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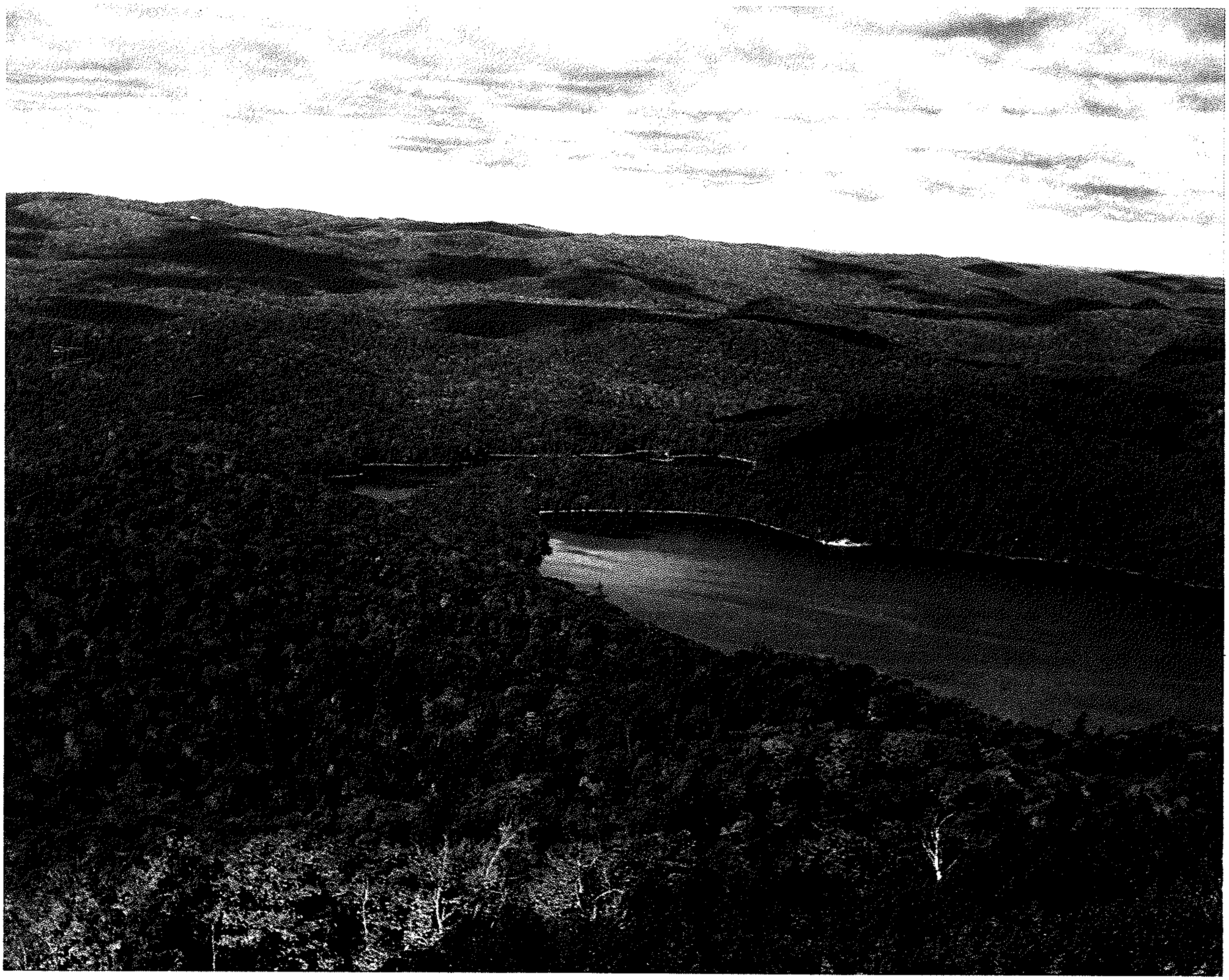
Forestry Newsletter

The Great Lakes Forestry Centre



Canada

ASSESSING THE EFFECTS OF REGIONAL AIR POLLUTANTS ON FOREST ECOSYSTEMS IN ONTARIO

Introduction

Regional air pollution is caused by the increased acidity of precipitation as a result of the presence of dilute sulfuric and nitric acids. The influence of acid deposition on forest ecosystems may be direct, as when tree tissues are injured, or it may be more subtle, resulting in changes in soil fertility or in reduced resistance of trees to climatic extremes and to attacks by insects and diseases. The objectives of the air pollution research program of the Canadian Forestry Service are to determine deposition levels or concentrations of pollutants that must not be exceeded if the continued productivity and well being of forests are to be assured. Dose/response relationships for different tree species, soils, climatic regions and pollutants are being sought. Forests are being monitored regularly for disorders or incipient stress, especially in the context of changing levels of pollutants and other environmental characteristics. It is important to establish adequate baselines for future comparison so that long-term forest and soil changes can be recognized.

