United States Department of Agriculture

Broad-Scale Climate Change Monitoring Evaluation Report for the Southern Region

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for:
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Summary of Findings and Results

Table 1. Climate change monitoring summary of findings and results

Monitoring Question	Year Updated	Do monitoring results demonstrate intended progress or trend toward Southern Region targets?	Based on the evaluation of monitoring results, may changes be warranted?	If a change may be warranted, where may the change be needed?[2]
How has climate variability changed and how is it projected to change across the region?	2018 (First Evaluation) 2020	See Note: Precipitation See Note: Climate Extremes See Note: Land Cover Changes No: Increasing Temperatures No: Sea Level Rise	Yes	Plan Monitoring Program Forest Plans Management Activities Forest Assessment
How is climate variability and change influencing the ecological, social, cultural, and economic conditions and contributions provided by plan areas in the region?	2018 (First Evaluation) 2020	Yes: Prescribed Fire No: Nonnative Invasive Species No: Forest Health No: Animal and Plant Communities No: Water Resources No: Wildfire No: Recreation Use and Satisfaction No: Extreme Weather	Yes	Plan Monitoring Program Forest Plans Management Activities Forest Assessment
What effect do management units in the region have on a changing climate?	2018 (First Evaluation) 2020	Yes: Overall Carbon Sequestration No: Aging Forests Resulting in a Reduction in Carbon Sequestration	Yes	Plan Monitoring Program Forest Plans Management Activities Forest Assessment

Note: For these elements, the interval of data collection is beyond this reporting cycle, or more time and data are needed to understand status or progress of the plan component, or methods and results are inadequate to answer monitoring question...

Introduction

Purpose

This report is a 2020 update to a 2018 draft copy that was not completed. The purpose of the regional broad-scale monitoring strategy 5-year evaluation report is to help responsible officials determine whether a change is needed in forest plan direction, such as plan components or other plan content that guide management of resources in the plan area. The regional broad-scale monitoring strategy evaluation report represents one part of the Forest Service's overall monitoring program, designed to provide efficiency for biennial monitoring evaluation conducted on each national forest unit (36 CFR 219.12(d)). The monitoring evaluation report is not a decision document—it evaluates monitoring questions and indicators presented in the 2016 Southern Region Broad Scale Monitoring Strategy.[1] The Southern

1 U.S. Department of Agriculture, Forest Service. 2016. Southern Region Broad-Scale Monitoring Strategy, Version 1.0. 45 p. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd493775.pdf.

Region Broad Scale Monitoring Strategy, though initiated in 2016 for the Southern Region, is built over time based on the ongoing implementation of the 2012 Planning Rule and related complementary efforts.

Monitoring and evaluation are continuous learning tools that form the backbone of informed decision making. Broader-scale monitoring is required to disclose results at least every 5 years, but the regional office will produce an evaluation more often for monitoring questions for which more frequent evaluation and reporting is justified. This is our first written report of this evaluation since the broad-scale monitoring strategy was finalized. This report indicates whether a change to forest plans, management activities, monitoring program, or forest assessment may be needed based on the new information.

The Southern Region's broad-scale monitoring strategy addressed one (1) of eight (8) topics required under Forest Service Handbook (FSH) 1909.12 (36 CFR 219.12(a)(5)), plus the additional topic of social, economic, and cultural sustainability.

- (vi) Measurable changes on the plan area related to climate change and other stressors that may be affecting the plan area.

Monitoring Objectives

There are several objectives for this report, including:

- Deliver broader scale monitoring information from the broad-scale monitoring strategy for consideration at the plan level.
- Assess the current condition (status) and trend, where applicable, of selected forest resources.
- Document implementation of the broad-scale monitoring strategy, including changed conditions or status of key characteristics used to assess accomplishments and progress toward achievement of the selected plan components.
- Evaluate relevant assumptions, changed conditions, management effectiveness, and progress towards achieving the selected desired conditions, objectives, and goals described in land management plans.
- Address needed changes to current attribute details associated with each monitoring question based on new best available science. Present recommended change opportunities to the responsible officials.

How to Use this Report

This report is a tool and a resource for the Forest Service, specifically the Southern Region, to assess the condition of forest resources in relation to forest plan direction and management actions. It is also a tool and a resource for the public to learn more about how the Forest Service is managing forest resources. The broad-scale monitoring strategy identified "alerts" and "adaptive management strategies" associated with each monitoring question, which will be used to guide both evaluation of indicators and a regional response.

The broad-scale monitoring strategy evaluation report is designed to help the public, as well as Federal, State, local government, and Tribal entities, especially national forests within the Southern Region anticipate key steps in the overall monitoring programs. These steps include upcoming opportunities for public participation and how the public will be informed of those opportunities, and how public input will be used as the monitoring programs progress. The broad-scale monitoring strategy evaluation report is also intended to help people better understand reported results in relation to past and future monitoring reports on national forests within the Southern Region and the broad-scale monitoring strategy that is issued at the regional level.

How Our Southern Region Broad-Scale Monitoring Strategy Works

Monitoring and evaluation requirements are established through the National Forest Management Act at 36 CFR 219. Additional direction is provided by the Forest Service in Chapter 30 – Monitoring – of the Forest Service Handbook (FSH 1909.12, Chapter 30, and Section 33).

In the context of the broader-scale the three (3) main monitoring goals are to establish monitoring questions that:

- Can best be answered at a geographic scale broader than one forest plan area;
- Can be coordinated with the relevant responsible officials, State and Private Forestry, Research and Development, partners, and the public; and
- Are within the financial and technical capabilities of the region and complements other ongoing monitoring efforts.

Providing timely, accurate monitoring information to responsible officials, national forests within the Southern Region, and the public is a key intent of the broad-scale monitoring strategy. The broad-scale monitoring strategy evaluation report for the Southern Region is the vehicle for disseminating this information.

Monitoring Evaluation

Monitoring Activities

The following sections present the most current information (data and evaluations) for all monitoring questions contained within the 2016 version of the broad-scale monitoring strategy for monitoring element: Measurable changes on the plan area related to climate change and other stressors that may be affecting the plan area (also known as Climate Change and Other Stressors) (36 CFR 219.12(a)(5)(vi)). All three monitoring questions identified to address this monitoring element during the current evaluation period are addressed in the following sections of this report:

Monitoring Question 1 – How has climate variability changed and how is it projected to change across the region?

Monitoring Question 2 – How is climate variability and change influencing the ecological, social, cultural, and economic conditions and contributions provided by plan areas in the region?

Monitoring Question 3 – What effect do management units in the region have on a changing climate?

Monitoring Question 1: How has climate variability changed and how is it projected to change across the region?

Table 2. Monitoring collection summary

For Monitoring Question 1:	Year
Data was last collected or compiled	2018
Next scheduled data collection/compilation	2020
Results were last evaluated in	2018
Next scheduled year for evaluation of data in an evaluation report	2025

Table 3. Detailed inventory of the source, frequency, scale, and subregions for each monitoring question indicator

Source	Frequency	Scale	Subregion(s)
Monitoring Question 1: How has climate variability changed and how is it projected to change across the region?			
Sea Level Rise and Land Cover Changes			
Historical sea level trend data: National Oceanographic and Atmospheric Administration (NOAA), Sea Level Trends. Forecasted future coastal high tide flooding data: U.S. Climate Resilience Toolkit	6 years	National Forest Plan Areas	Coastal Plain
Climate Extremes			
USDA - Southeast Regional Climate Hub – Climate by Forest Tool (NOAA Climate Explorer	2 years	Ecological Subsection	Regionwide
Temperature			
USDA - Southeast Regional Climate Hub – Climate by Forest Tool (NOAA Climate Explorer	6 years	National Forest Plan Areas	Regionwide
Precipitation			
USDA - Southeast Regional Climate Hub – Climate by Forest Tool (NOAA Climate Explorer	6 years	National Forest Plan Areas	Regionwide
Water Balance			
See also monitoring question 2	6 years	National Forest Plan Areas	Regionwide

Information Sources

The monitoring elements or indicators are defined as sea level rise and land cover changes, climate extremes, temperature, precipitation, and water balance.

Sea Level Rise

Historical sea level trend data: National Oceanographic and Atmospheric Administration (NOAA), Sea Level Trends: https://tidesandcurrents.noaa.gov/sltrends/sltrends.html.

Forecasted future coastal high tide flooding data: U.S. Climate Resilience Toolkit (Climate Explorer): https://toolkit.climate.gov/.

Temperature and Precipitation

This climate summary is based on global climate models developed for the United Nations Intergovernmental Panel on Climate Change and available from NOAA's Climate Explorer web application (https://crt-climate-explorer.nemac.org/). The Climate Explorer produces graphs and maps showing observed historical and modeled future conditions for two possible greenhouse gas emissions scenarios.

Observed Historical Climate Data – For all observed data, the gray bars are plotted with respect to the 1961–1990 mean using Livneh, et al. dataset.[2] The black line shows actual historical observations.

Data Application Programming Interface (API) and Requests – The values that are displayed are based on the bounding box of the selected ecoregion. See also: DeGaetano, A.T., W. Noon, and K.L. Eggleston (2014): Efficient Access to Climate Products in Support of Climate Services using the Applied Climate Information System Web Services, Bulletin of the American Meteorological Society, 96, 173–180.

Modeled Data – The modeled data are LOCA downscaled CMIP5 model realizations. This includes the hindcast gray bands and the projected bands for the representative concentration pathways 4.5 and 8.5 emission scenarios. Each year, the band is defined by the highest model value for that year across all 32 models. [3][4]

For more detailed information on the specific changes in each ecological subsection and the time scales over which they are expected to occur, see appendix B of this report for a static time series (figure 1 through figure 7) of the four ecoregions represented in the table 4 below. For other ecoregions, visit the Climate by Forests Tool (http://climate-by-forest.nemac.org/).

Do monitoring results demonstrate intended progress toward Southern Region national forest plan targets?

At the regional level, it is difficult to prescribe a target and evaluate an accomplishment, but the region has capitalized on existing Agency work such as the baseline carbon assessments conducted under the climate change scorecard, the assessment and monitoring conducted under the Watershed Condition Framework, and the monitoring of climate change indicators occurring in the Forest Inventory and Analysis program, by ensuring integration of these activities into the land management planning process. Best available science information is also used to assess current climate change conditions, trends, and stressors and provide responses via management actions in order to restore ecological integrity. At the national forest level, forest plans will include plan components to maintain or restore ecological integrity, so that ecosystems can resist change, are resilient under changing conditions, and are able to recover from disturbance.

Please refer back to table 1 for an assessment of each monitoring question indicator for the 5-year report. Climate change monitoring question 1 was created to address a portion of this monitoring element. Individual national forest units are directed by the 2012 Planning Rule to address climate change effects when the national forests update their monitoring programs, forest assessments, forest plans, and management activities.

2 https://www.esrl.noaa.gov/psd/data/gridded/data.livneh.metvars.html.

3 Taylor K.E.; Stouffer R.J.; Meehl G.A. 2012. An overview of CMIP5 and the experiment design. Bulletin of the American Meteorological Society, 93, 485-498, doi:10.1175/bams-d-11-00094.1.

4 The line in each is a weighted mean that applies this strategy:

Sanderson, B.M.; Wehner, M.F. 2017.Weighting strategy for the Fourth National Climate Assessment. In: Wuebbles, D.J.; Fahey, D.W.; Hibbard, K.A.; Dokken, D.J.; Stewart, B.C.; Maycock T.K., eds. Climate Science Special Report: A Sustained Assessment Activity of the U.S. Global Change Research Program. U.S. Global Change Research Program, Washington, DC, USA: 644-653.

Based on monitoring results are changes needed to forest plan direction, management activities, or the monitoring program?

In the short-term, there is no need for change in individual national forests' plan direction, management activities, or monitoring arising from this evaluation. Periodic evaluation (about 5 years) of the climate monitoring should continue to detect any changes not currently projected as models improve.

The significant changes in temperature should be considered in future long-term planning efforts, including those that apply to ecological systems and recreation uses on the national forests, especially within the Southern Region.

Monitoring Results

Indicator – Sea Level Rise

The NOAA provided the following historical sea level trend information. The U.S. Climate Resilience Toolkit (Climate Explorer) provided coastal high tide flooding forecast information for four (4) Southern Region national forests located near the Atlantic Ocean and Gulf of Mexico and may be at risk of adverse effects from sea level rise. The 2016 broad-scale monitoring strategy shows the Francis Marion National Forest as at risk of being impacted by sea level rise.

Apalachicola National Forest – Apalachicola, Florida: The relative sea level trend is 2.56 millimeter per year with a 95 percent confidence interval of plus or minus 0.62 millimeter per year based on monthly mean sea level data from 1967 to 2019 which is equivalent to a change of 0.84 feet in 100 years. Forecasted 2036 coastal high tide flooding is expected to increase to 14 days per year under the representative concentration pathway 4.5 (low greenhouse gas emissions scenario) and 43 days per year under the representative concentration pathway 8.5 (high greenhouse gas emissions scenario), and increasing in 2065 to 86 days (low) and 305 days (high).

Croatan National Forest – Beaufort, North Carolina: The relative sea level trend is 3.22 millimeter per year with a 95 percent confidence interval of plus or minus 0.35 millimeter per year based on monthly mean sea level data from 1953 to 2019 which is equivalent to a change of 1.06 feet in 100 years. Forecasted 2036 coastal high tide flooding is expected to increase to seven (7) days per year under the representative concentration pathway 4.5 (low greenhouse gas emissions scenario) and 17 days per year under the representative concentration pathway 8.5 (high greenhouse gas emissions scenario), and increasing in 2065 to 34 days (low) and 265 days (high).

Desoto National Forest – Bay Waveland, Mississippi: The relative sea level trend is 4.81 millimeter per year with a 95 percent confidence interval of plus or minus 0.79 millimeter per year based on monthly mean sea level data from 1978 to 2019 which is equivalent to a change of 1.58 feet in 100 years. Forecasted 2036 coastal high tide flooding is expected to increase to 58 days per year under the representative concentration pathway 4.5 (low greenhouse gas emissions scenario) and 107 days per year under the representative concentration pathway 8.5 (high greenhouse gas emissions scenario), and increasing in 2065 to 253 days (low) and 351 days (high).

