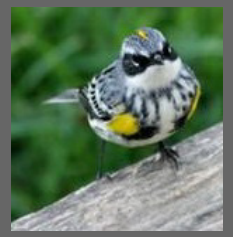
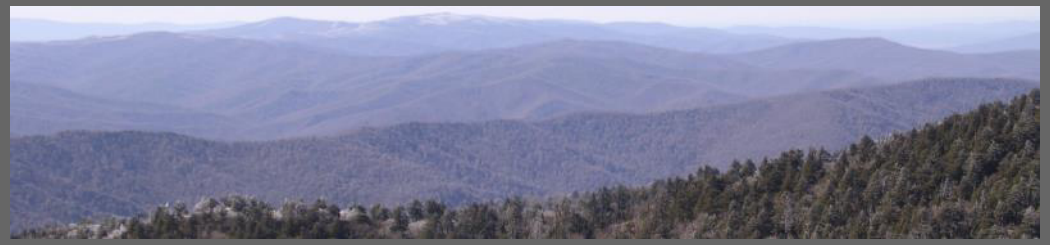
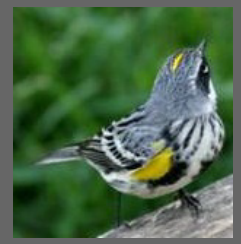
Ohio Oak Adaptive Silviculture for Climate Change (ASCC): Climate Change Considerations

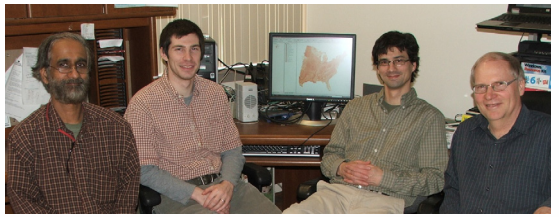




Stephen Matthews, Anantha Prasad, Matt Peters, and Louis Iverson, Patricia Leopold, Maria Janowiak
School of Environment and Natural Resources
USDA Forest Service, Northern Institute of Applied Climate Science

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Forest, birds, and climate change

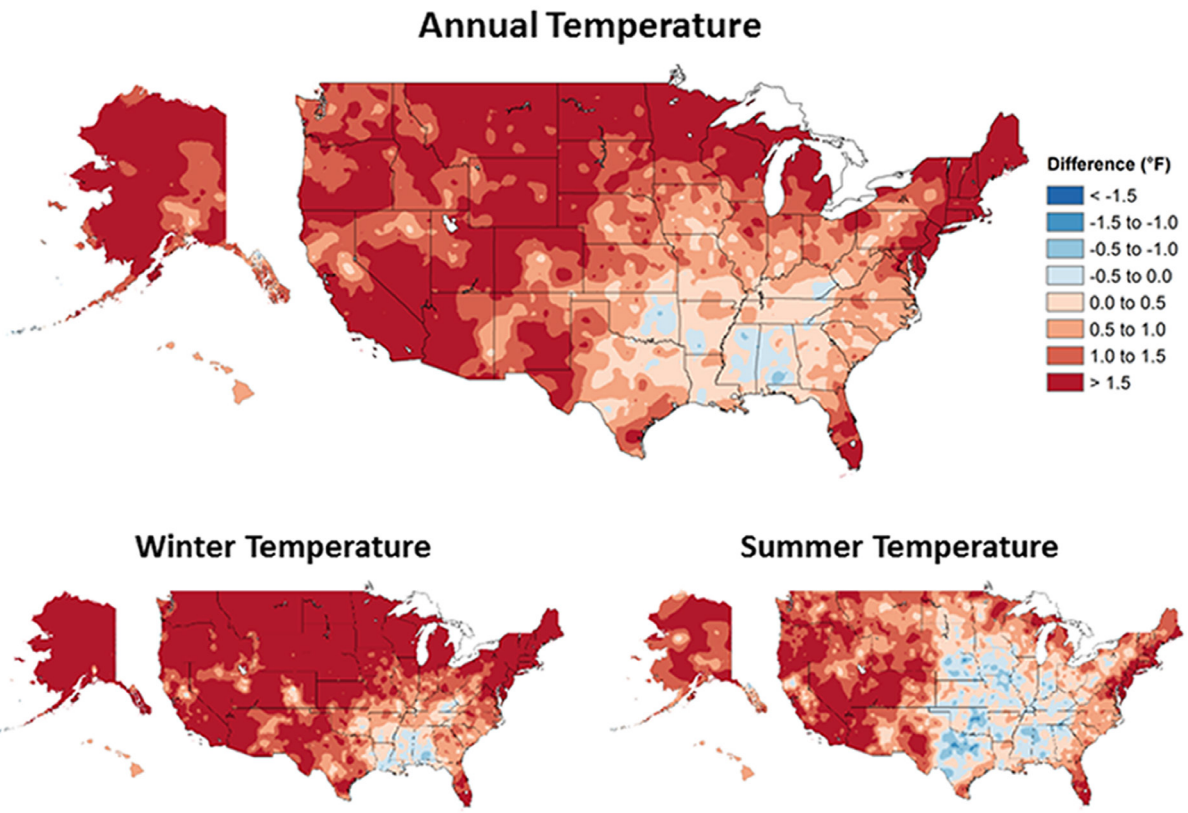
- The climate is changing, and it is impacting forests in many ways.
- The magnitude of continued accelerated change requires adaptation strategies aimed to maintain healthy and productive forests.
- Tools for adapting forest and their habitats in light of climate change (www.fs.fed.us/nrs/atlas)
- Collaboration in research and partnerships in shared stewardship are of critical importance.



