

Nigula bog, Estonia © NB Dise

POLICY BRIEF

Nitrogen pollution and climate change reduce carbon storage and biodiversity of peatlands

Peatland ecosystems store exceptionally high amounts of carbon as peat. Globally, peatlands contain twice as much carbon as all forests combined, while only covering 3% of the Earth's land space. The average loss of only a centimeter of peat from the world's peatlands would release an amount of carbon dioxide (CO₂) equal to about one third of the global annual fossil fuel combustion. Peatlands have been drained and mined for centuries to exploit their carbon-rich soil for agriculture, forestry, fuel and horticulture. This turns peatlands from a carbon "sink" to a carbon "source", and drained peatlands now account for almost 6% of the world's man-made CO₂ emissions every year. The EU is the world's second largest CO₂ emitter from drained peatlands after Indonesia.

Much of the focus on peatland protection in Europe has been on mitigating direct physical impacts. This policy brief focuses on the far less recognized indirect and 'unseen' threats to peatlands: air pollution and changes in precipitation, temperature and nutrients. It is based on the results of the BiodivERsA PEATBOG project investigating the impacts of nitrogen pollution and climate change on the biodiversity and ecosystem functioning of peatlands across Europe.

Main findings

- Elevated **reactive nitrogen deposition can change the functioning and biodiversity of peatlands**, and **increase their sensitivity to climate change**;
- Enhanced reactive nitrogen increases the growth of vascular plants at the expense of peat-forming mosses;
- Warming and drought of nitrogen-enriched peatlands **threaten their long-term carbon storage capacity** and **release stored CO₂ into the atmosphere, contributing to climate change**.

Key policy recommendations

- It is advised that **a network of early warning systems be set up in peatlands across Europe** to monitor changes in nitrogen saturation, biodiversity, and carbon sequestration;
- **'Nitrogen pollution protected areas'**, analogous to **marine protected areas**, should be established in the most vulnerable peatland areas in Europe;
- It would be beneficial to **include the protection of peatlands in the aims of the EU Water Directive**;
- **Peatland restoration could be incorporated into carbon accounting rules** under the EU Climate Package and national accounting;
- Member States should be encouraged to **designate all potential carbon storage 'hot-spots', including peatlands, as sensitive areas under the reformed Common Agricultural Policy (CAP)**;
- Cross-compliance standards set by the CAP, particularly **the EU Nitrate Directive and its enforcement by Member States**, could help limit nitrogen release via leaching or volatilisation from agriculture in sensitive peatland areas.

The context

Europe has large areas of semi-natural peatland (mainly **bogs**, **fens** and **heathland**), concentrated in northern latitudes and alpine/montane regions. Peatlands provide vital ecosystem services: they store carbon, filter and regulate the flow of water into streams and reservoirs, buffer against downstream flooding, retain pollutants, and form part of our cultural heritage. In addition, peatlands provide a home for important wildlife and support unusual and rare species that are uniquely adapted to low nutrient levels and often highly acidic soils, such as peat-forming *Sphagnum* mosses, carnivorous plants like *sundew*, or vascular plants such as sedges. The **EU Habitats Directive's Annex 1** lists more than a dozen such habitats, many of which are prioritised for nature conservation.

In a functioning bog system, the slow decomposition of plant material accumulates as peat and locks up CO_2 absorbed from the atmosphere. Peatlands are thus essential for climate change mitigation because they store exceptionally high amounts of carbon as peat. However, like other oxygen-restricted habitats, peatlands can emit methane (CH_4), a potent greenhouse gas (GHG). In an established, functioning peatland, the global cooling effect of long-term carbon accumulation outweighs the global warming effect of methane emission, and peatlands are strong net carbon sinks.

However, if a peatland is degraded through drainage or mining it can turn from a GHG sink to a GHG source. Drained peatlands now account for almost 6% of the world's man-made CO_2 emissions every year.

As peat formation and therefore carbon storage is enhanced by cold, wet and nutrient-poor conditions, warmer temperatures and extreme climate events, particularly intense summer droughts, can have the same effect as drainage, releasing carbon that has been accumulating for hundreds or thousands of years.

Peatlands are also very sensitive to air pollution, particularly high loads of reactive nitrogen in precipitation. Nitrogen compounds originate from the excessive use of natural and chemical fertilizers in agriculture, and through energy generation from fossil fuels. Reactive nitrogen is now the most prevalent pollutant in the atmosphere across most of Europe. This causes soil acidification and nutrient enrichment, enhancing the growth of vascular plants at the expense of peat-forming mosses. Highly concentrated reactive nitrogen in gases, aerosols and particles can also directly damage sensitive mosses and is the main component of acute regional-scale pollution episodes such as those recorded across much of Europe in March 2014.

