Water Framework Directive **2000/60/CE.**

Simulated flows are direct runoff, percolation, groundwater recharge, subsurface lateral flows, soil moisture variation, actual evapotranspiration, agricultural diffuse nitrates, phosphor, pesticides, organic matter, sediment yields, and dispersed domestic nitrates. The model is physically based, without calibration (except subsoil vertical/horizontal permeability of vadose zone); crop growth and agricultural practices are also simulated.

Results based on 30 years climatic and statistical agricultural or domestic data provide an lighting on the groundwater and surface water risk of nitrate pollution from the soil nitrate runoff and leaching, in relation with the driving forces/pressures of climate and anthropic activities. Predictive scenario's (climatic change, agricultural practices and land use ,…) are also simulated.

3.3 Characterisation of the vadose zone

The unsaturated vadose zone with its intrinsic properties (thickness, hydrodynamic properties) has a considerable part in, notably, groundwater contamination risk. It is thus important to characterize its state by, if possible, integrated indicators in relation with the soil solution. The criteria used here to characterize the vadose zone in relation with the nitrate problematic are representative transfer time of nitrate up to groundwater and nitrate storage capacity of the vadose zone.

The values result from EPICgrid simulations; this is possible because the representation of the vadose zone is physically based in the model, including parameters as, notably, hydraulic conductivity and effective porosity.

The solute mean travel time through the vadose zone was estimated by a « impulse-impulsive answer » simulation. In this case, nitrates are applied at a fixed date; the model follows the wave of propagation through the vadose zone and estimate the travel time up to groundwater. The nitrate amount applied is important in order to neglect the effects of storage in the vadose zone.

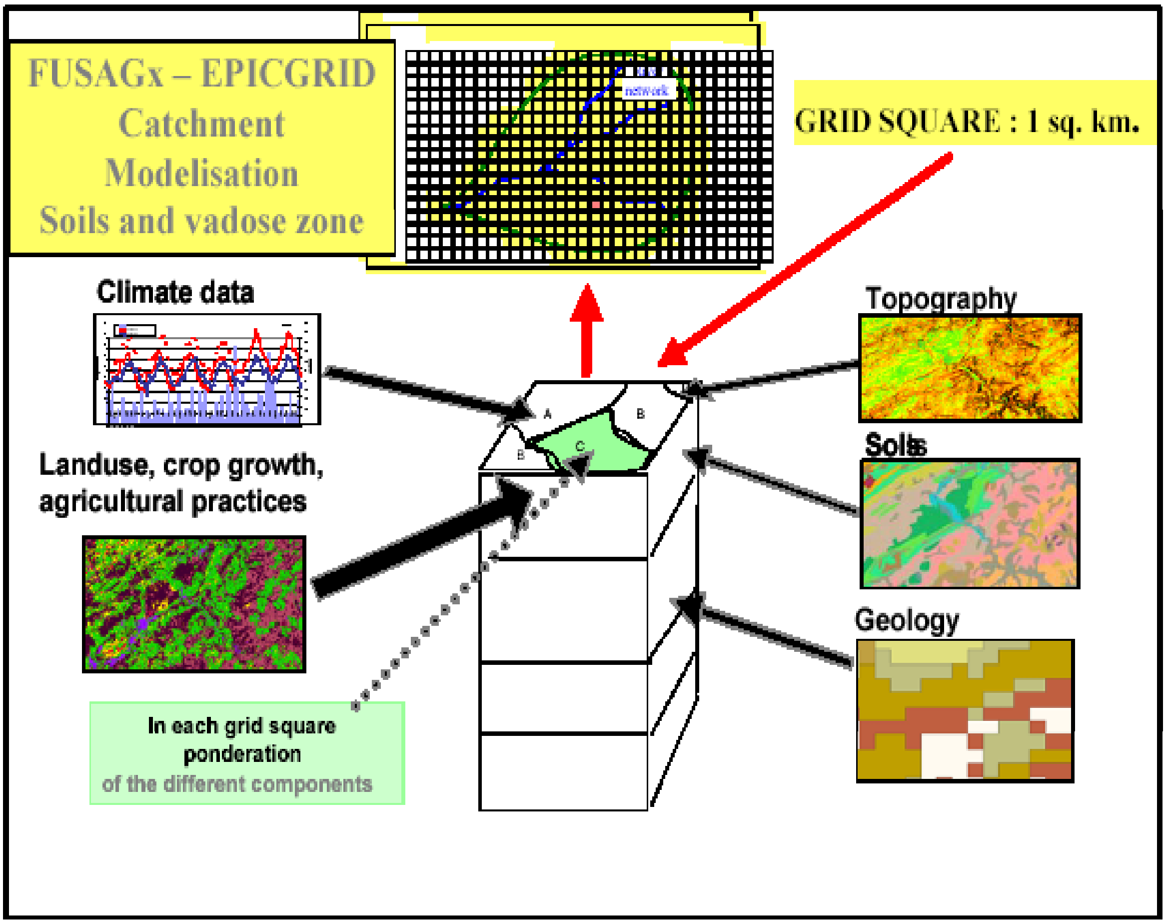


Figure 3.0.1: Structure of the EPICgrid_PIRENE model

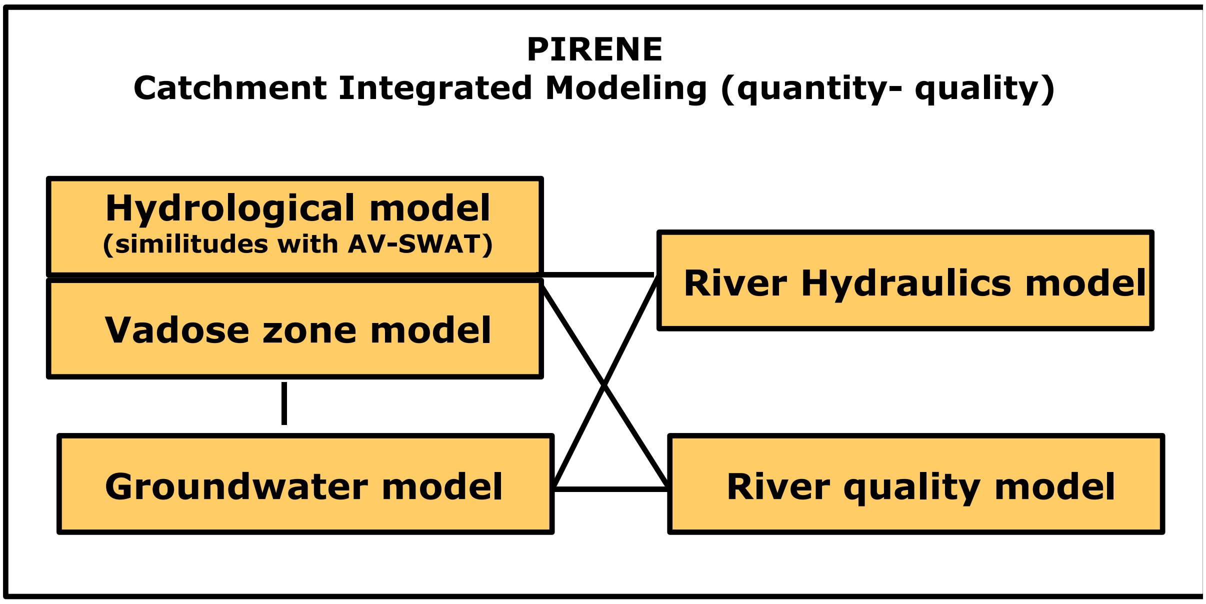
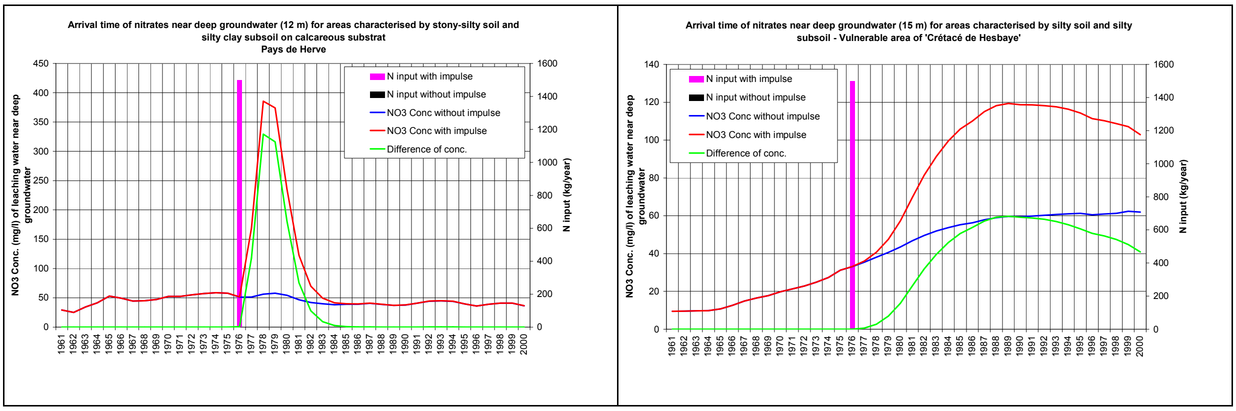


Figure 3.0.2: Structure of the PIRENE model

Figure 3.3 presents two types of response; on the left, a fast transfer through the vadose zone (part of the Pays de Herve), on the right, a slow transfer through the vadose zone (many years) (Geer catchment).


Arrival time of nitrates near deep groundwater (12 m) for areas characterised by stony-silty soil and silty clay subsoil on calcareous substrat
Pays de Herve

Arrival time of nitrates near deep groundwater (15 m) for areas characterised by silty soil and silty subsoil - Vulnerable area of 'Crétacé de Hesbaye'

Figure 3.3: EPICgrid model : Examples of time transfer for two different vadose zones

Slow transfer implies a greatest inertia of the system. For the Geer catchment, prospective simulations realised for the fifty future years show that the stabilisation of nitrates supply is reflected only several years later for the most shallow groundwater, and much later for the deepest groundwater.

Another parameter implies in natural attenuation is the storage capacity of the vadose zone. This storage capacity is very different from one substratum to another.

The

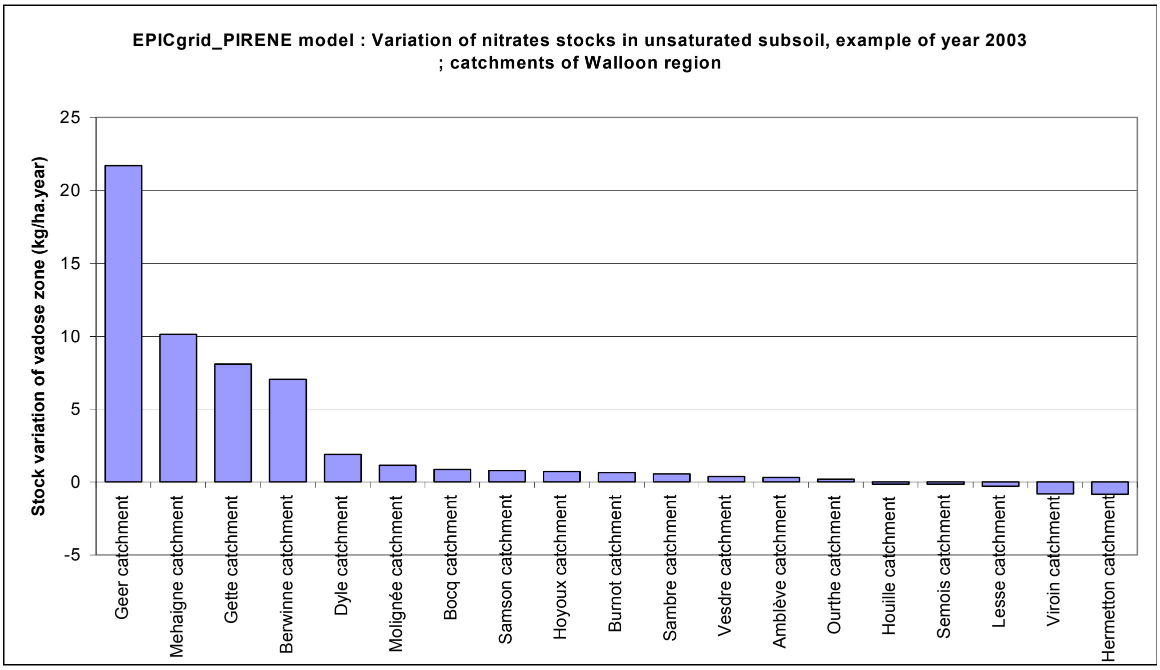


Figure 3.3: EPICgrid model: storage of the vadose zone

shows the storage variation of the vadose zone for the year 1993 for different Walloon catchments. We can note however that the retard effect of the vadose zone (damping and storage) has to counteractig effects because if it moderates the leaching effects up to groundwater, this effect is provisional and the recovery capacities of the contaminated medium will be slowed down.

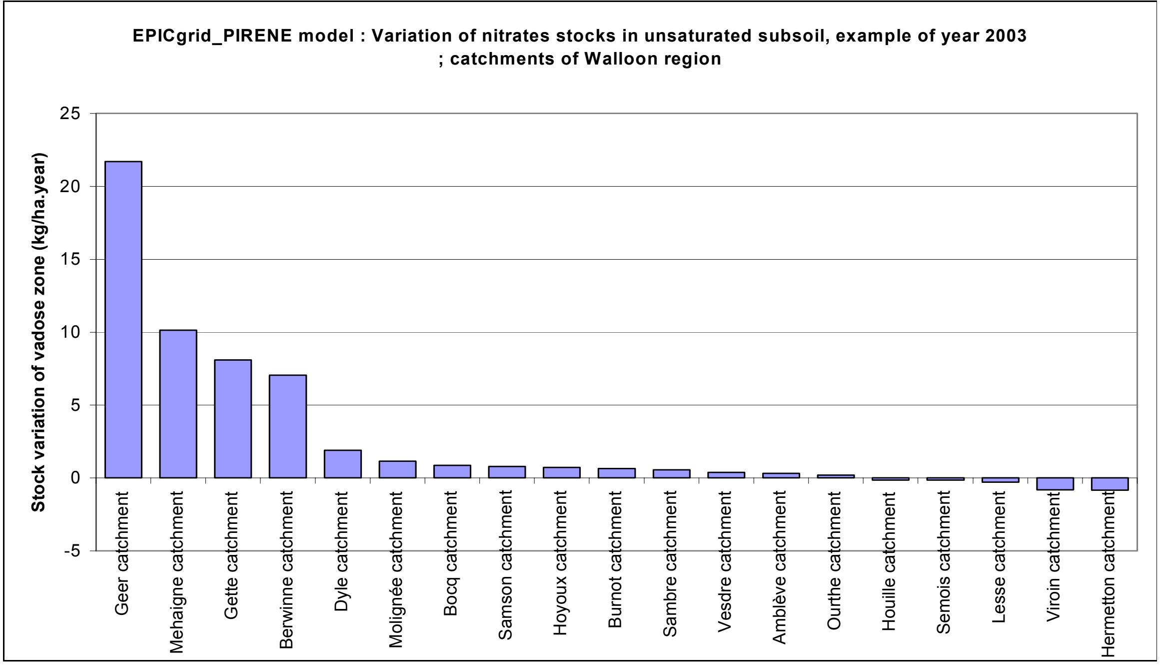


Figure 3.3: EPICgrid model: storage of the vadose zone

3.4 Environmental pressures in relation with nitrates

3.4.1 Rainfall

The relation between annual precipitations and simulated nitrate concentrations of leaching water is reported in Figure 3.5 for the Geer catchment example ; this figure shows that only 10% of the mean annual concentrations variation is explained by the

annual rainfall, while 54% of the explication is given by this same annual rainfall regarding to the annual leaching nitrates quantity (
Figure); a detailed analysis of the chronological results brings to the fore an effect of rainfall especially sensitive during a succession of rainy years and all the more marked since the groundwater recharge is superficial.

