Stable isotope techniques for determining relative rates of nitrogen cycling and sources of nitrate lost from forest ecosystems

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Human activities, such as the burning of fossil fuels and production of fertilizer, have increased the amount of nitrogen deposited onto terrestrial ecosystems. In addition to changes in atmospheric deposition of nitrogen, other human-induced disturbances have led to dramatic shifts in forest composition of the United States over the last 100 years. Tree species composition of many forests is changing in response to introduced pests and pathogens, competition with introduced plant species and changes in climate. Understanding the combined effects of increased nitrogen inputs and changes in plant species composition on forest nitrogen cycling is critical to our understanding of forest biogeochemistry and nutrient budgets. It is also important to understand controls on nitrogen retention because nitrogen lost from forested watersheds can cause detrimental impacts such as forest nutrient imbalances, acidification and eutrophication of waterways. Despite several decades of research on the effects of atmospheric nitrogen deposition, there is still significant uncertainty about the factors that regulate nitrogen retention and loss in forest ecosystems.

The use of natural abundance stable isotopes of nitrogen and oxygen has proven to be a powerful tool for tracing the sources of NO_3- in water, from inputs to leaching, as it moves through an ecosystem. The evaluation of natural abundance $\delta^{15}N$ values in atmospheric deposition has been used to partition sources of nitrogen, such as coal-fired power plants vs. tailpipe exhaust, since each of their isotopic signatures is distinct. Similarly, the natural abundance $\delta^{18}O$ values of $^{15}NO_3$- in atmospheric inputs and soil leachate have been used as a tool to partition sources of NO_3- between precipitation and NO_3-produced microbially during nitrification. Accurate determination of $\delta^{15}N$ and $\delta^{18}O$ of NO_3- is necessary for successfully determining sources of NO_3- lost from terrestrial ecosystems. In this talk I present a novel way to measure the natural abundance isotopic composition of NO_3- in atmospheric deposition, canopy throughfall or soil solution samples. This method includes the combination of ion exchange resin beads with the denitrifier method to both identify sources of nitrate and to calculate total fluxes of nitrogen.

This method was tested in the laboratory and used in a study to quantify rates of nitrogen inputs to the forest and to determine rates of nitrogen losses from healthy, declining and preemptively cut eastern hemlock (Tsuga canadensis) stands in both an urban forest at the Arnold Arboretum in Boston, MA, and a rural forest at Harvard Forest in Petersham, MA. The hemlock woolly adelgid (Adelges tsugae Annand), an introduced aphid-like insect from Japan, threatens hemlock stands throughout the eastern United States. The hemlock woolly adelgid was first reported in forests of the eastern United States in the early 1950s and is currently leading to mortality of eastern hemlock trees from Georgia to Massachusetts. We found that rates of nitrogen inputs to the forest floor were 4-5 times greater, and rates of nitrogen losses via leachate were more than ten times greater, at the Arnold Arboretum compared to Harvard Forest. Our results also show that current management regimes used to control the hemlock woolly adelgid, such as salvage cutting, may be reducing nitrogen losses in urban areas due to rapid regrowth of vegetation and the associated uptake of nitrogen by those plants. In contrast, cutting of trees in rural areas may be leading to proportionately greater losses of nitrogen in those sites, though the total magnitude of nitrogen lost is still smaller than in urban sites. Results of this study suggest that the combination of the hemlock woolly adelgid, atmospheric nitrogen inputs and management practices lead to changes in the nitrogen cycle within eastern hemlock forest ecosystems.