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Determining threshold responses of plant-soil feedbacks to nitrogen deposition

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Abstract
Change associated with nitrogen deposition in the soil will alter ecosystem function and diversity. This study looks at precisely how plants and soil will interact to respond to the addition of N at various levels and in different forms.

Keywords
Ecology Evolutionary and Organismal Biology, Nutrient management, Conservation practices, Soils and agronomy

Disciplines
Ecology and Evolutionary Biology | Natural Resources Management and Policy | Soil Science

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Abstract: Change associated with nitrogen deposition in the soil will alter ecosystem function and diversity. This study looks at precisely how plants and soil will interact to respond to the addition of N at various levels and in different forms.

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Budget:
$48,325 for year one

Q How can research determine how nitrogen increases affect certain ecosystems?

A The project developed infrastructure and baseline data to study the effect of chronic, low-level nitrogen addition in grassland ecosystems, such as tall grass prairie.

ECOLOGY

Background

Humans are altering the global climate and nutrient supplies that have important consequences for plant community production and diversity. The interactions and potential for feedback among these greatly affected planetary boundaries are poorly understood, but their maintenance is critical for ecosystem services and human livelihood.

Plants and the organisms in their rhizosphere are important regulators of these critical ecosystem functions. However, these interactions also are sensitive to changes in the environment, such as alterations in plant community composition or increased nutrient inputs in the Midwest, for example. Fertilized native plant communities are taller and are dominated by invasive species such as smooth brome. Belowground, high-nutrient environments tend to be dominated by bacteria and their consumers, which enhance N cycling and nutrient leakage from the community.

The long-term goal for the project is to understand how N deposition impacts the stability of coupled plant-soil (CPS) interactions, as these interactions contribute to diversity maintenance and ecosystem function. The overall objective of this project is to determine threshold responses to nutrient enrichment in mesic perennial grasslands of the type that are being proposed 1) to mitigate agricultural nutrient and soil loss and 2) as candidates for biofuel cropping systems.

The central hypothesis of the project is that nutrient enrichment decouples plant-soil interactions, and results in non-linear changes in ecosystem functioning. The proposed experiment leverages the data and infrastructure of an established global experimental network, the Nutrient Network (NutNet: www.nutnet.org) to establish a new gradient experiment that complements and follows NutNet's established protocols and design: NitNet (for Nitrogen Network). To provide a firm foundation for NitNet, there were three project objectives:

1. Establish three NitNet sites along an east-west gradient across Iowa;
2. Deploy monitoring stations throughout the state to quantify both wet N-deposition and gaseous N-levels; and
3. Quantify coupled-plant-soil indicators of N deposition thresholds.

ISU undergraduate students Jordann Bickley (junior) and Michael Polzin (senior) setting up project site at Indian Creek Nature Center.

The working hypothesis for the third objective is that the specificity of organisms in the rhizosphere declines with nutrient enrichment. Also, that those plant species that increase in dominance following N-enrichment are relatively less dependent on CPS specificity than those species that decrease in dominance.

Approach and methods

Three sites were established in restored prairies along an east-west transect across Iowa: Chichaqua Bottoms GreenBelt in Polk County; Ahart-Rudd Natural Resource Area, which is owned and managed by Crawford County Conservation; and Indian Creek Nature Center in Linn County. Data collected at these sites included information on plant community structure, plant net primary production, soil nutrients, plant nutrients, and soil microbial community structure and function. Applications of fertilizer and data collection will occur annually for at least five years.

In order to understand how systems are responding to low levels of nitrogen input, it is necessary to know the form and quantity of ambient N inputs. This is particularly critical in Iowa, which has an abundance of non-point N pollution sources, including fertilizer runoff from row crops and NH_3 emissions from feedlots. Because of the modest scale of current N deposition monitoring, the general understanding of N deposition is primarily derived from model extrapolations, but site-level deposition rates often can be orders of magnitude greater than model estimates of N-deposition. Understanding the timing, distribution, and type of N deposition will enhance prediction of the functional responses of the ecosystem to these inputs. The statewide dataset will provide context within which to place these data and allow for extrapolation to other regions.

Researchers set out to determine ambient N-deposition at both the NitNet sites (n=3) and the network of ISU research farms (n =12). They deployed two types of nitrogen collectors, one for N-deposition through precipitation and a second for gaseous ammonia (NH_3) collectors. In addition to these monitors, there was a weather station with a tipping bucket precipitation monitor placed at each NitNet site.

Results and discussion

Results at this time are limited because the researchers are still analyzing extracts from the past summer's (2014) collection. There were no significant differences from baseline in community composition, net production or soil nutrients at the Nit-Net sites after one year. The researchers currently (early 2015) are analyzing the samples from the monthly collections of the NH_3 and wet-deposition monitors collected from the farms and the research. The collection and analysis of the yearlong collectors will occur in early May 2015.

The team noted that N-deposition had not occurred for a long enough period to find substantial differences in the newly established plots. However, collected data from the established gradient (0, 10, 50 and 100 kg of N ha-1 yr-1) at the Chichaqua site provided more evidence to suggest that the response to N addition is non-linear.

In summary, how the community changes in response to low levels of nitrogen remains a conundrum. Plant-soil sampling from a previously established site (with five years of nutrient input) has not offered definitive answers about plant and soil community changes at low levels of nitrogen. In some cases (such as plant biomass, cover and richness) the amount of N does not affect that variable. In other cases, there are proportional changes in the variable related to the amount of N added, especially in the behavior of specific species. (For example, little bluestem cover decreases in a linear way with added nitrogen.)

Finally, in some cases such as soil N and C, total phospholipid fatty acids (PLFA) and changes in species cover, only the N10 treatment affects the variable. (PLFA and PLFA richness are measures of microbial community size and diversity, respectively.) The mechanism for these differences is unclear and long-term monitoring at more sites, such as those established with this grant, is required to answer questions concerning plant-soil interactions.

Conclusions

Plant interactions with organisms in the soil surrounding their roots can regulate C sequestration and contribute to diversity-driven patterns in productivity that are critical for continued ecosystem health. With this series of experiments, the PIs tried to identify the threshold effects of N deposition on plant-soil interaction although data on this point remains inconclusive. However, by linking nutrient-driven changes in plant-soil interactions with C storage, the research addresses a critical gap in understanding of the "black box" belowground processes that regulate plant productivity in general as well as diversity responses to global climate change.

Impact of results

- Establishment of three sets of plots for long-term monitoring of plant community composition was accomplished.
- The two PIs were awarded a grant from the National Science Foundation to continue the work started by this project: Harpole WS, Biederman LA. 2014-2016. A Global Test for Non-linear Responses of Grassland Diversity to Nitrogen Deposition. $300,000.

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Education and outreach

The PIs are working on four manuscripts for peer-reviewed publications, including three with undergraduate students.

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Leveraged funds

Supplementary funding was received for Brittney Ross's study from the Department of Ecology, Evolution and Organismal Biology. Additional funds ($5,000) came from National Science Foundation grants to Harpole and Biederman (mentioned in the Impact section). These funds were used to employ undergraduate research assistants to manufacture additional nitrogen collectors.