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Longleaf Pine Restoration for Water Resources

Longleaf pine woodlands are characterized by relatively low density of the trees and continuous groundcover. This structure is ideal for supporting high water yield. Photo by Stephen Golladay.

Water is an essential element for all life on Earth. While two-thirds of the Earth is covered with water, freshwater resources are surprisingly scarce. Globally, humans are already using more than half of the available freshwater every year. The Jones Center at Ichauway has long recognized this issue and developed an integrated water research and education program to address these issues. We use our study area, the lower Flint River Basin of southwestern Georgia, as a case study to understand the consequences of, and provide solutions to, problems of water scarcity. Our water program asks three fundament questions:

- How does water availability change throughout the year, and what do these changes mean for rivers, streams, and wetlands?
- How do climate change and human water use affect water availability and quality in the region?
- What management and conservation actions are needed to provide for human and environmental needs?

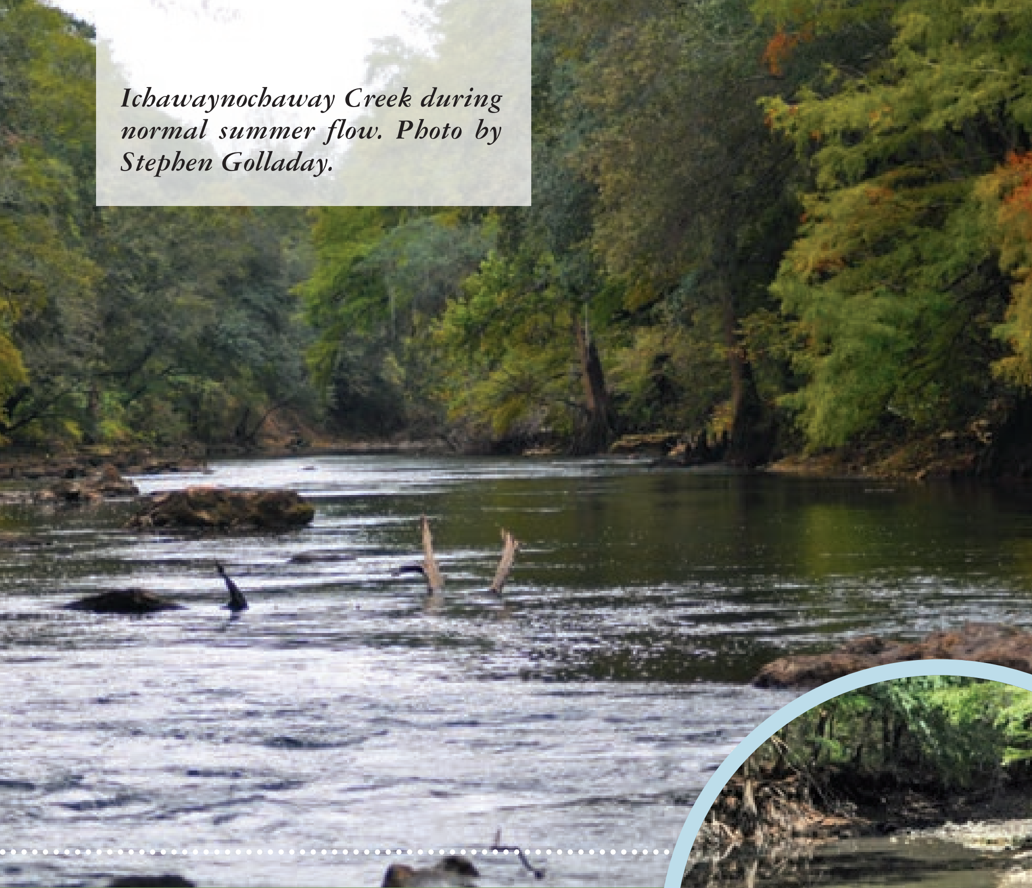
This last question ties back to longleaf pine in some surprising ways.

Increasing water scarcity & higher water demand by modern forests

The southeastern U.S. receives abundant rainfall, but increasing human demand, climate change, and multiyear severe droughts have combined to create extended periods of water scarcity. Recent droughts are more frequent and severe, and combined with rising temperatures are increasing the regional demand for water. We are seeing undesirable consequences, including degraded streams, rivers and wetlands, loss of native plants and animals, and threats to human health. While many of the water conservation efforts to date have focused on reducing agricultural water use, we must also recognize that forests are large water consumers. Changes in forest management over the last century, including loss of native longleaf forest, denser replanting for economic gain or carbon sequestration, and fire suppression, have all contributed to higher water demand by modern forests. Restoring longleaf pine may help mitigate stress on water resources and add resilience to threatened aquatic ecosystems.

