Recent destabilization of soil carbon cycle linked to the recovery from acidification

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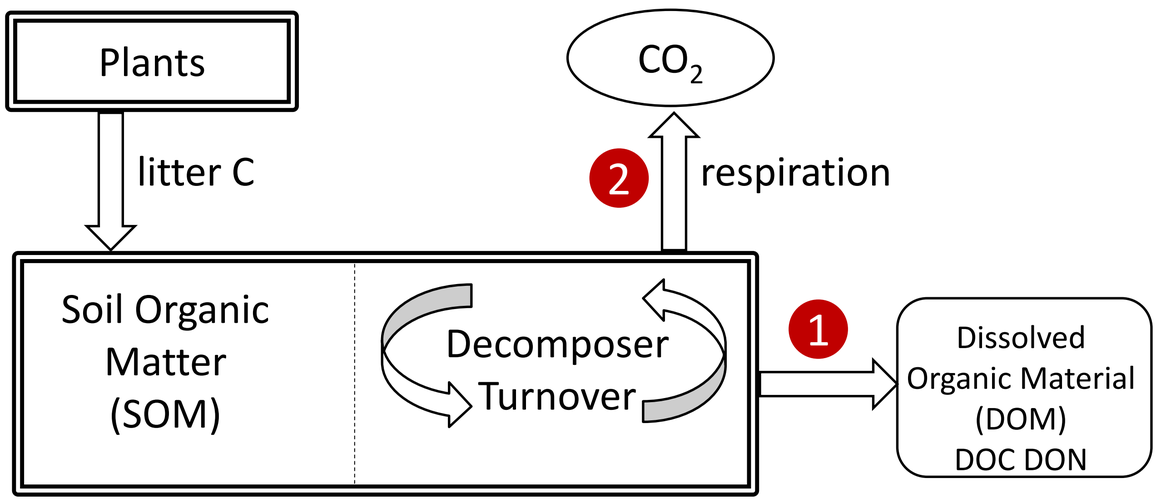
Soil Carbon Cycle

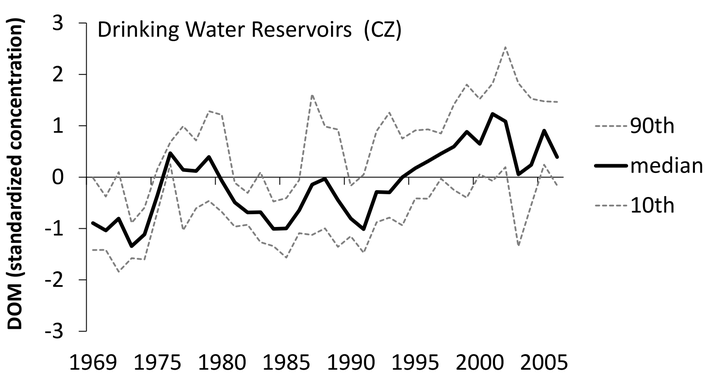


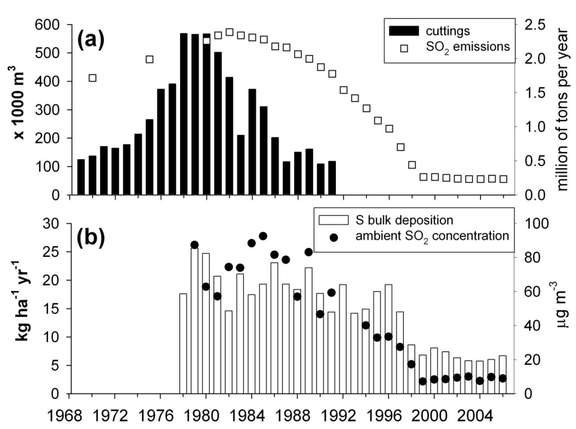
Conclusions

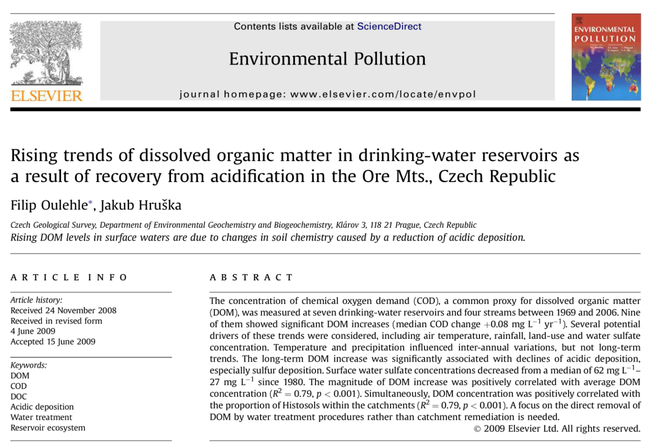
Sulphur (S) and nitrogen (N) deposition are important drivers of the terrestrial carbon (C) cycling. It is now clear that atmospheric deposition pollutant has impacted on the wider biogeochemical cycle of forest ecosystems, including the ecosystem C balance. Taking into account that much of Europe and North America has experienced acid deposition, it is possible that recent measurements of C fluxes from these regions might not be representative of systems in long-term balance with climatic conditions, but of systems subject to additional anthropogenic pressures, and in many cases undergoing transient change as deposition levels decline.

