Developing Resilient Forests
Tools and management practices

MICHELLE THOMPSON, STEVE MCNULTY, MICHAEL GAVAZZI, AND PUSKAR KHANAL, MAY 2, 2025

US Department of Agriculture Southeast Climate Hub & Clemson University

Introduction

- Michelle Thompson
- Climate Science Communication Specialist
- Clemson University Department of Forestry & Environmental Conservation/ United States Forest Service Southeast Climate Hub

CLEMSON UNIVERSITY

USDA Climate Hubs
U.S. DEPARTMENT OF AGRICULTURE

Outline

1. Resilient forestry in the U.S.

2. What is the Climate Hub?

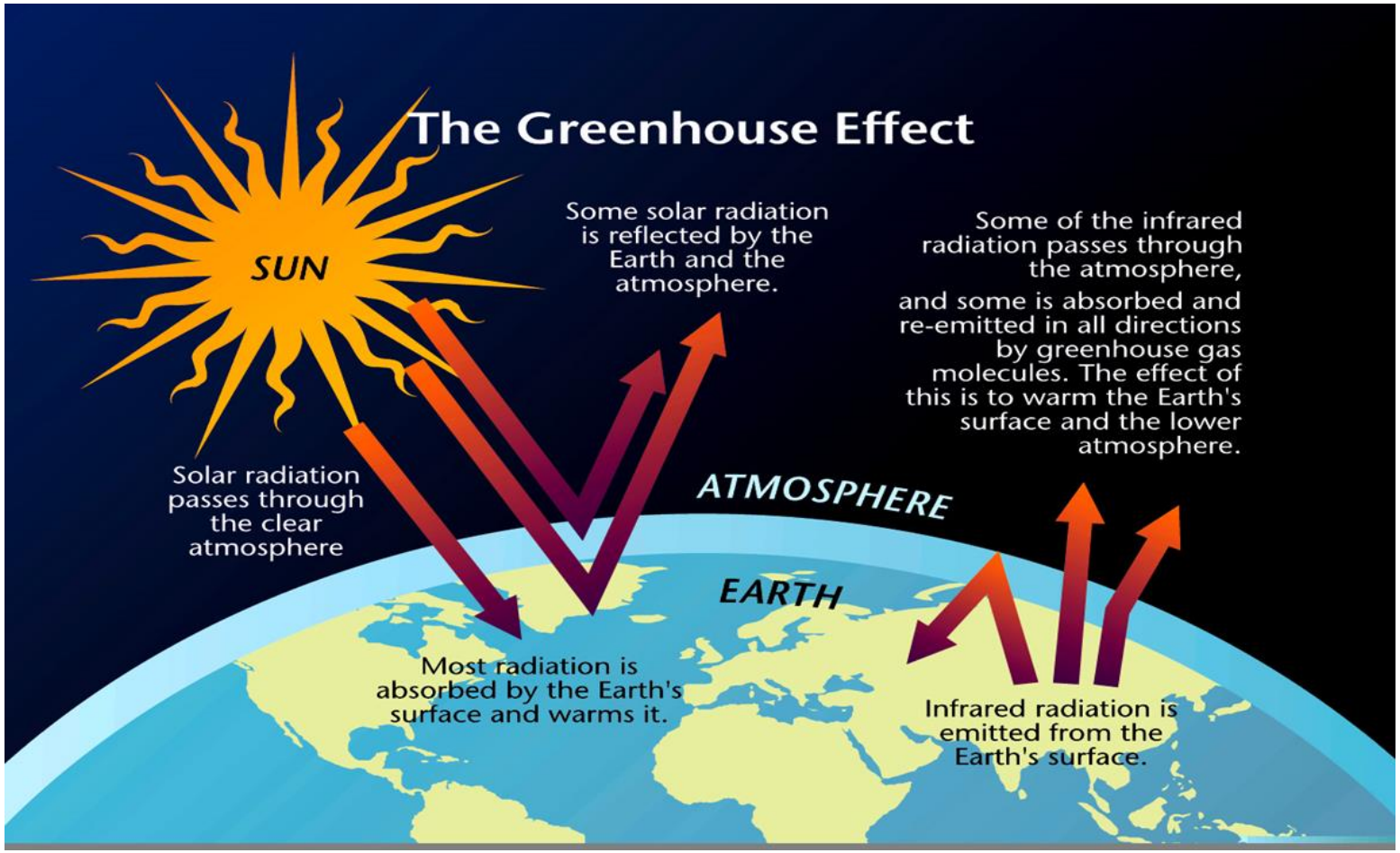
3. Overview of the Climate Hub tools and resources

Resilient forestry in the U.S.

Key moments in U.S. resilient forest management

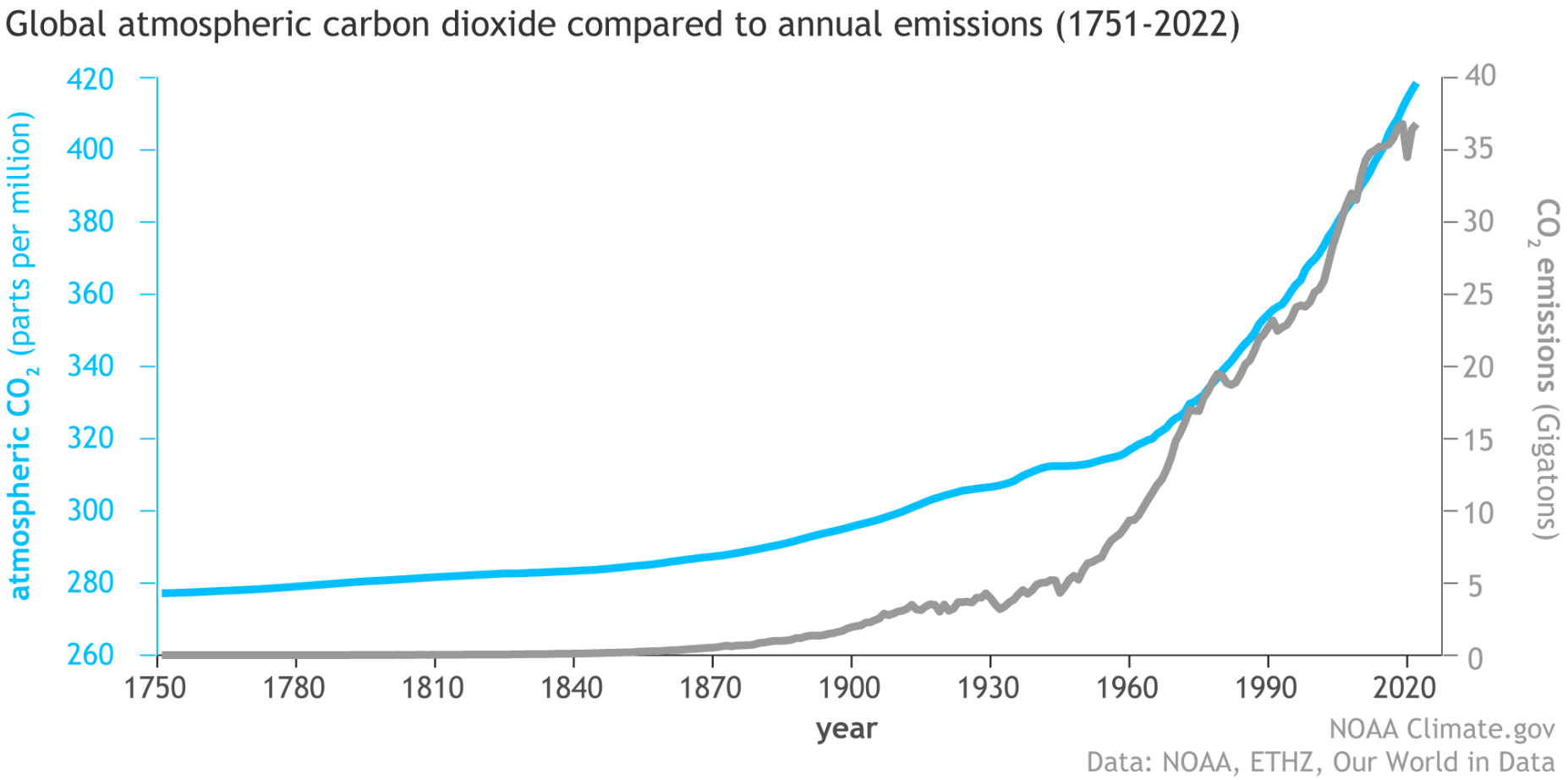
- 1713- Origin of sustainable forest management concept by Carl von Carlowitz
- Founding of U.S., intense and unsustainable logging followed
- 1904-1940 Chestnut blight destroyed chestnut populations
- 1930s CCC planted trees, U.S. became more sustainable
- Climate change