Francis Marion National Forest – Charleston, South Carolina: The relative sea level trend is 3.32 millimeter per year with a 95 percent confidence interval of plus or minus 0.19 millimeter per year based on monthly mean sea level data from 1901 to 2019 which is equivalent to a change of 1.09 feet in 100 years. Forecasted 2036 coastal high tide flooding is expected to increase to 23 days per year under the representative concentration pathway 4.5 (low greenhouse gas emissions scenario) and 49 days per year under the representative concentration pathway 8.5 (high greenhouse gas emissions scenario), and increasing in 2065 to 85 days (low) and 245 days (high).

National Forest Ecological Subsections

The following results reflect updates from observational climate data beginning in the 1950s through present day, as well as climate projections from the representative concentration pathway 4.5 (low emissions) and 8.5 (high emissions) climate model scenarios. Both scenarios project an increase in daily average maximum and minimum temperature, an increase in the days per year in which the temperature reaches above 90 degrees Fahrenheit, and a decrease in the days per year in which the temperature falls below 32 degrees Fahrenheit. By mid-century (2036–2065), mean projected changes in temperature variables are statistically significant over the baseline (1961–1990).

Four national forest ecological sub-sections were chosen as representative to the Southern Region due to their geographic location and landscape characteristics in the region. Those used for assessing indicators include:

- National Forests in Mississippi: Southern Loessial Plains
- Ouachita National Forest: Athens Piedmont Plateau
- National Forests in Florida: Florida Central Highlands
- National Forests in North Carolina: Southern Blue Ridge Mountains

Element or Indicator – Climate Extremes and Temperature

Table 4 provides the trend and range of mean changes for various temperature variables forecast under representative concentration pathways 4.5 and 8.5, for the time period of 2036–2065. Each variable in each representative region indicates an overall warming trend. The magnitude of change varies by location.

More information for the Southern Region will provide a greater understanding of how this variability will affect forest management and planning. In later sections of this report, the implications of this for Southern Region national forests will become clearer. Plant and animal communities throughout the region will be affected similarly, with minor differences between some species.

Table 4. Projected range of mean change in temperature variables by the period 2036–2065, using representative concentration pathways 4.5 and 8.5

Temperature Variables		Boston Hills	Piney Woods	Southern Blue Ridge Mountains	Upper Clay Hills
Average daily maximum temperature	Trend	+	+	+	+
	Range of change	3.2–6.7ºF	3.4–6.5ºF	3.3–6.6ºF	3.1–6.2ºF
Average daily minimum temperature	Trend	+	+	+	+
	Range of change	3.1–6.5ºF	3–6.2ºF	3.1–6.2ºF	3.2–6.1ºF
Days per year maximum temperature above 90º Fahrenheit	Trend	+	+	+	+
	Range of change	29.6–64.7 days	35.3–65.7 days	25.2–60 days	35.4–69.8 days
Days per year minimum temperature below 32º Fahrenheit	Trend	-	-	-	-
	Range of change	14.6–31.4 days	10.5–23.2 days	15.3–31.8 days	11.7–24.4 days

Projections suggest that future warming is expected, resulting in 25 to 70 more days above 90 degrees Fahrenheit and 11 to 32 fewer freezing days per year in the four national forest ecological sub-sections listed above in table 4.

Element or Indicator – Precipitation, Water Balance

Trends in precipitation and water balance are less clear than those of temperature (table 5). While the range of change in forecasted dry days per year includes the possibility of a decrease, and increase, or no change, the projection lean towards an increase in dry days in three of the four representative ecoregions, with Southern Blue Ridge Mountains being the exception.

Table 5. Projected range of mean change in precipitation and drought variables by the period 2036–2065, using representative concentration pathways 4.5 and 8.5

Precipitation and Drought Variables		Boston Hills	Piney Woods	Southern Blue Ridge Mountains	Upper Clay Hills
Number of dry days per year	Trend	+/-	+/-	+/-	+/-
	Range of change	-2.7–10.1 days	-1.1–15.8 days	-8.6–4.6 days	-3.8–9.7 days
Total precipitation	Trend	+/-	+/-	+/-	+/-
	Range of change	-3–5.5 inches	-4.3–5.9 inches	-1–6 inches	-4.2–4.4 inches
Days per year over 2 inches precipitation	Trend	+/-	+/-	+/-	+/-
	Range of change	-0.4–0.7 days	-0.3–0.8 days	-0.5–0.2 days	-0.4–0.4 days

Precipitation was historically variable and will likely continue to be variable from one year to the next. There does appear to be a trend toward a modest increase in total precipitation, with little change in the number of dry days per year. Changes in total precipitation and in days per year with over two (2) inches of precipitation include a considerable amount of uncertainty when accounting for both representative concentration pathways 4.5 and 8.5 scenarios (table 5).

Status and Trend of the Monitoring Indicator in Relation to the Target

In the short-term, there is no need for change in forest plan direction, management activities, or monitoring arising from this evaluation. Periodic evaluation (about 5 years) of the climate monitoring should continue to detect any changes not currently projected as models improve. The significant changes in sea level rise and temperature should be considered in future long-term planning efforts, including those that apply to ecological systems and recreation uses on the national forests.

What level of confidence is there in the accuracy and precision?

Uncertainty exists with the range of scenarios provided in any climate projection. The strength of the trend in temperature towards warmer temperature indicated relatively good certainty in the direction, though the magnitude will depend on other variables such as population growth and greenhouse gas emissions. Less certainty exists with precipitation and water balance. Most variables do not provide a clear trend, though increased variability in the timing and magnitude of precipitation and drought events is possible.

Accuracy - Accuracy of a variety of sources of error, some of which are addressed through the consideration of uncertainty, and other that are unaddressed and beyond the technical scope of this analysis. Accuracy is primarily assessed through the consideration of historical model performance as compared with historical observations (i.e., model performance), the considering of results from multiple models (i.e., model agreement or uncertainty), and emissions scenario uncertainty. Each interpretation section in this report addresses both characteristics of accuracy. There are other limitations of this data that are inherent to the systems, models, and assumptions used to develop them that are not readily assessed, but should be considered contextually as the results in this report are considered alongside other source of information, including findings from peer reviewed literature and local expertise.

Reliability – The results presented in this section are based on peer reviewed science.

Relevance – Relevance is assessable through geographic and attribute level considerations. The Climate Explorer tool summarizes results at the county scale, which is not perfectly coincident with the boundaries of our area of interest, but given the coarseness of the climate data and other sources of uncertainty, the selected county provides a representative sample that can be reasonably applied to the area of interest as a whole. While there are a multitude of potential climate variables that are relevant to the mission and operations Sothern Region national forests, the standard attributes provided by the Climate Explorer cover the major physical variables of temperature and precipitation sufficiently to give their influences on resources and management activities due consideration.

Adaptive Management Considerations

Adaptive management considerations related to impacts of the climate on national forests within the Southern Region are discussed in the next section under Monitoring Question 2: Climate Variability Influence on Ecological, Social, Cultural, and Economic Conditions.

The 2012 Planning Rule requires monitoring of climate change and other stressors that may be affecting the forest plan area (36 CFR Part 219 – PLANNING – Subpart A – National Forest System Land Management Planning (sections 219.1–19.19). 219.12(a)(5)(vi) – Measurable changes on the plan area related to climate change and other stressors that may be affecting the plan area). The status of the monitoring indicators for monitoring question 1 shows a need for national forests in the Southern Region to address short and long term climate change effects and stressors to forest ecosystems and the human environment (table 6). Increasing temperatures are currently the most significant effect impacting national forest ecosystems and the human environment. National forests will need to also address effects of changes to precipitation, climate extremes, and sea level rise. Land cover is not covered in the body of this report, see appendix A.

Table 6. Summary of where change may be warranted based on monitoring question 1 results

Where Change May be Warranted:	Change Warranted?
Plan Monitoring Program	Yes
Forest Plans	Yes
Management Activities	Yes
Forest Assessment	Yes

Monitoring Question 2: How is climate variability and change influencing the ecological, social, cultural, and economic conditions and contributions provided by plan areas in the region?

Table 7. Monitoring collection summary

For Monitoring Question 2:	Year
Data was last collected or compiled in	2018
Next scheduled data collection/compilation	2020
Results were last evaluated in	2018
Next scheduled year for evaluation of data in an evaluation report	2025

Table 8. Detailed inventory of the source, frequency, scale, and subregions for each monitoring question indicator[5]

Monitoring Question 2: How is climate variability and change influencing the ecological, social, cultural, and economic conditions and contributions provided by plan areas in the region?			
Non-native Invasive Species			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	4 years	National Forest Plan Areas	Regionwide
Forest Health			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	2 years	National Forest Plan Areas	Regionwide
Prescribed Fire			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	2 years	National Forest Plan Areas	Regionwide
Recreation Use and Satisfaction			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	2 years	National Forest Plan Areas	Regionwide
Wildfire			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	2 years	National Forest Plan Areas	Regionwide
Jobs and Income			
Source	*Frequency*	*Scale*	*Subregion(s)*
See Socioeconomic Report	10 years	Unit Plan Areas of Influence	Regionwide
Phenology			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	10 years	National Forest Plan Areas	Regionwide
Forest Status and Trends			
Source	*Frequency*	*Scale*	*Subregion(s)*
TACCIMO	6 years	National Forest Plan Areas	Regionwide

5 From table A-1, appendix A of the Southern Region Broad Scale Monitoring Strategy, 2016.

Information Sources

The monitoring elements or indicators are defined as non-native invasive species, forest health, prescribed fire, recreation use and satisfaction, and wildfire. Jobs and income, phenology and forest trends and status are not covered in the body of this report (see appendix A).

Information used in this section is summarized from Assessments of the Potential Effects of Climate Change on the Southeast United States for the Southern Region National Forests. The assessments are known as Template for Assessing Climate Change Impacts and Management Options (TACCIMO) summaries. TACCIMO is a web-based application that connects federal, state, and private land managers and planners with climate change science they can trust. TACCIMO is a collaborative effort among the USDA Forest Service Eastern Forest and Western Wildland Environmental Threat Assessment Centers and the National Forest System (https://www.fs.usda.gov/ccrc/tools/taccimo).

Do monitoring results demonstrate intended progress toward Southern Region national forest plan targets?

See response for monitoring question 1.

Based on monitoring results are changes needed to forest plan direction, management activities, or the monitoring program?

No changes in Southern Region national forest plan direction, management activities, or the monitoring are needed during the short term.

The significant changes in temperature and drought need to be considered in future long-term planning efforts, including those that apply to ecological systems and recreation uses on the national forests.

Monitoring Results

A recent 2020 research summary: Assessing the Potential Effects of Climate Change on the Southeast United States, addressed climate change effects and response mitigations for monitoring elements that are defined as forest health, animal and plant communities, water resources, recreation and extreme weather. Consolidated summaries for each Southern Region national forest unit are presented in appendix D of this report.

Forestlands are experiencing increased threats from fire, insect and plant invasions, disease, extreme weather, and drought. Scientists project increases in temperature and changes in rainfall patterns that can make these threats occur more often, with more intensity, and/or for longer durations. Although many of the effects of future changes are negative, natural resource management can help mitigate these impacts.

The Southeast United States faces continued increasing temperatures and variation in precipitation due to climate change. Extreme weather events like drought, hurricanes, and wildfires are projected to increase or worsen due to climate related effects. Saltwater intrusion is affecting wetlands and coastal forests along the coast, changing vegetation and affecting wildlife. The threat from invasive insects and diseases is projected to increase with warmer temperatures. Although many of the effects of future changes are negative, natural resource management can help mitigate these impacts. Responses informed by the best available science information enable natural resource professionals within the Forest Service to better protect the land and resources and conserve the Southern Region's forestlands into the future.

Forest Health – Southeast forests will be affected by many factors including extreme weather, shifts in plant hardiness zones, sea level rise and saltwater intrusion, and increased pressure from invasive plants and pests, drought, and wildfire frequency. Increasing temperatures will worsen disturbance due to invasive plants and insects. Warmer temperatures due to climate change are converting saltwater marsh to mangroves and shifting where the marsh to mangrove ecotone exists. Sea level rise will increase soil salinity levels in coastal communities. Coastal forest retreat due to saltwater intrusion and the formation of "ghost forests" has been documented along the Southeast U.S. coastline. In addition, coastal wetlands have seen plant community shifts due to higher levels of salinity.

Animal Communities – Some bird species along the coast have been negatively affected by development of ghost forests and consequent habitat loss. Certain amphibian and insect species such as the red legged salamander or the Diana Fritillary that are highly dependent on elevation are becoming more and more isolated due to habitat fragmentation and loss.

Plant Communities – Suitability conditions are projected to change for different tree species, with certain species having more adaptive capacity (southern pines, oaks, and hickories) than others (balsam fir, red spruce, eastern hemlock, and sugar maple) due to pests and climate competition.

Changes in growing season and flowering dates are also possible with increasing minimum temperatures. Projected increase in temperatures can allow invasive pests and plants to increase their spread.

Water Resources – With climate change projected to cause warmer temperatures and variable precipitation in the future, water resources will likely be even more affected by drought and extreme weather events.

Severe drought impacts could lower streamflow in forested watersheds. Increased water temperature due to warming climate can potentially lead to an increase in toxic algal blooms in lakes.

Recreation – Changes in precipitation due to drought could negatively impact water based outdoor recreation like canoeing, kayaking, and motorized activities. Increase in temperature can impact visitors comfort. Climate change can also have impacts on culturally significant natural resources.

Extreme Weather – Extreme precipitation events are becoming more likely; however, there are longer dry periods between storms. Increasing drought frequency and a projected increase in dry season, as much as 156 days in some areas, will increase the risk of wildfires. Not only are extreme precipitation events becoming more likely, hurricanes are becoming more severe and are able to sustain damaging conditions for longer periods of time. These events have large impacts on nearby estuaries and coastal waters, including negatively impacting carbon sources and sinks.

What level of confidence is there in the accuracy and precision?

