Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Quantifying Changes in Evapotranspiration and Carbon Sequestration in a Restored Longleaf Pine System

A. Christopher Oishi [1], Thomas O'Halloran [2], Devendra Amatya [1], Ge Sun [1], Carl Trettin [1]

1 USDA Forest Service, Southern Research Station

2 Clemson University, Baruch Institute of Coastal Ecology and Forest Science

Southern Research Station

ACES: A Community on Ecosystem Services, December 10, 2024

This work was supported by:

- USDA National Institute of Food and Agriculture (NIFA), Agriculture and Food Research Initiative (AFRI), Sustainable Agricultural Systems Award number 2022-67019-3630
- US Department of Energy, Office of Science, Biological and Environmental Science, Award number DE-SC0023310
- NASA ECOSTRESS Award number 22-ESAT22-0056
- USDA Forest Service, Southern Research Station
- Clemson University, Baruch Institute of Coastal Ecology and Forest Science

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

U.S. DEPARTMENT OF ENERGY | Office of Science

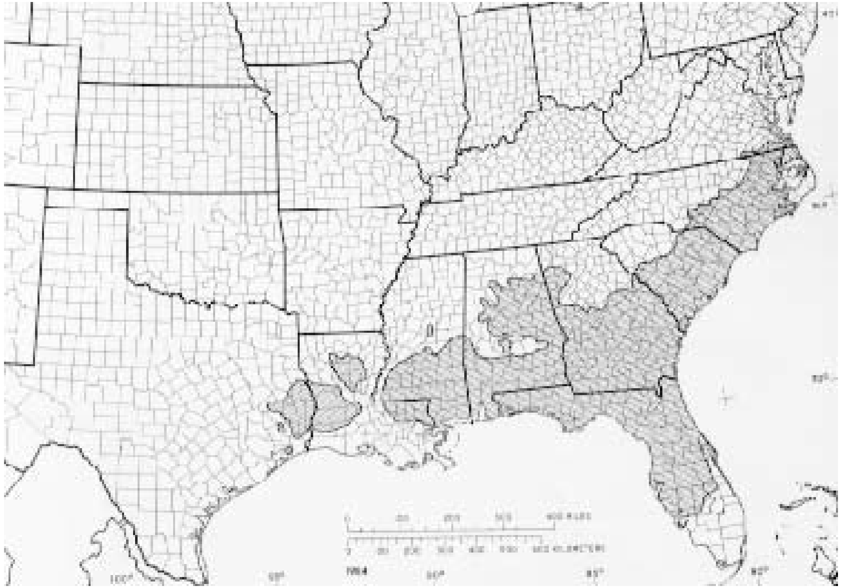
BARUCH INSTITUTE OF COASTAL ECOLOGY AND FOREST SCIENCE
College of Agriculture, Forestry and Life Sciences

Jet Propulsion Laboratory
California Institute of Technology | ECOSTRESS

Southern Research Station

Longleaf and loblolly: a tale of two pines

Native range of longleaf pine (*Pinus palustris*)



Baker and Langdon, 1990

Longleaf and loblolly: a tale of two pines

VanderSchaaf 2023

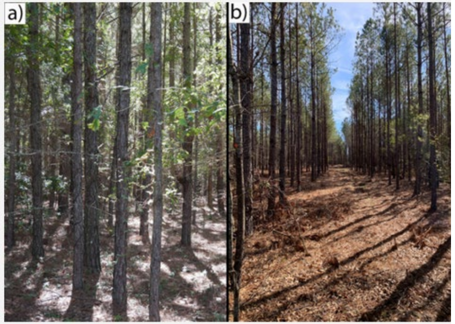
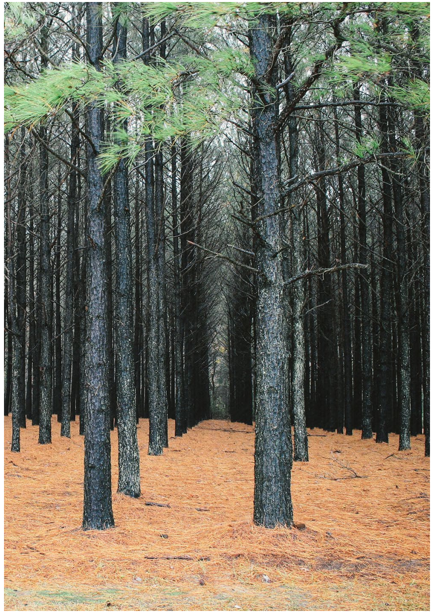
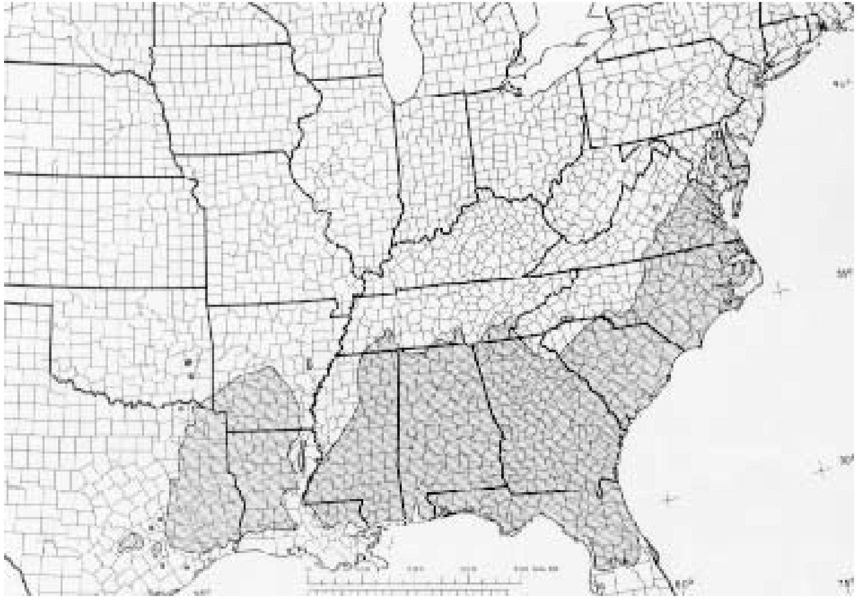


