**Title:** Nuisance species compromise the carbon sequestration potential in an Eastern US temperate deciduous forest

**Authors (tentative / incomplete list, not in order):**

Krystal Bagnaschi

Rachel Hoffman

Iris Kennedy

Erin MacMonigle

Caroline Troy

Cameron Dow

Jen Jordan

Valentine Herrmann1 ( Orcid ID : 0000-0002-4519-481X)

David Mitre

Jess Shue

Luca Morreale

William McShea

Kristina J. Anderson-Teixeira1,2\* ( Orcid ID : 0000-0001-8461-9713)

**Author Affiliations:**

1. Conservation Ecology Center; Smithsonian’s National Zoo & Conservation Biology Institute; Front Royal, Virginia 22630, USA
2. Forest Global Earth Observatory, Smithsonian Tropical Research Institute, Apartado Postal 0843-03092, Panama City, Panama

\*corresponding author: [teixeirak@si.edu](mailto:teixeirak@si.edu); +1 540 635 6546

**Running head:**

for submission to Anthromes joint special collection in New Phytologist/ Plants, People, Planet: <https://www.newphytologist.org/news/view/332>

# Abstract

* temperate deciduous forests play a critical role in the global carbon cycle, accounting for a substantial portion of the global forest C sink
* The dominant view imbued in Earth System Models is that, at least within the eastern US, the biome is likely to remain a C sink for the remainder of the 21st century
* However, these models do not incorporate nuisance species – i.e., species whose local abundance has been dramatically increased as a result of human activities and that are causing ecological harm.
* Nuisance species are known to increase tree mortality (non-endemic pests and pathogens) and decrease recruitment (deer, non-endemic plants) throughout the (Eastern US) temperate deciduous biome, yet we don’t know net effect on current and future C cycling
* Here, we use 15 years of detailed census data from a large forest dynamics plot with a deer exclosure to understand how nuisance species are affecting C cycling
* we show increased biomass mortality, reduced ∆AGB (only outside deer exclosure?), reduced AGB (only outside deer exclosure?)
* if current trends continue, forest will continue to lose C sequestration capacity/ likely to be C source in future
* thus, C sequestration potential of temperate deciduous forests is overestimated

**Keywords**:

# 1 Papers to read

* earth system models (pay special attention to predictions and uncertainty for eastern US)
  + - * do they say anything about nuisance species?
  + (**ahlstrom\_robustness\_2012?**)
* Miller *et al.* (2023)
  + what were there metrics? would it be worth applying their metrics to our forest in order to classify by their system?

# 2 Introduction

The temperate forest biome plays a critical role in the global carbon cycle, accounting for almost half of the net global forest carbon (C) sink (**harris\_global\_2021?**), with deciduous forests representing a substantial portion of this, sequestering >300 Tg C yr-1 (**pugh\_role\_2019?**). Although currently a C sink, the future of the biome remains uncertain. The dominant view imbued in Earth System Models is that, at least within the eastern US, the biome is likely to remain a C sink for the remainder of the 21st century (Wu *et al.*, 2023; **finzi\_carbon\_2020?**), albeit with declining CO2 sequestration capacity (Ahlström *et al.*, 2012). Yet, global C models predict a wide range of future trajectories of CO2 sequestration (**ahlstrom\_robustness\_2012?**; **arora\_carbon\_2020?**), and current global C models do not represent some influential mechanisms (e.g., **fatichi\_moving\_2014?**). One mechanism that is not represented in global C models is the impact of nuisance species – i.e., endemic or non-endemic species that, as a result of human influence, have much greater abundance in an ecosystem than they did historically, resulting in undesirable ecological consequences (**refs?**). Similarly, the impact of nuisance species on forest carbon budgets is not considered in machine learning/niche models that seek to project future forest distribution and carbon stocks (**?** Wu *et al.*, 2023), nor in carbon offset projects (**???** **refs?**). This is problematic in that nuisance species – including non-endemic insect pests and pathogens, non-endemic plants, and over-abundant herbivores – are dramatically impacting carbon cycling in temperate deciduous forests around the world (**refs?**).

## 2.1 (paragraph on tree mortality from non-endemic pests and pathogens)

Non-endemic pests and pathogens have been important driver of mortality (Anderson-Teixeira *et al.*, 2021).

