The ecological impact of atmospheric deposition on European forests in the time of climate change

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European forests represent an invaluable asset for wood production, biodiversity conservation and to combat climate change. Concern for the possible effects of transboundary air pollution on forest health led in 1985 to the launch of the International Co-operative Programme for the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) under the United Nations Economic Commission for Europe (UNECE). The objectives were to monitor spatio-temporal changes in forest condition across the UNECE region and to identify driver-response relationships. The methods adopted (i) cover from plot design to field and laboratory measurements, with comprehensive Quality Assurance/Quality Control; (ii) include a multi-level monitoring concept, with a probabilistic component (ca. 6000 Level I plots) and an intensive component (ca. 600 Level II plots); (iii) were all internationally agreed; and (iv) are continuously updated. Such a monitoring system remained unrivalled to detect the impact of climate extremes and the combined effects of air pollution, climate change, forest management and biotic factors on key ecological features and processes of European forests. Here we show the observed impact of atmospheric deposition and air pollution on the health, productivity, diversity and biogeochemistry of European forests at continental scale and over the past three decades. We observed a suite of largely interrelated effects across the entire ecosystem, from canopy trees, to the understory vegetation, soil chemical properties and soil microbial community. Effects vary from visible foliar injury on native plants (caused by ozone), to defoliation and foliage discoloration of canopy trees (atmospheric deposition, precipitation deficit, pests and diseases), reduction of tree growth (deposition, climate), change in nutrient availability in soil and plants (deposition), diversity of lichens, bryophytes and mycorrhiza (deposition, climate, stand). We also show how the effects of deposition and air pollution were modulated by climate, site / stand condition, and forest management.