① Soil acidity constraints on DOM leaching from soils

Long-term observations






Environmental Pollution 157 (2009) 3433–3439

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Rising trends of dissolved organic matter in drinking-water reservoirs as a result of recovery from acidification in the Ore Mts., Czech Republic

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Rising DOM levels in surface waters are due to changes in soil chemistry caused by a reduction of acidic deposition.

ARTICLE INFO

Article history:
Received 24 November 2008
Received in revised form
4 June 2009
Accepted 15 June 2009

Keywords:
DOM
COD
DOC
Acidic deposition
Water treatment
Reservoir ecosystem

ABSTRACT

The concentration of chemical oxygen demand (COD), a common proxy for dissolved organic matter (DOM), was measured at seven drinking-water reservoirs and four streams between 1969 and 2006. Nine of them showed significant DOM increases (median COD change +0.08 mg L^{-1} yr^{-1}). Several potential drivers of these trends were considered, including air temperature, rainfall, land-use and water sulfate concentration. Temperature and precipitation influenced inter-annual variations, but not long-term trends. The long-term DOM increase was significantly associated with declines of acidic deposition, especially sulfur deposition. Surface water sulfate concentrations decreased from a median of 62 mg L^{-1}–27 mg L^{-1} since 1980. The magnitude of DOM increase was positively correlated with average DOM concentration ($R^2 = 0.79$, $p < 0.001$). Simultaneously, DOM concentration was positively correlated with the proportion of Histosols within the catchments ($R^2 = 0.79$, $p < 0.001$). A focus on the direct removal of DOM by water treatment procedures rather than catchment remediation is needed.

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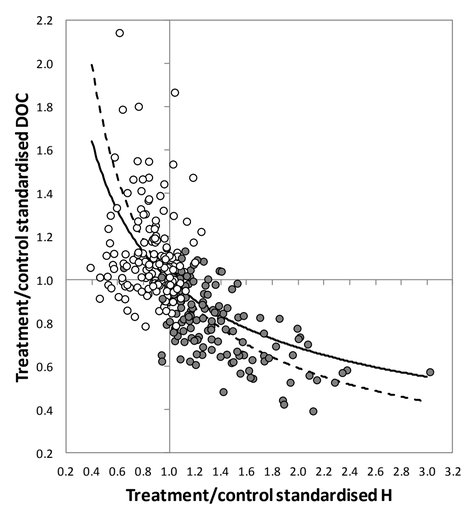
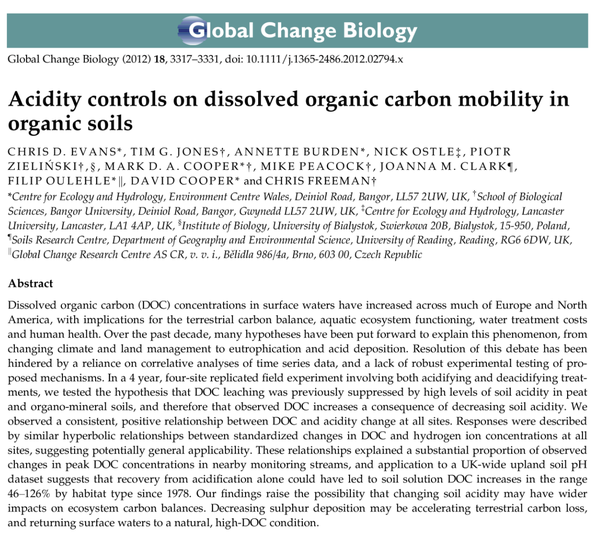
Field experimental evidence




Global Change Biology

Global Change Biology (2012) 18, 3317–3331, doi: 10.1111/j.1365-2486.2012.02794.x

