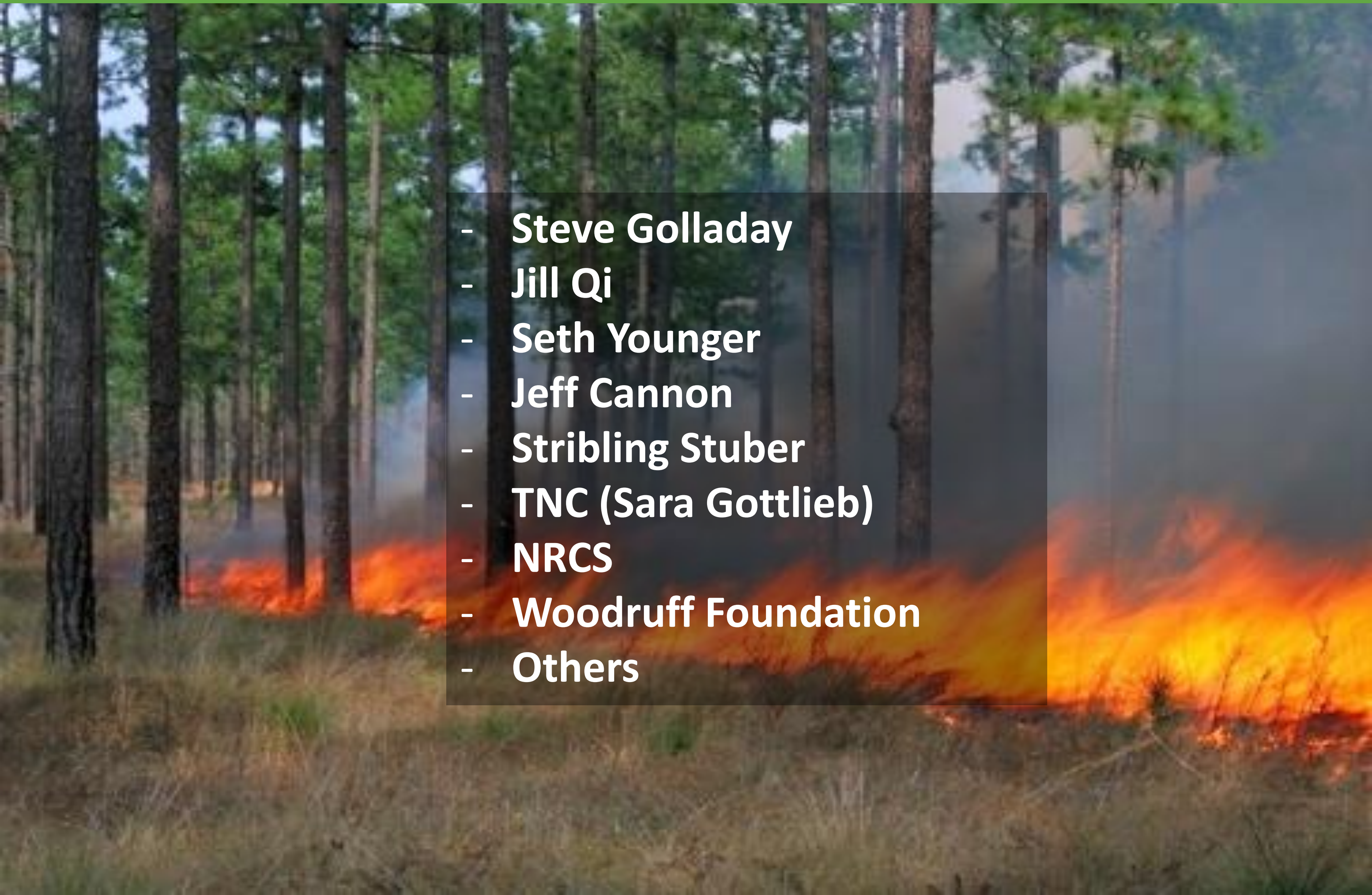
Longleaf Pine Restoration as a Strategy to Increase Streamflow

Steven Brantley

THE JONES CENTER AT ICHAUWAY

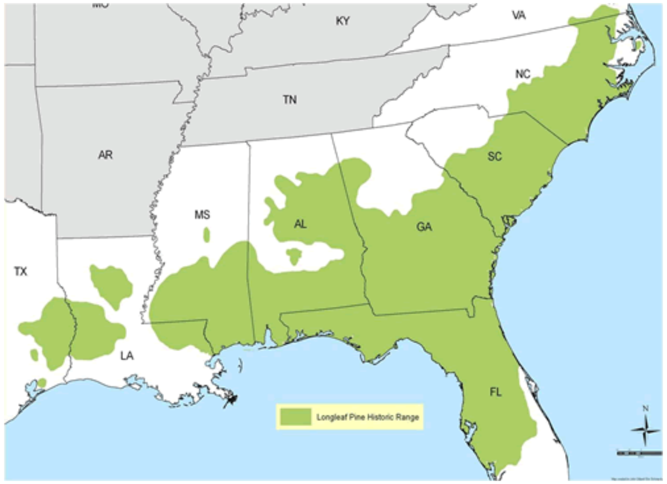
Acknowledgements



- Steve Golladay
- Jill Qi
- Seth Younger
- Jeff Cannon
- Stribling Stuber
- TNC (Sara Gottlieb)
- NRCS
- Woodruff Foundation
- Others

Longleaf Pine Ecosystems

- High Biodiversity
- Endemic species
- Aesthetics, Culture, and Economics
- Long-lived C sink
- *Improves water yield*