Figure 7. Twenty-year-old planted loblolly pine before (a) and after (b) a fourth-row thinning. Image credit: Janet Steele, Clemson Cooperative Extension.



https://chattoogariver.org/

Native range of loblolly pine (*Pinus taeda*)



Boyer, 1990

Ecosystem services from longleaf pine systems

- Plant diversity
- Wildlife habitat
  - –Ecologically threatened and sensitive species
  - –Hunting and birdwatching
- Non-timber forest products
- Aesthetics/recreation
- Climate resilience and long-term stability

USDA Forest Service

Ecosystem services from longleaf pine systems

Water resources

Precipitation = Evapotranspiration + Water Yield

If restoration of longleaf systems reduces ET

- Potential for greater supply of surface and ground water
- Potential for greater resilience to drought

Science of the Total Environment 902 (2023) 165999

Contents lists available at ScienceDirect

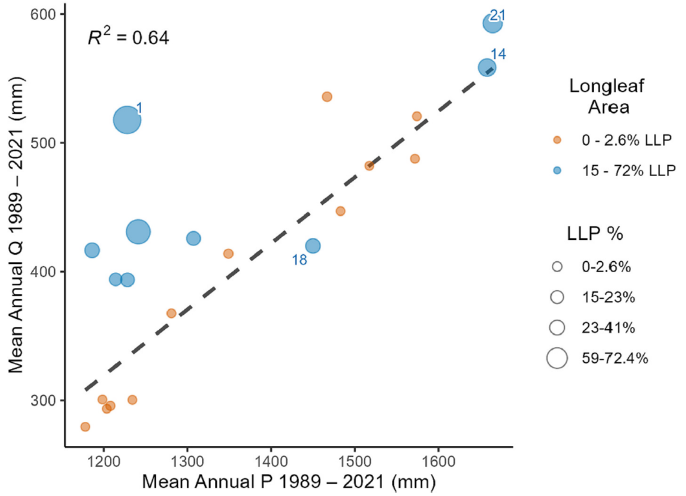
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Impacts of longleaf pine (*Pinus palustris* Mill.) on long-term hydrology at the watershed scale

Seth E. Younger *, Jeffery B. Cannon, Steven T. Brantley

The Jones Center at Ichauway, Newton, GA, United States of America



ig. 4. Mean annual streamflow by mean annual precipitation 1989–2021 with significant Theil-Sen regressions.

Ecosystem services from longleaf pine systems

Carbon sequestration

Net uptake = Photosynthesis – Respiration – Other Losses

Restored longleaf systems may have

- Reduced short-term carbon uptake
- Potential for greater resilience to climate and other disturbances
- Potential for stable, long-term storage

Methods: Eddy covariance

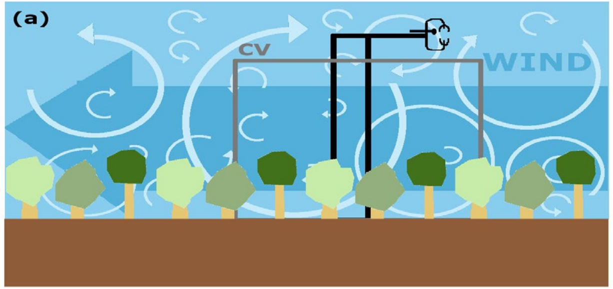
Quantifying the exchange of mass and energy above the forest canopy

High-frequency measurements of:

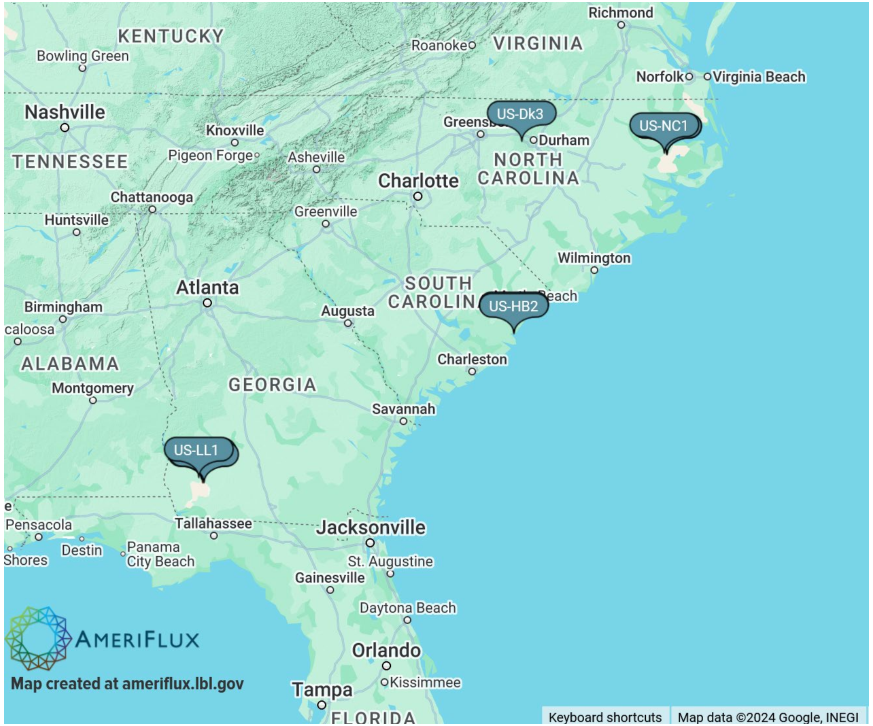
- Air mixing (turbulent eddies)
- Concentration of water vapor and carbon dioxide

