Controls on Carbon Dynamics by Ecosystem Structure and Climate for Southeastern U.S. Slash Pine Plantations

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Introduction

Planted pine forests (plantations) in the southeastern U.S. are an important fraction of the continent's total carbon balance. They contain > 6 Pg C and averaged close to 0.4 Tg C yr^{-1} in net accumulation between 1990 and 2000, equivalent to ~12% of annual U.S. carbon emissions. Forest carbon dynamics are affected by a range of factors, including stand age (time since last harvest), genetic composition, understory composition and structure, site quality, management history (e.g., fertilization) and fire history, in addition to variations in climate. Multi-year droughts have affected the region in the past and predictions indicate an increase in the frequency of drought events. How this variability will affect the capacity of these ecosystems to sequester carbon is not well known.

We synthesized eddy covariance data, physiological measurements, and biometric measurements to assess the carbon dynamics across nine years from two slash pine (*Pinus elliottii* var *elliottii)* plantations in north Florida; a newly planted stand (Mize tract, MT) and a mid-rotation stand (Donaldson tract, DT). During the decade of study, the region experienced a larger range in water availability than recorded over the previous century, including two multi-year droughts (1999 – 2002 and 2006 – 2008), separated by a three year wet period.

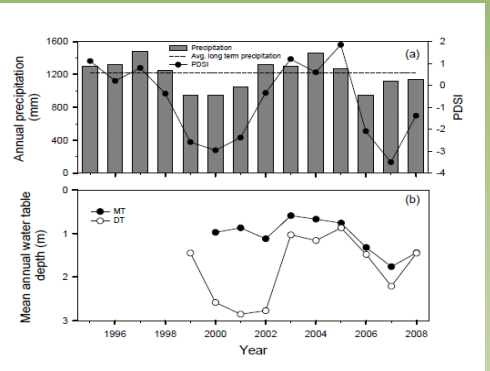
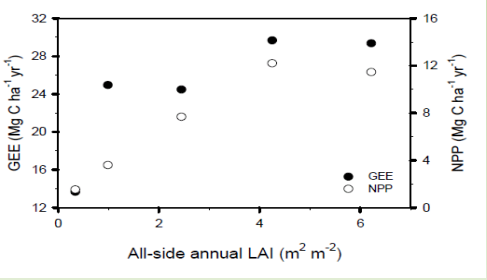


Figure 1. (a) 33-yr averages of annual precipitation and Palmer Drought Severity Index (PDSI). PSDI < -3 is considered a severe drought; (b) Mean annual depth to the water table the two ecosystems, with differences likely due to the lack of deep roots at MT.

Figure 2. Annual gross ecosystem carbon exchange (GEE) and net primary productivity (NPP) as a function of annual leaf area index (LAI) during the first years of stand development (MT).



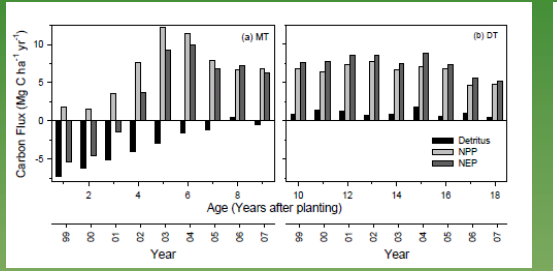


Figure 3. Annual net ecosystem production (*NEP*), total (*NPP*) and carbon fluxes in the detrital pool during stand development: (a) Mize tract (MT), (b) Donaldson Tract (DT).

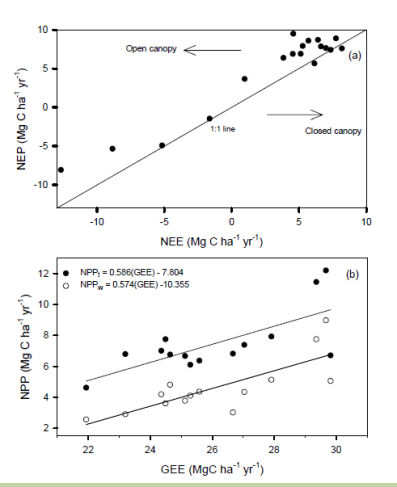
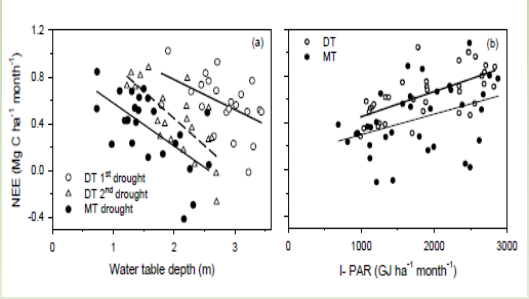


Figure 4. (a) Comparisons of annual NEP to NEE, and (b) total NPP_t and woody NPP_w as related to annual GEE in the two ecosystems.

