The use of an indicator for nitrate concentrations at different scale levels

Smit, A.[1*], Roelsma, J.[1], Berge, H.F.M. ten[2] & Boels, D.[1]

[1] *Alterra, Wageningen UR, the Netherlands*
[2] *Plant Research International, Wageningen UR, the Netherlands*

[*] *E-mail: bert.smit@wur.nl*

Abstract

The project 'Focus on Nitrate (2000-2004)' aims to establish and test indicators for NO_3^- concentrations in groundwater (regression models) in dairy and arable farms. In this paper we show the models resulting from the analyses and discuss the use of the models at different scale levels.

Background and objectives

Leaching of nitrate from agricultural lands to groundwater is a problem in the Netherlands, as well as in other regions of Europe. While action programs are being implemented to reduce NO_3^- emissions, there is a need to monitor progress at farm level as well as regional or national scales. Monitoring of nitrate concentrations is labor-intensive and expensive. Therefore there is a need for indicators.

Materials and methods

The Focus on Nitrate study was based on a procedure to acquire an even representation of soil types, groundwater regimes, and crops prevailing in the sand districts of the Netherlands. About 60 different combinations of soil-crop-groundwater regime were identified, and are referred to as 'land use units' (LUU). Observations refer to $20m^2$ 'spots' distributed among these LUU's. At each spot soil mineral N was measured at three depths (0-30, 30-60 and 60-90 cm) in autumn, the nitrate concentration in the top 1m groundwater was measured in spring. In addition many other observations were made (Hack-ten Broeke *et al.,* 2004). The search for indicators and establishment of regression models was performed on 478 spots, distributed among 34 farms. The models were tested on accuracy and applicability for different scale levels. For testing data from LUU's distributed among 19 farms were used. (Smit *et al.*, 2004) In addition LUU's in three regions, were sampled (about 300 spots) (Roelsma *et al.*, 2003)

Results and discussion

The results from the model development show that for all soil-crop-groundwater regime combinations the best performance was obtained if we used the NO_3^- part of N_{min}, denoted as $N_{min,NO3}$, summed over 90 cm depth. Differences between land use and ground water regime were only expressed by different intercepts (Figure 1). The explained variance of the simplest models ranged from 21% for grass, 24% for maize to 36% for arable crops, while the standard errors amounted respectively 49.8 mg/l, 65.6 mg/l and 59.6 mg/l. The performance could be slightly increased by adding other parameters like cumulative precipitation during summer or winter, or N-rate; although the explained variances increased only by a few percent and the decrease of the standard errors were 5 mg/l at most. However, testing showed that the more complicated models were less stable. Aggregation to farm levels and regional scale level brings much improvement.

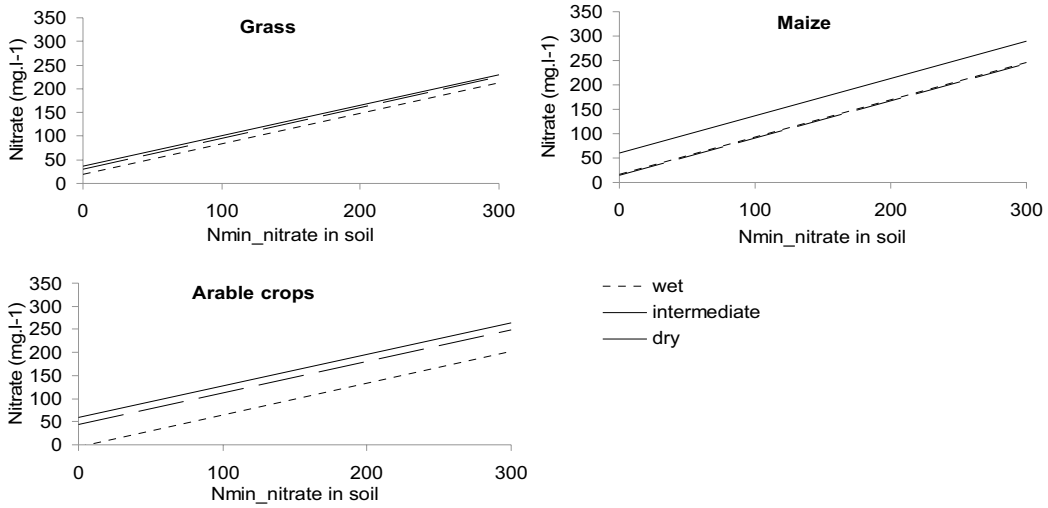

Figure 1. *Response of NO_3^- concentration in groundwater to residual mineral soil N (Nmin-NO3) according to the regression model obtained from data for grass, maize and arable crops. Based on pooled 2000/2001, 2001/2002 and 2002/2003 data.*

Predictions of NO_3^--concentrations at the whole farm level are composed from the individual LUU-nitrate values, given a specified farm composition (the respective areas of LUU's). The nitrate concentrations at whole-farm level were predicted better than the predictions at the individual 'spots'. Linear regression analysis of these results showed a significant relation, although at higher values (> 68.7 mg.l^{-1}) the predicted nitrate concentrations are under estimated (Figure 2).