Key results

Impacts of nitrogen deposition on peatlands' carbon sequestration and methane emission

PEATBOG research and other studies suggest that low to moderate levels of nitrogen deposition may enhance short-term carbon accumulation by increasing the growth of vegetation. However, the PEATBOG project shows that in the long term, excess nitrogen can reduce the abundance of sensitive peat-forming *Sphagnum* mosses, increase the abundance of vascular plants, and increase the nitrogen content of vegetation. This reduces the rate of peat production and increases the production of easily-decomposable plant material, leading to higher rates of decomposition and CO_2 release. Nitrogen ultimately accumulates in the peat soil and may be released to groundwater and downstream surface waters, which has further impacts on aquatic ecosystems and may fuel the growth of harmful algae.

Nitrogen-enriched peatlands may be poised to change rapidly from carbon sinks to sources if a long-term warming trend persists, particularly if the frequency of periodic drought increases. Such climate conditions are favourable for the invasion of non-peat forming grasses and shrubs. Crucially, however, these vascular plants can only thrive if there is sufficient nitrogen in the ecosystem to support them. PEATBOG has shown that a long-term temperature increase imposed

on a peatland receiving long-term elevated nitrogen deposition triggers a far more vigorous growth of vascular plants than the same treatment in a less-polluted peatland. Such conditions are expected to be more frequent in the future. Under these circumstances, peatlands are poised to change rapidly as the environment becomes more favourable for the invasion of grasses and shrubs. This change may be irreversible.

Nitrogen pollution may also come from irrigation water run-off from agricultural fields with nitrogen fertilizers. Bogs and heathlands in semi-natural regions generally do not release large amounts of the GHG nitrous oxide (N_2O) since they usually do not receive high levels of nitrogen-rich runoff directly. However, PEATBOG has shown that the ability of a peatland to adsorb nitrogen deposition onto surface *Sphagnum* moss (the 'nitrogen filter') declines with long-term exposure to elevated deposition (Figure 1). Concentrations of reactive nitrogen then build up in the peat porewater and can leach into subsurface water and groundwater, potentially causing eutrophication of downstream ecosystems.

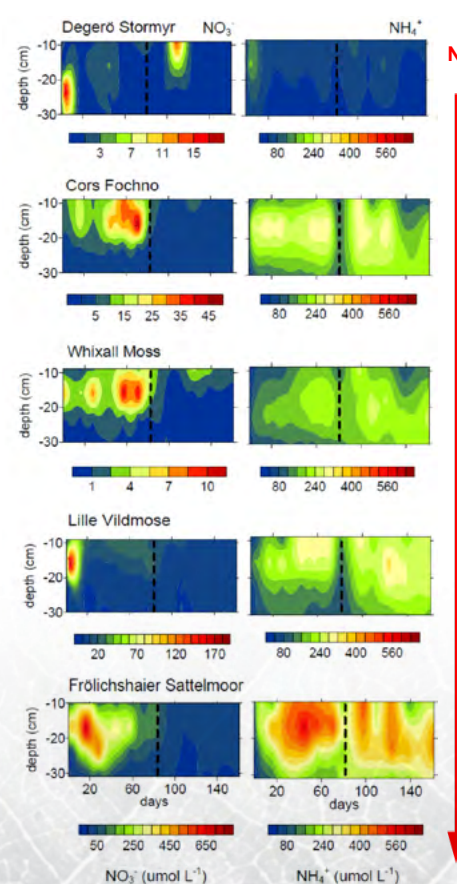
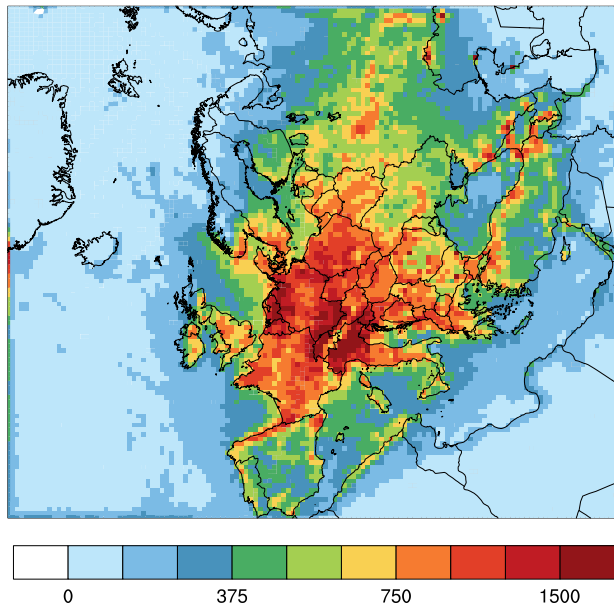


