# Environmental monitoring in heterogeneous soil-landscapes; A Dutch case study

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**Abstract**
There is scope for developing environmental monitoring programs at the landscape level to address the feedback mechanisms at this scale. For a Dutch landscape dominated by dairy farming we have i) derived the environmental goals for atmospheric quality and water quality and ii) assessed the current environmental quality using a combination of measurements and model calculations. The analysis was limited to nitrogen (N) and phosphorus (P) compounds which are the chemical elements most closely related to agriculture. Environmental goals at the landscape scale were derived for five individual indicators: $NH_3$ emission, critical atmospheric N deposition, N in surface water, P in surface water and $NO_3$ in the upper groundwater.
In the study area, the $NH_3$ emission goal for 2010, is not exceeded in 2004. However, simulation results suggest that critical N deposition rates on nature areas are exceeded on more than half of the area (53%), mainly as a result from non-agricultural sources and sources outside the NFW region. For the region as a whole, annual $NO_3$ concentrations in the upper groundwater almost never exceed the EU threshold of 50 mg/L. The national N standards for surface water regarding N and P are only slightly exceeded

**Key Words**
Environmental quality, dairy farming, nitrogen, phosphorus.

## Introduction

The spatial heterogeneity of agricultural soil-landscapes is mostly not taken into account in environmental policies. Most environmental goals have been defined at national level or farm level but not at the landscape level. Consequently, most environmental monitoring programs are operational at national level or farm level. There is scope however for developing monitoring programs from a regional landscape and watershed perspective because of the extent of environmental contaminants, their potential for transport through complex hydrological and atmospheric pathways and the impacts beyond local conditions (Bruns and Wiersma 2004). In this study, we used the DPSIR framework as a tool to distinguish between various environmental indicators. For a Dutch landscape dominated by dairy farming we have i) derived for environmental goals for atmospheric quality and water quality and ii) assessed the current environmental quality using a combination of measurements and model calculations (STONE and Initiator). The potential for setting up a regional environmental monitoring network that supports self governance was explored. The analysis was limited to nitrogen (N) and phosphorus (P) compounds which are the chemical elements most closely related to agriculture.

The research was performed in the Northern Friesian Woodlands (NFW), which is located in the province of Friesland in the North of The Netherlands (Figure 1). A large part of the 600 $km^2$ area as been appointed as a Dutch National Landscape because of the small scale parcelling structure, a high concentration of hedge-rows bordering the individual fields and the occurrence of many pingo-remnants from the Weichsel glacial period. The area dominantly consists of sandy soils (Gleyic Podzols) at elevations of 1 to 5 m above mean sea level. Clay soil and peat soil are found in the north and the west of the study area in lower landscape positions.

Agriculture dominates the landscape using 76% of the total area. Mostly this is grassland (69%) used for dairy farming. Surface water occupies 5% of the area and the remainder is used for built-up (13%) and nature (6%). In 2004, 92% (1169) of the total number of farms were animal farms, mostly dairy farms. Environmental goals at the landscape scale were derived for five individual indicators: NH3 emission, critical atmospheric N deposition, N in surface water, P in surface water and NO3- in the upper groundwater. Based on areal fractions, a provincial goal of 12 kton $NH_3$/yr can be calculated for the province of Friesland using the national EU derived emission ceiling as input. With the model Initiator (De Vries *et al.* 2003), the NH3 emission goal for the NFW region was calculated at 2.6 kton $NH_3$/yr for 2010. To derive the regional goals for critical N deposition, the inventories of Bal *et al.* (2006) were used which indicate critical N

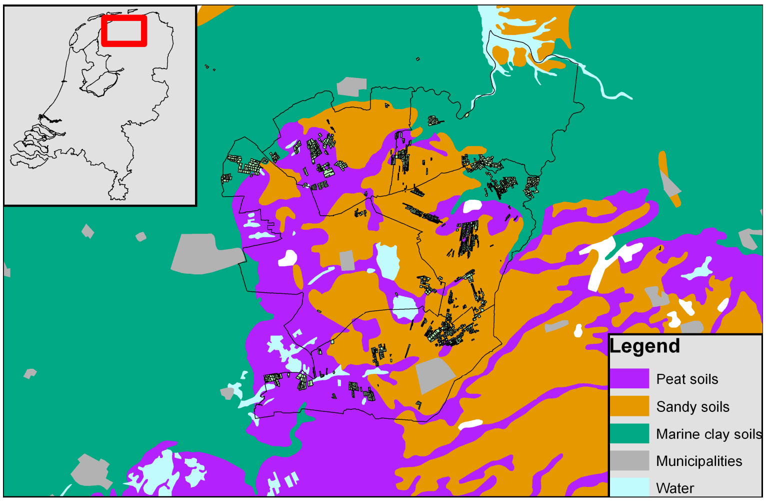

**Figure 1. Distribution of soils in the study area, in the North of the Netherlands.**

deposition targets for specific types of vegetation. The provincial map for nature areas was then used to map the critical N deposition targets for the NFW region. According to this approach, more than 9000 ha (15%) in the NFW region is targeted at nature area with critical N depositions ranging from 400 mol N/ha/y to 2500 mol N/ha/y. The EU threshold of 50 mg $NO_3$/L was adopted (EC, 1991) as a goal for nitrate concentrations in the upper groundwater for all soil types. For surface water quality, the EU Water Framework directive specifies a good ecological and chemical quality to be reached by 2015. At EU level, no specific thresholds are specified but the Dutch Commission on Integrated Water management has specified thresholds for N and P. For the summer-period (April 1 – October 1) for stagnant surface waters, the N concentration limit is set at 2.2 mg N/L whereas the P concentration limit is set at 0.15 mg P/L.