Acidity controls on dissolved organic carbon mobility in organic soils

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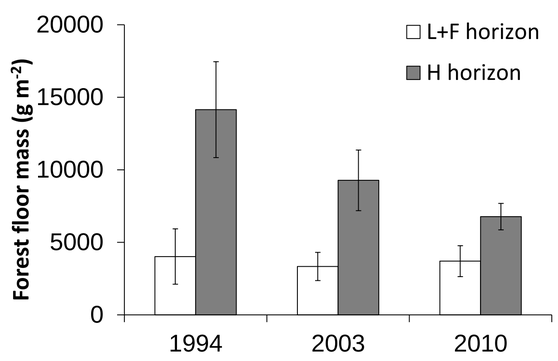
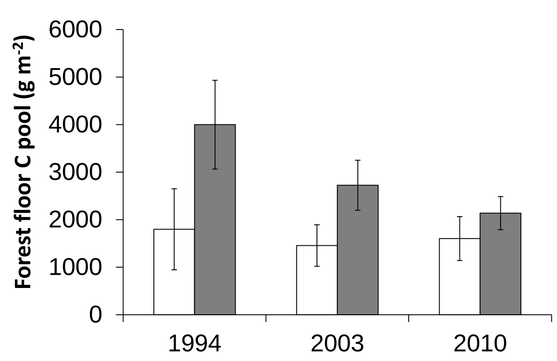
Abstract

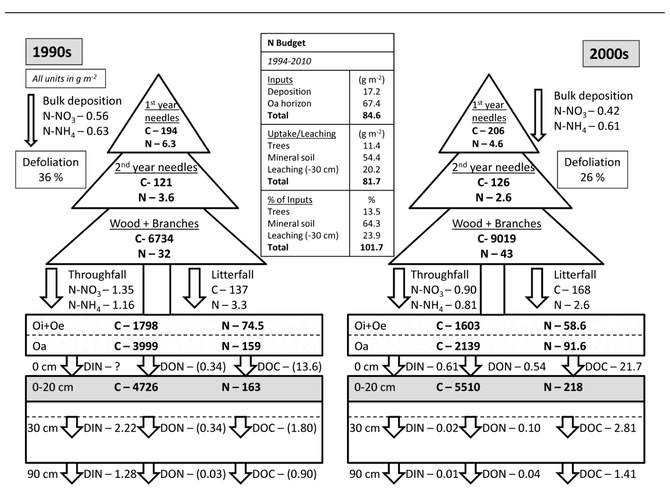
Dissolved organic carbon (DOC) concentrations in surface waters have increased across much of Europe and North America, with implications for the terrestrial carbon balance, aquatic ecosystem functioning, water treatment costs and human health. Over the past decade, many hypotheses have been put forward to explain this phenomenon, from changing climate and land management to eutrophication and acid deposition. Resolution of this debate has been hindered by a reliance on correlative analyses of time series data, and a lack of robust experimental testing of proposed mechanisms. In a 4 year, four-site replicated field experiment involving both acidifying and deacidifying treatments, we tested the hypothesis that DOC leaching was previously suppressed by high levels of soil acidity in peat and organo-mineral soils, and therefore that observed DOC increases a consequence of decreasing soil acidity. We observed a consistent, positive relationship between DOC and acidity change at all sites. Responses were described by similar hyperbolic relationships between standardized changes in DOC and hydrogen ion concentrations at all sites, suggesting potentially general applicability. These relationships explained a substantial proportion of observed changes in peak DOC concentrations in nearby monitoring streams, and application to a UK-wide upland soil pH dataset suggests that recovery from acidification alone could have led to soil solution DOC increases in the range 46–126% by habitat type since 1978. Our findings raise the possibility that changing soil acidity may have wider impacts on ecosystem carbon balances. Decreasing sulphur deposition may be accelerating terrestrial carbon loss, and returning surface waters to a natural, high-DOC condition.

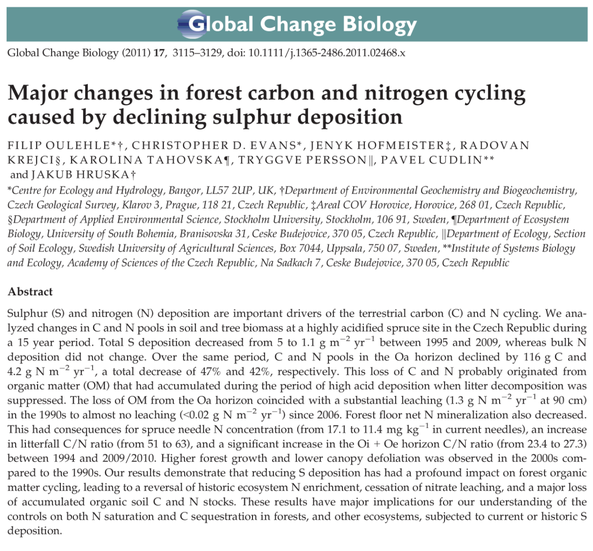
② Soil acidity constraints on soil decomposition

