UNITED
NATIONS

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Economic and Social Council

Distr.
GENERAL

ECE/EB.AIR/WG.1/2008/10
8 July 2008

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

EXECUTIVE BODY FOR THE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Working Group on Effects

Twenty-seventh session
Geneva, 24–26 September 2008
Item 4 of the provisional agenda

RECENT RESULTS AND UPDATING OF SCIENTIFIC AND TECHNICAL KNOWLEDGE

LINKS BETWEEN CLIMATE CHANGE AND AIR POLLUTION EFFECTS USING SITE-SPECIFIC DATA

Report by the Programme Centre of the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems and the Coordination Centre for Effects of the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends

INTRODUCTION

1. The results of the dynamic modelling work on 163 Finnish forested catchments are presented in this report in accordance with the Convention's 2008 workplan (ECE/EB.AIR/91/Add.2, item 3.6 (c)) approved by the Executive Body at its twenty-fifth session.

2. It is anticipated that implementation of the Convention's Gothenburg Protocol[1] will cut European emissions of sulphur (S) by at least 63%, nitrogen (N) oxides by 41% and ammonium by 17% by the year 2010 as compared to 1990. Dynamic process-oriented models are required to evaluate the timescales of the (chemical) response of soils and surface waters to the resulting changes in deposition. Dynamic models have been used for deposition scenario assessment at selected ICP Integrated Monitoring sites (e.g. Jenkins et al. 2003, Hutchins 2007). These models allow for the assessment of alternative policy-relevant emission scenarios. Recently, dynamic modelling has also become an important part of the effects-oriented work under the Convention on the European scale (Hettelingh et al. 2007).

3. Environmental factors other than anthropogenic deposition may affect the chemical and biological responses of soils and surface waters to changes in atmospheric deposition. Dynamic model simulations make several assumptions with respect to future environmental conditions. They are usually based on assumed deposition scenarios derived from future S and N emissions and also from scenarios for future land-use practices such as forest cutting and replanting. There are, however, other environmental factors that may change in the future and may affect recovery of ecosystems. These confounding factors add to the uncertainty in predictions. Climate change is one important confounding factor. Others may include the impact of other pollutants such as heavy metals and toxic organic pollutants, as well as shifts in the biological components of the ecosystems caused, e.g. by the invasion of exotic species.

4. In response to environmental concerns, the use of biomass energy has become an important mitigation strategy against climate change. For example, the European Union (EU) has set a target of doubling the share of renewable energy sources in gross inland energy consumption to 12% by 2010. Additional targets have been set for the year 2020. Accordingly, forest harvesting practices are expected to shift from more traditional stem-only harvesting (SOH) practices to whole-tree harvesting (WTH).

5. Accordingly, an increasing effort is being made to assess the connections between air pollution impacts and climate change-related processes and activities. This document summarizes the main findings from recent detailed catchment modelling work using the MAGIC model framework; extensive soil, surface water and deposition data sets; and scenarios for deposition, climate change and forest harvesting. Data for 163 Finnish forested catchments have been used for the development and demonstration of these concepts. A more extensive summary of this work is available in the ICP Integrated Monitoring *Annual report 2008* and further technical details in Aherne et al. (2008) and Posch et al. (2008).

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[1] The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

I. MATERIALS AND METHODS

6. The 163 study sites, located throughout Finland, belong to monitoring networks maintained by the Finnish Environment Institute (SYKE). Soil physico-chemical properties were described using a network of 488 permanent plots, established as part of the eighth national forest inventory.

7. Historic and future soil and surface water chemistry (1880–2100) was simulated for each catchment using the MAGIC model framework. The required model inputs were obtained from site-specific observations and data interpolated from regional assessments. Considerable emphasis was placed on generating site-specific model inputs for each study catchment.

8. The spatial distribution of S and N deposition in the 50 km × 50 km grid (the EMEP50 grid) for the years 1990 and 2000 were taken from the eulerian dispersion model of the Meteorological Synthesizing Centre-West of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP/MSC-West) (Tarrasón et al. 2005). The depositions of base cations (the sum of calcium, magnesium, potassium and sodium (Ca^{2+}+Mg^{2+}+K^{+}+N^{a+}) and chloride (Cl^{-})) were mapped on the 0.250º × 0.125º longitude-latitude grid for the period 1991–1995 by interpolating observations from a nationwide network. S and N deposition history in the EMEP50 grid for the period 1880–1990 was obtained from Schöpp et al. (2003).

9. The long-term average annual net uptake of base cations (Ca^{2+}+Mg^{2+}+K^{+}) and N by forests in the catchments was calculated from the average annual volume growth and the nutrient concentrations in the harvested (removed) biomass (stem over bark). Long-term average annual net uptake values were available for Finland in the 0.250º × 0.125º grid.

10. Three future scenarios for S and N deposition for the period 2010–2100 were used:

(a) The "current legislation" (CLe) scenario, which assumes the implementation of the Convention's 1999 Gothenburg Protocol and the EU National Emission Ceilings (NEC) Directive;

(b) A scenario developed by the European Commission's Clean Air for Europe (CAFE) programme;

(c) The "maximum feasible reductions" (MFR) scenario, which assumes the implementation of all technically feasible emission reduction measures by 2020 (Amann et al. 2005).

11. All deposition scenarios included the same emission values between 1880 and 2010. From 2010 onwards the three emissions scenarios are introduced achieving their final values in 2020. Emissions were assumed to remain constant thereafter.