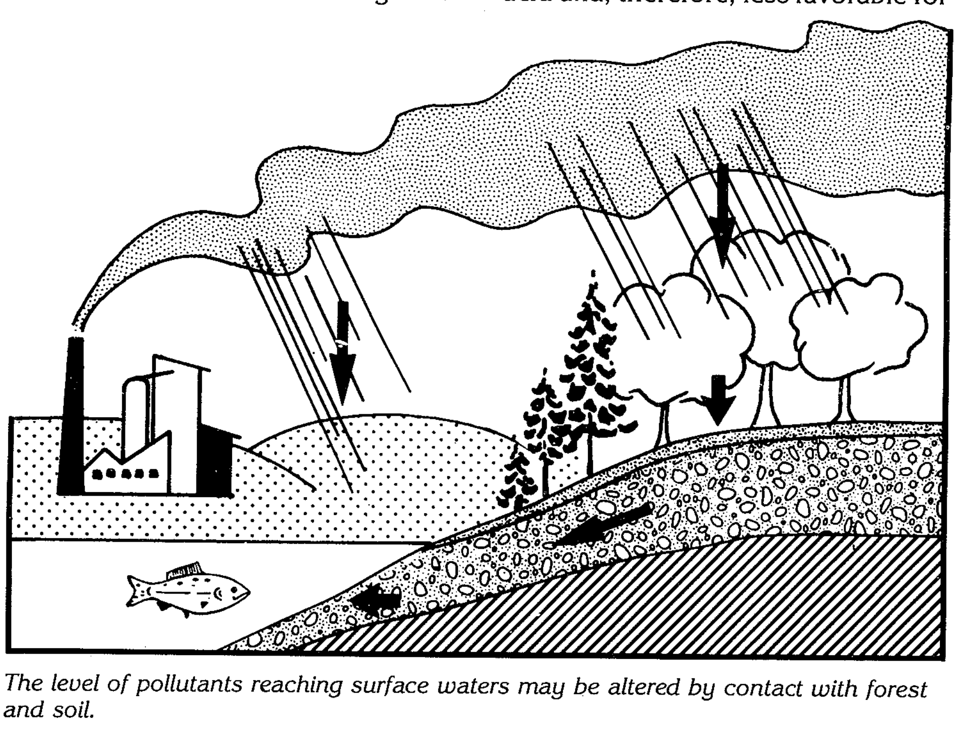
At the Great Lakes Forestry Centre (GLFC) a team of scientists has been investigating the effects of acid deposition on Ontario forests since the late 1970s. The work includes studies on the impact of acid deposition on forest soils, hydrologic processes and forest productivity; on the influence of nutritional factors on jack pine growth on infertile soils; on the effect of environmental chemical factors on tree form and function; and on the effect of an increase in rain acidity on tree diseases.

Project scientists are cooperating with atmospheric and aquatic scientists from the Department of the Environment, fisheries biologists from the Department of Fisheries and Oceans, and resource managers from the Ontario Ministry of Natural Resources in an investigation of hydrology and element budgets in the Turkey Lakes Watershed (TLW) north of Sault Ste. Marie. They also maintain close contact with investigators who are doing related work at CFS Maritimes in New Brunswick and the Laurentian Forestry Centre in Quebec, the Ontario Ministry of the Environment and the United States Forest Service. In addition, they are involved in cooperative investigations with scientists in the Federal Republic of Germany.