The Greenhouse Effect

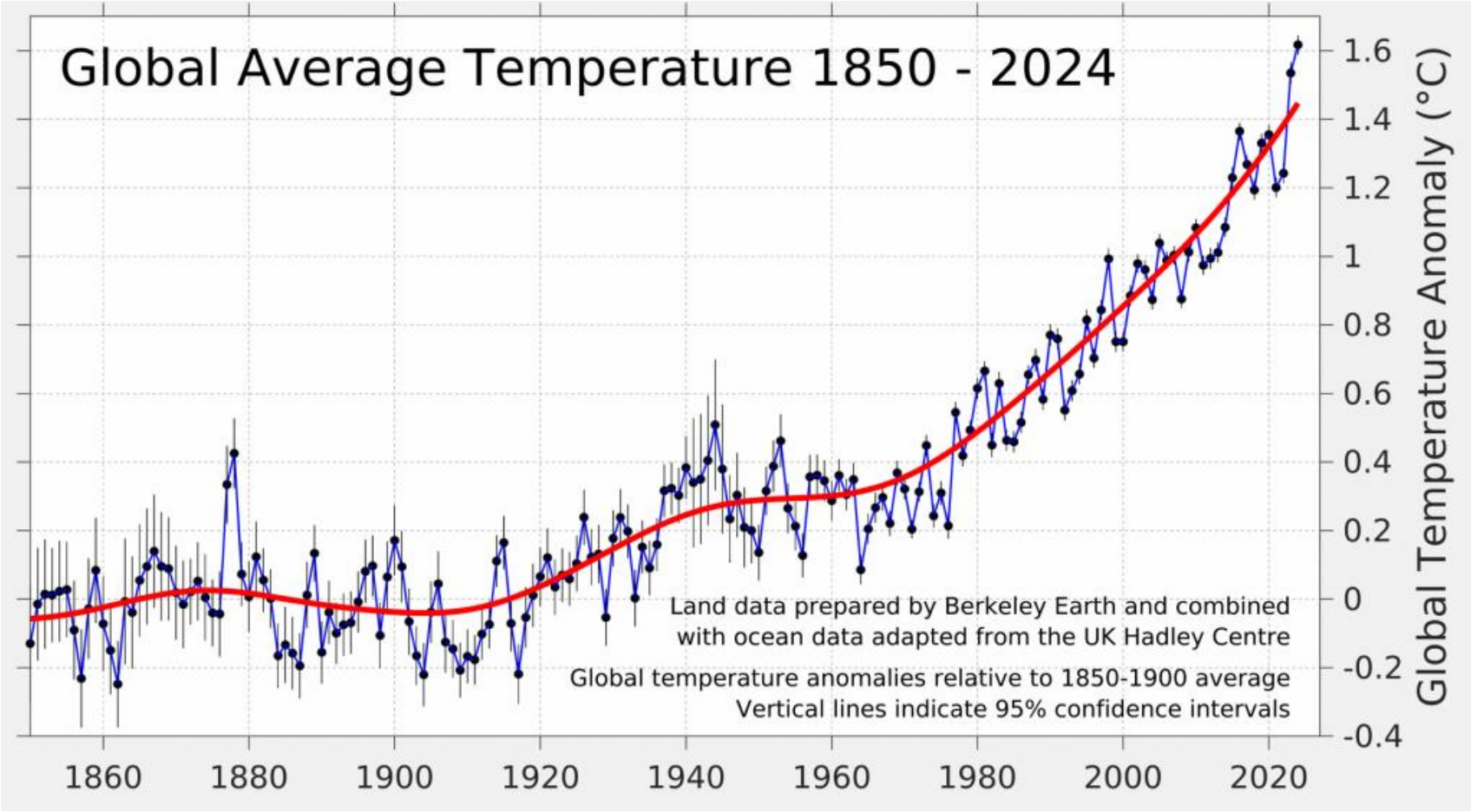


Source: *Climate Change Impacts on the US, NAST, 2000*

Historical Atmospheric Carbon Dioxide

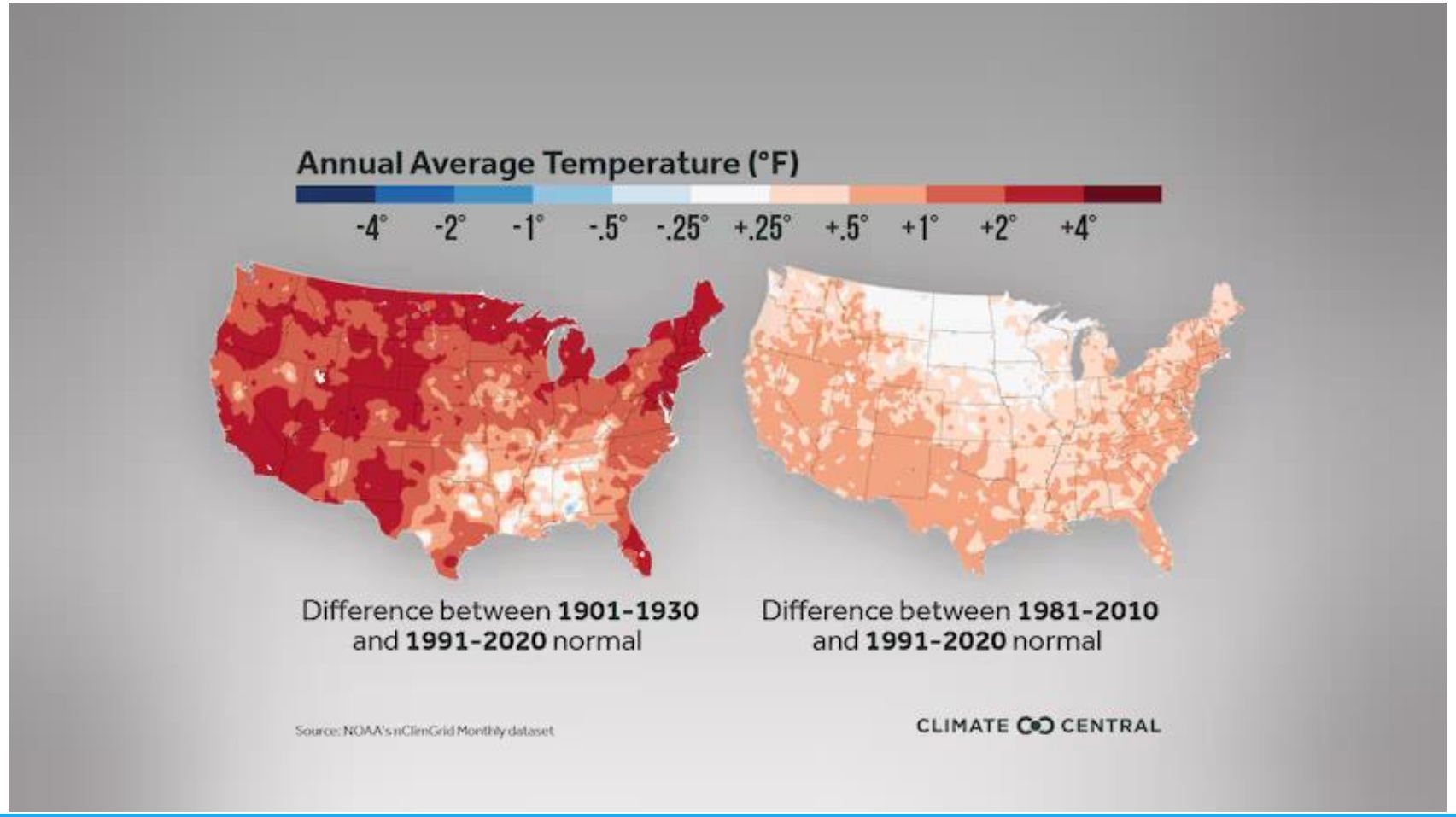


Global Temperature

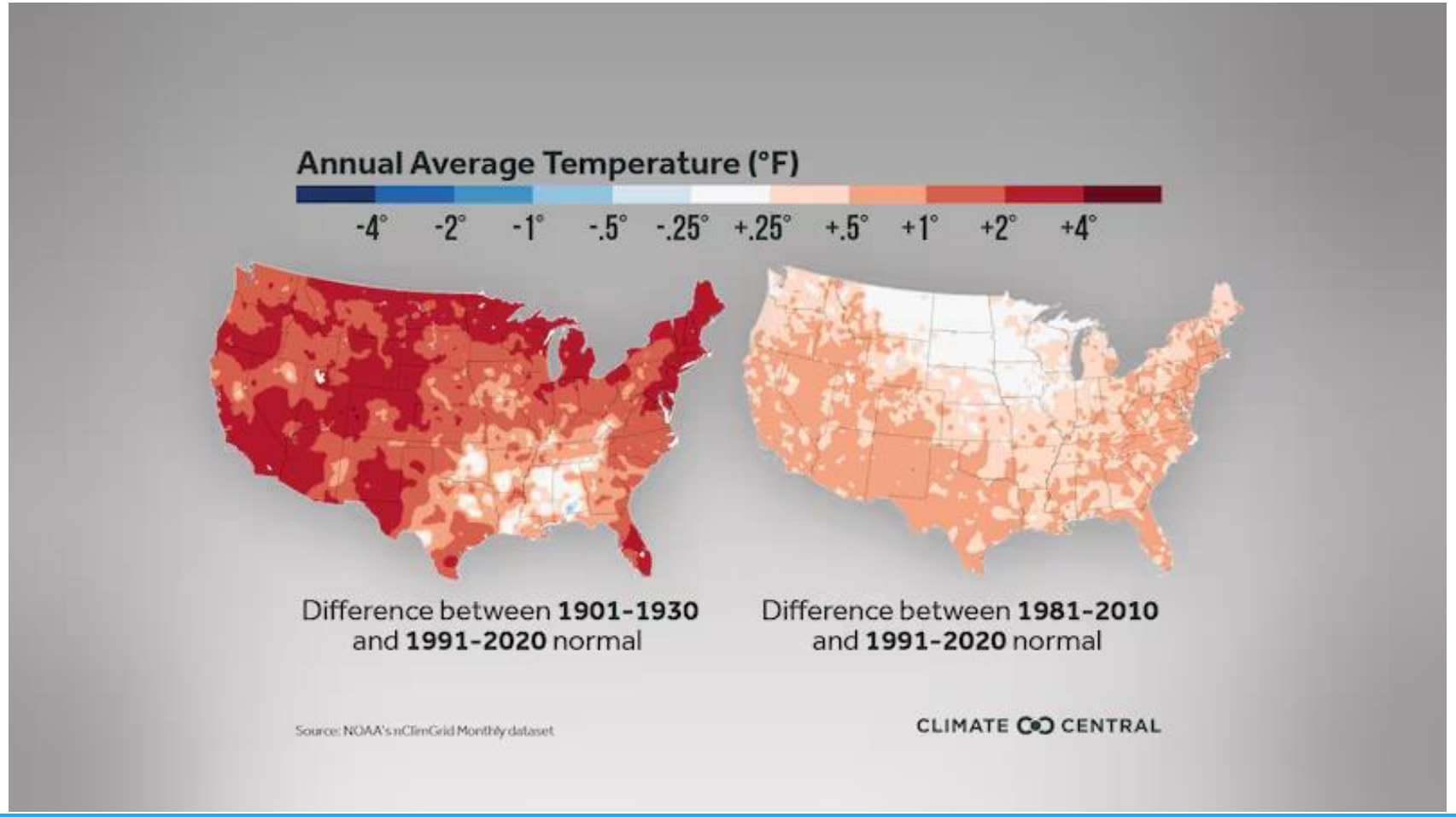


https://berkeleyearth.org/global-temperature-report-for-2024/

Climate trends in the US: Warming



Climate trends in the US: Warming



Impacts

Soil moisture stress

Heat stress

Weed and pest pressure

Lower productivity

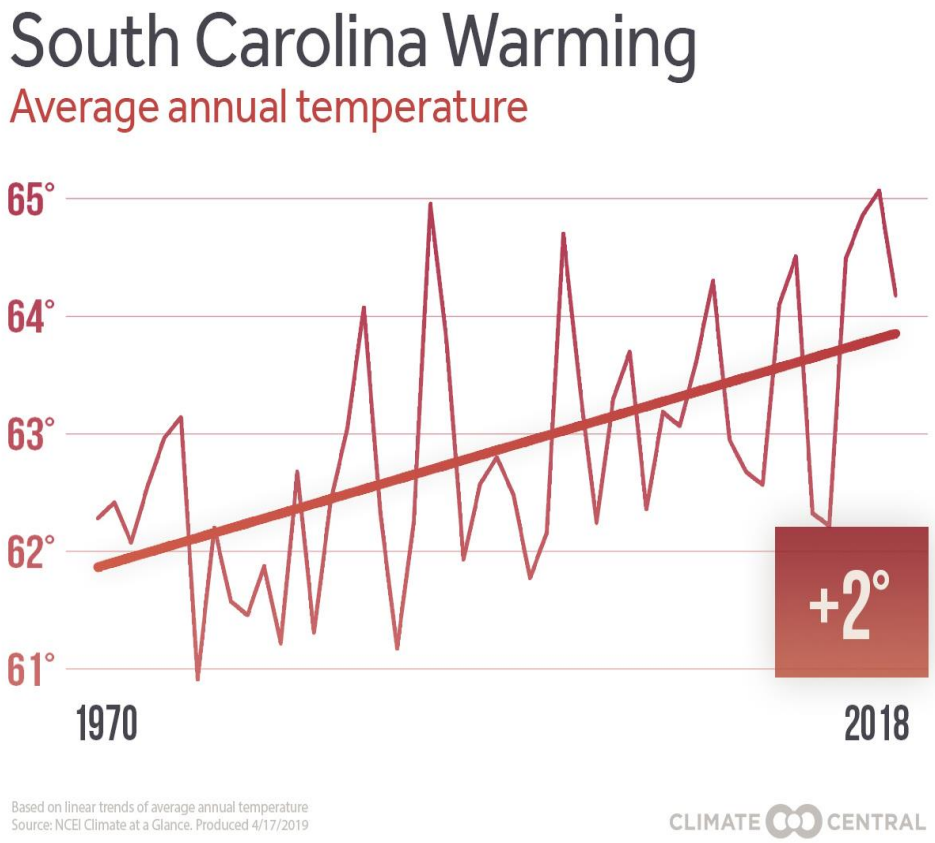
Increased mortality

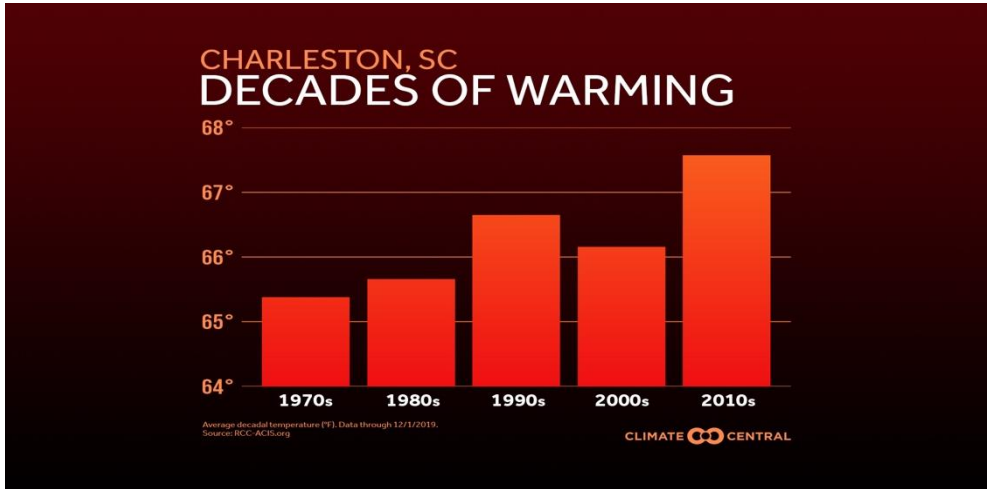
Species & habitat migration

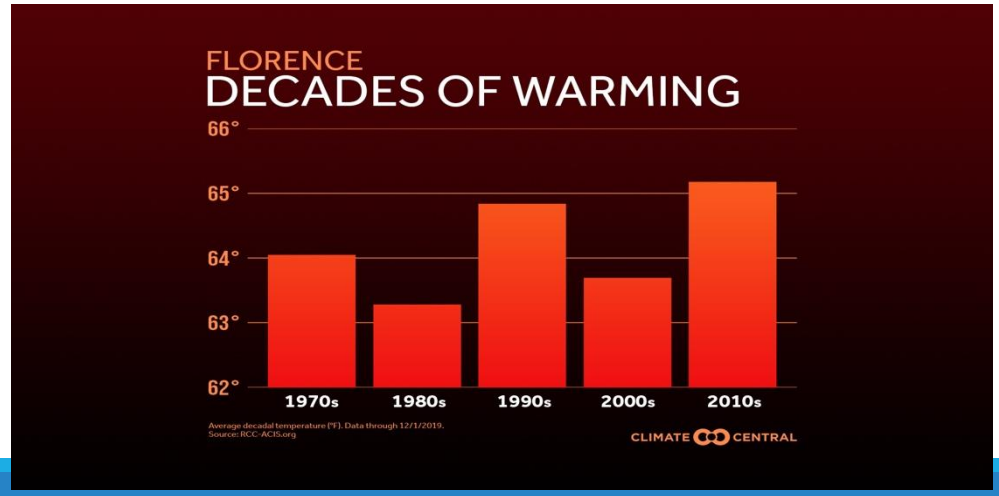
Climate trends in the US: Warming

Impacts
Changes to fruit set and growing degree days

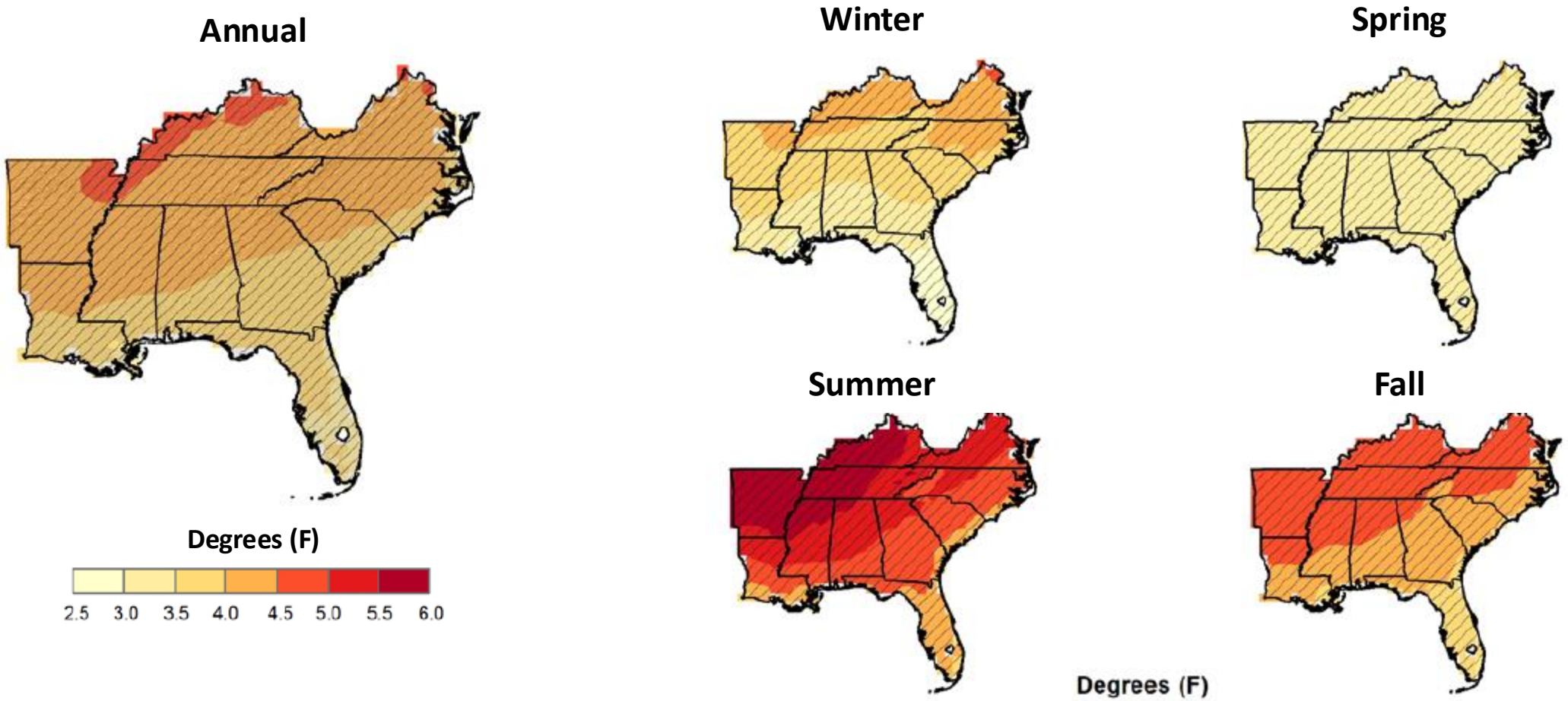