Figure 5. Relationships between NEE after canopy closure and: (a) depth to water table during drought years; and (b) intercepted PAR during wet years for both ecosystems.



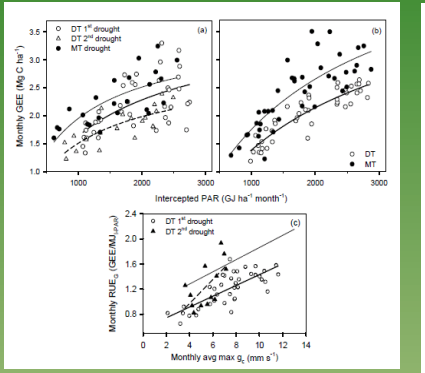
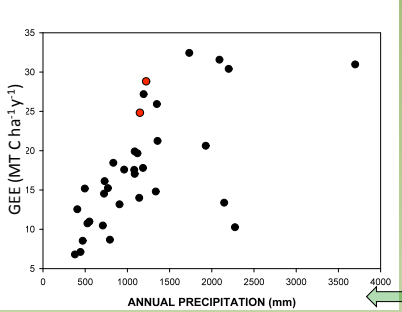


Figure 6. Monthly *GEE* as a function of intercepted *PAR* during drought years (a) and wet years (b); and (c) Monthly *RUE* related to average maximum canopy conductance during the two droughts at DT, with the thin line for MT (without data points shown for clarity).



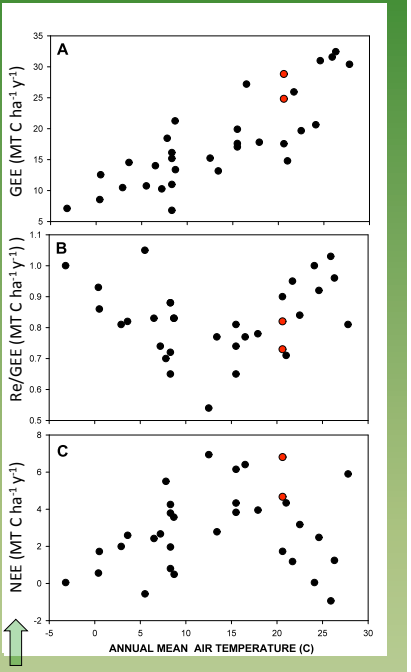


Figure 7. Relationships between (a) GEE, (b) Re/GEE and (c) NEE, and annual mean air temperature for 35 forests from the tropics to boreal zones (Fluxnet), including the two ecosystems represented here. Red points are the MT and DT sites.

Figure 8. Relationship between GEE and annual precipitation for 35 forests from the tropics to boreal zones (Fluxnet), including the two ecosystems represented here. Red points are the MT and DT sites.

Conclusions

Net ecosystem carbon accumulation measured using both eddy covariance and biometry showed the same trends and magnitudes during plantation development.

- The newly planted site (MT) released 15.6 Mg C ha^{-1} during the first three years after planting, then became a carbon sink in year four.
- Increases in net carbon uptake during the early stages of stand development were driven by aggrading leaf area.
- After canopy closure, both sites were continuous carbon sinks, with net carbon uptake fluctuating between 4 and ≈ 8 Mg C ha^{-1} yr^{-1} depending on environmental conditions.
- Drought reduced net ecosystem carbon exchange by approximately 25% through its negative effect on both LAI and radiation-use efficiency (RUE), which resulted in a larger impact on GEE than on Re.
- Results indicate that responses to drought involve complex interactions among water availability, LAI and RUE. In the larger context, these ecosystems remain carbon sinks in the landscape under current management strategies and climatic variability.

Corresponding authors; hgholz@nsf.gov, hloescher@neoninc.org "This poster is based on a manuscript in revision by the same authors, titled: *Controls on carbon dynamics by ecosystem structure and climate for southeastern U.S. slash pine plantations*".