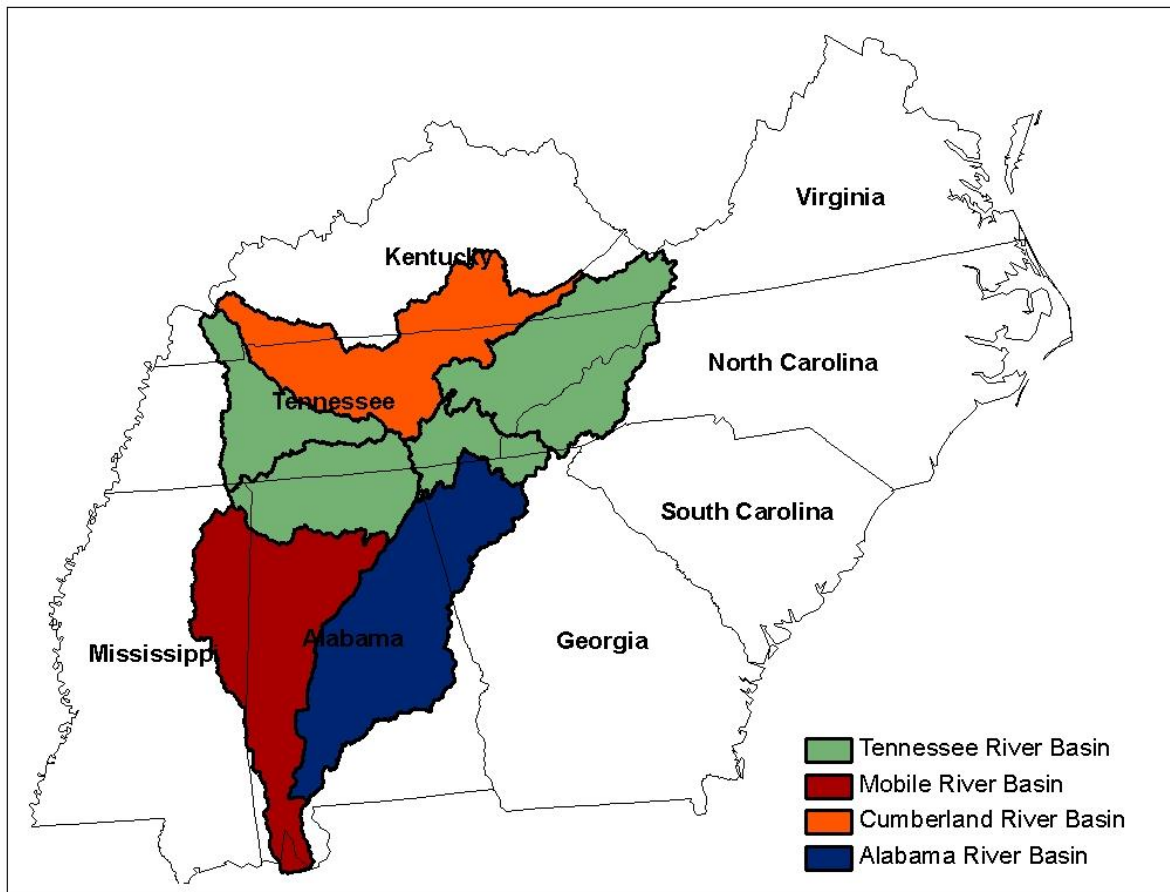


# Vulnerability of the Southeastern United States to Climate Change

## Executive Summary

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**Study Region**

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## Summary

### **Southern US Regional issues and Impacts:**

Abundant and clean water is fundamental to the viability of aquatic ecosystems, human welfare, and economic growth and development. Forested watersheds provide the cleanest and most regulated water of all land uses. Large areas of managed and unmanaged private and public forest land currently represent over 50% of the southeastern US and serve a critical role in providing clean water for the southern US. Over the last century, high quality water has been supplied at relatively low cost in this region. However, this is poised to change with increasing population and ensuing land use change, changing climate and climate variability.

