Final Progress Report
Sustainability Science Program, Harvard University
Term: September 1, 2011 – August 31, 2012
Submitted: July 2012

Name: Eben North Broadbent

Your field(s):
Biology, Conservation Biology, Ecology, Remote Sensing

Your degree program, institution, and (expected) graduation date:
PhD in Biology at Stanford University, June 2012

Faculty host(s) at Harvard name and department:
Noel Michele Holbrook, Department of Organismic and Evolutionary Biology

Description of SSP-related research activity:

Title: Predictors of Leaf Trait Variation in Tree Species During Forest Succession in the Bolivian Amazon

Abstract: Secondary forests encompass large areas of the tropics and play an important role in the global carbon cycle. During secondary forest succession, simultaneous continuous changes occur in stand structural attributes, soil properties, and in the composition of tree species, among other factors. Most studies classify tree species into categories based on their regeneration requirements. We use a high-resolution secondary forest chronosequence to assign tree species to a continuous gradient in species successional status assigned according to their distribution across the chronosequence. Species successional status, not stand age or differences in stand structure or soil properties, was found to be the best predictor of leaf trait variation. Foliar $\delta_{13}C$ had a significant positive relationship with species successional status, indicating changes in foliar physiology related to growth and competitive strategy, but was not correlated with stand age, whereas soil $\delta_{13}C$ dynamics were largely constrained by plant species composition. Foliar $\delta_{15}N$ had a significant negative correlation with both stand age and species successional status, resulting – most likely - from a large initial burning enrichment in both soil $_{15}N$ and $_{13}C$ and not closure of the nitrogen cycle. Foliar %C was not correlated with either stand age or species successional status but was found to have significant phylogenetic signal. Results from this study are relevant to understanding the dynamics of tree species growth and competition during forest succession and highlight possibilities of, and potentially confounding signals affecting, the utility of leaf traits to understand community and species dynamics during secondary forest succession.

Identification of the problem you address:
Secondary forests are of global relevance for biodiversity, carbon sequestration and cycling, and human use, among other reasons. Better understanding the factors constraining secondary forest succession is therefore of great importance.

Key question asked about the problem:
The overarching research question is whether leaf trait variation during forest succession is explained principally by changes in: (a) stand age, (b) forest structure, or (c) soil properties, or, alternatively, by (d) shifts along a continuous gradient of species varying in environmental niche preference and growth strategy? In addition, we investigate phylogenetic signal as a predictor of leaf trait variation.

The methods by which you answered that question:
We use a high-resolution forest succession chronosequence following slash-burn agriculture to evaluate the biotic and abiotic predictors of leaf trait variation in 20 tropical tree species encompassing a continuous gradient from early to late successional status. Biotic predictors include stand structural characteristics,

taxonomic and phylogenetic analyses, and species successional position, calculated as the stand age at which each species becomes most abundant. Abiotic predictors include a suite of soil properties, including fertility and structure measurements.

Principle literature upon which the research drew:
Tropical forest ecology.

Empirical data acquisition description:
In total, 15 successional stands, with stand ages ranging from 4-47 years, and two primary forest stands were included in the study. Forest inventories were conducted using one 10 x 80 meter transect located diagonally across each stand. Soil cores (2 x 4 ″; AMS, Inc., American Falls, ID) were collected for three randomly chosen locations at depths of 0-10, 10-20, and 20-30 cm. Tree species selected for foliar analyses were identified to encompass a wide taxonomic range and to be present in as many age stands as possible. Two to three top of canopy trees of each study species were randomly chosen from each stand provided the particular species was present. In total, 149 tree individuals encompassing 20 species, or approximately 10% of all tree species, were selected. From these individuals we collected 10-15 fully expanded mature leaves from two separate locations within the full sunlight portion of each individual's crown either by hand or using a shotgun. Statistical analyses for this and all following sections were carried out using JMP v.7.0.1 (SAS Institute, Inc.) and in R v.2.9.2 (http://www.R-project.org).

Geographical region studied:
This study was carried out in the community of Molienda (municipality of Bolpebra and department of Pando) in the Bolivian Amazon (11°26'28.189" S, 69°09'30.06" W). The forest is considered lowland tropical moist forest with mildly undulating topography, has a mean annual rainfall of 1800 mm, and has a pronounced dry season extending from May to September.

Recommendations that might be relevant for your problem:
The interplay among soil and foliar factors, with more specific quantification of competitive processes during forest succession, requires further investigation and will be the focus of future work.

A description of the final product(s) you have/are aiming to produce:
"Predictors of Leaf Trait Variation in Tree Species During Forest Succession in the Bolivian Amazon" comprises both a Dissertation chapter and will be submitted to a peer-reviewed publication by the end of August 2012.

