Extended abstracts No. 367

NITROGEN AND DISSOLVED ORGANIC CARBON (DOC) LOSSES FROM A DEGRADED PEATLAND IN NORTH-EASTERN GERMANY

Bärbel Tiemeyer
Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Agricultural Climate Research, Bundesallee 50, D-38116 Braunschweig, Germany. Phone: +49(0)531-5962644, E-mail: baerbel.tiemeyer@vti.bund.de

Petra Kahle
Faculty of Agricultural and Environmental Sciences, Rostock University

SUMMARY

Nitrogen (N) and dissolved organic carbon (DOC) concentrations and losses were studied for two years in a small catchment dominated by a degraded peatland used as intensive grassland. Concentrations in the groundwater were spatially and temporally very variable with nitrate being the most dynamic component. DOC losses were 66 kg/ha in the wet year 2006/07 and 39 kg/ha in the dry year 2007/08. Total N losses amounted to 42 and 31 kg/ha. In both years, dissolved organic N losses accounted for around 15% of the total N losses and thus form a relevant component of the N losses from drained peatland catchments.

KEY WORDS: water quality, peatland hydrology, grassland, nitrate, drainage

INTRODUCTION

Most of the once ecologically valuable peatlands in Western Europe as well as in Mecklenburg-Vorpommern (North-Eastern Germany) have been drained in the course of the intensification of agriculture. Peat degradation and mineralisation frequently caused high nitrate losses, while the effect on dissolved organic carbon (DOC) and nitrogen (DON) losses is less clear. DOC losses form a part of the carbon balance and influence biogeochemical cycling and drinking water quality of the receiving waters. As most studies on DOC and nitrogen focus on upland peatlands and/or re-wetted sites (e.g. Gibson *et al.*, 2009; Dawson *et al.*, 2002), there is a distinctive lack on baseline data for lowland peatlands under agricultural use. Even less is known on DON than on DOC although some studies suggest that DOC and DON do not necessarily follow the same dynamics (Kalbitz and Geyer, 2002). Thus, we want to show how hydro-meteorological conditions influence the DOC, nitrate and DON concentrations in and losses from an artificially drained lowland catchment with organic soils.

MATERIALS AND METHODS

The study site

The study site is a small (85 ha) catchment in the pleistocene lowlands of North-Eastern Germany. Long-term mean annual precipitation, reference crop evapotranspiration, and temperature are 665 mm, 490 mm and 8.2°C, respectively. The catchment consists of intensive grasslands mainly on organic soils and arable land on mineral soils. Average annual nitrogen fertilization was around 200 kg/ha. The properties and depths of the organic soils are spatially variable, but they are all drained by ditches and occasional tile drains. The arable land within the catchment is not artificially drained. At the catchment outlet, a sampling station measured the water level via a pressure sensor and collected, depending on the flow conditions, daily to weekly water samples with an automatic sampler. Weekly discharge gauging was conducted to develop a rating curve. Climate data was recorded nearby. Twelve dip-wells in transects A and B on shallow organic soils and six dip-wells in transect C on deep organic soils were sampled weekly during the winter season. Details on the study site and the field methods can be found in Tiemeyer *et al*. (2007). Here, we report on results from November 2006 to October 2008.

Laboratory methods

NO_3^- and NH_4^+ were analyzed by ion chromatography (Metrohm GmbH). DOC and total nitrogen (TN) were determined from filtered samples (0.45µm) by combustion and infrared detection (Dimatec GmbH) and chemilumiscence detection (Mitsubishi GmbH), respectively. DON is calculated as the difference of TN and mineral N (NO_3-N + NH_4-N). Besides the samples from the ditch, DOC concentrations were only determined for samples from the dip-wells in transect C, and TN only during winter 2007/08.