Coupled micrometeorological measurements

Half-hourly estimates of evapotranspiration and net ecosystem exchange of carbon



Regional synthesis of eddy covariance sites



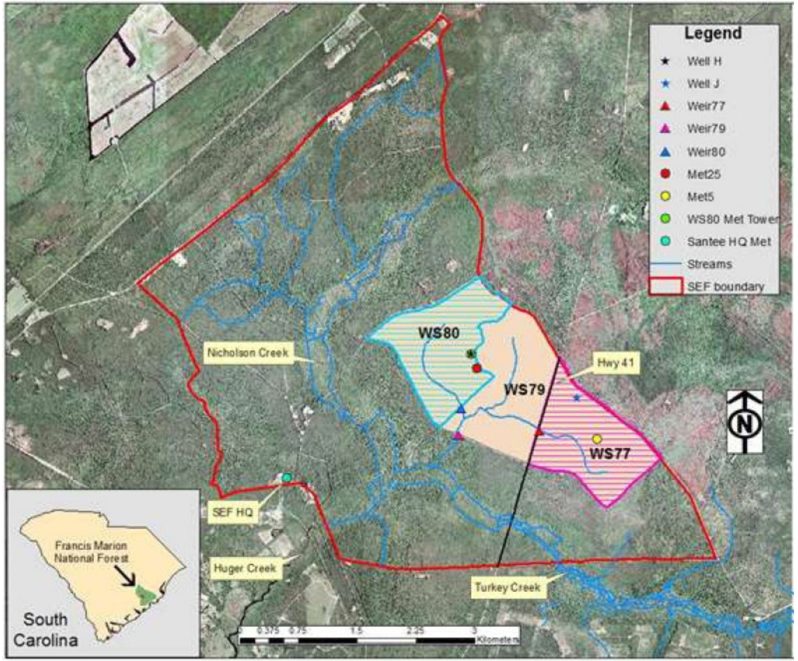
- Medium-aged loblolly plantation, mesic soil (US-Dk3)
- Harvested and planted loblolly pine, loamy/wet site (US-NC3)
- Medium-aged loblolly pine plantation, loamy/wet site (US-NC2 & US-NC3)

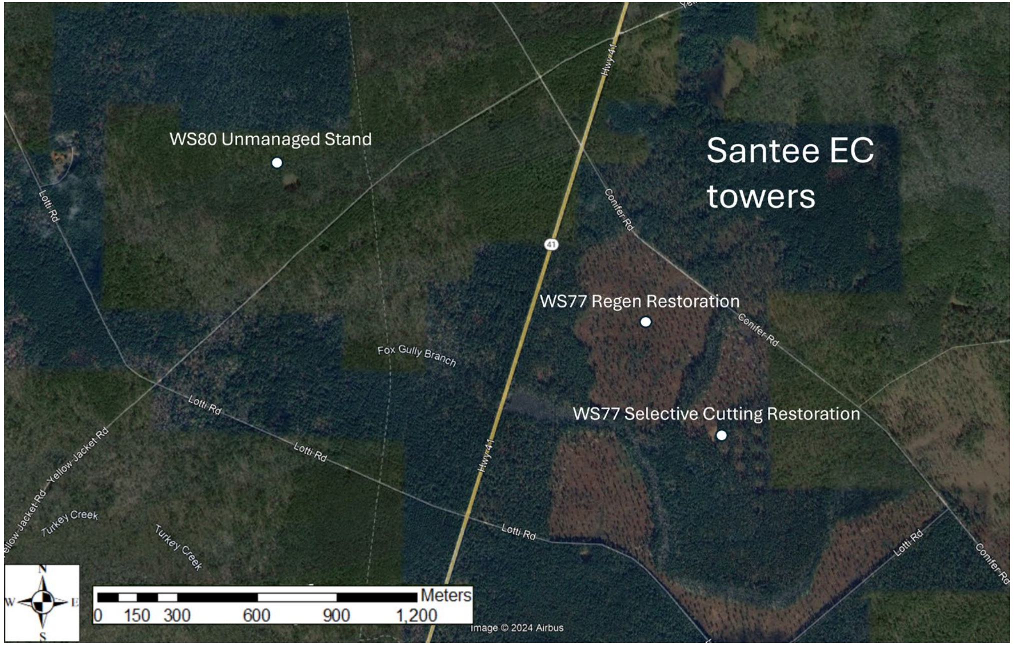
- Mature longleaf system, xeric site (US-xJE)
- Old longleaf pine systems, xeric, intermediate, and mesic sites (US-LL1, US-LL2, US-LL3)
- ***NEW: Harvested and planted longleaf pine, sandy-dry site (US-HB3)***
- ***NEW: Mature longleaf pine, mesic site (US-HB2)***

Research objectives

1) Quantifying total ecosystem carbon sequestration rates and water use for longleaf compared to loblolly throughout the anticipated lifespan of the stand
   - Leverage existing data and initiate new sites
   - Consider alternative management pathways
2) Identifying the key environmental drivers that affect tree- and stand-level productivity at a seasonal or annual scale and determine ecosystem resilience to severe weather
3) Developing models that can predict ecosystem carbon sequestration and water use across the range of soil types and predicted future climates throughout the southeastern coastal plain and lower piedmont

Methods: Site locations





Watershed 80

- Mature, mixed loblolly & longleaf pine with deciduous hardwoods
- Natural regeneration following blowdown during Hurricane Hugo in 1989
- 160 ha watershed area

24 m tall tower initiated in spring 2022

Watershed 77

"Regeneration" harvest

- 2021: Near-total cutting and thinning
- 2022: prescribed burn and pesticide
- 2023: longleaf planted
- 2/10/2024: prescribed burn