Water budgets 101

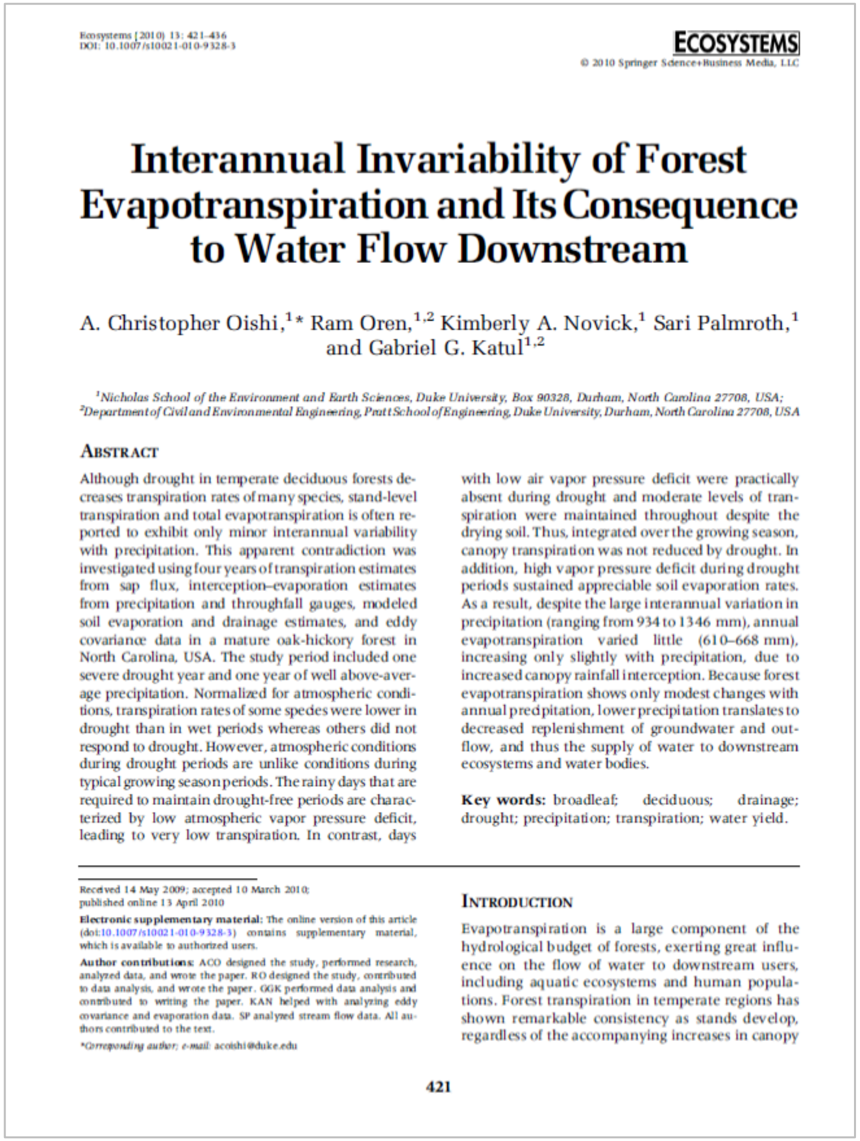
$$\text{Yield} = \frac{\text{Precipitation} - \text{Evapotranspiration}}{\text{Watershed Area}}$$

- Precipitation ↕
  - High variability
  - Drier growing seasons
  - Longer, more severe droughts
- Evapotranspiration ↑
  - Irrigation
  - Warmer temperatures
  - *Changes in forest management*
- Yield ↓
  - Flow is critically low in some years

Ichawaynochaway Creek in 2012

Photo by Steve Golladay

Conceptual model



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ECOSYSTEMS

Interannual Invariability of Forest Evapotranspiration and Its Consequence to Water Flow Downstream

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Abstract

Although drought in temperate deciduous forests decreases transpiration rates of many species, stand-level transpiration and total evapotranspiration is often reported to exhibit only minor interannual variability with precipitation. This apparent contradiction was investigated using four years of transpiration estimates from sap flux, interception–evaporation estimates from precipitation and throughfall gauges, modeled soil evaporation and drainage estimates, and eddy covariance data in a mature oak-hickory forest in North Carolina, USA. The study period included one severe drought year and one year of well above-average precipitation. Normalized for atmospheric conditions, transpiration rates of some species were lower in drought than in wet periods whereas others did not respond to drought. However, atmospheric conditions during drought periods are unlike conditions during typical growing season periods. The rainy days that are required to maintain drought-free periods are characterized by low atmospheric vapor pressure deficit, leading to very low transpiration. In contrast, days with low air vapor pressure deficit were practically absent during drought and moderate levels of transpiration were maintained throughout despite the drying soil. Thus, integrated over the growing season, canopy transpiration was not reduced by drought. In addition, high vapor pressure deficit during drought periods sustained appreciable soil evaporation rates. As a result, despite the large interannual variation in precipitation (ranging from 934 to 1346 mm), annual evapotranspiration varied little (610–668 mm), increasing only slightly with precipitation, due to increased canopy rainfall interception. Because forest evapotranspiration shows only modest changes with annual precipitation, lower precipitation translates to decreased replenishment of groundwater and outflow, and thus the supply of water to downstream ecosystems and water bodies.

Key words: broadleaf; deciduous; drainage; drought; precipitation; transpiration; water yield.

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Author contributions: ACO designed the study, performed research, analyzed data, and wrote the paper. RO designed the study, contributed to data analysis, and wrote the paper. GGK performed data analysis and contributed to writing the paper. KAN helped with analyzing eddy covariance and evaporation data. SP analyzed stream flow data. All authors contributed to the text.

