Nitrogen Versus Phosphorus Limitation: A Factorial Fertilization Experiment in Temperate Hardwood Forests

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The MELNHE Experiment

Experimental tests of N and P limitation in temperate forest systems are few, and those few have been short-term with very high rates of fertilization. In 2011 we began long-term low-level additions of N, P, and N+P in 13 forest stands distributed across three sites in the White Mountain National Forest of New Hampshire. At Bartlett Experimental Forest (BEF), which is underlain by granite, we have three young, three mid-aged, and three mature stands. At both Hubbard Brook Experimental Forest (HBEF), on granodiorite, and Jeffer Brook (JB) on amphibolite (metamorphosed basalt), we have one young and one mid-aged forest stand. Each stand has four plots treated annually with N (30 kg/ha/yr as NH4NO3), P (10 kg/ha/yr as CaH2PO4), both N and P, and control. These relatively modest rates are designed to alter site fertility while minimizing artifacts associated with high doses of fertilizer. These treatments allow us to test for N co-limitation and to challenge balanced forest nutrition and thereby induce mechanisms that maintain co-limitation, such as those represented in the Multiple Element Limitation Model (MEL).

Nutrient Manipulations in Stands of Different Ages in Three Sites

In 2015, in eight additional stands, P resorption was less with P addition and N resorption was less with N addition, but there were not significant interactions with N and P.

Summary

Foliar N+P in the untreated mid-aged and mature stands indicate that most of our sites are P-limited rather than N-limited. Consistent with P limitation, plots receiving P moved into the co-limited range, and those receiving N were even more P-limited after 5 years of treatment, according to their foliar N:P ratios. Tree growth responded more to P addition than to N addition in mid-aged and mature stands (P = 0.02). These results are surprising because temperate forests on glacialized soils have been presumed to be N-limited, but they are consistent with predictions of the MEL model, parameterized for our experimental conditions. Given the evidence for P limitation to aboveground growth, we expected to find reduced root biomass under P addition. Instead, we found that roots increased in response to P in the young stands. Roots marginally decreased in response to P in the old stands. Perhaps root turnover was reduced by P addition, consistent with reduced microsite depletion; greater root biomass need not reflect greater investment belowground. A better understanding of the capacity of ecosystems to balance the acquisition of limiting resources is needed to manage ecosystems in the face of continuing environmental change.

Bibliography


Li, W., R.D. Yanai, M.C. Fisk, M.A. Vadeboncoeur, B.A. Quintero, and T.J. Fahey. 2015. Soil respiration in 2016 was significantly reduced by N addition (p = 0.02). In 2015, in eight additional stands, P resorption was less with P addition and N resorption was less with N addition, but there were not significant interactions with N and P.

Soil respiration in 2016 was significantly reduced by N addition (p = 0.02). There was no effect of P (p = 0.50) and the interaction of N+P was also not significant (p = 0.30). We did not expect belowground carbon allocation by roots to be reduced by N addition, but this result is consistent with a depression of decomposition rates.

Foliar N and P in 2015 for maple and beech in mid-aged and mature stands. N:P ratios between 14 and 16 are considered to indicate co-limitation (Skagwell 2006). These below 10 and above 20 indicate N and P co-limitation, respectively (Bloomer and Melznerman 1996).

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