Issue Brief

Order Code MB84204

ACID RAIN: DOES IT CONTRIBUTE TO FOREST DECLINE?

(ARCHIVED--03/28/85)

UPDATED 01/24/85

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ISSUE DEFINITION

Some forests in various parts of the world are showing signs of declining productivity. Although research has attempted to find its cause, a definite link between acid rain and this decline has not yet been established. The research, however, has engendered considerable scientific debate. This debate over acid rain's role in U.S. forest decline is a source of controversy in congressional deliberations on whether to legislate emissions controls and reduce the amount of pollutant that is believed to be a possible precursor of acid rain -- sulfur oxides.

Should acid rain be implicated in this decline, the debate on emission reductions could be influenced by the fact that large dollar values may be at stake. Total value of U.S. forest products in 1977 was approximately $28 billion. A 2% decline, for example, could amount to $560 million.

This minibrief describes the major hypothesis explaining why acid rain may be contributing to forest decline, along with the major arguments against this hypothesis. For additional information on acid rain and current legislation for pollutant emissions controls, see IB83016 -- Acid Rain: Current Issues, and IB83005 -- Clean Air Act: An Overview.

BACKGROUND

Throughout central Europe, the Scandinavian countries, and parts of North America, some forests are showing signs of damage and decline. These forests first suffer what is called crown dieback. It begins with loss and discoloration of foliage and branches in the crown of the tree, then progresses downward and inward, decreasing the productive potential of the tree. There is no conclusive evidence as to why this phenomenon is occurring, and there is both scientific and political controversy over identifying the primary cause.

However controversial identification of a primary cause might be, a growing portion of the research generally concludes that acid rain is at least a contributor to the decline of forests. Most scientists agree that although the vulnerability of North American forests to acid rain and other airborne pollutants has not been fully documented, these pollutants must be suspected because the characteristics of these high elevation forests cause them to be receptors of high rates of acid and trace metal inputs and because of the increase in air pollution over the past few decades. Many scientists also hold that no single pollutant is responsible, but rather several pollutants (including sulfur and nitrogen oxides, heavy metals, and ozone) acting singly, in combination, or synergistically contribute to the damage and decline of forests.

Where is Forest Decline Occurring?

A general survey of the countries having forests suffering from crown dieback serves to give this problem a context. The problem appears to be most severe in West Germany, where 34% of the forests have been categorized as damaged, dying, or dead. Czechoslovakia and Poland both report about a half million hectares of forest damage (a hectare equals 2.471 acres). In

Romania, approximately 56,000 hectares of a 6.3 million hectare forest have been affected. Twenty-five percent of the fir and 10% of the spruce in Switzerland are reported damaged. The United Kingdom, Italy, France, the Netherlands, Austria, and Yugoslavia have also experienced forest damage.

The forest decline picture in North America is not as severe, widespread, or visible. Most of the affected forests are in the same areas that have lakes that are sensitive to acid deposition. Soils are sensitive for many of the same reasons as lakes: they are in regions recently glaciated, with large areas of exposed granitic and other noncalcareous bedrock. These soils are often thin and have low acid-neutralizing capability. The regions affected include parts of New York, New England, Ontario, Quebec, the Canadian maritime provinces, parts of upper Minnesota, Michigan and Wisconsin, parts of southern Appalachia, including Tennessee and North Carolina and parts of California, Washington, Oregon and Idaho. It must be remembered, however, that one cannot conclude that all soils in these regions are always uniform in their characteristics. Also, soil type is not the only variable that may correlate with lake acidification -- elevation, precipitation, watershed and genetic characteristics also play a role.

The area in the United States showing the greatest evidence of forest decline is the Appalachian mountain range. Red spruce, which grows throughout the Appalachians from the Northeast to Georgia, is the species that seems to be most affected. The most severe damage has been observed in the high elevations of New York, Vermont, and New Hampshire, where balsam fir and white birch also show signs of damage. In Vermont, over half the red spruce has been reported dead in a specific area called Camel's Hump.

Similar forest decline symptoms have also been observed in pitch, shortleaf, and loblolly pines in the New Jersey Pine Barrens and spruce, shortleaf pine, hemlock, fraser fir, hickory, and other species in Tennessee. Decline of ponderosa and jeffery pine stands in California has been generally attributed to ozone damage.

The Predominant Hypothesis

Although the fact that forests are declining is indisputable, there is no conclusive evidence as to the cause of this decline. This is due primarily to the complexities of the forest ecosystem, which includes associated soils, air, and aquatic biotas. Furthermore, the long life cycle of the forest and the lack of specific data for a complete life cycle complicates this research even more.

The most popular, best documented, and most controversial theory about the causes of forest decline is that of the German scientist Dr. Bernard Ulrich. His theory, based on two decades of research, is the basis for much current research. Many other theories have been advanced and refined, but Dr. Ulrich's remains the principal explanation for forest decline in Germany and Camel's Hump in Vermont and is the focal point for both supporting and refuting research.

Dr. Ulrich believes that acid deposition is the primary (but not only) cause of forest decline and death. He suggests that an ecosystem goes through three stages from the time acid deposition begins to when its effects are fatal:

(1) Pollutants are deposited in dry and wet forms on forest vegetation and

soils and accumulate in the ecosystem. These pollutants are acidic (or are precursors to acidic) substances, primarily nitrogen and sulphur oxides from anthropogenic sources. At first, the nitrogen and sulphur act as fertilizers, and a short-term increase in forest productivity is experienced because nitrogen or sulphur is usually the limiting growth factor in forest soils, particularly nitrogen.