The 13 states comprising the southeastern US are among the Nation's most densely populated, and this region's population growth rate is projected to exceed the US average for the next several decades. Recent land use projections suggest that 12 million forest acres will be lost to urban uses by the year 2020, mostly from the southern Appalachians. This impending forest to urban land use conversion, including new roads and commercial development required to support expanding populations, will potentially degrade and deplete water quality and quantity across the region. As forests shrink and become more fragmented, their ability to produce high quality water, moderate and dampen the effects of extreme rainfall events, and sustain healthy aquatic ecosystems will also diminish.

Climate change and increasing climatic variability will also contribute to change in the regions water quality and quantity concerns. While exact future climatic conditions are uncertain, projections suggest that the southern US will be warmer (2 to 4°C), and between 20% wetter to 10% drier than present by the end of the 21st century. Models also project more frequent El Niño-like conditions with increased extreme rainfall event frequency. Climate change and increased climate variability will both directly and indirectly influence water quantity and quality. For example, increased temperature could decrease streamflow by increasing evapotranspiration (ET), although this may be buffered by increased annual precipitation. Subsequently, lower streamflow in turn will decrease water supply, degrade aquatic communities, and diminish water quality. Concurrently, extreme rainfall events will increase flood severity and frequency, negatively affecting human safety, human welfare, and aquatic community functioning. . Most importantly, climate change and variability have the potential to interact with land use change and exacerbate the impacts on water quality and quantity.

Forested watersheds efficiently trap and filter suspended sediments. The forest litter layer directly protects soils from rainsplash erosion. The forest litter layer also is highly porous and rainfall intensity rarely exceeds infiltration rates. As a result, except in areas where the forest floor has been removed or soils have been severely compacted, overland flow is rare hence natural rates of soil erosion are very low from forested watersheds. Where rates of soil erosion are higher, such as from agricultural fields, exposed soil is easily carried into streams following intense rain fall events. Fortunately, many of these impacts are often rapidly reversible (or greatly reduced) with reforestation and afforestation.

The aquatic components of forested watersheds are tightly linked to upland and riparian components. These linkages include both structural and functional processes that impact the physical, chemical, and biological attributes of aquatic ecosystems. For example, biological and physical processes that occur in the uplands can influence aquatic ecosystems through the transport of materials (e.g., water, sediment, nutrients) and energy from the upland to the aquatic component. The riparian zone or near stream area has a more direct influence; vegetation in the near stream area alters the quality and quantity of light reaching the stream. This is especially important in small headwater streams, where sunlight shading regulates stream temperature. Near stream vegetation also provides nutrients, organic matter and coarse woody material to streams, and riparian soils influence nutrient and water fluxes as they move from upland areas, through the riparian zone, and into the streams. Forest watershed research shows a direct linkage between land use and disturbances in the upland areas and aquatic ecosystem structure and function. Non-forest land uses and disturbances that occur in the riparian zone have the greatest potential for altering aquatic ecosystem structure and function, including the persistence, diversity, and production of fish and other aquatic organisms.

### **Watershed Issues:**

The southern United States is a very large area within which regional variations in climate change and variability, population and land use change are projected to occur over the next century. It is not possible to develop detailed stress impacts assessments on water quality and quantity for all watershed across the region, it is possible to select few, especially significant watershed for study. The Tennessee, Alabama, Mobile, and Cumberland River basins represent unique and ecologically important watersheds within the Southern United States.

For example, The Tennessee and Cumberland River Basins host the highest number of fish, mussels and crayfish species, and the highest number of endemic freshwater fauna in North America. Of the 319 species of fish, 67 occur nowhere else (i.e. endemic). Among the 125 species of mussels, 20 are endemic. Further, 40 of the 65 species of crayfish are endemic. More than 57 species of fish and 47 species of mussels are federally listed as endangered. Among the top 40 most critical US watersheds ranked by number of imperiled freshwater fish and mussel species, half are in Tennessee. Tennessee is home to the most diverse freshwater fauna of any state in the US. Over 300 fish species have been found in Tennessee, and of these, the vast majority are native. These fish represent 29 families and 18 orders, ranging from primitive sturgeons to modern perciform groups. Percidae is the largest family with 93 species, including 90 darters. Second in size is the Cyprinidae (i.e., minnows) with 83 species. The Tennessee and Cumberland River systems hold the state's richest diversity, with 205 and 261 endemic species respectively. At least 91 of their combined species are restricted to these watersheds. Similarly, the Alabama and Mobile River Basins are almost as equally diverse. Each with hundreds of unique, threatened, or endangered species of aquatic vertebrate species