## Material and methods

Calculations for the emission of $NH_3$ and the deposition of N in the NFW were performed for 2004 with the integrated nutrient model Initiator2 in combination with the atmospheric OPS transport model (Jaarsveld 2004). Nationally available GIS datasets were used as inputs, including the 1: 50,000 scale soil and hydrology map, the LGN land use map, the GIAB dataset on animal numbers and the national parcel registration system. A distribution module was included to simulate the application of manure N to the individual fields. The model STONE was used for mapping soil chemical characteristics at a spatial resolution of 250x250 m which was used as input for the INITIATOR model.

An assessment of water quality in the region with regard to N and P was done using a combination of modelling and measurements. The monitoring network from the regional Water Board for surface water yielded monthly data for the years 2000 to 2005 for six locations in the NFW area, four locations were in the peat area; one location was in the clay area; and one location was in the sand area. These data can be used for status monitoring through time (trend monitoring) but are not suitable for compliance monitoring that is requested by the Water Framework Directive (Knotters and Brus 2008).

Monitoring data on nitrate concentrations in the upper groundwater at the provincial scale were not available. $NO_3$ concentrations in the upper groundwater and N and P loading of surface waters were modelled using the STONE model. Additionally, a validation was performed for nitrate concentration in the upper groundwater for farms on sandy soils (Sonneveld *et al.* 2010).

## Results

Both $NH_3$ emissions from point locations (stables, storage) as well as emissions from fields (manure application) appear to be uniformly distributed throughout the area. Within relatively small distances (< 1 km) large variations in field emissions can be found however ranging from < 10 kg $NH_3$-N/ha/y to > 40 kg $NH_3$-N/ha/y. For 2004, a total emission of 2.4 kton NH3/yr was calculated. This implies that for 2004 there was no exceedance of the downscaled EU NEC goal (2.6 kton $NH_3$/yr) for the NFW region.

The largest rates of atmospheric inputs of N are calculated for the central-eastern part of the study area (> 30 kg N/ha/y). Calculated deposition rates for most of the area are between 5 to 10 kg N/ha/y. Apart from agricultural sources inside the NFW region, also other (industrial) sources and sources outside the NFW area contribute to the total N deposition (Table 1). It appears that a major part of the N deposition, 72%, corresponding with 17.5 kg N/ha/y, is due to non-agricultural sources and NOx sources outside the NFW region. Accordingly, less than a third of the total N deposition comes from agricultural sources within the NFW region. Especially in the central part of the region, the Initiator2 model calculates for 2004 N deposition levels that exceed the critical levels substantially. For 2004, critical N deposition values are exceeded on almost 53% of the total area with (planned) nature.

**Table 1. Sources for N deposition in the study area in 2004.**

| Sources | Deposition (kg N/ha/y) | | Deposition (%) | |
|---|---|---|---|---|
| Total $NO_x$ deposition + $NH_3$ from non-agricultural sources (background) | | 17.5 | | 72 |
| $NH_3$ from stables and storage facilities | 2.7 | | 11 | |
| $NH_3$ from land application of manure | 4.2 | | 17 | |
| Total $NH_3$ deposition from agriculture | | 6.9 | | 28 |
| Total N deposition | | 24.5 | | 100 |

Calculated average $NO_3$ concentrations are below the 50 mg/L threshold throughout the entire year. Over the entire year, the NO3 concentration fluctuates more or less between 10 and 30 mg/L with an annual average of 15 mg/L. Thus, the 50 mg/L threshold is for the entire NFW region not exceeded on an annual basis. Low $NO_3$ concentrations are especially found in areas with peat and clay soils, probably due to higher denitrification rates, whereas higher $NO_3$ concentrations, sometimes locally exceeding the 50 mg/L threshold, are mostly found in the (drier) sandy regions. For the period 2000-2005 a downward trend was observed for N and P in surface water, with some fluctuations between the years. For 2005, the median N concentration was below the 2.2 mg/L threshold but the upper boundary of the confidence interval exceeded this threshold for the previous years. For P, all median concentrations in the surface water were below the 0.15 mg/L threshold.

## Conclusions

In the NFW study area, the down-scaled national NH3 emission goal for 2010, based on the NEC directive, is not exceeded in 2004. However, simulation results suggest that critical N deposition rates on nature areas are exceeded on more than half of the area (53%), mainly as a result from non-agricultural sources and sources outside the NFW region. For the region as a whole, annual $NO_3$ concentrations in the upper groundwater almost never exceed the EU threshold of 50 mg/L. The national N standards for surface water regarding N and P are only slightly exceeded for the summer period and monitoring data indicates a decreasing trend in time. From the viewpoint of self-governance, monitoring by regional organizations has the most potential for indicators that are related to sources. Environmental monitoring networks should preferably be maintained by formal (governmental) institutions, also because of monitoring obligations. There is room for developing simple monitoring kits for farmers with the aim to establish feedback loops between monitoring and their farming strategies.

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