South Carolina climate trends: Warming





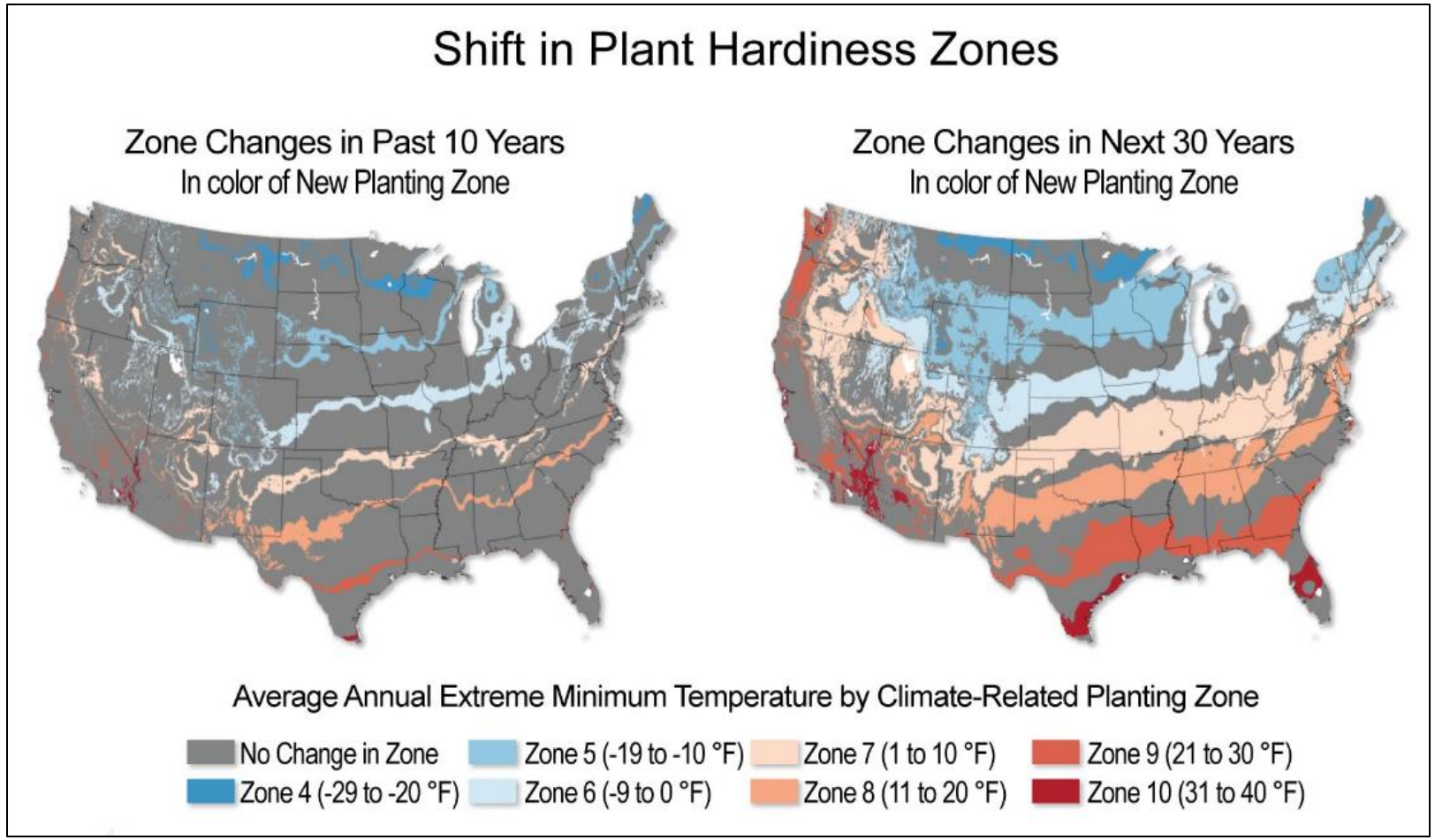


South Carolina climate forecasting: Warming (2041-2070)

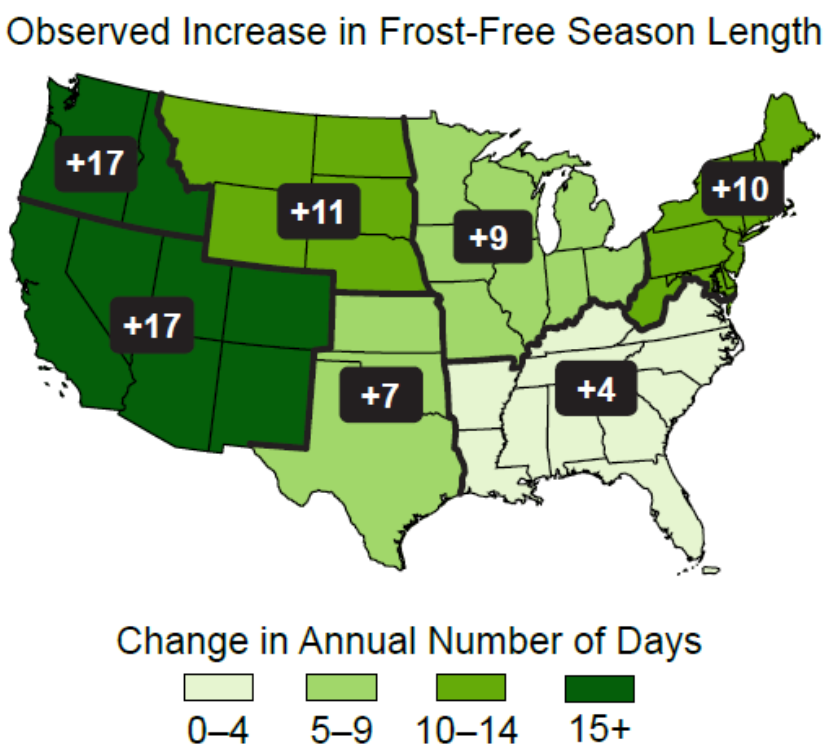


Source: *NOAA Technical Report, 2013*

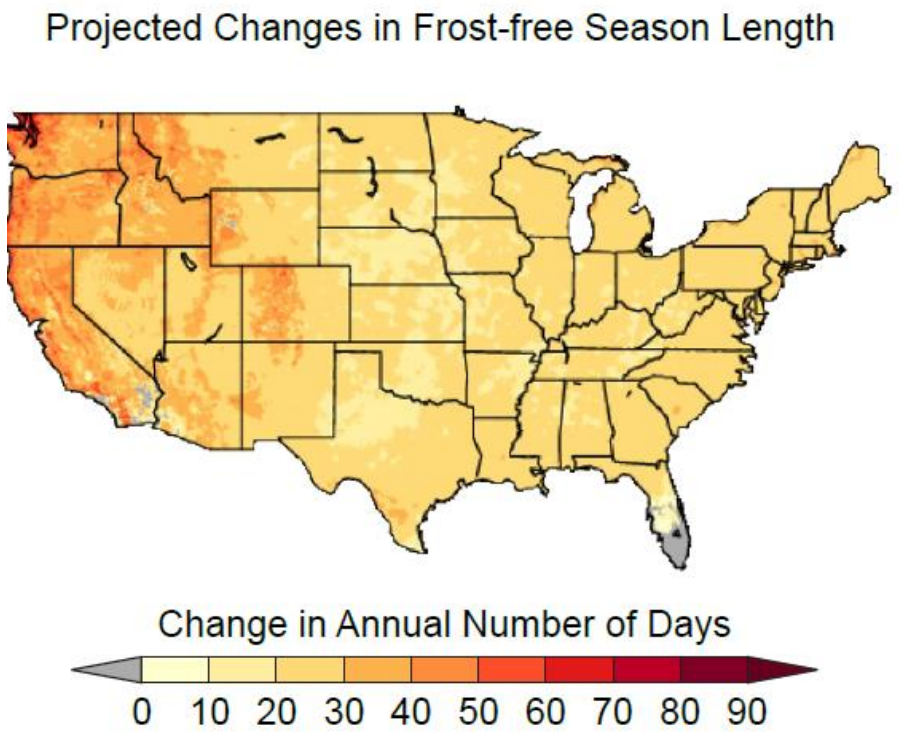
Climate trends in the US



Climate trends in the US: Frost-free season



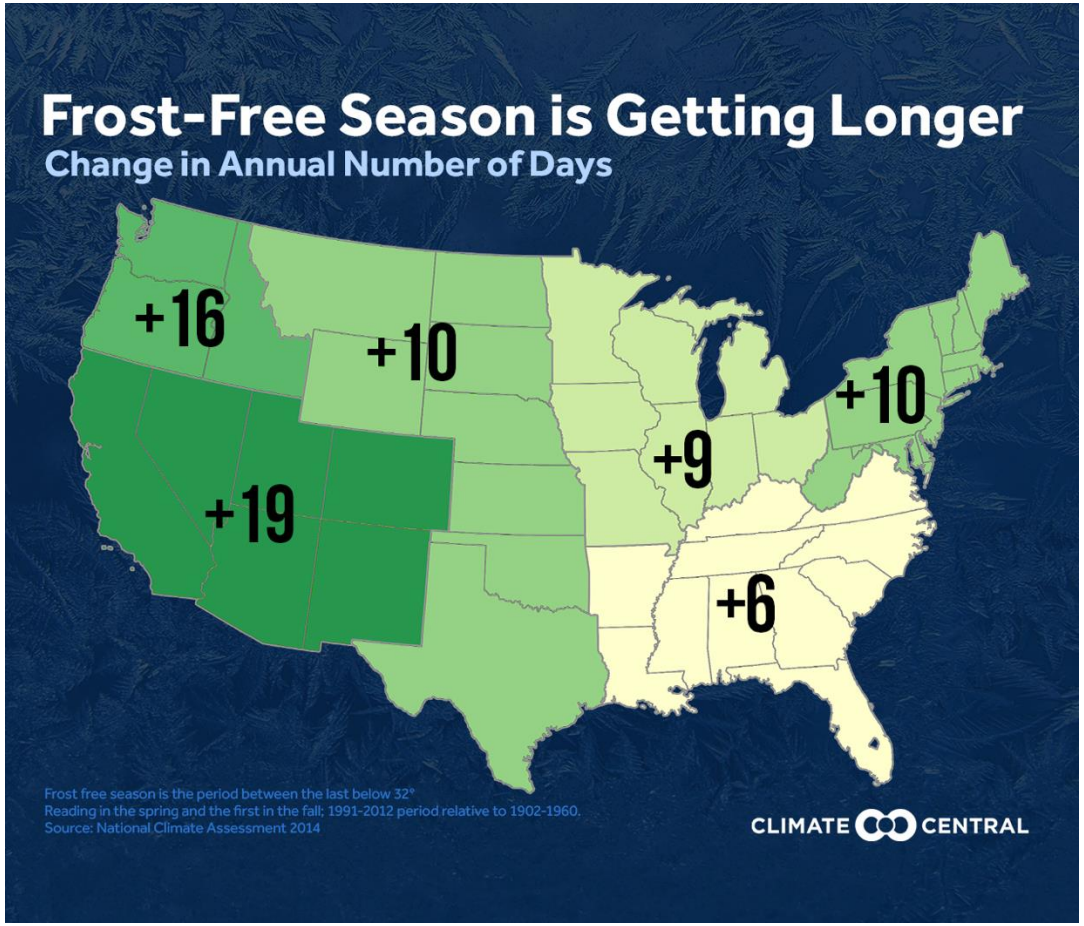
1901 - 2015



2036 - 2065

Climate trends in the US: Frost-free season

- Frost-free season impacts
  - Last spring frost is earlier
  - First fall frost is later
  - Growing season ~ 1 week longer
- Benefits
  - Longer growing season
  - More time for photosynthesis
- Challenges
  - More insect generations or growth
  - Late freezes
  - Potential phenological mismatches