### **Watershed Study:**

Given the unique and sensitive nature of these four basins, a study was conducted to assess the impacts of climate change and variability, and land use and population change on; 1) watershed water availability; and 2) stream water turbidity as an indicator

of water quality. Two separate ecosystem models were developed to assess stress impacts watershed water quality and quantity.

Projected changes in water supply within the study area were developed with the assistance of the Water Supply Stress Index (WaSSI) model. The Hadley and Canadian climate change scenarios were combined with a vegetation hydrology model, US census population projections, anthropogenic water demand and use data, and land-use/land-cover data to examine future chronic and episodic water shortages across the four watershed study area. Model output was scaled to the USGS eight digit Hydrologic Unit Code watershed scale for the study region and projected using a Geographic Information System (GIS). Additional information regarding this model can be found at *Sun, G, S.G. McNulty, J. Moore Myers, and E. Cohen. 2008. Impacts of Multiple Stresses on Water Demand and Supply across the Southeastern United States American Water Resources Association Journal. (In Press).*

Projected changes with stream water quality as indicated by changes in water turbidity was assessed using multi-linear regression relationships that were established between measured historic stream water turbidity, 24 hour precipitation events, and land cover. Land cover classes included predominantly forest, agriculture, urban, grass, or impervious surface. Strong correlations were found the amount of agricultural land and 24 hour precipitation events, and in stream turbidity. The equation developed from these relationships was then applied the four watershed study area using projected 5, 10, 25, and 50 year 24 hour storm events. The linear regression equation was run at a 12 digit USGS Hydrologic Unit Code resolution and projected across the study area using a (GIS).

### **Major Findings from Watershed Study**

- General findings
  - o General circulation models predict that the study area will become warm by 2 - 4°C during the 21<sup>st</sup> century (a rate roughly equal to the rest of the southern US)
  - o Population change in the study area is projected to below the rate for much of the southern US over the next several decades
- Water quantity findings
  - o Currently , the study area has more forest land and receives more precipitation than most of the southern US
  - o the study area is less dependent on ground water compared to other areas across the southern US
  - o a lower dependence on ground water makes the study area more prone to water shortages due to episodic drought
  - o the occurrence of water stress for both humans and aquatic species will likely increase during the 21<sup>st</sup> Century
    - the rate of climate and population change within these watersheds will determine how much more frequently water stress occurs

- **the Tennessee River Basin is projected to experience the greatest and most frequent occurrences of water stress while the Mississippi River Basin (primarily western regions) will see the least amount of water stress**
- Water quality
  - The intensity of extreme precipitation events (i.e., events of 2 inches or more within a 24 hour period) have increased by over 30% during the past century.
  - The lower Mississippi and Alabama River Basins experienced the highest rates of precipitation
  - General circulation models predict that climate variability will continue to increase during the 21<sup>st</sup> century
    - Therefore, 100, 50, 25 and 10 year extreme rain events of the past, will occur more frequently (e.g., a historic 100 year event will happen every 50 years)
    - Within the study area stream turbidity was related to rain fall intensity and amount of forest cover
    - **Across all four basins, 65% of the streams will experience serious or extreme levels of turbidity every 10 years**
    - **While climate change will very likely temporarily increase stream turbidity, the steep topography and heavy forest cover within the four watershed greatly assists in minimizing negative long-term stream turbidity and negative biodiversity impacts**
    - **Although climate change will not likely negatively impact long-term stream turbidity, changes in water temperature associated with climate change, or change in land use associated with demographic change could negatively impact aquatic biodiversity across the study area**