6 m tall tower initiated in spring 2022

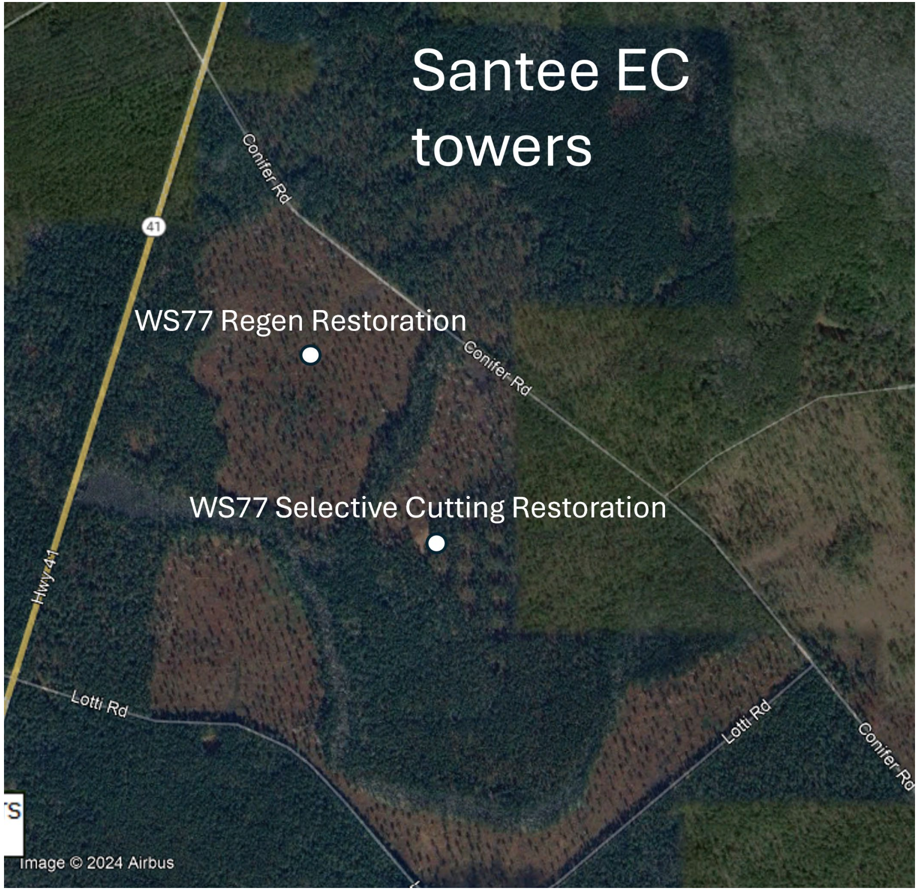
Watershed 77

"Thinned" and "group selection" treatments

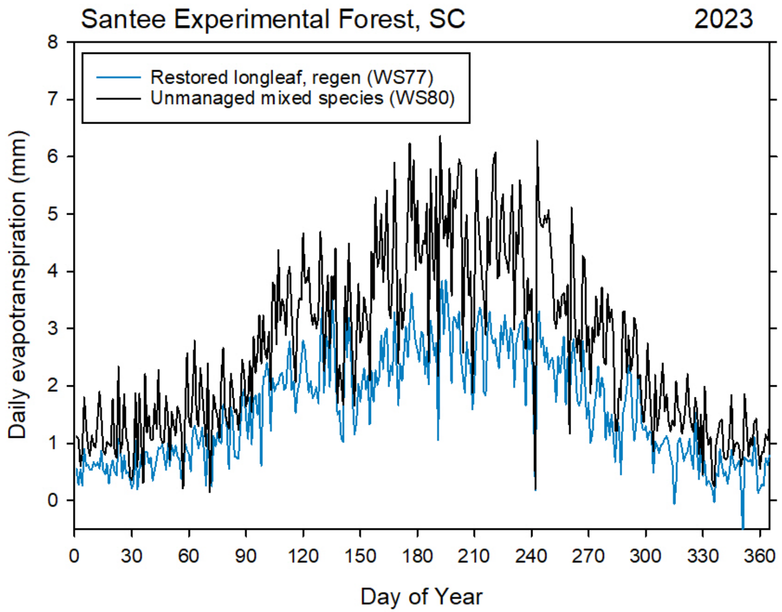
- 2021: selective cutting of hardwood and some loblolly pine trees
- 2022: prescribed burn and pesticide 2023: longleaf planted
- 2/10/2024: prescribed burn

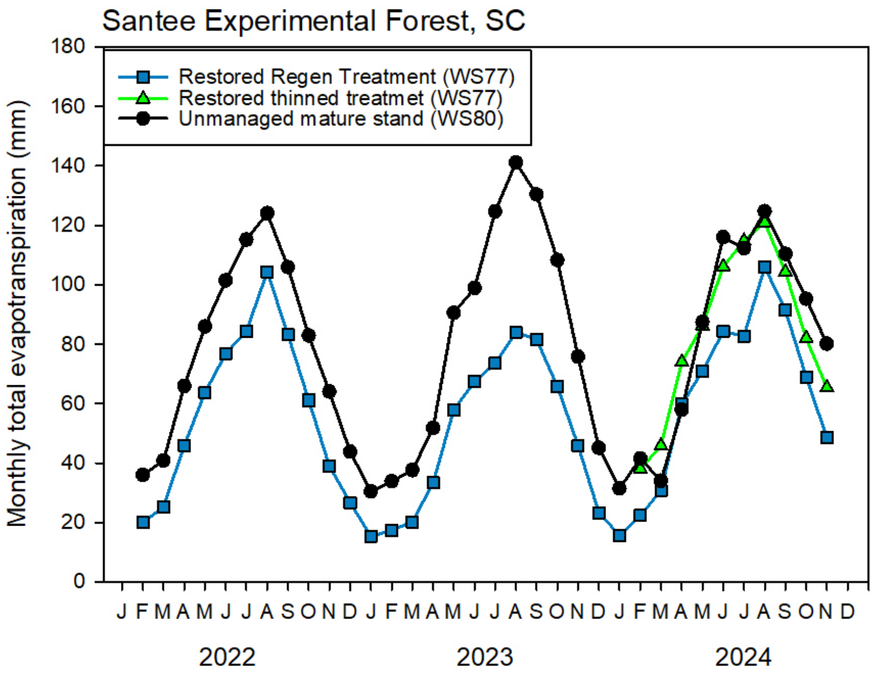
25 m tall tower initiated in spring 2024