(2) The ecosystem becomes destabilized as it is continuously subjected to and accumulates increasing amounts of pollutants. This destabilization is caused as acid percolates through the soil, and base cations (ions with a positive charge) essential to the tree's nutrition become displaced by hydrogen ions from the incoming acids. These cations, including potassium, magnesium and calcium, are then leached, or removed, from the rooting zone.

The continuing input of acids causes the soils to become more acidic over time, with a lowering of the soil pH. At low pH levels trace elements become soluble, and the aluminum ion, which is usually tightly held in the soil, is displaced. Aluminum and other trace elements are then available in the soil solution to be taken up by the tree or leached out of the soil. Increased amounts of aluminum, as well as other trace elements, can be toxic to trees.

The increased amount of aluminum and associated decrease in calcium affects the fine feeder roots of the tree and inhibits the uptake of water and nutrients, dehydrating the tree and depriving it of essential nutrients. This can also affect the ability of the forest to regenerate because of the effects on the roots of seedlings.

Vegetative effects are the first visible sign that the forest is ill. Direct pollutant deposition on the foliage and indirect effects through the soil can cause cellular necrosis, yellowing of the vegetation, and breakdown of the leaf or needle wax that blocks pores and allows water to evaporate; thus the tree can dehydrate. The magnesium at the center of the cholorophyll molecule is used to buffer the sulphur dioxide and is leached from the vegetation. Consequently, the tree's photosynthetic rate and capability is decreased because of a breakdown of the chlorophyll molecule; color is lost along with the tree's ability to photosynthesize, or manufacture food and repair cellular damage.

(3) The effect of this destabilization on individual trees and the ecosystem is dieback. It may be seen on taller trees first; then it works from the outside of the stand towards the center, causing increasing decline of the stand. This decline can eventually lead to mortality and subsequently to a new ecosystem with different species that are better adapted to the new, more acidic, environment.

Major Arguments Against the Hypothesis

Many scientists disagree with the Ulrich theory that acid rain is the primary cause of forest decline. These scientists do not believe that conclusive evidence has been found that completely unravels the complexities of the problem and that definitively links acid rain with forest dieback and decline, especially for the decline that is occurring in North America. The main controversy centers around the aluminum mobilization aspect of Ulrich's theory. Two other factors, drought and natural soil formation processes, are also believed by some to be possible causes of this decline, and increased acidity in certain environments.

Studies of declining spruce and fir have determined that roots were calcium deficient relative to those of healthy trees, but that healthy and declining trees contained the same concentrations of aluminum. In addition, the parallel decrease in the fine roots and increase of aluminum in the soil solution is questioned because some research has found that marked decreases of roots preceded the increase of aluminum. Finally, declining fir has been observed on calcaeous soils, which could preclude both the aluminum toxicity or calcium deficiency theories.

A number of scientists hypothesize that a series of dry summers interfered with root regeneration and could have promoted forest dieback by predisposing the trees to acid rain. Drought stress is important because in combination with other predisposing factors related to site condition it has triggered forest declines in the past. Core samples show this type of response during the 1960s in the Northeast United States may have triggered the dieback seen now. It has been argued that a recovery usually follows a decline, but a recovery to the current decline is not yet in sight. Few people believe that the German forest and the red spruce on Camel's Hump are redeemable. Also, it is not known which came first - -the drought, which predisposed the tree to pollutants, or the pollutants, which made the tree more susceptible to drought or other environmental stresses.

Another theory is that natural weathering and soil formation processes are more significant in the acidification of soils and waters and the leaching of nutrients and toxic metals from soils than anthropogenic sulphur and nitric acids. According to this hypothesis, changing land use patterns -- for example, the return of forests after severe clear-cutting -- has caused a build-up of organic soil that in combination with the natural weathering process is causing the acidification of lakes and streams.

Soil acidification is, in fact, a natural process. Soil is formed in part by the decomposition of organic matter. As organic matter is decomposed, both organic and inorganic acids are formed. The most widely found are organic acids such as carbonic, humic, fulvic, and tannic.

But these acids are relatively weak and although they can cause some leaching, they do not account for the low pH values found in many soils. Inorganic acids, such as sulfuric and nitric acids, are much stronger and are primarily responsible for acidic soil conditions. These strong acids -- the same found in acid rain -- have been found in acidified lake waters. In addition, acidified lakes have been found above tree line, placing them above reforested areas, and watersheds with and without changes in their land use patterns have been observed to acidify at equal rates.

Summary

Forest decline is occurring in several areas throughout the world. Although conclusive evidence cannot yet pinpoint the primary cause, acid rain, along with other air pollutants, is suspected to contribute to the decline of forests. The hypothesis advanced by Dr. Bernard Ulrich presents the best documented, but still very controversial, explanation of the role of acid rain. Many scientists disagree with how acid rain might factor in forest decline, and several scientists have advanced theories contrary to that of Dr. Ulrich. Scientists also differ as to the effectiveness of proposed legislation on North American forests: some believe this legislation is not needed because the cause of the problem is not definitively known; others believe that forest decline will continue if

legislation is limited to sulfur dioxide reduction and does not encompass other air pollutants.

Research continues to try to pinpoint the primary cause and identify the roles that acid rain and air pollution igeneral play in the forest decline phenomenon.