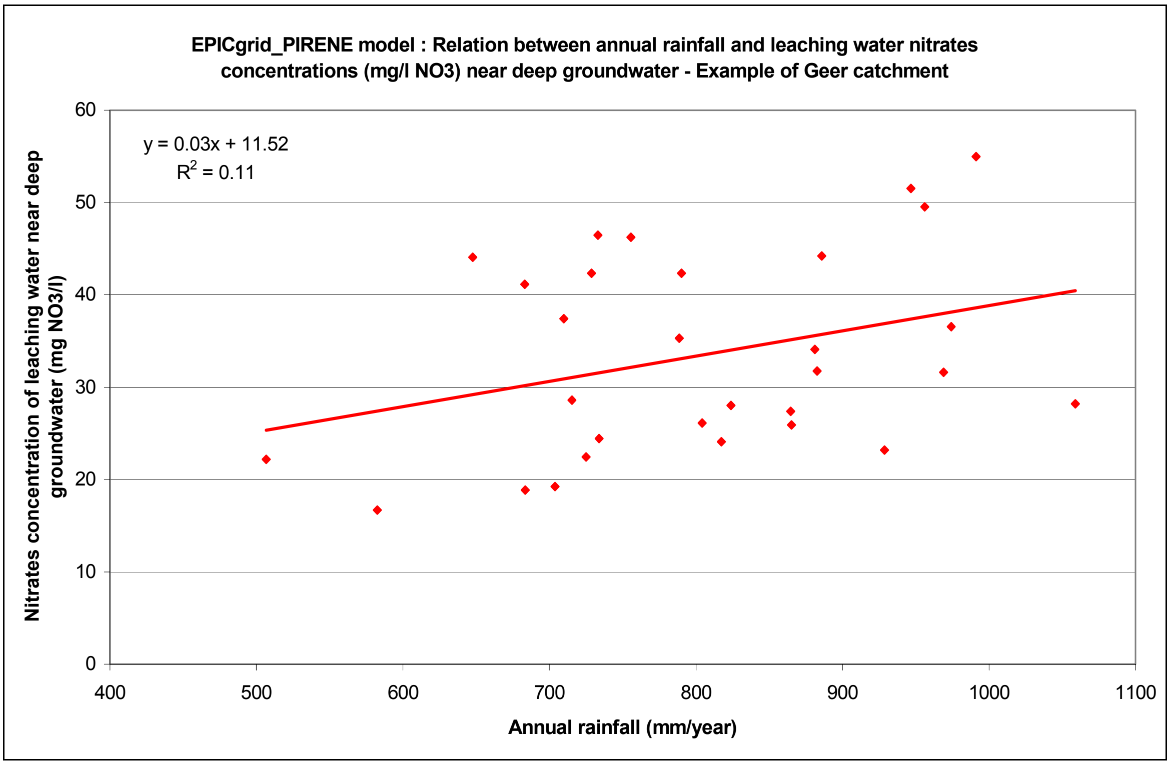


Figure 3.0.3a: EPICgrid_PIRENE model : Relation between annual rainfall and leaching water nitrates concentrations (mg/l NO3) near deep groundwater – Example of Geer catchment

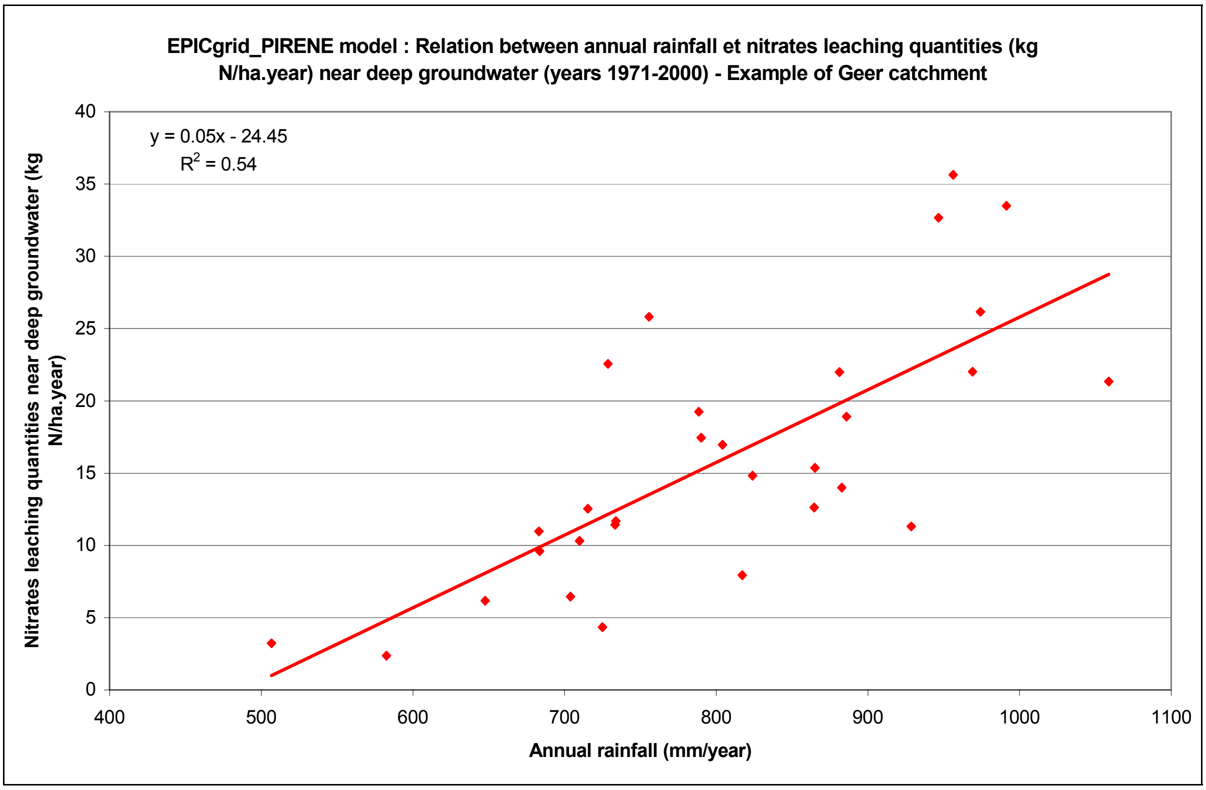


Figure 3.4b: EPICgrid_PIRENE model : Relation between annual rainfall et nitrates leaching quantities (kg N/ha.year) near deep groundwater (years 1971-2000) – Example of Geer catchment

3.4.2 Land use

Landuse maps of the studied areas (Figures 7 to 10) were extracted from the CARHY project landuse map (Laime et Dautrebande, 1995). The landuse map of the CARHY project results from the analysis of four satellite images (LANDSAT) token at four distinct moments between August 1990 and March 1993. It covers the Walloon Region entirely. The soil occupation classes are :

- stretch of water
- deciduous tree
- resinous tree
- urban areas
- grassland
- weeded crops
- unweeded crops

For the Flemish part of the Geer catchment, the landuse is extracted from the Corine project landuse map. This map does not allow an hydrological distinction of crops types (weeded and unweeded crops); it limit the use of this map within the framework of applications such as those.

Each type of landuse makes the object of a distinct modelling. The EPICgrid model takes into account among others the sowing and harvest dates, the tillage operations, the daily evolution of crops development.

The Geer catchment is a catchment with a dominant agricultural component. The deep silty soils with good properties of water retention and infiltrability, the relief not very hilly, are so much elements favourable to crop development ; these ones cover more or less than 65% of the catchment area. Space remaining is divided between pastures (15% of the catchment), housing (13%) and forests (7%).

The ‘Pays de Herve’ is a region with fertile soils but relatively heavy and often not very deep; the topography is uneven. These factors justify that this region is mainly covered by pastures, these ones represent more than 50% of the region area. The Néblon catchment is located in the Condroz. The region is fairly hilly, plateaus are broken with valleys, rivers and depressions ; the soil is generally fertile but of variable depth. So, the pedoclimatic context of this region is like that the landscape is divided between crops (31% of the catchment area), pastures (42%) and forests (24%).

The Meuse alluvial plain, downstream of this confluence with the Sambre, is characterized by an important urbanization and industrialization.

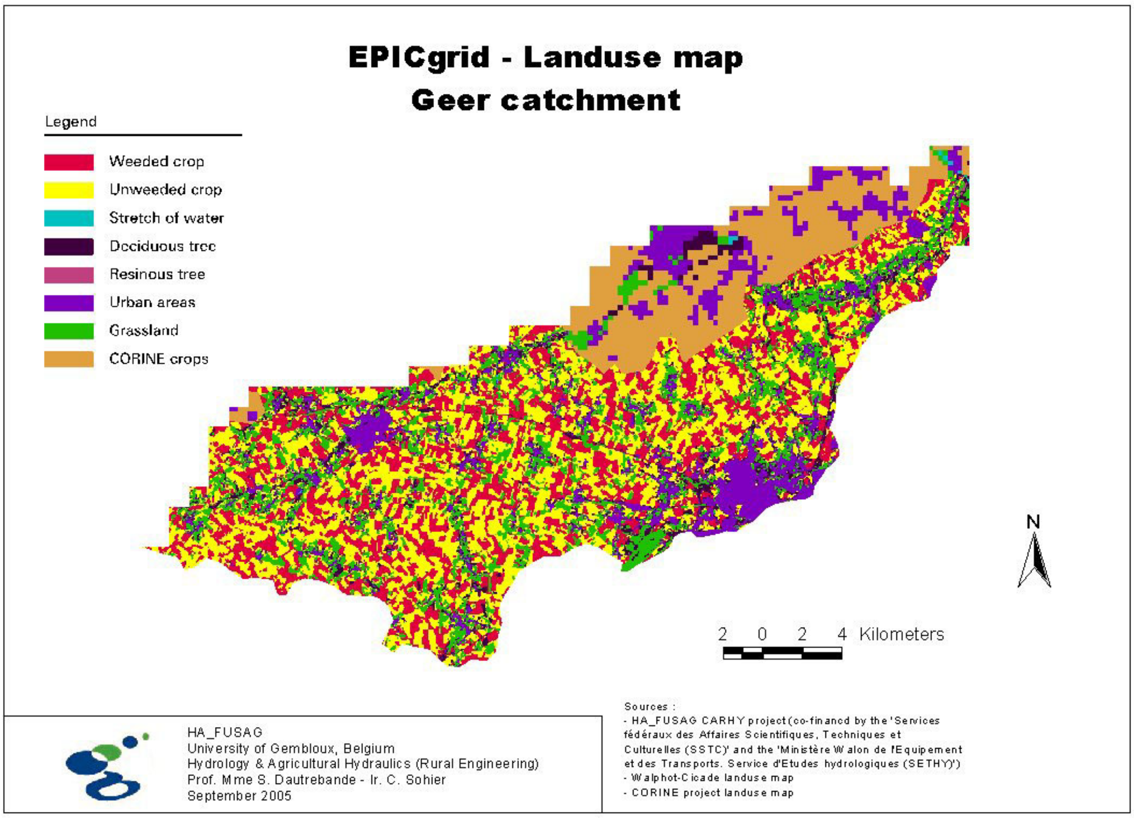


Figure 3.0.4: EPICgrid – Landuse map – Geer catchment

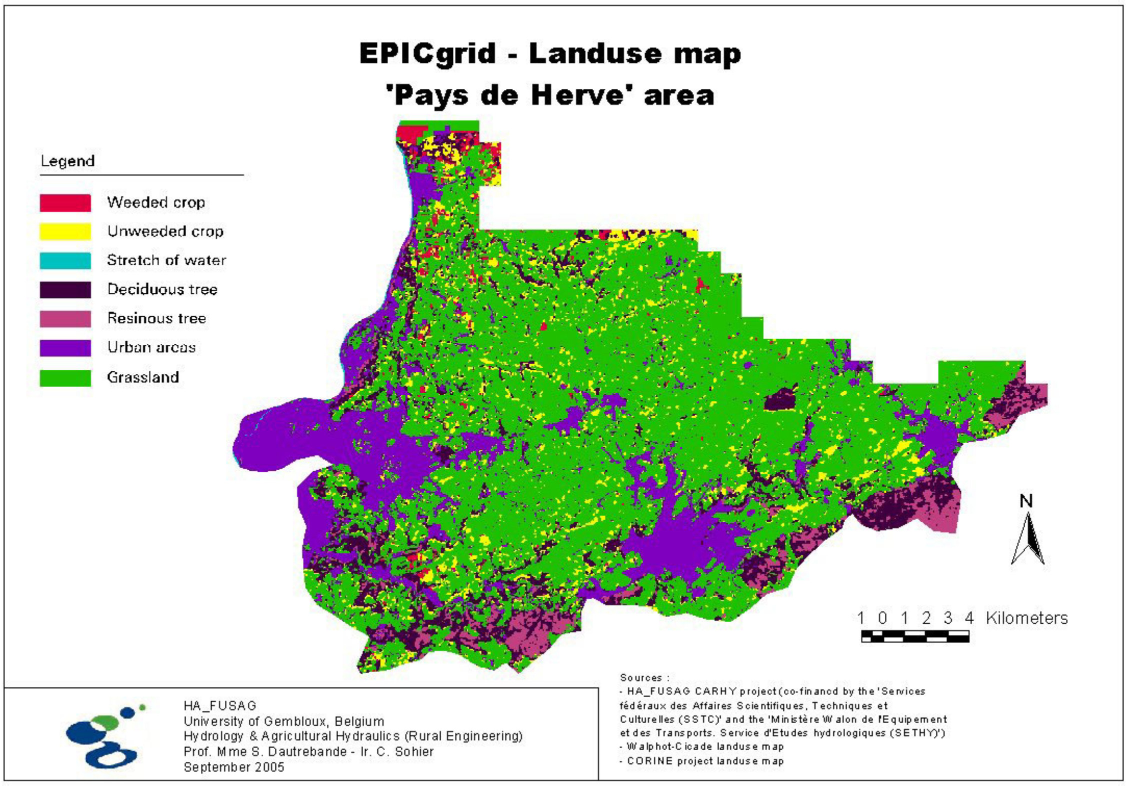


Figure 3.0.5: EPICgrid – Landuse map – ‘Pays de Herve’ area

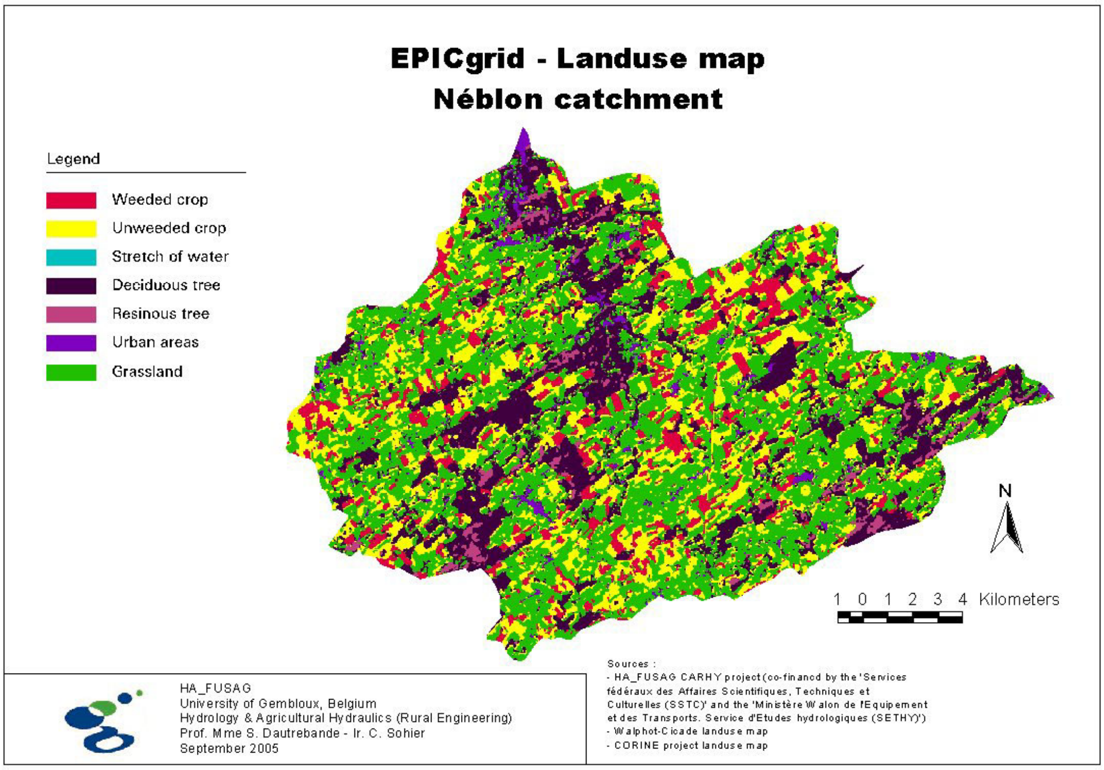
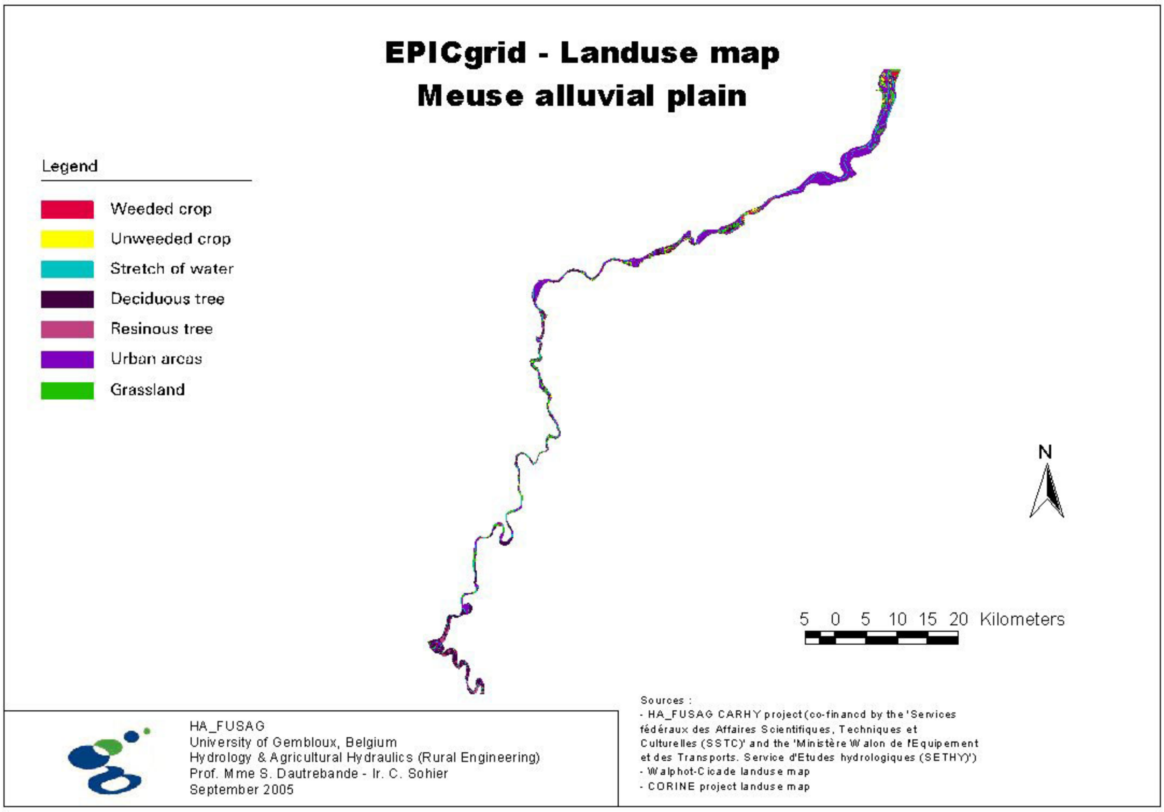


Figure 3.0.6: EPICgrid – Landuse map – Néblon catchment



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September 2005

Sources :
- HA_FUSAG CARHY project (co-financd by the 'Services fédéraux des Affaires Scientifiques, Techniques et Culturelles (SSTC)' and the 'Ministère Walon de l'Equipement et des Transports. Service d'Etudes hydrologiques (SETHY)')
- Walphot-Cicade landuse map
- CORINE project landuse map

Figure 3.0.7 : EPICgrid – Landuse map – Meuse alluvial plain

3.5 The nitrates input

3.5.1 Nitrates input from agricultural diffuse sources (crops, breeding)

The nitrogen spreading on the agricultural field has a double origin: effluents of breeding (nitrogen mainly in organic form) and chemical fertilizers (nitrogen in mineral form); in agricultural practices, the effluents of breeding are brought mainly on the meadow and the heads of rotation crops : the beet, the potato and the corn. Mineral manure is brought to the culture according to successive amounts.

