The impacts of acid and nitrogen deposition on:

Upland Heath

Upland heath covers extensive areas of moorland between enclosed farmland and montane regions on nutrient poor, acidic surface soils (usually peats or peaty podzols) in the north and west of the UK. A product traditionally of burning and grazing management, the plant community is dominated by heather (*Calluna vulgaris*) and other shrubs including bilberry (*Vaccinium myrtillus*). The economically and ecologically important vegetation provides grazing for grouse, sheep and deer, and habitat for diverse bryophytes, lichens, invertebrates and raptor birds. Large areas were lost in the 20th century due to changing land use, over-grazing and management neglect. In parts of Britain, high levels of sulphur dioxide and acid rain have damaged the soils and vegetation of upland heath and related moorland ecosystems. Recently, nitrogen (N) deposition has become recognised as an additional threat to the structure and function of these nutrient-poor communities.

The distribution of inputs of acidity and nitrogen across the UK

Energy production through the combustion of fossil fuels results in the emission of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) into the atmosphere. Food production also causes pollutant emissions: ammonia (NH_3) from farm animal units and both ammonia (NH_3) and nitrous oxide (N_2O) from intensive fertiliser use. These pollutants are transported in the atmosphere affecting air quality and rainfall chemistry across the UK. This has resulted in acidification of soils and waters in acid-sensitive areas such as many upland habitats and has also contributed to N enrichment of semi-natural areas. Reductions in emissions due to policy control measures have resulted in lower quantities of sulphur and nitrogen oxides falling on different habitats but, due to increases in emissions from shipping, recovery has not been as fast as hoped for. Ammonia emissions increased sharply from the 1950s to 2000 and currently remain at these peak levels.

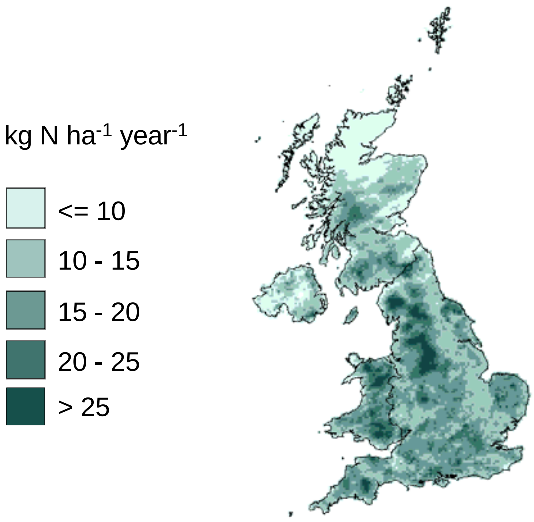

Fig 1a. Nitrogen (NOx + NHx) deposition measured 2003-2005

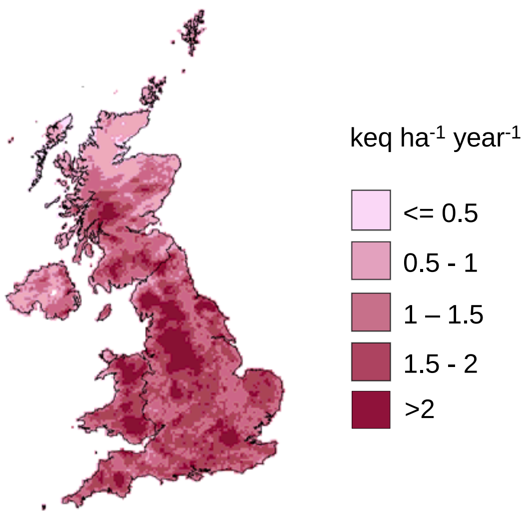

Fig 1b. Total acid deposition (S + NOx + NHx) measured 2003-2005

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Evidence of acidification and N-enrichment effects at the national scale

There are various sources of information which indicate vegetation, soils and waters have been affected by acidic and N deposition. A review of the evidence for the UK was brought together by the National Expert Group on Transboundary Air Pollution (NEGTAP) (http://www.nbu.ac.uk/negtap/home.html). The evidence for N enrichment of vegetation includes two national monitoring programmes – the Countryside Survey and the New Plant Atlas for the UK – which identified shifts in species composition towards more nutrient-demanding species in the latter half of the 20th century (Preston *et al*. 2002, Haines-Young *et al*. 2003) (e.g. Figure 2).

