Forests and Future Water Stress in the Southeast

Stephanie Worley Firley

How will future water supplies be impacted by a changing climate, an increasing population, and shifting land uses and land cover? Will there be enough water to sustain humans and ecosystems alike? And what can be done to help forests adapt to limited water supplies in the future?

"You don't miss your water 'til the well runs dry." A common phrase has taken on a much more literal meaning for many people recently affected by water shortages. The past few years have been especially unusual for water issues in the southeastern United States, a region that has historically been relatively water rich. Ongoing drought conditions have forced a rethinking of how water is used as well as a renewed focus on water supplies and their origins.

Forests have an indispensable role in providing clean water. Forested watersheds not only capture and store water; they also improve water quality, regulate streamflows, and keep erosion in check. But climate change and variability are already compromising the ability of some forests to perform vital services within the hydrologic cycle. The impacts of drought resulting from altered precipitation patterns coupled with warmer air temperatures in some areas—which are expected to intensify as time goes on—are influencing forest compositions and processes. As forest hydrologic patterns change with the climate, forest landowners and managers will be faced with some important decisions to ensure adequate water supplies.

The Impacts of Drought on Trees and Forests

The effects of drought on forests differ depending on where drought occurs. Trees in arid landscapes—such as the western United States where drought is a natural and regular occurrence—are more able to handle periods of drought. Drought happens less frequently in the East, but portions of the southeastern United States unaccustomed to prolonged dry spells have been especially hard hit by drought that has persisted during 7 of the past 10 years. Drought during the last three growing seasons (2006 to 2008) has been among the worst of the past century in some areas.

The relationship between drought and productivity is complex. At a local scale, growing sites can be predisposed to drought based on topography, soils, species composition, and climate trends. Trees growing on typically dry sites tend to have deep, extensive root systems for locating water, but these trees usually appear physiologically older than trees of the same chronological age growing on moister sites. Trees on moist sites tend to produce more biomass aboveground and may not have developed the root systems necessary for reaching water farther away, making them more vulnerable to damage from drought.

Just as some trees can more readily adapt in drought-prone areas, different tree species have different responses to drought. Generally, deciduous trees, which can drop leaves and reduce the demand for moisture during winter and times of serious water shortages, may be more likely to survive dry periods. Additionally, mature trees fare much better than seedlings and saplings in moderate drought conditions, usually succumbing only when drought becomes and remains severe for extended periods.

A tree becomes stressed by drought when, through the process

of evapotranspiration, more water (as vapor) is released from leaves to the surrounding air than the tree's roots are able to take up from the available water supply. Trees can respond to drought by closing their stomata (the leaf pores that are involved in gas exchange with the atmosphere), allowing them to conserve moisture that would otherwise be lost through these openings. Though trees continue to respire, this water conservation strategy also slows or even stops photosynthesis, and, subsequently, normal healthy growth.

Drought that occurs during the growing season (March to October) affects tree health to varying degrees. For instance, early growing season drought slows the current season's growth. On the other hand, drought occurring late in a growing season can impact latewood (summer wood) growth in the current season as well as earlywood (spring wood) growth in the next growing season. The result is a reduced capacity for storing carbohydrates, the energy-rich "food" that trees produce during photosynthesis necessary for the healthy growth of all plant parts. What remains uncertain is how the cumulative effects of drought over multiple growing seasons affect individual trees as well as a whole forest—and the forest's ability to function effectively as an agent in the hydrologic cycle. The effects of drought may last for years, even after drought conditions have subsided.

Projections of Future Water Stress

Unusual drought conditions in the Southeast have recently caused great concern for forest land managers as well as city managers. Water deficits have necessitated many municipal water conservation efforts—voluntary and, in some cases, mandatory—and have prompted studies to determine what future water stress might look like in the region. Recognizing the environmental and economic consequences of widespread water shortages, researchers from the U.S. Forest Service's Southern Global Change Program (SGCP) decided to examine the many aspects of water stress in an effort to formulate an outlook for future water availability in the Southeast.

"Water supplies throughout the U.S. are increasingly stressed, but there has been an overall lack of information about water availability and water use," says Ge Sun, a research hydrologist with SGCP located in Raleigh, North Carolina. "We know that the climate is changing. We also know that the human population in the southeastern U.S. is the fastest growing in the country and with that growth comes development. Some individual hydrological models exist that incorporate the effects of climate change, population growth, and land use change, but they are not necessarily designed to interact to project water stress across large regional areas. Also, few studies have examined the combined interactions of water supply and demand, which are closely linked. Serious water shortages such as those we experienced in Raleigh in 2007 brought to light the need for a big picture assessment."

To get that big picture, the researchers set out to create a full water budget taking into account all components of historic supply and demand within a human-impacted watershed. Available water supply was estimated by precipitation amounts—minus losses from evapotranspiration—in addition to groundwater and return flow (the water that goes back to the system after it is used). Water demand was

determined by combining commercial, domestic, industrial, irrigation, livestock, mining, and thermoelectric needs. The researchers formulated water budgets for 666 watersheds throughout the Southeast. Then, they developed alternative scenarios to measure the potential individual and combined impacts of climate, land use, and population on future water supply and demand. Some clear patterns emerged from their analysis, resulting in a projection of water stress in the Southeast through the year 2020.

