Extended abstract No. 201/35

FIRST RESULTS OF THE SOIL WATER, NUTRIENT AND VEGETATION DYNAMICS OF A REWETTED MIRE IN THE GERMAN HARZ NATIONAL PARK

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SUMMARY

This study aimed to investigate changes of the nutrient and vegetation dynamics of a drained mire caused by rewetting to assess the long-term success for the mires regeneration. We measured relevant parameters for the water balance like precipitation, water table levels and discharge amounts as well as nitrogen (N), phosphorus (P) and carbon (C) concentrations of the mire pore water and peat soil and other relevant parameters for the nutrient dynamic like oxygen levels and redox potentials in the mire pore water and pH and electric conductivity in the mire pore water and peat soil before and after rewetting. Our results showed significant increasing water table levels at the rewetted mire zones and decreasing nitrate (NO_3-N) and ammonium (NH_4-N) concentrations in the mire pore water. Temporary increasing P concentrations in the mire pore water and decreasing P contents in the peat soil after rewetting suggests a rising P mobility. Changes of vegetation like spruce dieback and an increase of wetland species like *Carex canescens, Agrostis canina* and *Eriophorum angustifolium* were observed already one year after rewetting.

KEYWORDS: mire, rewetting, phosphorus mobilisation, peat soil, wetland species

INTRODUCTION

In the past many mires were damaged, degraded or destroyed by intensive land use resulting in changes of their water and nutrient balance. Currently the functions of intact mires as habitats for specialised and rare animal and plant species as well as nutrient and carbon sink have been gaining growing interest. During the last years a lot of research and practical activities have been done for the regeneration of mires (Succow and Joosten , 2001). An increase of water table levels by different rewetting measures may cause a regeneration of mires (Pfadenhauer, 1998; Nick *et al.*, 2001). The main aim of rewetting is the re-establishment of a stable water balance with permanently high water saturation with small water table level fluctuations as a requirement of peat accumulating plant species (Edom and Wendel, 1998).
Our study aimed to investigate changes of the water and nutrient balance in a drained mire in the German Harz National Park to evaluate the success of rewetting for a long-term regeneration of the mire. The main objectives were to:

i) measure and compare relevant parameters for the water and nutrient balance (such as water table level, discharge amount, oxygen level, redox potential, electric conductivity, N-, P-and C-concentrations) of the mire (soil water and peat soil) before and after rewetting and
ii) document changes in vegetation structure and composition within the investigation area.

MATERIALS AND METHODS

Area of investigation

Investigations were made in the drained mire Blumentopfmoor situated in the development zone of the Harz National Park (51°48`N, 10°37`E; 650-680 m a.s.l.), central Germany (Federal state Saxony-Anhalt). The catchment area amounts to about 1.17 km² and drains into the river Holtemme. Schiemenz (1973) described that most of the peat in the local area was excavated between 1750 and 1776. Afterwards the area was used by forestry and was therefore intensive drained until the foundation of the Harz National Park in 1990. Our measurements presented peat layer thickness up to 2.5 m, but in the central investigation area the thickness mostly averages between 0.9 and 1.4 m. The mire has an area of 19 ha and can be characterised as nutrient poor and acid. In the drained area the peat soil shows a more or less strong mineralisation of the upper layer as a result of the former drainage. The area is today dominated by spruce forest on moist till wet sites. In addition to that there are some small remnants of sub-natural mire vegetation and *Molina caerulea* dominated sites. More detailed information about the study site was described by Tauchnitz *et al.* (2010).

Rewetting

Rewetting started in 2005 with the successive placement of several wooden barriers in selected ditches of the drainage network. In august 2009 we diverted a part of a stream into the central investigation area and slightly modified the course in June 2010 (Tauchnitz *et al.*, 2010; Osterloh *et al.*, 2011).

Variants of investigation

We studied five variants within the study area being differentiated by their vegetation, water table level, peat form and thickness and date of rewetting.
Variant 1 characterises a naturally regenerated open site dominated by plant species like *Eriophorum vaginatum*, *Vaccinium oxycoccus* and *Sphagnum magellanicum* and a peat depth between 1.2 and 1.5 m. **Variant 2** characterises a 2005 rewetted site in an open spruce forest, dominated by plant species like *Sphagnum ssp.*, *Calamagrosis villosa*, *Juncus effuses* and *Carex nigra* and a peat depths about 0.9 m. **Variant 3** characterises a forest glade which was rewetted in 2009. Before rewetting measures started the site was dominated by forest species like *Avenella flexuosa*, *Calamagrostis villosa* and *Galium saxatile*. *Juncus effusus* and *Polytrichum commune* were interspersed. After the rewetting *Avenella flexuosa* nearly disappeared and *Carex canescens* and *Agrostis canina* occurred and tend to dispread. The peat depth at this site balances between 0.9 and 1.1 m. **Variant 4** characterises a site in an open spruce forest. The site was rewetted in 2010. Dominant plants are *Vaccinium myrtillus*,

Avenella flexuosa and *Polytrichum formosum*. *Molinia caerulea* ist regularly interspersed. *Carex canescens* occurred with rewetting. **Variant 5** is nearby and similar to variant 4. Dominant plants are *Avenella flexuosa*, *Vaccinium myrtillus*, *Galium saxatile* and *Molina caerulea*. It differs from the other variants through permanent low water level round about 0.3 m under ground.