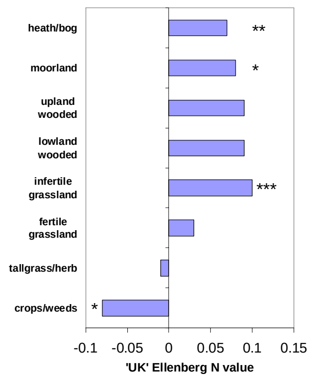

*Figure 2. The change in UK fertility score for different habitats between 1990 and 1998 taken from the most recent UK Countryside Survey (redrawn from Haines-Young et al., 2003). A low value is associated with low fertility and a high value with high fertility. Statistically significant changes are marked as * P<0.05, ** P<0.01, *** P<0.001.*

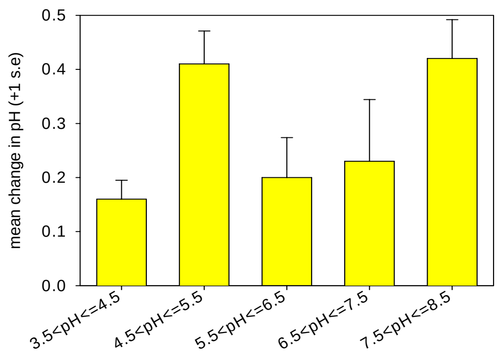

Figure 3. The increase in soil pH (0-15cm) from 1978-1998/9 at 767 sites across Great Britain (NEGTAP 2001)

Acidification of soils and waters recorded in some areas during the 20th century are now being reversed, reflecting the success of emission policies to reduce levels of acid deposition in the environment (e.g. Figure 3). There are still areas at risk, however, due to increases in sulphur emissions from shipping.

Why does air pollution affect our soils, vegetation and waters?

Although rainfall is naturally acidic, additional acidity either introduced directly by sulphur dioxide and nitrogen oxides or formed during the breakdown and uptake of ammonia has affected waters, soils and vegetation in the UK. The pH of lakes and rivers fell during the last century, in turn affecting populations of fish, invertebrates and water plant communities. Soils also became more acidic, affecting organic matter breakdown and soil nutrient balance. Soil acidification increases the solubility of some elements such as aluminium in the soil solution, which can be toxic to plant roots at high concentrations. Pollutants are also deposited to vegetation directly as gases, aerosols and in fogs and mists, and can cause direct damage to plants at high concentrations.

Emissions of nitrogen oxides and ammonia can lead to N enrichment (eutrophication). These problems can result in a loss of biodiversity in sensitive ecosystems because N-loving species benefit at the expense of other species of conservation interest that contribute so much to the character of semi-natural habitats. This happens due to nutrient imbalances, increased susceptibility to climatic stress and higher levels of insect or fungal damage which all affect the balance of competition between species.

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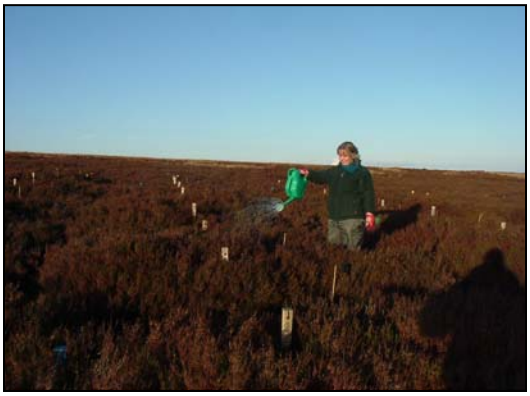
Current evidence for air pollution effects on upland heaths

The influence of current acid and nitrogen deposition on upland heath and similar moorland ecosystems is seen against the background of lasting effects of historical pollution since the Industrial Revolution. In the worst-hit areas, such as the Southern Pennines, the increased soil acidity, loss of base cations and inputs of metals have left a long-term legacy which appears to constrain present-day ecological recovery. In the 1980s, it was predicted that, following a reduction in emissions of sulphur dioxide, ecological improvements in polluted moorlands would be slowed due to the influence of continuing high rates of N deposition; research in recent years supports this view.



Experimental nitrogen addition on a Welsh moor

Lichens and bryophytes provide the main above-ground biodiversity in many upland heath communities and a long term N addition experiment near Ruabon in North Wales found these plants to be highly sensitive to N inputs (Pilkington *et al*., 2007). Acidification has occurred over extensive areas of the UK. Indeed a link between peat acidification and rainfall acidity across Scotland was established in the 1980s (Skiba *et al*., 1989). Soil acidification slows the growth rate of plants, some more than others, so communities change. Research has shown that decomposition of plant litter slows down in acidified soils, substantially so at heavily polluted sites, and this is not sustainable in the longer term. Peat acidification can reduce the population of enchytraeid worms, important to the first stage of litter decomposition, and can reduce substantially the colonization of heather roots by beneficial mycorrhizal fungi.