Methods: Site locations

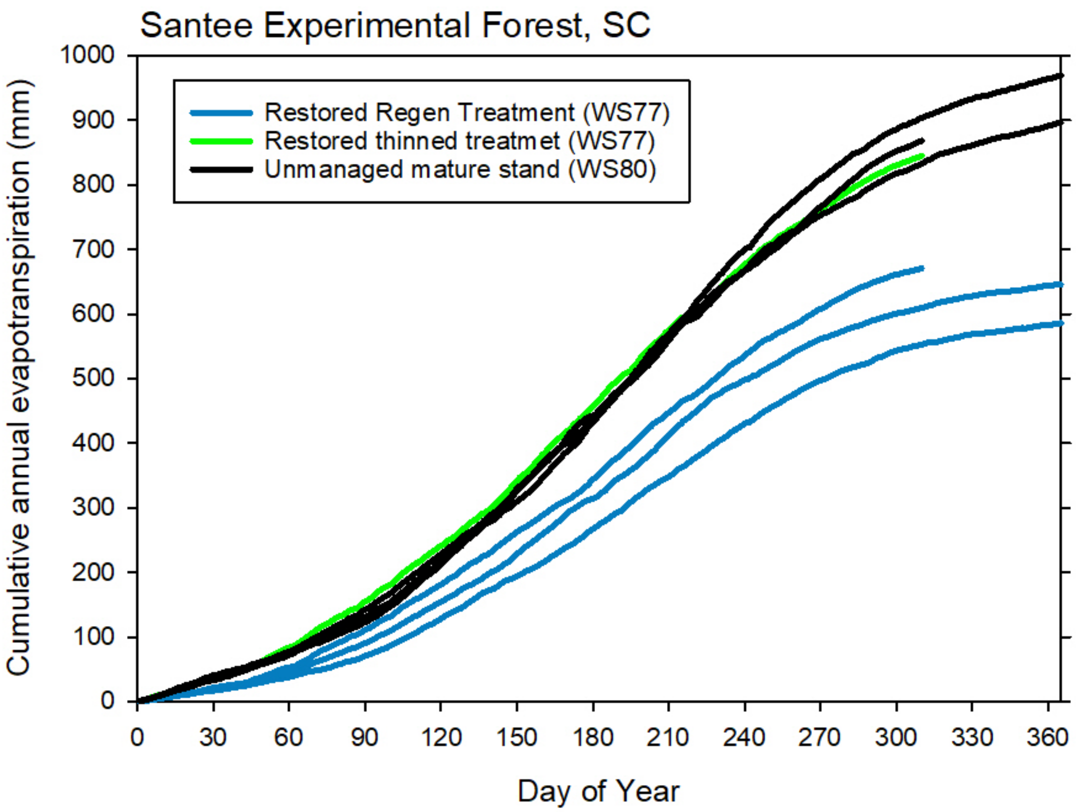


Results: evapotranspiration





Results: evapotranspiration



Mean annual precipitation

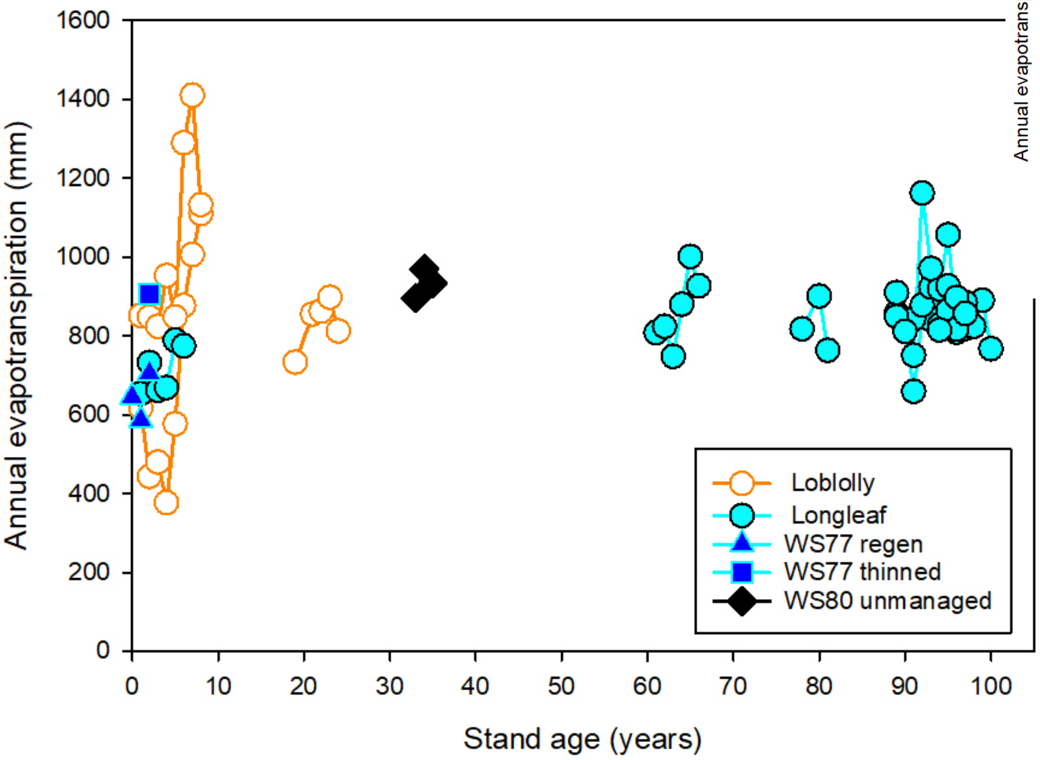
1,370 mm

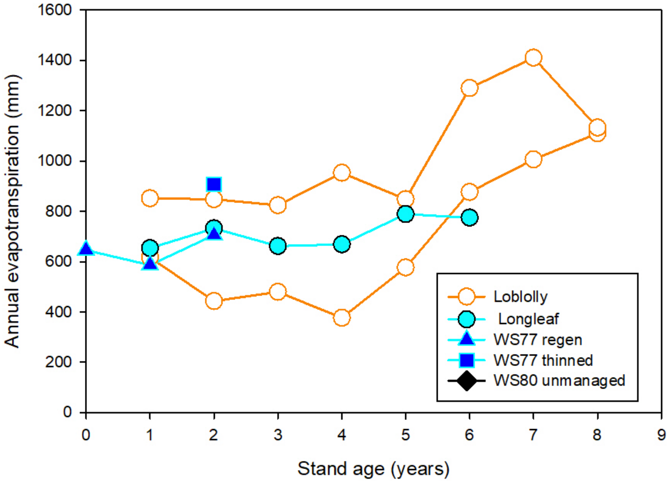
Range (past 15 years):