A water cycle refresher

While most types of forests benefit water quality, compared to alternate land uses like cities or farms, there are large differences in the amount of water consumed by different forest types. To understand why we must understand the basics of the hydrologic cycle. The ultimate source of water is rainfall in most of the Southeast. As rainfall passes through forests, much of the water is captured in the foliage of trees, shrubs, and grasses, and absorbed by leaf litter. Called “interception,” this water generally evaporates and never makes it into the soil. Water that does make it to the soil may then be taken up by plant roots and transpired through leaves to support metabolic



Ichawaynochaway Creek during normal summer flow. Photo by Stephen Golladay.

Eddy-covariance towers compare water use of different forest types across the Southeast. Tower instruments measure wind speed, wind direction, and concentrations of trace gases like water vapor and carbon dioxide to determine how much carbon the forest takes in and how much water it takes to support the forest. Courtesy of The Jones Center at Ichauway.

Chickasawhatchee Creek, a tributary of the Ichawaynochaway Creek, during the severe drought in summer 2011. Note the exposed rocks that would normally provide habitat for aquatic organisms. Photo by Stephen Golladay.

activity like growth. Water that makes it through these two barriers is free to percolate through the soil to either recharge groundwater, re-fill wetlands, or support streamflow. The difference between precipitation and combined transpiration and interception is often called "water yield."

Why longleaf pine?

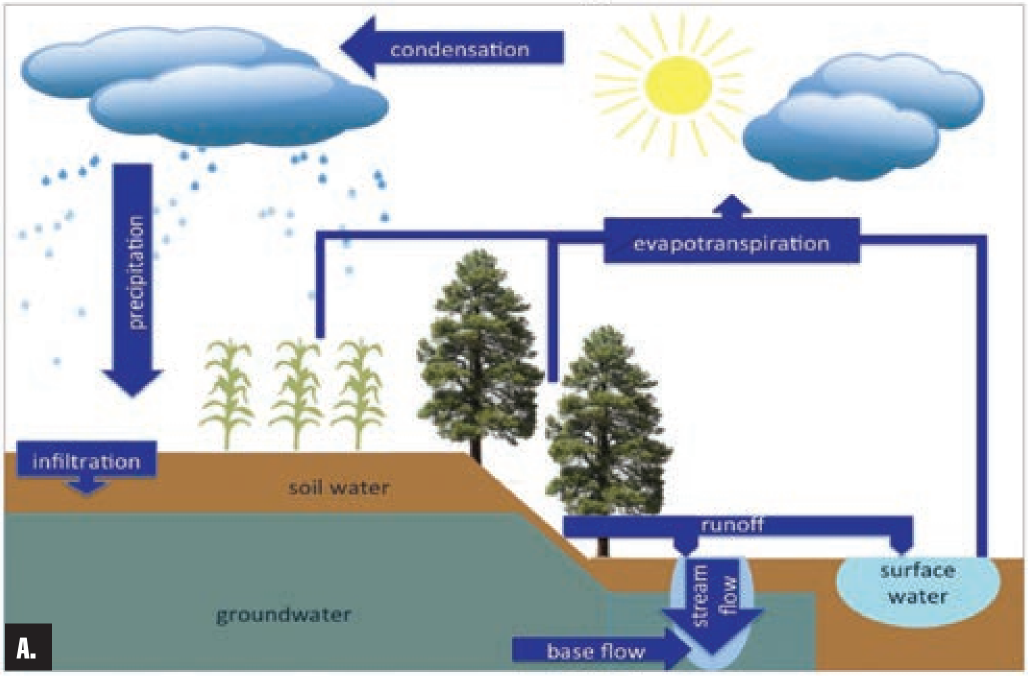
The benefits of longleaf pine forest restoration are obvious to many people: high biodiversity, protection of endemic species, excellent wildlife habitat, and the unique aesthetics of open pine woodlands. But longleaf pine may also provide benefits for water supplies. Thinking about the forest as a barrier to water movement, it naturally follows that forest structure affects how much precipitation is available to support aquatic systems. **In many ways, the structure of longleaf pine woodlands is ideal for supporting high water yield while also improving water quality.** The relatively low density of trees means that less water is used in transpiration, and the relatively open canopy means less water is lost to interception. Native groundcover and warm-season grasses like wiregrass may also have lower water use than a dense shrub understory common to many fire-suppressed forests. Wiregrass is both highly efficient in water use and relatively slow-growing compared to many other understory plants. Lastly, longleaf pine may be more responsive to drought in that it naturally slows down its metabolic activity when conditions become stressful. While this may slow longleaf growth, it also reduces forest water consumption when water is most scarce.

On average, **a stand of longleaf pine managed with prescribed fire to control hardwood encroachment and maintain native groundcover typically uses about 15% less water than a typical mixed pine-hardwood forest with no fire. And the same longleaf stand would use about 30% less water than a typical loblolly or slash pine plantation** planted for commercial timber production (Brantley et al. 2017). In areas like southwestern Georgia, where transpiration and interception typically consume two-thirds of precipitation, these reductions can have a strong impact on water yield. And since streamflow is essentially just the leftover rainfall that is not used by vegetation or extracted by humans, reducing forest water use should naturally improve streamflow during times of similar rainfall.