USDA FOREST SERVICE DEPARTMENT OF AGRICULTURE

NIACS Northern Institute of Applied Climate Science

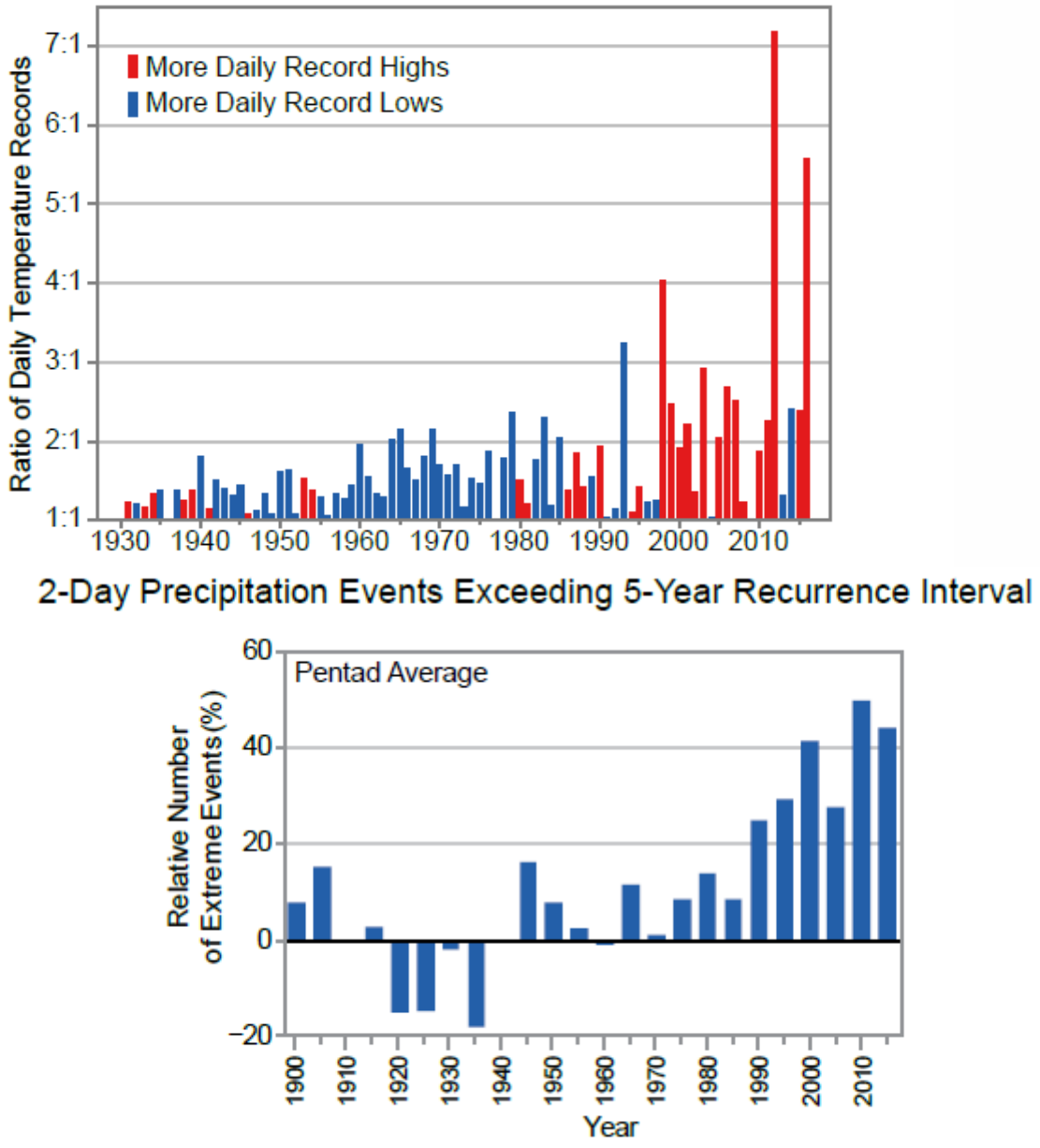
Effects on Forests



National Climate Assessment IV

Annual average temperature over the contiguous United