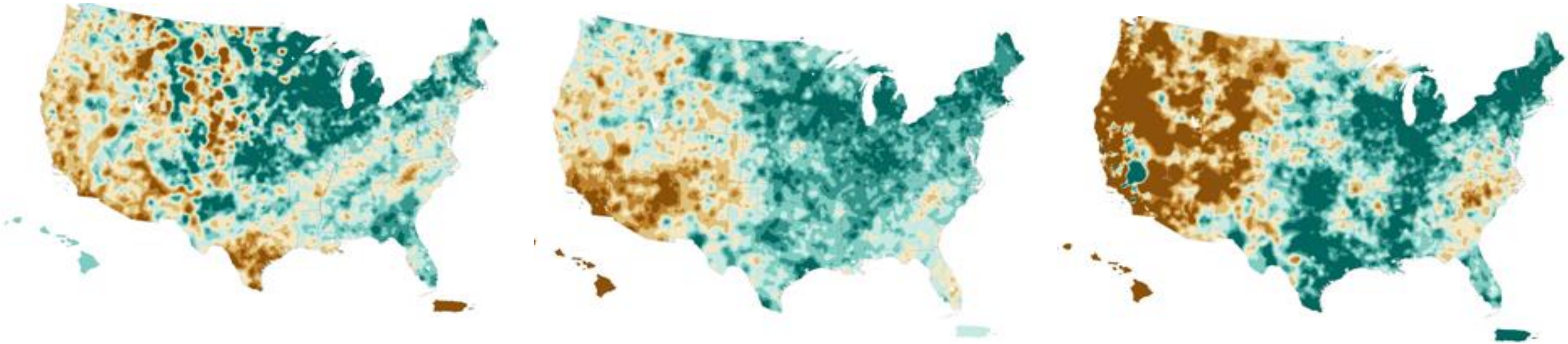
Source: *Climate Central, 2014*

Climate trends in the US: Precipitation

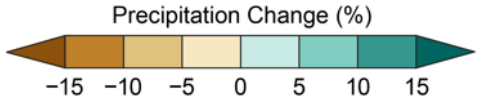
Winter Precipitation

Annual Precipitation

Summer Precipitation

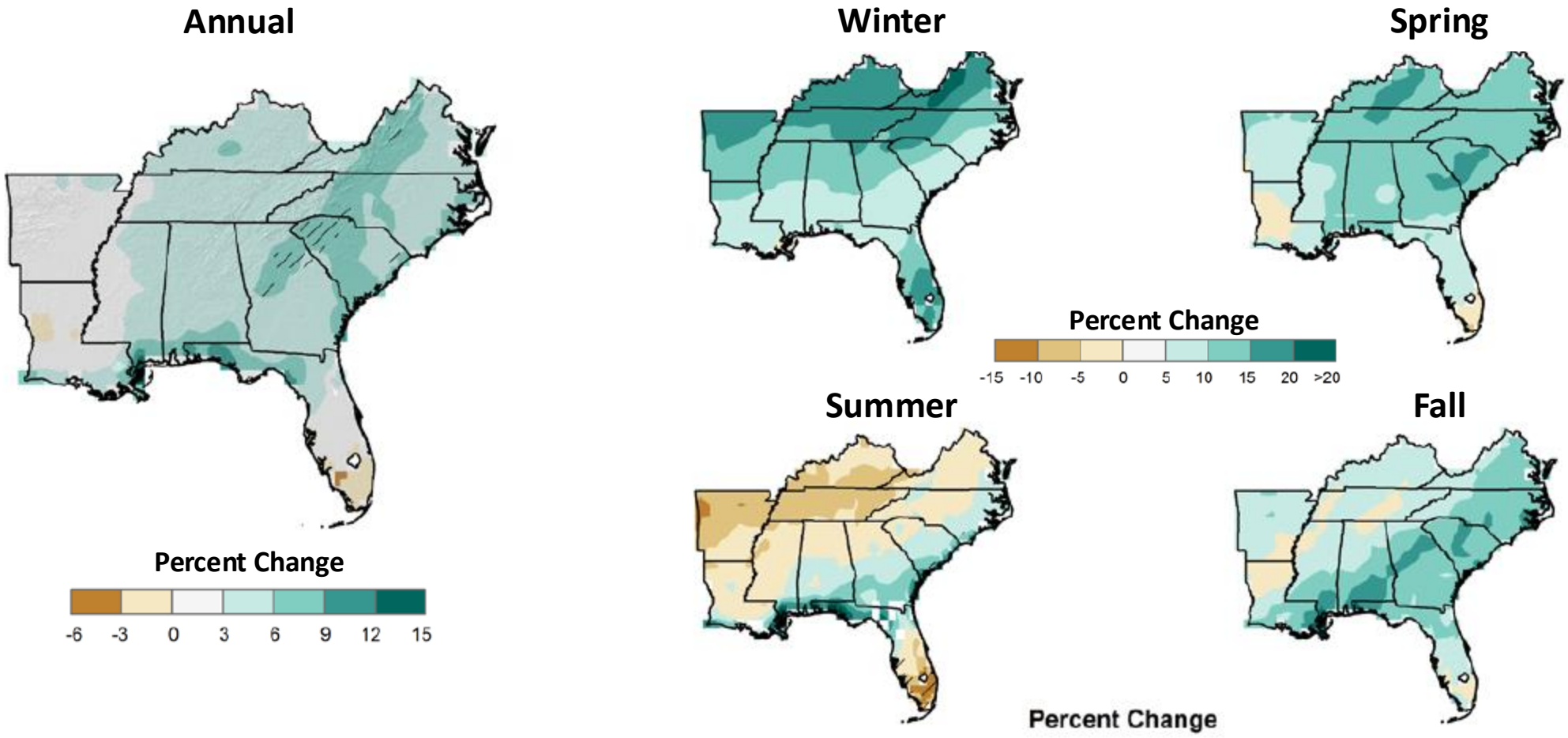


Comparing 2002-2021 to 1901-1960



Sources: *NCA 2023*

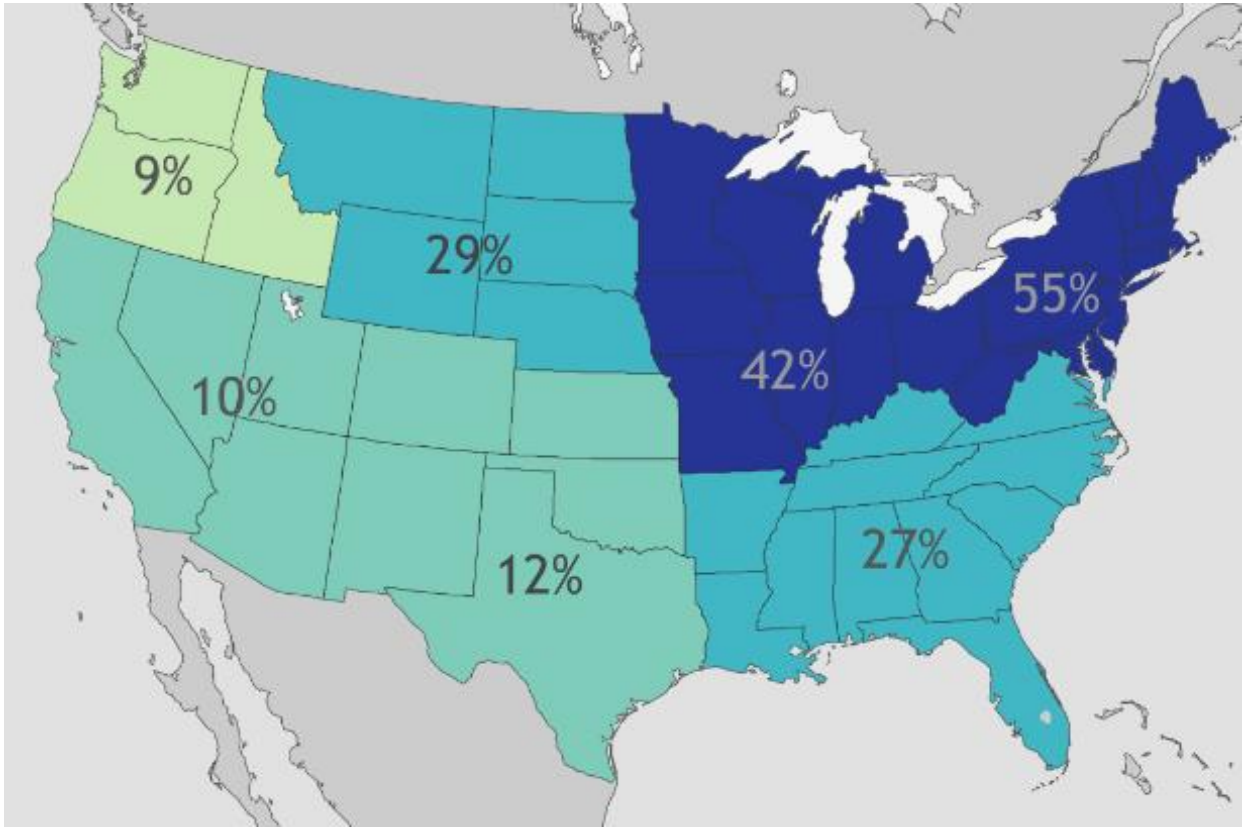
South Carolina climate forecast: Precipitation
(2041-2070)



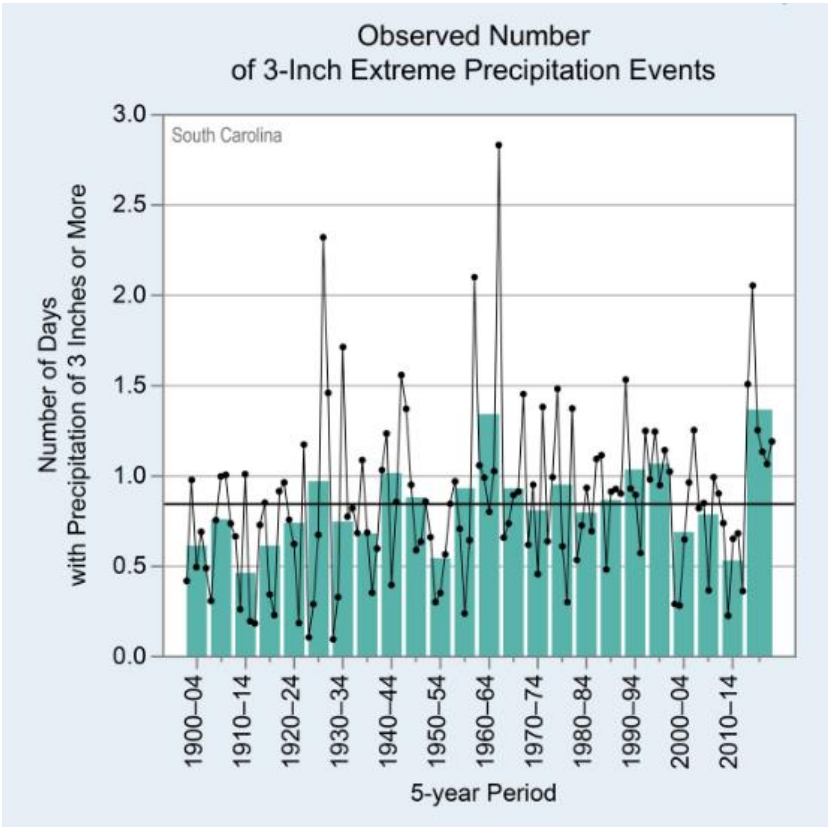
Source: *NOAA Technical Report, 2013*

Climate trends in the US: Precipitation Variability

Observed change in extreme precipitation (1958 – 2016)



Observed change (1900 - 2020)



Sources: *NOAA*

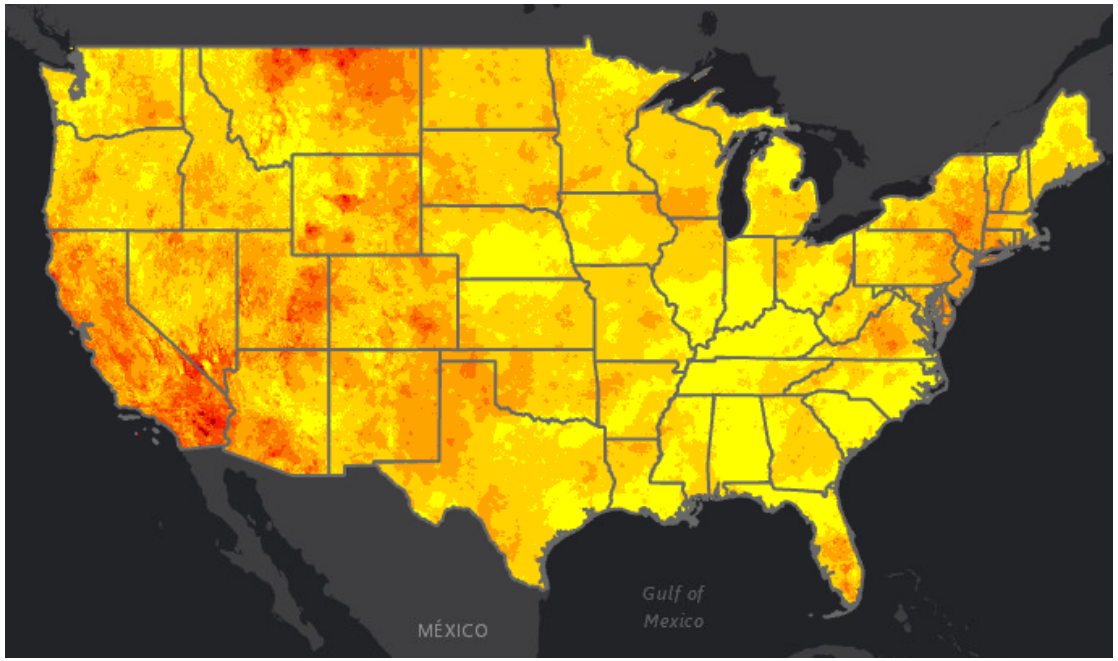
Climate trends in the US: Precipitation

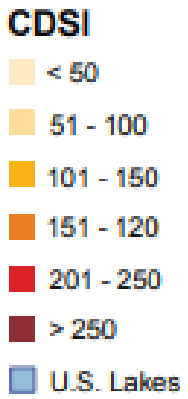
- Decreased Storm Frequency
  - Drought
  - Water supply
  - Wildfire
  - Pests/ insects
- Increased Storm Intensity
  - Flooding
  - Wind damage
  - Soil erosion
  - Damage to infrastructure
  - Delayed planting/ harvesting

Drought stricken longleaf pine. Photo credit: Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org

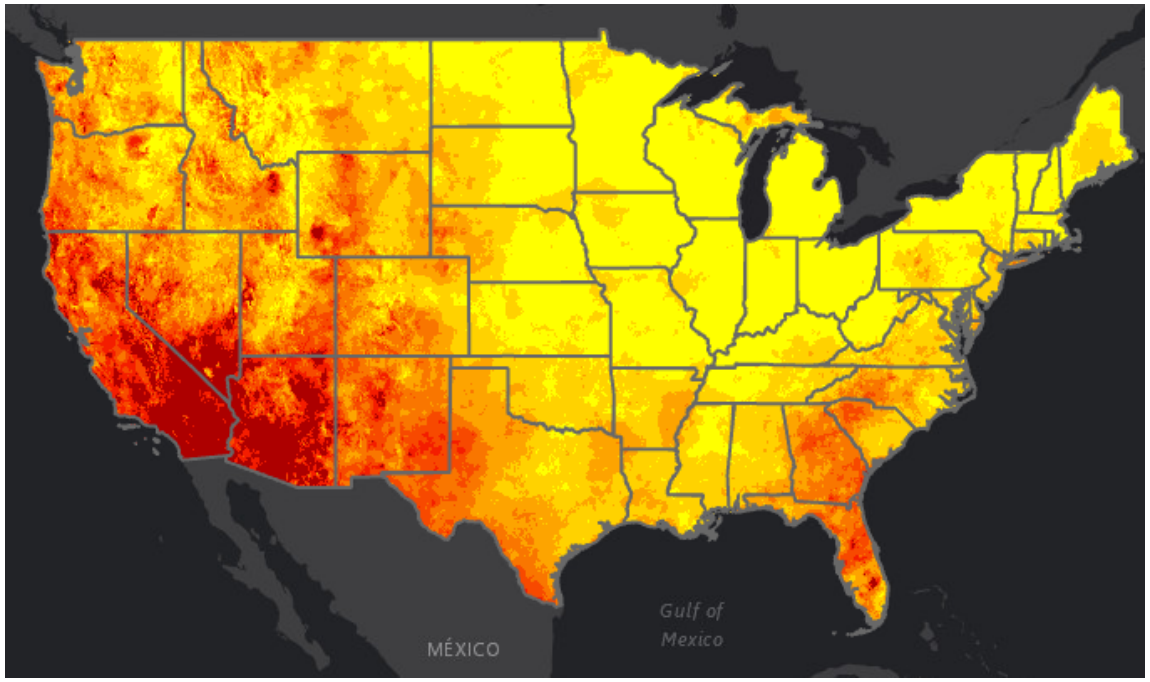
Climate trends in the US: Drought

1960 - 1986





1987 - 2013



Sources: *NOAA*

Climate trends in the US: Hurricane Risk

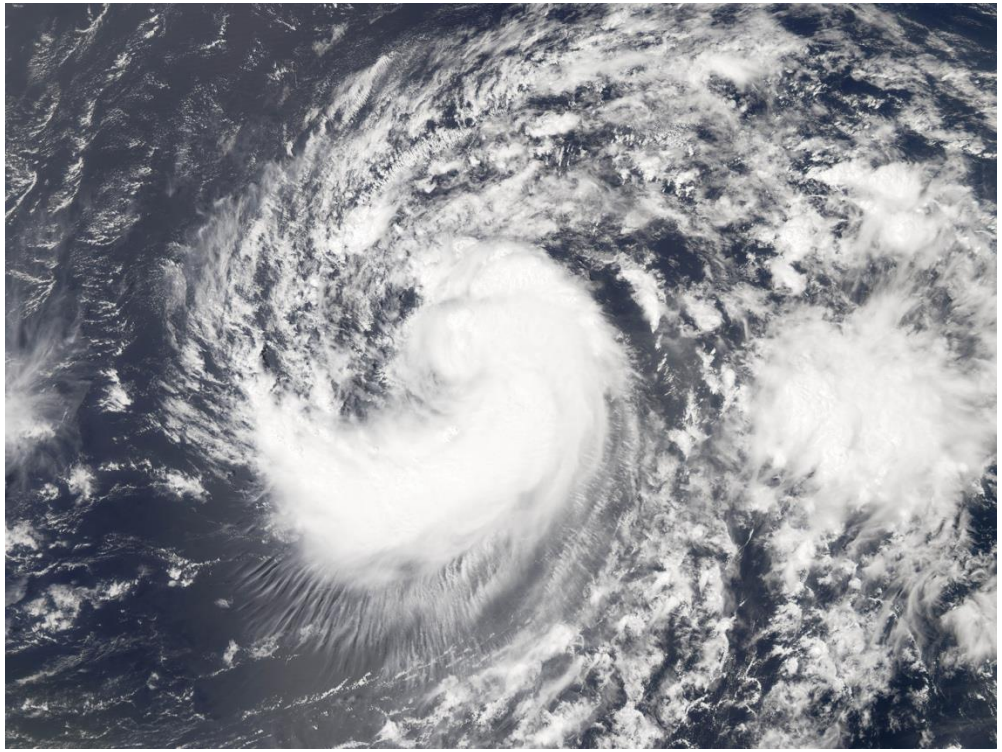
Trends and Forecasts

- Frequency may not change
- Shift toward more higher category storms (4 & 5)
- Higher rainfall/event

Impacts

- Increased fuel loading
- Increased invasives and pests
- Increased flooding
- Carbon Sequestration
- Productivity?