Investigated parameters of the water and nutrient balance

Table 1 indicates the measured parameters together with the measuring techniques of the water and nutrient balance studies.

Table 1. Investigated parameters of the water and nutrient balance

object	parameter		interval
	qualitative	quantitative	
precipitation	pH^{1*},σ^{2*},N_t^{5*}, NH_4-N^{3*}, NO_3-N^{3*4*}, PO_4-P^{3*4*}	precipitation amount^{A}*	monthly
soil water, discharge, ditches	Eh^{1*},O_2^{1*},pH^{1*},σ^{2*}, N_t^{5*}, DOC^{5*}, NH_4-N^{3*}, NO_3-N^{3*4*}, PO_4-P^{3*4*}	water level^{B}*, discharge amount^{C}*	monthly
peat soil	Oven-dry density^{6*},pH^{1*},σ^{2*}, N_t^{5*}, NH_4-N^{3*},NO_3-N^{3*4*},PO_4-P^{3*4*},C_t^{5*}	dry mass	annual

^{1}*potentiometric, ^{2}*conductometric ^{3}*photometric, ^{4}*ion-chromatographic, ^{5}*oxidative (TOC-analyzer), ^{6}*gravimetric 105°C,
^{A}*automat (UGT GmbH) & manual (bulk, totalisator), ^{B}*piezometer (manually with water pipe, automatically with gauge sensor), ^{C}*gauge sensor (UGT GmbH), gauging weir (free overflow)

RESULTS

Water balance and dynamics

The precipitation amount in the investigation area (discharge year 1.11.-31.10.) was 1292 mm (2005), 1267 mm (2006), 2269 mm (2007), 1634 mm (2008), 1253 mm (2009), 1384 mm (2010) and 1074 mm (2011). Figure 1 shows the changes of water table levels at different mire zones. Shortly after rewetting in 2005, 2009 and 2010 we observed significantly and visibly increasing water table levels at the affected mire zones, especially at variant 3 (Fig. 2 and Fig. 3). At the regenerated mire zone (variant 1) permanently high water saturation during the whole study period was noticed even in times with low precipitation amounts (2011).

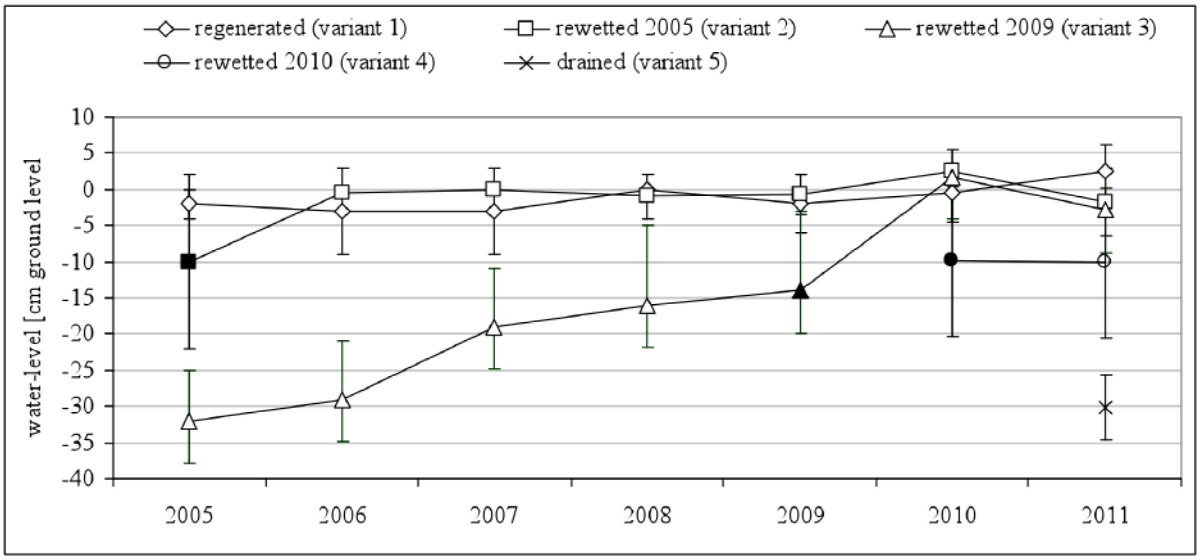

Fig. 1: Development of the water table level (cm below mire surface) at different investigated sites in the hydrological years 2005-2011. The black fillings describe the start of rewetting at the respective site.