Effects of Biogeochemical Cycles

In a natural forest ecosystem the cycle of elements between soil and vegetation maintains the chemical composition of the soil solution in a favorable state for meeting the nutrient requirements of a productive forest. The basics of a bioelement cycle are: input to the ecosystem from the atmosphere and mineral weathering, uptake from soil by trees and other vegetation, and transfer from trees to soil by a variety of processes including litterfall, canopy leaching by precipitation, root slough, and output from the tree rooting zone associated mainly with soil leaching. Ecosystem nutrient reserves are enhanced when atmospheric inputs are incorporated into the cycle and outputs from the tree rooting zone are minimized. Studying the circulation of nutrients in forest ecosystems therefore becomes essential in analyzing stress in these ecosystems.

In the past decade there has been an increasing awareness of the magnitude of strong acid deposition in the northern hemisphere. Along with this awareness has come concern that acid deposition may alter nutrient cycles in such a way that soil and soil water may become more acid and, therefore, less favorable for



The level of pollutants reaching surface waters may be altered by contact with forest and soil.

forest growth. For example, an increase in the acidity of soil water could reduce the availability of nitrogen (N), phosphorus (P), and base cations [potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na)] and could increase the solubility of trace metals such as manganese (Mn) and aluminum (Al).

Turkey Lakes Tolerant Hardwood Study

In 1979, a 1200-ha forested watershed centered on a small chain of lakes culminating in Turkey Lake, some 50 km north of Sault Ste. Marie, was selected as a calibrated watershed for interdisciplinary research. To obtain daily information on the quality of air and precipitation at the watershed, a monitoring station was established and operated to the standards of the existing Air and Precipitation Monitoring Network in eastern Canada.

Changes in water quality are determined by the collection and chemical analysis of precipitation that is transported through the soil.

The GLFC effort is focussed largely on biogeochemistry of old-growth sugar maple-yellow birch forest on the shallow Precambrian till soils of TLW. To obtain information on the export of water and ions from the forest to the lakes, flow monitoring stations were established in 1980 on 14 small terrestrial streams. Six additional intermittent streams were monitored periodically. To examine the influence of vegetation and soil on water chemistry in the forest and the cycle of ions between vegetation and soil, three terrestrial study sites were established within the watershed. Specifically, tree biomass, bioelement content, litter production, litter decomposition, throughfall, stemflow, forest floor percolate, mineral soil percolate, and soil chemical composition are being examined at one or more of these sites. Soil, plant and water samples are analyzed for pH, major ions, nutrients, and trace metals. We now have approximately six years of continuous data from these studies. Finally, to examine forest growth within the watershed 40 permanent sample plots were established and have been resampled to determine the periodic annual incremental growth over the past five years.

All the TLW soils examined are strongly acidic, their base content varying in the surface horizons. The exchangeable bases in the surface mineral horizons of the TLW soils have the effect of buffering the soils against mineral acidity. Acids entering the mineral soil are largely neutralized and do not pass through the soil into ground and drainage waters. Present levels of SO_4^{2-} deposition from the atmosphere, however, have raised SO_4^{2-} levels in soil solution and increased calcium leaching.

Litterfall was important in replenishing Ca removed from the soil through plant uptake and leaching. In the annual economies of N, S, and Ca of the present stand, fluxes of these elements associated with biomass accumulation and with the litter production/decomposition cycle are large in relation to atmospheric contributions.

Kirkwood Jack Pine Study

In 1977 GLFC established a long-term lysimeter experiment on the effect of continuous acid loading (at environmentally realistic levels) on the chemical composition of soil and soil percolate from reconstructed profiles of two northern Ontario coniferous forest soils. Results from the experiment indicate a stage-by-stage process of element loss. In the pH 2-treated soils, exchangeable bases were depleted, and there was a mobilization of trace metals, chiefly Al. Results point up the importance of SO_4 -- adsorption in regulating, first, SO_4 -- and, second, base cation movement in certain forest soils.

In many eastern Canadian podzolic soils, the supply of exchangeable bases is often considerably less than in the Turkey Lake soil; consequently, the risk of further depletion of base cations by acid precipitation is reduced. In very strongly acid soils the leachate was dominated by H^+ or Al or both. The question of the action of nitrate and sulfate inputs on soils and the subsequent effect on soil solution chemistry, as related to plant nutrition, is still being debated vigorously. Scientists are now examining in more detail the role of nitrate in relation to positive or negative responses of vegetation. Recent studies confirm that nitrate may be released by forest ecosystems and pass to aquatic systems or, conversely, may be retained by them. Nitrate as a mobile anion leaches cations and is involved in the solubilization of basic aluminum sulfate, from which acidification results.

