Assessment of Forest Sensitivity to Nitrogen and Sulfur Deposition in New England and Eastern Canada

Conference of New England Governors and Eastern Canadian Premiers
Forest Mapping Group Pilot Phase Report

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Executive Summary

Acidic Deposition in Northeastern North America

Although sulfur emissions have decreased as a result of SO_2 control programs, projected emissions of acidifying sulfur and nitrogen compounds are expected to have continuing negative impacts on forests. These emissions present some of the most serious long-term threats to forest health and productivity in northeastern North America. Excess sulfur and nitrogen deposition may reduce the supply of nutrients available for plant growth. Nutrient depletion leads to increases in the susceptibility of forests to climate, pest and pathogen stress which results in reduced forest health, reduced timber yield, and eventual changes in forest species composition.

Forest Sensitivity Mapping Project

Conceived by the Conference of the New England Governors and Eastern Canadian Premiers (NEG/ECP), under the direction of its Committee on the Environment, their 1998 Acid Rain Action Plan called for the formation of a Forest Mapping Working Group to conduct a regional assessment of the sensitivity of northeastern North American forests to current and projected sulfur and nitrogen emissions levels. This group is charged with identifying specific forested areas most sensitive to continued sulfur and nitrogen deposition and estimating deposition rates required to maintain forest health and productivity.

How Was This Assessment Done?

Evaluating forest sensitivity to acidic deposition requires information on: pollution loading to forest landscapes; the interaction of pollutants with forest canopies; plant nutrient requirements; and the ability of soils to buffer acid inputs and replenish nutrients lost due to acidification. Recent scientific advances in estimating each of these factors have made it feasible to produce maps of forest sensitivity to acid inputs from atmospheric nitrogen and sulfur. An integral part of this project was an open dialog with scientists, air resource specialists, foresters, and members of provincial, state and federal governments about data, methodology, and interpretation of results. The development of appropriate methods, models and mapping techniques, and the identification of data requirements, have been completed and are reported in this Pilot Phase Report for one state (Vermont) and one province (Newfoundland).

Forest Sensitivity Assessment Metrics

Critical load of sulfur + nitrogen is the level of deposition below which no harmful ecological effects occur for a forest ecosystem.

Deposition index is the difference between the critical load and current deposition and is used to identify sensitive forest ecosystems.

The approach we have used to determine acceptable levels of deposition is an ecological assessment based on a steady-state, ecosystem mass balance for nutrient cations (calcium, magnesium, and potassium). Two metrics (*critical load* and *deposition index*) express the result of this assessment. The *critical load* of sulfur + nitrogen is the level of deposition below which no harmful ecological effects occur for a forest ecosystem (Figure 1). The *deposition index* is the difference between the critical load and current deposition (Figure 2) and is used to identify sensitive forest ecosystems. The magnitude of the deposition index indicates the severity of nutrient depletion caused by sulfur and nitrogen deposition. When exports of these nutrient cations are greater than inputs to an ecosystem, a condition known as *cation depletion*, inadequate levels of nutrients may develop in both soils and plants. Inadequate nutrient levels have been linked to a wide range of forest health problems, reduced growth rates, and increased mortality.