Fig. 2: Variant 3 in June 2009.

Fig. 3: Variant 3 in October 2010, the result of the rewetting is clearly visible (spruce dieback, high water table levels, changes in the mixture of the herbal layer).

The following evaluation of nutrient balance and nutrient dynamics in soil water and peat soil focus on variants 1-3.

Nutrient balance and dynamics in peat soil

The comparison of the variants 1-3 (Table 2) showed significant differences within the soil parameters bulk density, content of NH_4-N and NO_3-N and the C/N-ratio. The lowest bulk density with 49 g l^{-1} was observed at the regenerated mire zone (variant 1) whereas the 2005 and 2009 rewetted mire zones (variants 2 and 3) showed higher bulk densities with 169 g l^{-1} and 207 g l^{-1} respectively. High bulk densities indicated mineralisation, decay and shrinkage processes as a consequence of drainage. In addition variant 1 showed the significant lowest content of NO_3-N and PO_4-P. Table 3 shows peat soil parameters of variant 2. Significant decreases of NH_4-N, NO_3-N and PO_4-P concentration since the beginning of rewetting (2005) until now (2011) were observed.

Table 2. Parameters of the peat soil from different sites (variant 1-3), different letters describe significant differences between the sites ($p < 0.05$; 0.2 m depth)

parameter	**regenerated Variant 1**	**rewetted 2005 Variant 2**	**rewetted 2009 Variant 3**
n	4	4	4
ρt (g l^{-1})	49 ± 3 (a)	169 ± 14 (b)	207 ± 37 (b)
NH4-N (g m^{-2})	2,2 ± 2,0 (a)	4,8 ± 0,9 (a)	3,8 ± 2,8 (a)
NO3-N (g m^{-2})	0,02 ± 0,02 (a)	0,2 ± 0,2 (b)	0,4 ± 0,1 (b)
PO4-P (g m^{-2})	0,4 ± 0,1 (a)	1,1 ± 0,2 (b)	1,5 ± 0,3 (b)
Nt (%)	1,2 ± 0,6 (a)	1,5 ± 0,3 (a)	2,0 ± 0,2 (a)
Ct (%)	45,9 ± 3,6 (a)	46,3 ± 1,9 (a)	47,3 ± 2,0 (a)
C:N	54 ± 8 (a)	32 ± 6 (b)	24 ± 2 (b)
pH	3,7 ± 0,1 (a)	3,6 ± 0,1 (a)	3,5 ± 0,1 (a)
EC (µS cm^{-1})	67 ± 6 (a)	83 ± 16 (a)	76 ± 5 (a)

Table 3. Parameters of the peat soil from the 2005 rewetted site (variant 2), which showed differences in the chronological sequence 2005-2011; different letters describe significant differences between the years ($p < 0.05$; 0.4 m depth)

parameter	**2005**	**2006**	**2007**	**2009**	**2011**	**trend**
n	4	4	4	4	4	
NH_4-N (g m^{-2})	6.7 ± 2.6 (ab)	5.9 ± 3.0 (ab)	3.8 ± 0.9 (a)	2.3 ± 0.2 (b)	2.7 ± 1.0 (ab)	↓
NO_3-N (g m^{-2})	0.5 ± 0.4 (ab)	0.4 ± 0.2 (a)	0.2 ± 0.2 (ab)	0.08 ± 0.05 (ab)	0.01 ± 0.008 (b)	↓
PO_4-P (g m^{-2})	4.3 ± 0.5 (a)	2.0 ± 0.4 (b)	1.1 ± 0.2 (b)	1.8 ± 0.2 (b)	0.8 ± 0.4 (b)	↓

Nutrient balance and dynamics in soil water

Changes of relevant parameters at the 2009 rewetted mire zone (variant 3) are shown in Fig. 4. Associated with rising water table levels we observed decreasing contents of NH_4-N and NO_3-N with a lower temporal variation as well as increasing contents of PO_4-P in the first year after the rewetting. Furthermore the observed decrease of PO4 contents in the peat soil after rewetting indicates an increase of the P mobility caused by rising water table levels.