Agricultural practices are not homogeneous on the Walloon territory, in particular, of the fact of the intrinsic characteristics of the medium (ground, climate, topography...); the analysis of the nitrogen inputs and their temporal evolution was thus carried out on the basis of the "agricultural area" entities.

The mineral nitrogen input on the agricultural field were estimated on the basis of statistics published by the Agricultural Center of Economics (‘Centre d’Economie Agricole’ (CEA)); these statistics estimate, by agricultural area, the temporal evolution of the consumption of nitrogen mineral manures. It will be noted however that for the years before 1980, these statistics are available only on a national scale; an extrapolation has thus being carried out to obtain values by agricultural area. Figure 3.0.8 presents the consumption of nitrogen mineral manures for agricultural areas of ‘Région limoneuse’ (Geer catchment), ‘Condroz’ (Néblon catchment) and ‘Région herbagère de Liège’ (Pays de Herve).

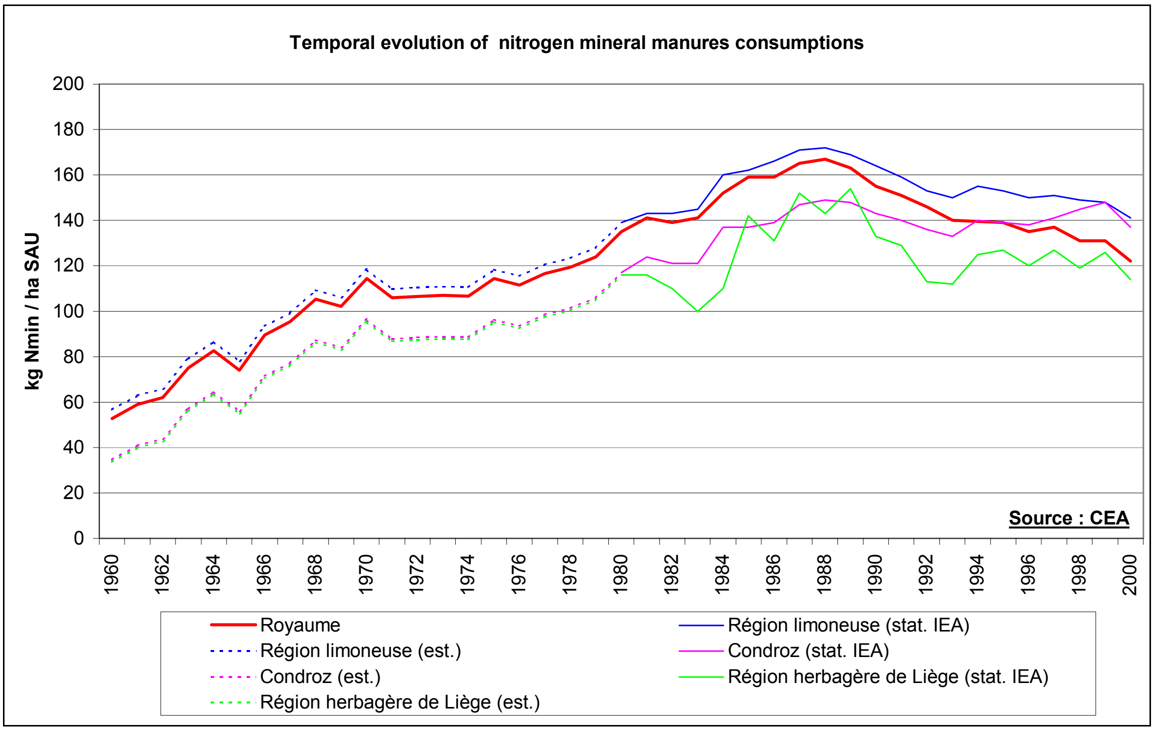

Figure 3.0.8: Temporal evolution of nitrogen mineral manures consumptions (source : CEA)

The organic nitrogen inputs were calculated on the basis of livestock statistics collected by the National Institute of Statistics ('Institut National de Statisques' (INS)) and of data of nitrogen in faeces per animal category. The total amount of organic nitrogen is then split up into "controllable nitrogen" (stored in farming) and "uncontrollable nitrogen" (produced in pasture). Then the organic nitrogen amounts are distributed on the agricultural fields : "controllable nitrogen" on crops, "uncontrollable nitrogen" on grazing pastures (for some specific areas as the 'Pays de Herve', an input of "controllable nitrogen" is also realized on pastures).

Figure 3.10 presents the temporal evolution of organic nitrogen inputs on grazing pasture and on heads of rotation crops.

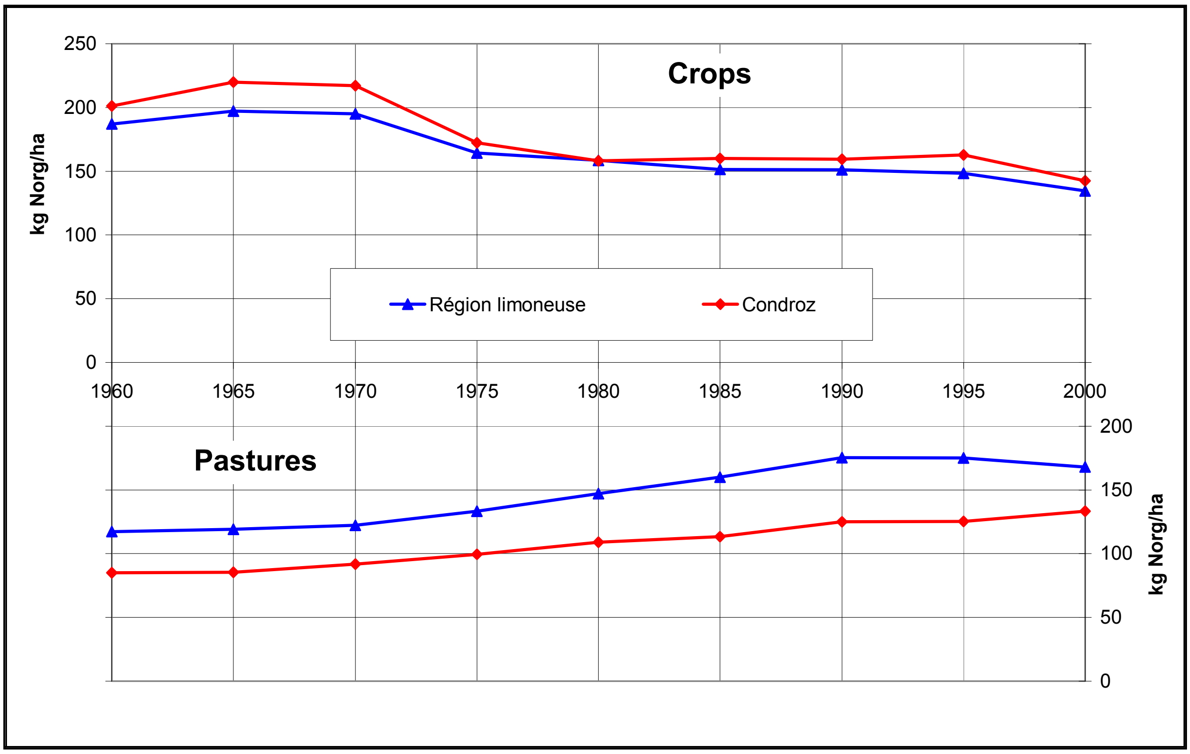

Figure 3.10: Temporal evolution of organic nitrogen inputs on grazing pasture and on heads of rotation crops

3.5.2 Nitrates input from dispersed domestic sources

As an example, for the 'Pays de Herve', dispersed domestic inputs are estimated by considering that 35% of housing are not connected to sewers (SPGE, 'Société Publique de Gestion de l'Eau' data).

For the 'Pays de Herve', it appears that domestic contribution is significant, even if a sensitive growth of concentrations is linked to high livestock pressure in pasture coupled with a land use evolution toward more contamination risk crop speculations (corn).

In synthesis, the Table 3.1 shows, for groundwater of Geer catchment, 'Pays de Herve' and Néblon catchment, the respective contributions of diffuse agricultural and dispersed domestic sources (on 35% non connected houses hypothesis), regarding to the nitrogen losses by leaching near deep groundwater.

For the Meuse alluvial plain, the discretisation used in the PIRENE program (kilometer discretisation) is not appropriate to characterize this narrow area with enough precision ; to do this, it is necessary to use a more detailed spatial representation (feasible with EPICgrid).

Table 3.1: EPICgrid_PIRENE model : Deep groundwater contamination risk by nitrates : evaluation of respective agricultural (crops, pastures, forests) and domestic contributions (mean 1998-2000)

	Contribution of agricultural and wooded areas	Contribution of housing areas (dispersed pollution)

	(diffuse pollution) (*)	(*) (**)
Geer catchment	88 %	12 %
Pays de Herve	52 %	48 %
Néblon catchment	93 %	7 %

(*) Expressed in percentage of the annual quantity of leached nitrogen near deep groundwater
(**) Hypothesis : rate of sewage of 65 %, rate of sewers leakage : 25 %

3.6 Overview of future work

HGULg will perform tests with correlation tools and transfer function models with the aim of land use practices to groundwater quality trends. In the same time, a groundwater and flow model will be developed for the Hesbaye aquifer in cooperation with BASIN R3, COMPUTE C2 and HYDRO H1. Trend analysis and aggregation results will be used as calibration and validation data sets for the model. This model will be used to perform trend analysis and forecasting in TREND 2.

3.7 Acknowledgment

This study is funded by the Ministry of Environment of the Government of the Walloon Region in Belgium in the framework of the PIRENE project.

4. Climatic and land use data for the Brévilles experimental catchment (BRGM)

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4.1 Introduction

The monitoring of the concentrations of various pollutants in surface water and groundwater resources is now established as a common activity in all member states in the EU. Although there is typically much effort deployed to collect the data themselves, these are often only used to check that concentrations meet regulatory requirements and there is therefore a general feeling that data should be further interpreted and valued, e.g. through their statistical analysis and the identification of positive or negative trends. Monitoring periods and the associated sampling frequency are typically too short to infer an adequate understanding of the system under study. In the case of groundwater monitoring, the concentrations measured usually reflect a past input of contaminants given the transfer times involved. There is therefore a strong need for time series to be expanded to a period longer than the actual monitoring, especially for environmental factors that are known to be key drivers in the transfer of contaminants in the environment (e.g. rainfall).

Monitoring of the concentrations of selected pesticides in piezometers and in a spring has been undertaken at a 2-week sampling frequency since 1999 at Brévilles (France). Although this collection of data constitutes one of the most comprehensive dataset available in the world, the monitoring period is still too short in relation to the estimated transfer times at the site. There was therefore a need as part of the work package TREND2 which is dedicated to the detection and examination of trends, to reconstruct time series for factors which are known to determine the environmental fate and transfer of pesticides, i.e. rainfall, potential evapotranspiration, and pesticide inputs in the catchment. The reconstruction of climatic series for the catchment was based on the cross examination of meteorological series for nearby stations while information on land use and pesticide usage was collected through farm surveys.

4.2 Reconstruction of a climatic dataset for Brévilles

4.2.1 Rainfall

Two rain gauges (American Sigma) were installed on the Brévilles catchment in May 2001 as part of the EU FP5 project PEGASE. The intention in installing 2 stations at a one-km distance was to assess the spatial variability of rainfall across the 3-km2 catchment and/or evaluate the uncertainty associated with rainfall measurements. The availability of local scale rainfall data also enabled a comparison to be made with nearby MétéoFrance (the French Met Office) stations to assess their representativity.

The two rain stations only provided rainfall data from 2001 and data were therefore collected from MétéoFrance to cover older time periods. A number of stations were initially considered, including Buhy, located 500 m north of the first rain gauge. The homogeneity of the Buhy station was assessed by comparing the data with neighbouring stations (Trappes, Beauvais, Evreux; Figure 4.1). The exercise consisted in plotting cumulative rainfall for the various stations for the period 1988 to 1992 and investigate the linearity of the relationships. Cumulative rainfall data were found to be linearly related to the data for other stations according to a 1:1 line (data not shown) and the station was therefore retained for subsequent use. The rainfall time series for Buhy was however limited in time and included many data gaps, which means that additional sources of data had to be sought.

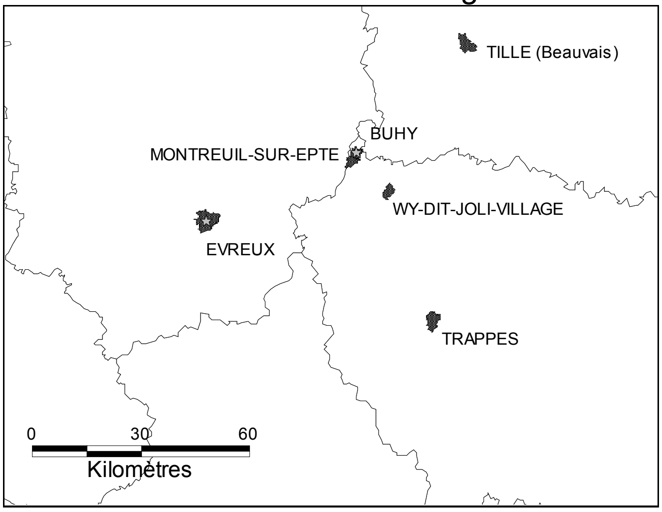


Figure 4.1. Map showing the location of the various meteorological stations used to reconstruct the rainfall dataset. The Brévilles catchment is located 500 metres from the Buhy station.

A total of four MétéoFrance met stations with rainfall data available from at least 1968 were identified: Boissy l'Aillerie (27 km to the East, not shown on Figure 41), Trappes (48 km to the south east), Evreux (37 km to the west) and Beauvais (45 km to the north east). The homogeneity of the four stations against data for Buhy for the period 1988 to 1992 was investigated (see example chart on Figure 42) and only two of these stations (Beauvais and Evreux) were retained as adequate to represent the Brévilles rainfall. Out of these two stations, the 1:1 linear fit was best for Beauvais and this station was therefore retained.

The final rainfall dataset therefore comprised rainfall series for four different meteorological stations, Beauvais for the period January 1950 to August 1998, Buhy for the period September 1998 to May 2001, and the two on-site rainfall stations for the period starting from June 2001. The rainfall data for Beauvais and Buhy were slightly corrected by a multiplication factor (1.0175 and 0.9725, respectively) to ensure the homogeneity of the overall rainfall series. The proximity of the two multiplication factors to unity to 1 further demonstrated that the stations were largely related to the rainfall data on site.

Figure 4.3 presents long-term average monthly rainfall data over the period 1950 to 2004 and associated standard deviations, and rainfall data for the years 2004 and

2005. The annual average rainfall over the period 1950-2004 is 693 mm a^{-1} with a standard deviation (1 σ) of 127 mm a^{-1}.

The distribution of average monthly rainfall is fairly even throughout the year although a significant variability in monthly rainfall can be noted over the 55-year period. With regard to the last two years, January and August 2004 were the wettest month on record while this was the case for April and June during the year 2005.

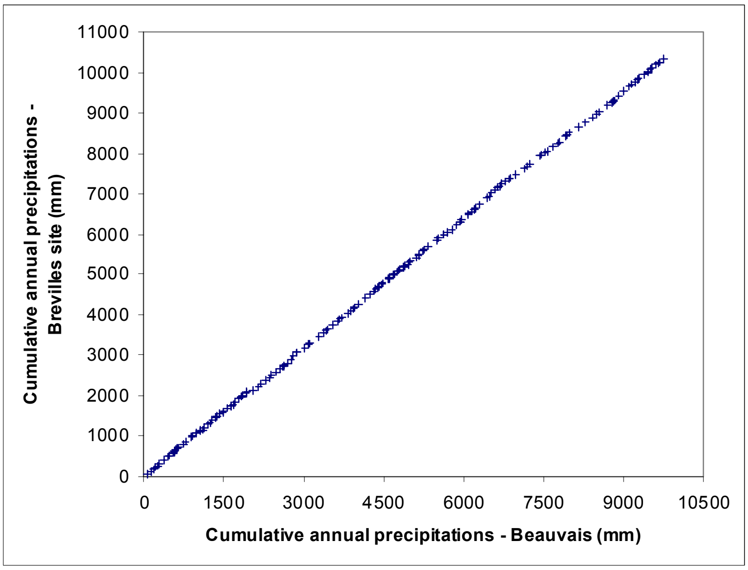


Figure 4.2. Chart plotting the cumulative rainfall data for Beauvais and the Buhy

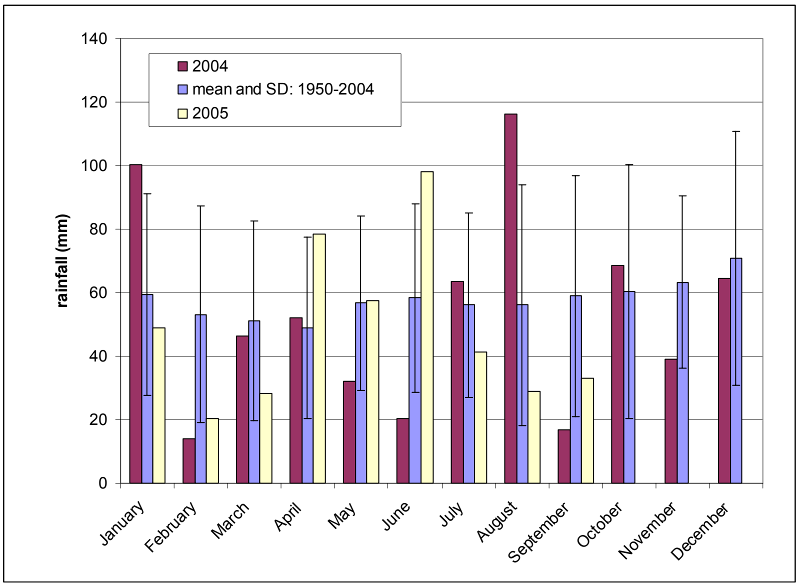


Figure 4.3. Average monthly rainfall over the period 1950 to 2004 and associated standard deviations, and rainfall data for the years 2004 and 2005

4.2.2 Potential evapotranspiration

The meteorological station installed on the Brévilles catchment in 2001 did not allow the collection of climatic variables which are required to calculate potential evapotranspiration (PET). PET data were therefore obtained from MétéoFrance who estimates PET using the Penman-Monteith approach on a 10-day basis. Beauvais was selected as one of the closest station to Brévilles with the longest data series for

PET (data available from 1949). As for rainfall (see section above), the homogeneity of the data was evaluated by plotting the cumulative PET data for various stations. A significant change in slope was observed and the data for the period extending from 1950 to 1965 was thus multiplied by a correction factor. The resulting data series are presented in Figures4.4 and 4.5.