Sources: Myers & van Lear 1998, Verbout et al 2007, McNulty 2002



Source: NASA

Climate trends in the US: Hurricane Risk

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Sources: Myers & van Lear 1998, Verbout et al 2007, McNulty 2002

Climate trends in the US: Invasive Species

Plants:

Trends and Forecasts

- Increased stress
- Northward expansion
- Disturbance

Impacts

- Tree mortality
- Habitat destruction/fragmentation
- Decreased species richness
- Increased fuel loading

Japanese Stiltgrass
(*Microstegium vimineum*)

Kudzu
(*Puerari montana*)

Climate trends in the US: Invasive Species

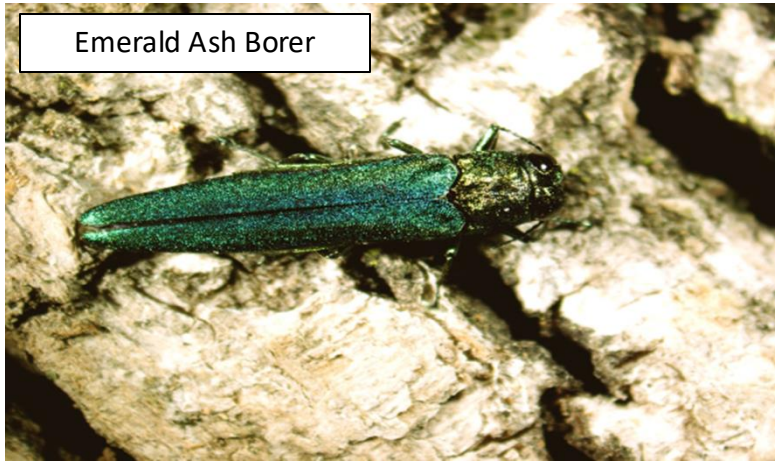
Insects:

Trends and Forecasts

- Longer breeding season
- Higher winter temperatures
- Increased over-winter larva survival rate
- Northward expansion
- Drought stress
- Disturbance

Impacts

- Tree mortality
- Habitat destruction/fragmentation
- Decreased species richness



Climate trends in the US: Wildfire

Cross-cutting Impacts

- Decreased:
  - Aesthetics
  - Productivity
  - Carbon Sequestration & Storage
  - Culturally important species

- Increased:
  - Mortality
  - Habitat destruction
  - Fragmentation

Sources: *NOAA*

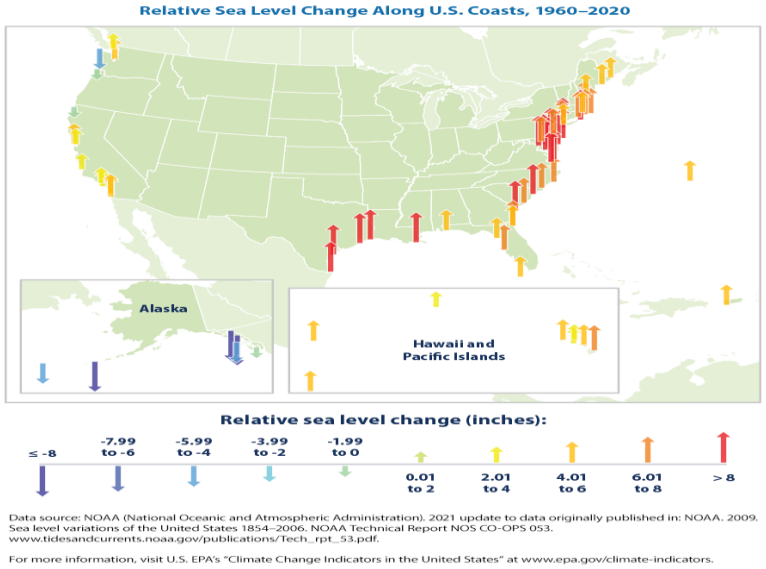
Climate trends in the US: Sea Level Rise, Soil Salinization and Saltwater Intrusion/ Inundation

Trends and Forecasts

- SLR rate: 3.8 mm/yr (1.5 in/decade)
- High variability
- Timing of salinization events depends on tropical storm occurrence and SLR

Impacts

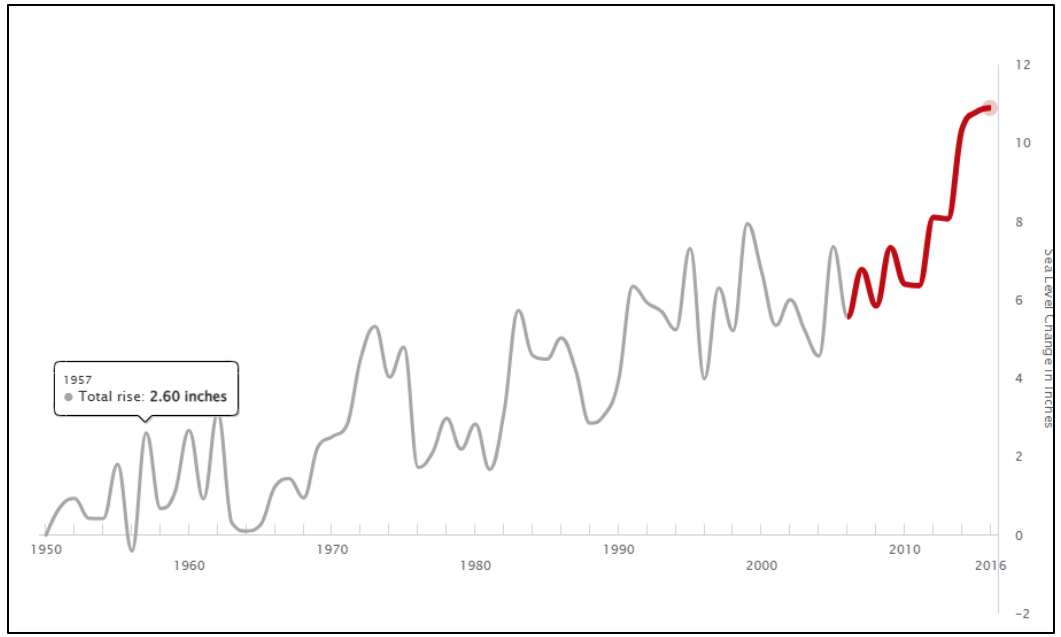
- Decreased vigor and growth
- Increased mortality and insect problems
- Culturally important sites, working lands threatened



Source: *RCI, NECH, NRCS*

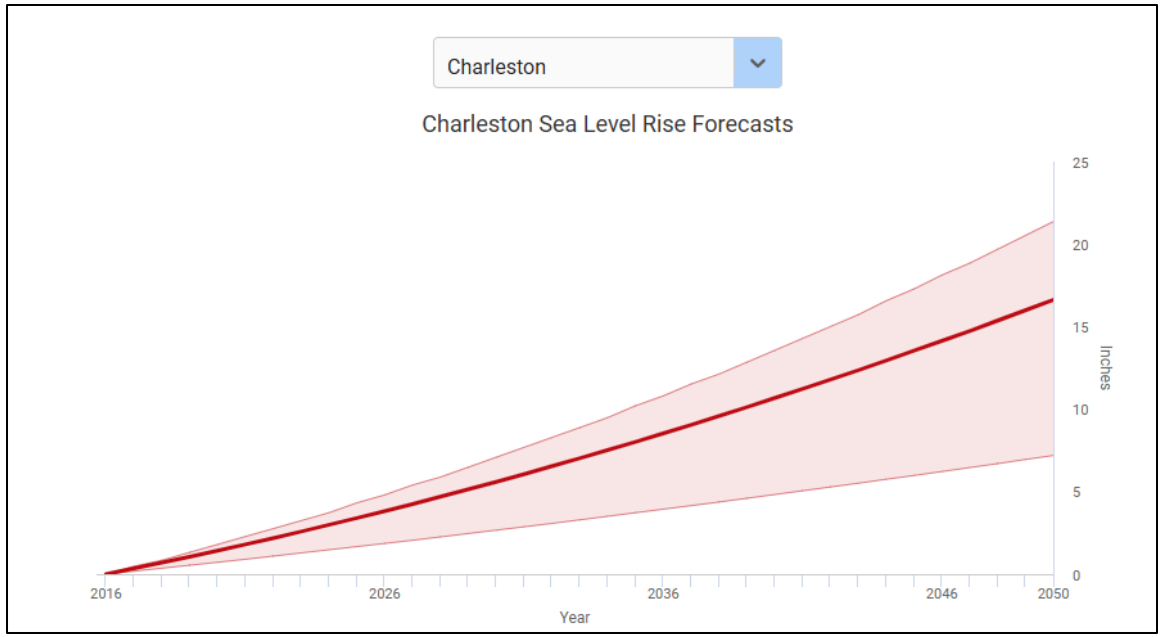
South Carolina climate trends: Sea Level Rise

Historical SLR: 1950 - 2016



Charleston, SC

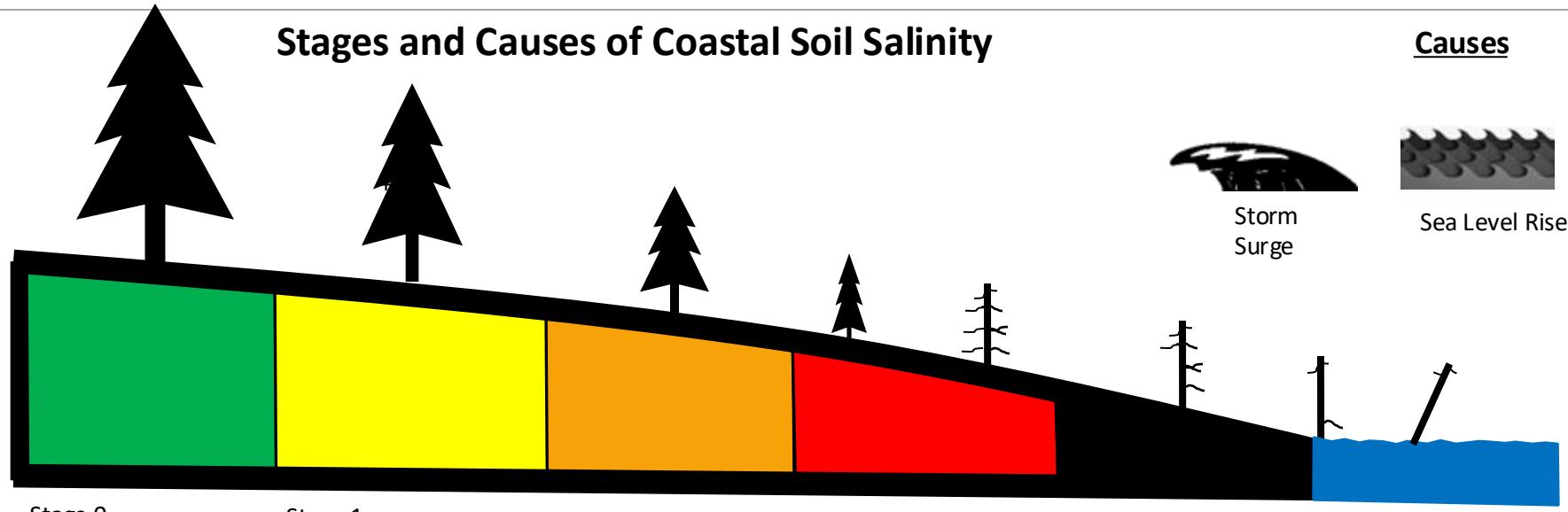
Projected: 2016 - 2050



Charleston, SC

Source: SeaLevelRise.org

Soil Salinization



Stage 0 Non-Impacted	Stage 1 Sporadic Salinity	Stage 2 Reoccurring Episodic Salinity	Stage 3 Low Chronic Salinity	Stage 4 High Chronic Salinity	Stage 5 Chronic Surface Water	
EC = < 2 dS m^{-1}	EC = 2 < 4 dS m^{-1}	EC = 4 < 8 dS m^{-1}	EC = 8 < 16 dS m^{-1}	EC = 16 < 25 dS m^{-1}	EC = >25 dS m^{-1}	
Commercial	Commercial	Commercial	Non-Commercial	Non-Commercial	Saltwater Marsh	**Uses**
No	Yes	No	No	No	No	**Mitigation?**
No	Yes	Yes	Yes	No	No	**Adaptation?**
No	No	No	No	Yes	Yes	**Wetland Restoration/Easement?**

Management considerations

- Climate variation is a threat to forest management and productivity
- Leads to disturbances including droughts, hurricanes, wildfires, sea level rise, invasive species, and changes to precipitation patterns
- Each of these causes secondary effects including increased risk of other disturbances, decreases in growth and carbon storage, and adds complications/ unknowns to management
- Resilient forestry is a method that can be used to support adaptive management decisions

Resilient Forestry

"The ability of communities, economies, and ecosystems within South Carolina to anticipate, absorb, recover, and thrive when presented with environmental change and natural hazards."

- South Carolina Office of Resilience

Resilient Forestry: Synergies & Conflicts

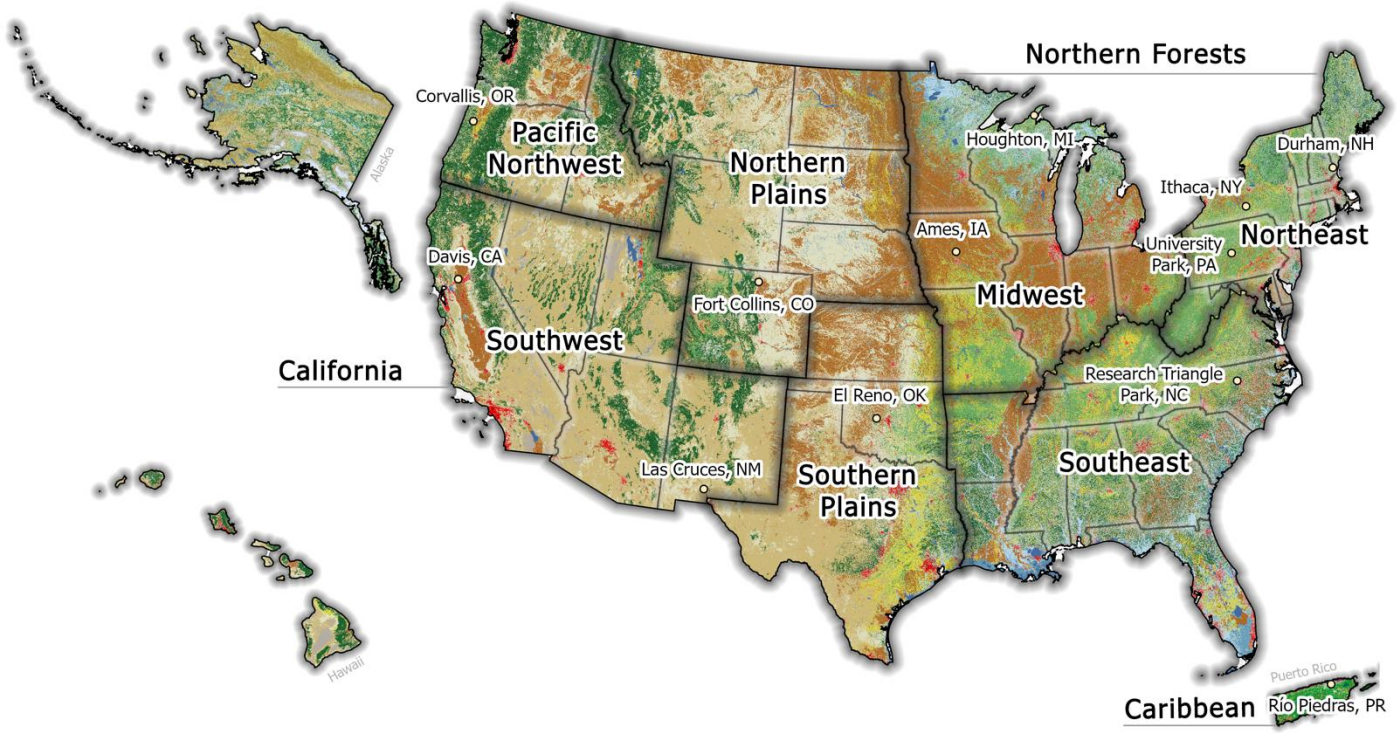
- Many goals to manage for, some will be in conflict
  - i.e. a lower stand density protects against wildfire, drought, and insects, and higher stand density is beneficial for hurricanes

The best resilient forestry management will depend on where you are, what the risks are, and what you want from your forests

What is the Climate Hub?

