Is the nitrogen we're adding to the air too much of a good thing, NERC asked in a £6 million programme. Catharine Stott reports on a selection of the projects.

Global Atmospheric Nitrogen Enrichment

Every organism on Earth needs nitrogen but humans have doubled the amount of nitrogen that plants and animals can use (fixed nitrogen) in circulation. The nitrogen comes from agriculture – from nitrogenous fertilisers and nitrogen fixing crops such as soyabeans, from animals and human waste and from burning fossil fuels.

About 380,000 tonnes of nitrogen in various forms are deposited on the UK each year. The highest amounts, 80 kg per hectare, fall on the Pennines, Lake District and parts of Wales. This isn't far off the amount farmers put on some crops in a year. The pollution either falls directly as particles or is dissolved in rain, mist and snow. It also gets washed into our streams and rivers and then into the sea. Everywhere it changes the make-up of species, perhaps irreversibly.

This is why NERC spent £6 million on a programme called Global Atmospheric Nitrogen Enrichment (GANE), with extra funding from the Scottish Executive Environmental and Rural Affairs Department (SEERAD). Over 130 scientists worked on the programme, which ran from 1998 to 2004.

First let's look at where nitrogen pollution comes from. Agriculture is an important source. Keith Goulding, of Rothamsted Research, and colleagues found that there is less soluble organic nitrogen in crop fields than under grass or trees, probably because the soil gets turned over much more. Also adding manure may increase leaching. People need to think long-term about how they manage the land.

Nitrogen pollution also comes in the form of nitrous oxide, a powerful greenhouse gas. The good news from GANE is that the Intergovenmental Panel of Climate Change (IPCC) may be overestimating how much nitrous oxide is emitted. Dave Reay, of the University of Edinburgh, and colleagues, found that the amount being emitted from drainage ditches in fields is less than half the IPCC's estimate.

How can farmers reduce emissions? Ullie Dragosits, of the Centre for Ecology & Hydrology (CEH) Edinburgh, and colleagues, created a computer model to study ammonia, nitrous oxide and nitrate in individual fields and farms. The model can be used to find ways to reduce pollution, such as planting trees downwind of sources, such as poultry


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farms, to soak up nitrogen.

Humans aren't the only creatures that create nitrogen pollution hotspots. Seabird colonies do too, but are they a problem? Sarah Wanless, from CEH Banchory, and colleagues, found that only in remote northern and western areas are seabirds the main producers of ammonia.

Nitrogen that is attached to carbon is called organic nitrogen. Until now researchers only measured the inorganic nitrogen in rain and snow to find out how much was being deposited. But Neil Cape and colleagues from CEH and other institutions made the first reliable measurements of organic nitrogen in rain. They discovered about one third of the nitrogen in UK rainfall is organic, and therefore people have been greatly underestimating the total amount of nitrogen pollution from the atmosphere.

Once nitrogen has hit the ground, the landscape plays a big part in how much it gets into rivers and streams. Rachel Helliwell, of the Macaulay Institute, and colleagues, found that the most gets into surface waters in uplands areas where the hills are steep and the soil is thin and lacking in organic matter. This is the landscape of the Pennines, Lake District and Wales.

Malcolm Cresser, of the University of York, and colleagues, found that heather burning and bracken encroachment made it easier for nitrates to leach from the soil into streams and rivers. In another project Malcolm and his team found that the amount of organic nitrogen in upland streams is 1.0-3.5kg a year, and this must be included in calculations of nitrogen pollution. It must also be included in calculations for rivers and estuaries. Duncan Purdie, of the National Oceanography Centre, Southampton and colleagues studied the river Test, which contains freshwaters and salty estuarine waters. Organic nitrogen accounted for up to 10% of the nitrogen in the freshwaters, and up to 50% in estuarine samples. Its sources included sewage works and fish farms, but some of it was absorbed by the salt marshes.

Once it has got into the soil and water, nitrogen affects wild plants. Some species thrive on extra nitrogen, while others cope badly. One of the most serious and insidious effects of nitrogen pollution is to change the make-up of plant communities and decrease biodiversity.

Many acidic and chalky grasslands, which can contain many different and perhaps rare wild flowers and plants, receive high doses of nitrogen pollution. John Lee and colleagues from the University of Sheffield discovered that these ecosystems can store nitrogen by rapidly locking it away in the soil. However, if the high amounts of pollution continue, then the diversity of wild flowers is reduced. This is because just a few species, such as grasses and species thrive on the extra nitrogen, and out-compete those, such as wild thyme, which do not cope so well.

Nitrogen pollution has helped grasses replace heathers in UK heathlands and moorlands. Using computer simulations, Mike Ashmore, of the University of York, and colleagues found that to quickly return heathlands to their former glory means reducing pollution, and active management, and even that could take 20-30 years.

As for lichens, Alistair Headley, of the University of Bradford, and colleagues, discovered that all species are repopulating areas once badly affected by sulphur dioxide pollution from coal burning. However, between 1980-2000 nitrogen-loving species have spread, especially in rural areas.

Even in relatively unpolluted areas nitrogen pollution is affecting plants. In the Atlantic oakwoods on the west coast, it is changing which species of mosses, liverworts and lichens grow on the trees, Ruth Mitchell and colleagues from CEH found.

Lucy Sheppard and colleagues from CEH Edinburgh used a unique system for finding out what happens to bog plants downwind from a 100,000-bird poultry unit. They found that lichens and mosses died, but other species, such as cranberry, thrived, and the damaged area grew as the nitrogen dose accumulated.

And what about soil organisms? Jim Prosser, of the University of Aberdeen, and colleagues, wanted to know if bacteria that use nitrogen were affected by nitrogen and sulphur pollution. Surprisingly, they found that this didn't seem to be the case in upland, acidic grasslands, but that may be because such bacteria aren't very active in acidic soils.

The thing about atmospheric pollution of any sort is that it travels around the world. Johanna Laybourn-Parry, of the University of Nottingham, and colleagues studied the movements of nitrogen in melting snow in an Arctic tundra ecosystem. They found that soil micro-organisms, mosses and lichens quickly locked nitrogen away in the soil. Other research by Clare Robinson showed that over the long term, even low inputs of nitrogen can alter the biodiversity of Arctic tundra.

This, and other GANE research, will help the UK fulfil its obligations on controlling pollutants and greenhouse gases. It will also help find ways to prevent or reduce pollution and help damaged ecosystems recover.

If you want to know more about GANE, visit the www.ncl.ac.uk/gane or http://gane.ceh.ac.uk. Or order an information pack about the research from www.nerc.ac.uk/insight/publications/ orderpubs.asp