12. Future climate change (temperature and precipitation) was derived from the HadAM3 and ECHAM4/OPYC3 general circulation models under two emission scenarios of the Intergovernmental Panel on Climate Change (Nakićenović et al. 2000). Future scenarios for runoff were obtained with the Finnish watershed simulation and forecasting system.

13. Two future (2010–2100) scenarios for forest harvesting were used: (a) a “stem-only harvesting” (SOH) or “base” scenario, which assumes a constant net uptake (business as usual); and (b) a “whole-tree harvesting” (WTH) scenario, which assumes a constant gross uptake. Both harvesting scenarios were equal between 1880 and 2010, i.e. constant net uptake (SOH). From 2010 onwards the WTH scenario was phased in linearly until 2020 and assumed to be constant thereafter. The SOH scenario remained constant throughout the period 2010–2100.

14. The potential influence of future changes in surface water concentrations of dissolved organic carbon (DOC) on lake acid status was explored using two simple empirical models. They related to changes in climate (temperature) and S deposition and reflected the uncertainty in the mechanisms and drivers behind observed DOC increases.

II. MAIN FINDINGS AND CONCLUSIONS

15. Simulations suggested that only the MFR scenario would result in significant recovery of soils and surface waters. It would return water quality close to pre-acidification values at the studied catchments. Based on current process descriptions, the direct influence of climate change (temperature and runoff) had very little impact on model simulations for the sites.

16. Climate-induced changes could exert a significant influence on future surface water chemistry. The two exploratory simple empirical DOC models indicated that changes in S deposition or temperature could have a confounding influence on the recovery of surface waters. The corresponding increases in DOC concentrations might offset the recovery in pH due to reductions in S and N depositions.

17. Climate-induced changes in processes were generally not specifically incorporated in current versions of biogeochemical models. These models would need to be modified to incorporate the drivers and mechanisms by which climate changes affect the key biogeochemical processes.

18. The use of forest biomass for energy production has become an important mitigation strategy against climate change. To meet this demand, future harvesting is expected to shift from SOH to WTH. The increased use of forest harvest residues for biofuel production is predicted to have a significant negative influence on the base cation budgets causing re-acidification at the study catchments (see figure).

19. Sustainable forestry management policies would need to consider the combined impact of air pollution and harvesting practices. A need exists for further emission reductions to mitigate the negative impacts of WTH, if such a policy is implemented. Additionally, increased fertilizer use, such as wood ash applications, might be required to maintain soil nutrient status and lake-water quality in these forested ecosystems.

20. The comprehensive modelling framework summarized here provides a suitable tool for detailed studies regarding the connections between air pollution impacts and climate change related processes and activities.

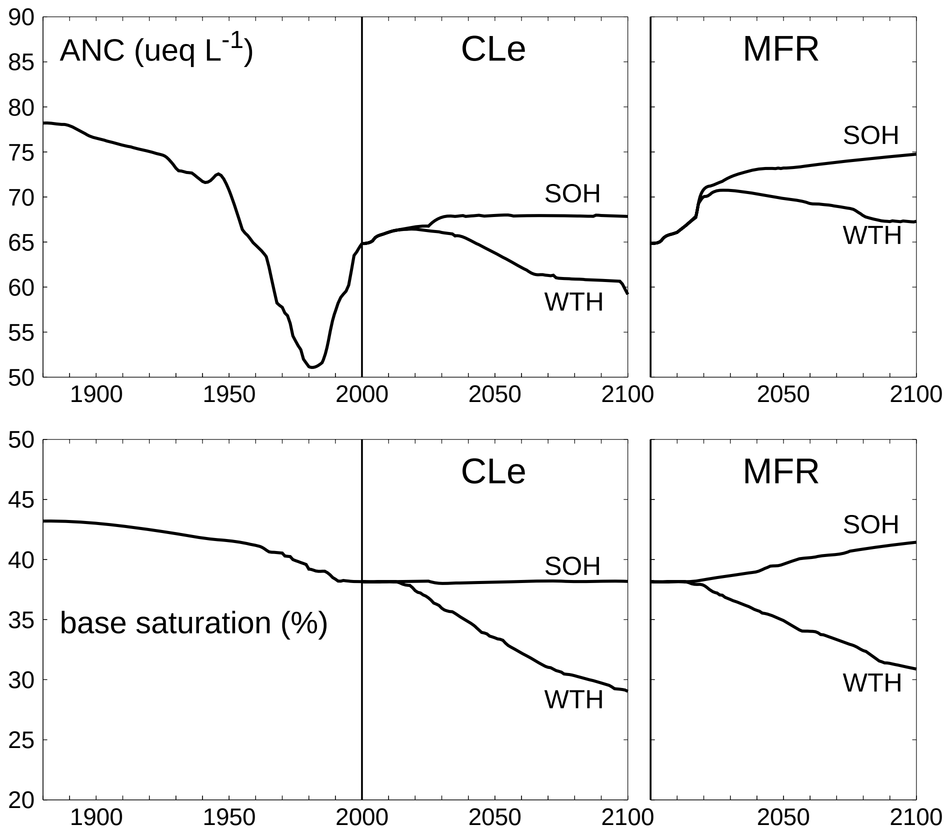

Figure. Temporal development of the median of lake-water acid neutralizing capacity (ANC) (top) and the catchment soil base saturation (bottom) for the 163 study catchments under the two emission scenarios (current legislation (CLe): left panel; maximum feasible reductions (MFR): right panel) and two forest harvest (biomass energy) scenarios (stem-only (SOH) and whole-tree harvesting (WTH)) (Aherne et al. 2008).

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