Project Title: Filling gaps in the aboveground carbon budget of the SSHO CZO

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Statement of Proposed Work

Forest productivity affects carbon uptake and storage within an ecosystem and plays a major role in ecosystem functions such as forest-atmosphere gas exchange and soil development. A project has been underway at SSHO since fall 2011 to calculate the aboveground net primary productivity (ANPP) of the forest in the watershed. ANPP is calculated for a deciduous forested ecosystem by adding annual wood growth and leaf litter carbon production. In SSHO, two years of leaf litter mass data have been collected; however key gaps remain preventing the calculation of ANPP. Leaf litter carbon (C) concentration values are needed to convert leaf litter biomass to foliar carbon production and radial stem growth data are needed to model annual wood increment. **The proposed seed project will provide the foliar chemistry and tree stem growth data necessary to complete ANPP estimates for the watershed.** The project will also provide measurements of nitrogen additions to the soil by leaf litter, and measures of carbon isotope discrimination of trees reflected in leaf litter. These data will add to the C and N element cycles being calculated in the watershed, as well as link element cycles to hydrologic stress experienced by the forest across diverse topographic positions.

Annual leaf litter inputs of C and N: Leaf biomass dropped by the forest canopy in fall 2011 and 2012 was collected in 35 traps distributed throughout the SSHO watershed, sorted by species, and measured for dry mass (g m^{-2}). Leaf litter C and N concentrations are needed for each species to convert biomass to annual C and N additions by the litter. We currently have C and N concentration data for six of the 10 dominant tree species from a previous research project, but need values for four species with top dominance in the watershed (*Quercus prinus*, *Quercus rubra*, *Tsuga canadensis*, and *Fraxinus americana*). Leaf litter samples from each of these species will be ground and measured for C and N concentrations. Leaf litter C and N concentrations will be used to estimate C and N contributed to the forest floor from annual leaf litter production. Robust estimates of ANPP depend on calculation of leaf litter carbon production, which will be possible with the foliar chemistry analysis.

Contribution of tree stem growth to ANPP: ANPP calculations for SSHO are further limited by lack of data for wood growth of trees in the watershed. We have tree diameter measurements at two dates (2008 and 2012) for nearly all of the 2000+ trees in the watershed, which can be used to estimate wood growth per year. However, the potential error associated with field measurements of tree diameter make these data of limited use. Calculations of ANPP will be greatly strengthened with radial growth increment data so that we can combine wood and leaf litter production for calculation of ANPP in 2011 and 2012. We propose to collect increment cores from approximately 200 trees representing the 10 dominant species in the watershed and stems from a range of sizes. Annual radial growth will be used to estimate annual stem wood production, which will be combined with litter production data to estimate annual 2011 and 2012 ANPP for the SSHO watershed. Moreover, tree-ring samples will provide a 50+ year time series of stem growth increment across the watershed that will be used to reconstruct temporal and spatial trends in ANPP.

C isotope as indicators of element and water cycling in the SSHO: Finally, we proposed to take advantage of the leaf chemistry analysis to assess potential influences of C, N, and water cycling in the watershed through analysis of C isotope ratios. Foliar carbon isotope ratios indicate the degree of water stress experienced by a leaf at the time of carbon fixation. Heavier C isotopes ($\delta^{13}C$) will be fixed during photosynthesis as leaf water stress increases, causing an increase in foliar $\delta^{13}C$. Patterns in $\delta^{13}C$ in leaf litter across slopes, elevations, and micro-topography in the SSHO will indicate locations in the watershed where trees are more prone to drought stress. Four tree species (*Quercus prinus, Quercus rubra, Acer saccharum*, and *Acer rubrum*) have been selected for analysis of carbon isotope signatures due to their widespread distribution in the watershed, their diverse ecological strategies, and their overlap as focal species of other projects underway at the CZO.

The proposed field and laboratory work will be completed by an undergraduate research assistant supervised by the PI and Lauren Smith. Lauren has lead data collection in fall 2011 and 2012 at SSHO and will take the lead on data analysis for the seed grant, including calculations of ANPP at scales ranging from microsite, to slope, and to watershed. Foliar samples will be prepared for analysis in the PI's lab in the Forest Resources Building by the undergraduate research assistant. Chemical analyses will be done with the EA-IRMS Thermo Delta V Advantage analyzer with peripheral Coztech elemental analyzer at the EESI Laboratory for Isotopes and Metals in the Environment. Sample preparation and laboratory analysis of foliar samples will take place in February-April, 2013. Field sampling of tree cores will take place in May-July, 2013. Once data collection and sample analyses are completed, data will be uploaded to the SSHO CZO website. Physical leaf litter and tree ring samples will be archived in the PI's lab.

