**Title:** Assessing leaf to whole-plant acclimation to nutrient addition and light availability using aboveground nitrogen concentrations

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**Abstract:** Physiological theory suggests that plants should acclimate to changes in environmental conditions by allocating resources in a such a way that would maximize carbon uptake per resources used. Photosynthetic optimization is one of the most widely examined aspects of this theory. Recent theoretical developments have provided an avenue for predicting optimal photosynthetic acclimation to changing conditions, including changing temperatures, moisture conditions, atmospheric carbon dioxide levels, and light. However, the theory lacks a nutrient availability component. Nonetheless, the fidelity of the nitrogen-free theory to field observations suggests that nitrogen availability may not influence photosynthetic traits, including leaf nitrogen availability and photosynthetic capacity. Instead, these traits have been shown to be driven by light, temperature, and moisture gradients. This suggests that plants are utilizing nitrogen available to optimize within-leaf biochemistry in response to environmental conditions, thus maximizing the amount of nitrogen available for production of new tissue and/or storage. As such, the theory suggests that the primary driver of fertilization-induced increases in gross primary productivity is an increase in leaf area, rather than an increase in per leaf area photosynthesis as is commonly assumed in large-scale terrestrial biosphere models.

Here, we propose to use leaf- and whole-plant nitrogen data from the Nutrient Network to assess photosynthetic optimization theory in response to light, climate, and NPK fertilization. Leaf nitrogen content will be used a proxy for photosynthetic capacity. Our analyses will use the plant nitrogen data, along with light availability and climate data to test the nutrient-free leaf biochemical optimization theory. Our hypotheses, based on the nutrient-free optimization theory, are that (1) the fertilization-stimulation of leaf nitrogen will only occur at low light levels, as a result of increases in leaf nitrogen storage in closed-canopy environments. This low stimulation will be the result of leaf optimization to light availability. However, (2) we expect the positive response of whole-plant-level nitrogen to fertilization to increase with light, indicating that changes in leaf area are the primary drivers of GPP increases with fertilization. The modulation with light will be the result of canopy closure in high light environments. (3) At the leaf level, we expect the fertilization-induced stimulation of leaf N to increase as water availability decreases as plants increase water use efficiency at low water availability. However, (4) we expect a positive fertilization-induced stimulation of whole-plant and ecosystem N in response to water availability as a result of increased leaf area. We will also further investigate questions related to different nutrient additions as well as light by water interactions.

The NutNet experiment and plant nitrogen content datasets are ideal for testing the proposed hypotheses for how plants respond to nutrient availability at the leaf and whole-plant level. This study will advance our understanding of plant function and the results will ultimately be used to improve future projects of global carbon, water, and nutrient cycling.