Long-term observations








Global Change Biology

Global Change Biology (2011) 17, 3115–3129, doi: 10.1111/j.1365-2486.2011.02468.x

Major changes in forest carbon and nitrogen cycling caused by declining sulphur deposition

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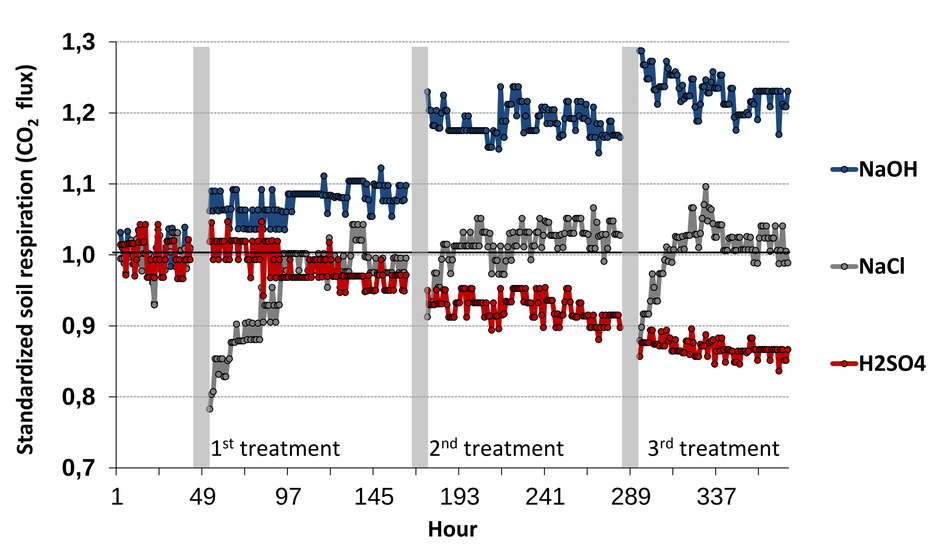
Abstract

Sulphur (S) and nitrogen (N) deposition are important drivers of the terrestrial carbon (C) and N cycling. We analyzed changes in C and N pools in soil and tree biomass at a highly acidified spruce site in the Czech Republic during a 15 year period. Total S deposition decreased from 5 to 1.1 g m^{-2} yr^{-1} between 1995 and 2009, whereas bulk N deposition did not change. Over the same period, C and N pools in the Oa horizon declined by 116 g C and 4.2 g N m^{-2} yr^{-1}, a total decrease of 47% and 42%, respectively. This loss of C and N probably originated from organic matter (OM) that had accumulated during the period of high acid deposition when litter decomposition was suppressed. The loss of OM from the Oa horizon coincided with a substantial leaching (1.3 g N m^{-2} yr^{-1} at 90 cm) in the 1990s to almost no leaching (<0.02 g N m^{-2} yr^{-1}) since 2006. Forest floor net N mineralization also decreased. This had consequences for spruce needle N concentration (from 17.1 to 11.4 mg kg^{-1} in current needles), an increase in litterfall C/N ratio (from 51 to 63), and a significant increase in the Oi + Oe horizon C/N ratio (from 23.4 to 27.3) between 1994 and 2009/2010. Higher forest growth and lower canopy defoliation was observed in the 2000s compared to the 1990s. Our results demonstrate that reducing S deposition has had a profound impact on forest organic matter cycling, leading to a reversal of historic ecosystem N enrichment, cessation of nitrate leaching, and a major loss of accumulated organic soil C and N stocks. These results have major implications for our understanding of the controls on both N saturation and C sequestration in forests, and other ecosystems, subjected to current or historic S deposition.

Lab experimental evidence



To assess influence of soil acidity on SOM decomposition, H horizon from spruce forest has been treated with alkaline (NaOH), neutral (NaCl) and acid (H_2SO_4) solutions (800 µeq/L in 3 doses) over 17 days incubation. Soil respiration was measured in one hour interval with LiCor 8100. Solution applications had immediate effect on DOC concentration in soil water and on soil respiration. In the end of the experiment, alkaline solution enhanced soil respiration by 20% compared to control, whereas acid treatment suppressed soil respiration by 15% compared to control. Neutral treatment has only short-term effect (suppression) on soil respiration. Altered soil respiration is probably a direct result of DOC bioavailability for microbes under different treatments, rather then direct pH effect on soil microbial communities.