min: 930 mm

max: 2,170 mm

Results: evapotranspiration

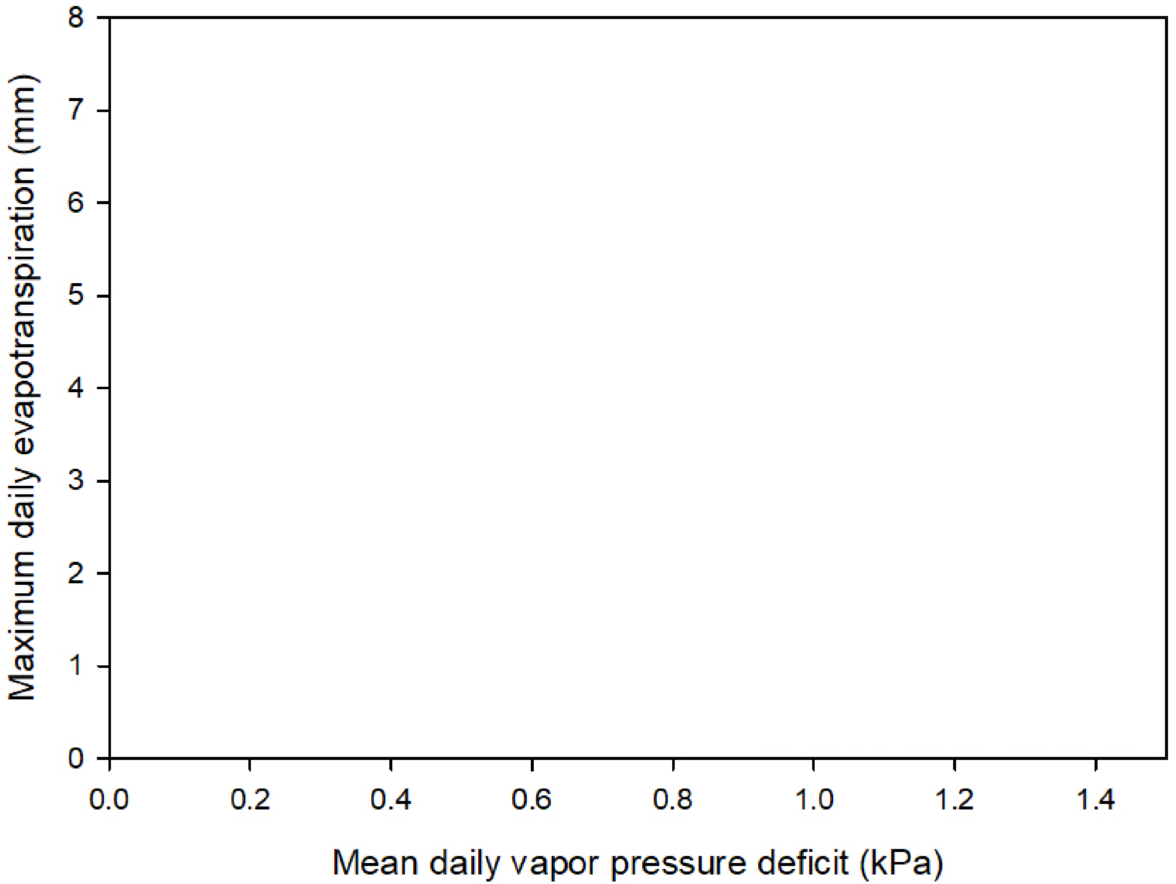




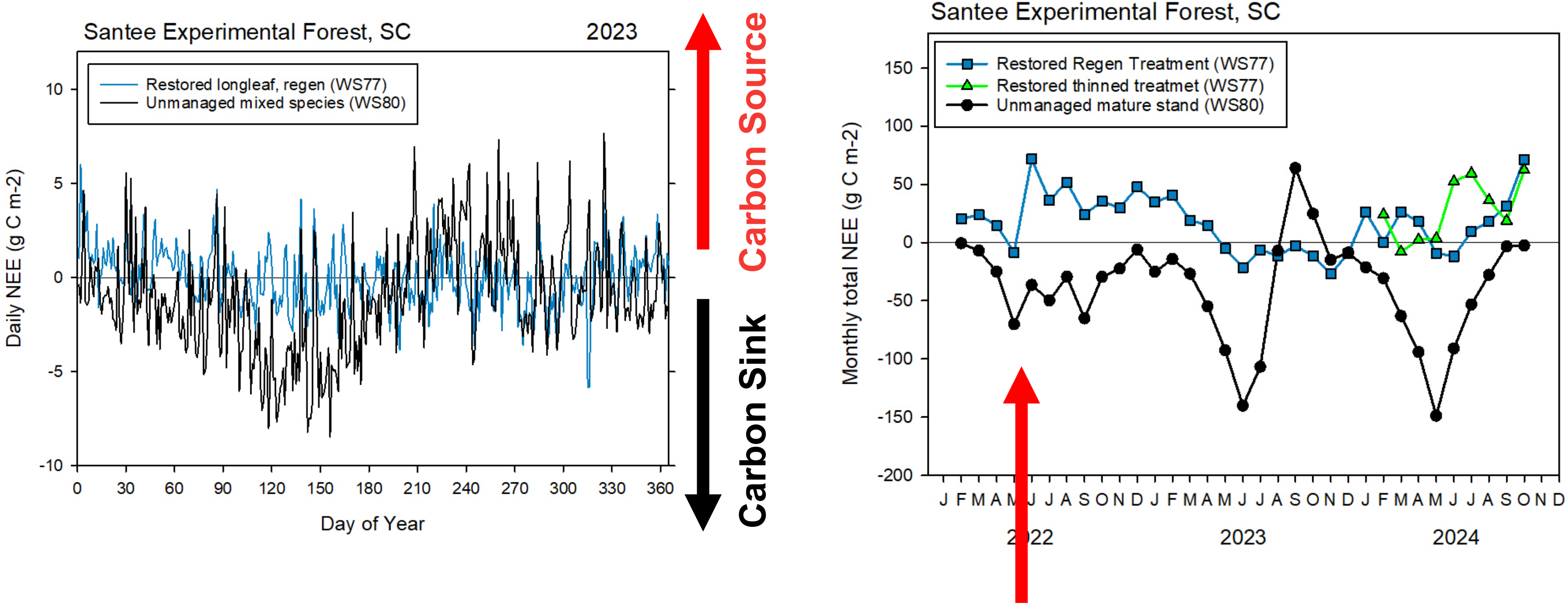
Is mean annual ET consistent among forest types after stand establishment?

Accounting for local climate

- Vapor pressure deficit (VPD) is the atmospheric demand for water
- Warmer air can hold more water and drive higher ET