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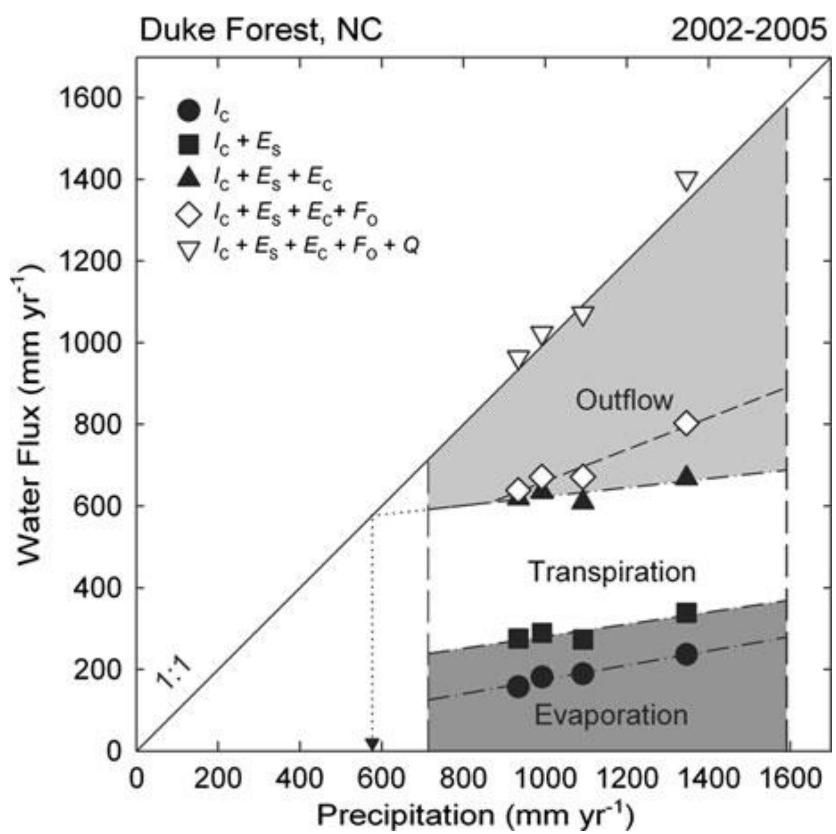
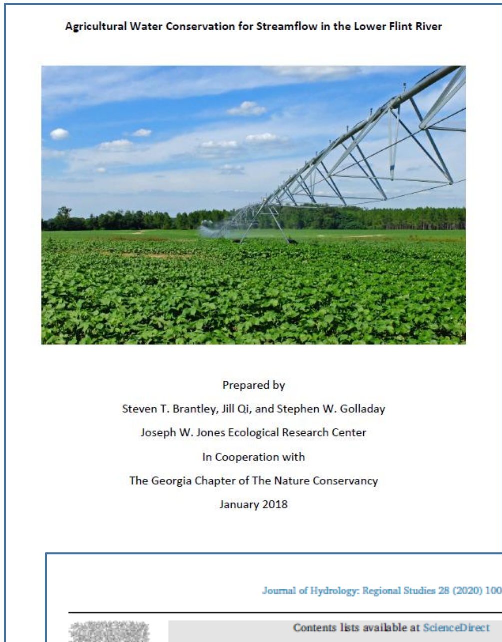
Introduction

Evapotranspiration is a large component of the hydrological budget of forests, exerting great influence on the flow of water to downstream users, including aquatic ecosystems and human populations. Forest transpiration in temperate regions has shown remarkable consistency as stands develop, regardless of the accompanying increases in canopy



Irrigation reduction



Agricultural Water Conservation for Streamflow in the Lower Flint River

Prepared by

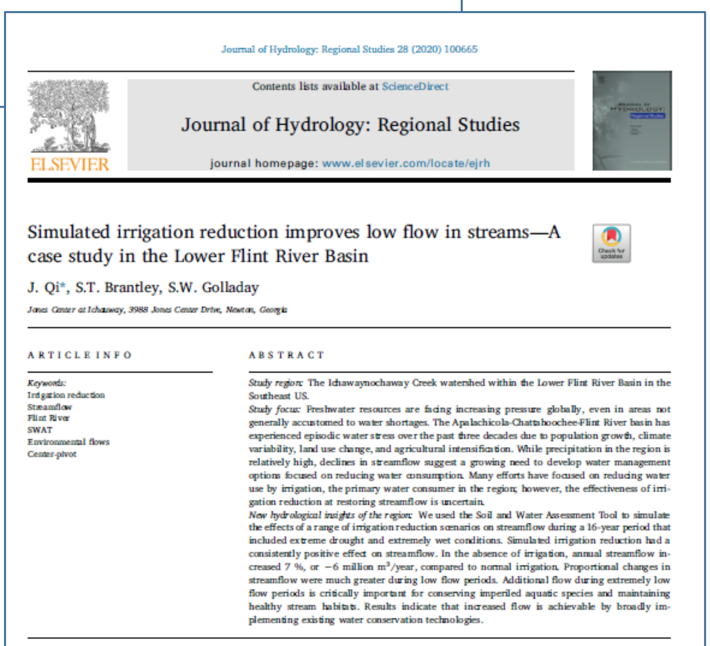
Steven T. Brantley, Jill Qi, and Stephen W. Golladay

Joseph W. Jones Ecological Research Center

In Cooperation with

The Georgia Chapter of The Nature Conservancy

January 2018



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Simulated irrigation reduction improves low flow in streams—A case study in the Lower Flint River Basin