States has increased by 1.2°F (0.7°C)

National Climate Assessment 2014 & 2017



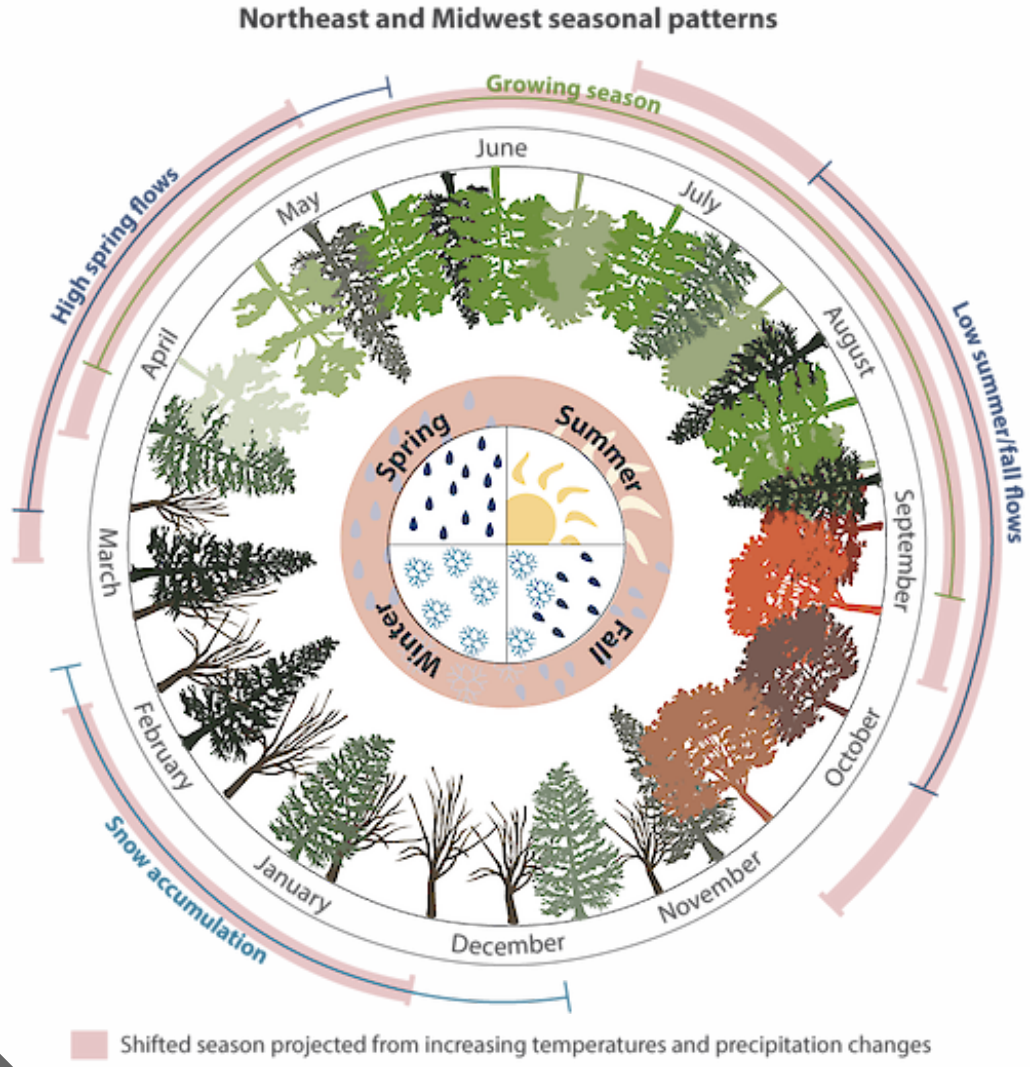
Not only is there a consistent trend of warming a corresponding incidence of extreme conditions can drive ecosystem change