The information used in this section is based on summaries of peer reviewed research provided by the USDA Forest Service Eastern Forest and Western Wildland Environmental Threat Assessment Centers (https://www.fs.usda.gov/ccrc/tools/taccimo).

Adaptive Management Considerations

The following monitoring question 2 adaptive management considerations are based on the Assessments of the Potential Effects of Climate Change on the Southeast United States for the Southern Region National Forests discussed above.

Forest Health

Response: Develop a coordinated system of monitored and controlled entrance points that control the majority of water flow inland from the shoreline and high-value water and land restoration areas in order to reduce salt-intrusion as well as to preserve marshes and swamps.

Response: Efforts to restore ecological integrity to impacted ecosystems (e.g., managing for longleaf and shortleaf pine) can have positive effects on disease and pest resistance, as well as wildfire and drought resilience.

Animal Communities

Response: Conserve buffer areas along riparian habitats to provide habitat for amphibian species.

Response: High elevation areas are crucial refugia for many species. Preventing the addition of new roads and heavy equipment in these areas can maintain habitat connectivity.

Response: Create habitat corridors, assist in species movement, increase national forest management unit sizes, and identify high- value conservation lands adjacent to national forests.

Plant Communities

Response: Manage for tree species with high adaptive capacity.

Response: Early detection and rapid response is the most effective way to respond to invasive species and should be implemented where possible.

Water Resources

Response: Reduce impact on aquatic ecosystems affected by drought by favoring tree species that are fire tolerant and have relatively low water use (e.g., longleaf pine).

Response: Remove invasive species that use more water to reduce stress on the aquatic ecosystems.

Recreation

Response: Enact monitoring to determine when it is safe for recreational activities to take place in water recreation areas and communicate effectively to visitors the potential risks of higher temperature or high water levels.

Response: Work with local indigenous populations and cultural groups to provide resources for them to adapt to the climate driven changes on their cultural sites.

Extreme Weather

Response: Manage tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and fire.

Response: Communicate early warnings to visitors of extreme weather events.

The 2012 Planning Rule requires monitoring of climate change and other stressors that may be affecting the plan area (36 CFR Part 219 – PLANNING – Subpart A – National Forest System Land Management Planning (sections 219.1–219.19). 219.12(a)(5)(vi) – Measurable changes on the plan area related to climate change and other stressors that may be affecting the plan area). The status of the monitoring indicators for monitoring question 2 shows a need for national forests in the Southern Region to address short and long term climate change effects and stressors to forest ecosystems and the human environment (table 9). National forests will need to also address effects of changes to non-native invasive species, forest health, animal and plant communities, water resources, wildfire, recreation use and satisfaction and extreme weather.

Table 9. Summary of where change may be warranted based on monitoring question 2 results

Where Change May be Warranted:	Change Warranted?
Plan Monitoring Program	Yes
Forest Plans	Yes
Management Activities	Yes
Forest Assessment	Yes

Monitoring Question 3: What effect do management units in the region have on a changing climate?

Table 10. Monitoring collection summary

For Monitoring Question 3:	Year
Data was last collected or compiled in:	2013
Next scheduled data collection/compilation:	2019
Results were last evaluated in:	2018
Next scheduled year for evaluation of data in an evaluation report:	2025

Table 11. Detailed inventory of the source, frequency, scale, and subregions for each monitoring question indicator.[6]

Monitoring Question 3: What effect do management units in the region have on a changing climate?			
Carbon Stocks and Fluxes			
Source	*Frequency*	*Scale*	*Subregion(s)*
Forest Inventory and Analysis (FIA)	6 years	National Forest Plan Areas	Regionwide

Information Sources

The monitoring elements or indicators are defined as carbon stocks and fluxes. The broad-scale monitoring strategy lists greenhouse gas emissions as an attribute detail and it has been deleted from analysis in this report. The information source used in this section is a 2020 research summary white paper by Dugan and others (2020)[7] provides the most current research information about carbon sequestration in the Southern Region and is summarized below. Dugan and others (2020) addressed three main carbon sequestration topics:

- Baseline Carbon Stocks and Flux
- Factors Influencing Forest Carbon
- Future Carbon Conditions

Do monitoring results demonstrate intended progress toward Southern Region national forest plan targets?

Climate change monitoring question 3 was added to address a portion of this monitoring element the 2012 Planning Rule. Individual national forest units are directed by the planning rule to address climate change effects when the forests update monitoring programs, forest assessments, forest plans, and management activities.

6 From table A-1, appendix A of Southern Region Broad-scale Monitoring Strategy, 2016.

7 Dugan, A.; McKinley, D.C.; Turpin, P. 2020. Forest carbon assessment for the Southern Region. U.S. Department of Agriculture, Forest Service. Unpublished report. 26 p. Available at the Southern Region, Regional Office, 1720 Peachtree Road, NW Ste. 816N Atlanta, GA 30309-2405.

Based on monitoring results are changes needed to forest plan direction, management activities, or the monitoring program?

Forest carbon stocks have been stable and changes in carbon stocks arising from disturbances and management activities have been small relative to the total quantity of carbon stored within the Southern Region's national forests. However, Southern Region carbon sequestration rate is slowing overall, based on the dataset used, because forests within the Southern Region are becoming older (half are more than 80 years of age). The rate of carbon uptake and sequestration generally decline as forests age. Accordingly, projections from the Resource Planning Act assessment indicate a potential age-related decline in forest carbon stocks in the Southern Region (all land ownerships) beginning in the 2020s.

Future forest plan assessments and revisions need to address short and long term climate change effects to forest ecosystems and the need to manage tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and fire (shown under the Adaptive Management Considerations section below).

Monitoring Results

Dugan and others (2020) found that forests in the Southern Region are maintaining a modest carbon sink. Carbon stocks increased by about 29.7 percent on average across the Southern Region between 1990 and 2013, and negative impacts on carbon stocks caused by disturbances and environmental conditions have been modest, not exceeding forest growth. According to satellite imagery, timber harvesting has been the most prevalent disturbance detected within the Southern Region since 1990. However, harvests during this period have been relatively small and low intensity. Forest carbon losses associated with harvests have been small compared to the total amount of carbon stored in the Southern Region, resulting in a loss of about 2.4 percent of non-soil carbon from 1990 to 2011. These estimates represent an upper bound because they do not account for continued storage of harvested carbon in wood products or the effect of substitution. Carbon storage in harvested wood products sourced from national forests within the Southern Region increased since the early 1900s. Recent declines in timber harvesting have slowed the rate of carbon accumulation in the product sector.

The biggest influence on current carbon dynamics in the Southern Region is the legacy of intensive timber harvesting and land clearing for agriculture during the 19th century, followed by a period of forest recovery and more sustainable forest management beginning in the early to mid-20th century, which continues to promote a carbon sink today. However, forests within the Southern Region are becoming older (half are more than 80 years of age). The rate of carbon uptake and sequestration generally decline as forests age.

Carbon dioxide emissions are projected to increase through 2100 under even the most conservative emission scenarios. Several models project greater increases in forest productivity when the CO_2 fertilization effect is included in modeling. However, the effect of increasing levels of atmospheric CO_2 on forest productivity is transient and can be limited by the availability of nitrogen and other nutrients. Productivity increases under elevated CO_2 could be offset by losses from climate-related stress or disturbance.

Climate and environmental factors, including elevated atmospheric CO_2 and nitrogen deposition, have also influenced carbon accumulation within the Southern Region. Recent warmer temperatures and precipitation variability may have stressed forests, causing climate to have a negative impact on carbon accumulation in the 2000s. Conversely, increased atmospheric CO_2 and nitrogen deposition may have enhanced growth rates and helped to counteract ecosystem carbon losses due to historical disturbances, aging, and climate.

The effects of future climate conditions are complex and remain uncertain. However, under changing climate and environmental conditions, forests of the Southern Region may be increasingly vulnerable to a variety of stressors. These potentially negative effects might be balanced somewhat by the positive effects of longer growing season, greater precipitation, and elevated atmospheric CO2 concentrations. However, it is difficult to judge how these factors and their interactions will affect future carbon dynamics within the Southern Region.

Template for Assessing Climate Change Impacts and Management Options (TACCIMO) research summaries indicate forestlands are experiencing increased threats from fire, insect and plant invasions, disease, extreme weather, and drought. Scientists project increases in temperature and changes in rainfall patterns that can make these threats occur more often, with more intensity, and/or for longer durations, which may affect forest carbon dynamics. For instance, elevated temperatures may also increase soil respiration and reduce soil moisture through increased evapotranspiration, which would negatively affect growth rates and carbon accumulation.

Modeled results of recent climate effects indicate that years with elevated temperatures, such as in the 2000s, have generally had a negative effect on carbon uptake in the Southern Region. Heat stress is also projected to limit growth and carbon uptake of some Southern pines and hardwood species. Mean annual precipitation projections across the Southern Region vary, with projected decreases in the western part and increases in the Southern Appalachian Mountains, although uncertainty remains relatively high. More intense precipitation and extreme storm events are expected to continue increasing in the Southern Region. The potential for reduced soil moisture and drought is also predicted to increase, especially later in the growing season as increased temperatures drive evapotranspiration. Although a longer growing season may increase annual biomass accumulation, droughts could offset these potential growth enhancements and increase the potential for other forest stressors. Drought-stressed trees may also be more susceptible to insects, pathogens and damage from wildfires.

Changes in climate are expected to drive many other changes in forests through the next century, including changes in forest establishment and composition. Some Southern Region tree species are expected to be particularly vulnerable in the future as climate conditions drive declines or failures in species establishment or habitat suitability. Model projections suggest that many northern conifer species, including balsam fir, red spruce, and black spruce, are the most vulnerable to climate change—particularly at lower elevations or more southerly locations and at the end of this century. The potential for future declines of northern species increase the risk of carbon losses in forest communities dominated by these species, particularly under scenarios of greater warming. Climate-driven failures in species establishment further reduce the ability of forests to recover carbon lost after mortality-inducing events or harvests. Although future climate conditions also allow for other future-adapted species to increase, there is greater uncertainty about how well these species will be able to take advantage of new niches that may become available (Dugan and others 2020).

Status and Trend of the Monitoring Indicator in Relation to the Target

Carbon sequestration in the Southern region, based on datasets referenced, are becoming older (half are more than 80 years of age). The rate of carbon uptake and sequestration generally decline as forests age. Projections from the Resource Planning Act assessment indicate a potential age-related decline in forest carbon stocks in the Southern Region (all land ownerships) beginning in the 2020s (Dugan and others 2020).

What level of confidence is there in the accuracy and precision?

The following are abbreviated summaries from Dugan and others (2020):

Despite some uncertainty in annual carbon stock estimates, there is a high degree of certainty that carbon stocks in the Southern Region have increased from 1990 to 2013.

The uncertainty between annual estimates can make it difficult to determine whether the forest and/or region is a sink or a source in a specific year. However, the trend of increasing carbon stocks from 1990 to 2013 over the 23-year period suggests that the Southern Region is a modest carbon sink.

One model error has resulted from a change in Forest Inventory Analysis sampling design, which led to an apparent change in forested area. Change in forested area may reflect an actual change in land use due to reforestation or deforestation. However, given that the Southern Region has experienced minimal changes in land use or adjustments to the boundaries of the national forests in recent years, the change in forested area incorporated in the carbon calculation tool is more likely a data artefact of altered inventory design and protocols.

The analysis of carbon storage in harvested wood products also contains uncertainties. The collective effect of uncertainty was assessed using a Monte Carlo approach. Results indicated a ±0.05 percent difference from the mean at the 90 percent confidence level for 2013, suggesting that uncertainty is relatively small at this regional scale.

There is uncertainty associated with estimates of the relative effects of disturbances, aging, and environmental factors on forest carbon sequestration trends.

Monitoring Discussion and Findings

Given the complex interactions among forest ecosystem processes, disturbance regimes, climate, and nutrients, it is difficult to project how forests and carbon trends will respond to novel future conditions. The effects of future conditions on forest carbon dynamics may change over time. As climate change persists for several decades, critical thresholds may be exceeded, causing unanticipated responses to some variables like increasing temperature and $CO2$ concentrations. The effects of changing conditions will almost certainly vary by species and forest type. Some factors may enhance forest growth and carbon uptake, whereas others may hinder the ability of forests within the Southern Region to act as a carbon sink, potentially causing various influences to offset each other. Thus, it will be important for forest managers to continue to monitor forest responses to these changes and potentially alter management activities to better enable forests to better adapt to future conditions (Dugan and others 2020).

Forested area within the Southern Region will be maintained as forest in the foreseeable future, which will allow for a continuation of carbon uptake and storage over the long term. Across the broader region, land conversion for development on private ownerships is a concern and this activity can cause substantial carbon losses. The Southern Region will continue to have an important role in maintaining the carbon sink, regionally and nationally, for decades to come (Dugan and others 2020).

Adaptive Management Considerations

An adaptive management response to climate change effects are addresses under monitoring question 2 above (Assessments of the Potential Effects of Climate Change on the Southeast United States for the Southern Region National Forests). The assessments recommend management of tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and fire.

The 2012 Planning Rule requires monitoring of climate change and other stressors that may be affecting the plan area (36 CFR Part 219 – PLANNING – Subpart A – National Forest System Land Management Planning (sections 219.1–219.19). 219.12(a)(5)(vi) – Measurable changes on the plan area related to climate change and other stressors that may be affecting the plan area). The status of the monitoring indicators for monitoring question 3 indicates a need for national forests in the Southern Region to address short and long term climate change effects and stressors to forest ecosystems and the human environment (table 12). National forests will need to also address the effects of changes to carbon sequestration.

Table 12. Summary of where change may be warranted based on monitoring question 3 results

Where Change May be Warranted:	Change Warranted?
Plan Monitoring Program	Yes
Forest Plans	Yes
Management Activities	Yes
Forest Assessment	Yes

Appendix A. Monitoring Items Not Evaluated in Detail

Land cover changes, phenology, and forest status and trends are not evaluated in detail: (A) interval of data collection is beyond this reporting cycle; (B) or more time and data are needed to understand status or progress of the plan component; (C) or methods and/or results are inadequate to answer monitoring question.

