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Short- and Long-Term Dynamics of Leaf, Wood, and Fine-Root Production at the ORNL FACE Site

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The major components of a woody plant (leaves, wood [stem and coarse root], and fine roots) are produced under different phenological cycles, which could influence ecosystem carbon, nutrient, and water cycling. However, current understanding of leaf, wood, and root dynamics are generally developed in isolation because studies rarely measure production of these components simultaneously, especially at sub-annual time steps. The interplay among different tissue types at the intra-annual scale, therefore, remains largely unknown. One of the benefits of DOE BER funding of long-term experiments has been the multi-year focus on the components of net primary production, and their response to environmental change. To address the knowledge gap, we assess leaf, wood, and fine-root production at monthly and finer time steps from the intensively studied Oak Ridge National Laboratory (ORNL) Free-Air CO_2 Enrichment (FACE) site. For each tissue type, we quantify a number of important phenophases that have been previously identified in the literature, including the start, end, peak, duration, and lead-lag between different tissue types. A multivariate statistical model of production dynamics is developed to address three questions: (i) How is phenology of different components related? (ii) To what extent is the timing of production influenced by environmental drivers (daylength, temperature, precipitation, soil water and temperature, CO_2) versus the production of other tissues (i.e., exogenous compared with endogenous control)? (iii) How is production phenology related to annual production in a given year?

The phenology of leaf, wood, and fine-root production for *Liquidambar styraciflua* at the FACE site was revealed: among the three components, leaves have the shortest production season, which is constrained to the spring as expected; the peak of wood production coincides with the end of leaf production, and in some years, a small fraction of wood is produced before leaf expansion; fine root is generally produced in two phases, including a pulse in the early spring that precedes leaf expansion and a more uniform production that follows wood production and lasts into late fall. We found that production phenology varied more across years than among treatment rings and between CO_2 treatments. We aim to use this empirical groundwork as a foundation to guide the representation of intra-annual production dynamics in ecosystem models, as well as to stimulate new hypotheses and analyses to better understand the dynamic, co-varying components of woody plant growth.