RESULTS AND DISCUSSION

Hydrology

Figure 1 shows the hydro-climatic conditions during the study period. Both years were warmer (10.0 and 9.0°C) than average, and annual precipitation sums of 934 and 554 mm mark exceptionally wet and dry years. While the precipitation (383 and 346 mm) and the discharge (179 and 177 mm) were similar during the two winter periods, the summer periods made the difference between the two years. Given the long-term summer precipitation average of 391 mm, the summer of 2007 was extraordinary rainy with a precipitation of 551

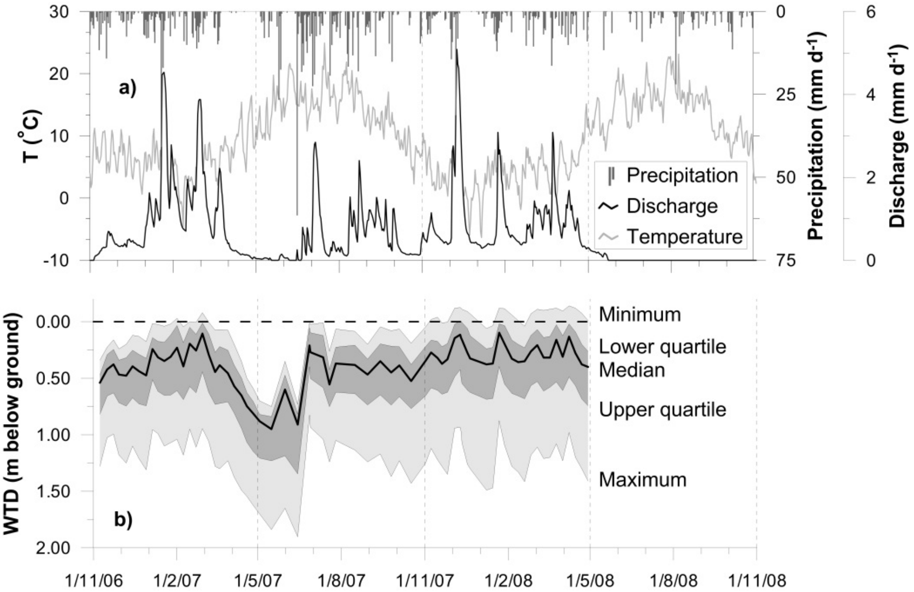

Figure 1: Hydrological conditions during the study period: a) Precipitation, air temperature and discharge and b) water table depths (median, quartiles, minimum and maximum from 24 dip-wells). No groundwater data is available for the summer of 2008.

mm. Accordingly, in this year, the summer discharge (91 mm) was higher than that of dry winters (Tiemeyer *et al.*, 2007). Due to this wet summer, the average groundwater (GW) level was, despite slightly less precipitation, higher in winter 2007/08 (0.38 m) than in winter 2006/07 (0.51 m). As in other summers, the median GW level still dropped to 0.95 m during the dry spell in April and May 2007, demonstrating the heavy disturbance of the peatland. Due to the high spatial variability of the GW level, spatially heterogeneous biogeochemical processes can be expected. The ditch integrates all these responses together with GW flow from the non-drained part of the catchment and, given the heterogeneous geological situation of the area, possibly also deeper groundwater.

DOC and nitrogen concentrations

DOC concentrations in the ditch are shown in Fig. 2a. The average concentration of 24.9 mg/L is quite high for a lowland peatland, especially given that only a part of the catchment is covered by organic soils. There is no effect of either year or season on the concentrations, which is quite surprising in the light of the shifting hydrological conditions. Although the highest concentrations were measured in the beginning of the study period, suggesting a flush of pore water enriched with DOC when flow towards the ditch is initiated, no overall effects of temperature (data not shown) or discharge (Fig. 3) could be detected.