A sharp contrast in monthly PET was noted between summer and winter months while the inter-annual variability was fairly limited in comparison to that for rainfall. The long-term average annual PET was 724 mm with a standard deviation of 50 mm.

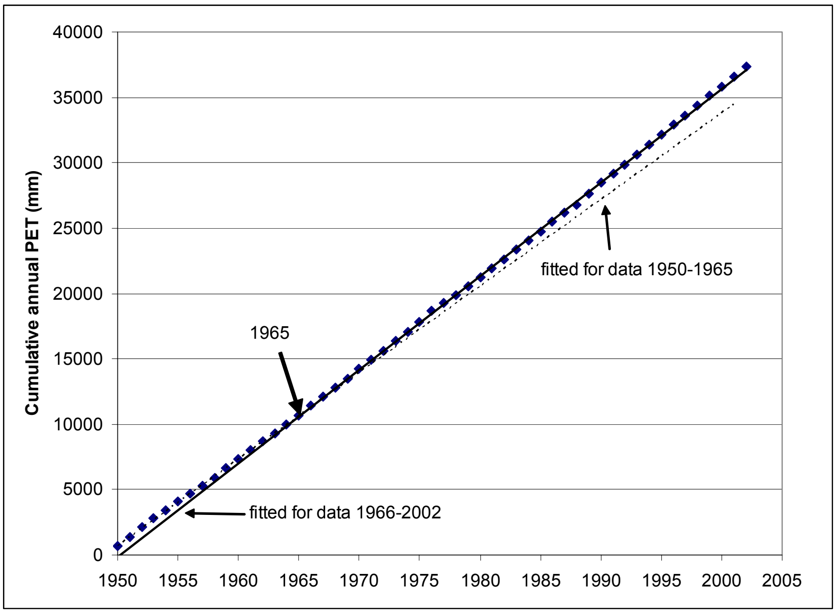


Figure 4.4. Cumulative annual PET data for the period 1950-2002

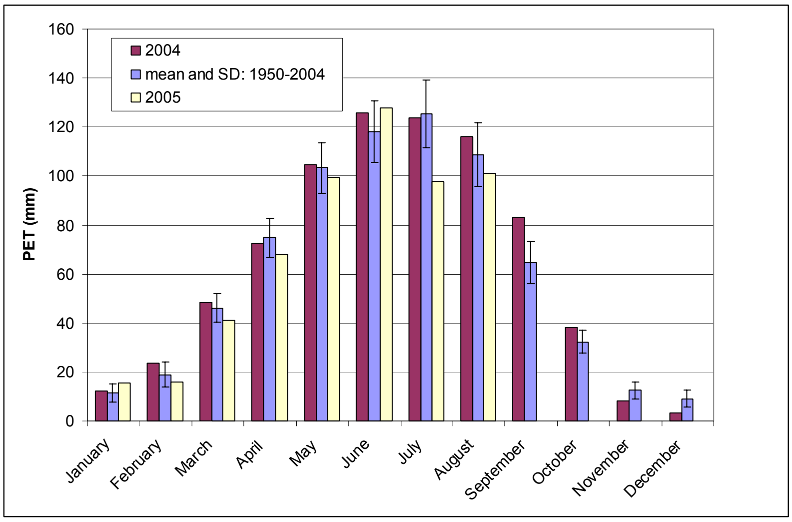


Figure 4.5. Long-term (1950-2004) averages for monthly PET data and data for 2004 and 2005

4.2.3 *Wind direction and speed*

Information on daily wind speeds can provide useful when trying to assess the percentage of the pesticide spraying solution that has reached its target and the soil surface for specific application dates. An indication of the wind characteristics on the catchment was obtained by examining wind data for the Wy-dit-Joli-Village meteorological station, some 13 km south east of the Brévilles catchment (Figure 4.1). Figure 4.6 presents wind directions for the period extending from June 2001 to December 2002. Monthly average wind speeds over the period ranged from 2 to 4 m/s.

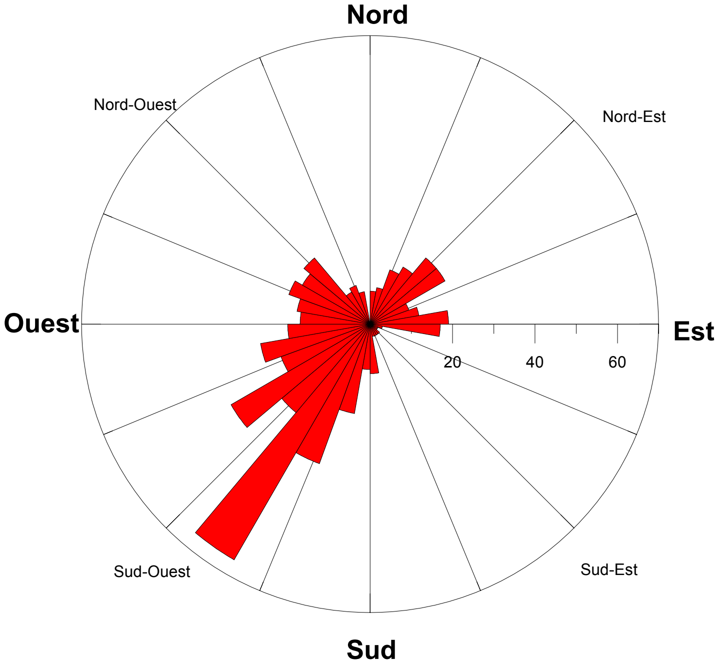


Figure 4.6. Distribution of wind directions for the Wy-dit-Joli-Village meteorological station

4.3 Reconstruction of former land use

Given the transfer times involved for a pesticide to reach groundwater resources from its initial application to farmland, observed time series of concentrations in the various points across the pesticide are the results of past applications. It is therefore essential from a knowledge-gain point of view that information on past land use and associated applications of pesticides on the various fields of the catchment is obtained.

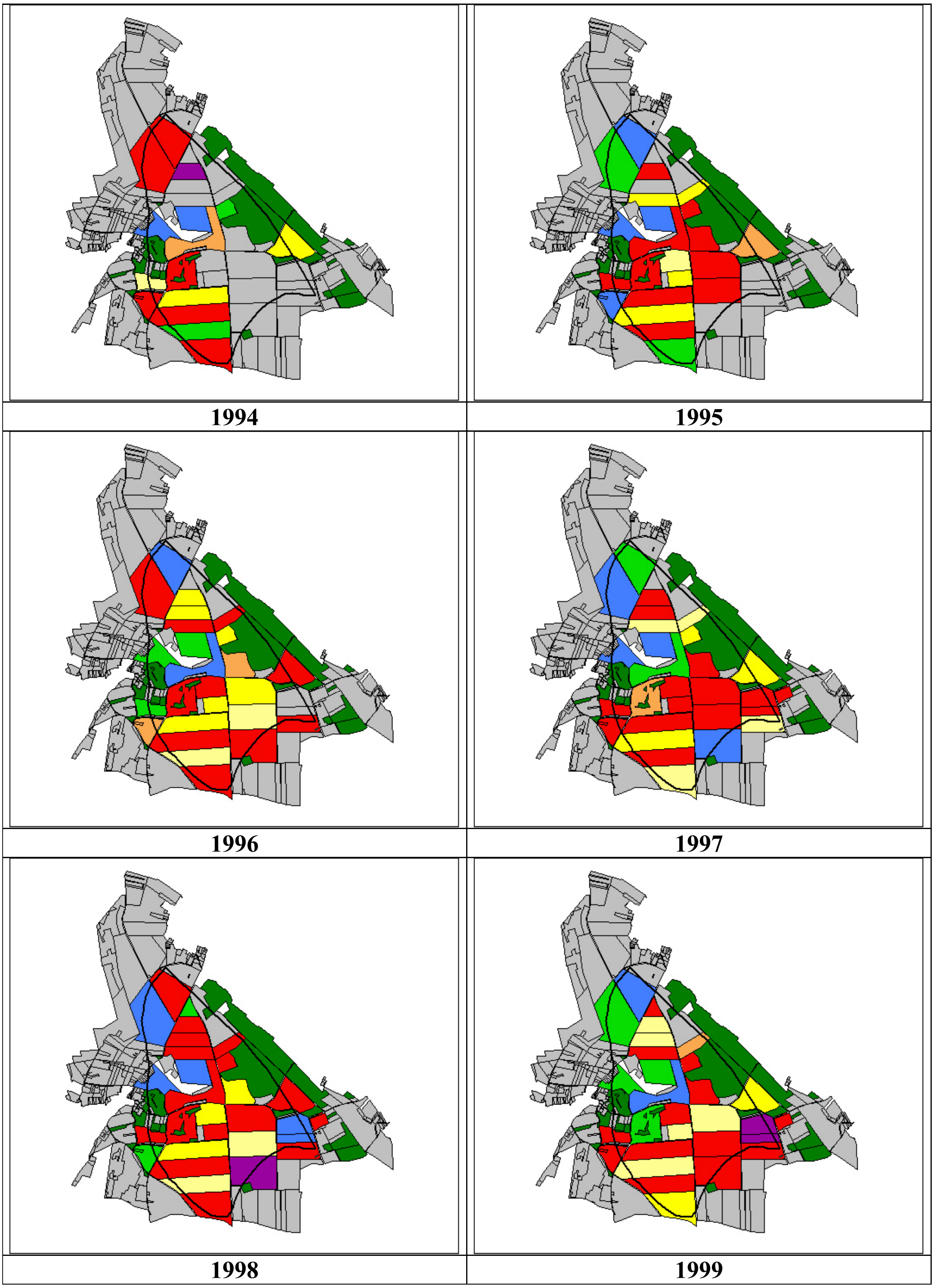
4.3.1 *Farm surveys*

Data on land used and pesticide applications were reconstructed by conducting interviews with the farmers who have fields on the catchment (cf deliverable R1.6). The accuracy of the data collected was difficult to estimate given the fact that these were usually based on people memories. Also, knowledge was lost in cases where farmers retired. Still, it is believed that the information collected is of value as alternative approaches are based on more regional and non-geographically referenced data types such as agricultural statistics or distributor records.

4.3.2 Reconstructed land use and pesticide usage statistics

Figures 4.7 and 4.8 present the land use on the hydrogeological catchment for the 10-year period 1994 to 2004, based on the results of the interviews conducted with farmers. The distribution of the maize crop (in yellow in Figures 7 and 8) across the catchment is of particular interest since significant concentrations of atrazine, an herbicide which is almost exclusively used on maize in the catchment, were detected at the Brévilles spring and led to the disuse of the spring for drinking water purposes. The fact that there was little change in the number of hectares cropped with maize is due to the fact that maize is used for forage purposes.

Table 4.1 provides a summary of changes in maize production on the catchment over the period 1971-2003 and associated pesticide inputs for atrazine, chlortoluron and isoproturon. The interview data only covered the period starting in 1994. Data for the years before were obtained by applying regional statistics on the temporal evolution of maize cropping to the existing Brévilles data. Atrazine application rates for a given year were taken as the maximum allowed by the French registration authorities.



1994

1995

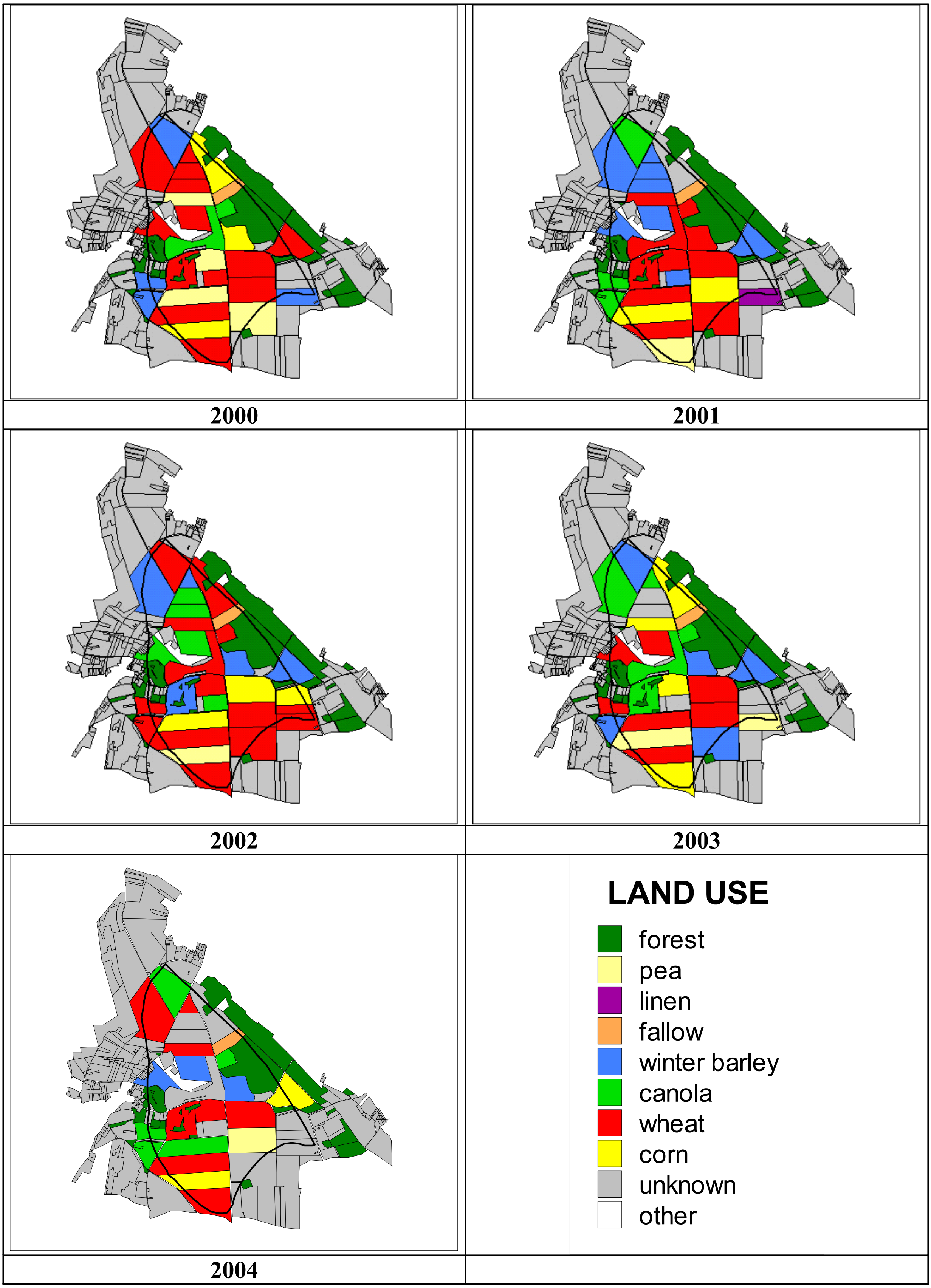
1996

1997

1998

1999

Figure 4.7. Distribution of crops for the period 1994 to 1999 on the Brévilles catchment. The legend is presented on Figure 4.8.



2000

2001

2002

2003

2004

Figure 4.8. Distribution of crops for the period 2000 to 2004 on the Brévilles catchment.

Table 4.1. Reconstructed land use and pesticide inputs on the Brévilles catchment (AT = atrazine; IPU = isoproturon; CTU = chlortoluron).

	Land use (LU)		Pesticide treatment (PT)					
Crop year	Surface planted with maize (ha)	area covered with LU information (%)	Surface treated with IPU (ha)	Surface treated with CTU (ha)	Applied dose (kg/ha)			area covered with PT information (%)
					At	CTU	IPU	
2003[a]	28.6	100	21.6	8.1	0	1.00	1.00	29[e]
2002[a]	29.3	100	76.7	37.3	0	1.43	1.57	92[e]
2001[a]	24.2	100	90.7	50.8	0	0.87	1.20	92[e]
2000[a]	23.2	100	78.3	31.5	0	1.18	0.45	92[e]
1999[a]	11.4	100	72.8	22.4	1.0 (11.4)[c]	0.60	1.10	92[e]
1998[a]	24.6	100	62.9	24	1.2 (18.4)[c]	1.24	0.15	85[e]
1997[a]	28.9	100	75.2	39.3	1.2 (18)[c]	1.23	1.04	85[e]
1996[a]	27.6	80[e]	94.3	32.1	1.0 (27.6)[c]	0.67	0.47	85[e]
1995[a]	21.8	80[e]	62.2	29.3	1.1 (12.2)[c]	1.03	0.83	56[e]
1994[a]	14.6	80[e]	72.2	0	1.1 (11.7)[c]	0.84	0.00	56[e]
1990-93	25-35	0			1.5			0
1976-90[b]	25-35	0	-	-	2.5	-	-	0
1975[a]	24.3	37[e]	-	-	2.5[d]	-	-	0
1974[a]	31.6	43[e]	-	-	2.5[d]	-	-	0
1973[a]	32.2	43[e]	-	-	2.5[d]	-	-	0
1972[a]	29.2	43[e]	-	-	2.5[d]	-	-	0
1971[a]	17.2	43[e]	-	-	2.5[d]	-	-	0

[a] 1994-2003 and 1971-1975: data collected from the farmers of the recharge area
[b] 1976-1993: estimation based on regional data, reduced to catchment scale
[c] in parentheses: the treated surface (ha) with this application rate
[d] 1970-1975: approved application rate
[e] information provided by farmers

4.4 Conclusions and perspectives

Numerous monitoring data are being collected throughout the EU for regulatory compliance or research purposes. The interpretation of these data is typically difficult because the observed concentrations (the present) often relates to past inputs to the system and to climatic conditions since the inputs occurred. Obtaining reliable historical information is clearly an hindrance to a better understanding of current water pollution. In the present case, meteorological data for rainfall and PET were reconstructed for the Brévilles catchment from the year 1950. Given the lack of detailed official records on crop production, former land use for small scale catchments such as Brévilles can only be obtained by relying on the memories of the farmers. Although past regional statistics on cropping and land use are available, they are unlikely to reflect the detailed conditions in a given small agricultural catchment and they are unhelpful in assigning a crop to a particular field on the catchment. One of the possibilities which has not yet been investigated at Brévilles is the analysis of past aerial photographs to reconstruct the former boundaries of the fields and to evaluate the likely land use at the time. Reconstructed time series for rainfall, PET, land use and pesticide inputs will be subsequently fed into models within the context of TREND2 to try to explain the pesticide concentrations which have been observed across the Brévilles catchment since 1999. The data are also likely to be of interest to modellers from the COMPUTE work package within a context of model evaluation.