Economics indicators, including employment and income, are evaluated in a separate report titled Broad-Scale Socioeconomic Monitoring Evaluation Report for the Southern Region, prepared by Allison Borchers.

Appendix B. Summary of Monitoring Question 2 Ecological Sub-Sections

Data Sources

Data API and requests:

The values being displayed are based on the bounding box of the selected ecoregion. The bounding box is used in a request for data from the Applied Climate Information System: http://www.rcc-acis.org/. See also:

DeGaetano, A.T.; Noon, W.; Eggleston, K.L. 2014. Efficient access to climate products in support of climate services using the Applied Climate Information System Web Services. Bulletin of the American Meteorological Society. 96: 173–180.

Modeled data:

The modeled data are LOCA downscaled CMIP5 model realizations. This includes the hindcast gray bands and the projected bands for the representative concentration pathways 4.5 and 8.5 emission scenarios. Each year, the band is defined by the highest model value for that year across all 32 models. See:

Taylor K.E.; Stouffer R.J.; Meehl G. A. 2012. An overview of CMIP5 and the experiment design. Bulletin of the American Meteorological Society. 93: 485–498. doi:10.1175/bams-d-11-00094.1.

The line in each is a weighted mean that applies this strategy:

Sanderson, B.M.; Wehner, M.F. 2017.Weighting strategy for the fourth national climate assessment. In: Wuebbles, D.J.; Fahey, D.W.; Hibbard, K.A.; Dokken, D.J.; Stewart, B.C.; Maycock T.K., eds. Climate science special report: a sustained assessment activity of the U.S. Global Change Research Program. U.S. Global Change Research Program, Washington, DC, USA: 644–653.

Observed data:

For the observed data, the bars (that are now gray to be consistent with Climate Explorer) are plotted with respect to the 1961–1990 mean using the Livneh et al. dataset: https://www.esrl.noaa.gov/psd/data/gridded/data.livneh.metvars.html.

Reference for the methodology:

Livneh, B.; Rosenberg, E.A.; Lin, C.; Nijssen, B.; Mishra, V.: Andreadis, K.M.; Maurer, E.P.; Lettenmaier. D.P. 2013. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States: Update and Extensions. Journal of Climate. 26. doi: 10.1175/JCLI-D-12-00508.1.

Table 13. Ecological sub-sections national forest areas and acreages

National Forest (NF) Name	Ecological Sub-Sections	Total Acres
Chattahoochee-Oconee National Forests	Chert Valley	96
	Lower Foot Hills	30,720
	Metasedimentary Mountains	124,965
	Midland Plateau Central Uplands	116,413
	Piedmont Ridge	11,609
	Sandstone Ridge	64,619
	Schist Hills	8,397
	Schist Plains	4,002
	Shaley Limestone Valley	426
	Southern Blue Ridge Mountains	506,514
Chattahoochee-Oconee NF Total		867,761
Cherokee National Forest	Great Valley of Virginia	5,790
	Metasedimentary Mountains	437,153
	Sandstone Hills	1,744
	Shaley Limestone Valley	18
	Southern Blue Ridge Mountains	212,120
Cherokee NF Total		656,825
Daniel Boone National Forest	Eastern Knobs Transition	18
	Kinniconick and Licking Knobs	207,318
	Miami-Scioto Plain-Tipton Till Plain	41,526
	Pine and Cumberland Mountains	83
	Rugged Eastern Hills	133,015
	Southern Cumberland Mountains	19,138
	Southwestern Escarpment	310,300
Daniel Boone NF Total		711,398
Francis Marion and Sumter National Forests	Carolina Slate	67,894
	Charlotte Belt	220,613
	Charlotte Belt-North	264
	Coastal Marsh and Island	39,064
	Lower Foot Hills	13,527
	Lower Terraces	217,174
	Southern Blue Ridge Mountains	70,680
	Upper Terraces	3,402
Francis Marion and Sumter NF Total		632,619
George Washington and Jefferson National Forest	Black Mountains	6,306
	Central Blue Ridge Mountains	584
	Eastern Allegheny Mountain and Valley	27,104
	Eastern Coal Fields	52,017
	Great Valley of Virginia	118,883
	Northern Blue Ridge Mountains	207,861

National Forest (NF) Name	Ecological Sub-Sections	Total Acres
	Northern High Allegheny Mountain	38,124
	Northern Ridge and Valley	6,776
	Pine and Cumberland Mountains	27,504
	Ridge and Valley	1,183,903
	Rolling Limestone Hills	5,355
	Southern Blue Ridge Mountains	117,751
	Western Coal Fields	60
George Washington and Jefferson NF Total		1,792,227
Kisatchie National Forest	Piney Woods Transition	978
	Red River Alluvial Plain	10,716
	South Central Arkansas	59,213
	South Central Arkansas Flatwoods	1,330
	Southern Loam Hills	530,750
	Southwest Flatwoods	5,590
Kisatchie NF Total		608,578
Land Between the Lakes National Recreation Area	Western Pennyroyal Karst Plain	171,251
Land Between the Lakes NRA Total		171,251
National Forests in Alabama	Chert Valley	664
	Moulton Valley	17
	Quartzite and Talladega Slate Ridge	190,638
	Sandstone Mountain	161,490
	Sandstone Plateau	2,457
	Sandstone-Shale and Chert Ridge	28,309
	Schist Plains	15,931
	Shale Hills and Mountain	18,023
	Southern Loam Hills	84,058
	Upper Clay Hills	145,449
	Upper Loam Hills	23,563
NFs in Alabama Total		670,601
National Forests in Florida	Eastern Beach and Lagoons	22,845
	FL Gulf Coast Flatwoods-Bays and Barrier Islands	402,339
	Florida Central Highlands	361,884
	Florida Northern Highlands	2,830
	Gulf Southern Loam Hills	126,889
	Okeechobee Plain	13
	Okefenokee Swamp	106,779
	South Coastal Plains	46,823
	Upper Terraces	129,906
NFs in Florida Total		1,200,307
National Forests in Mississippi	Deep Loess Hills and Bluffs	20,952
	Delmarva Upland	6,153

National Forest (NF) Name	Ecological Sub-Sections	Total Acres
	Fragipan Loam Hills	305
	Interior Flatwoods	198
	Jackson Hills	99,011
	Jackson Prairie	333
	LA-MS Gulf Coast Flatwoods-Bays and Barrier Islands	50,530
	North Mississippi River Alluvial Plain	61,473
	Northern Loessial Hills	135,291
	Northern Pontotoc Ridge	26,622
	Southern Clay Hills	143,193
	Southern Loam Hills	416,310
	Southern Loessial Plains	186,152
	Upper Clay Hills	42,761
	Upper Loam Hills	1,821
NFs in Mississippi Total		1,191,104
National Forests in North Carolina	Carolina Slate-North	46,543
	Lower Terraces	97,368
	Metasedimentary Mountains	350,079
	Midland Plateau Central Uplands-North	7,939
	Southern Blue Ridge Mountains	684,495
	Southern Triassic Uplands	4,855
	Tidal Area	63,275
	Water	0
NFs in North Carolina Total		1,254,552
National Forests in Texas	Blackland Prairie	10,427
	Eastern Rolling Plains	93
	Piney Woods Transition	295,537
	Red River Alluvial Plain	7,430
	Sabine Alluvial Valley	35,843
	Sand Hills	17,420
	South Central Arkansas	69,201
	Southern Loam Hills	220,281
	Southwest Flatwoods	1,114
	Texas Grand Prairie	497
	Western Cross Timbers	19,513
NFs in Texas Total		677,357
Ouachita National Forest	Athens Piedmont Plateau	97,188
	East Central Ouachita Mountains	349,787
	Eastern Arkansas Valley and Ridges	89
	Fourche Mountains	700,267
	Mount Magazine	9,670

National Forest (NF) Name	Ecological Sub-Sections	Total Acres
	Red River Alluvial Plain	15,152
	Southwestern Arkansas	11,614
	West Central Ouachita Mountains	600,146
Ouachita NF Total		1,783,914
Ozark-St. Francis National Forest	Boston Hills	564,674
	Boston Mountains	294,953
	Crowley's Ridge	19,614
	Eastern Arkansas Valley and Ridges	29,313
	Mount Magazine	100,935
	North Mississippi River Alluvial Plain	3,163
	Springfield Plateau	48,942
	White River Hills	98,847
Ozark-St. Francis NF Total		1,160,441
Grand Total		**13,378,937**

Legend (for all graphs shown in figures 1 through 7)

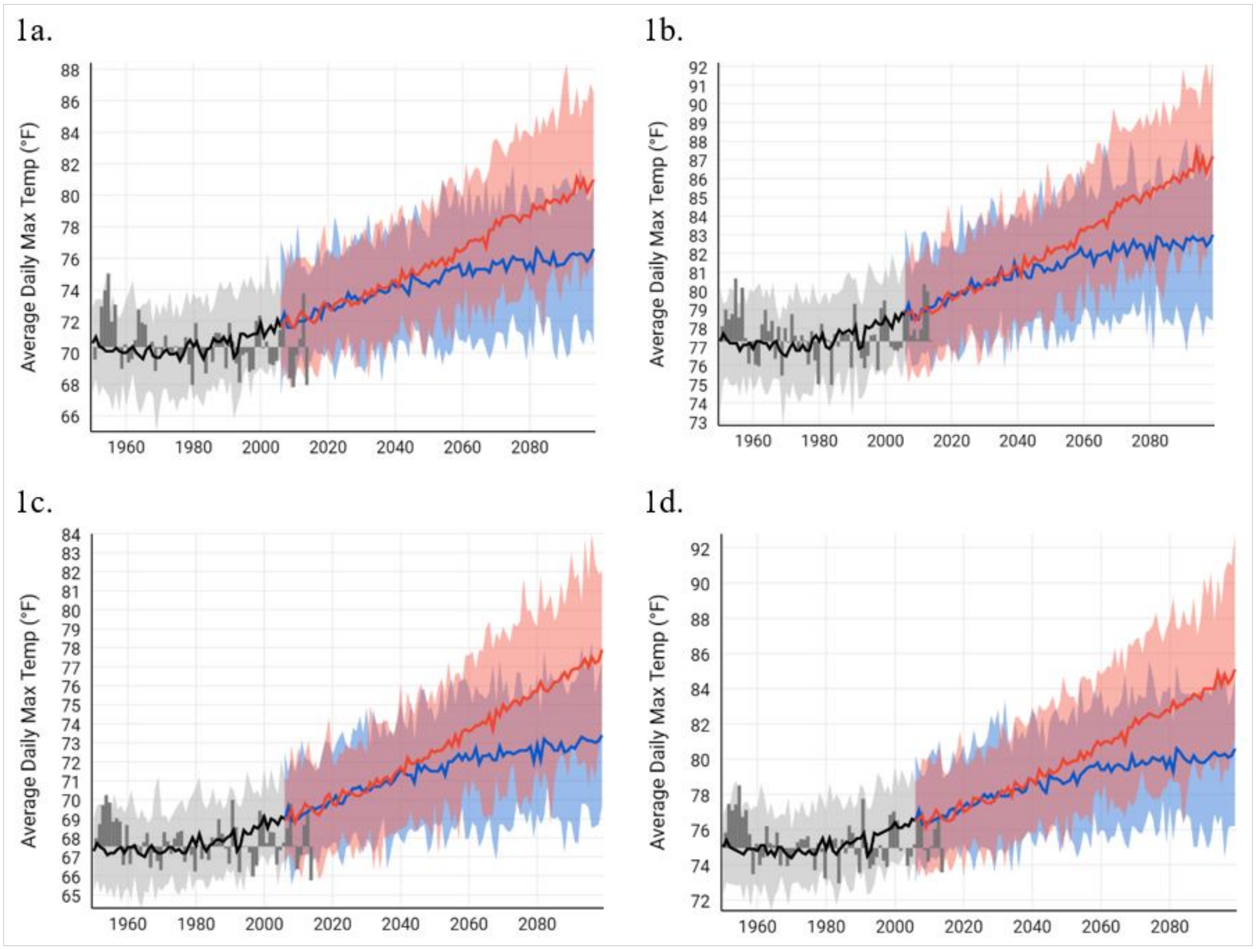

Figure 1. Average daily maximum temperature. (1a) Ozark-St. Francis National Forest – Boston Hills; (1b) National Forests in Texas – Piney Woods Transition; (1c) National Forests in North Carolina – Southern Blue Ridge Mountains; (1d) National Forests in Alabama – Upper Clay Hills.