What effect does longleaf restoration have on streams and wetlands?

The ideal way to answer this question would be a large-scale experiment that restores longleaf pine on hundreds of acres, and then measures stream responses against a reference watershed without restoration. Such an experiment is currently underway at Santee Experimental Forest in South Carolina, but those results will not be available for several years. To begin understanding the benefit of longleaf restoration in the meantime, we used a well-respected USDA streamflow model to understand how changing forest cover can improve streamflow. Such models are based on real-world processes

THE WATER CYCLE



A. The water cycle can be thought of as a simple budget. *Incoming precipitation is balanced against the evaporation of water from land, including forests. What is left over contributes to groundwater, wetlands, streams, and rivers. Reducing evaporation through land management can increase water output.* **B. What happens to rain when it comes into the forest? Much depends on the structure and density of trees.** *A large portion of incoming rain never makes it to the ground as it is intercepted by leaves and branches and simply evaporates back to the atmosphere. Rainfall that does make it to the forest floor may be absorbed by the duff layer and evaporate or be taken up by tree roots and used by the tree. These processes can benefit water quality by slowing rainfall and protecting soil. But too much water use by forests can reduce water supplies. Courtesy of Stribling Stuber & Haley Ritger, The Jones Center at Ichauway.*

like climate, soil variability, and vegetation cover, and allow us to test the effects of forest management on streamflow under a wide range of climate conditions. We tested whether longleaf pine restoration affected streamflow in our home watershed, the Ichawaynochaway Creek. This ~1,000 square-mile watershed lies squarely in the native range of longleaf pine forest, which has been reduced to less than 5% of its historic area. **Our model showed that increasing longleaf cover to ~30% of the watershed reduced forest water consumption and increased streamflow by 9%. Maybe, more importantly, October streamflow increased by about 50%. This is critical since October is often the driest month of the year and the time when aquatic ecosystems are under the most stress.** And this was accomplished by only converting other forest types to longleaf pine, thus leaving agricultural lands alone (Qi et al., in preparation).

Longleaf restoration can also have a major impact on how wetlands work. Although relatively small in area compared to the surrounding forest, geographically isolated wetlands are an important part of the longleaf pine landscape. These wetlands are known for extremely high biodiversity for both plants and amphibians. They can also take in and store large amounts of carbon and can help improve water quality. Many wetlands are slowly losing their ability to support amphibians and provide other ecosystem services due to lack of water during drought and increased water demand from climate change. However, longleaf restoration provides a potential remedy. **Our research shows that removing hardwoods like water oak and live oak, and reintroducing fire in the wetland "contributing area"— essentially the wetland watershed — reduces demand for water and improves wetland hydrology** (Golladay et al., in revision). Improving land management around wetlands may mean earlier wet-up and longer inundation periods, both of which can help maintain wetland function.

Regional policy to support local solutions

If there is any perceived downside to restoring longleaf for water yield, it may come from the perception of longleaf as a poor carbon sink. In many ways, water yield and carbon sequestration are competing interests since water loss and carbon intake are fundamentally linked in plants. **Sequestering atmospheric carbon is an important strategy for climate change mitigation, but doing so at the expense of water supplies and native forest cover may be unwise.** Current policies that incentivize carbon sequestration tend to promote dense, fast-growing forests that show high short-term carbon gains. These policies also converge with economic interests in having fast-growing forests. Emerging research is showing that the long-term carbon benefits of such forestry might be exaggerated due to the massive release of carbon from soils during harvest (James and Harrison 2016). Another tactic is to promote the conservation of older forests and larger trees that tend to store more carbon in soils and roots. **Sustainable harvests provide some economic benefits while protecting soil carbon.**

Isolated wetlands are integral components to the longleaf pine ecosystem, supporting high levels of biodiversity. Photo by Lisa Lord.

And this type of management—the periodic thinning of the forest—actually promotes higher water yield and sustained water quality.

As we gain a better understanding of how longleaf pine restoration benefits water resources, we need to identify opportunities to incorporate these benefits into on-the-ground restoration. Restoring longleaf for water yield alone may or may not be a viable solution. However, adding the water-saving benefits of longleaf restoration to existing programs that promote restoration for wildlife or other benefits may help tilt landowners towards longleaf restoration as a financially viable option. Removing barriers based on the perception that longleaf is a poor carbon sink may also become important. Having a sustainable supply of freshwater has certainly always been a valuable ecosystem service. That importance is only increasing as human demands and climate change alter the equation in the southeastern U.S. Adding water-based incentives into existing conservation and restoration programs that focus on threatened and endangered species may help accelerate the restoration of this endangered ecosystem.

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