Figure 1. Nitrate (NO_3^-) and ammonium (NH_4^+) concentration in peat porewater from mesocosms taken from five peatlands and treated with $30 \text{ kg N ha}^{-1} \text{ y}^{-1}$ over 150 days. Plots are ordered from top to bottom by increasing long-term nitrogen deposition, from the 'clean' Degerö Stormyr bog in Sweden to the 'polluted' Frölichshäier Sattelmoor in Germany. The dotted line on day 75 marks raising the water table to nearer the surface (more anaerobic conditions). Vertical axis shows depth of the profile from -10 cm to -30 cm. Concentrations are colour coded in the order red> orange> yellow> green> blue. Note the increasing breakthrough of both NO_3^- and NH_4^+ in the profiles as long-term N deposition increases.

Nitrogen, peatlands and biodiversity



A central part of the PEATBOG project was an unprecedented survey of the species composition of 59 peatlands across the peat-forming region of Europe and covering the range of nitrogen deposition and climate for these ecosystems (Figure 2). PEATBOG showed a continental-scale decline in the number of peatland plant species with both increasing mean annual temperature and increasing nitrogen deposition (Figure 3). Importantly, these can be demonstrated as distinct relationships, so nitrogen deposition exacerbates climate change effects. Vegetation from low-pollution sites was the most vulnerable to nitrogen deposition, with sensitive *Sphagnum* species shifting to species more tolerant of nutrients and pollution.

Figure 2. Nitrogen deposition across Europe (from European Evaluation and Monitoring Programme). Nitrogen deposition is colour coded in the order red> orange> green> blue > light blue.

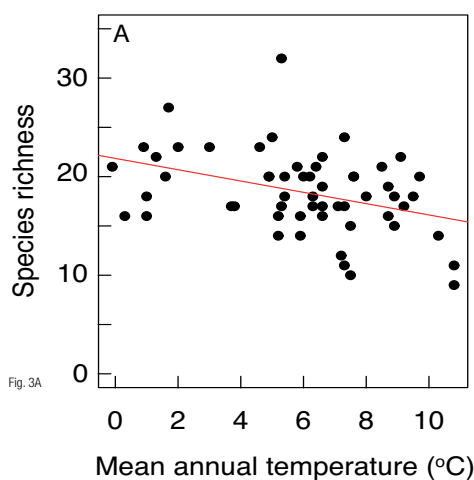


Fig. 3A

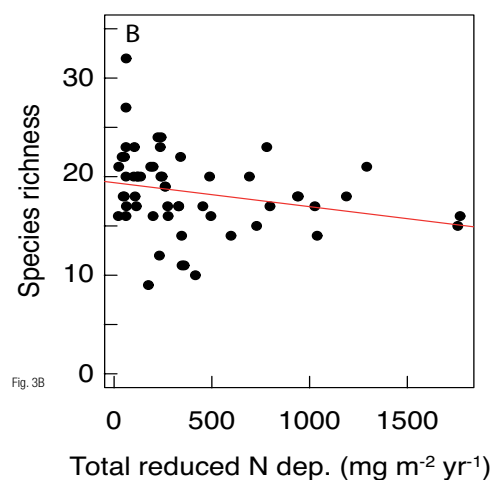
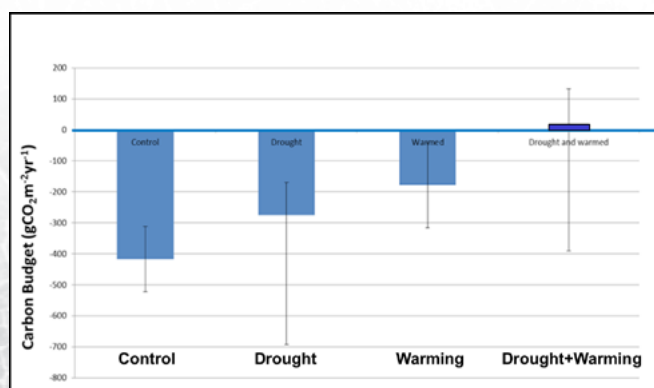


Fig. 3B

Figure 3. Decline in average plant species richness in study plots at PEATBOG survey sites with (A) increasing mean annual temperature, and (B) increasing nitrogen deposition. After Robroek et al.: *Peatland functional diversity decreases with environmental change as a result of changing community trait composition*. (Manuscripts in preparation).

