Isotopic Investigation of Reactive Nitrogen Deposition Along a Highway Road Gradient

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Introduction

Though it is well understood that mobile emissions on highways create "hotspots" of air pollution, there is limited understanding of the effects of these emissions on the surrounding environment and human health. For example, dry nitrogen deposition from automobile exhaust may have important implications for near-road ecosystems, including adverse effects on plant communities.

This research uses stable isotopes of carbon and nitrogen in plant tissue and gas samples to determine the spatial extent and impacts of highway pollution, including CO_2 and NO_x. The major sources of CO_2 and NO_x, including fossil fuel combustion and biogenic emissions, have distinct isotopic signatures. Plant tissue incorporates atmospheric CO_2 and NO_x and thus reflects the isotopic signature of local emissions. Therefore, stable isotope analysis of C and N in plant tissue can be used to trace the contribution of anthropogenic and biogenic sources of CO_2 and NO_x to vegetation.

Methods

Gradient

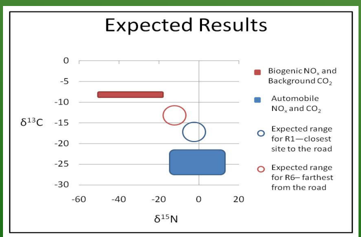
Six sites were established in a gradient perpendicular to I-76 near Donegal, PA. Sites were located at 2, 12, 30, 91, 188 and 460 meters from the road. ~33,000 vehicles per day travel this section of the highway.

Grasses

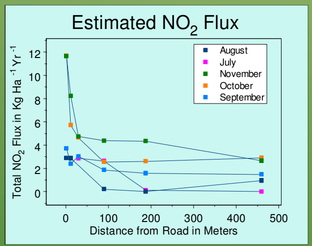
Each site contained two types of grasses: one Switchgrass (*Panicum virgatum*) and one Bentgrass (*Agrostis perennans*). All grasses were potted in similar potting soil to reduce isotopic variation. Plants were also grown in plastic pots to isolate the roots from local soils, thereby restricting plant nutrients to the potting soil and atmospheric deposition. Plants were sampled prior to deployment and then monthly for 4 months. Samples were dried, ground and analyzed for isotopic composition of carbon and nitrogen.

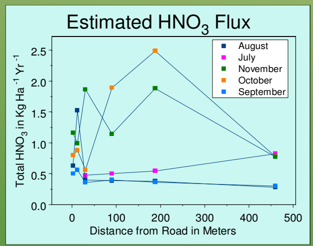
Gases

Passive samplers were deployed at each site to collect dry nitrogen deposition of three species (NO_2, HNO_3 and NH_3). In addition, CO_2 samples were collected in Tedlar bags. Samples were taken monthly for 5 months and then analyzed for concentration and isotopic composition.



Results- Nitrogen Gas Concentrations





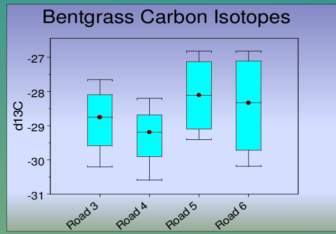
NO_2 concentrations rapidly decrease with distance from the road. In all months, the two sites closest to the road had the highest NO_2 deposition. HNO_3 flux follows similar patterns for July, August and September. However, in October and November, sites farther from the road had higher HNO_3 deposition. This could reflect changing oxidation patterns during colder months, in which HNO_3 takes longer to form, and therefore deposits farther from the road.

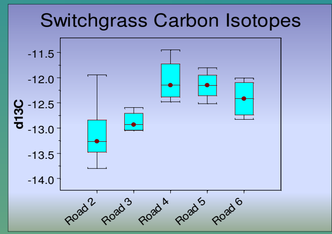
It is important to note that these figures are a first approximation of nitrogen flux. Values were calculated using concentration of N collected on the filter of the passive sampler normalized to the number of days exposed and the filter area. Therefore, this estimate assumes that all the N collected on the filter can be extrapolated to a larger area to calculate flux. These estimates do not incorporate a deposition velocity, which is key in making flux calculations. Ongoing work includes modeling deposition velocities for this site and incorporating that data into the flux calculations.

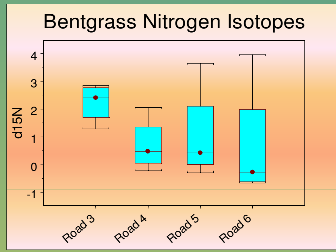
Results- Carbon and Nitrogen Isotopes in Plant Tissue

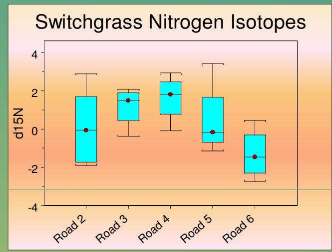
CO_2 from fossil fuels has a more negative isotopic signature than background atmospheric levels. Therefore, we expect that carbon in plants closer to the road should have a lower isotopic signature from being exposed to automobile emissions. For both Bentgrass and Switchgrass, the results support our hypothesis.

We expected nitrogen isotopes would be more positive close to the road reflecting an automobile signature and more negative far from the road because of biogenic NO_x production. The results varied for Bentgrass and Switchgrass. Bentgrass had more positive values close to the road, while Switchgrass peaked at site 4. The isotopic signatures of N gas samples may allow us to interpret these trends. For example, we may be able to determine the source of N to plants (NO_2, HNO_3 or NH_3) and the assimilation patterns (ie., uptake through the roots or stomata).



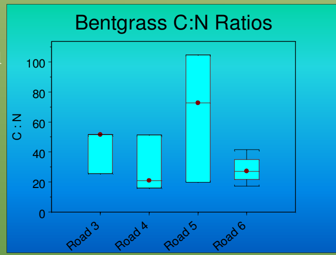


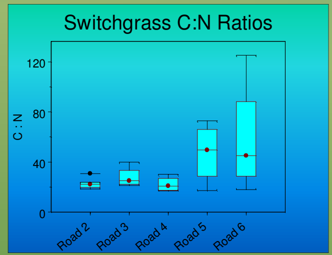




Results- C:N Ratios in Plant Tissue

Lower C:N ratios indicate more nitrogen in plant tissue. Plants near the road would be expected to have more N in their tissue because of exposure to higher atmospheric N concentrations. While this relationship is not clear with Bentgrass, in Switchgrass the closest sites have the lowest C:N ratios, and therefore have the most N in their tissue.





Discussion and Implications

Along the gradient, higher concentrations of CO_2 and NO_x from automobile emissions near the roadway have altered the isotopic composition and nitrogen content of experimental plants. Furthermore, the highest levels of N deposition were within 30 meters of the road, resulting in concentrated areas with very high N fluxes. This has important public policy implications; U.S. roadways are not regulated as point sources of pollution despite this spatial pattern of concentrated N deposition.

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