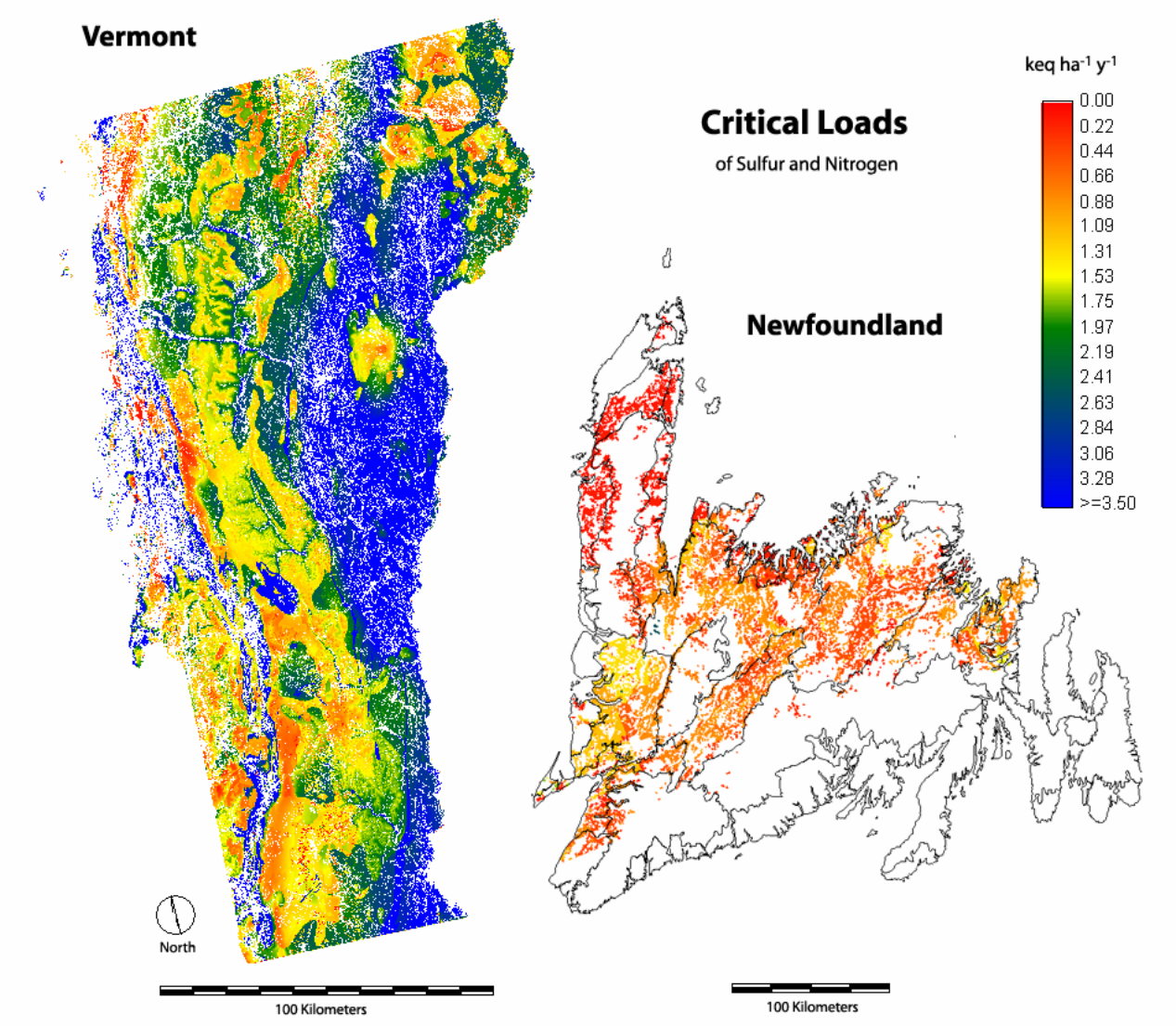

Figure 1. Critical load of sulfur + nitrogen deposition to upland forested areas of (a) Vermont and (b) Newfoundland. Sulfur + nitrogen atmospheric deposition rates higher than the critical load result in greater exports of nutrient cations (Ca^{2+}, Mg^{2+}, K^{+}) than inputs and eventual deterioration of soil fertility, forest health, and forest productivity. Critical loads are expressed in kilo-equivalents per hectare per year; nitrogen deposition includes both ammonium + nitrate forms.

Forest Sensitivity Findings

Sensitive forest areas were mapped in both Vermont and Newfoundland under the current emissions levels of sulfur and nitrogen (Figure 2). In Vermont, current levels of S + N deposition create the conditions for cation depletion in 31% of upland forests (561,127 ha). In Newfoundland, it is predicted that current levels of sulfur + nitrogen deposition are causing cation depletion in 23% of upland forests (456,845 ha).

Sensitive Forest Area Results:

- 31% of Vermont forests
- 23% of Newfoundland forests

Factors that increase forest sensitivity include: high levels of nitrogen and sulfur deposition, low mineral weathering rates, and tree species with high nutrient demands. High elevation forests and areas closest to emission sources experience the highest levels of nitrogen and sulfur deposition. Low mineral weathering rates occur in association with particular geologic and climatic factors. Requirements for soil nutrients vary according to the species currently growing in a forest, because tree species have different nutrient requirements for health and growth. Sugar maple trees, for example, have a high demand for calcium.