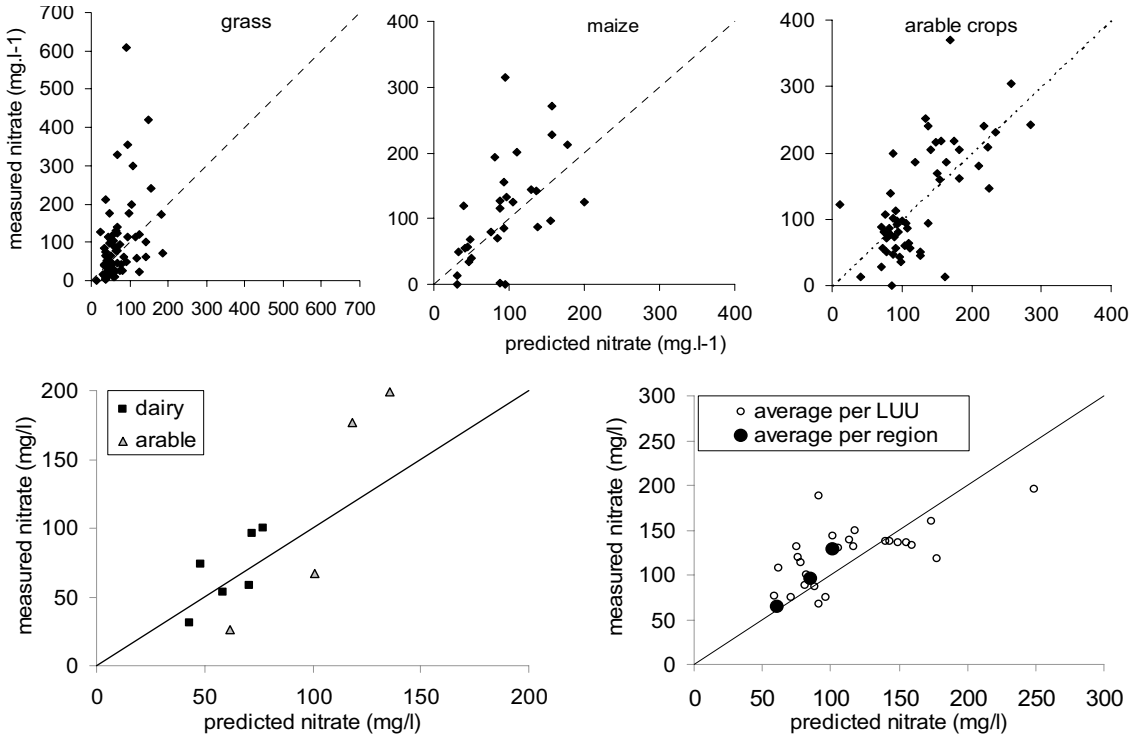

Figure 2. *Predicted and measured nitrate concentrations (mg.l-1) at 'spot-level' (upper graphs), at farm-level (lower left graph) and regional scale (lower right graph). Based on 2003/2004 test data.*

Predictions of NO_3^--concentrations for LUU at the regional level also appeared to be rather good. Using de LUU per region an average value per region could be composed. These results indicate that predicting the nitrate concentrations in the upper groundwater

When using these models for monitoring, it should be kept in mind that the models are only applicable at the current range of nitrate concentrations. Decreasing N rates in order to diminish the mineral N in soil and eventually the nitrate concentrations may also mean that the models become less useful. Therefore, monitoring nitrate concentrations by measuring mineral N in soil and predicting nitrate concentrations in groundwater should be combined with measurements in groundwater. Only in this way, the models can be adjusted to new situations.

Conclusions

The use of the soil-crop-groundwater regime combinations or LUU's appeared to be a very useful approach. The data collected at the relatively small spots could be aggregated to different larger scale levels, varying from farm level tot regional level. The accuracy of the predictions increased at larger scales. The models can be used for monitoring nitrate concentrations, but they should be updated frequently as N rates in Dutch agriculture are continuously subject to change.

References

Berge H.F.M. ten, Burgers S.L.G.E., Hack-ten Broeke M.J.D., Smit A., Gruijter J.J. de, Velthof G.L., Schröder J.J., Oenema J., Ruijter F.J. de, Radersma S., Hoving I.E. and Boels D. (2004)
Nitrogen rate, surplus or residue? Performance of selected indicators for nitrate leaching. In: Hatch D.J., Chadwick D.R., Jarvis S.C. and Roker J.A. (Eds) Controlling nitrogen flows and losses. 12th N-workshop. Wageningen Academic publishers, Wageningen. pp 397-405.

Hack-ten Broeke M.J.D., Burgers S.L.G.E., Smit, A. Berge H.F.M. ten, Gruijter J.J. de, Hoving I.E., Knotters M., Radersma S and Velthof G.L. (2004).
Ontwikkeling van een indicator om te Sturen op Nitraat. Gegevens en regressieanalyse op basis van drie meetseizoenen (2000-2001, 2001-2002 en 2002-2003). (in Dutch) Reeks Sturen op nitraat 12, Alterra rapport 1053, Wageningen, 117 p.

Roelsma J., Rougoor C.W. and Dik P.E. (2003).
Regionaal nitraatmonitoringsconcept RENIM. Ontwikkeling en toetsing van een eenvoudige methodiek voor het monitoren van de uitspoeling van nitraat naar het grondwater in zand- en lössgebieden. (in Dutch) Reeks Sturen op nitraat 7, Alterra rapport 911, Wageningen, 117 p.

Smit A, Burgers S.L.G.E., Berge H.F.M. ten, Gruijter J.J. de, Hack-ten Broeke M.J.D., Hoving I.E., Knotters M., Radersma S and Velthof G.L. (2004).
Ontwikkeling van een indicator om te Sturen op Nitraat. Toetsing van de regressiemodellen voor nitraat. Reeks Sturen op nitraat 13, Alterra rapport 1058, Wageningen, 56 p.