CONCLUSION

We can conclude that the rewetting measures were directly followed by a significant and stable rise of the water table close to the ground surface. In the central investigation area we observed a rapid spruce dieback and an expansion of wetland species, especially *Carex canescens*, *Agrostis canina* and *Eriophorum angustifolium.* Sustained high and low variable water table level resulted in lower variability within the studied parameters in the soil water. We noticed a downward trend in the concentration of NH_4-N and NO_3-N in the soil water and in the peat soil. Lower PO_4-P concentration in the peat soil and higher PO_4-P concentration in

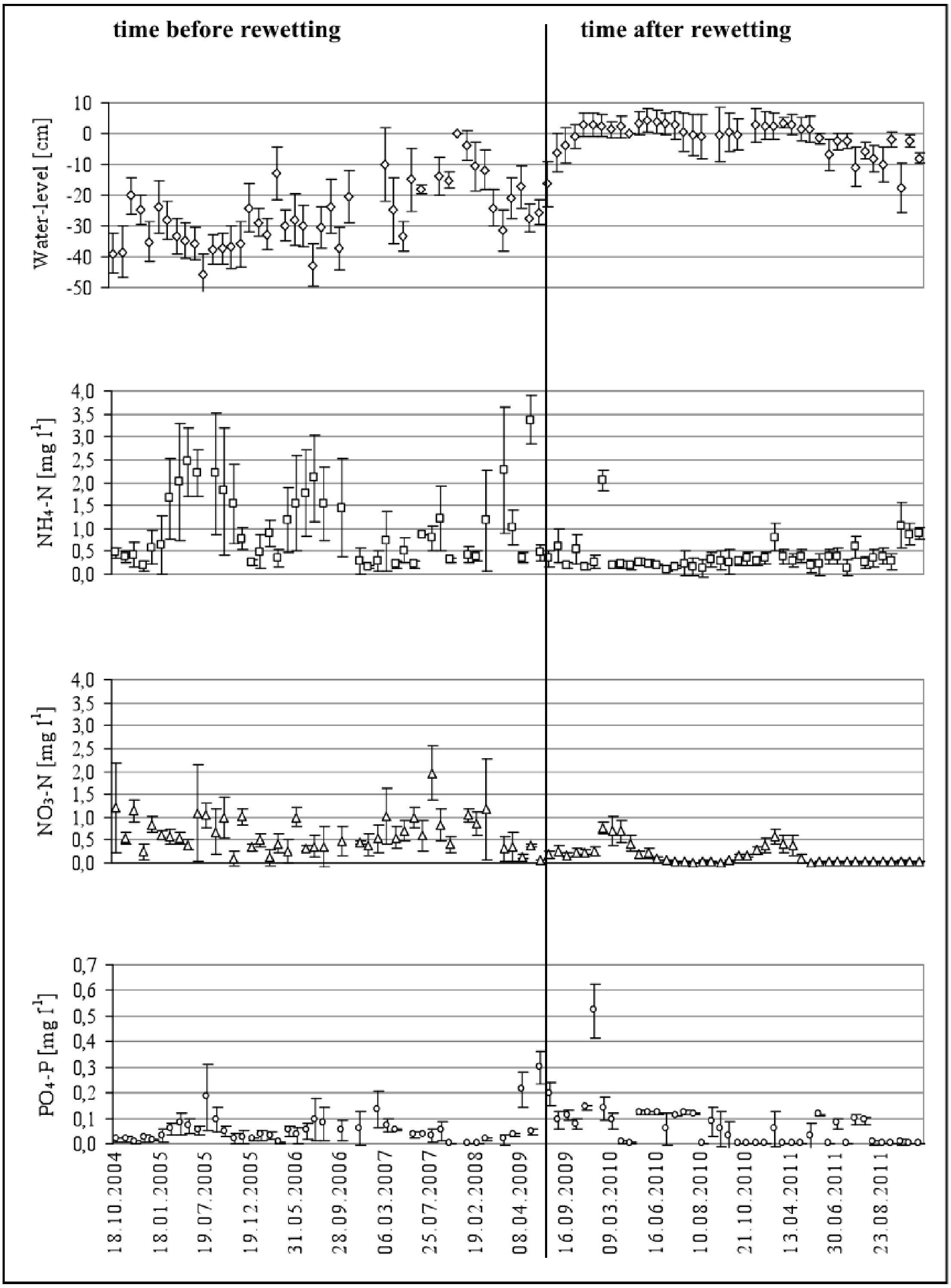

Fig. 4: Development of the water-table level and the content of NH_4-N, NO_3-N and PO_4-P in the soil water (variant 3, rewetted in august 2009).

the soil water within the first year after rewetting led to a temporary discharge of P out of the mire as a result of the rewetting.

It is necessary to continue the monitoring programme as long as possible to get reliable information about the long-term effect of the rewetting measures regarding soil water quality, peat soil development and changes in vegetation structure. Furthermore we will analyse the nutrient load by inflow, deposition and outflow to get evidence about the retention capacity of the mire.

ACKNOWLEDGEMENTS

We would like to thank the Federal state of Saxony-Anhalt (Germany) for the funding within the European agricultural fund for rural development (ELER). Additional we like to thank the staff of the Harz National Park for their assistance of our research and for the realisation of the rewetting measures.

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