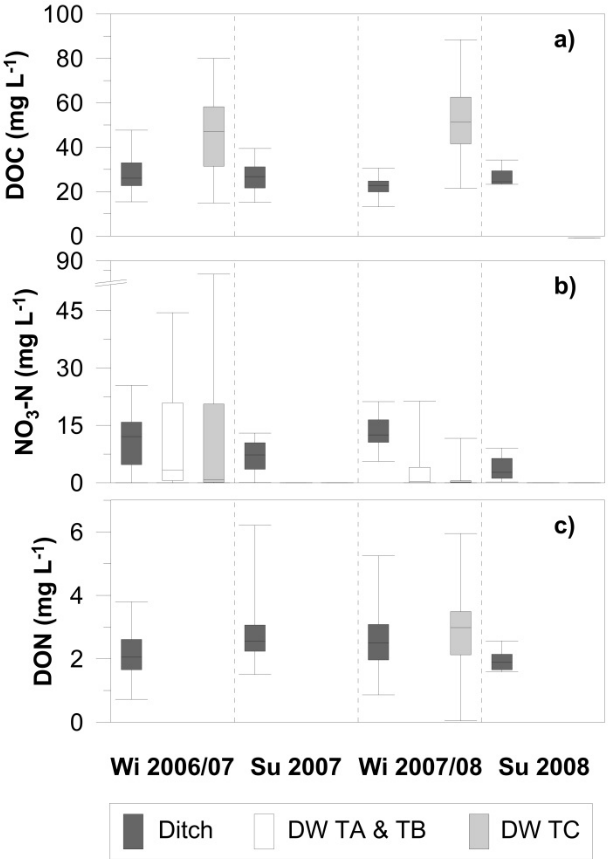

Figure 2: Boxplots of a) dissolved organic carbon (DOC), b) nitrate-nitrogen (NO_3-N), and c) dissolved organic nitrogen (DON) concentrations at the catchment outlet and in the dip-wells in shallow (transects A and B) and deep (transect C) organic soils during the four studied seasons.

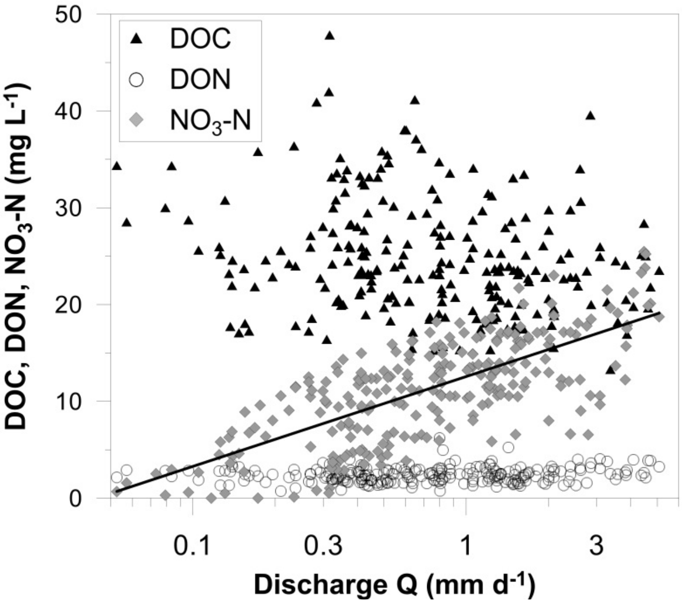

Figure 3: Relationship between the discharge (Q) and the concentrations of dissolved organic carbon (DOC), nitrate-nitrogen (NO_3-N), and dissolved organic nitrogen (DON) in the ditch including the correlation between log Q and NO_3-N ($R^2 = 0.52$).

DOC concentrations in the groundwater were higher than in the ditch, which is not surprising given that the dip-wells of transect C were installed in the part of the catchment with the highest C_{org} content (on average, 36.8% in 0-30 cm depths and 45.2% in 60-90 cm). Average DOC concentrations of 50.6 mg/L are within the typical range of degraded peatlands; Fiedler *et al*. (2008) measured, for example, an average DOC concentration of 82 mg/L in the GW of a deeply drained fen also used as grassland. Kalbitz and Geyer (2002) found mainly lower DOC concentrations (20-76 mg/L), but their soils did also have lower contents of C_{org} than ours. The wet conditions from June 2007 to April 2008 – which are similar to those of recently re-wetted fens – had no clear effect on the groundwater DOC concentrations. Generally, the effect of re-wetting on DOC concentrations is inconsistent and seems to depend on a number of factors such as the degradation status of the peat, the C_{org} content and the pH. While some authors found considerably higher DOC concentrations in re-wetted, highly degraded fens (Kalbitz and Geyer 2002), others report significantly lower DOC concentrations after re-wetting (Fiedler *et al*. 2008) or no change at all (Gibson *et al*., 2009).