"According to our findings, climate change is the greatest contributing factor to water stress in the study region for several reasons. Future climate change in some areas will likely change patterns of rainfall, and the warmer temperatures that are also predicted will increase evaporation rates. This will naturally diminish the available water supply and also produce a greater need for water withdrawals for irrigation," says Sun.

"Population pressures will also increase water stress in the Southeast, especially in fast-growing metropolitan areas in the Piedmont region and Florida. Some of these places are already water stressed because average precipitation amounts are low or because they contain large areas of irrigated land or because large amounts of water are needed to run thermoelectric facilities. So, greater human demands for water will further stress groundwater and surface water sources. In some less populated areas that have seldom experienced water stress in the past, the effects of climate change could cause similar shortages.

"Land use and land cover changes will also affect future water yields in the Southeast. Increases in land area used for agriculture and irrigation will significantly add to demand and reduce the amount of water available for other purposes. Because land use and land cover changes alter hydrologic balances in an ecosystem, they also influence water supply. Trees use a lot of water, so in watersheds where forest land is removed, stream water yield can be augmented somewhat, and water stress would actually decrease to some extent in some areas," says Sun. "But, for a host of reasons, removing forests is not the solution to the issue of future water stress. We have to balance the tradeoffs among water quantity, water quality, and other ecosystem services that forests provide."

Living with Drought and Water Stress

Humans must be able to adapt in the face of water shortages. For example, by improving infrastructure and water delivery systems, choosing agriculture appropriate for local conditions, collecting rainwater, and recycling gray water, demand for water in homes and businesses can be reduced. But this is just one aspect of water conservation; water sources—especially forests that contribute to water supplies—must also be considered.

Across the U.S., over 180 million people receive water from forested watersheds. Almost 30 percent of U.S. forest land is in the Southeast, and of this, almost 90 percent is privately owned. Managing this forestland wisely can keep ecosystems functioning and water flowing.

Since forests regulate the hydrologic cycle, removing forests diminishes water quality, thereby reducing the quantity of water suitable for human use as well as for livestock, irrigation, and aquatic habitat. Care must be taken to keep forest land intact—most especially where forests border riparian areas—to conserve soil, improve water storage capacity, maintain seasonal water flow patterns, and preserve stream flow and temperatures for aquatic life.

Forest landowners and managers should select appropriate growing sites and choose drought- and disease-resistant species when planting. As a rule of thumb, native species are most adapted to local conditions and should be able to tolerate gradual change. And conifers require much more water over time to survive, so deciduous species may be better choices in water stressed areas depending on the desired qualities for the site, such as habitat

and food for wildlife.

Warmer, dryer conditions can allow invasive insects to survive during winter, enabling them to complete more lifecycles during a year. Drought-stricken trees are more susceptible to attack and mortality due to insects as well as diseases. Forest landowners and managers must be vigilant with regard to the detection, monitoring, and treatment of forest pests.

An overcrowded forest requires a lot of water, so reducing the density of vegetation makes more water available to the remaining trees. Non-native invasive plants in particular can disrupt relationships in a forest ecosystem and affect the ecosystem's natural response to drought conditions. Controlling weedy plants can provide other benefits in addition to reduced water use, not the least of which is lower risk of serious damage from wildfire.

Though a warmer and drier climate could become the norm in the southeastern U.S., extreme weather events will also likely occur in a changing climate. During large storms, intact forests minimize or prevent flooding, erosion, and landslides. Storm-damaged forestland should be reforested or allowed to regenerate. With the ability to remove large amounts of heat trapping carbon dioxide from the atmosphere, forests can also offer part of the solution to the issue of future climate change and further consequences for water supplies.

Drought as an Agent of Change

As forest landowners and managers work to keep forests healthy, more water can be made available for human needs. But nothing stays the same. Forest types and compositions do and will change. The forests in the Southeast today are quite different from the forests of 100 years ago, or even 30 years ago.

Wildfires, storms, and forest pests have always entered into the cycles of life in forest ecosystems. Similarly, drought conditions resulting from a warmer and drier climate will be another agent of inevitable change that will impact these cycles.

Ultimately, promoting resiliency in forests is essential for adaptation to water stress and drought. When water and soil conservation are top management goals, a forested watershed can recover and continue to function in the hydrologic cycle and provide other ecosystem services through times of disturbance and change. The pressing need for resilient forests will challenge forest landowners and managers, but could also inspire innovation for the long-term sustainable management of these irreplaceable resources.

About the Author

Stephanie Worley Firley is a communications assistant for the U.S. Forest Service Eastern Forest Environmental Threat Assessment Center in Asheville, North Carolina. The Southern Global Change Program is a research team within the Eastern Forest Environmental Threat Assessment Center. For more information, contact Ge Sun at (919) 515-9498 or gesun@fs.fed.us, or visit www.forestthreats.org.

References

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