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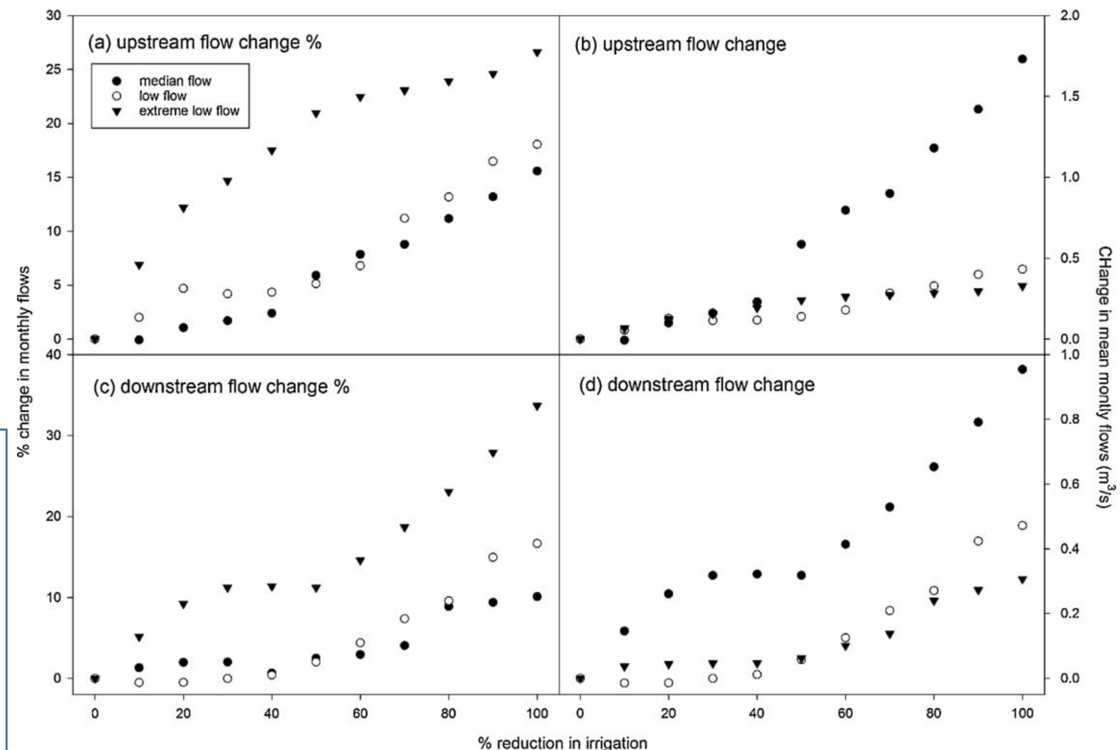
ABSTRACT

Study region: The Ichawaynochaway Creek watershed within the Lower Flint River Basin in the Southeast US.

Study focus: Freshwater resources are facing increasing pressure globally, even in areas not generally accustomed to water shortages. The Apalachicola-Chattahoochee-Flint River basin has experienced episodic water stress over the past three decades due to population growth, climate variability, land use change, and agricultural intensification. While precipitation in the region is relatively high, declines in streamflow suggest a growing need to develop water management options focused on reducing water consumption. Many efforts have focused on reducing water use by irrigation, the primary water consumer in the region; however, the effectiveness of irrigation reduction at restoring streamflow is uncertain.

New hydrological insights of the region: We used the Soil and Water Assessment Tool to simulate the effects of a range of irrigation reduction scenarios on streamflow during a 16-year period that included extreme drought and extremely wet conditions. Simulated irrigation reduction had a consistently positive effect on streamflow. In the absence of irrigation, annual streamflow increased 7 %, or ~6 million m^3/year, compared to normal irrigation. Proportional changes in streamflow were much greater during low flow periods. Additional flow during extremely low flow periods is critically important for conserving imperiled aquatic species and maintaining healthy stream habitats. Results indicate that increased flow is achievable by broadly implementing existing water conservation technologies.



The Longleaf Option

Why might longleaf benefit water yield?

- Generally lower density, less leaf area
- Lower per-tree transpiration than slash/loblolly pine or hardwoods
- C4 grass understory--higher water use efficiency and lower leaf area
- Prescribed fire suppresses mid-story growth
- LLP responds to drought—uses less water when water is less available

- Evapotranspiration↓
  - Stand-level ET only 70-80% of slash/loblolly ET

- Water yield should go up

The Longleaf Option

Does it work? Isolated wetland case study

esa ECOSPHERE

Forest restoration increases isolated wetland hydroperiod: a long-term case study