Description of major other intellectual or professional advancement activity(ies) over the past academic year:

Main advancement:
Completion and submission of dissertation:

Broadbent, Eben N. 2012. Tropical forests across temporal and spatial scales. PhD dissertation, Biology Department, Stanford University.

New publications:

Broadbent EN, Almeyda Zambrano AM, Dirzo R, Durham WH, Driscoll L, Gallagher P, Salters R, Schultz J, Colmenares A. 2012. The effect of land use change and ecotourism on biodiversity: a study of Manuel Antonio, Costa Rica, from 1985-2008. *Landscape Ecology* 27:731-744.

Publications in preparation:

Broadbent EN, Almeyda Zambrano AM, Asner GP, Field CB, Kennedy-Bowdoin T, Knapp D, Rosenheim B, Burke D, Giardina C, Cordell S. In prep. Modeling microclimate and ecophysiology of a tropical rainforest using airborne waveform LiDAR and hyperspectral fusion.

Broadbent EN, Almeyda Zambrano AM, Asner GP, Soriano M, Ramos de Souza H, Field CB, Peña-Claros M, Adams R, Giles L. In prep. Determinants of foliar properties during forest succession following slash-burn agriculture in the Bolivian Amazon.

Broadbent EN, Almeyda Zambrano AM, Asner GP, Sereceda M. In prep. Social and edaphic factors influencing swidden agricultural decisions in the Peruvian Amazon.

Broadbent EN, Araujo E, Daily G, Montero J. In prep. Forest disturbance alteration of Nymphalid butterfly vertical niche partitioning in the Osa Peninsula, Costa Rica.

Almeyda Zambrano AM, Broadbent EN, Asner GP, Knapp D, Durham WH. In prep. Road infrastructure development and deforestation in Southwest Amazonia: A tri-national frontier study.

Almeyda Zambrano AM, Broadbent EN, Duchelle AE, Asner GP, Knapp D, Babigumira R, Wunder S, Durham WH. In prep. Household land cover and land use in a dynamic frontier: integrating landscape and landholding scales.

Almeyda Zambrano AM, Broadbent EN, Duchelle AE, Asner GP, Knapp D, Babigumira R, Wunder S, Durham WH. In prep. Livelihood trajectories and deforestation among smallholders in Southwest Amazonia

Consulting:

A. Ecosystem Component of the Institutional Analysis and Livelihood Security Threat Assessment in the Osa-Golfito Region of Costa Rica, Harvard University and the Stanford Woods Institute for the Environment.

B. Mangrove and peat forest biomass in Cancun, Mexico and Papua, Indonesia, United States Forest Service (USFS)

Citations for reports, papers, publications, and presentations that built on your fellowship research:

Broadbent EN, Almeyda Zambrano AM, Dirzo R, Durham WH, Driscoll L, Gallagher P, Salters R, Schultz J, Colmenares A. 2012. The effect of land use change and ecotourism on biodiversity: a study of Manuel Antonio, Costa Rica, from 1985-2008. *Landscape Ecology* 27:731-744.

Abstract: Development in biodiversity rich areas is of global concern. While development may lead to socioeconomic benefits, this often comes concomitant with biodiversity loss and deforestation. Biodiversity rich areas present the opportunity for both improvements in socioeconomic conditions and conservation; however numerous challenges exist. Costa Rica's Manuel Antonio National Park presents an ideal case study to investigate the balance between alternative forms of development which have contrasting environmental impacts. The Manuel Antonio region is a highly dynamic landscape experiencing deforestation, from agriculture, cattle ranching and oil palm plantations; and also reforestation from abandonment of land holdings and nature oriented tourism. Landscape dynamics are closely intertwined with the livelihoods and perspectives on biodiversity conservation of local communities, determining ecological sustainability. We use an analysis combining multi-temporal remote sensing of land cover dynamics from 1985 to 2008 with questionnaire data from local families on their socioeconomic status, perspectives on conservation, and perceived changes in local wildlife populations. Our results show that, while regeneration occurred and forest fragmentation in the area decreased from 1985 to 2008, Manuel Antonio National Park is rapidly becoming isolated. Decreasing ecological connectivity is related to the rapid expansion of oil palm plantations adjacent to the park and throughout the lowland areas. Perceived decreases in wildlife abundance and compositional change are evident throughout the area, with local communities attributing this primarily to illegal hunting activities. Nature based tourism in the area presents an effective strategy for conservation, including reductions in hunting, through increased valuation of biodiversity and protected areas, and socioeconomic advantages. However, without urgent efforts to limit deforestation and preserve the remaining forested corridor connecting the park to core primary forest, the ability to maintain biodiversity in the park will be reduced.

Principal collaborators outside Harvard:
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Susan Cordell, Institute of Pacific Islands Forestry

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