History of the Climate Hubs

- Created in 2014 by the U.S. Department of Agriculture to address risks posed by climate change to working lands
- Consists of 10 regional hubs
- Southeast Regional Climate Hub covers AL, AK, GA, FL, KY, LA, MS, NC, SC, TN, and VA
- Rich history of working lands, important to U.S. economy
- Facing pressures



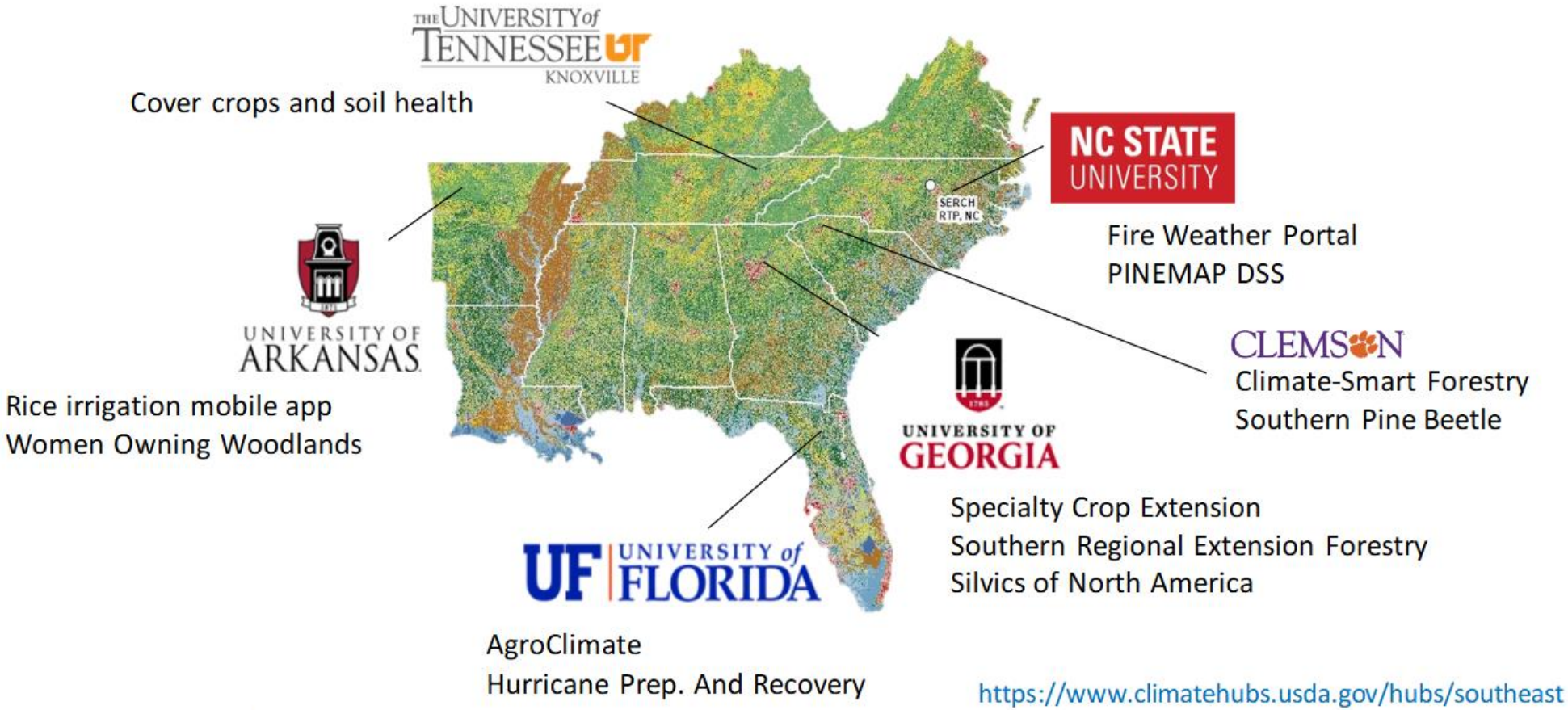
Our Mission:

"The mission of the Climate Hubs is to develop and deliver science-based, region-specific information and technologies, with USDA agencies and partners, to agricultural and natural resource managers that enable climate-informed decision-making, and to provide access to assistance to implement those decisions."

What are Climate Hubs doing?

- Develop and deliver tools
  - Connect land managers with tools to assist adaptation/ mitigation
- Regional Vulnerability Assessment
  - Connect land managers to science
- Partner with LGUs and Extension
- Outreach and Education
  - Leading workshops and continuing education
  - Outreach to extension, farm groups, forestry groups, tribal groups

What are Climate Hubs doing?



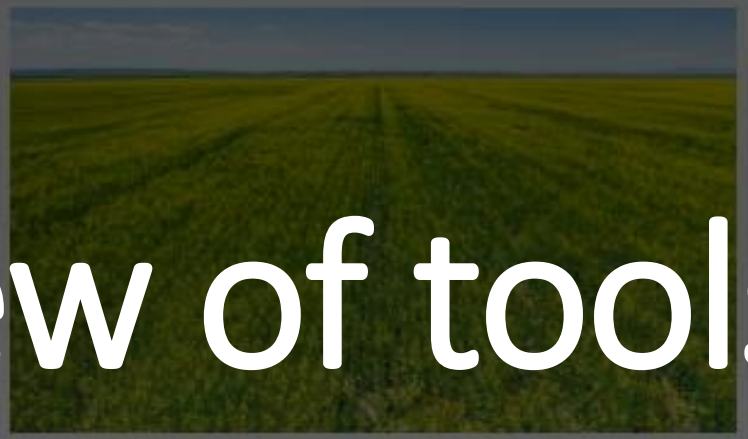
https://www.climatehubs.usda.gov/hubs/southeast

Current Projects

- Drought Preparation and Recovery Guides in the Southeastern United States, for 14 different commodities
- Disturbance Guides for the Southeast by disturbance type
- Updating TACCIMO to be more effective for users
- Salinization on working lands guide

Southeast Topics

Explore content from the Southeast Climate Hub that pertains to specific topics within climate change.



Overview of tools and resources

Bioenergy

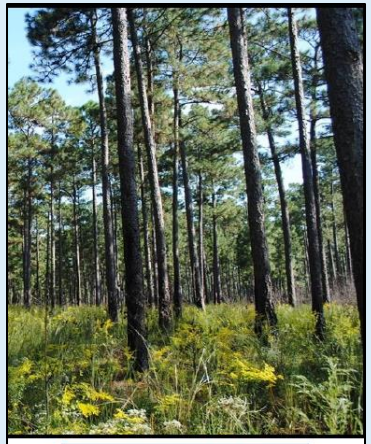
Carbon & Greenhouse Gases

Climate Science

Crops

Economics

Emerging Forest Threats Fact Sheets



SOUTH CAROLINA'S

EMERGING FOREST THREATS

Healthy Forests Management Options

WHY DOES IT MATTER TO ME ?

It is important for private forest landowners to prepare for the likelihood of increasing threats to their forest lands. Private forests make up the largest holdings of forestlands in the southeastern U.S. These properties collectively will be crucial in protecting the overall health of our landscape. Management that uses the most current forest science will better enable landowners to protect their land and resources, and to contribute positively to the conservation and productivity of South Carolina's forestlands.

EMERGING THREATS & HEALTHY FOREST MANAGEMENT

events. Adaptation options include thinning to reduce stand water stress, maintaining a canopied riparian zone to reduce stream temperatures, incorporation of drought-resistant species, and using prescribed burns to reduce fuel loads and wildfire risk. Monitoring for signs of disease or pest activity will alert landowners to the problem and allow for actions for stopping outbreaks early.

Threats from Wildfire - Increased fuel loads and more frequent droughts could increase wildfire frequency and intensity within the southeast, with South Carolina already experiencing $1 million of fire caused forest damage each year. Other impacts include habitat destruction and fragmentation, and biodiversity decline. Prescribing burning to reduce fuel loads and periodic thinning are important control methods. Salvage logging after extreme weather events or significant timber losses reduces fuel loads and the chances for pest or disease outbreaks. Incorporating fire-resistant species such as longleaf pine may also mitigate wildfire risks.

Threats from Flooding - Extreme precipitation events from storms and hurricanes can harm coastal and inland forests, especially recently established plantations. Flooding is a common disturbance within the Southeast U.S. due to the frequency of extreme (more than 2.5" in a day) rainfall events. Floods impact forest productivity by altering soil conditions and exposing or burying root systems. Reductions in stream water quality, aquatic habitat, the aesthetic value of recreational areas, and soil productivity can all occur after floods. Management practices to mitigate damages include post-disturbance revegetation, maintaining the areas natural hydrology and riparian zone health, planting flood-tolerant tree species, monitoring susceptible trees for outbreaks or fungal growth, and implementing proper erosion control structures such as culverts and drainage ditches where needed.

Threats from Hurricanes/Tornadoes - Hurricane Matthew caused $200 million in forest damage across the state in 2019. Additionally, tornadoes can be locally destructive and cause up to $5 million per year in forest damage. Increases in hurricane intensity and storm frequency are related to warming air and water temperatures. Therefore, annual forest damage is likely to increase in the coming years. Hurricanes and tornadoes cause habitat and recreational area destruction, reduce biodiversity and water quality, and can cause inland soil salinization from storm surges. Adaptation practices to reduce wind damage impacts include rotational harvesting to reduce stand age uniformity, incorporating wind resistant tree species, and modifying thinning frequencies.

Threats from Ice Storms - Ice storms are another, lesser known threat to southeastern forests. The most likely area to see ice storms is northern South Carolina. However, this area could shift northward with warming winters. As ice builds on branches, the weight of the ice exceeds the carrying capacity of the branch and it breaks. Pines collect more ice compared to hardwoods because they retain their needles year-round, and the needles hold the ice. Additionally, pines branches break under less weight than hardwoods, so pines are particularly vulnerable to ice storms. As little as ¼' of ice can cause breakage. Adaptation practices includes decreasing tree density, adjusting thinning timing frequencies to reduce the probability of damage after fresh thinning, and planting/regenerating breakage-resistant tree species. Post-disturbance monitoring will aid in preventing pest outbreaks and attacks on green timber.

Threats from Sea Level Rise - Accelerated sea level rise has been correlated with warming sea surface and air temperatures. Due to this trend, southeastern coastal states like South Carolina have experienced soil salinity issues moving further inland, resulting in severe forest damage and the overall loss of workable lands. Other impacts include vegetation changes, biodiversity, habitat loss, water quality declines, and increased invasive species outbreaks. Planting more salt-resistant species is one adaptation option for creating salt-tolerant forest stands that are more resilient to storm surge. As soil salinity becomes a chronic issue, implementing short-rotation woody crops may help retain profits while decreasing risks from storm surge events. Drainage system installation may reduce the probability of developing salinity issues by lowering the height of the soil water table.

Summary– Many threats impact the economic and ecosystem value of South Carolina's forestland. Threats such as wildfires, hurricanes, soil salinization from storm surge and sea-level rise, and insect and invasive species outbreaks have always existed, but are now being amplified by warming temperatures and changes in rainfall frequency and amounts. The adaptation methods listed on this sheet are just a few of the available options that help forest land managers improve resilience and reduce risk. Consult your local forest extension agent or a county forester for more information about threats and corrective measures appropriate for your forest.

FOR MORE INFORMATION ON MANAGEMENT OPTIONS FOR YOUR WOODLANDS:

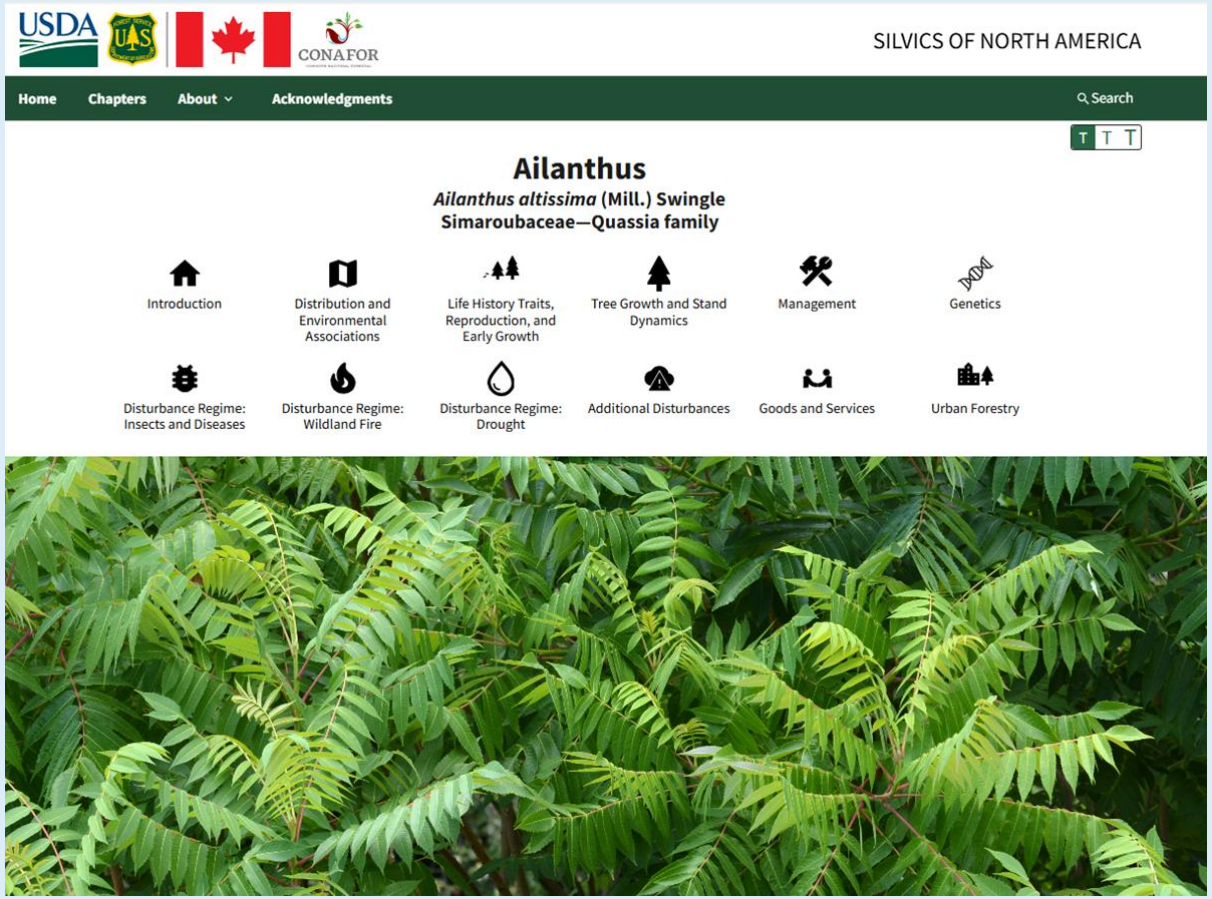
Contact the South Carolina Forestry Commission Office at 803-896-8800
www.trees.sc.gov

https://www.climatehubs.usda.gov/hubs/topic/emerging-forest-threats-state-fact-sheets

Silvics of North America: Updated

New to SNA

- Forecasted Distribution
- Urban Forestry
- Invasive Species
- Indigenous Uses?