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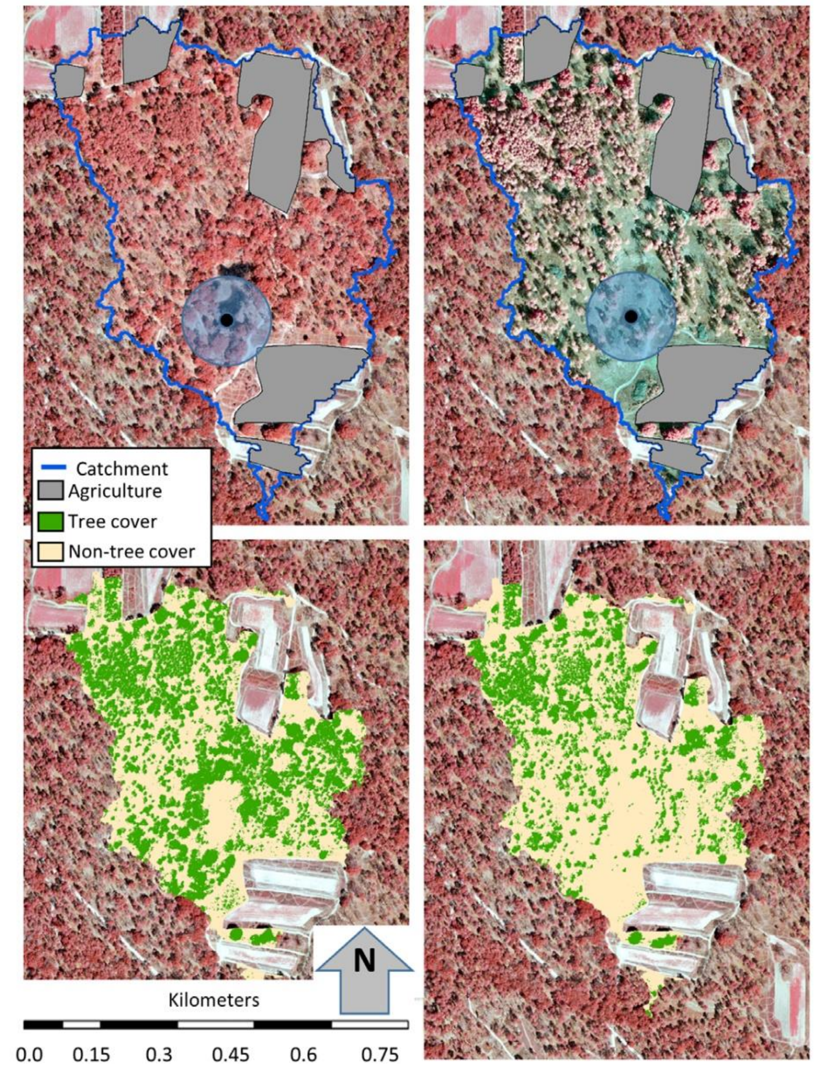
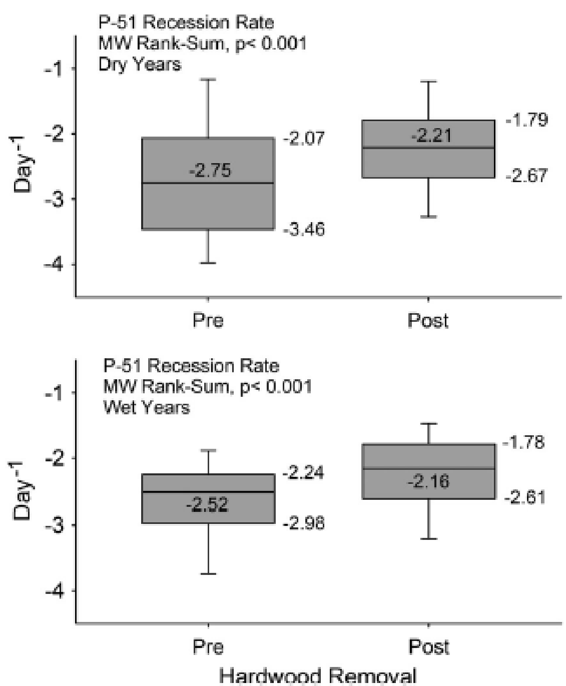
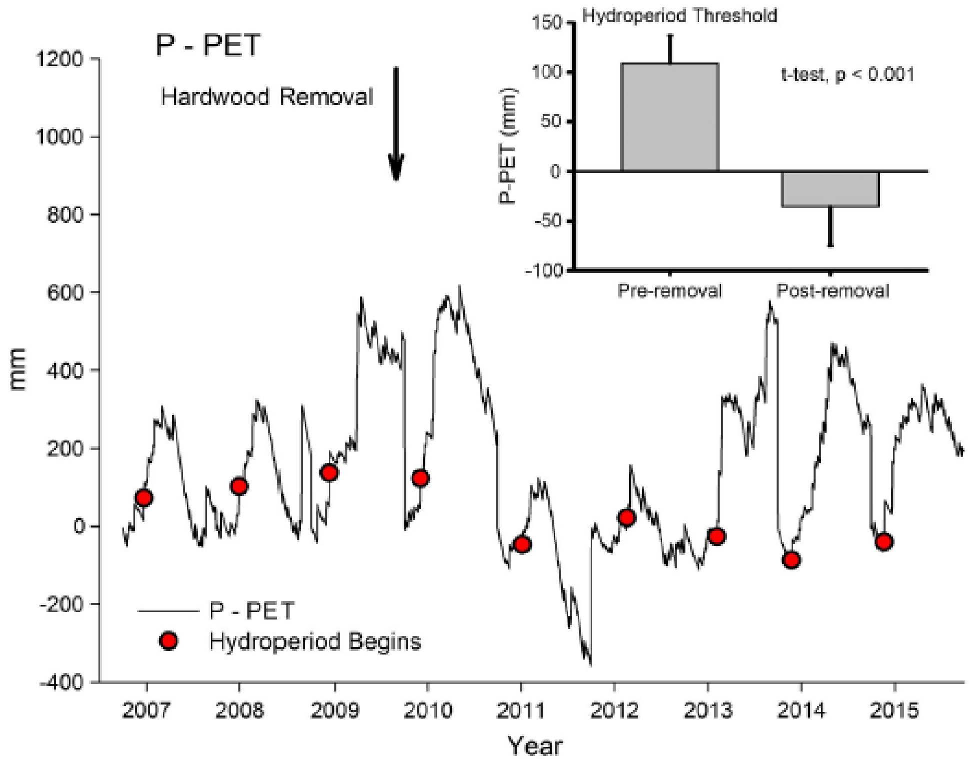
Abstract. Geographically isolated wetlands (GIWs) are well known as "hotspots" for biodiversity and other ecosystem services, making their value on landscapes disproportionate to the area they occupy. GIWs are dependent on regular cycles of inundation and drying, which makes hydrology a primary controlling variable for sustaining functions and associated ecosystem services. Although human activity has degraded GIWs in many regions, relatively little work has focused on upland management as a way of sustaining, or even improving, GIW structure and function. We present a case study of longleaf pine forest restoration, by hardwood removal, on the characteristics of a wetland hydroperiod over a 10-year study. Our study wetland, W-51, is 0.89 ha with a catchment area of 31.2 ha located on a ~11,400-ha private preserve in Baker County, Georgia (31.250° N, 84.495° W). Beginning in 2006, continuous water level and climate data were recorded in the wetland and adjacent well transects across the wetland catchment. In autumn 2009, hardwoods were removed or deadened in the catchment resulting in a 37% reduction in tree cover. The effects on the hydrologic system were measured through 2016 by examining pre- and post-removal water levels, water yield ecosystem (WYe), and standardized recession rates (RR_{std}). The study included periods of above and below normal rainfall. Generally, wetland hydroperiods began in December and ended in May, but varied with rainfall pattern and amount. Hardwood removal increased WYe and decreased RR_{std} resulting in greater catchment water availability as reflected in water levels. Hardwood removal affected both the ascending and recessing limbs of wetland hydroperiods, substantially increasing the availability of ponded water in the wetland. Our results quantify changes in wetland hydrologic characteristics associated with forest management activities, which appear to have reduced forest water demand. Our study was a management case study, limited in scope but conducted in a realistic setting. More extensive studies (paired, replicated designs) are needed to better understand the implications at both the local scale, that is, managing critical aquatic habitat for wildlife populations, and at the regional scale, that is, providing support for landscape-scale connectivity and water yields.