## 2.2 (paragraph on recruitment failure because of deer and non-endemic plants)

* white-tailed deer (*Odocoileus virginianus* ) is important endemic nuisance species, over-abundant because of human influence

McGarvey *et al.* (2013)

The capacity to regenerate following disturbances, including ongoing gap formation through mortality of canopy trees, critically influences long-term forest dynamics. Regeneration depends first upon seed production and then upon seedling recruitment, survival, and growth into trees. When any one of these steps fails, the stage is set for disturbance to push forest ecosystems over a tipping point, whereby there is little chance that a forest will recover to it’s pre-disturbance state in the foreseeable future (**refs?**). Global change pressures can set the stage for such critical transitions by gradually shifting baseline conditions, making post-disturbance recovery unlikely despite the persistence of mature trees (**anderson-teixeira\_altered\_2013?**; **mcdowell\_pervasive\_2020?**; **refs?**). In the mid-Atlantic region of eastern North America, forests face a severe “regeneration debt”, meaning that there are insufficient juveniles of current canopy tree species to replace the mature cohort when they eventually die (Miller & McGill, 2019; Miller *et al.*, 2023). Low juvenile abundance in the region is driven by a combination of over-abundant deer, competition with non-endemic species, and possibly climate change (Miller & McGill, 2019; Miller *et al.*, 2023; **russell\_interactions\_2017?**). The juveniles that are present tend to represent a different, more mesophytic set of species (*Acer spp.*, *Fagus grandifolia*) than currently dominate much of the region (*Quercus spp.*, *Carya spp.*, Miller & McGill (2019); (**nowacki\_climate\_2015?**)]–a dynamic driven by fire suppression and mesophication (**refs?**).

Here, we use 15 years of detailed census data from a large forest dynamics plot including a 4-ha deer exclosure to test the following hypotheses: (1) canopy tree mortality and associated biomass loss are increasing, in large part due to non-endemic nuisance species (pests & pathogens) (2) growth and recruitment (outside deer exclosure) have not kept pace with tree mortality, resulting in declining AGB (-∆AGB) (3) C stocks have declined (-∆AGB), and will decline further if current trends continue

# 3 Materials and Methods

## 3.1 Study site

## 3.2 Data collection

## 3.3 Analyses

# 4 Results

# 5 Discussion

# 6 Conclusions (optional)

# Acknowledgements

* Funding: ForestGEO

# Conflict of Interest statement

The authors declare no conflict of interest.

# Authors’ contributions

*[Name of author 1] and [Name of author 2] conceived the ideas and designed methodology; [Name of author 1] and [Name of author 3] collected the data; [Name of author 2] and [Name of author 4] analysed the data; [Name of author 1] and [Name of author 4] led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.*

# Data availability

# References

**Ahlström A, Schurgers G, Arneth A, Smith B**. **2012**. [Robustness and uncertainty in terrestrial ecosystem carbon response to CMIP5 climate change projections](https://doi.org/10.1088/1748-9326/7/4/044008). *Environmental Research Letters* **7**: 044008.

**Anderson-Teixeira KJ, Herrmann V, Cass WB, Williams AB, Paull SJ, Gonzalez-Akre EB, Helcoski R, Tepley AJ, Bourg NA, Cosma CT, *et al.*** **2021**. [Long-Term Impacts of Invasive Insects and Pathogens on Composition, Biomass, and Diversity of Forests in Virginia’s Blue Ridge Mountains](https://doi.org/10.1007/s10021-020-00503-w). *Ecosystems* **24**: 89–105.

**McGarvey JC, Bourg NA, Thompson JR, McShea WJ, Shen X**. **2013**. [Effects of Twenty Years of Deer Exclusion on Woody Vegetation at Three Life-History Stages in a Mid-Atlantic Temperate Deciduous Forest](https://doi.org/10.1656/045.020.0301). *Northeastern Naturalist* **20**: 451–468.

**Miller KM, McGill BJ**. **2019**. [Compounding human stressors cause major regeneration debt in over half of eastern US forests](https://doi.org/10.1111/1365-2664.13375). *Journal of Applied Ecology* **56**: 1355–1366.

**Miller KM, Perles SJ, Schmit JP, Matthews ER, Weed AS, Comiskey JA, Marshall MR, Nelson P, Fisichelli NA**. **2023**. [Overabundant deer and invasive plants drive widespread regeneration debt in eastern United States national parks](https://doi.org/10.1002/eap.2837). *Ecological Applications* **33**: e2837.

**Wu C, Coffield SR, Goulden ML, Randerson JT, Trugman AT, Anderegg WRL**. **2023**. [Uncertainty in US forest carbon storage potential due to climate risks](https://doi.org/10.1038/s41561-023-01166-7). *Nature Geoscience*: 1–8.