Nitrogen deposited to heather moorland initially accumulates in the mosses and higher plants and then builds up in the surface soil layers where the slow rates of decomposition and mineralization of organic latter limit the leakage of N into waters. The amount of N leaching as a proportion of deposition has been found to be much greater in some areas, like the Southern Pennines, than in others (Curtis *et al.*, 2004). Detailed research in this area indicates that microbial retention of the high N inputs is reduced in heavily polluted and frequently burnt moorland soils (Cresser *et al*., 2004). The reduction in lower plant cover in the moorlands of the most polluted regions also means that this vegetation, especially the moss layer, is less able to absorb and retain atmospheric N inputs.

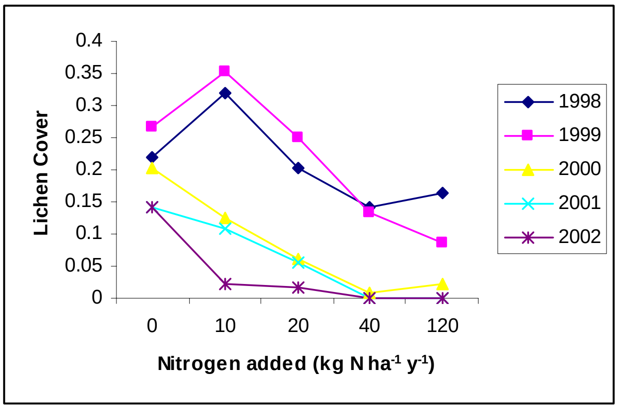


Figure 4. The changing effect of ammonium nitrate additions on lichen cover in the first 5 years of an experimental on a Welsh moor

Heather is the dominant and most valued species of moorlands but evidence for direct effects of N pollution on it is equivocal. Some pot experiments found strong, adverse effects on roots and mycorrhizas, yet studies around the country found very good heather growth in well managed moors even in regions with the highest acid and N deposition (Milne *et al*., 2002). In the Ruabon field experiment, monthly additions of ammonium nitrate solutions since 1989 have not substantially changed the condition of the dominant heather plants, despite major changes to lower plants below the canopy (Figure 4.) and to soil chemistry.

Damage to the dominant shrubs may result indirectly from environmental stresses such as freezing, exposed conditions or insect (heather beetle) herbivory, both of which can be exacerbated by N deposition, increasing injury in heather shoots.

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How will climate change and management affect the impacts of air pollution?

The combined effects on upland heaths of climate change, rising CO_2 and air pollution are hard to predict. In cleaner regions low levels of soil N availability could limit the stimulation of growth normally caused by rising CO_2, but in areas of high N deposition the response to CO_2 may be increased. Warming, as already experienced since the 1980s, and in some upland areas most noticeable in winter, will have major effects on upland plant, animal and microbial life. There should be greater potential for lowland species to take to the higher ground but also increased threats for upland specialist organisms. However, the naturally acidic soils along with the unfavourable pollution climate - high rates of acid and N deposition, polluted cloud water and elevated exposure to ozone - in upland moorlands will likely affect competition between species, but in ways we cannot yet predict.

Regular management is probably the key to maintenance of good heather moorland condition in polluted areas of the country; experimental work indicates that N inputs advance the development of heather so that burning or cutting needs to be practised more often. However, overgrazing by sheep or deer should also be prevented; Mitchell and Hartley (2005) added N to experimental moorland plots in the Cairngorms and found that heather suffered significant decline, accompanied by an increase in grasses, only when grazing was allowed.

UK actions being taken to help reduce air pollution

Protocols under the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP), have already led to substantial emissions reductions for sulphur dioxide and nitrogen oxides. As a result, acid deposition in the UK has declined by approximately 50% over the past 12 years, mainly due to reductions in sulphur emissions. Under the latest CLRTAP agreement (the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) UNECE parties have agreed more stringent emission ceilings for SO_2 and NO_x as well as the first emission ceilings for NH_3, to be met from 2010. A major driver for agreement of these ceilings was the aim to reduce exceedance of critical loads for acidification and eutrophication across Europe. Critical loads are defined as the amount of acidity or nutrient N deposited on an ecosystem that, if exceeded, could lead to damage of that ecosystem. Critical loads are improved and refined as new data on ecosystem impacts become available. A recent update of UK critical loads has been undertaken and the report is available at: www.critloads.ceh.ac.uk .

Further Information

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