5. Reconstruction of former land use for the subcatchment in the Elbe Basin (IETU)

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5.1 Nitrogen surplus changes in time

Assessment of the nitrogen surplus resulting from Agriculture Emission in Schleswig-Holstein and especially region of Bille-Kruckau has been made on the base of review of information accessible through the Internet including published reports on nutrient emissions in the sub-catchments of the German watersheds (Horst et al. 2003) reports concerning state of the aquifer in state of Schleswig-Holstein. Also statistical data retrieved from German Statistical Office and European Environmental Agency have been used.

5.1.1 Methods applied in calculation of nitrogen surplus

In Germany, the estimation of the nutrient surpluses has been made within the framework of the project "*Nutrient emissions into river basins of Germany on the basis of a harmonised procedure".* The focus of the project has been put on estimation of nutrient emission into surface water via different environmental compartments.

In calculation of emissions in the sub-catchments of the German catchment via the various point and diffuse pathways the **MONERIS** model has been used (**Mo**delling **N**utrient **E**missions in **Ri**ver **S**ystems). Beneath is a draft description of the MONERIS model.

The basic inputs into the model are data on discharges, data on water quality and a Geographical Information System which integrates digital maps as well as statistical information of different administrative levels. Whereas the discharges of municipal waste water treatment plants, of direct industrial discharges and from fish farms enter the river system directly, the sum of the diffuse nutrient emissions into the surface waters is the result of different pathways realised by several runoff components (Fig. 5.1).

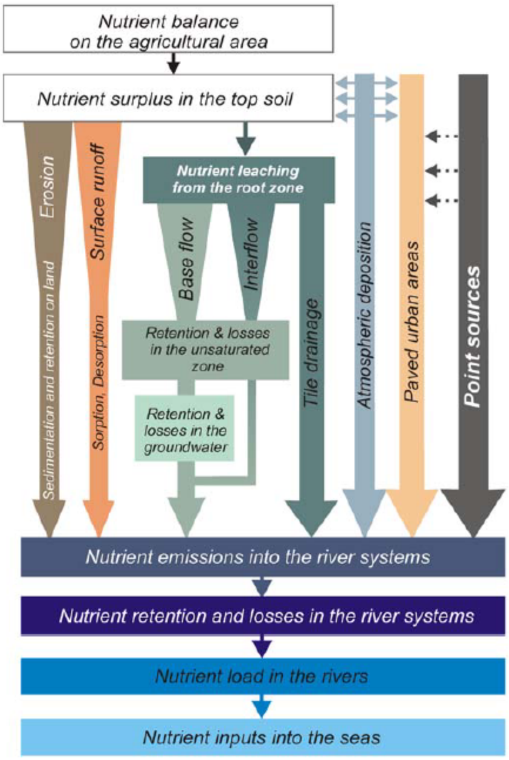


Fig. 5.1. Pathways and processes in MONERIS

MONERIS takes seven pathways into account: (1) discharges from point sources; (2) emissions into surface waters via atmospheric deposition; (3) emissions into surface waters via groundwater; (4) emissions into surface waters via tile drainage; (5) emissions into surface waters from paved urban areas; (6) emissions into surface waters by erosion; (7) emissions into surface waters via surface runoff (only dissolved nutrients).

Within the diffuse pathways, various processes of transformation, loss and retention are identified. To quantify and forecast the nutrient emissions in relation to their causes requires knowledge of these transformation and retention processes. This is not yet possible through detailed dynamic process models because the current state of knowledge and existing databases is limited for medium and large river basins.

5.1.2 Results of estimates of nutrient surpluses from agriculture and their changes

According to Horst et al. (2003), diffuse nutrient inputs are predominantly caused by agriculture. The annual nutrient surplus of agricultural land is one of the major factors determining the scale of nutrient loadings to catchments from diffuse sources. Since there is much information available on the regional differentiation of nutrient inputs in individual catchments, it is also necessary to regionalize the nutrient surpluses. The report of the project "*Nutrient emissions into river basins of Germany on the basis of a harmonised procedure*" (Behrendt et al, 2003) delivers us with results in cartographical and tabular forms. In this report example of maps are presented for description of the nitrogen surplus in Germany in general and in Schleswig-Holstein Fig. 5.4 and Fig. 5.5 provide an overview of nitrogen surpluses of agricultural land in 1995 and in 1999. Fig. 5.6 gives the picture of changes between 1995 and 1999.

Fig. 5.4 presents the state in year 1995. The region of the study area belongs to three N-surplus range zones 60-80, 80-100, 100-120 kg/(ha/a) N. The level of surplus rises in north-west direction. Similar situation one can observe on Fig. 5.5 describing the state in 1999, however there are differences. Still the area of interest belongs to three N-surplus range zones but the area of lower N-surplus ranges rises while the area of higher N-surplus range i.e. 100-120 kg/(ha/a) N decreases. The same trend can be observed for the whole Elbe catchment (Table 5.1).

Table 5.1. Nitrogen surpluses of agricultural land in Elbe catchment for the years 1985, 1995 and 1999 as well as their changes.

N-surplus	**N-surplus**	**N-surplus**	**Change**	**Change**
1985	1995	1999	85 to 99	85 to 95
kg/ha N	kg/ha N	kg/ha N	[%]	[%]
119	63	57	-52	-47

The development of nitrogen surpluses from 1950 to 1999 in Schleswig Holstein is shown in table bellow and on the graph (Table 5.1, Fig. 5.2).

Table 5.1. Development of N-surpluses [kg/(ha /a) N] in Schleswig Holstein from 1950 to 1999

Year	**N-surpluses** kg/ha N	**Year**	**N-surpluses** kg/ha N	**Year**	**N-surpluses** kg/ha N	**Year**	**N-surpluses** kg/ha N	**Year**	**N-surpluses** kg/ha N
1950	40.5	1960	52.8	1970	94.4	1980	134.1	1990	125.5
1951	35.5	1961	60.6	1971	94.4	1981	135.7	1991	113.8
1952	47.5	1962	64.4	1972	94.0	1982	118.1	1992	112.4
1953	43.5	1963	67.3	1973	101.3	1983	141.9	1993	105.7
1954	43.7	1964	74.4	1974	91.8	1984	122.6	1994	102.2
1955	41.0	1965	77.4	1975	104.0	1985	125.4	1995	106.3
1956	44.3	1966	80.4	1976	123.5	1986	129.9	1996	99.0
1957	48.5	1967	76.1	1977	116.7	1987	133.6	1997	88.8
1958	47.6	1968	78.5	1978	115.1	1988	128.9	1998	88.3
1959	59.4	1969	80.7	1979	120.3	1989	125.9	1999	98.1

Above data have been elaborated in terms of descriptive statistics.

Parameter	**Value** kg/ha N	**Remarks**
Minimum	35.5	Year 1951
Maximum	141.9	Year 1983
Range	106.4	
Mean	91.1	arithmetic
Std deviation	31.2	
Median	94.4	
Lower quartile	65.125	
Upper quartile	117.75	

The minimum value of N-surplus was 35,5 and was calculated for the year 1951, Maximum 141.9 is reached in year 1983. Arithmetic mean is similar to median (about 91-94).

On the basis of the N-surplus data long-term trends in N-surpluses for Schleswig Holstein has been calculated. The formula of trend of N-surplus changes may be described in form of the fifth degree polynomial:

$$y = 7E\text{-}06x^5 - 0{,}0669x^4 + 264.11x^3 - 521182x^2 + 5E{+}08x - 2E{+}11$$

where:

y denotes N-surplus in kg/ha/year while **x** denotes year. The polynomial produces good fitting to data. The R^2 (determination) coefficient equals 0.9669 (correlation 0.9833).

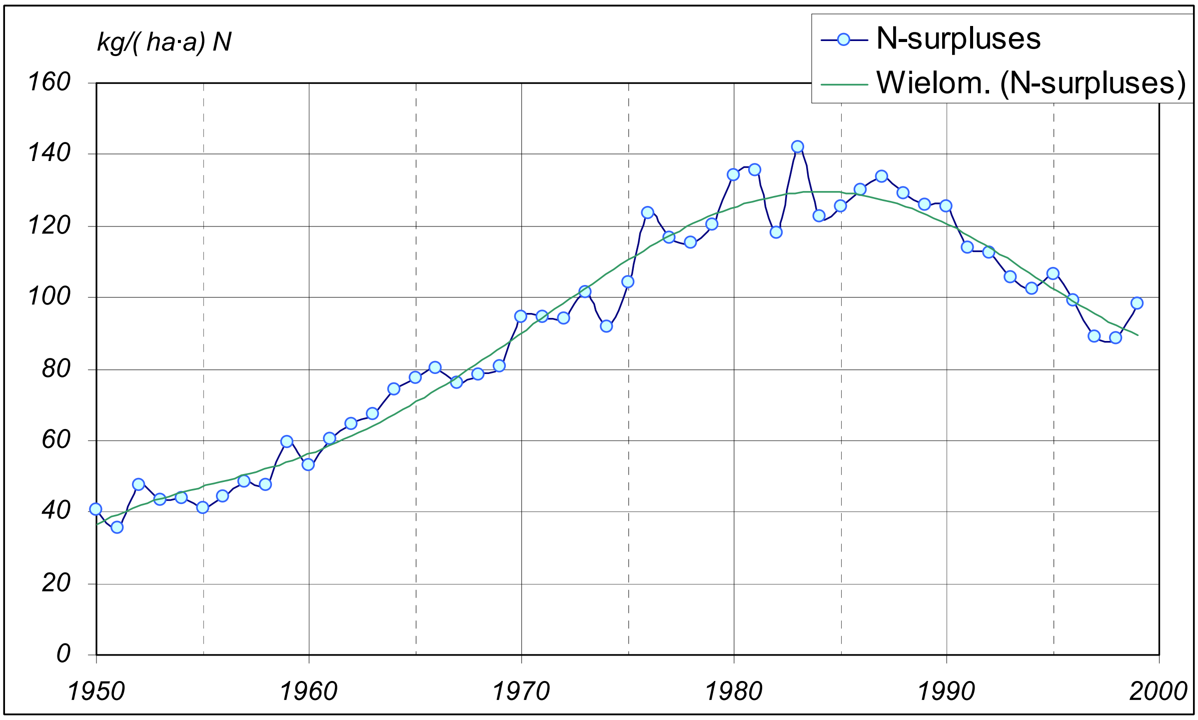


Fig. 5.2. Graph of the development of N-surpluses [kg/(ha·* a) N] in Schleswig Holstein from 1950 to 1999

Analysing the above curve it is possible to distinguish two sections. The first represent increasing trend in N-surplus and spans the time between 1950 and 1985. Since 1995 decreasing trend can is observed. Similar trends can be observed for other German watersheds.

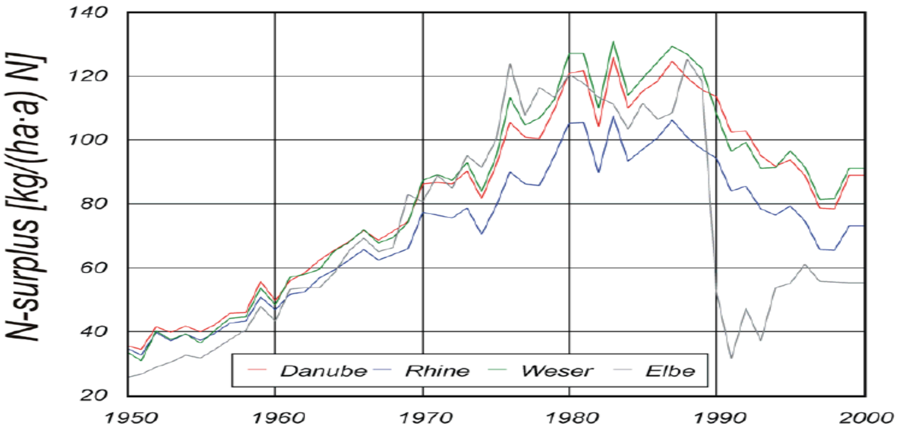


Fig. 5.3. N-surpluses of agricultural land in the Water basins and the German parts of the Danube, Rhine, and Elbe basins from 1950 to 1999

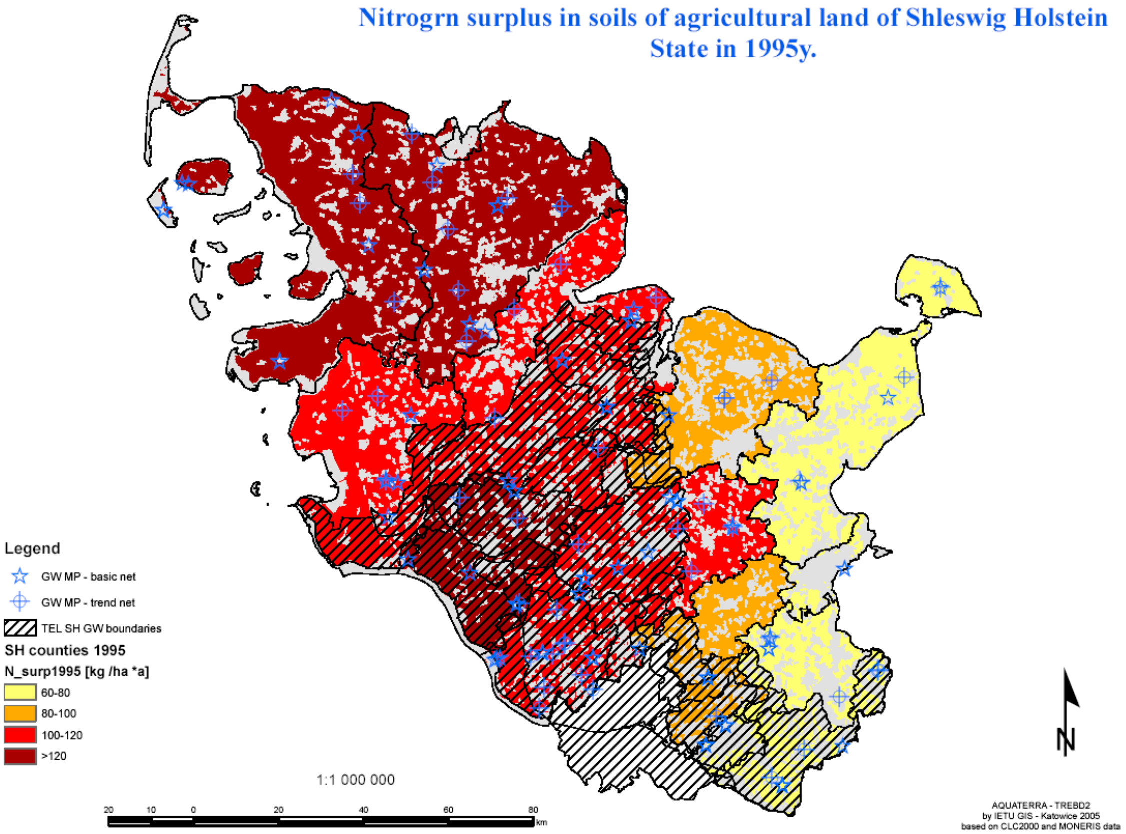


Fig. 5.4 Nitrogen surpluses of agricultural land in 1995 (Horst et al. 2003)

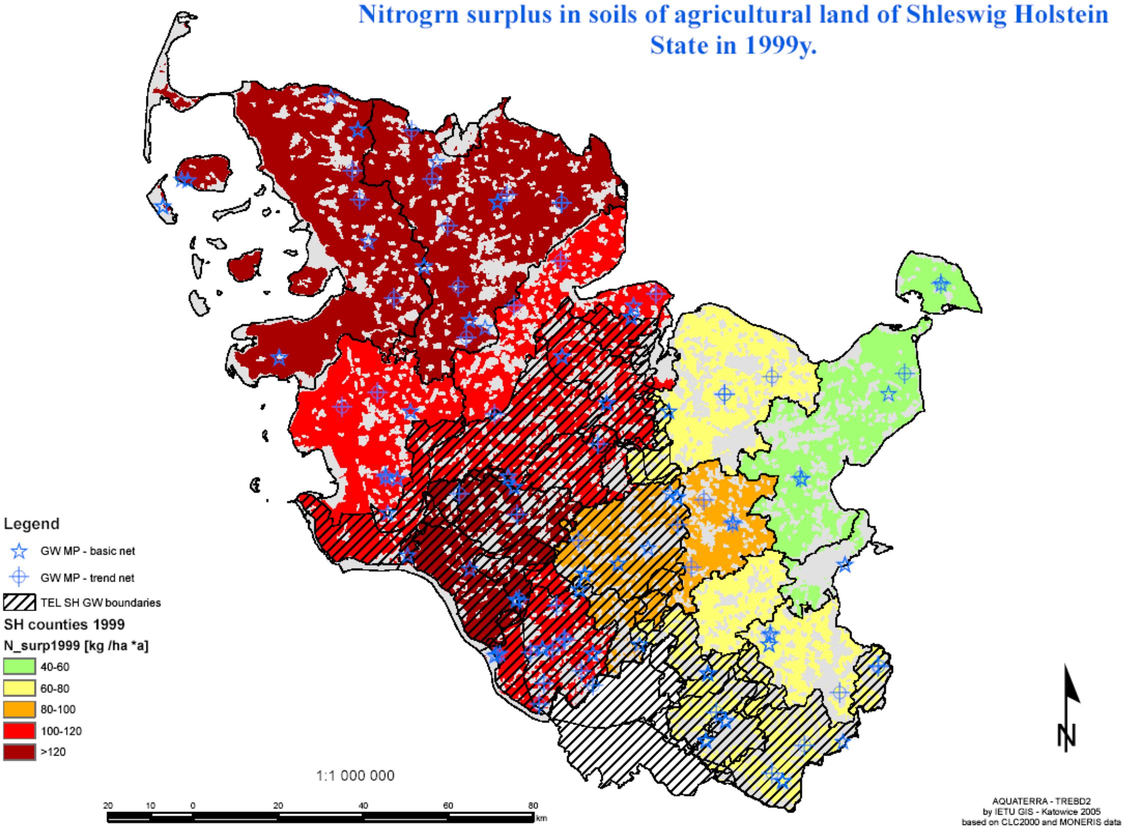


Fig. 5.5 Nitrogen surpluses of agricultural land in 1999 (Horst et al. 2003)

