What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major activities

This report covers the 4th year of a 5-year grant. The MBL component of the grant is in years 1 and 5, with no activity in years 2-4 other than maintaining contact with the other project members and attending meetings (I will attend the Hubbard Brook meeting in July 2014). There are therefore no new findings to report.

Specific objectives

significant results

key outcomes or other achievements

What opportunities for training and professional development has the project provided?

The analyses of interactive N and P cycles using the MEL model continue to be a part of the modeling courses in the Semester in Environmental Sciences program here at MBL (http://ecosystems.mbl.edu/SES/) and of the Brown-MBL graduate program (https://courses.brown.edu/courses/spring-2013/envs-2680-s01). Based on work in the Brown modeling class this past semester, Marc Hayes has incorporated a C-N biogeochemical model into his dissertation work on harvest and fire in African dry forests; I am helping with that model. Chelsea Nagy continues development of her model of tropical C-N-P interactions.

How have the results been disseminated to communities of interest?

The modeling component of the project has resulted in one publication thus far (reported last year in the fastlane reporting system):

Rastetter, EB, R.D. Yanai, R.Q. Thomas, M.A. Vadeboncoeur, T.J. Fahey, M.C. Fisk, B.L. Kwiatkowski, and S.P. Hamburg. 2013. Recovery from disturbance requires resynchronization of ecosystem nutrient cycles. Ecological Applications 23:621-642.

The work was presented to a joint MBL-University of Chicago workshop in April 2014, a Workshop convened by Bruce Hungate of Arizona State University in February 2014, and a workshop of pale0- /neo-ecosystem perspectives convened by Kendra McLauchlan in May 2013

What do you plan to do during the next reporting period to accomplish the goals?

We are gearing up for the modeling analysis to be conducted in year 5. That analysis will build on the earlier analysis and publication (Rastetter et al. 2013; described in last year's report).

Framework of proposed analysis--

I. The slow trickle of nutrients coming into terrestrial ecosystems from outside sources is typically less than 10% of the nutrient requirement of the vegetation at maturity; sometimes much less than 10% (e.g., in the Arctic we calculate about 2%). Thus there is a strong dependence on internally cycled nutrients and at least the short-term response to disturbance is largely fueled by the redistribution of nutrients already in the ecosystem. Nevertheless, to fully recover, the ecosystem needs to entrain N and P from this slow outside trickle to recover the nutrients lost in, and immediately following, the disturbance.

II. Because of the strong dependence on internally cycled nutrients, the relative N versus P limitation of the vegetation should be related to the relative rates of internal cycling of the two nutrients. If the stoichiometrically adjusted P cycle is fast relative to the N cycle, then the vegetation would be expected to be N limited. If the stoichiometrically adjusted N cycle is fast relative to the P cycle, then the vegetation would be expected to be P limited.

III. However, limitation on the rate of organic matter (OM) and nutrient accumulation in the ecosystem (biomass plus soils) during primary or secondary succession should depend on the stoichiometrically adjusted supply rates of the two nutrients to the ecosystem rather than the cycling rates within the ecosystem. If the supply rate of N is higher than that of P, then the OM and nutrient accumulation would be expected to be limited by P. If the supply rate of P is higher than that of N, then the OM and nutrient accumulation would be expected to be limited by N.

IV. The N:P ratio of the internal cycling rates could be completely independent of the N:P ratio of the supply rates to the ecosystem. Thus, the long-term limitation of organic matter accumulation could be completely independent of what limits plant growth.

V. However, if the supply rates of N and P to the ecosystem are biologically mediated (e.g., N fixation, biologically mediated weathering rates), then the supply rates could be coupled to the internal cycling rates. If the stoichiometrically adjusted, internal P cycle is fast relative to the N cycle, then the biologically mediated supply of N should be intensified (e.g., symbiotic and non-symbiotic N fixation). If the stoichiometrically adjusted, internal N cycle is fast relative to the P cycle, then the biologically mediated supply of P should be intensified (e.g., mycorrhizal attack of apatite).

VI. There is also the internal soil cycle for nutrients (mineralization/immobilization), which is typically faster (maybe much faster) than the overall soil-plant cycle. What is the role of this soil cycle in long-term versus short-term limitation of primary production? We have already analyzed this role for N alone (e.g., the faster the soil cycle the more responsive the vegetation is to CO_2; Rastetter et al 1997). What effect does the N:P ratio of this cycle have on the rest of the ecosystem?

Rastetter, EB, R.D. Yanai, R.Q. Thomas, M.A. Vadeboncoeur, T.J. Fahey, M.C. Fisk, B.L. Kwiatkowski, and S.P. Hamburg. 2013. Recovery from Disturbance Requires Resynchronization of Ecosystem Nutrient Cycles. Ecological Applications 23:621-642.

Rastetter, E. B., G. I. Ågren and G. R. Shaver. 1997. Responses of N-limited ecosystems to increased CO_2: A balanced-nutrition, coupled-element-cycles model. Ecological Applications 7:444-460.

Products

Rastetter, EB, R.D. Yanai, R.Q. Thomas, M.A. Vadeboncoeur, T.J. Fahey, M.C. Fisk, B.L. Kwiatkowski, and S.P. Hamburg. 2013. Recovery from disturbance requires resynchronization of ecosystem nutrient cycles. Ecological Applications 23:621-642.

Participants

Impact

What is the impact on the development of the principal discipline(s) of the project?

This work advances a new perspective on the nature of nutrient limitation of ecosystem function at different time scales. In particular, to accumulate the large biomass and organic matter pools, ecosystem nutrient cycles have to be both tight and synchronized. That synchronization has to adapt to the changing stoichiometry driven by allometric changes in vegetation as it matures. The long-term entrainment of nutrients into the ecosystem cycles makes production more and more dependent on the internal nutrient cycling rates and less dependent on outside nutrient sources.

What is the impact on other disciplines?

The perspective developed here should illuminate the constraints on C sequestration in terrestrial ecosystems and thereby influence perspectives on the limits of climate change and its mitigation. The perspectives here should also provide insights that foster better informed management strategies for forests and other ecosystem resources.

What is the impact on the development of human resources?

The analyses of interactive N and P cycles using the MEL model continue to be a part of the modeling courses in the Semester in Environmental Sciences program here at MBL (http://ecosystems.mbl.edu/SES/) and of the Brown-MBL graduate program (https://courses.brown.edu/courses/spring-2013/envs-2680-s01). Based on work in the Brown modeling class this past semester, Marc Hayes has incorporated a C-N biogeochemical model into his dissertation work on harvest and fire in African dry forests; I am helping with that model. Chelsea Nagy continues development of her model of tropical C-N-P interactions.

What is the impact on physical resources that form infrastructure?

none

What is the impact on information resources that form infrastructure?

The model used here is readily available on the web and runs on a desk-top PC (http://ecosystems.mbl.edu/Research/Models/mel/meldownload.html).

What is the impact on technology transfer?

The model used here is readily available on the web and runs on a desk-top PC (http://ecosystems.mbl.edu/Research/Models/mel/meldownload.html).

What is the impact on society beyond science and technology?

A mechanistic understanding the interactions of C-N-P in terrestrial ecosystems is vital to the management and restoration of ecosystems in the face of climate change, land-use change, and changing disturbance regimes. This works aims to advance that mechanistic understanding.

Changes/Problems
none