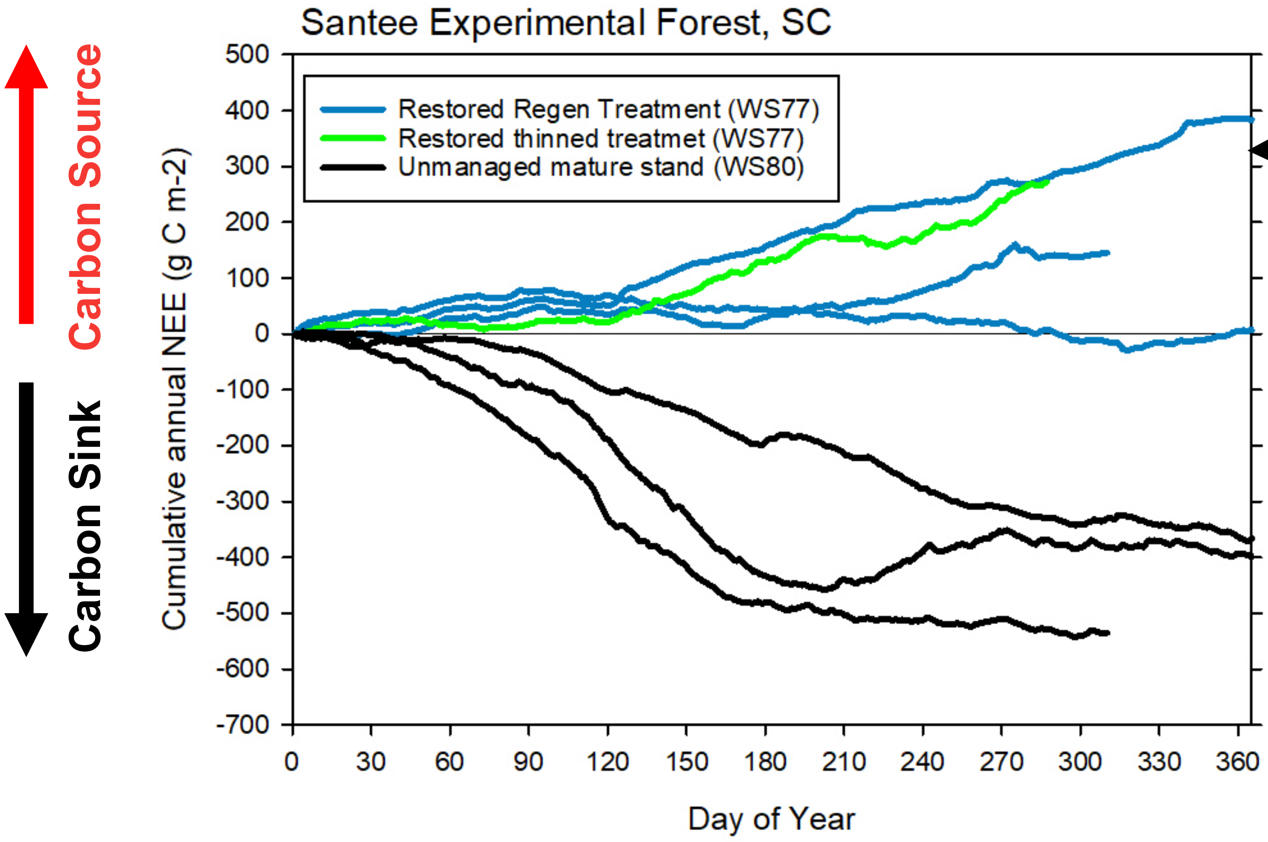
Results: carbon uptake and storage



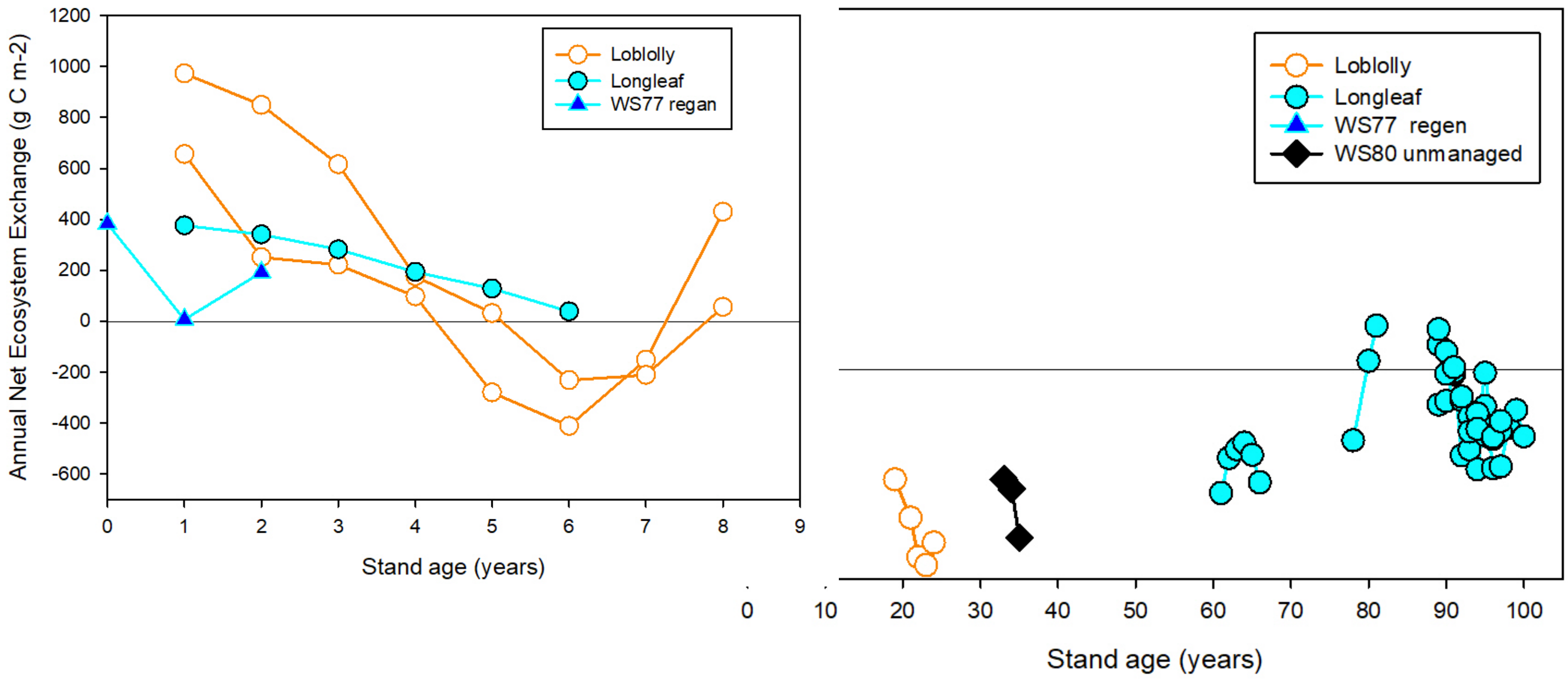
Low precipitation and water table depth

Southern Research Station

Results: carbon uptake and storage



Results: carbon uptake and storage



Conclusions

Short-term effects of restored watersheds in Santee Experimental Forest

- Stand-replacement restoration intervention (clearcut/regeneration harvest)
  - Immediate decrease in evapotranspiration
  - Short-term ecosystem carbon source (~10 years)
- Thinning/selective harvest restoration intervention
  - Negligible short-term change in evapotranspiration
  - Reduced carbon uptake

Conclusions

General effects of conversion to longleaf pine systems

- Longleaf systems have lower ET than loblolly plantations, under similar climate conditions
  - High vapor pressure deficit can drive high ET
- Stand conversion for both longleaf and loblolly systems transition from a carbon source to sink at similar rates
- Mature longleaf and loblolly stands have comparable carbon sequestration rates
- Maximum sink strength of intermediate-aged longleaf stands is still uncertain

Acknowledgements

Francis Marion National Forest

Technical and field support by:

- Julie Arnold, Andy Harrison, Alex Smith, Christine Sobek, and Seth Strickland (USFS)
- Jeremy Forsythe, Mike Kline, and Daniel Schermaier (Clemson)

Ameriflux data sources:

- Chris Oishi, Kim Novick, Paul Stoy (2018), AmeriFlux BASE US-Dk3 Duke Forest - loblolly pine, Ver. 4-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1246048
- Gregory Starr (2021), AmeriFlux BASE US-LL1 Longleaf Pine - Baker (Mesic site), Ver. 2-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1773395
- Gregory Starr (2021), AmeriFlux BASE US-LL2 Longleaf Pine - Dubignion (Intermediate site), Ver. 1-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1773396
- Gregory Starr (2021), AmeriFlux BASE US-LL3 Longleaf Pine - Red Dirt (Xeric site), Ver. 1-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1773397
- Asko Noormets, Ge Sun, Michael Gavazzi, Steve McNulty, Jean-Christophe Domec, John King (2024), AmeriFlux FLUXNET-1F US-NC1 NC_Clearcut, Ver. 4-6, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1902836
- Asko Noormets, Ge Sun, Michael Gavazzi, Jean-Christophe Domec, Steve McNulty, Guofang Miao, Maricar Aguilos, Bhaskar Mitra, Kevan Minick, John King, Linqing Yang, Prajaya Prajapati (2024), AmeriFlux BASE US-NC2 NC_Loblolly Plantation, Ver. 16-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1246083
- Asko Noormets, Michael Gavazzi, Maricar Aguilos, John King, Bhaskar Mitra, Jean-Christophe Domec (2023), AmeriFlux FLUXNET-1F US-NC3 NC_Clearcut#3, Ver. 3-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/2204872
- NEON (National Ecological Observatory Network) (2023), AmeriFlux FLUXNET-1F US-xJE NEON Jones Ecological Research Center (JERC), Ver. 3-5, AmeriFlux AMP, (Dataset). https://doi.org/10.17190/AMF/1985443