Products of research

- ANPP in the SSHO through space and time

  ANPP data will be produced at the spatial scales of watershed, slope, elevation, micro-topographic position, and species. The temporal range of ANPP data is from annual to cumulative over 50+ years (depending on the age of the trees in the watershed).

- Leaf litter inputs of C and N to the forest floor

  C and N inputs to the forest floor ($g\ m^{-2}\ yr^{-1}$) for 2011 and 2012 will be produced at the spatial scales of watershed, slope, elevation, and species.

- $\delta^{13}C$ values of leaf litter across the watershed

  $\delta^{13}C$ values of leaf litter in 2011 and 2012 will be produced at the spatial scales of watershed, slope, elevation, and species.

The following "Proposed SSHO Interactions" outlines how these data will be combined with existing projects underway in the watershed.

Proposed SSHO Interactions

Strong and direct synergies exist between the proposed seed project and research underway at SSHO. Attempts to complete the C and N budgets for the watershed are underway by J Kaye and collaborators. These budgets require the measurements of leaf litter C and N inputs to the forest floor made through this proposed seed grant. Furthermore, C isotope data produced by the project are essential for tracking the movement of carbon through the ecosystem.

Spatial patterns of ANPP, leaf litter biomass, and litter quality (represented by foliar C:N) can be compared to soil depth measurements made by H Lin to relate forest productivity to soil development.

Patterns in carbon isotope discrimination can be combined with tree physiology research underway by K Gaines in D Eisssenstat's lab to assess hydrologic stress of trees based on species and topographic position. The C isotope values are a proxy for water use efficiency, and we will provide data from across the watershed that can be compared to intensive hydrological measurements made on individual trees for K Gaines' dissertation research.

The PI and L Smith will seek out GIS support to create extrapolated surfaces of ANPP, leaf litter C and N inputs, and C isotope ratios across the watershed. These GIS layers will be compatible with GIS layers already available for many components of the SSHO regolith.

L Smith (MS student) will lead a publication of the ANPP results in an ecological journal that will include M Kaye, J Kaye, and D Eissenstat as collaborators. Smith and M Kaye will work with K Gaines and D Eissenstat to combine carbon isotope results with tree physiology in a publication. We will contribute the ANPP data to work lead by J Kaye to publish a carbon budget for the watershed. This publication may include flux tower net ecosystem productivity data currently managed by K Davis.

M Kaye has already received permission from the Stone Valley Forest Land Management office to collect increment core samples for trees in the SSHO watershed. Leaf litter samples and tree ring samples will be archived in M Kaye's lab in the Forest Resources Building at Penn State. They will be archived with metadata including date, location, and method of collection. Leaf litter C and N deposition data will be added to the leaf litter biomass dataset already uploaded as geospatial data to CZO website. GIS layers produced for ANPP, leaf litter C and N deposition, and C isotopes be uploaded to the CZO website as well.

Results of prior support to work in SSHO

The SSHO CZO provided funds for Lauren Smith's Graduate Research Assistantship in the 2011-2012 academic year, as well as summer wages for 2012. Lauren is a MS student in the Graduate Degree Program in Ecology, and since fall 2011 has collected a suite of data at SSHO. In fall 2011 and 2012 Lauren made weekly measurements of leaf litter biomass from 35 litter traps in the watershed. In spring 2012 Lauren installed approximately 100 dendrobands in the watershed and monitored stem growth bi-monthly during the growing season. Lauren, accompanied by M Kaye's lab group, measured the diameter of every tree (2000+) in the watershed in fall 2012. The raw data collected by Lauren has been uploaded to the CZO website ("Tree data" and "Litter/Dendroband Data") and remains password protected until she publishes her research. Lauren is in her fourth and final semester of her master's program and is in the process of writing her thesis. Lauren plans to publish her master's work with data from the CZO in ecological journals.