On the Air

Technical Notes on Important Air Quality Issues

Energy Research & Technology Applications
Public Power Institute

Nitrogen Saturation

Nitrogen saturation related to acidic deposition may impact the health of high-elevation forest and aquatic ecosystems. Symptoms associated with ecosystem N saturation may be more prevalent as elevated atmospheric N inputs and changes in ecosystem structure unbalance system N utilization/retention capacity. This issue has important environmental policy implications.

What is Nitrogen Saturation?

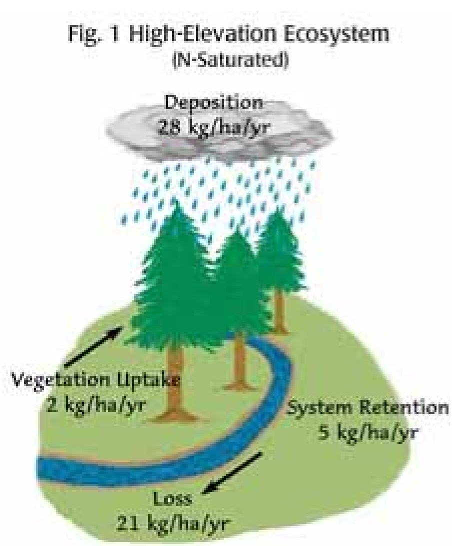


Fig. 1 High-Elevation Ecosystem (N-Saturated)

Global levels of N deposition—often in the form of acidic deposition—have increased dramatically in the past century as a result of increased NOx emissions from fossil-fuel combustion and use of N-containing fertilizer. Studies in both Europe and North America provide some evidence that the health of high-elevation ecosystems may be degraded by excessive N deposition.

Simply put, N saturation occurs when N input exceeds an ecosystems' capacity to effectively use or retain N. This is most likely to occur in slow-growing, old-growth forests at high elevations (**Figure 1**). These high-elevation forest ecosystems may be subjected to excessive N input from cloudwater which can more than double the amount received by lower-elevation ecosystems. The combination of high N input and slow growth, which requires less N, leads to excess system N and subsequently high N loss rates.

Nitrogen saturation is not a problem for typical ecosystems where N availability is a growth-limiting factor (**Figure 2**). Atmospheric N deposited on typical ecosystems is almost all assimilated in growth and nutrient cycling processes. Consequently, N loss rates are very low.

What are the Consequences of Nitrogen Saturation?

Nitrogen not incorporated into growth processes can be either retained or transported into ground and surface water. Excess N may result in:

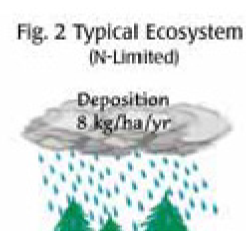
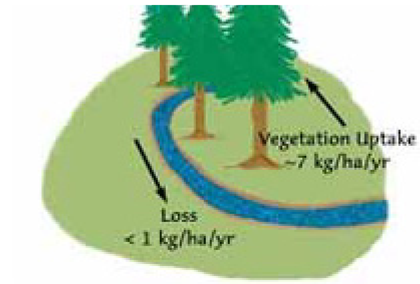


Fig. 2 Typical Ecosystem (N-Limited)

- Loss of essential nutrient cations such as calcium and potassium as they are leached along with N. Nutrient deficiencies may result.
- Increased levels of mobilized aluminum which can be toxic to plants and/or inhibit root uptake of essential nutrients.
- Increased nitrate, aluminum, and acidity in ground and surface waters can degrade

stream habitat for fish and other aquatic life.

- Increased N-related stresses, such as nutrient deficiencies, may increase ecosystem susceptibility to other biological (e.g., disease and insects), climatological (e.g., drought), and manmade (e.g., ozone) stresses.



System Complexity

Ecosystem N dynamics are complex and highly variable. In addition to the variation in N input (atmospheric deposition), assimilation, and loss (mineralization, ground and surface water), other ecosystem characteristics, such as stand structure, abundance of woody debris/litter, species composition, and developmental stage, greatly influence the distribution and movement of N.

Under conditions of N saturation, N availability to plants and microorganisms is high and the need for N conservation is minimal. This is expressed by faster loss of canopy N, net N release from system components (plants, soils, litter, etc.) by means of microbial processes, and N loss to ground and surface water.

Conversely, more typical ecosystems are conservative with regard to N. Canopy N is retained longer and losses are slower. Nitrogen in the forest floor is immobilized and there is little opportunity for N mineralization. This results in low N availability for plants and no measurable N loss to ground and surface water.

Understanding the magnitude and significance of such highly complex system components is critical in understanding N dynamics and predicting the overall impact of natural and manmade factors on ecosystem health.

Conflicting Evidence

The Environmental Protection Agency (EPA) Acid Deposition Standard Feasibility Study (1995) accepted N saturation in the Southern Appalachians as inevitable, given historic and current deposition rates. The NPS also asserts that the Southern Appalachians are suffering from N saturation. However, there is little quantitative evidence supporting either of these assertions.

Evidence from the high-elevation Noland Divide Watershed in the Great Smoky Mountains indicate some N leaching in ground and surface water, as would be expected under N saturation. However, toxicity has not been observed in the field and there are only limited reports of nutrient deficiency effects. These findings are suggestive of an intermediate level of N saturation, but the evidence is not conclusive.

How is TVA Responding to This Issue?

TVA is participating in a cooperative Acid Deposition Standards project to build a N-critical load model for the high-elevation Noland Divide Watershed. This model will estimate the rate of N movement through different system components under varying deposition and stand conditions. Other project participants include the National Biological Service, EPA, and NPS.

By addressing the issue of potential N saturation, this project will provide evidence as to whether or not additional reductions in NOx emissions may be justified to protect ecosystem health. Also, in developing and testing this model, the project will also provide information on a potential regulatory approach.

Preliminary Findings

The high-elevation ecosystems of the Southern Appalachians are dominated by red spruce and Fraser fir forests. In the Smoky Mountains, Fraser fir began dying in large numbers in the late 1980s after infestation by the balsam woolly adelgid–a natural phenomena. Consequently, what was once a slow-growing, old-growth forest may soon exhibit the regeneration dynamics of a younger, fast-growing forest.

Also, the large-scale conversion of standing trees to downed timber may play a critical role in N dynamics. As the downed timber decays, the carbon-to-N ratio changes due to microbial action. Microbial respiration and leaching cause the amount of carbon to decrease, while N immobilization causes the N in wood to increase. These early results suggest that the recent die-off of Fraser fir may have inadvertently provided a short-term mechanism to mitigate potential N saturation.

Information Contacts

Niki S. Nicholas
(423) 632-1676
nsnicholas@tva.gov

John D. Joslin
(423) 632-1737
jdjoslin@tva.gov

Last updated on 3-07-00.
Inquiries and comments should be sent to wjparkhurst@tva.gov.