Environmental science

Acidification and decline of Central European forests

from Nico van Breemen

WHAT is probably the most complete set of data available on the effects of atmospheric sulphur and nitrogen on the weathering of soil and rock, and on the composition of drainage water in forested and agricultural areas, is reported on page 31 of this issue by Thomas Paces[1]. Of particular interest is that one of the areas (all of which are in Czechoslavakia) is characterized by extremely high sulphur inputs and a complete dieback of spruce forest, a situation that may be typical of several industrial regions in eastern Europe. Paces concludes that the forest in the industrial region is strongly acidified. But is acidification responsible for the dieback?

Dry deposition of sulphur dioxide is responsible for 75 per cent of the acidification in the industrial region whereas wet deposition (acid rain in the strict sense) contributes only 15 per cent to the total acid load of the system studied. In relatively remote forests, the acid load is only about a third of that in the industrial region, and the contributions of wet and dry deposition to the total acid load are about equal. Soil acidification is considerable in such areas but the drainage water is almost neutral. Agricultural activities (fertilizer application and harvesting) contribute considerably to the acid load of soil and rock, resulting in increased mineral weathering.

Changes in the chemical composition of water of the Elbe river over the past 80 years indicate that these conclusions, although based on data drawn from four small representative watersheds, are valid for large areas. All the four have similar bedrocks, soils and climates but differ in their exposure to atmospheric pollution and land use. Paces combines detailed hydrological measurements and estimates of chemical input and output (including records of fertilization and harvesting) over five to seven hydrological years with a recently developed steady-state model of weathering, to quantify acid production and consumption by known geochemical and biological processes. Inputs of sulphur and nitrogen by dry deposition were estimated from measured concentrations and published values of deposition velocities.

Although some authors still contest that atmospheric deposition of anthropogenic sulphur and nitrogen seriously contribute to acidification of soils[2,3], Paces's data are in agreement with several independent lines of evidence for increased environmental acidification as a result of atmospheric deposition. The first direct evidence for the strong soil acidification in Central Europe of the past decades came from *p*H measurements of old and new soil samples by Butzke[4]. At a workshop at Uppsala last September, C.O. Tamm from the University of Uppsala reported a small drop in the *p*H of forest soils over the past 50 years in northern Sweden but a much larger acidification in the southern part of the country. Tamm attributes the small *p*H decrease in the north mainly to biological processes and the large decrease in the south to atmospheric inputs. Other input-output budgets[5], geochemical studies of soil weathering profiles[6] and simulation models of soil acidification[7] also lead to the same inescapable conclusion: the rate of acidification of forest soils in a large part of Europe (and north-eastern America) is greatly accelerated by atmospheric pollution. Although this acidification has markedly depressed the *p*H of sensitive forest soils in Central Europe, forest soils in the United States and Canada seem still to be able to buffer the *p*H in a range that can be considered normal.

Although there is general agreement that the acidification of lakes and streams is detrimental to fish and other biota[8], the relation between soil acidification and the widespread decline in forests of Central Europe is still controversial; the link between the acidification of soil and death of spruce forests indicated by Paces is not proven. Usually, direct effects of atmospheric gases, including photo-oxidants, may be more important than soil acidification in damaging trees. Nevertheless, the removal of base cations and release of potentially toxic aluminum by acidification must be detrimental to trees and other forest plants.

In the long run, soil acidification may be a bigger problem than the direct effects of gases on vegetation: although a reduction in pollutant emission would have an almost instantaneous effect on air quality, recovery of acidified soils is presumably very slow and is only possible if sufficient quantities of weatherable silicate minerals are still present.

In that respect, the acidification of agricultural soils (also demonstrated by Paces) is a minor problem. The acidifying effects of harvesting and fertilizer application are normally counteracted by liming. Additional effects of atmospheric acids can easily be undone in the same way.

Liming, however, probably offers no practical solution for forests. Apart from the fact that acid deposition rates are higher in forests than on land[9] and the problem of how lime could be applied in forest areas, forest liming could result in undesirable side effects from increased decomposition of organic matter, nutrient imbalances, increased susceptibility to pests and diseases and changes in the species composition of the ground vegetation. Both the direct effects of atmospheric pollution and the long-term problems associated with acidification of the environment can only be solved by a reduction in the emissions of gaseous sulphur, nitrogen and hydrocarbons. □

1. Paces, T. *Nature* **315**, 31 (1985).
2. Krug, E.C. *Nature* **313**, 73 (1985).
3. Tabatabai, M.A. *CRC Crit. Rev. Envir. Control* **15**, 65 (1985).
4. Butzke, H. *Forst u. Holzwirt* **36**, 542 (1981).
5. van Breemen, N., Driscoll, C.T. & Mulder, J. *Nature* **307**, 599 (1984).
6. Mazzarino, M.J., Heinriches, H. & Fölster, H. in *Effects of Accumulation of Air Pollutants in Forest Ecosysystems* (eds Ulrich, B. & Pankrath, J.) 113 (Reidel, Dordrecht, 1983).
7. Kauppi, P., Kämari, J., Posch, M., Kauppi, L. & Matzner, E. *Europ. Ecol. Modelling* (in the press).
8. Muniz, I.P: Phil. Trans.R.Soc **B305** 517 (1984).
9. Ulrich, B and Pankrath, J. (eds) *Effects of Accumulation of Air Pollutants in Forest Ecosystems* (Reidel, Dordrecht, 1983).

Nico van Breemen is in the Department of Soil Science and Geology, Agricultural University, 6700 AA Wageningen, The Netherlands.

Primate cognition

Can apes learn to count?

from Brendan McGonigle

DANZIGER once described mathematics as the language of size, natural language as the language of sort. Are these languages confined to the human brain? Although research (and controversy) continues on whether apes share important features of our natural language system, attention is now turning to the question of whether they might also possess the rudiments of a number system. Thus, on page 57 of this issue, Tetsuro Matsuzawa reports on the 'use of numbers' by a chimpanzee[1].

Matsuzawa claims that the ape successfully identified six arabic numbers by selecting from a keyboard the numeral that was appropriate to the number of objects displayed. In addition, it provided the appropriate colour name and category label for some 300 sample types, stringing these into, for example, '3 red pens'.

The study is perhaps unique in requiring a level of description of an array of objects in terms of both numerosity and the type of object displayed. These findings are surely provocative, the fairgound appeal of an ape that selects numerals felicitously apart. Do they, however, imply that the chimpanzee is endowed with the rudiments of a system of calculation which finds a refined and rarified expression in the axiomatic systems devised by man? Only a convergent programme of comparative developmental research into the natural or intuitive calculus of animals and humans