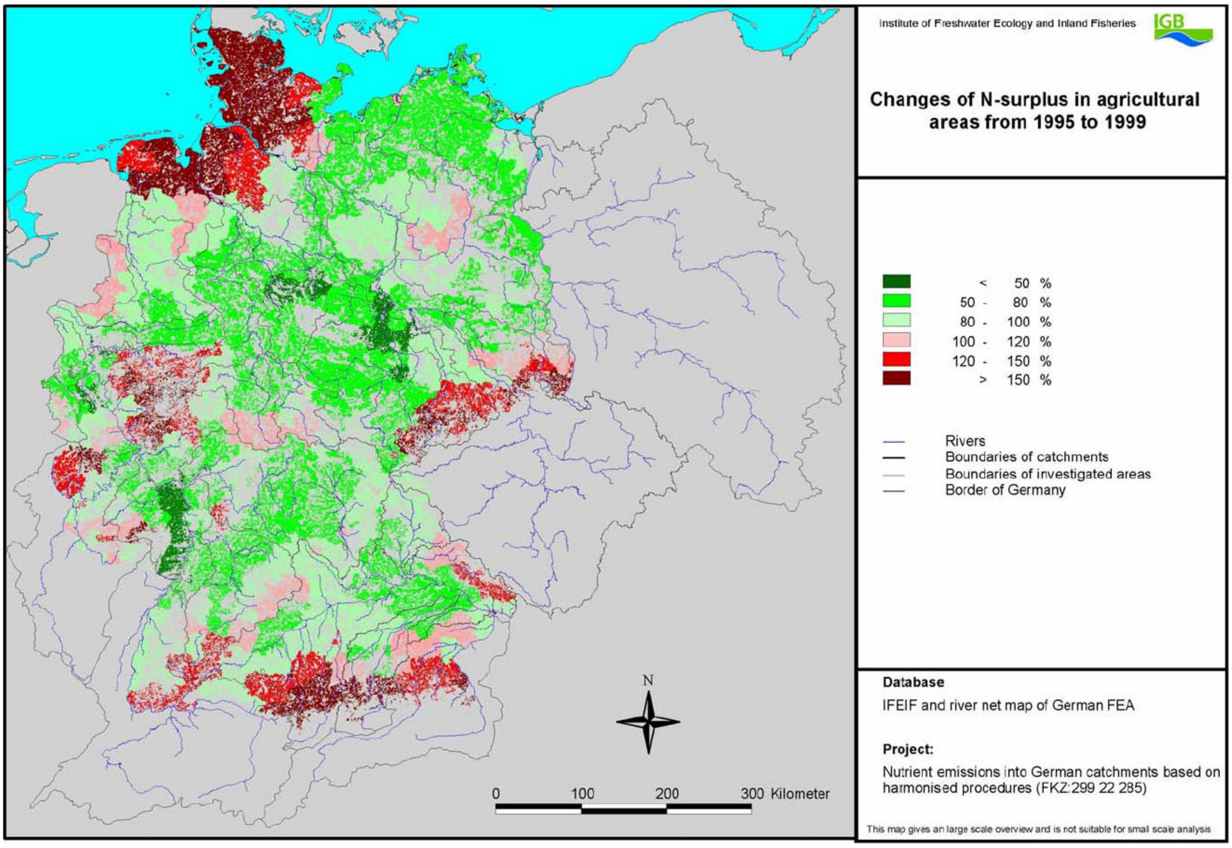
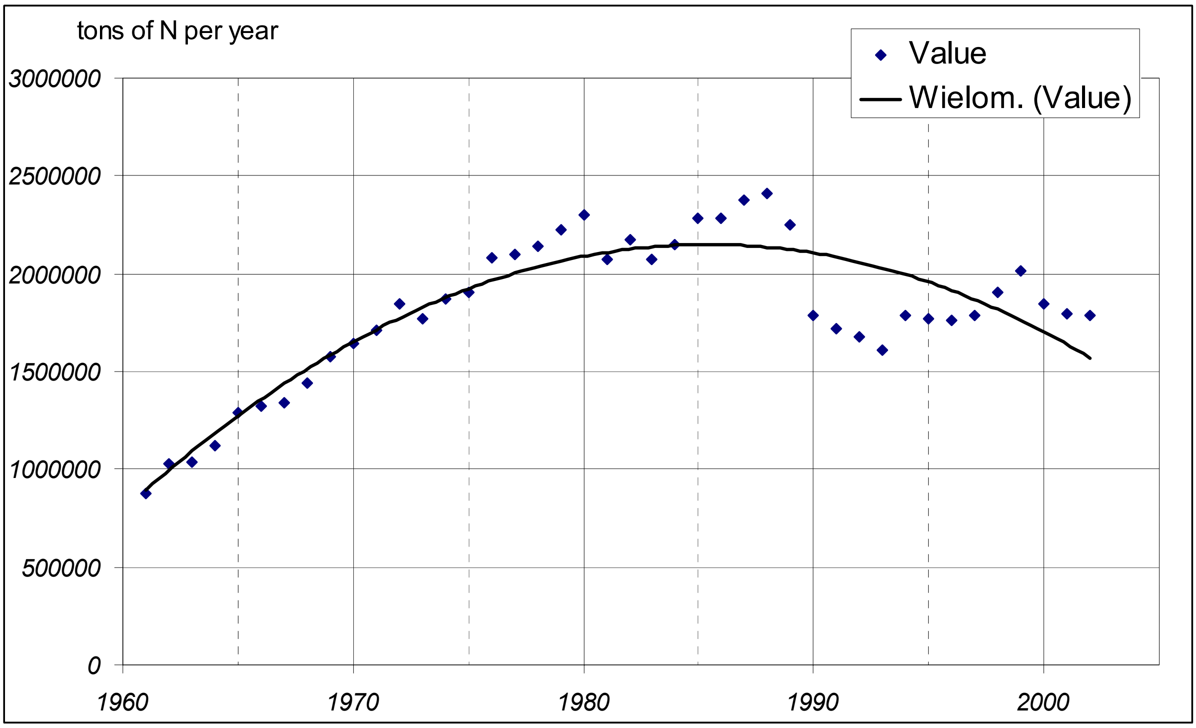


Fig. 5.6 Changes in nitrogen surpluses of agricultural land from 1995 to 1999 (Horst et al. 2003)

5.1.3 Changes in parameters influencing nitrogen emission into GW Schleswig-Holstein

Fertiliser consumption including nitrogen consumption constitute one of the factors impacting the groundwater quality. The statistics of fertiliser consumption in Germany is available on the server of European Environment Agency (EPA, see references). On the base of the data the graph representing the changes of N consumption over time and trend line have been constructed.



The trend in N fertilizer consumption may be represented by the second order polynomial and in this case is depicted by following formula:
where:

$$y = -2106.3x^2 + 8E+06x - 8E+09$$

y denotes N-consumption in Germany in tons/year while **x** denotes year. The R^2 (determination) coefficient equals 0.8092 (correlation 0.8996).
The trend line similar to curve depicting N-surplus changes may be divided into two section. The first representing increasing trend in fertilizer consumption, the second (later) the reverse trend. The point of trend change is situated in the middle of 80-ties. The correlation between N-surplus in Schleswig-Holstein and N fertilizer consumption in Germany is about 0.9.

5.1.4 Relation between soil depth and Nitrogen concentration in groundwater in Schleswig-Holstein

As a result of bio-chemical processes N-nitrate content decreases with increasing of soil and groundwater depth. Decreasing concentration of nitrate is result of the denitrification process under anaerobic condition during which nitrate form of nitrogen is transformed through transitive forms into elementary nitrogen. The last as a gas escapes into atmosphere. The relation between nitrate concentration in groundwater and depth of aquifer and water age is presented below (Fig. 5.7).

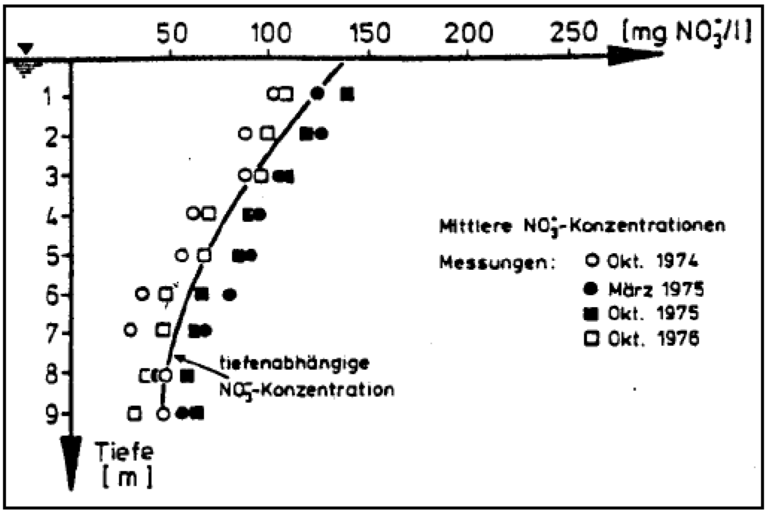


Fig. 5.7a. Relation between depth of aquifer and concentration of nitrate in the Schleswig-Holstein study area (Landesamt für Natur und Umwelt des Landes Schleswig-Holstein, 2001).

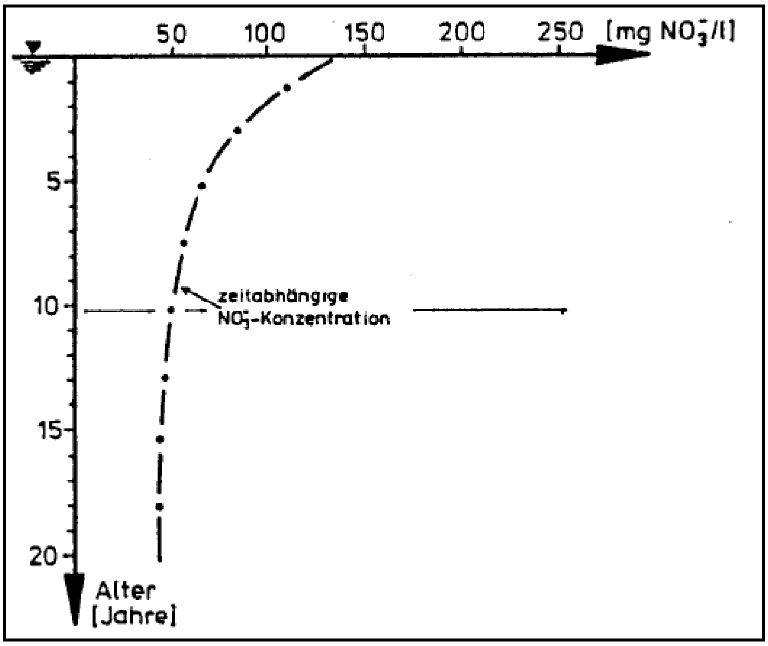


Fig. 5.7b. Relation between groundwater age and concentration of nitrate in the Schleswig-Holstein study area

This natural attenuation process of the water contaminated with nitrogen influences also results of the monitoring in Schleswig-Holstein. Thus in analysing the results of groundwater monitoring it is crucial to take into consideration except changes of nitrogen load into groundwater but also the age of the waters and the depth of the installed screens for collecting groundwater samples.

5.2 History of land use in Elbe - Schleswig Holstein

Type of land use/ land cover is a factor that has an important influence on water and groundwater balance as well as on water chemistry. Thus the change of landuse/landcover pattern has to give effects observed as changes in the chemicals level in groundwater.

Due to this reason, analysis of geochemical trends have to be connected with analysis of land use change. Data repository of EEA was selected for this purposes as a basic source of the information. Two maps of land use/land cover developed within CORINE project were selected. Both maps are available for public. First map presents state of land use in 1990 (CLC90) and second presents state of land use in 2000 year (CLC2000).Generally both maps were developed with application of the same technical rules.

CLC90 map is available as projected on sphere and CLC2000 is available as projected on ellipsoid GRS80. The projection is well documented. But difference between sphere and ellipsoid introduce some distortions that can be a source of errors during comparative analysis. To reduce the possible errors resulted from differences in datum we have fitted the CLC90 map to the CLC2000 map. The average linear error of map fitting is on the level of 100 meters (1 grid cell) what results in difference of total area on the level of 0,05% (about 7km^2).

Both maps were clipped with boundaries of Schleswig-Holstein country and statistics of land cover/land use classes were calculated for both time horizons - 1990 and 2000.

Results are presented in tables below.

5.2.1 Land use in 1990

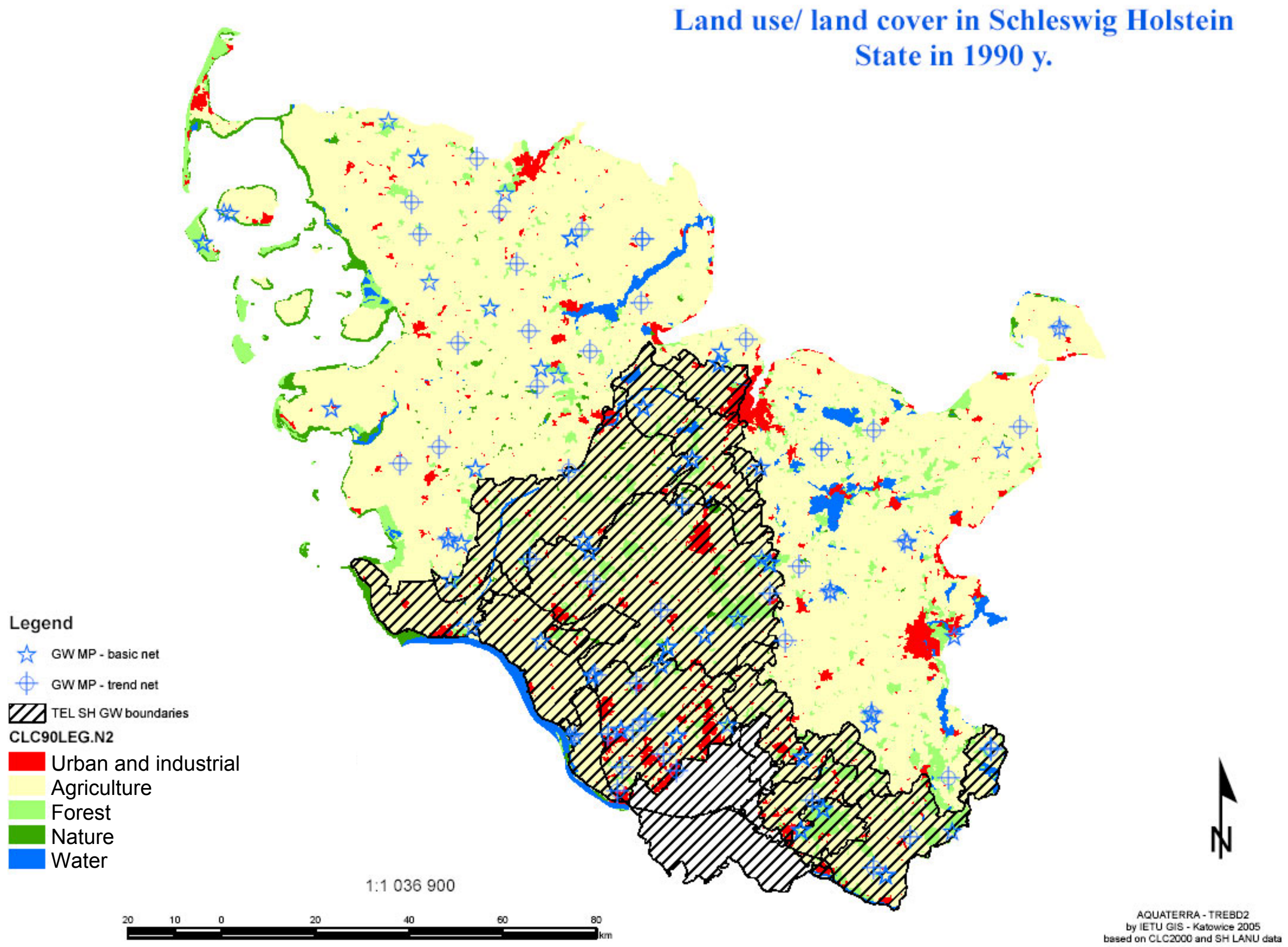
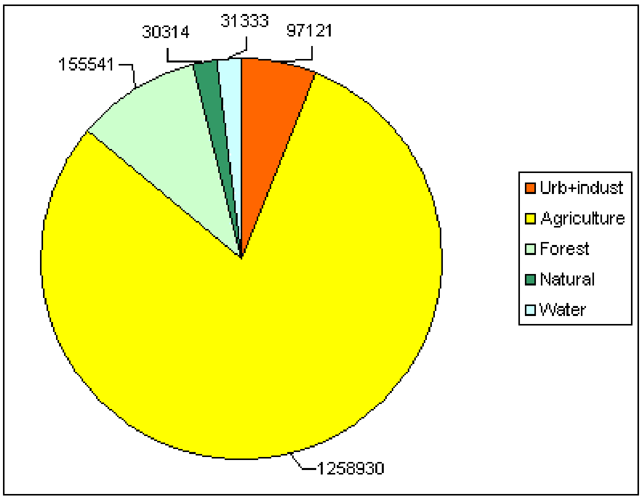