Average NO_3-N concentrations in the ditch were higher during the second (13.1 mg/L) than during the first (10.9 mg/L) winter. During summer, NO_3-N concentrations were lower than during winter (6.9 and 3.6 mg/L) in both years due to higher microbial activity and plant uptake of nitrogen, especially in the dry summer 2008. This is reflected by a weak correlation (R^2=0.18) between temperature and NO_3-N. Overall, the NO_3-N concentrations are high and 50 % of all samples exceed the drinking water limit of 11.3 mg/L. Only 8% of the samples are lower than 2.5 mg/L which corresponds to a “good water quality” according to the European Water Framework Directive. This is even more serious as there is a clear positive correlation (R^2=0.52) between the discharge and the NO_3-N concentrations (Fig. 3) and thus large volumes of water carry high NO_3-N concentrations. Ammonium-nitrogen (NH_4-N) was not found at the catchment outlet.

During the first winter, NO_3-N concentrations in the groundwater were partially extremely high (Fig. 2b) due to the mineralisation of organic matter which can be very high in drained peatlands (Höper, 2002). At our study site, C:N ratios of 9-18 in 0-30 cm depth and additional fertiliser application create a favourable environment for nitrogen release. As observed in the year preceding our study (Tiemeyer *et al.*, 2007), the temporal NO_3-N concentration patterns in the GW were similar to the ditch. Although the concentration levels differed strongly between the single dip-wells, NO_3-N concentrations generally rose with rising GW levels. This can be explained by mineralisation during relatively dry periods and subsequent transport to the GW by rainfall events. Snowmelt events tended to cause a dilution pattern, but significant snowmelt did not occur during our study period. Average NH_4-N concentrations were near zero.

Although small concentration peaks still occurred in the second winter at rising GW levels – or, better *after* lower GW levels –, the wet summer 2007 had by then completely changed the NO_3-N concentration dynamics in the groundwater. There, the average NO_3-N concentration dropped from 11.1 to 2.4 mg/L. This was especially striking at those dip wells in transect C (deep peat) where average NO_3-N concentrations of 47.9 and 24.1 mg/L in the first winter decreased to 0.8 and 1.5 mg/L in the second winter. These low NO_3-N concentrations can be explained by both denitrification and – as the GW level during the winter 2007/08 itself was not exceptionally high – decreased mineralization during the preceding wet summer period. NH_4-N concentrations were still low (0.5 mg/L on average).

These results raise the question why the ditch dynamics were decoupled from the GW dynamics in the second year of the study. We believe that there are two reasons for this observation. First, a part of the grassland was converted to arable land in spring 2007, which can lead to a mobilisation of nitrate even from mineral soils (Sheperd *et al.*, 2001). Second, after the wet summer, the ditches in the catchment were renewed, and some new drains were laid. This also affected the freshly ploughed arable land. Although we did not directly measure leaching from this "new" arable land, this combination seems a plausible explanation for the high NO_3-N concentration in the ditch despite decreasing concentrations in the groundwater of the grassland.

DON concentrations were relatively low both in the ditch and in the groundwater (Fig. 2c). Factors influencing the DON concentrations are difficult to determine; there is no effect of either the discharge (Fig. 3) or the temperature. There is also no correlation between DOC and DON in the ditch water, supporting the assumption that different processes govern the release of DOC and DON (Kalbitz and Geyer, 2002).

DOC and nitrogen losses

Annual DOC losses were 66 kg/ha in the wet year 2006/07 and 39 kg/ha in the dry year 2007/08 (Fig. 4). Compared to nitrogen, the DOC losses during the wet summer were relatively high as there was no temperature effects. DOC losses from peat catchment as measured by Dawson *et al.* (2002) or Gibson *et al.* (2009) are frequently higher (108-191 kg/ha) than our values, but as in many other studies, these authors focussed on drained and re-wetted upland areas with high discharge rates while data on lowland peatlands is scarce. When comparing our DOC and N losses to other studies, it has to be taken into account that only a part of the catchment is covered by organic soils.

