Investigating the CO$_2$ Response of Secondary-Succession Forests at Duke and Oak Ridge FACE Experiments Simulated with ELM-FATES-CNP

Bharat Sharma$^1$, Anthony Walker$^1$, Ryan Knox$^2$, Charlie Koven$^2$, Rosie Fisher$^3$, Elizabeth Agee$^4$, Ram Oren$^5$, Rich Norby$^1$, Daniel Ricciuto$^1$, Xinyuan Wei$^1$, and Xiaojuan Yang$^1$

$^1$Oak Ridge National Laboratory
$^2$Lawrence Berkeley National Laboratory
$^3$Center for International Climate Research
$^4$DOE Office of Scientific and Technological Information
$^5$Duke University, AGU Annual Meeting

December 27, 2023

Abstract

Abstract content goes here
Investigating the CO$_2$ Response of Secondary-Succession Forests at Duke and Oak Ridge FACE Experiments Simulated with ELM-FATES-CNP

Bharat Sharma$^1$, Anthony Walker$^1$, Ryan Knox$^2$, Charlie Koven$^3$, Rosie Fisher$^3$, Elizabeth Agee$^4$, Ram Oren$^5$, Rich Norby$^6$, Daniel Ricciuto$^7$, Xinyuan Wei$^8$, Xiaojuan Yang$^9$

$^1$Oak Ridge National Laboratory; $^2$Lawrence Berkeley National Laboratory; $^3$Center for International Climate Research; $^4$DOE Office of Scientific and Technical Information; $^5$Duke University

Correspondence: sharmabh@ornl.gov

**Introduction**

- Many terrestrial biosphere models have suggested that elevated atmospheric CO$_2$ (eCO$_2$) has caused a large fraction of land C sequestration during recent decades and predict that this sequestration will continue to increase in the future.
- First-generation Free Air Carbon Dioxide Enrichment experiments (FACE) provide information on eCO$_2$, nitrogen (N), and decade-long demographic process interactions in secondary forests and plantations, e.g., Duke and Oak Ridge National Lab (ORNL).
- We observe contrasting patterns of net primary productivity (NPP) at Duke and ORNL.
- The results of FACE experiments in Duke and ORNL face experiments with ELM-FATES-CNP to investigate and improve NPP representation of secondary plantation forests in which the FACE experiments were sited.

**Objective**

- Long-term: Evaluate the interactions of stand development with nutrient dynamics and their influence on ecosystem eCO$_2$ responses using ELM-FATES-CNP, a nutrient-enabled and size-structured vegetation demo-graphics model with carbon and nutrient cycling.
- Here we present simulations of Duke and ORNL FACE experiments with ELM-FATES-CNP to investigate and improve NPP representation of secondary plantation forests in which the FACE experiments were sited.

**Methods**

- Nutrient-enabled ELM-FATES-CNP (Knox et al., 2023) is recently developed and can run with both relative demand (RD) and equilibrium chemistry approximation (ECA) representations of nutrient acquisition. ELM-FATES is run within the Offline Land Model Testbed (OLMT).
- ELM-FATES-CNP includes a dynamic allocation scheme whereby the target leaf fine-root biomass ratio (L2FR) is a function of relative carbon and nitrogen and phosphorus storage.
- Code versions:
  - ELM: 86eb6f85 (30 Jan 2023); FATES: 06e6aee (4 Dec 2022); OLMT: 0ac86b8d
- Study sites:
  - Duke: Carbon-only simulation
  - Oak Ridge: Above and below ground wood mass removed
  - Storage: fine root biomass, and below
  - Wood mass removed
  - Storage: Storage mass, and below ground mass removed
  - Basal: Storage mass removed
  - Storage: Storage mass removed
  - Ag: Aboveground wood mass removed
  - Time: fine root mass removed
  - Basal: Basal/default CNP simulation

**What is slowing the post-disturbance recovery rate in FATES?**

1. The ELM soil decomposition goes into nitrogen immobilization override, due to a large influx of litter carbon from the logging and the high C:N ratios of litter compared with soil pools. Fixed stoichiometry of the soil pools and microbial carbon use efficiencies exacerbate the problem. To simulate a more realistic growth rate of the plantation, we removed carbon from various litter but kept the nutrients to decrease the C:N ratios of litter pools and increase N availability and uptake.

2. The dynamic fine-root allocation scheme in ELM-FATES-CNP regulates uptake of nutrients. This scheme seeks to adjust resource allocation above- and below-ground for plant growth to be equally limited by carbon, nitrogen and phosphorus. There is high sensitivity of NPP and biomass to the choice of coefficient of Proportional Integral Derivative (PID) controller coefficients.

**Summary**

- NPP and nutrient responses are well captured with ELM-FATES-CNP at Duke in the simulated equilibrium forest. However, the PNL related decline is not captured by the model at Oak Ridge.
- The FACE site plantations were established about a decade before the start of FACE experiments at Duke and Oak Ridge. To align the simulated forest age with the FACE site plantation age, we simulated a logging event a year prior to plantation establishment and allowed FATES to regenerate the forest naturally.
- Growth rate of NPP in the simulated secondary plantation forests is much slower than observed.

**Selected References:**


**FACE-MDS**