Decline of European forests

SIR—Forests are more than trees. In their Commentary article on the status of European forests, Blank *et al.*[1] based their account on the results of national surveys of the health of tree crowns. Their discussion of forest decline is mainly from a population perspective, which does not give due weight to the soil aspects of the problem. We suggest that an ecosystem approach provides a more complete picture.

Measurement of input–output budgets for the principal ions is a prerequisite for a classification of the status of a forest as an ecosystem. In 1979, Ulrich *et al.*[2] showed that, in central Europe, acid deposition can be the main driving force in these budgets. At Solling and Lange Bramke (FRG), two sites for which ecosystem budgets are available from before and after the start of forest decline, acid deposition has caused changes in the pools of major ions in the soil. Among these changes are decreasing storage of magnesium and increasing storage of nitrogen[3,4]. Such budgets have now been measured at over 100 sites, and the results are alarming[5].

One of the advantages of monitoring ion fluxes is that throughput measurements give a cheap and reliable indicator of the total atmospheric input of sulphate[6]. In Europe the fluxes of hydrogen ion and sulphate beneath forest canopies closely match the large-scale distribution of concentrations of sulphur dioxide[5]. They follow the same north–south gradients, with a maximum belt across Britain, the Netherlands, West Germany, Czechoslovakia, East Germany, Poland and the Soviet Union. In these areas the output fluxes in seepage water are dominated by sulphate and nitrate; in other areas that are not subject to acid deposition, chloride, bicarbonate and organic anions dominate.

In Europe there are large regional gradients in atmospheric loadings and in soil sensitivity to acidification. We can reasonably assume that almost all soils in the high-deposition area have undergone long-term, gradual changes in their nutrient status. In that case there will have been two possible responses — first, that essential nutrients such as magnesium became limiting, especially as the previously limiting nutrient nitrogen was increasing; second, that potentially toxic ions such as aluminium, manganese and hydrogen increased when calcium and magnesium decreased, with adverse consequences for the functioning of the fine root system[3,4]. That is why Ulrich *et al.*[2] predicted large-scale forest decline in central Europe as long ago as the mid-1970s.

We think that two factors led to the increasing awareness of forest decline after 1982: the appearance of completely new symptoms (at least regionally, the occurrence of yellowing), and a parallel occurrence of other unspecific symptoms (crown thinning). The surveys of needle mass in the following years brought all the different symptoms into a one-dimensional damage classification for each site, resulting in confusion about the possible causes[7]. For Norway spruce alone there are at least three (possibly five) different types of damage[8].

Some of these above-ground mainly unspecific symptoms are probably a consequence of short-term climatic fluctuations over periods of up to seven years. Yet such short-term effects may still be influenced by the acid–base status of the soil, as exemplified by the response of nitrate[9]. The fact that these changes include periods of recovery, as pointed out by Blank *et al.*[1], does not mean that gradual deterioration of central European forests is not occurring.

Perhaps the clearest example comes from the Harz mountains, where for the first time regional damage inventories by infrared aerial photography were carried out separately for the two main symptom types[10]. The distribution of both types, yellowing (type 1) and loss of green or brown needles (type 2) are clearly related to soil sensitivity (and deposition) factors[4,10]. If both types are pooled into a total damage figure for Norway spruce, all correspondence with the possible stress factors discussed by Blank *et al.*[1] is lost. A hypothesis based on soil acidification as the key predisposing factor described such differences in damage symptoms locally for the Bramke Valley, as well as regionally for the Harz[4] and for central Europe[3].

As in the early 1980s, indirect effects of acid deposition on the acid–base status of forest soils have emerged as a major factor in understanding the status of forest ecosystems in Europe. The implications for forest management and air-pollution control policy are considerable; the increasing acceptance of the concept of critical load in controlling sulphur and nitrogen emissions is a step in the right direction. Many of the causal links to explain short-term variations in tree health, or the role of direct effects (for example by ozone), are still missing. But the points made above show that there is a view of forest decline rather different to the one expressed by Blank and his colleagues.

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1. Blank, L.W., Roberts, T.M. & Skeffington, R. *Nature* **336**, 27–30 (1988).
2. Ulrich, B., Mayer, R. & Khanna, P.K. *Deposition of Air Pollutants and Their Consequences in Forest Ecosystems at the Solling (FRG)* (Schriften der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt **58**, 1979).
3. Ulrich, B. in *Advances in Environmental Science*, Vol. 4 (Adriano, D.C. ed.) (Springer, Berlin, in the press).
4. Hauhs, M. in *Advances in Environmental Science*, Vol.5 (Adriano, D.C. ed.) (Springer, Berlin, in the press).
5. Hauhs, M., Rost-Siebert, K., Paces, T., Vigerust, B. & Raben, G. in *The Role of Nitrogen in the Acidification of Soils and Surface Waters* (eds Malanchuk, J. & Nilsson, J.) 5/1–5/41 (USEPA/Swedish EPA, 1989).
6. Lindberg, S.E. & Garten Jr, C.T. *Nature* **336**, 148–151 (1988).
7. Blank, L.W. *Nature* **314**, 311–314 (1985).
8. *Forschungsbeirat Waldschäden/Luftverunreinigungen* (Report 2, Karlsruhe, 1986).
9. Matzner, E. *Ion Cycling in Two Forest Ecosystems in the Solling Mountains* (Berichte des Forschungszentrums Waldökosysteme **40**, 1988).
10. Stock, R. *Forst und Holz* **43**, 283–286 (1988).

BLANK *ET AL.* REPLY—Although Hauhs and Ulrich say they provide a different view of forest decline to that which we presented in our Commentary article, we note that there are now many areas of agreement. There have been considerable changes from the earlier arguments put forward by Ulrich and colleagues[1], the most important of which is the acceptance of regional decline types and the importance of short-term climatic fluctuations in damage development. We are in agreement with Ulrich and colleagues that the forest damage surveys have severe limitations, and that the results cannot be used to quantify the role of some factors (for example air pollution). We also agree that forest decline can no longer be seen as a one-way street, but that there has been recovery, indicating reversibility.

The area of continuing disagreement revolves around whether the current recovery is a transient phenomenon in a continuing decline, or is a clear sign of a reverse. The concept of continuing forest decline depends upon the argument that soil acidification is the long-term driving force across Europe. This view ignores the existence of regional decline types with distinct symptoms and combinations of causal factors. As we pointed out in our article, and as Hauhs and Ulrich agree, there are at least three, probably five, types of Norway spruce decline. We know now that at least one of these types is not related to soil acidification (type 3 decline in the foothills of the Alps, caused by needle-cast fungi[2]).

The main step forward has been in understanding the causes of type 1 spruce decline (needle yellowing in the German *Mittelgebirge*; *montane Vergilbung*[2]). We know that the symptoms result from magnesium deficiency[3]. The soils in the areas concerned have always been marginal for magnesium because of its slow release by weathering and low atmospheric input. Depletion of exchangeable magnesium has been accelerated by planting Norway spruce monocultures and by increased leaching resulting from relatively high inputs of mobile anions. Increased soil

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