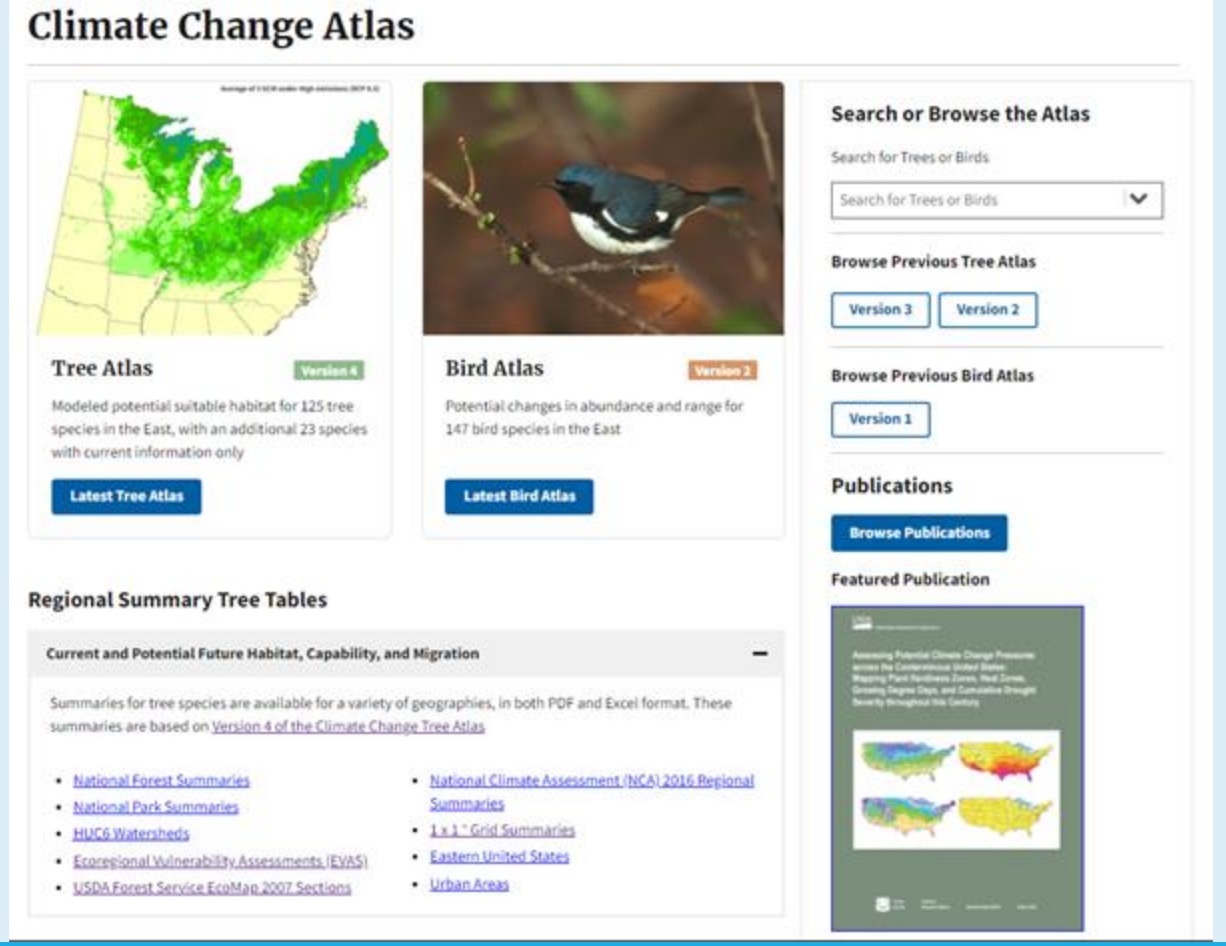


Source*: RCI, NECH, NRCS*

Climate Change Tree Atlas

- **Updated model results**
- **Results in several formats** (State, EcoMap, HUC6 watersheds, 1° x 1°, etc.)
- **New information** about colonization potential (SHIFT) and overall ability to tolerate future conditions (Capability)
- **Better tutorials and explanations** throughout the site.

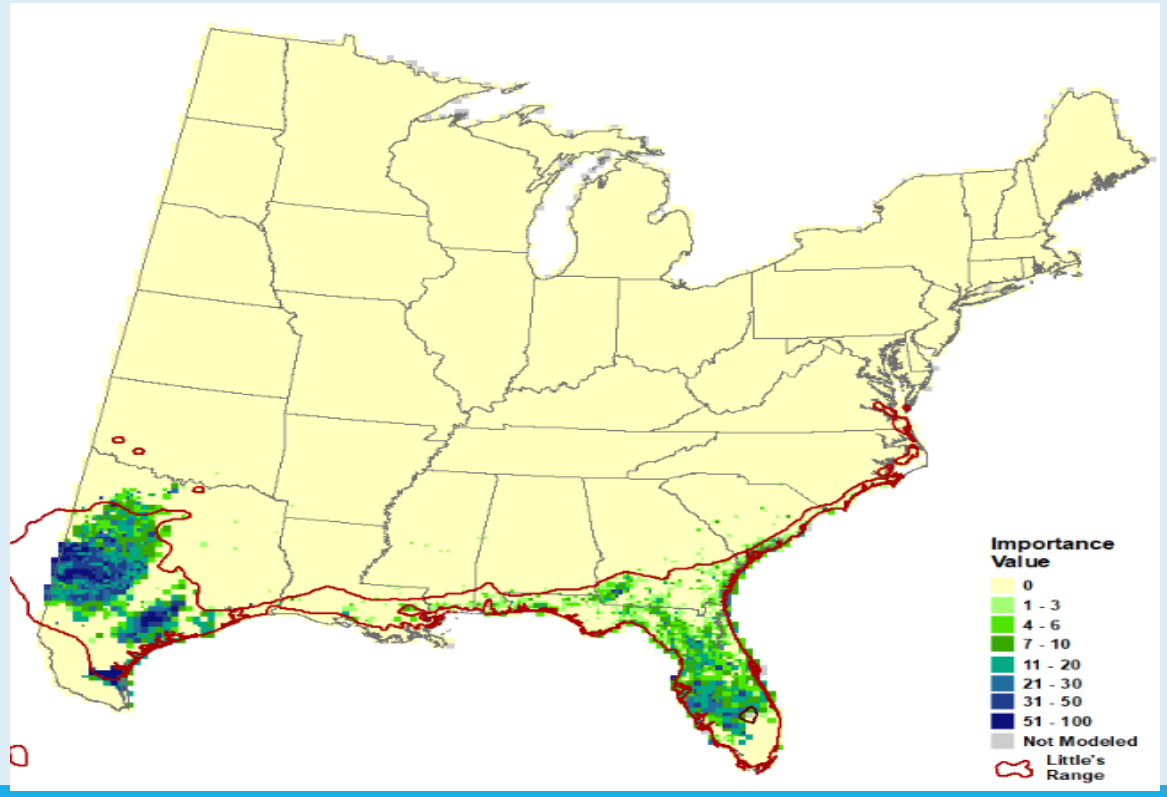
https://www.fs.fed.us/nrs/atlas/tree/



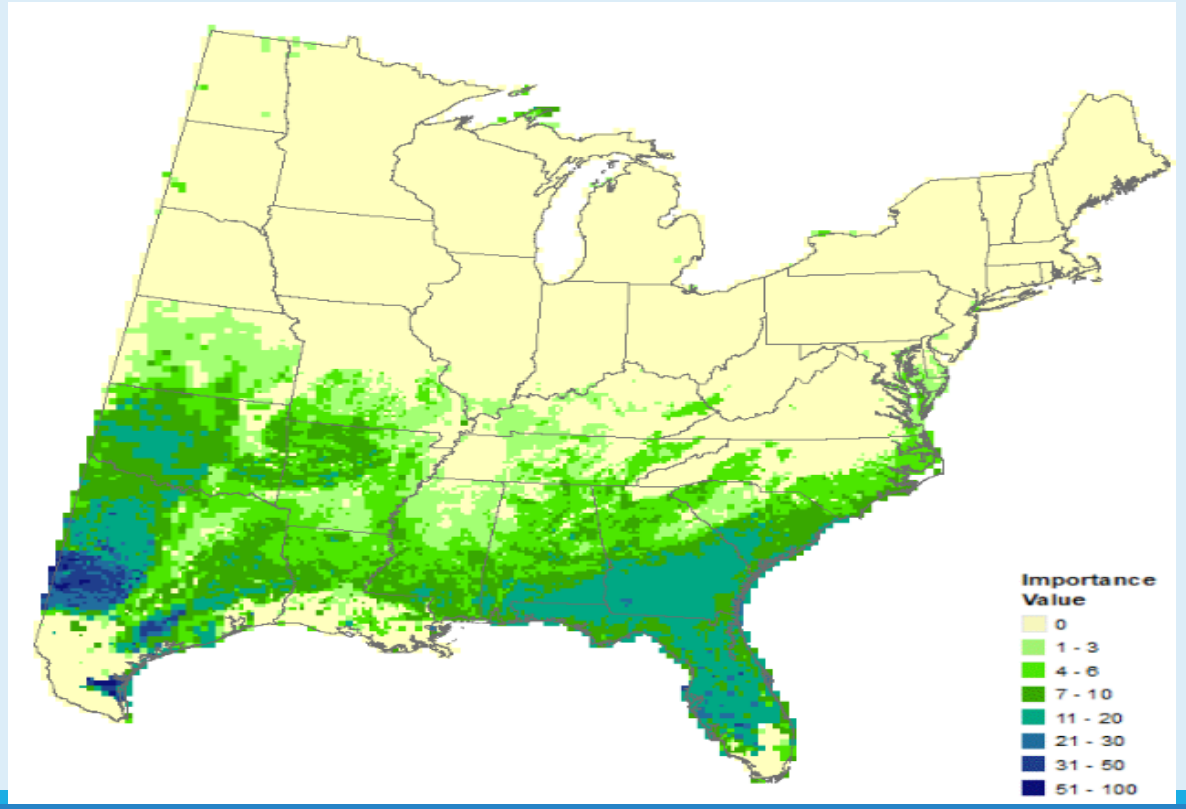
Climate Change Tree Atlas

Live Oak – *Quercus virginiana*

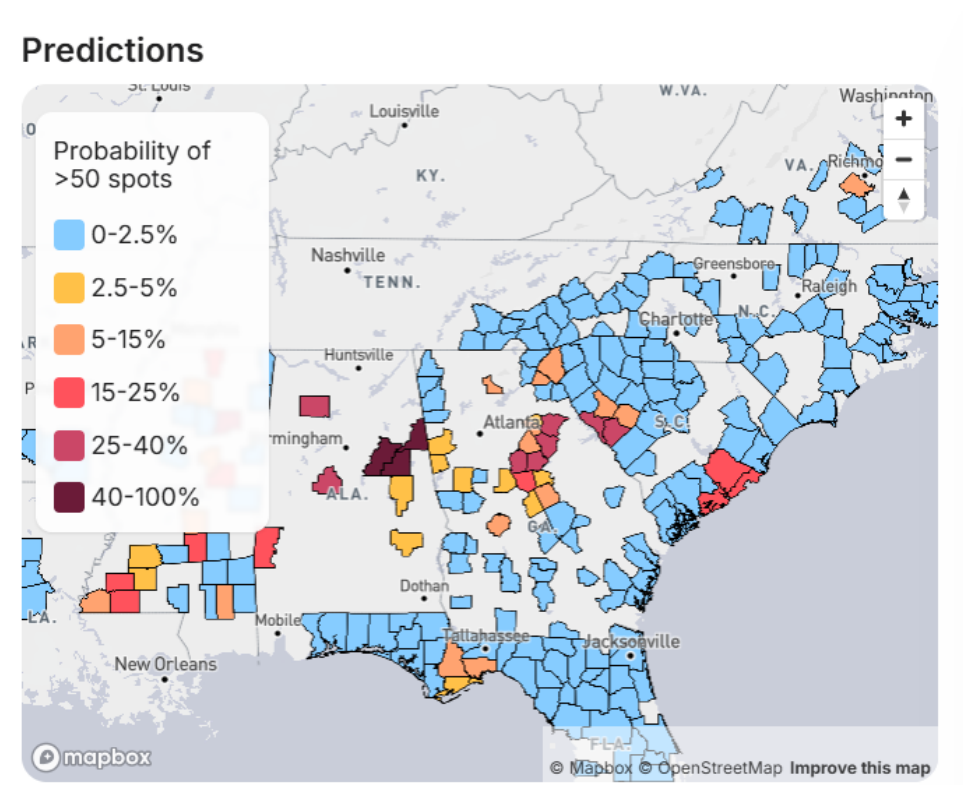
Current Range

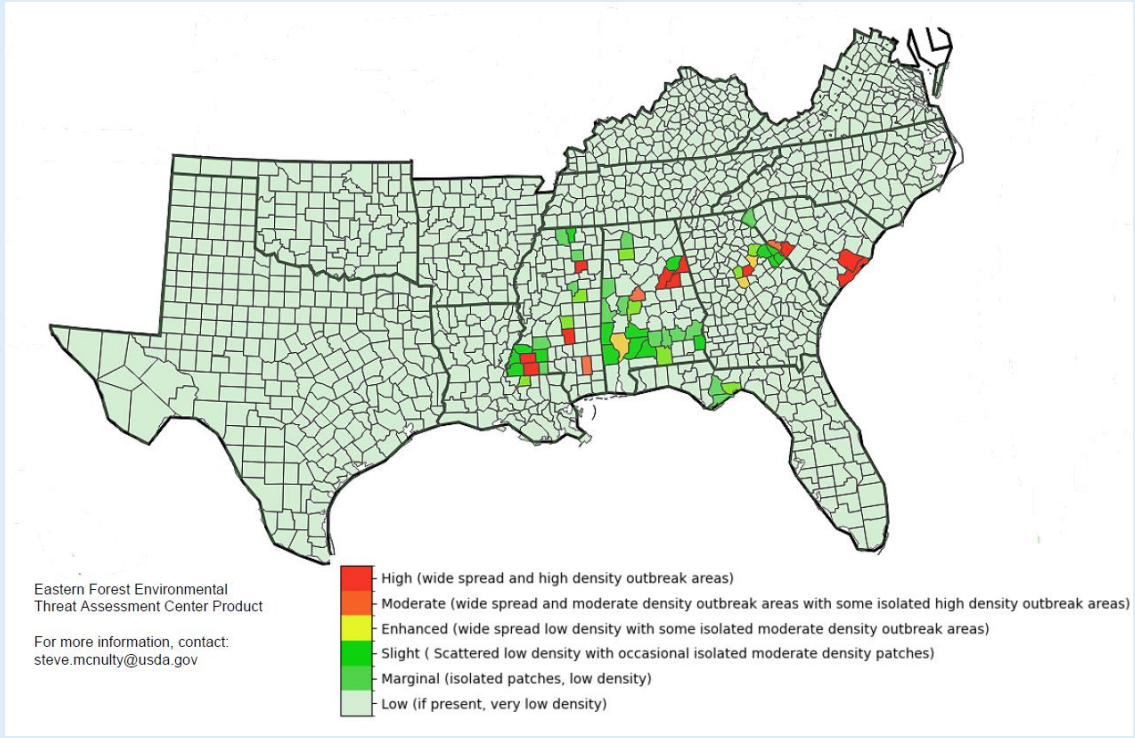


Projected (RCP 4.5)



