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Growing up with stress - carbon sequestration and allocation dynamics of a broadleaf evergreen forest

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Evergreen forests have the potential to sequester carbon year-round due to the presence of leaves with a multi-year lifespan. Eucalypt forests occur in warmer climates where temperature and radiation are not imposing a strong seasonality. Thus, unlike deciduous or many coniferous trees, many eucalypts grow opportunistically as conditions allow. As such, many eucalypts do not produce distinct growth rings, which present challenges to the implementation of standard methods and data interpretation approaches for monitoring and explaining carbon allocation dynamics in response to climatic stress. As a consequence, there is a lack of detailed understanding of seasonal growth dynamics of evergreen forests as a whole, and, in particular, of the influence of climatic drivers on carbon allocation to the various biomass pools.

We used a multi-instrument approach in a mixed species eucalypt forest to investigate the influence of climatic drivers on the seasonal growth dynamics of a predominantly temperate and moisture-regulated environment in south-eastern Australia. Ecosystem scale observations of net ecosystem exchange (NEE) from a flux tower in the Wombat forest near Melbourne indicated that the ecosystem is a year-round carbon sink, but that intra-annual variations in temperature and moisture along with prolonged heat waves and dry spells resulted in a wide range of annual sums over the past three years (NEE ranging from ∼4 to 12 t C ha-1 yr-1). Dendrometers were used to monitor stem increments of the three dominant eucalypt species. Stem expansion was generally opportunistic with the greatest increments under warm but moist conditions (often in spring and autumn), and the strongest indicators of stem growth dynamics being radiation, vapour pressure deficit and a combined heat-moisture index. Differences in the seasonality of stem increments between species were largely due to differences in the canopy position of sampled individuals. The greatest stem increments were recorded in the years with highest NEE, but NEE was not a strong seasonal driver of stem increment. Recently developed terrestrial lidar scanners (VEGNET) monitored the daily changes in canopy dynamics with a comparable temporal resolution to dendrometer and eddy covariance measurements. Growth of each canopy stratum was distinctly seasonal, and we detected contrasting responses to climatic stress along the canopy height gradient. Leaf turnover was predominantly in summer and was initiated by prolonged heat stress and isolated storm events. Leaf shedding and replacement happened concurrently, with leaves being mainly discarded from the middle stratum and replaced in the top stratum.

Due to our novel multi-instrument approach and the high temporal resolution of tree to ecosystem-scale growth dynamics we were able to demonstrate that above ground carbon allocation to stem and crown pools followed separate seasonal dynamics that did not necessarily follow the same seasonality as ecosystem scale carbon sequestration. Our findings will ultimately improve our understanding of the effects of short- and long-term variability in temperature and moisture stress on carbon allocation dynamics to the above ground biomass pools for broadleaf evergreen ecosystems.