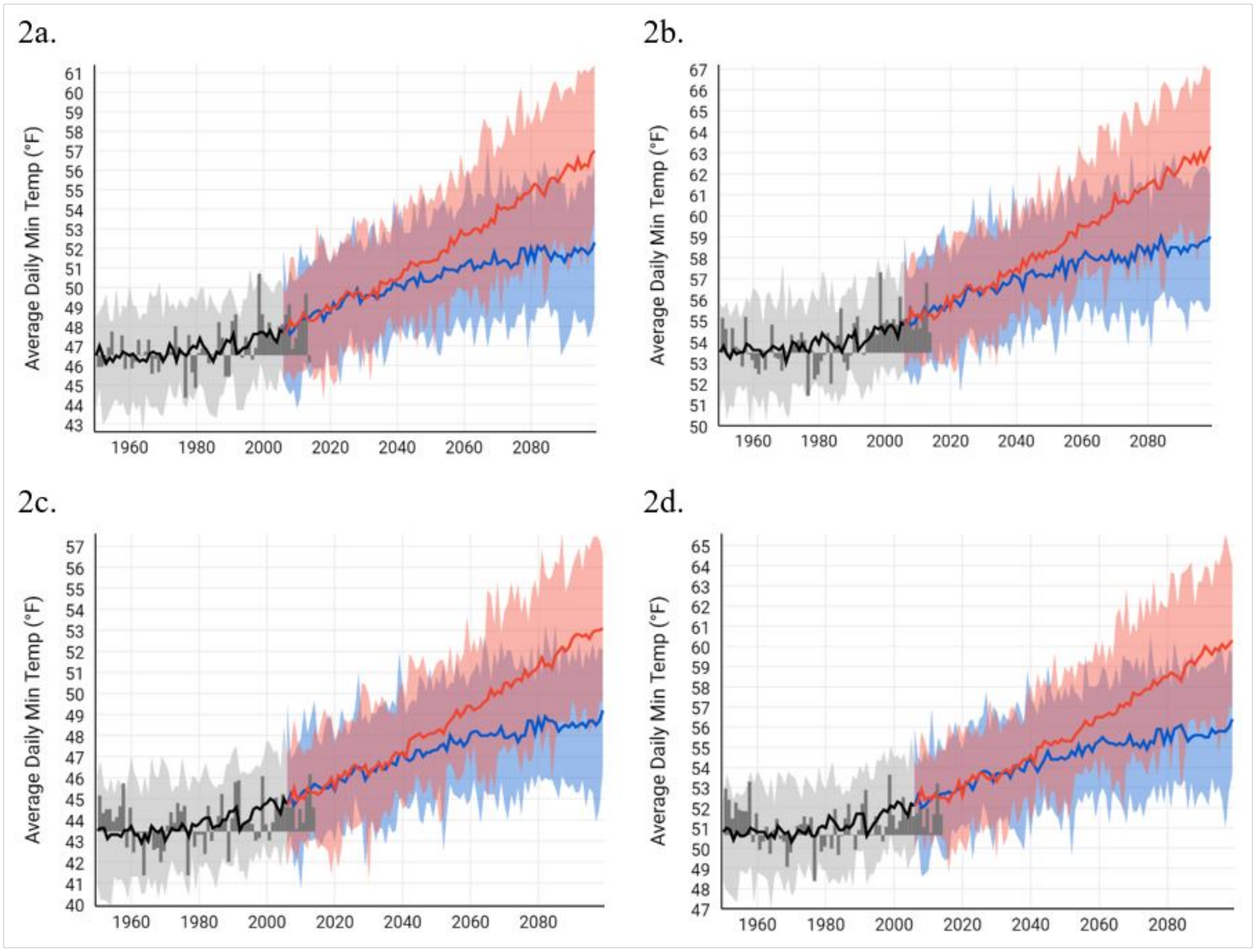

Figure 2. Average daily minimum temperature. (2a) Ozark-St. Francis National Forest – Boston Hills; (2b) National Forests in Texas – Piney Woods Transition; (2c) National Forests in North Carolina – Southern Blue Ridge Mountains; (2d) National Forests in Alabama – Upper Clay Hills.

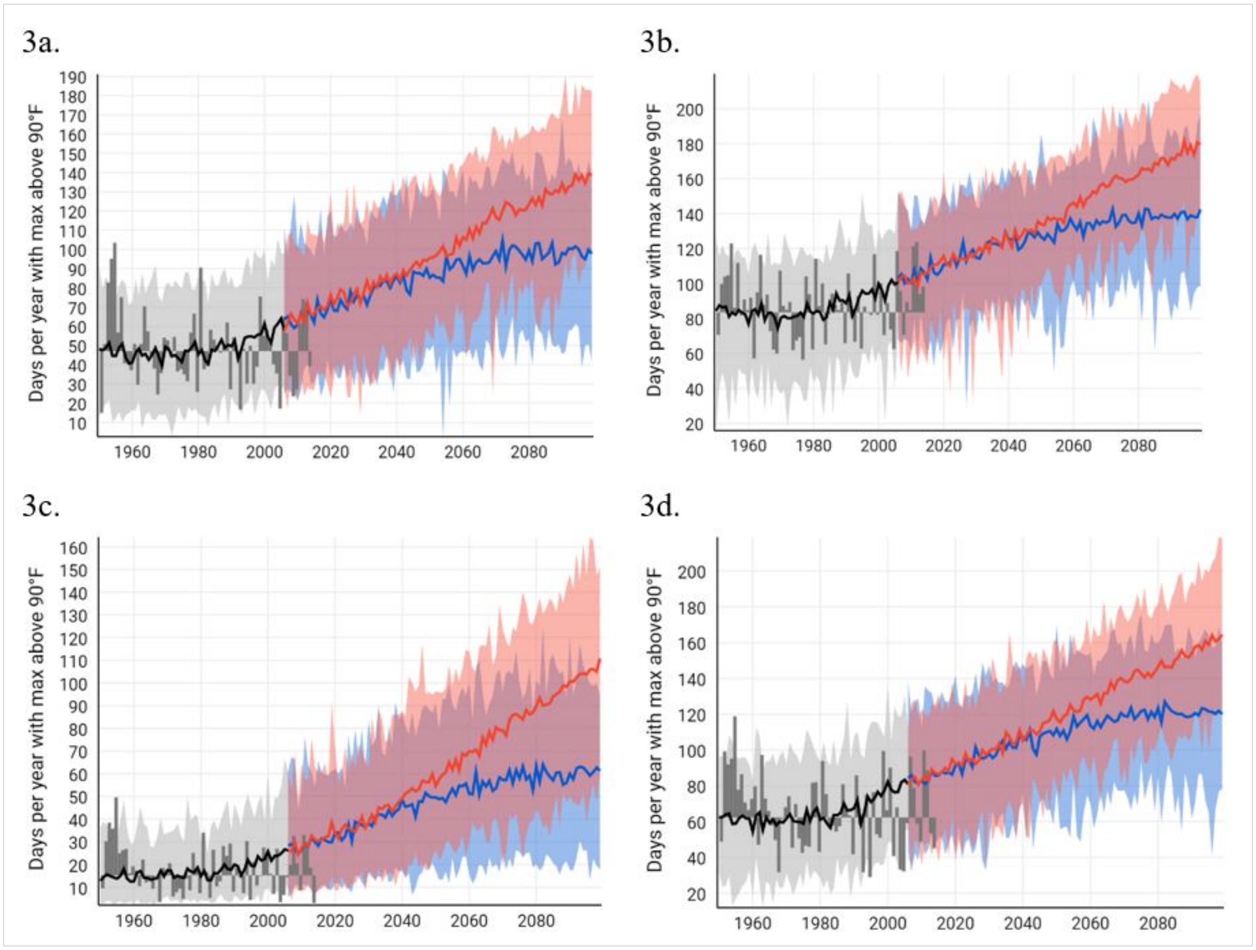

Figure 3. Days per year with a maximum temperature above 90 degrees Fahrenheit. (3a) Ozark-St. Francis National Forest – Boston Hills; (3b) National Forests in Texas – Piney Woods Transition; (3c) National Forests in North Carolina – Southern Blue Ridge Mountains; (3d) National Forests in Alabama – Upper Clay Hills.

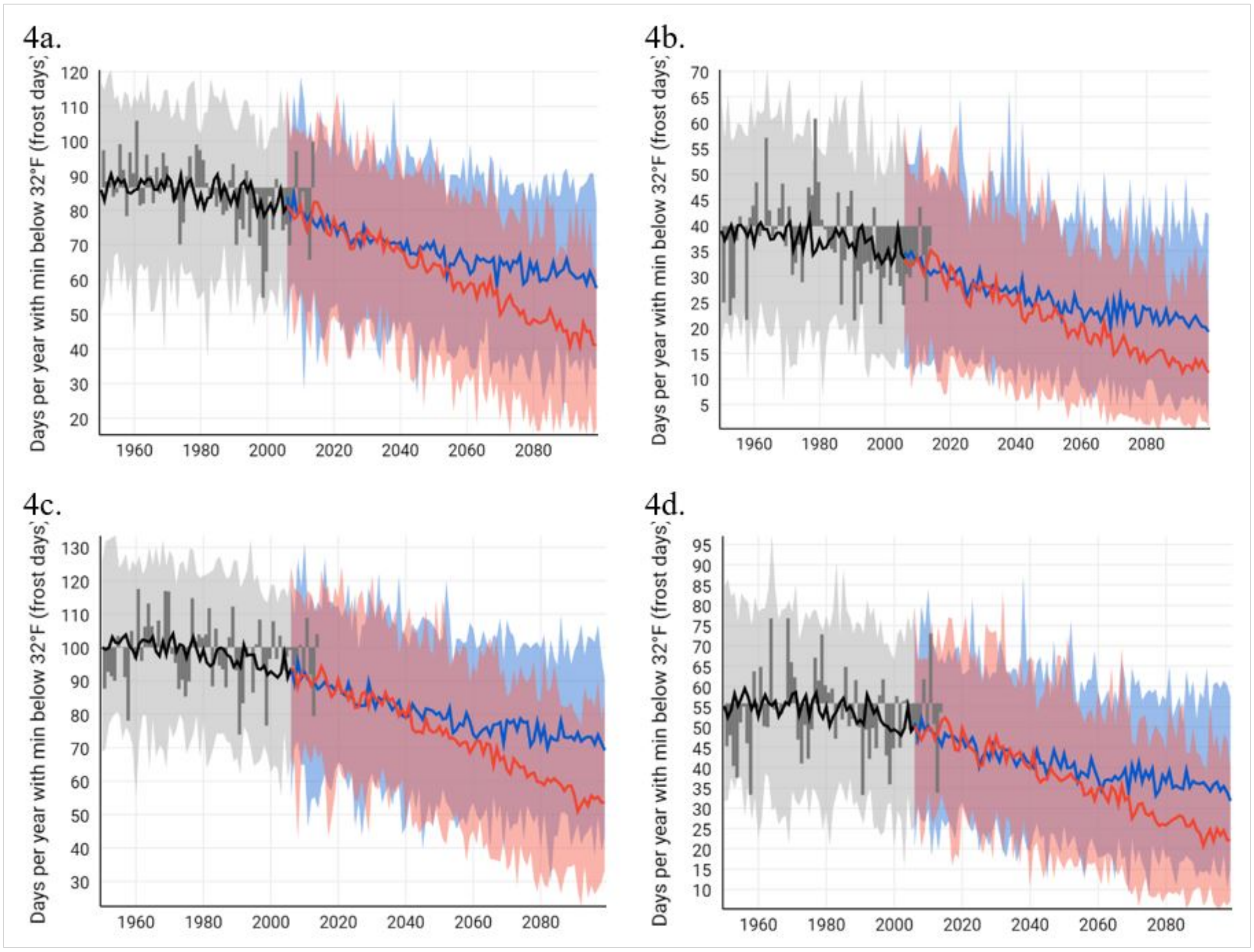

Figure 4. Days per year with a minimum temperature below 32 degrees Fahrenheit. (4a) Ozark-St. Francis National Forest – Boston Hills; (4b) National Forests in Texas – Piney Woods Transition; (4c) National Forests in North Carolina – Southern Blue Ridge Mountains; (4d) National Forests in Alabama – Upper Clay Hills.

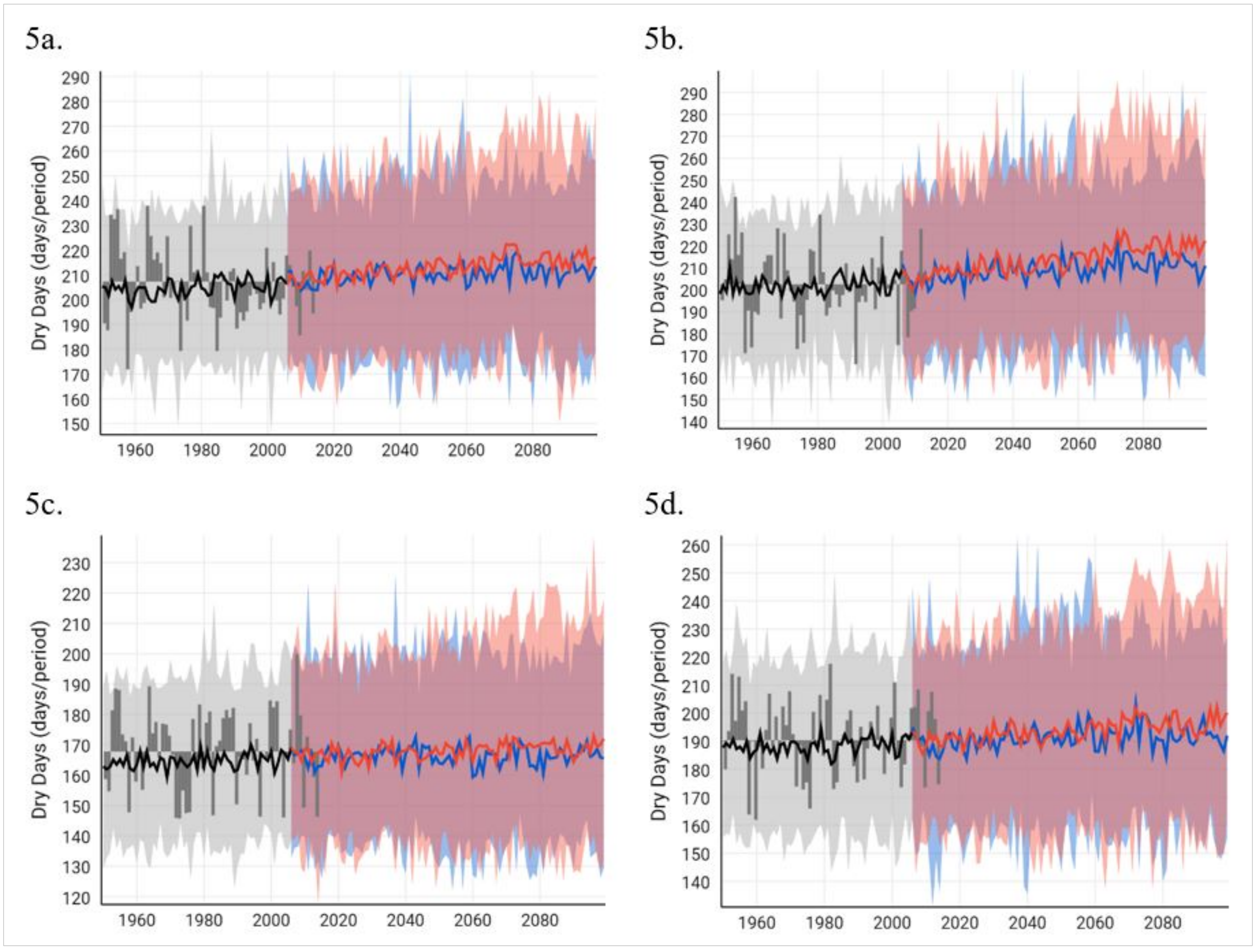

Figure 5. Dry days. (5a) Ozark-St. Francis National Forest – Boston Hills; (5b) National Forests in Texas – Piney Woods Transition; (5c) National Forests in North Carolina – Southern Blue Ridge Mountains; (5d) National Forests in Alabama – Upper Clay Hills.

