Soil nitrogen availability increases the positive effect of aridity on water use efficiency

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Background/Question/Methods

Terrestrial biosphere models commonly predict leaf photosynthesis based on positive relationships between soil nitrogen, leaf nitrogen, and photosynthetic capacity. While positive empirical relationships between soil nitrogen and leaf nitrogen are common, recent work leveraging photosynthetic least-cost theory indicates that interactions between aboveground climate and soil nitrogen may be a more reliable predictor of leaf nitrogen allocation than soil nitrogen alone. Specifically, the theory predicts that increasing aridity will increase leaf nitrogen allocation, which will allow individuals to maintain photosynthesis at lower water use. It also predicts that soil nitrogen availability should increase the positive effect of aridity on leaf nitrogen allocation and water-use efficiency. However, few direct tests of this theory exist, and the timescale that plants respond to is unknown. To test the theory, we measured leaf nitrogen and water-use efficiency at 25 sites scattered across a precipitation and soil nitrogen availability gradient in Texas. We estimated aridity at recent (average of the previous month) and more distal (average of the previous 15 growing seasons) timescales using the standardized precipitation evapotranspiration index.

Results/Conclusions

There was no effect of either aridity estimate, soil nitrogen, or functional type on leaf nitrogen per leaf area. These patterns were driven by similar directional effects of aridity, soil nitrogen, and functional type on leaf nitrogen per leaf mass and specific leaf area. Variance in leaf nitrogen per leaf mass was driven by a three-way interaction between previous month aridity, soil nitrogen, and functional type. This interaction indicated that leaf nitrogen per leaf mass generally increased with previous month aridity, and that this positive effect increased with soil nitrogen. Variance in water-use efficiency was best explained by a three-way interaction between previous 15-year growing season aridity, soil nitrogen, and functional type. This interaction indicated that increasing previous 15-year aridity increased water-use efficiency, and that this effect increased with increasing soil nitrogen. Patterns for both leaf nitrogen per leaf mass and water-use efficiency were observed in C_3 graminoid, C_3 forb, and C_3 leguminous species, but not C_4 graminoid species. These results support patterns expected from photosynthetic least-cost theory, providing additional context to understanding nitrogen-water use tradeoffs across environmental gradients.