Fig. 5.8a Land use in Schleswig Holstein - state for 1990



Note, Sea water classes (521, 522, 523) excluded from analysis

Fig. 5.7b General land use structure in Schleswig Holstein - state for 1990y

Table 5.2 Statistical characteristics of land use / land cover classes in 1990. (Colors correspond to land use classes in Figure 5.7b)

No	LU code level 1	LU code-level3	Count	Average area	Maximum	Minimum	StdDev	Area1990	
1	1	**111**	10	99,93	418,65	34,70	118,25	999,25	
2	1	**112**	1007	77,56	2959,00	0,05	186,51	78106,70	
3	1	**121**	106	56,15	206,10	0,10	37,12	5951,65	
4	1	**122**	19	16,18	41,39	0,46	14,50	307,51	
5	1	**123**	29	34,94	200,50	0,69	50,08	1013,19	
6	1	**124**	17	141,61	507,91	0,69	140,49	2407,37	
7	1	**131**	43	44,29	109,85	0,64	20,59	1904,50	
8	1	**132**	12	36,29	56,63	24,71	9,83	435,54	
9	1	**133**	1	44,52	44,52	44,52	0,00	44,52	
10	1	**141**	25	34,66	114,49	0,19	25,03	866,47	
11	1	**142**	113	45,00	325,62	0,16	44,06	5084,68	97121,37
12	2	**211**	1097	632,95	220125,40	0,64	7109,22	694349,99	
13	2	**222**	6	39,59	70,18	24,22	16,46	237,56	
14	2	**231**	1505	302,37	203200,98	0,00	5387,78	455071,96	
15	2	**242**	481	179,09	2892,05	0,64	241,76	86144,53	
16	2	**243**	377	61,34	341,82	0,44	43,41	23126,03	1258930,07
17	3	**311**	823	72,87	1603,31	0,00	131,31	59973,39	
18	3	**312**	411	133,75	5428,36	0,01	349,48	54969,69	
19	3	**313**	345	55,33	534,43	0,64	57,79	19090,04	
20	3	**321**	73	136,59	2544,34	0,46	329,95	9971,34	
21	3	**322**	26	111,98	1041,50	0,69	219,97	2911,38	
22	3	**324**	4	43,44	57,28	35,95	9,45	173,75	

23	3	***331***	*70*	*96,40*	*1432,36*	*0,38*	*259,95*	*6748,25*	
24	3	***333***	*49*	*34,76*	*252,29*	*0,44*	*47,80*	*1703,22*	*155541,06*
25	4	***411***	*87*	*52,41*	*295,72*	*0,64*	*58,96*	*4559,72*	
26	4	***412***	*121*	*81,62*	*499,18*	*0,69*	*88,37*	*9876,35*	
27	4	***421***	*76*	*100,07*	*937,36*	*0,11*	*161,92*	*7605,53*	
28	4	***423***	*87*	*95,08*	*1224,52*	*0,01*	*224,41*	*8271,95*	*30313,54*
29	5	***511***	*98*	*37,35*	*888,83*	*0,69*	*129,72*	*3660,43*	
30	5	***512***	*209*	*132,40*	*4402,53*	*0,64*	*421,83*	*27672,14*	*31332,56*
31	5	***521***	*8*	*287,48*	*1559,35*	*0,69*	*543,53*	*2299,83*	
32	5	***522***	*13*	*626,04*	*6923,31*	*0,69*	*1905,78*	*8138,51*	

5.2.2 Land use in 2000

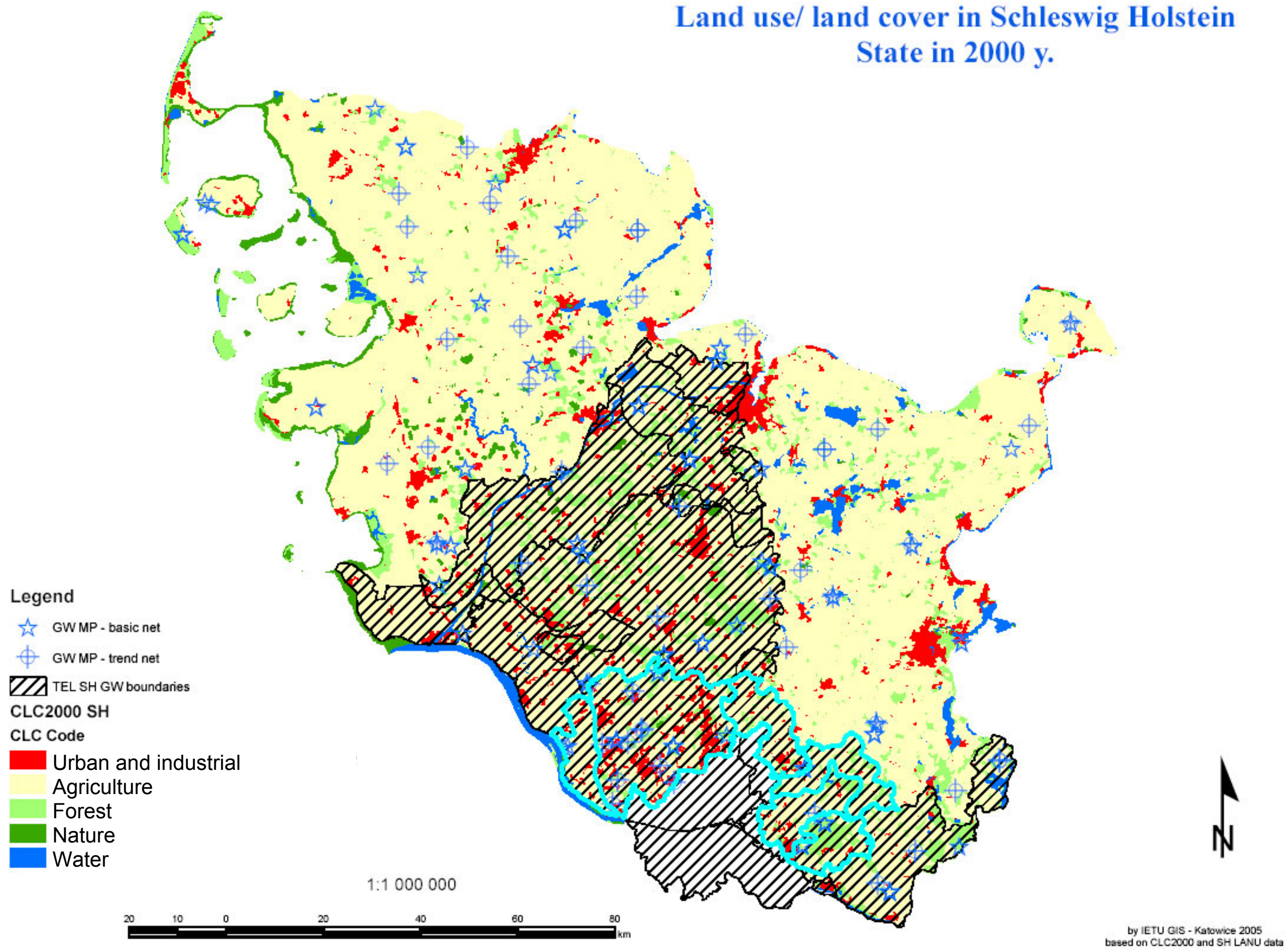


Fig. 5.8a Land use / land cover in Schleswig Holstein - state in 2000

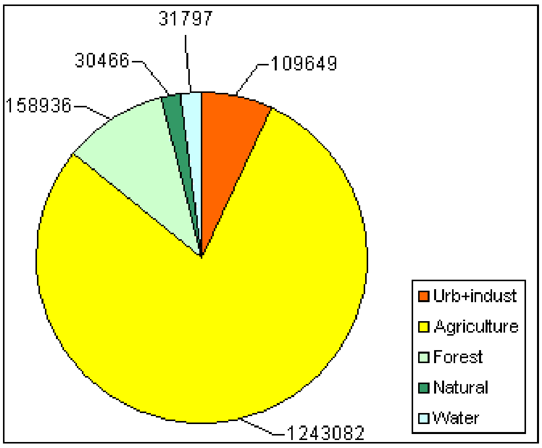


Fig. 5.8b General land use structure in Schleswig Holstein - state in 2000y

Table 5.3 Area of land use / land cover classes in Schleswig Holstein. State for 2000. . (Colors correspond to land use classes in Figure 5.8).

No	LU code level 1	LU code level 3	Count	Average	Maximum	Minimum	StdDev	Area_level3	Area_level1
1	1	***111***	*10*	*104,3*	*403,67*	*36,78*	*118,54*	*1042,96*	
2	1	***112***	*801*	*106,85*	*4438,46*	*0,06*	*232,31*	*85585,68*	
3	1	***121***	*112*	*68,07*	*287,82*	*25,28*	*48,48*	*7623,88*	
4	1	***122***	*10*	*35,25*	*44,5*	*4,71*	*11,91*	*352,52*	
5	1	***123***	*16*	*69,52*	*223,73*	*3,62*	*65,29*	*1112,24*	
6	1	***124***	*16*	*152,72*	*511,78*	*26,08*	*139,72*	*2443,57*	
7	1	***131***	*51*	*55,42*	*339,19*	*25,42*	*46,39*	*2826,41*	
8	1	***132***	*15*	*47,99*	*98,09*	*26,23*	*20,55*	*719,81*	
9	1	***133***	*11*	*44,16*	*114,61*	*2,55*	*30,98*	*485,81*	
10	1	***141***	*25*	*47,74*	*113,16*	*4,17*	*25,49*	*1193,44*	
11	1	***142***	*107*	*58,53*	*208,7*	*9,29*	*35,03*	*6262,3*	109648,6
12	2	***211***	*759*	*882,58*	*215730,15*	*0,12*	*8506,65*	*669876*	
13	2	***222***	*3*	*86,54*	*191,49*	*25,28*	*91,32*	*259,61*	
14	2	***231***	*995*	*456,51*	*154894,64*	*0,01*	*5468,39*	*454223,3*	
15	2	***242***	*545*	*173,26*	*3980,49*	*0,07*	*286,98*	*94428,86*	
16	2	***243***	*356*	*68,24*	*236,86*	*0,92*	*39,22*	*24294,56*	1243082
17	3	***311***	*643*	*94,4*	*1585,06*	*0,16*	*141,87*	*60696,29*	
18	3	***312***	*302*	*171,54*	*5344,39*	*0,65*	*402,58*	*51804,58*	
19	3	***313***	*322*	*69,05*	*529,3*	*2,26*	*59,36*	*22233,99*	
20	3	***321***	*56*	*183,83*	*2650,27*	*14,87*	*373,42*	*10294,42*	
21	3	***322***	*25*	*126,37*	*1030,88*	*25,65*	*221,44*	*3159,26*	
22	3	***324***	*27*	*78,55*	*319*	*3,14*	*74,52*	*2120,73*	
23	3	***331***	*27*	*257,64*	*1380,71*	*3,3*	*389,03*	*6956,15*	
24	3	***333***	*26*	*64,25*	*285,82*	*25,31*	*58,52*	*1670,56*	158936
25	4	***411***	*64*	*71,94*	*298,88*	*0,3*	*61,11*	*4603,86*	
26	4	***412***	*93*	*96,68*	*510,2*	*25,39*	*89,71*	*8991,04*	

27	4	***421***	*37*	*241,29*	*968,03*	*23,57*	*256,2*	*8927,87*	
28	4	***423***	*31*	*256,24*	*1217,8*	*3,5*	*281,42*	*7943,55*	30466,32
29	5	***511***	*6*	*595,1*	*2573,11*	*118,35*	*972,73*	*3570,59*	
30	5	***512***	*159*	*177,53*	*4358,19*	*6,55*	*488,36*	*28226,64*	31797,23
31	5	***521***	*6*	*393,98*	*1590,73*	*39,01*	*615,61*	*2363,86*	
32	5	***522***	*2*	*3964,74*	*6720,39*	*1209,09*	*3897,08*	*7929,48*	
33	5	***523***	*2*	*887,78*	*1279,22*	*496,34*	*553,58*	*1775,56*	

Note, Sea water classes (521, 522, 523) excluded from analysis

It can be concluded that general land use / land cover pattern during 10 years period is not changed.

The agriculture area constitutes the main source of diffuse nitrogen emission into GW in the study area. Changes in agricultural land use in counties of Schleswig-Holstein are presented in table below.

Table 5.4 Changes of land occupied by agriculture in SH counties in period 1996-2000

Name of the county	1996			2000			Change percent
	Total [ha]	Area [ha]	percent	Total [ha]	Area [ha]	percent	
The state of Schleswig-Holstein	1577055	1150599	72,96	1576297	1137897	72,19	-1,10
Flensburg, Kreisfreie Stadt	5644	1414	25,05	5646	1386	24,55	-1,98
Kiel, Landeshauptstadt, Kreisfreie Stadt	11682	4058	34,74	11839	3998	33,77	-1,48
Lübeck, Hansestadt, Kreisfreie Stadt	21414	8508	39,73	21414	7835	36,59	-7,91
Neumünster, Kreisfreie Stadt	7156	3359	46,94	7157	3212	44,88	-4,38
Dithmarschen, Landkreis	143635	112875	78,58	142937	111766	78,19	-0,98
Herzogtum Lauenburg, Landkreis	126301	77005	60,97	126301	76350	60,45	-0,85
Nordfriesland, Landkreis	204942	160838	78,48	204744	159124	77,72	-1,07
Ostholstein, Landkreis	139155	103925	74,68	139149	102566	73,71	-1,31
Pinneberg, Landkreis	66427	44597	67,14	66426	43247	65,11	-3,03
Plön, Landkreis	108253	75893	70,11	108270	74488	68,80	-1,85
Rendsburg-Eckernförde, Landkreis	218576	165095	75,53	218549	164221	75,14	-0,53
Schleswig-Flensburg, Landkreis	207150	162336	78,37	207159	162183	78,29	-0,09
Segeberg, Landkreis	134432	96732	71,96	134436	95305	70,89	-1,48
Steinburg, Landkreis	105657	80428	76,12	105645	79376	75,13	-1,31
Stormarn, Landkreis	76629	53537	69,87	76627	52841	68,96	-1,30
Average			59,27			58,26	-1,85

The decrease of land area occupied by agriculture is observed based on CORINE data as well as on administrative data.

5.2.3 The land use changes at monitoring points

The second step of analysis was devoted to the identification of land use/land cover class in direct vicinity of groundwater monitoring points.

We have assumed that dominant class within a radius of 200 m will be selected as type of land use that is represented by monitoring point. Additionally we have checked the land use in radius 200-300m. This data were described as land use / land cover in neighbourhood of monitoring point. We have selected this method of analysis due to lack of information on direction of water movement in each monitoring point as well as lack of data on water velocity. In case of availability of water flow direction other method should be selected. This second method should take into account land use identified by vector of about 5 years length on the direction of water inflow.

Results for individual wells are listed in Annex I. Table 5.6 summarizes the overall results.

Table 5.6 The structure and changes of land use at groundwater monitoring points (number of screens) in Tide-Elbe watershed

CLC-Name	**CLC CODE**	**Screens in 1999**		**Screens in 2000**		**Change of Land Use/Land Cover [number of screens]**		
		Count	**%**	**Count**	**%**	**Lack**	**Probable**	**Probable in neighbourhood**
Non-irrigated arable land	211	49	58.33	49	58.33	49	0	1
Pastures	231	10	11.90	13	15.48	10	3	4
Annual crops associated with permanent crops	241	12	14.29	0	0.00	0	12	9
Complex cultivation patterns	242	0	0.00	9	10.71	0	9	0
Land principally occupied by agriculture, with significant areas of natural vegetation	243	3	3.57	3	3.57	3	0	0
Deciduous forest	311	3	3.57	3	3.57	3	0	0
Coniferous forest	312	7	8.33	7	8.33	7	0	0
	Total	**84**	**100.00**	**84**	**100.00**	**72**	**12**	**14**

On the total 84 groundwater measuring points (screens) within boundaries of Tide Elbe watershed, only 10 screens is located on the land classified as „*occupied by forest*" including 3 screens in *broadleaf forest* and 7 screens in *coniferous forest*.
The rest of screens are located on the land classified as „*agricultural areas*". Nearly 60 % of measuring points represent *arable land*. About 15% of all screens represent *pastures*. Nine screens (10,7 %) represent the *complex cultivation pattern* (in 1990 classified mainly as *annual crops associated with permanent crops*).

In case of 85% of all screens installed at monitoring points the land use did not changed. Real changes of land use can be linked only with three monitoring points were the pastures were replaced by annual crops and vice versa.

Analysis of land use history in period 1990 - 2000 shows that this factor (land use change) within boundaries of the Schleswig-Holstein Tide-Elbe watershed should be excluded from further trend analysis.

5.3 Further analysis

It is forecasted that results of nitrogen measurements in groundwater will be analysed with application of factor analysis to discover differences induced by different land use types as well as by differences in N-surplus. These results would support spatial analysis of geochemical state of groundwater body.

Based on results of nitrogen surplus history it is assumed that trends of nitrogen in shallow groundwater form two parts – one „increasing" (before 1983) and second decreasing (after 1983). It is a working hypothesis that similar trends should be observed in monitoring data. Type of trend should depend generally on depth of a screen. It means some monitoring points can reflect increasing trend while other decreasing, depending on the depth of the screen. Results will be published in forthcoming deliverables within the TREND2 work package. Collaboration with other workpackages of AquaTerra is foreseen, but it has not yet been decided which specific workpackages are concerned.

6. Discussion

The establishment of tools for trend analysis in groundwater is essential for the prediction and evaluation of measures taken within context of the Water Framework Directive and the draft Groundwater Directive. This report describes the historic development of contaminant inputs into the groundwater system for the TREND 2 subcatchments. The historic input data are essential to interprete and understand time trends in groundwater, which is the focus of coming deliverables. The emphasis is on diffuse contaminants and includes figures of 1950-present nitrogen inputs fot the Wallonian and Dutch Meuse catchments and the German Schleswig-Holstein catchments. For the Dutch Meuse basin also historical inputs of P, K, S, Ca, Mg, Na, Zn and Cd were estimated. Inputs of the pesticide atrazine were estimated for the small French Brévilles catchment, using interview with farmers.