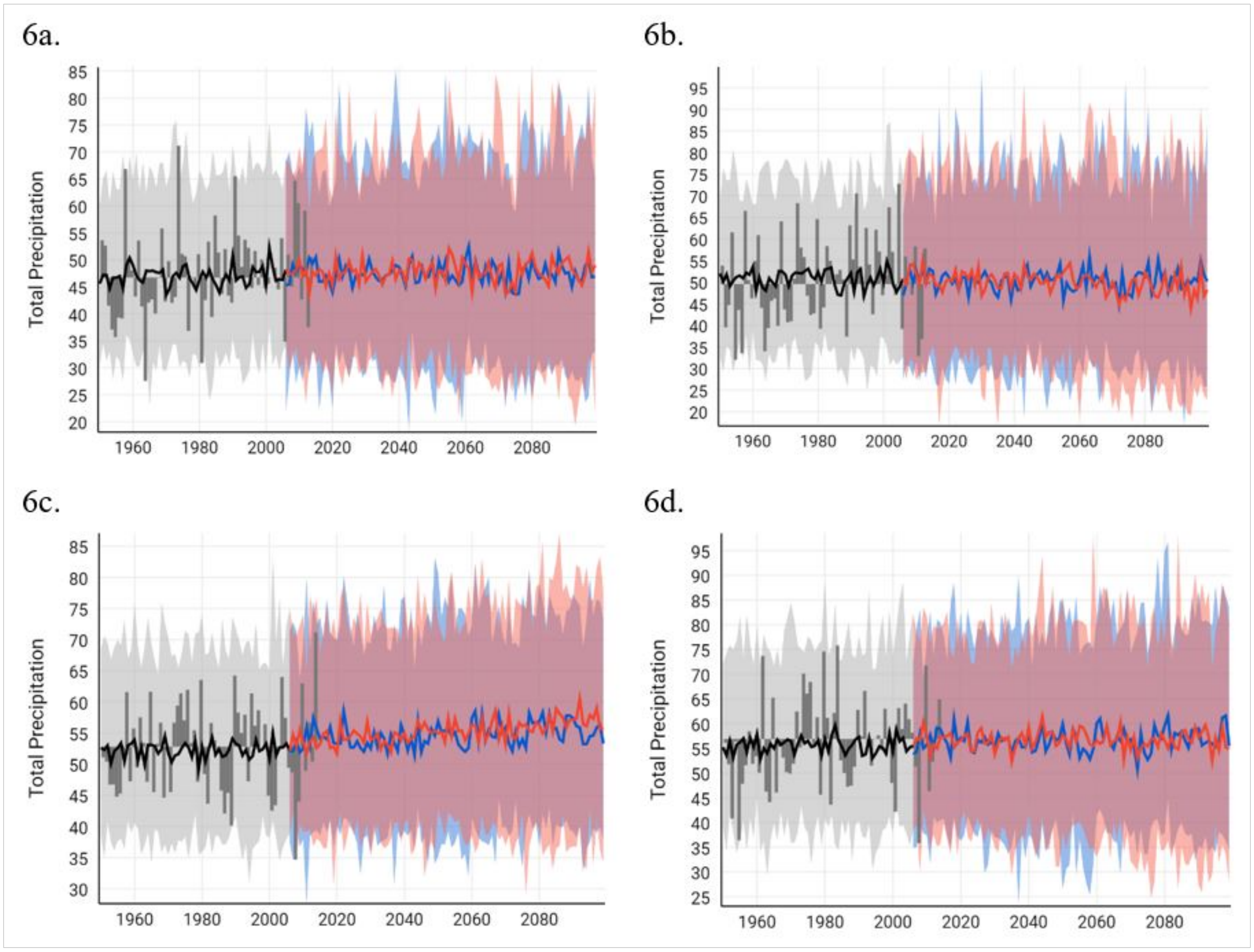

Figure 6. Total precipitation. (6a) Ozark-St. Francis National Forest – Boston Hills; (6b) National Forests in Texas – Piney Woods Transition; (6c) National Forests in North Carolina – Southern Blue Ridge Mountains; (6d) National Forests in Alabama – Upper Clay Hills.

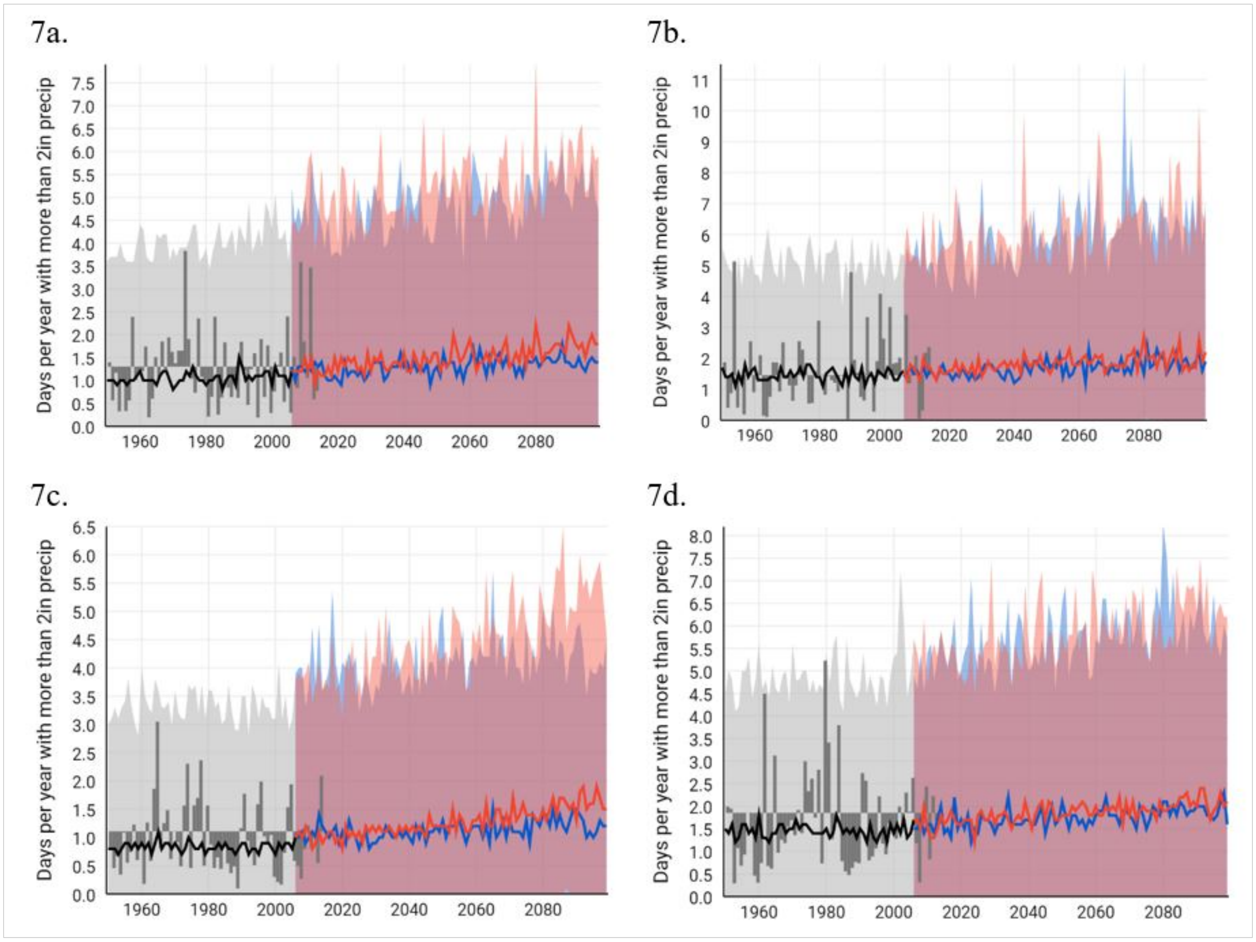

Figure 7. Days per year with more than 2 inches precipitation. (7a) Ozark-St. Francis National Forest – Boston Hills; (7b) National Forests in Texas – Piney Woods Transition; (7c) National Forests in North Carolina – Southern Blue Ridge Mountains; (7d) National Forests in Alabama – Upper Clay Hills.

Appendix C. Summary of Southern Region National Forest Potential Effects of Climate Change Assessments

Indicator	Impact	Response
Non-native Invasive Species Biological Diversity	NATIONAL FORESTS IN ALABAMA Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetle will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in these forests, including kudzu are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS OUACHITA NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Certain invasive plant species found in these forests, including Japanese honeysuckle are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA NATIONAL FORESTS IN MISSISSIPPI SUMTER NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetles, will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in this forest, including kudzu and Japanese honeysuckle are expected to increase dramatically as they are able	NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST THE LAND BETWEEN THE LAKES RECREATION AREA NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST Manage tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and fire. Monitor for new invasive species moving into areas where they were not traditionally found, especially following events such as hurricanes and fire. EL YUNQUE NATIONAL FOREST NANTAHALA and PISGAH NATIONAL FORESTS Monitor for new invasive species moving into areas where they were traditionally not found, especially following hurricane events in high-elevation communities.

Indicator	Impact	Response
	to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. DANIEL BOONE NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Extremes in temperature or rainfall also stress forest vegetation making it more likely to die when attacked by insects and disease, such as the hemlock woolly adelgid and the two-lined chestnut borer. GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetles, will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in these forests, including kudzu, Japanese honeysuckle, and Amur honeysuckle are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. KISATCHIE NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetles, will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in this forest, including kudzu, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. THE LAND BETWEEN THE LAKES RECREATION AREA Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species, including the	FRANCIS MARION NATIONAL FOREST Monitor for new invasive species moving into areas where they were not traditionally found, especially following events such as hurricanes and fire. NANTAHALA and PISGAH NATIONAL FORESTS Monitor for new invasive species moving into areas where they were traditionally not found, especially in high-elevation communities.

Indicator	Impact	Response
	Japanese honeysuckle, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. OZARK-ST. FRANCIS NATIONAL FORESTS Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as the red oak beetle and southern pine beetle will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in these forests, including kudzu are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. EL YUNQUE NATIONAL FOREST Biological Diversity – Plants and animals at risk will respond to environmental changes by adapting, moving, or declining. Species with high genetic variation will be better able to survive in new conditions. Higher temperatures will cause many species to shift ranges up in elevation. However, in some cases, the rate of warming combined with land use changes will restrict the ability of plants and animals to move into suitable habitat. Highland species with restricted habitats and are more likely to be negatively impacted by climate change than are lower elevation species. In montane cloud forests in El Yunque, narrow thermal ranges may pressure these high elevation species beyond their upper elevational limits. FRANCIS MARION NATIONAL FOREST Biological Diversity - Plants and animals at risk will respond to environmental changes by adapting, moving, or declining. Species with high genetic variation will be better able to survive in new conditions. Higher temperatures will cause many species to shift ranges, generally moving to track their suitable habit (e.g., northward or up in elevation). However, in some cases, the rate of warming combined with land use changes will restrict the ability of plants and animals to move into suitable habitat. The species most likely to be negatively impacted by climate change will be highly specialized and habitat restricted, effecting threatened and endangered species more than common species.	

Indicator	Impact	Response
	Forest Health - Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, and higher temperatures will likely allow these species to increase in number. Destructive insects, such as bark beetles, will be better able to take advantage of forests stressed by more frequent drought. Certain invasive plant species, including cogongrass, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. NANTAHALA and PISGAH NATIONAL FORESTS Biological Diversity - Plants and animals at risk will respond to environmental changes by adapting, moving, or declining. Species with high genetic variation will be better able to survive in new conditions. Higher temperatures will cause many species to shift ranges, generally moving to track their suitable habit (e.g., north or up in elevation). However, in some cases, the rate of warming combined with land use changes will restrict the ability of plants and animals to move into suitable habitat. The species most likely to be negatively impacted by climate change will be highly specialized and habitat restricted. Forest Health - Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, and higher temperatures will likely allow these species to increase in number. Destructive insects, such as bark beetles, will be better able to take advantage of forests stressed by more frequent drought. Certain invasive plant species, including kudzu, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions and already cover a large expanse, allowing them to rapidly move into new areas. NATIONAL FORESTS AND GRASSLANDS IN TEXAS Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetles, will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species, found in these grasslands, including Chinese tallow trees, are expected to increase dramatically as they are able to tolerate a	

Indicator	Impact	Response
	wide range of harsh conditions, allowing them to rapidly move into new areas. UWHARRIE NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes currently limit many forest pests, but higher temperatures will likely allow these species to increase. Destructive insects, such as bark beetles, will be better able to take advantage of forests stressed by more frequent drought. Certain invasive plant species found in the Uwharrie, including kudzu and honeysuckle, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas.	
Forest Health Regionwide	REGION WIDE Southeast forests will be affected by many factors including extreme weather, shifts in plant hardiness zones, sea level rise and saltwater intrusion, and increased pressure from invasive plants and pests, drought, and wildfire frequency. Increasing temperatures will worsen disturbance due to invasive plants and insects. Warmer temperatures due to climate change are converting saltwater marsh to mangroves and shifting where the marsh to mangrove ecotone exists. Sea level rise will increase soil salinity levels in coastal communities. Coastal forest retreat due to saltwater intrusion and the formation of “ghost forests” has been documented along the Southeast U.S. coastline. In addition, coastal wetlands have seen plant community shifts due to higher levels of salinity.	REGION WIDE Develop a coordinated system of monitored and controlled entrance points that control the majority of water flow inland from the shoreline and high-value water and land restoration areas in order to reduce salt-intrusion as well as to preserve marshes and swamps. Efforts to restore ecological integrity to impacted ecosystems (ex. by managing for longleaf and shortleaf pine) can have positive effects on disease and pest resistance, as well as wildfire and drought resilience.
Forest Health Animal Communities	REGION WIDE Some bird species along the coast have been negatively affected by the development of ghost forests and consequent habitat loss. Certain amphibian and insect species such as the red legged salamander or the Diana Fritillary that are highly dependent on elevation are becoming more and more isolated due to habitat fragmentation and loss. NATIONAL FORESTS IN ALABAMA Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. The endangered gopher tortoise will likely be severely affected by increasing drought conditions due to climate	REGION WIDE Conserve buffer areas along riparian habitats to provide habitat for amphibian species. High elevation areas are crucial refugia for many species. Preventing the addition of new roads and heavy equipment in these areas can maintain habitat connectivity. Create habitat corridors, assist in species movement, increase national forest management unit sizes, and identify high- value conservation lands adjacent to national forests. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS

Indicator	Impact	Response
	change. Bird species, such as red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes food more difficult to come by. CHEROKEE NATIONAL FOREST Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Bird species, such as the hooded warbler, are threatened by impacts of climate change. Available habitat for the Carolina northern flying squirrel may disappear completely by the year 2060. Alternatively, mammals such as deer and bears may increase due to higher survival rates during warmer winters. CROATAN NATIONAL FOREST SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Bird species, such as red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes their food sources more difficult to come by. Alternatively, mammals such as deer and bears may increase. DANIEL BOONE NATIONAL FOREST Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Greater ambient temperatures may be harmful to the endangered Indiana bat and the Virginia big-eared bat as well. Alternatively, mammals such as deer and black bears may increase due to higher survival rates resulting from warmer winters. NATIONAL FORESTS IN FLORIDA NATIONAL FORESTS IN MISSISSIPPI Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Bird species, such as red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes food sources more difficult to come	CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST EL YUNQUE NATIONAL FOREST UWHARRIE NATIONAL FOREST Maintain piles of natural woody debris in areas of high amphibian diversity to supplement habitats that retain cool, moist conditions. Create habitat corridors, assist in species movement, increase national forest management unit sizes, and identify high- value conservation lands adjacent to national forests. THE LAND BETWEEN THE LAKES RECREATION AREA FRANCIS MARION NATIONAL FOREST NANTAHALA and PISGAH NATIONAL FORESTS NATIONAL FORESTS AND GRASSLANDS IN TEXAS Maintain piles of natural woody debris in areas of high amphibian diversity to supplement habitats that retain cool, moist conditions. EL YUNQUE NATIONAL FOREST Enhance landscape connectivity by maintaining natural migration corridors between lowland and upland forests to allow species to move up-slope into cooler environments as climate warms. NANTAHALA and PISGAH NATIONAL FORESTS Enhance riparian corridors to provide shade to moderate increases in water temperature and stream flow that could decrease water quality and harm native trout populations.

Indicator	Impact	Response
	by. The endangered gopher tortoise will likely be severely affected by increasing drought conditions due to climate change. Alternatively, mammals such as deer and black bears may increase due to higher survival rates during warmer winters. GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Increasing water temperatures will also likely decrease populations of brook trout and greater ambient temperatures may also be harmful to the endangered Indiana bat. Alternatively, mammals such as deer and black bears may increase due to higher survival rates during warmer winters. KISATCHIE NATIONAL FOREST Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Avian species, such as the federally listed endangered red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes their food sources more difficult to come by. Alternatively, mammals such as deer may increase due to higher survival rates during warmer winters. THE LAND BETWEEN THE LAKES RECREATION AREA Wildlife species will be affected in different ways. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Greater ambient temperatures may be harmful to the endangered northern long-eared bat. OUACHITA NATIONAL FOREST Wildlife species will be affected in different ways. Amphibians such as salamanders may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. Bird species, such as red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes their food sources more difficult to come by.	

	OZARK-ST. FRANCIS NATIONAL FORESTS Wildlife species will be affected in different ways. Amphibians such as salamanders may be most at risk, due to dependencies on moisture and cool temperatures that could be altered. The Ozark hellbender is one such amphibian seeing a rapid decline in population and may be particularly affected. Greater ambient temperatures may be harmful to mammals such as the endangered Indiana bat. EL YUNQUE NATIONAL FOREST Wildlife – Wildlife species will be affected in different ways, depending on their needs. Climatic warming may push the narrow thermal tolerances of many species in tropical environments above their upper limits, prompting population losses and habitat changes that will affect animal communities. Because of their cool-adapted, range-restricted nature, high elevation amphibians, including Puerto Rican Coquí frogs, are especially vulnerable to future changes. More frequent drought conditions may increase the vulnerability of both reptiles and amphibians to water loss, disease, and parasites. Reduced rainfall may lead to decreased habitat quality for neotropical bird migrants wintering in El Yunque, while cavity- nesting birds, including the Puerto Rican Parrot, could see an increase in habitat competition and nesting predation with an increase in major hurricane disturbances. FRANCIS MARION NATIONAL FOREST Animal Communities - Wildlife species will be affected in different ways, depending on their needs. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered in a future climate. Bird species, even those that are presently increasing such as red cockaded woodpeckers, may see a decrease in population size as vegetation types change and heat stress makes migration more difficult. In order to adapt, arrival date and nesting times of some common birds may start earlier in the year. On the other hand, populations of large mammals such as deer and bears may increase with warmer winter temperatures due to a higher winter survival rate. NANTAHALA and PISGAH NATIONAL FORESTS Animal Communities - Wildlife species will be affected in different ways, depending on their needs. Amphibians may be most at risk, due to dependencies on moisture and cool temperatures that could be altered in a future climate. Populations of large mammals such as deer and bears may increase with warmer winter temperatures due to a higher winter survival rate. Birds, on the other hand, may decrease	

Indicator	Impact	Response
	in population size as vegetation types change and heat stress makes migration more difficult. In order to adapt, arrival date and nesting times of some common birds may start earlier in the year. Fish - Warmer air and water temperatures and changes in stream flow will affect the abundance and distribution of fish species. With higher water temperatures, fish communities in northern streams will begin to resemble communities in more southerly locations. Altered stream flow patterns can lead to decreases in water quality and oxygen content. Cold-water species, such as trout, will be the most vulnerable to population declines with future warming. The native brook trout may be most at risk, as warmer stream temperature and competition with invasive species will continue to reduce their populations.	
Forest Health Plant Communities	REGION WIDE Suitability conditions are projected to change for different tree species, with certain species having more adaptive capacity (southern pines, oaks, and hickories) than others (balsam fir, red spruce, eastern hemlock, and sugar maple) due to pests and climate competition. Changes in growing season and flowering dates are also possible with increasing minimum temperatures. Projected increase in temperatures can allow invasive pests and plants to increase their spread. NATIONAL FORESTS IN ALABAMA Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community composition. Species more resistant to these disturbances, such as longleaf pine, will be more resilient to a changing climate. Populations of other plants, including the endangered Alabama leather flower, will be particularly vulnerable to drier conditions. CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community	REGION WIDE Manage for tree species with high adaptive capacity. Early detection and rapid response is the most effective way to respond to invasive species and should be implemented where possible. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA KISATCHIE NATIONAL FOREST THE LAND BETWEEN THE LAKES RECREATION AREA NATIONAL FORESTS IN MISSISSIPPI UWHARRIE NATIONAL FOREST Focus restoration efforts in hurricane-resistant forests, such as longleaf pine as well as sweetgum or red oak hardwood, and promote the planting of longleaf pines over loblolly pine where feasible. Include a range of ages and species in forests to lessen potential loss from drought or infestation.

Indicator	Impact	Response
	composition. Species more resistant to these disturbances, such as shortleaf pine, will be more resilient to a changing climate. Populations of other plants, including the threatened large-flowered skullcap, may be particularly vulnerable because invasive species like the Japanese honeysuckle out-compete the native plant. CHEROKEE NATIONAL FOREST Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Populations of some plants, including the threatened blue ridge goldenrod, may be particularly vulnerable to warmer weather Hardwood- dominated forests may experience stress from higher temperatures, allowing pines and other fast-growing species to become more dominant at the expense of slower-growing species such as hickories and oaks. CROATAN NATIONAL FOREST GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community composition. Populations of some rare or endemic plants may be disproportionately impacted. Species more resistant to these disturbances, such as longleaf pine, will be more resilient to a changing climate. DANIEL BOONE NATIONAL FOREST Heat stress may limit the growth of some trees. Stresses from drought and wide-scale pest outbreaks have the potential to cause large areas of forest to die. Intense weather events, ice storms and fire, are also expected to lead to changes in plant community composition by knocking down the forest canopy and allowing aggressive species to invade an area.	CHEROKEE NATIONAL FOREST Focus restoration efforts in mixed shortleaf pine, known for their short foliage, strong wood, and resistance to disease in order to lessen vulnerability to the southern pine beetle, fungus, and impacts from severe storms. GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS OUACHITA NATIONAL FOREST Include a range of ages and species in forests to lessen potential loss from drought or infestation. OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST Focus restoration efforts in wind resistant forests, such as shortleaf pines as well as native hardwoods, and promote the planting of shortleaf pines over loblolly pine. Include a range of ages and species in forests to lessen potential loss from drought or infestation. OZARK-ST. FRANCIS NATIONAL FORESTS Replace fescue with native warm season grasses because they are more drought tolerant and endemic. FRANCIS MARION NATIONAL FOREST Manage tree densities where needed through sound forest management practices such as thinning and prescribed fire to maximize carbon sequestration while reducing the susceptibility of forest stands to water stress, insect and disease outbreaks, and wildfire. Focus restoration efforts in longleaf pine forests and promote the planting of longleaf pine over loblolly pine where feasible. NANTAHALA and PISGAH NATIONAL FORESTS Manage tree densities where needed through sound forest management practices to maximize carbon sequestration while reducing the susceptibility of forest stands to water stress, insect and disease outbreaks, and wildfire.

	NATIONAL FORESTS IN FLORIDA NATIONAL FORESTS IN MISSISSIPPI Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community composition. Populations such as the endangered green pitcher plant require moisture-rich soils and may decline due to increasing droughts. Species more resistant to these disturbances, such as longleaf pine, will be more resilient to a changing climate. KISATCHIE NATIONAL FOREST Invasive and aggressive plant and insect species may increasingly outcompete or negatively affect native species in the future. Higher temperatures will likely allow these species to increase. Destructive insects, such as southern pine beetles, will be better able to take advantage of forests due to factors such as increased drought. Certain invasive plant species found in this forest, including kudzu, are expected to increase dramatically as they are able to tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas. THE LAND BETWEEN THE LAKES RECREATION AREA Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as storms and fire, are also expected to lead to changes in plant community composition. Populations of some rare or endemic plants may be particularly vulnerable. Hardwood-dominated forests may experience stress from higher temperatures, allowing pines and other fast-growing species to become more dominant at the expense of slower-growing species such as hickories and oaks. OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as tornadoes, ice storms, and fire, are also expected to lead to changes in plant community	Focus restoration efforts in cove forests where cool microclimates buffer the effects of future warming and water stress. NATIONAL FORESTS AND GRASSLANDS IN TEXAS Include a range of ages and species in forests to lessen potential loss from drought or infestation.

Indicator	Impact	Response
	composition. Populations of some rare or endemic plants may be disproportionately impacted. Species more resistant to these disturbances, such as shortleaf pine will be more resilient to a changing climate. EL YUNQUE NATIONAL FOREST Terrestrial Ecosystems – Higher temperatures, changes in precipitation patterns, and any alteration in cloud cover will affect plant communities and ecosystem processes. Increasing night-time temperatures may affect tropical tree growth and induce tree mortality. Both intensified extreme weather events and progressively drier summer months in the Caribbean are expected to alter the distribution of tropical forest life-zones, potentially allowing low-elevation Tabonuco forest species to colonize areas currently occupied by Colorado forest. El Yunque's tropical montane cloud forests are among the world's most sensitive ecosystems to climate change. Cloud forest epiphytes may experience moisture stress due to higher temperatures and less cloud cover with a rising cloud base, affecting epiphyte growth and flowering. Plant communities on isolated mountain peaks will be most vulnerable, as they will not be able to adapt to the shifting-cloud base by moving to higher elevations. FRANCIS MARION NATIONAL FOREST Plant Communities - Heat stress may limit the growth of some southern pines and hardwood species. Additional stresses from drought, in combination with wide-scale pest outbreaks, have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community composition. An increase in disturbance may promote the establishment of longleaf pine at the expense of loblolly pine. Populations of bald cypress may be particularly vulnerable to future changes, including higher air and water temperatures. NANTAHALA and PISGAH NATIONAL FORESTS Plant Communities - Changing temperature and rainfall patterns may threaten the survival of high-elevation communities in mountain forests. Rising temperatures will allow species from lower elevations to migrate up-slope, changing the forest communities seen today.	