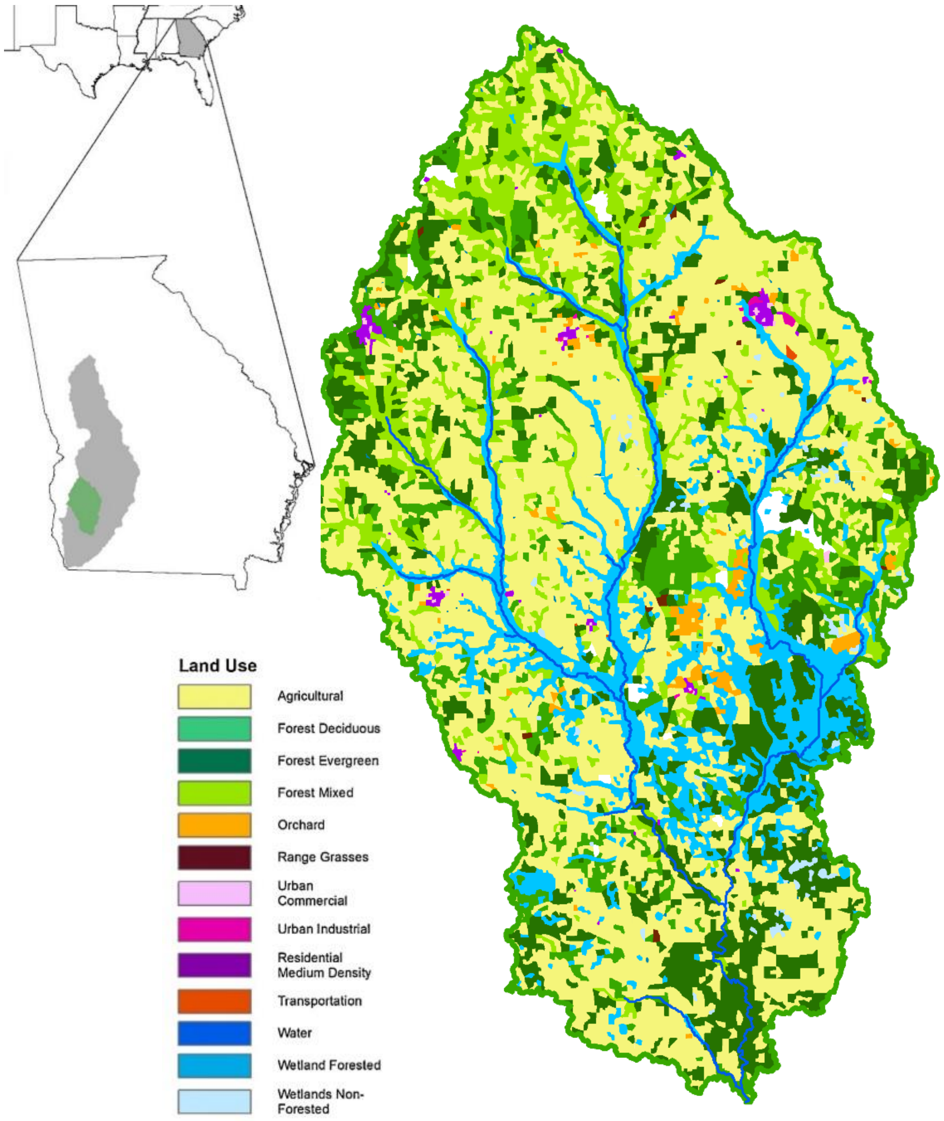
The Longleaf Option

Does it work? Isolated wetland case study





The Longleaf Option



Land use in the Ichawaynochaway Creek Basin

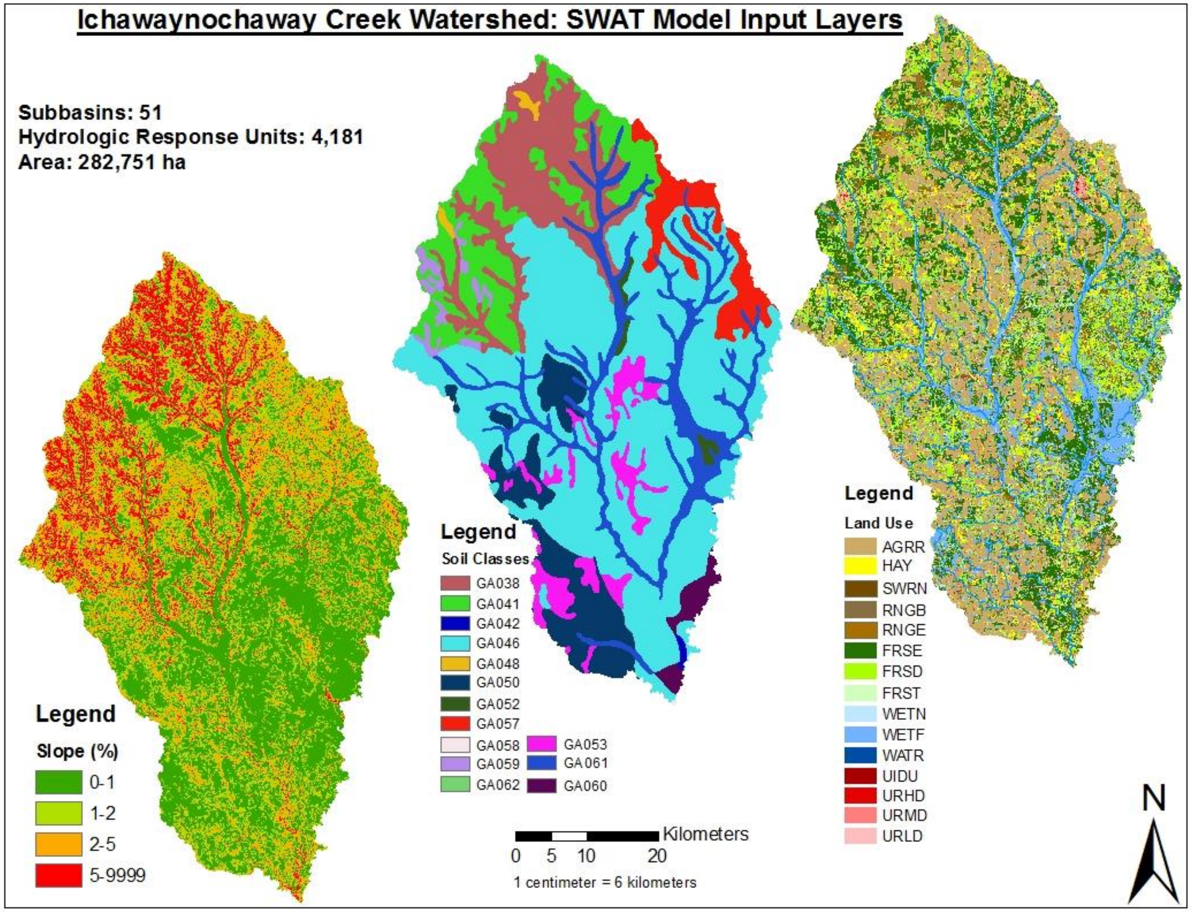
- 28% row crop
- 20% pasture
- 4 % urban (mostly upper)
- 48 % forested
  - *4% longleaf pine*
  - 11% forested wetlands
  - 15% upland hardwoods
  - 18% plantation pine

