The First LAI-Linked Predictive Model for Below- and Above-Ground Carbon Sequestration in Quaking Aspen

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<u>Background</u>: Forest ecosystem carbon is a key component to global climate initiatives and forest ecosystems are the primary ecotype used for carbon registration protocols. Although methodologies for estimating above-ground carbon sequestered are well established, using leaf area index (LAI) linked to basal area, **below-ground carbon estimates are hampered by the paucity and inconsistency of data for both coarse- and fine-root biomass** (1). As soil root carbon is a more stable carbon sink than above-ground carbon, **accurate below-ground carbon estimates are indispensable for modeling efforts** (2).

Objectives: I will measure the total biomass of quaking aspen in representative North American stands. LAI has strong positive correlations to coarse- and fine-root aspen biomass (3), (4). Above- and below-ground biomass and LAI will be determined in order to develop the first predictive model that relates LAI to above- and below-ground biomass for aspen. Quaking aspen (Populus tremuloides) is an excellent candidate for necessary root biomass sampling and carbon modeling. Populus is one of the most widely cultivated northern temperate tree genera in the world, and has both ecological and economic significance; in many ways, it is becoming a 'model tree' for biomass and carbon sequestration (5). The most widely distributed species in North America, aspen is extremely important ecologically for water quality and habitat. However, it is in decline in the western United States for reasons not yet fully understood. Aspen root systems are unique; this species regenerates vegetatively from shallow lateral roots, forming large clonal stands which can persist indefinitely, given the correct disturbance regime. These coarse roots, then, persist after removal or decomposition of aboveground biomass, and possibly for several such stand-replacing events. This is very different from roots of seed-regenerated trees, in which the root system dies with stem death and is subject to soil microorganism heterotrophy.

Expected Results: This study will generate a predictive model that relates quaking aspen LAI to above- *and* below-ground carbon allocation. It will also advance understanding of the ecology of a vegetatively reproducing forest species, an important but often overlooked niche (6). This research methodology may be applied to other species and used to explore below-ground relationships of other vegetatively regenerated forest ecosystems.

Moreover, an accurate model that related above-ground aspen LAI to below-ground biomass and persistence will be **useful economically** for forest managers and carbon accreditation. With the basal area: LAI relationship we will develop, **this model will be economical and practical across scales and for many interested parties, from small landholders to climate modelers**. For small landholders with small forests, income from carbon accreditation can be important in deciding whether to invest in afforestation. A persistent soil carbon stock in aspen stands, if present, would create significant financial incentive for afforestation with and preservation of aspen. Benefits would also accrue for global climate and for areas historically forested with aspen.

<u>Broader Impacts</u>: Through my ongoing volunteer work at high schools in Oakland Unified School District with minorities and disadvantaged students, **I will integrate the project and its activities with educational activities for a variety of students**. Interested students will be given the opportunity to involve themselves in the research, with **special effort made to employ underrepresented groups** as field assistants and involve them in the laboratory. Once developed, our LAI-carbon **model will be made available for download free of charge**. In addition to the peer-reviewed literature, we will make presentations at conferences for forest managers and environmental organizations.

<u>Methodology</u>: I will sample aspen in representative stands in western North America. Stands will be selected on the basis of prior disturbance regime, stand health, and ecotype. I will use several complementary methods to obtain a complete picture of leaf area, course root and above-ground biomass, and fine-root flux.

Leaf area: We will determine leaf area relationships by destructive sampling of approximately 30 trees. A random subset of leaves from each tree will be collected and weighed in the field, and subsequently scanned in the laboratory to determine leaf surface area. This will allow the prediction of leaf area at the stand level from basal area.

Above-ground biomass: We will use fixed-area inventories from plots we installed to estimate above-ground biomass. Canopy leaf weights and wood density will be used to predict carbon content with allometric equations.

Course root biomass: Since aspen roots are typically superficial, they are relatively easy to map. We will map root systems using ground-penetrating radar. This methodology is much less invasive and labor-intensive than excavation, and can be used to map changes in coarse-root biomass over time. Soil cores will be taken to standardize data sets and extrapolate root maps to biomass and carbon (7).

Fine root biomass: Fine-root biomass annual flux is best estimated over the course of one year using minirhizotrons (8). We will install minirhizotrons, capped plastic pipes measuring approximately 180 by 5 cm, at a 45 degree angle from the soil surface. We will then take photographs of roots which infiltrate the pipe throughout the course of the year, and determine root length and biomass by analysis with dedicated software. Root biomass, determined from soil cores at the beginning of the sampling period, will be extrapolated to the stand level. Using the initial root biomass and the initial minirhizotron values, we will find fine-root flux for the stand. *Analysis:* I will use regression analysis to develop leaf area prediction models from tree basal area and height of the crown base in aspen. Tree growth will be predicted from tree leaf area. Using data on root biomass and stand LAI, we will develop predictive equations that relate LAI to above- and below-ground tree carbon. Results will be integrated with MASAM, an existing forest stand health model, to provide tree restoration guidelines, LAI, and carbon estimates (9).

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