Indicator	Impact	Response
	Populations of species now existing on mountain peaks, including spruce-fir forests, will be most at risk in the future. Hardwood-dominated forests may experience stress from higher temperatures, allowing pines and other fast-growing species to become more dominant at the expense of slower-growing species such as hickories and oaks. UWHARRIE NATIONAL FOREST Heat stress may limit the growth of some southern pines and hardwood species. Stresses from drought and wide- scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to lead to changes in plant community composition. Species more resistant to these disturbances, such as longleaf pine, will be more resilient to a changing climate. Populations of other plants, including the endangered Schweinitz's Sunflower, may be particularly vulnerable to future changes.	
Forest Health Water Resources	REGION WIDE With climate change projected to cause warmer temperatures and variable precipitation in the future, water resources will likely be even more affected by drought and extreme weather events. Severe drought impacts could lower streamflow in forested watersheds. Increased water temperature due to warming climate can potentially lead to an increase in toxic algal blooms in lakes. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST	REGION WIDE Reduce impact on aquatic ecosystems affected by drought by favoring tree species that are fire tolerant and have relatively low water use (e.g., longleaf pine). Remove invasive species that use more water to reduce stress on the aquatic ecosystems. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST THE LAND BETWEEN THE LAKES RECREATION AREA NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS

Indicator	Impact	Response
	Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in waterways. Increased periods of drought may lead to poor water quality. CHEROKEE NATIONAL FOREST In the Southern Appalachian Mountains, high- elevation streams are most susceptible to acidification. As stream temperatures continue to rise, species shifting to higher elevations will be constrained by the acidification process. This increases the likelihood of local and regional extinction. DANIEL BOONE NATIONAL FOREST Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly affect depth and volume of water in lakes, streams, wetlands and underground water systems. Heavy downpours may lead to erosion and sedimentation in waterways as well as flooding and damage to forest roads and recreation sites. Periods of drought between rain events may affect species of fish, mussels and amphibians that are sensitive to fluctuations in water temperature and depth. KISATCHIE NATIONAL FOREST Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense storms can lead to greater erosion and more sedimentation in waterways. Increased periods of drought may lead to poor water quality, more variable stream flows, and loss of quality aquatic habitat. THE LAND BETWEEN THE LAKES RECREATION AREA Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense storms are leading to greater erosion and more sedimentation in waterways. OZARK-ST. FRANCIS NATIONAL FORESTS Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense storms can lead to greater erosion and	UWHARRIE NATIONAL FOREST Focus attention on and near smaller, isolated water systems that are more vulnerable and may not be able to absorb and benefit from wildfires and heavy rains that cause large floods or debris flow. Relieve groundwater and large reservoir use when there is ample surface water during wet periods or times of high water flow to recharge aquifers, provide temporary irrigation, decrease stored sediment loss, and construct small reservoirs. CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST THE LAND BETWEEN THE LAKES RECREATION AREA OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST Restore and reinforce vegetation in headwater and marsh areas to help alleviate runoff of sediment during heavy rain, reduce climate-induced warming of water, and decrease water sensitivity to changes in air temperature CHEROKEE NATIONAL FOREST To reduce acidity in headwaters, use liming techniques. To reduce temperatures, canopy enhancement is a primary strategy. CROATAN NATIONAL FOREST Focus attention on and near smaller, isolated water systems that are more vulnerable and may not be able to absorb and benefit from wildfires and heavy rains that cause large floods or debris flow. Develop a coordinated system of monitored and controlled entrance points that control the majority of water flow inland from the shoreline and high-value water and land restoration areas in order to reduce salt-intrusion as well as to preserve marshes and swamps.

Indicator	Impact	Response
	more sedimentation in waterways. Increased periods of drought may lead to poor water quality. EL YUNQUE NATIONAL FOREST Aquatic Ecosystems – Shifts in rainfall patterns due to climate change will lead to periods of flooding and drought that can significantly impact aquatic ecosystems and water resources. Increases in heavy downpours and more intense hurricanes in the wet season can lead to greater erosion and sedimentation in waterways. Riparian areas will see changes in structure and composition due to altered temperature, precipitation and run-off regimes as well as changes in the distribution of plant and animal species. Extended droughts in the dry season may significantly affect water resources by decreasing dissolved oxygen content. Freshwater aquatic communities during drought will experience crowding of species, leading to habitat squeezes and a decrease in reproductive output. FRANCIS MARION NATIONAL FOREST Coastal Ecosystems - Coastal areas in the Southeast have already experienced an average of one inch of sea level rise per decade over the 20th century, a rate that will continue to increase in the future. Rising seas, in combination with more intense hurricanes, will alter the composition of coastal marshes. As saltwater flooding expands, low-lying coastal wet forests could become marshland where land use barriers do not exist. Sea level rise can also increase the potential for saltwater intrusion into coastal freshwater tables. Increasing salinity of coastal aquifers may affect groundwater resources within three miles of the coast. Water Resources - Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in waterways. Increased periods of drought may lead to decreasing dissolved oxygen content and poor water quality in some areas. Groundwater-fed wetlands, such as Carolina bays, will be particularly vulnerable to changing climate as temperature and rainfall changes have the potential to lower groundwater table levels, altering the length of time that wetlands hold standing water. NANTAHALA and PISGAH NATIONAL FORESTS Water Resources - Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources.	FRANCIS MARION NATIONAL FOREST Protect existing coastal marshes by promoting healthy vegetation and restoring natural hydrology, and maintain coastal land buffers to allow for the natural inland migration of salt marshes as sea levels rise.

Indicator	Impact	Response
	Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in our waterways. Increased periods of drought may lead to decreasing dissolved oxygen content and poor water quality in some areas. Groundwater-fed wetlands such as high-elevation bogs will be particularly vulnerable to changing climate as temperature and rainfall changes have the potential to lower groundwater table levels, altering the length of time that wetlands hold standing water.	
Prescribed Fire	See Forest Health – Plant Communities	See Forest Health – Plant Communities
Recreational Use and Satisfaction	REGION WIDE Changes in precipitation due to drought could negatively impact water based outdoor recreation like canoeing, kayaking, and motorized activities. Increase in temperature can impact visitors comfort. Climate change can also have impacts on culturally significant natural resources. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST Environmental changes may negatively impact recreational experiences due to changes in the plant and animal communities that make those experiences unique. More days above freezing could	REGION WIDE Enact monitoring to determine when it is safe for recreational activities to take place in water recreation areas and communicate effectively to visitors the potential risks of higher temperature or high water levels. Work with local indigenous populations and cultural groups to provide resources for them to adapt to the climate. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA KISATCHIE NATIONAL FOREST THE LAND BETWEEN THE LAKES RECREATION AREA NATIONAL FORESTS IN MISSISSIPPI OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS UWHARRIE NATIONAL FOREST

Indicator	Impact	Response
	increase tick and mosquito populations throughout the year, leading to an increase in vector-borne illness. With more days of extreme heat, recreation areas could see decreased use in the summer if temperatures impact visitor comfort. DANIEL BOONE NATIONAL FOREST Changes in plant and animal communities as mentioned above may make some areas less attractive to recreation users. Tick and mosquito populations may increase due to warmer winters and extreme heat may result in less visitors during high heat conditions. EL YUNQUE NATIONAL FOREST Recreation – The Caribbean region, where year-round warm weather is the principle tourism resource, may see increasing competition from other regions as warm seasons expand globally. Sea level rise will affect coastal resorts, which may affect tourist and recreationist preferences throughout Puerto Rico. Climate change may affect recreation in El Yunque through changes to local ecosystems and resources that impact scenic values, as well as changes to weather patterns that may disrupt recreational activities and lead to changes in visitor use. Visitors to El Yunque may see impacts to the local plant and animal communities that make the forest unique. An increase in extreme weather events may increase damage to facilities and structures, reduce tourist access in some areas, and increase the need for road repairs. FRANCIS MARION NATIONAL FOREST Recreation - Environmental changes may negatively impact recreational experiences due to changes in the plant and animal communities that make those experiences unique. Fishing in coastal marshes could be affected, as intense storm events and rising sea levels may lead to degraded habitat conditions for game fish. More days above freezing could increase tick and mosquito populations throughout the year, leading to an increase in vector-borne illness. With more days with extreme heat, recreation areas could see decreased use in the summer if temperatures impact visitor comfort. NANTAHALA and PISGAH NATIONAL FORESTS Recreation - Environmental changes may negatively impact recreational experiences due to changes to the plant and animal communities that make those recreational experiences unique, along with an increase in haze that may reduce the visibility of mountain	Communicate early warnings for extreme weather to protect vulnerable groups from health impacts, such as heat illnesses, and monitor for early outbreaks of disease CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CHEROKEE NATIONAL FOREST NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS NATIONAL FORESTS IN MISSISSIPPI SUMTER NATIONAL FOREST Examine the goals for a water system or area of land when considering changing dynamics. For example, a stream managed mostly for recreation must balance the demand for rainbow trout from anglers with other aquatic and terrestrial impacts. EL YUNQUE NATIONAL FOREST Anticipate changes in visitor behavior and proactively plan to mitigate any seasonal increases in use.

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	views. While more days above freezing could increase use in some forest areas in the cooler seasons, more days with extreme heat could decrease use in the summer if temperatures impact visitor comfort. The fall foliage season may be affected as leaves change color later in the season and increasing stresses on forests impact the vividness of fall foliage displays.	
Wildfire	CHEROKEE NATIONAL FOREST Air Quality Since future emissions from wildfires will likely increase, emissions can have important air quality impacts both regionally and locally.	CHEROKEE NATIONAL FOREST Air Quality As climate change increases the potential for wildfire and prescribed fires become a forest management tool, smoke Appalachian Trail management tools can help managers with decisions on how to balance fire-related smoke and the importance of air quality in affected areas.
Jobs and Income	See Economics Analysis	See Economics Analysis
Phenology	See Forest Health – Plant Communities	See Forest Health – Plant Communities
Extreme Weather	REGION WIDE Extreme precipitation events are becoming more likely; however, there are longer dry periods between storms. Increasing drought frequency and a projected increase in dry season, as much as 156 days in some areas, will increase the risk of wildfires. Not only are extreme precipitation events becoming more likely, hurricanes are becoming more severe and are able to sustain damaging conditions for longer periods of time. These events have large impacts on nearby estuaries and coastal waters, including negatively impacting carbon sources and sinks. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS CROATAN NATIONAL FOREST NATIONAL FORESTS IN FLORIDA NATIONAL FORESTS IN MISSISSIPPI SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS	REGION WIDE Manage tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and fire. Communicate early warnings to visitors of extreme weather events. NATIONAL FORESTS IN ALABAMA CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS NATIONAL FORESTS IN FLORIDA GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST NATIONAL FORESTS IN MISSISSIPPI OZARK-ST. FRANCIS NATIONAL FORESTS SUMTER NATIONAL FOREST NATIONAL FORESTS AND GRASSLANDS IN TEXAS

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	The potential for severe storms is expected to increase in the future, including more intense hurricanes making landfall in the southern US. Extended periods of extreme high temperature and drought may lead to drier forest fuels which will burn more easily and contribute to larger and more frequent wildfires. More cloud-to-ground lightning due to warming may also increase wildfire ignitions. DANIEL BOONE NATIONAL FOREST GEORGE WASHINGTON AND JEFFERSON NATIONAL FORESTS KISATCHIE NATIONAL FOREST OUACHITA NATIONAL FOREST OZARK-ST. FRANCIS NATIONAL FORESTS The potential for severe storms is expected to increase in the future. Extended periods of extreme high temperature and drought may lead to drier forest fuels which will burn more easily and contribute to larger and more frequent wildfires. More cloud-to-ground lightning due to warming may also increase wildfire ignitions. EL YUNQUE NATIONAL FOREST Climate Trends – Average temperatures in El Yunque have increased over the past 30 years, and scientists predict warming will continue at an accelerated pace, however, climate models vary in the degree of warming. Projected decreases in precipitation in the Caribbean suggest drier wet seasons, and even drier dry seasons. Increasing sea surface temperatures may lift the base altitude of cloud formation and alter atmospheric circulation patterns. Any change in the cloud base height will further decrease precipitation in El Yunque. Extreme Weather – In the Caribbean, the occurrence of very warm days and nights is accelerating, while very cool days and nights are becoming less common, increasing the likelihood of extreme heat waves. The frequency of extreme precipitation events is expected to increase, leading to potential increases in inland flooding and landslides. Hurricane events are likely to become less frequent but more severe, with increased wind speeds, rainfall intensity, and storm surge height. As annual rainfall decreases over time in the Caribbean region, longer periods of drought are expected in the future. In Puerto Rico, where nearly all wildfires are associated with human activity, the interactions between climate warming and drying and increased human development have the potential to increase the effects of fire.	Identify areas that provide particularly valuable ecosystem services, like timber harvest or carbon sequestration, and are also vulnerable to extreme weather, like hurricanes or fires. Then plan conservation strategies accordingly to mitigate for extreme weather impacts and payment for ecosystem service programs. Prescribed burning can also be a management option for reducing the impacts of any future increases in wildfire potential emanating from climate change. CROATAN NATIONAL FOREST Focus attention on and near smaller, isolated water systems that are more vulnerable and may not be able to absorb and benefit from wildfires and heavy rains that cause large floods or debris flow. Relieve groundwater and large reservoir use when there is ample surface water during wet periods or times of high water flow to recharge aquifers, provide temporary irrigation, decrease stored sediment loss, and construct small reservoirs. NATIONAL FORESTS IN FLORIDA NATIONAL FORESTS IN MISSISSIPPI Develop a coordinated system of mature and healthy coastal mangroves, dunes, and wetlands that are resilient and resistant to the stress of climate change and protect against storm surge. This system provides valuable and cost-effective ecosystem services and many ancillary benefits. THE LAND BETWEEN THE LAKES RECREATION AREA Prescribed burning can also be a management option for reducing the impacts of any future increases in wildfire potential emanating from climate change. OUACHITA NATIONAL FOREST Identify areas that provide particularly valuable ecosystem services, like timber harvest or carbon sequestration, and are also vulnerable to extreme weather, like tornadoes or fires. Then plan conservation strategies accordingly to mitigate for extreme weather impacts and payment for ecosystem service programs. EL YUNQUE NATIONAL FOREST

Indicator	Impact	Response
	FRANCIS MARION NATIONAL FOREST Extreme Weather - The potential for severe storms is expected to increase in the future, including more intense hurricanes making landfall in the southern US, with potential increases in both inland flooding and coastal storm surge events. Under a more variable climate, extended periods of extreme high temperature and drought may lead to drier forest fuels which will burn more easily and at hotter temperatures and contribute to larger and more frequent wildfires. More cloud-to-ground lightning due to warming may also increase wildfire ignitions. NANTAHALA and PISGAH NATIONAL FORESTS Extreme Weather - The potential for severe storms is expected to increase in the future, including more intense hurricanes making landfall in the southern US, with potential increases in flooding and landslides in mountainous landscapes. Conversely, extended periods of drought and forest stress may lead to drier fuels which will burn more easily and at hotter temperatures, and contribute to more and larger wildfires. More cloud-to- ground lightning due to warming may increase wildfire ignitions, even in mountainous areas where fires are historically less common	Mitigate future negative effects on sensitive species following intense hurricane events by promoting the establishment of more disturbance-resistant species, such as palms.