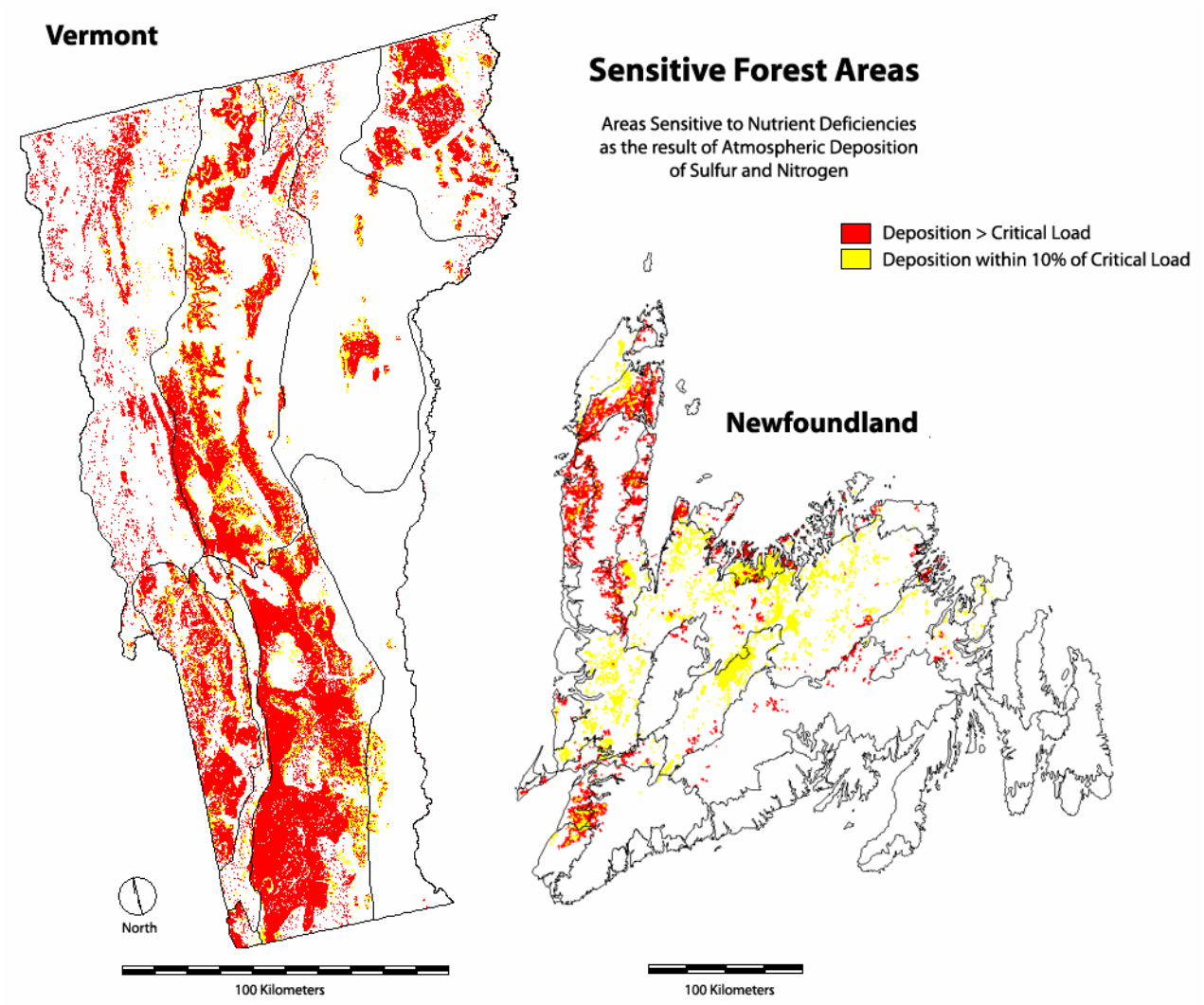

Figure 2. Forested Areas of (a) Vermont and (b) Newfoundland that are sensitive to the negative effects of combined atmospheric sulfur and nitrogen deposition. Red areas indicate current sulfur and nitrogen atmospheric deposition rates greater than the critical load. Yellow areas indicate current atmospheric deposition rates within 10% of the critical load.

Independent ecological indicators have been used to demonstrate that the assessment results are consistent with tree health observations from the region. Forests classified as sensitive by this approach exhibited crown health problems across Canada and in Vermont and lower tree growth in stands in Québec.

Projected Sulfur and Nitrogen Emission Levels and Future Forests

Modifications in pollutant emissions and deposition can affect the area and distribution of sensitive forests. We estimate that a 50% reduction in combined sulfur and nitrogen deposition would remediate the nutrient depletion problem on 78% of the sensitive forest area in Vermont and 68% in Newfoundland. Conversely, a 10% increase in combined sulfur and nitrogen deposition would cause an additional 12% and 8% of the currently unaffected forests to be classified as sensitive in Vermont and Newfoundland, respectively.

Solutions Are Possible:
A 50% reduction in N & S deposition can reverse forest effects by 78% in Vermont and 68% in Newfoundland.

Completing Forest Sensitivity Maps for Northeastern North America

Results of this pilot project provide compelling motivation to complete forest sensitivity maps for the entire New England and eastern Canada area. During the second phase of this project, regional data will be compiled to develop these valuable maps. Assessment components will be added to more accurately estimate the time span until forest health and productivity are compromised. Final maps for the region will be developed by the end of 2004, contingent upon funding.

Phase II will complete maps for all New England States and Eastern Canadian Provinces by 2004.

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