Effects on Tree Function

The TLW watershed is currently being used as a site for studies of physiological responses of dominant tree species to atmospheric deposition. In addition to basic growth information gathered as part of baseline monitoring, descriptive studies or nutrient cycling, two types of studies are being undertaken within the watershed: studies of cation uptake and loss across the leaf surface of the major tree species, and studies of photosynthesis and water relations.

The cation loss studies involve regular collections of plant material taken from the watershed over the course of the growing season. This material is used in experimental studies in the laboratory to investigate the uptake or loss of major nutrient cations across the leaf surface. A current working hypothesis is that the primary effect of acid deposition on tree growth is the loss of regulation of carbon acquisition, and water retention, brought about by cation loss. Studies of cation flux as a function of deposition acidity could provide information urgently required for estimating dry deposition of particulates on forest canopies.

Progress

Collections of foliage from sugar maple and yellow birch were made bimonthly during the summer of 1985. Synthesis of the results is just beginning but when complete should allow us to define more precisely the seasonal pattern of macro- and micro- elements in foliage at TLW. Additional analysis of the phytomass components of both species has been carried out. This will allow us to complete our picture of the distribution of macro- and micro- elements within individual trees and within the stand at the intensive site.

Samples of foliage from collections made in September and October 1985 were subjected to acid leaching experiments in the laboratory. Chemical analysis of the leachates has been completed for Ca, K, Mg and a number of trace metals. Leachate from the leaf surface is dominated by Ca and K, with Mg loss being an order of magnitude lower. The results obtained for the trace metals indicate that in most cases these elements are found at, or near, the detection limits of the most sensitive techniques at our diposal. The results obtained in the leaching experiments mirror those for throughfall and generally reflect the levels of these elements in the foliage. No apportionment of element washoff from internal leaching and dry deposition can be made at the present time, however, because of an insufficient data base. Preliminary indications are that cation loss is not strongly influenced by hydrogen ion concentrations below $10^{-3}M$.

A microprocessor-controlled facility to conduct simulated acid rain studies under controlled environment conditions has been constructed. This will allow experiments to be carried out on a year-round basis with an adequate number of treatments and replications. Seedlings of sugar maple and soil have been collected from TLW for the experiments so that the studies are geared to regional trees, soils and precipitation loadings.

Estimates of net photosynthesis and plant water relations are being made on semimature sugar maple and yellow birch under a variety of conditions. This is basic physiological information that is being used in conjunction with experimental studies of plant response to simulated acid precipitation. Growth chamber studies at GLFC are aimed at determining the photosynthetic effects, growth responses and symptomatology of young trees exposed to acid precipitation. Field investigations on semimature trees are considered essential to the interpretation of results obtained on these young trees.

Effects on Tree Diseases

A study was begun at Thessalon, Ontario in 1984 on the impact of an increase in precipitation acidity on tree diseases to determine the infection success and growth rate of *Armillaria* species inoculated in the roots of sapling balsam fir exposed to simulated rain of 2.6, 3.6 and 5.3 pH, and to monitor other diseases and mycorrhizae occurring naturally on the treated trees. The abundance of incident insect damage and tree fungi is being monitored at monthly intervals during the growing season. Tree growth rate, needle retention and color, and number of dead branches will be compared at the beginning and end of the experiment. Major and minor nutrient element concentrations of foliage and soil, cuticle development on needles and mycorrhizae, as well as *Armillaria* infection and development, will be compared among treatments at the end of the experiment in late 1987.

Root diseases are assessed on seedlings treated with simulated acid precipitation.

What is the evidence that acid precipitation is affecting forest ecosystems?

Although regional air pollutants have the potential for causing growth reductions in Canada and elsewhere, the data are still insufficient to permit a definitive statement about whether there has been or is likely to be a loss of forest productivity. Acid deposition has increased the cycling of nutrients in some of the forest ecosystems examined in eastern Canada. In particular, accelerated leaching of foliar and soil base cations has been reported. The chemistry of water within the forest ecosystem, however, is still controlled largely by the cycle of nutrients between the vegetation and soil. The effect of the increased cycling on nutrient uptake by forests is unknown.