Southern Pine Beetle Forecasts



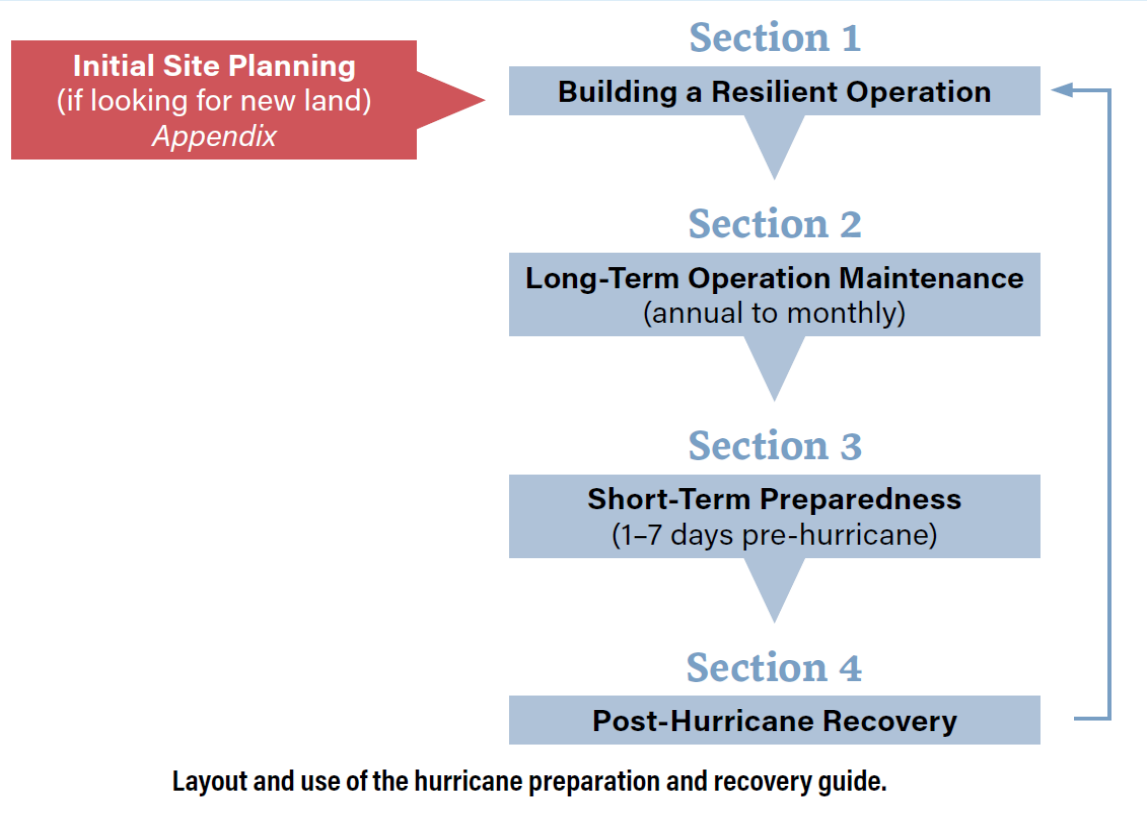


spbpredict.com

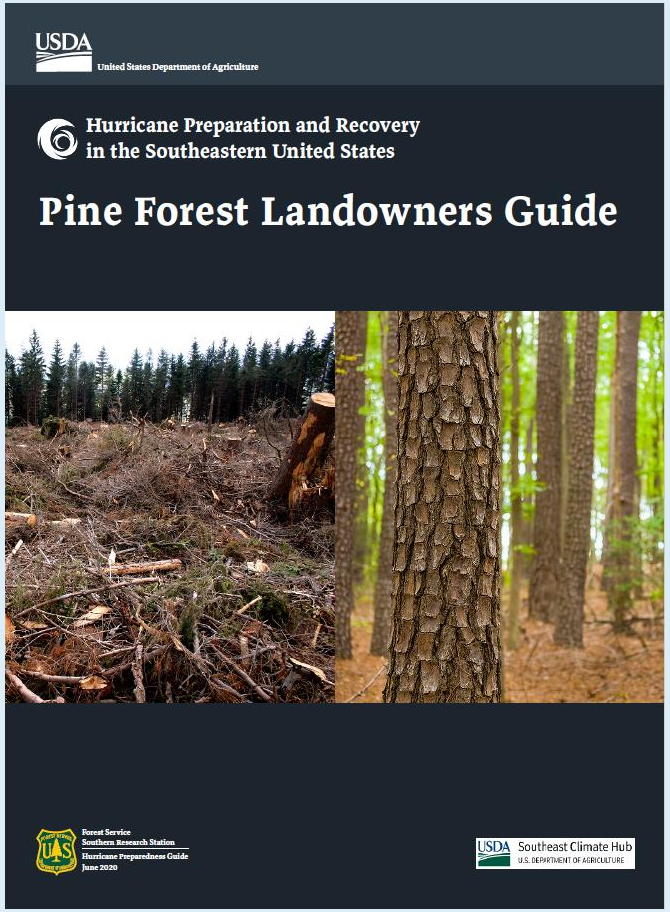
Designed and developed in the DALI Lab with USFS and state partners

Available in 2025

Hurricane Preparation & Recovery

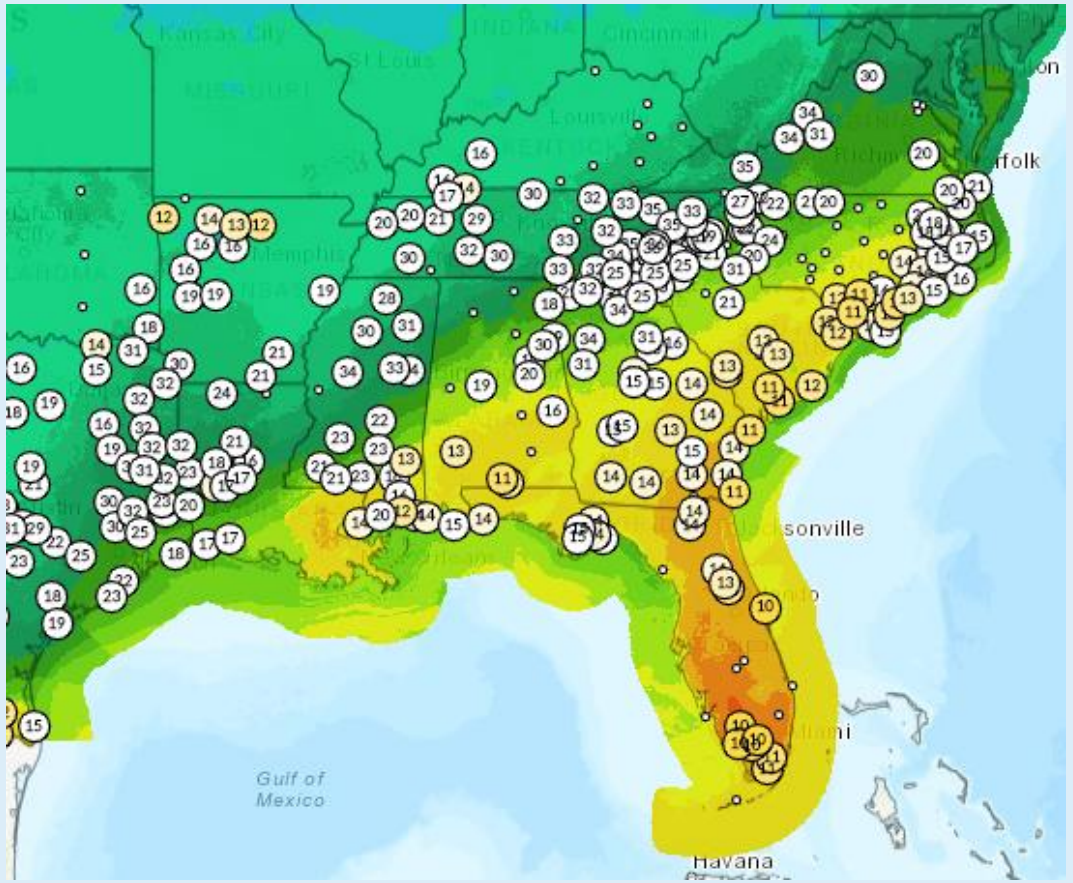


Layout and use of the hurricane preparation and recovery guide.



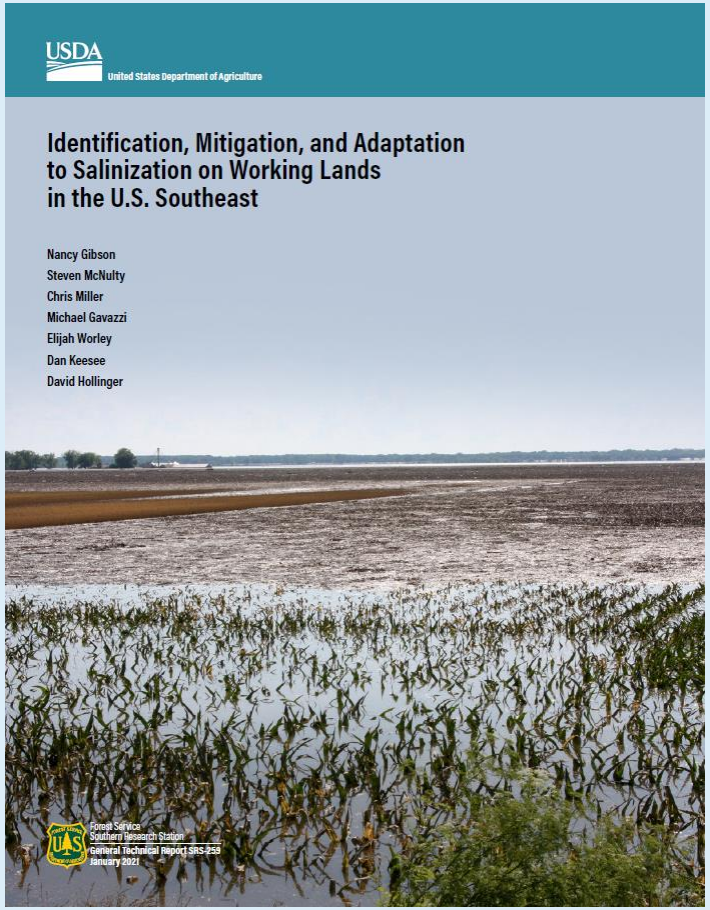
Fire Weather Intelligence Portal

- State Climate Office of NC
- Expand out of NC
- Modified based on stakeholder feedback



https://products.climate.ncsu.edu/fwip/

Soil Salinization Guide



Seedlot Selection Tool

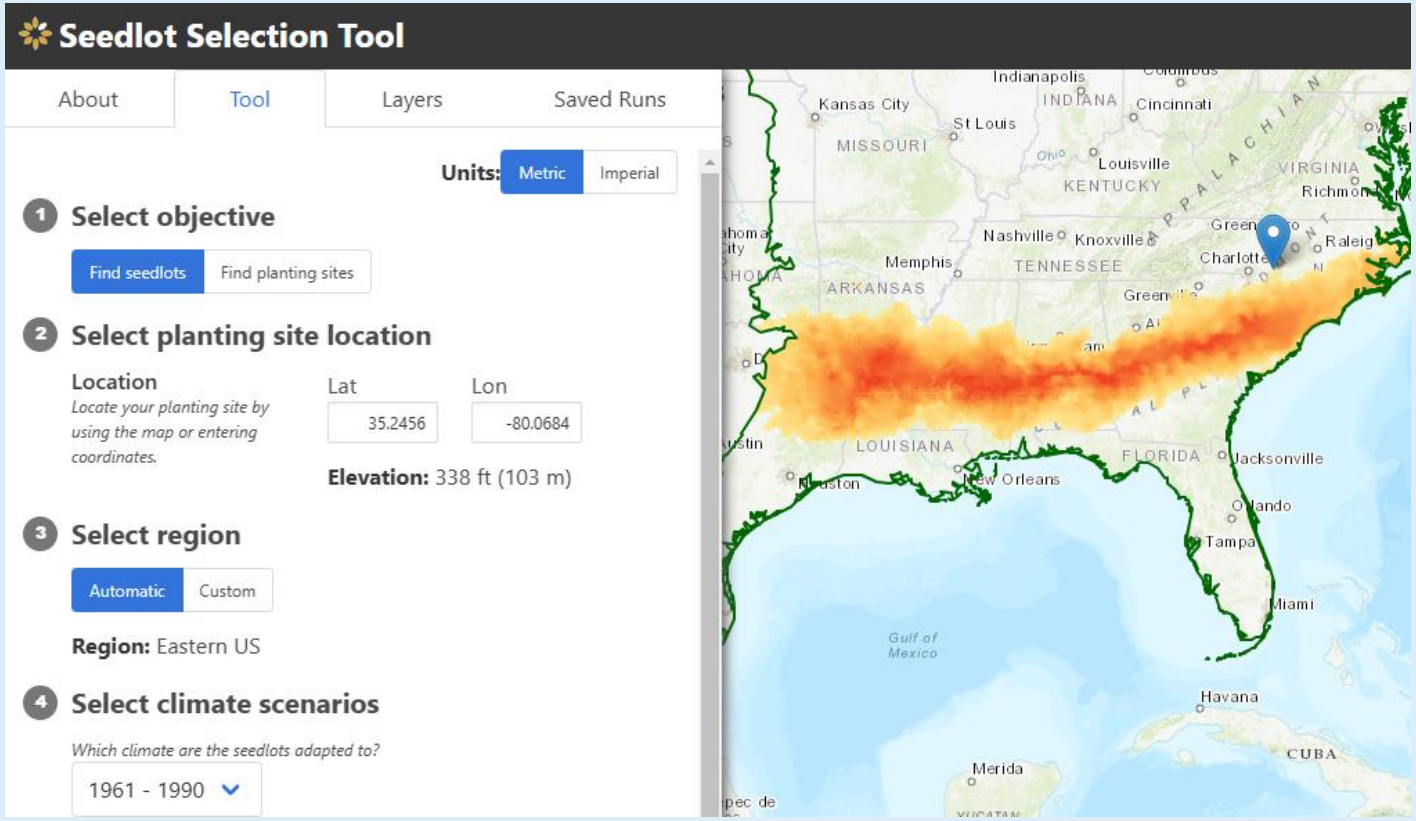
- Local ~~is best~~ might not be best?

Identify suitable seed collection zones for your planting site

OR

Identify suitable planting sites for your seed

- Map “climate analogs” based on different climate scenarios, timeframes, and ecosystem parameters



seedlotselectiontool.org/sst/

Take home message

- For working land managers, climate variability is more important than climate change
- The climate is and will always be variable
- Climate variability is increasing and will likely continue to increase
- **Increasing climate variability is a problem that can be addressed, by organizations and land managers**
- Check the Climate Hub for resources and tools to make informed decisions

Thank you!

Questions?

Michelle.Thompson@usda.gov