Increasing vulnerability of peatlands to droughts and pests

The rapid shift of nitrogen-polluted peatlands from carbon sinks to carbon sources will be exacerbated by the long-term warming trend and more frequent summer droughts in a



changing climate (Figure 4). A higher nitrogen concentration of vegetation increases its susceptibility to pathogens and pests, and can induce too-rapid growth, early senescence and lowered resilience to stress such as drought or fire. Ultimately, most of the elevated nitrogen in vegetation is returned to the soil through decomposition. This nitrogen-enriched soil is more likely to release nitrogen to groundwater and downstream surface waters, cascading impacts on aquatic ecosystems.

Figure 4. Net carbon balance of a peatland receiving intermediate background atmospheric nitrogen deposition (field experimental site at Cors Fochno, Wales), with experimental drought, warming and combined treatments in relation to controls. Negative values indicate net carbon storage; positive indicate net carbon emission. Bars show minimum and maximum range of data.

Policy recommendations

PEATBOG research has shown that elevated reactive nitrogen deposition can change the functioning and biodiversity of peatlands, and increase their sensitivity to climate change. Furthermore, warming and drought of nitrogen-enriched peatlands threaten their long-term carbon storage capacity and release stored CO₂ into the atmosphere, contributing to climate change.

Although no specific studies on the effectiveness and cohesion of current policies were conducted by PEATBOG during the production of this brief, the knowledge presented highlights **measures which can help better mitigate climate change and conserve peatlands and their biodiversity in Europe.**

These measures need to recognize that nitrogen pollution both reduces peatland diversity, and increases the sensitivity of peatland species to climate change.

The **Ramsar Convention** highlighted the importance of wetlands for climate in its **Guidelines for Global Action on Peatlands** in 2008. Similarly, the **EU 2020 Biodiversity Strategy** includes the protection and restoration of Europe's peatlands to safeguard their capacity to mitigate climate change. Biodiversity conservation measures shall be included into other relevant EU policies as outlined by the **EU 7th Environment Action Programme**.

The **EU Habitats Directive** specifies more than a dozen peatland habitat types (Annex 1). **It is important that Member States meet the obligations to establish Favourable Conservation Status for such peatlands.**

In the EU's new **Common Agricultural Policy (CAP)**, the protection of wetlands and carbon-rich soils was strengthened and is part of the permanent grassland eligibility condition for the green payment in Pillar 1. Member States are advised to designate all potential carbon 'hot-spots', including peatlands, as sensitive areas.

Incorporating peatland drainage and restoration into the carbon accounting rules under both the **EU Climate and Energy Package** and national carbon accounting, in accordance with the **UN Climate Convention's new land use and land use change accounting rules**, would provide an incentive to protect and restore these areas.

It would also be beneficial if the **protection of all peatlands be included in the aims of the EU Water Framework Directive (Article 1) and the EU Floods Directive (Article 7).**

However it is **important to protect European peatlands, not only from the threats of drainage and extraction, but also from nitrogen pollution.** Nitrogen pollution should be recognized as a threat to Europe's peatlands and a **network of early warning systems** in peatland bog systems should be set up across Europe to monitor changes in indicators of nitrogen saturation.

European emissions controls for nitrogen are based on the concept of critical loads, a 'minimum-effects' based approach. **Work supported by PEATBOG**, however, has shown that **species in low-pollution areas may be sensitive to even small levels of pollution**, and so a new approach of protecting vulnerable areas from all new pollution may be required.

'Nitrogen pollution protected areas', similar to **marine protected areas**, should be established in the most vulnerable peatland areas in Europe most likely to contribute to a strong increase of greenhouse gas emissions.

Finally, cross-compliance standards set by the CAP, and especially the **EU Nitrates Directive**, **can help limit nitrogen pollution from agriculture in sensitive peatland areas.**

All the measures mentioned above would contribute to achieving the objectives of the EU Biodiversity Strategy to halt biodiversity loss and ecosystem degradation by 2020, and to the EU's efforts to combat climate change.

Links to sources

PEATBOG information on www.sste.mmu.ac.uk/peatbog/
Scientific publications on www.sste.mmu.ac.uk/peatbog/publications/scientific/default.asp

Contact:

communication@biodiversa.org
www.biodiversa.org

About this Policy Brief

This Policy Brief is part of a series aiming to inform policy-makers on the key results of the biodiversity research projects funded by BiodivERsA and provide recommendations to policy-makers based on research results.

The series of BiodivERsA Policy Briefs can be found at www.biodiversa.org/policybriefs.

This publication was commissioned and supervised by BiodivERsA, and produced by IUCN.

The key research results presented here were validated by Nancy Dise, Centre for Ecology & Hydrology, Natural Environment Research Council, UK. Input was provided by IUCN UK.

The policy recommendations made do not necessarily reflect the views of all BiodivERsA partners, nor of IUCN.