6.1 General trend in nitrogen inputs

On a regional scale, all of these cases show increasing inputs up to about 1985 and a decrease afterwards due to regulations form that time on. This effect is present in all major river basins as depicted in Figure 5.3, and present in each of the Dutch, Wallonian and German cases in this report. However, total amounts of inputs differ considerably, as is summarized in Figure 6.1. N-inputs corrected for crop uptake in the Dutch lower Meuse basin reach a 1985 maximum of 250 kg $ha^{-1}yr^{-1}$, whereas N-inputs in the Wallonian and German case show maximum inputs of about 150 kg $ha^{-1} yr^{-1}$.

The overall general pattern of N-inputs into groundwater is typically in accordance with the trend reversal concept used in the draft Groundwater Directive (Figure 6.2). The three cases therefore are very useful to test methods for trend reversal in the forthcoming deliverables T2.3 and T2.4. Especially, deliverable T2.4 contains relevant examples of detection of trend reversal in monitoring data, which are compared with the input-curves established in the present report.

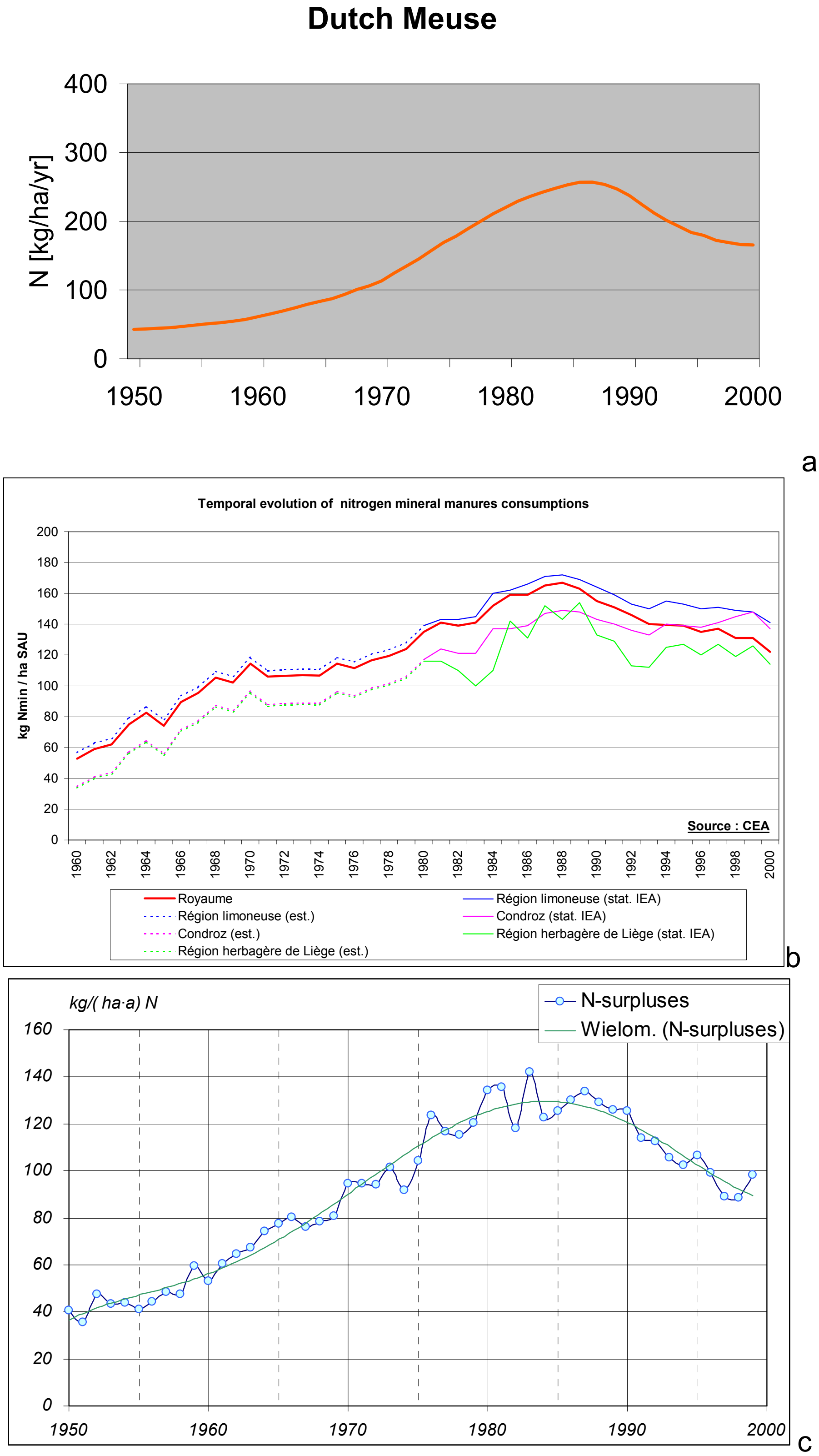


Figure 6.1: Historical N-surplus on agricultural land shows similar trends in Dutch (a), Wallonian (b) and German (c) cases but the total amounts of N-surpluses differ considerably.

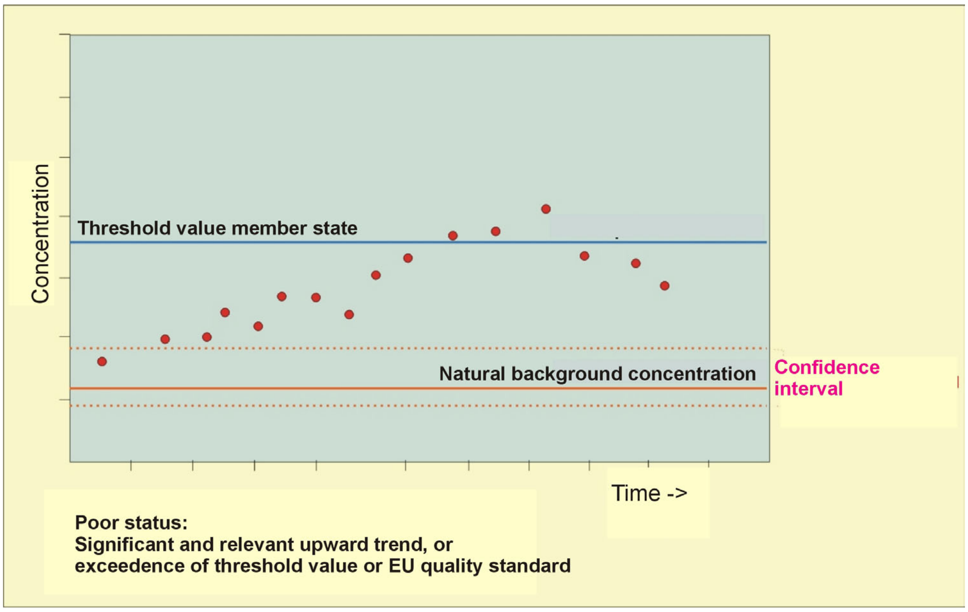


Figure 6.2 Trend reversal concept used in the draft Groundwater Directive (pers. comm. mr. Ph. Quevauviller)

6.2 Trends in other chemicals

Trends in inputs of other diffuse pollutants (cations and heavy metals) seem to be correlated to the well established nitrogen inputs, at least for the Dutch case. The actual use and leaching of individual pesticides may be different from the general trend, as a result of the legislation against specific pesticides and technological development of substituting products.

6.3 Concluding remarks

As mentioned in the introduction, an inventory of historical changes in land use and corresponding contaminant inputs is essential to understand and interprete trend analysis results. This Deliverable (T2.2) reports on these essential statistics to interprete the future results of the TREND2 workpackage, but also provides data which may be interestingfor other workpackages, such as INTEGRATOR 2, EUPOL, BASIN R1, R3 AND R4 and FLUX workpackages of AquaTerra.

7. References

Behrendt, H., Bach, M., Kunkel, R., Opitz, D., Pagenkopf, W.-G., Scholz, G. and Wendland, F. (2003). Nutrient emissions into river basins of Germany on the basis of a harmonised procedure. UBA-Texte, 191 p., Berlin.

CBS Statline (2005) Statistics Netherlands at http://statline.cbs.nl/

CBS (1991) Produktie van dierlijke mest 1988 (Animal manure production 1988, in Dutch), Staatsuitgeverij, ’s Gravenhage.

CBS (1987) Produktie van dierlijke mest 1986 (Animal manure production 1986, in Dutch) Staatsuitgeverij, ‘s Gravenhage.

CBS (1976) Produktie van dierlijke mest 1950-1974 (Animal manure production 1950-1974, in Dutch) Staatsuitgeverij, ‘s Gravenhage.

EPA Fertiliser consumption, European Environment Agency, http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=756

Evers, M.A.A. and Pothoven, R. (1995) Handboek meststoffen (Fertilizer manual, in Dutch), NMI Wageningen.

Heij, G.J. and Schneider, T. (1991) Acidification Research in the Netherlands, final report of the Dutch priority programme on acidification, Elsevier Amsterdam

Horst, B., Bach M., Kunkel R., Opitz D., Pagenkopf W-G, Scholz G. & Wendland F. (2003) Environmental Research Plan Of The Federal Environmental Ministry; Water Management; Project No: 29922285; Nutrient emissions into river basins of Germany on the basis of a harmonised procedure;; Founded By The Federal Environmental Agency.

Jansen, P.C. (1988) Belang van de strooisellaag voor de totale depositie in een dennenbos (Impact of litter on total deposition in a coniferous forest, in Dutch), Landschap 1989 nummer 2 147-161.

Kiwa Research and Consultancy (1998) Beschrijving SPREAD (SPREAD description, in Dutch) Nieuwegein

KNMI(/RIVM), 1982-1988, Chemical composition of precipitation over the Netherlands: annual report 1981 - annual report 1987

KNMI/RIVM, 1989-1995, Netherlands precipitation chemistry network: results 1988 - results 1991

Laime S. et Dautrebande S., 1995. Projet pilote CARHY - Rapport final. Unité d’Hydraulique Agricole, FUSAGx, 164p. et annexes.

Landesamt für Natur und Umwelt des Landes Schleswig-Holstein (2001) Landwirtschaft und Grundwasser Dokumentation der Veranstaltung im LANU am 11. Dezember 2001

LEI (2005) Land en tuinbouwcijfers (Agricultural statistics, in Dutch) ’s Gravenhage. (Available on www.lei.wur.nl)

Loman, H. (1989) Netto zuurbelasting van de bodem door atmospherische depositie (Netto atmospheric acidifying deposition, in Dutch), Instituut voor Bodemvruchtbaarheid, nota 207, Haren.

Menke, M.A. (1992) Belasting van de Nederlandse bodem met meststoffen : ten behoeve van de voor de Commissie Stikstof uitgevoerde landelijke berekeningen van de stikstofuit- en afspoeling vanuit de landbouw (Nutrient load on Dutch soil, in Dutch) RIZA.

NMI (2000) Praktijkgids bemesting. (Fertilizing guide, in Dutch) Wageningen

Pronk, A. (1983) Jaarstatistiek van de kunstmeststoffen 1981/’82. (Annual statistics of fertilizer, in Dutch) LEI, Per. Rapp. No. 66-81/82

RIVM/KNMI, 1995-2001, National Precipitation Chemistry Network. Monitoring results for 1994 - Monitoring results for 2000

Stuyfzand, P.S. (1991) De samenstelling van regenwater langs de Nederlandse kust (The composition of rain along the Dutch coastline, in Dutch) Kiwa-rapport SWE 91.010.

Van der Grift, B. and Van Beek, C.G.E.M. (1996) Hardheid van onttrokken grondwater 4, indicatieve voorspellingen (Hardness of pumped groundwater, in Dutch), Kiwa/Utrecht University

Appendix I

Assessment of the land use change in Bille-Kruckau watershed in period 1990-2000 at monitoring points

NAME	MP_ID	SCREEN	Measurements number	TREND_NET	BASIC_NET	WATERSHED	CLC90	CLC90_NEIGHBOURHOOD	CLC2000	CLC2000_neighbourhood	NO CHANGE	no change_neighbourhood	Likelihood of change
GROßHANSDORF	10L62023001 / 4428	1	25	FALSE	TRUE	ALSTER	211	311	211	311	TRUE	TRUE	LACK
GROßHANSDORF	10L62023002 / 4429	2	25	FALSE	TRUE	ALSTER	211	311	211	311	TRUE	TRUE	LACK
GROßHANSDORF	10L62023003 / 4430	3	25	FALSE	TRUE	ALSTER	211	311	211	311	TRUE	TRUE	LACK
GROßHANSDORF	10L62023004 / 4431	4	25	FALSE	TRUE	ALSTER	211	311	211	311	TRUE	TRUE	LACK
WOHLTORF	10L53133001 / 4447	1	7	FALSE	TRUE	BILLE	211		211		TRUE	TRUE	LACK
WOHLTORF	10L53133002 / 4448	2	6	FALSE	TRUE	BILLE	211		211		TRUE	TRUE	LACK
WOHLTORF	10L53133003 / 4449	3	6	FALSE	TRUE	BILLE	211		211		TRUE	TRUE	LACK
WITZHAVE-JAHRENSBERG	10L62086003 / 4623	1	18	TRUE	FALSE	BILLE	211		211		TRUE	TRUE	LACK
BARMSTEDT-STEINMOOR	10L56002033 / 3935	1	11	TRUE	FALSE	KRUCKAU	211	112	211	112	TRUE	TRUE	LACK
SEETERMÜHE	10L56045001 / 3726	1	13	FALSE	TRUE	KRUCKAU	211		211		TRUE	TRUE	LACK
SEETERMÜHE	10L56045002 / 3727	1	0	FALSE	TRUE	KRUCKAU	211	231	211	231	TRUE	TRUE	LACK
SEETERMÜHE	10L56045003 / 3728	1	0	FALSE	TRUE	KRUCKAU	211		211		TRUE	TRUE	LACK
ELLERHOOP-WIEREN	10L56014002 / 3933	2	2	TRUE	FALSE	PINNAU	211		211		TRUE	TRUE	LACK
HOLM-NORDOST	10L56028009 / 3929	1	18	TRUE	FALSE	PINNAU	211		211		TRUE	TRUE	LACK
RELLINGEN-HABICHTSTR.	10L56043007 / 3708	1	8	TRUE	FALSE	PINNAU	211	112	211	112	TRUE	TRUE	LACK
RELLINGEN-PAPENKAMP	10L56043016 / 8283	1	8	TRUE	FALSE	PINNAU	211		211		TRUE	TRUE	LACK
GÜLZOW-SÜDOST	10L53047012 / 4625	1	18	TRUE	FALSE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK
KITTLITZ HINTERM SEE	10L53062002 / 4621	1	1	TRUE	FALSE	SCHAALSEE-DELVEN	211	211	211	231	TRUE	FALSE	PROBABLE
KITTLITZ-SALEMER STR.	10L53062002 / 4645	1	18	TRUE	FALSE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK
LÜTAU	10L53087005 / 4513	1	7	FALSE	TRUE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK
LÜTAU	10L53087006 / 4514	2	25	FALSE	TRUE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK
LÜTAU	10L53087007 / 4515	3	25	FALSE	TRUE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK
LÜTAU	10L53087008 / 4516	4	25	FALSE	TRUE	SCHAALSEE-DELVEN	211		211		TRUE	TRUE	LACK

NAME	MP_ID	SCREEN	Measurements number	TREND_NET	BASIC_NET	WATERSHED	CLC90	CLC90_NEIGHBOURHOOD	CLC2000	CLC2000_neighbourhood	NO CHANGE	no change_neighbourhood	Likelihood of change
FITZEN	10L53029005 / 4624	1	18	TRUE	FALSE	SCHAALSEE-DELVEN	231	211	231	211	TRUE	TRUE	LACK
ELLERHOOP-WIEREN	10L56014001 / 3932	1	0	TRUE	FALSE	PINNAU	241		242		FALSE	TRUE	PROBABLE
HASLOH	10L56021001 / 3730	1	18	FALSE	TRUE	PINNAU	241	231	242	231	FALSE	TRUE	PROBABLE
HASLOH	10L56021002 / 3731	2	18	FALSE	TRUE	PINNAU	241	231	242	231	FALSE	TRUE	PROBABLE
HASLOH	10L56021003 / 3732	3	18	FALSE	TRUE	PINNAU	241	231	242	231	FALSE	TRUE	PROBABLE
HEIDGRABEN-SCHLANGENTWIETE	10L56023008 / 8282	1	8	TRUE	FALSE	PINNAU	241		242		FALSE	TRUE	PROBABLE
AHRENLOHE-HÖRNWEG	10L56048009 / 3928	1	18	TRUE	FALSE	PINNAU	241	211	231	211	FALSE	TRUE	PROBABLE
WEDEL-BÜNDTWIETE	10L56050015 / 3934	1	18	TRUE	FALSE	PINNAU	241		242		FALSE	TRUE	PROBABLE
TORNESCH	10L56048003 / 3587	1	18	FALSE	TRUE	PINNAU	243	112	243	112	TRUE	TRUE	LACK
TORNESCH	10L56048004 / 3588	2	18	FALSE	TRUE	PINNAU	243	112	243	112	TRUE	TRUE	LACK
TORNESCH	10L56048005 / 3589	3	18	FALSE	TRUE	PINNAU	243	112	243	112	TRUE	TRUE	LACK
SACHSENWALD-VIERTHE	10L53105018 / 4544	1	17	FALSE	TRUE	BILLE	311		311		TRUE	TRUE	LACK
SACHSENWALD-VIERTHE	10L53105019 / 4545	2	17	FALSE	TRUE	BILLE	311		311		TRUE	TRUE	LACK
SACHSENWALD-VIERTHE	10L53105020 / 4546	3	17	FALSE	TRUE	BILLE	311		311		TRUE	TRUE	LACK
TANGSTEDER FORST	10L62076008 / 4617	1	26	FALSE	TRUE	ALSTER	312		312		TRUE	TRUE	LACK
LANGENLEHSTENER HEI	10L53080001 / 4616	1	17	FALSE	TRUE	SCHAALSEE-DELVEN	312		312		TRUE	TRUE	LACK

Note:
Orange colour – high probability
Green colour – low probability