Requirements for representative measurements of water and solute fluxes in artificially drained lowland catchments

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Background and Objectives

- Artificial drainage is a common agricultural practice to improve soil moisture and aeration conditions, but it can lead to increased diffuse pollution of surface waters.
- To assess the environmental impacts of artificial drainage, monitoring is necessary, and these monitoring programmes need to be designed and interpreted carefully.

Scale Issues

- To evaluate the scale transition of the tile drainage signal, NO_3^- concentrations at the different scales were correlated.
- Although the regression equations ($0.26 < R^2 < 0.59$) were highly significant at $p = 0.01$, a scale effect is clearly visible (Fig. 3).
- Thus, results from plot-scale studies cannot be simply transferred to the catchment scale.

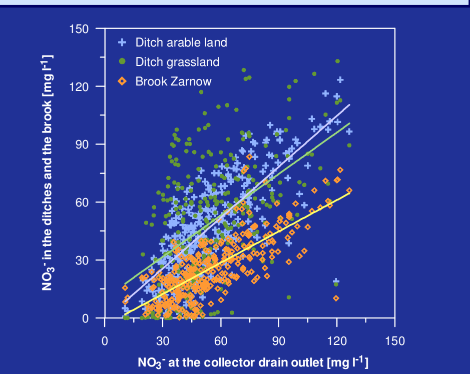

Figure 3: Correlation between NO_3^- concentrations at the collector drain outlet IA and at the other measurement stations (all data from 2003-07).

Intra-field Variability

- For two years (2001-2003), one field with identical drainage layout, crop rotation, tillage practice, climate and similar topsoil properties was sampled at two stations (IA and IB).
- Nonetheless, NO_3^- concentrations were slightly but significantly higher at station IA, while the discharge was much (60 %) higher at station IB.

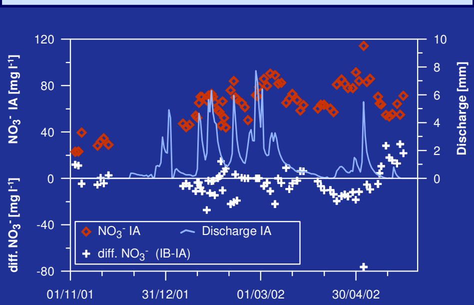

Figure 4: Discharge and NO_3^- concentrations at collector drain outlet IA and concentration differences between the two collector drain stations IB and IA.

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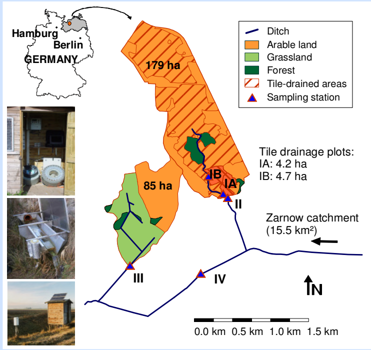
The Study Site

- Hierarchical sampling approach from 2001/02 to 2006/07 in a small pleistocene catchment (ø P = 664 mm, ø PET = 561 mm) in North-Eastern Germany with automatic sampling stations (Fig. 1) for water and discharge.



- Analysis of daily to weekly composite samples for nitrate (NO_3^-) using ion chromatography.

Load Estimation Methods

- Eight different load (*L*) estimation methods were tested for different sampling intervals:
  - **1**: Linear interpolation of the concentrations *c*
  - **2**: Linear interpolation of both *c* and the discharge *Q*
  - **3**: $L = \bar{c} \cdot Q$ (*Q* measured continuously)
  - **4**: $L = \bar{c} \cdot \bar{Q} \cdot n$
  - **5**: $L = \overline{cQ} \cdot n$
  - **6**: $L = \overline{cQ} / \bar{Q} \cdot Q$ (*Q* measured continuously)
  - **7**: Beale's Ratio estimator (Beale, 1962)
  - **8**: Regression method (quadratic equation)
- All methods yield a large variability of results for different subsamples of the same data set, and most methods are biased (Fig. 5).

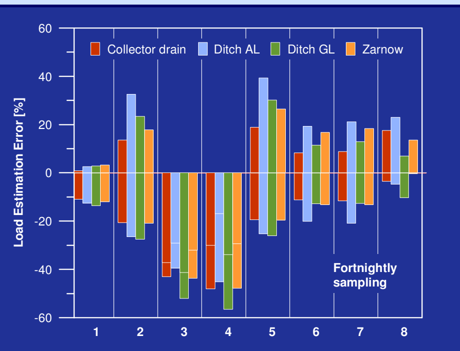


Figure 5: Minimal and maximal NO_3^- load estimates for fortnightly sampling and different load estimation methods at all sampling stations.

Conclusions

- To obtain meaningful interpretations, frequent sampling using automatic sampling stations is necessary as errors arising from the sampling design and from load estimation methods exceed those from sample treatment.
- When generalizing monitoring results, the length of the study period, intra-field variability and scale effects should be taken into account.

Spot vs. Composite Samples

- During one flow event, hourly samples were taken at the collector drain outlet (Fig. 2).
- Especially during increasing discharge rates, NO_3^- concentrations were highly dynamic.
- Spot sampling can lead to large errors as shown by standard deviations of up to 20 mg l^{-1}.

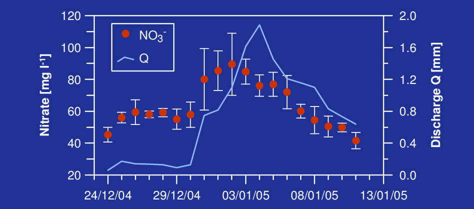


Figure 2: Daily discharge and average daily nitrate concentrations at the collector drain outlet IA. Error bars indicate the standard deviation (n = 24).

Sampling Interval

- The daily data set was "re-sampled" to test sampling intervals of 2, 3, 4, 7, 14 and 30 days yielding the accordant number of load estimates for each calculation method.
- Sampling intervals of up to 7 days may yield reasonable load estimates (Fig. 6), but process interpretation will still be very difficult.

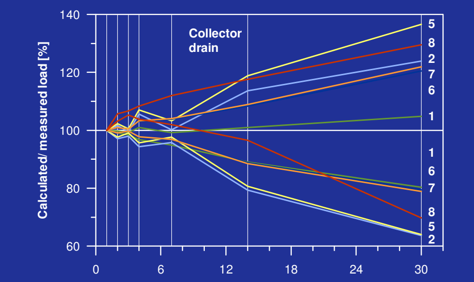


Figure 6: Minimal and maximal NO_3^- load estimates for different load estimation methods depending on the sampling interval (collector drain outlet IA).

Sample Treatment

- One set of samples was divided into four parts and i) analyzed after returning from the field, ii) stored at room temperature for 6 days, iii) stored in the fridge for 8 days and iv) stored in the freezer for 2 months before analysis.
- Nitrate concentrations were slightly higher after all three storage alternatives (Fig. 7).

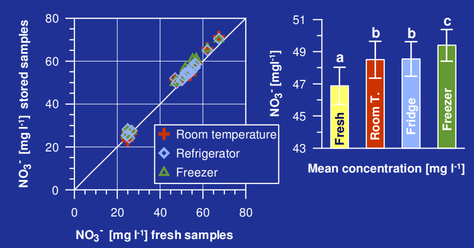


Figure 7: Nitrate concentrations depending on sample treatment (a, b, c = significantly different mean, p = 0.01). Error bars: Analytical standard error.

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