- Forest management may provide another tool for water conservation

The Longleaf Option

How does longleaf restoration impact streamflow?

- Simulation modeling
- Soil & Water Assessment Tool
- Process-based model
  - *Land cover*
  - Soils
  - Topography
  - Climate and streamflow data
  - Monthly time step

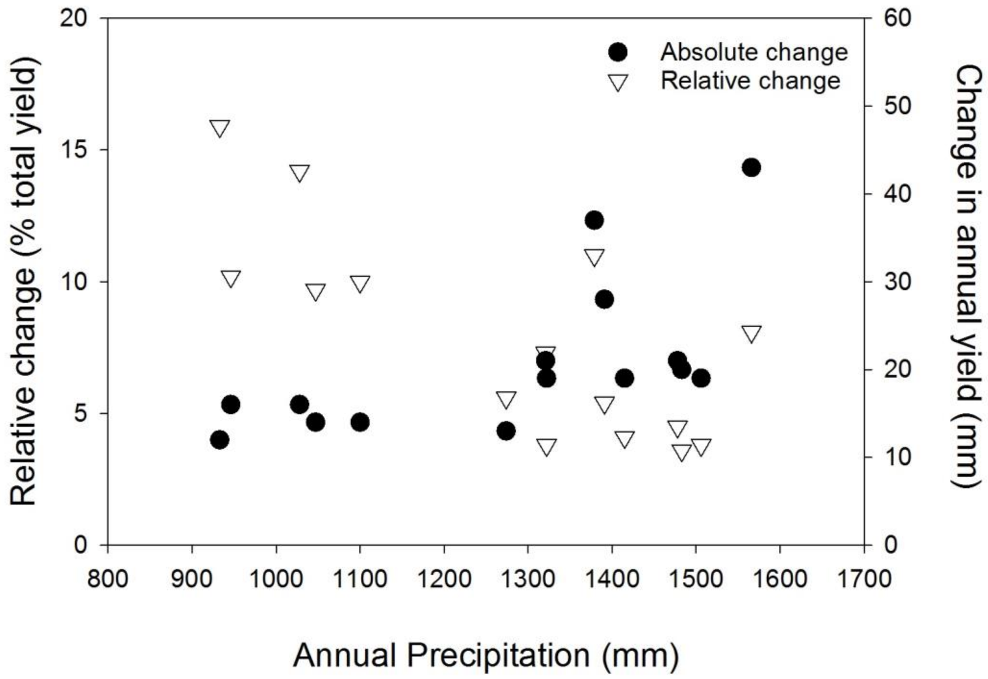


The Longleaf Option

How does longleaf restoration impact streamflow?