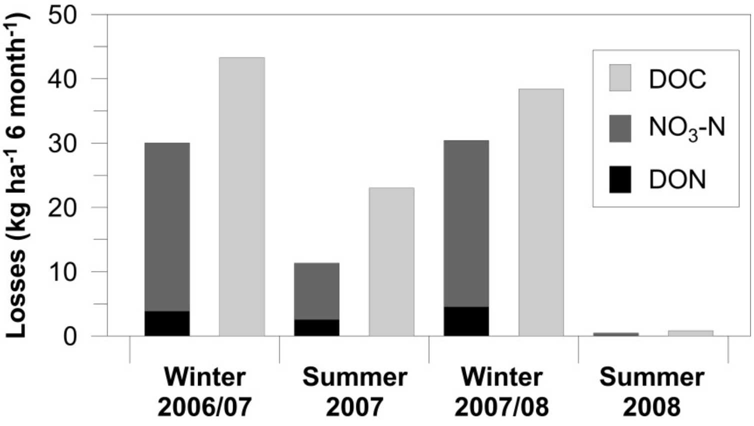

Figure 4: Seasonal dissolved organic carbon (DOC), nitrate-nitrogen (NO_3-N), and dissolved organic nitrogen (DON) losses from the study catchment.

Annual total N losses amounted to 42 and 31 kg/ha. Compared to other drained peatland catchments or lysimeter studies – e.g. Behrendt *et al*. (1996) measured losses of up to 135 kg NO_3-N/ha –, this is relatively low. NO_3-N is the main component of the N losses. The superposition of hydrological and management effects are probably the reason why the wet conditions from June 2007 to April 2008 were not reflected by decreasing NO_3-N losses from the catchment. In both years, DON losses accounted for around 15% of the TN losses and thus may form a relevant component of the N balance of drained peatland catchments.

CONCLUSIONS

We measured DOC and N concentrations in and losses from a grassland peatland under changing conditions. While the conditions during the first winter were typical for the region, the remainder of the study period saw a superposition of very wet conditions (in its effects, similar to re-wetting) and land use change. The results suggest that under re-wetting conditions, groundwater NO_3-N concentrations would decrease very quickly, while DOC concentrations would remain on a similar level. In this case, summer groundwater levels decide on NO_3-N concentrations in the subsequent winter. Further intensification of the land use, on the other hand, might increase the NO_3-N losses to receiving waters. DON accounted for around 15% of the total N losses, but factors influencing DON concentrations deserve further study.

ACKNOWLEDGEMENTS

We would like to thank Susanne Behn, Marianne Kietzmann, Monika Hopp and Sabine Wathsack for the laboratory analyses and Tilo Hartwig for his assistance with the field work.

REFERENCES

Behrendt, A., Mundel, G., Schalitz, G. and Hölzel, D. (1996) 25 Jahre Lysimeterforschung in Paulinenaue und Neukonzipierung der Untersuchungen (1992), ZALF-Berichte **26**, 6-27.

Dawson, J.J.C., Billet, M.F., Neal, C. and Hill, S. (2002). A comparison of particulate, dissolved and gaseous carbon in two contrasting upland streams in the UK. *Journal of Hydrology* **257**, 226-246.

Fiedler, S., Höll, B.S., Freibauer, A., Stahr, K., Drösler, M., Schloter, M. and Jungkunst, H.F. (2008). Particulate organic carbon (POC) in relation to other pore water carbon fractions in drained and rewetted fens in Southern Germany. *Biogeosciences* **5**, 1615-1623.

Gibson, H.S., Worrall, F., Burt, T.P and Adamson, J.K. (2009). DOC budgets of drained peat catchments: implications for DOC production in peat soils. *Hydrological Processes* **23**, 1901-1911.

Höper, H. (2002). Carbon and nitrogen mineralisation rates of fens in Germany used for agriculture. A review. In Broll, G., Merbach, W. and E.M. Pfeiffer (eds.), *Wetlands in Central Europe*, pp. 149-164. Springer, Berlin.

Kalbitz, K. and Geyer, S. (2002). Different effects of peat degradation on dissolved organic carbon and nitrogen. *Organic Geochemistry* **33**, 319-326.

Sheperd, M.A., Hatch, D.J., Jarvis, S.C. and Bhogal, A. (2001). Nitrate leaching from reseeded pasture. *Soil Use and Management* **17**, 97-105.

Tiemeyer, B., Frings, J., Kahle, P., Köhne, S. and Lennartz, B. (2007). A comprehensive study of nutrient losses, soil properties and groundwater concentrations in a degraded peatland used as an intensive meadow – implications for re-wetting. *Journal of Hydrology* **345**, 80-101.