— *N.W. Foster*

ACID RAIN NATIONAL EARLY WARNING SYSTEM (ARNEWS)

In 1984, as part of Canada's response to international concern about the effect of acid rain on the environment, the Canadian Forestry Service was charged with the responsibility for detecting damage caused by acid rain in Canadian forests. At the present time, detection of damage caused by acid rain[1] in Canadian forests poses numerous problems. Unlike damage to lakes and aquatic systems, damage to forest systems directly attributable to acid rain has not been observed in Canada except in a few areas near sources of heavy emissions. Therefore, it is expected that identifying the subtle early stages of damage and distinguishing them from more "normal" damage caused by insects, diseases, and abiotic agents will be quite difficult. The Forest Insect and Disease Survey (FIDS), because it was already involved in detecting and evaluating forest pest damage across Canada, was given the mandate to establish a system for accomplishing this task. For this reason, a nationwide system of permanent monitoring plots has been established across all major forest zones and geographical areas of the country. Information gathered from these plots will be integrated with that gathered from other programs on acid rain.

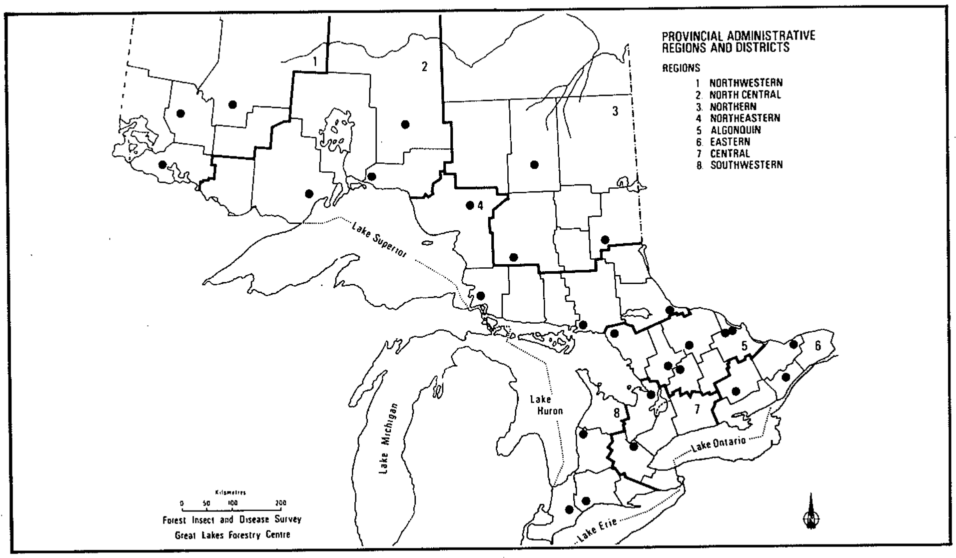
The objectives of the program are as follows:

1) to detect possible damage to forest trees and soils caused by acid rain or to identify damage sustained by Canadian forests (both trees and soils) that is not attributable to natural causes or management practices.

2) to monitor vegetation and soils over the long term so as to detect changes attributable to acid deposition and other air pollutants in representative forest ecosystems.

In Ontario, 27 plots have been established within the program (see map). They are located in stands of the province's major commercial tree species — white pine, jack pine, white spruce, black spruce, sugar maple, white birch, yellow birch, trembling aspen and red oak. A Norway spruce plantation is included as well.

Wherever possible, plots have been located in semimature stands to ensure that the trees are old enough to have been exposed to the effects of acid rain but young enough to accommodate the long-term nature of the project. As well, the plots are distributed among the various sulfur dioxide and nitrous oxide deposition zones in the province. Vertical and radial growth, crown structure and density are measured along with tree mortality. In addition, the presence and fluctuation of biotic and abiotic factors such as insects, diseases, drought or unusual rainfall, wind damage and winter drying are closely monitored. This is necessary to determine the condition or changes in the condition of forest stands so that the subtle initial stages of damage caused by acid rain can be detected. All parameters are measured in each plot during a base



Acid Rain National Early Warning System: 1987 plot locations.

[1]For the purpose of this study, the term 'acid rain' includes both wet and dry acid deposition, gaseous pollutants and particulates, and heavy metals, since all these factors, either alone or combined, can affect the health of forests.