- Simulated conversion of 230,000 forested acres to LLP: 4% → 35%

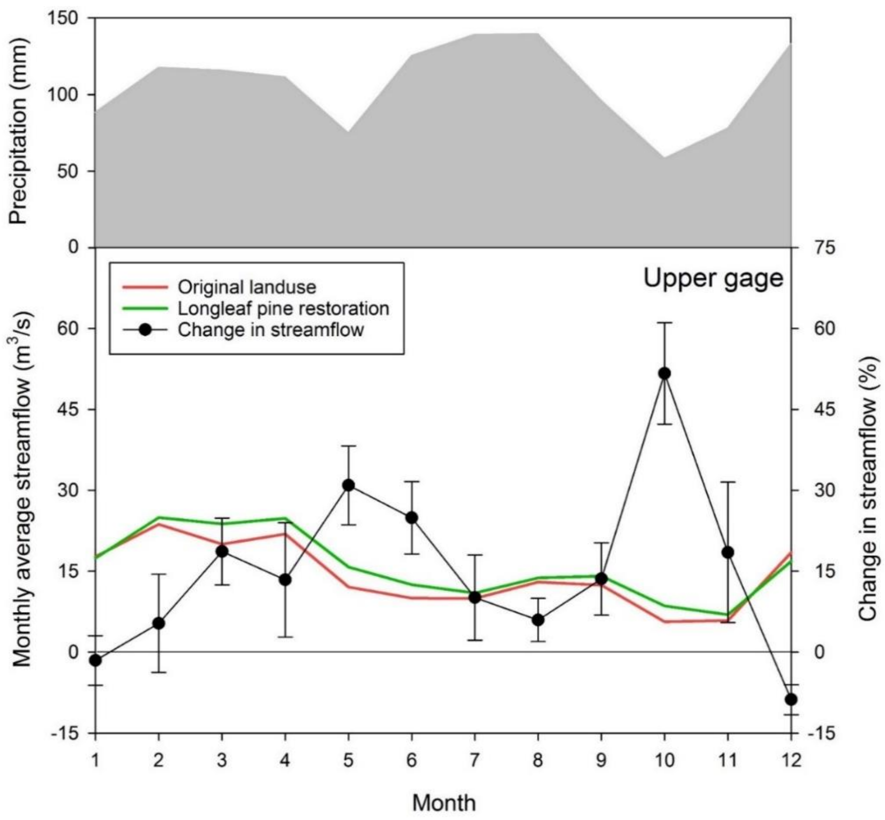
The Longleaf Option



How does longleaf restoration impact streamflow?

- Converted 230,000 forested acres to LLP: 4% → 35%
- **Modeled ET decreased as expected**
- **Annual water yield increased by 5.2%**
- **Most pronounced during periods of extreme low flow**

The Longleaf Option



How does longleaf restoration impact streamflow?

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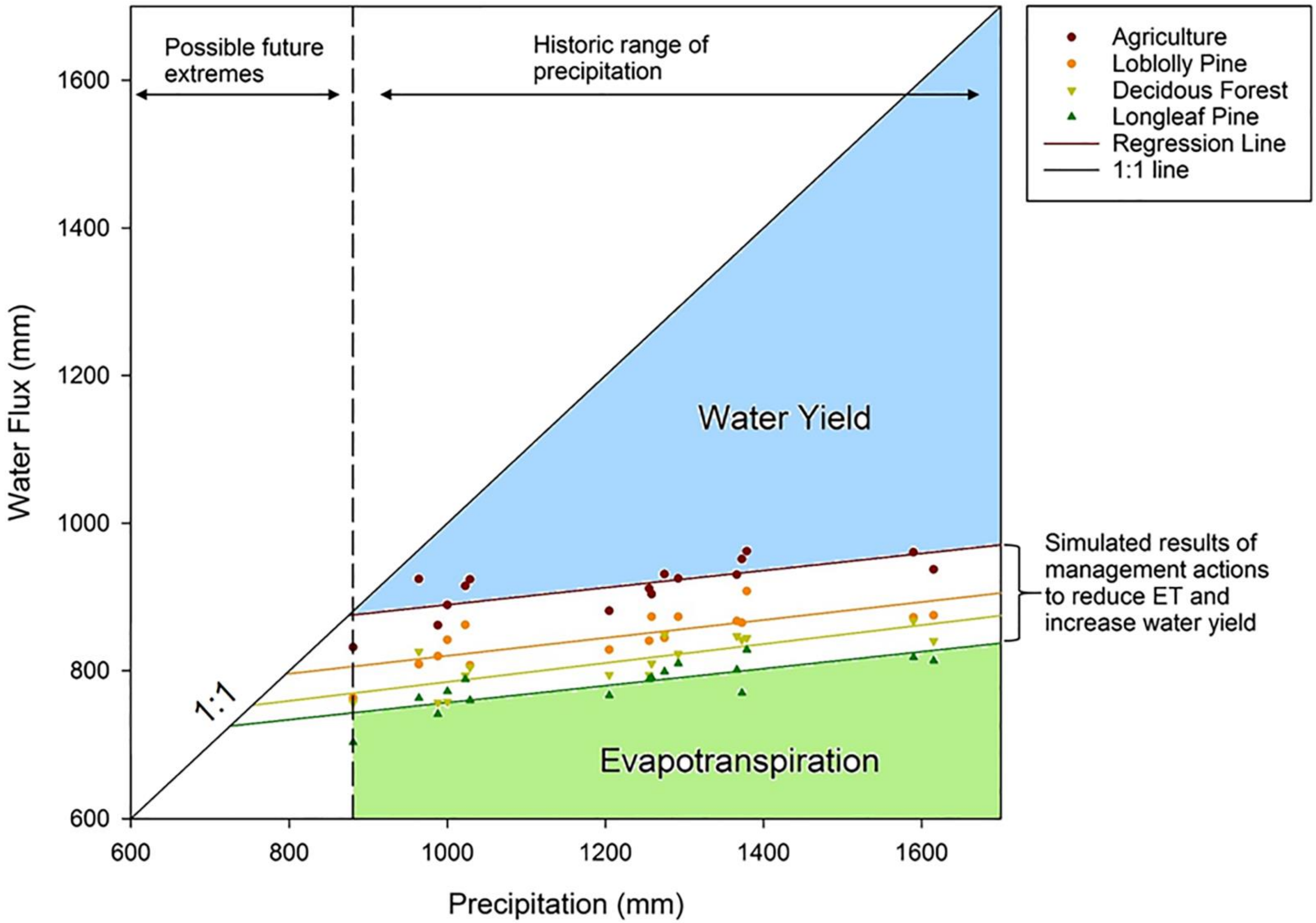
The Longleaf Option



Next steps

- Expanding the concept:
  - NRCS CEAP funding
  - Simulate in other watersheds across southeast
  - Simulate full-life-cycle longleaf restoration
  - Simulate real-world forest conservation practices
- Other Research:
  - Watershed-scale restoration (Santee Experimental Forest)
  - Linking higher water yield to aquatic and semi-aquatic systems

Questions?