Figures from IV National Climate Assessment

CFAES

Effects on Forests

SHIFTING SEASONS | SHIFTING STRESSORS | SHIFTING SPECIES



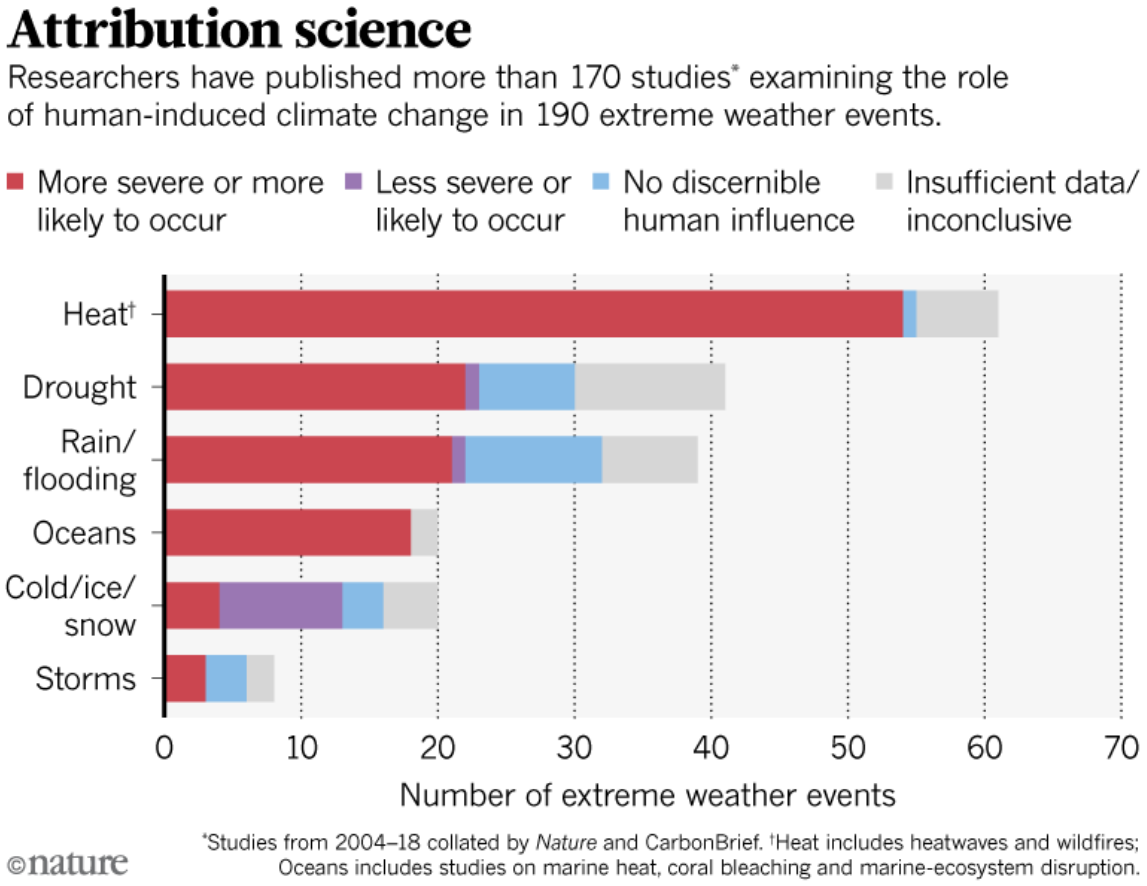
- Growing seasons have increased ~2 weeks in past century
- Projected increases of another 10-30 days by midcentury for much of US
- Altered phenology, e.g., earlier peak stream flow and plant flowering

NCA 2014 & 2017; Image: Brianne Walsh/UMCES

Effects on Forests

SHIFTING SEASONS | **SHIFTING STRESSORS** | SHIFTING SPECIES

Increasing likelihood of many extreme weather events



NCA 2017, Schiermeier 2018

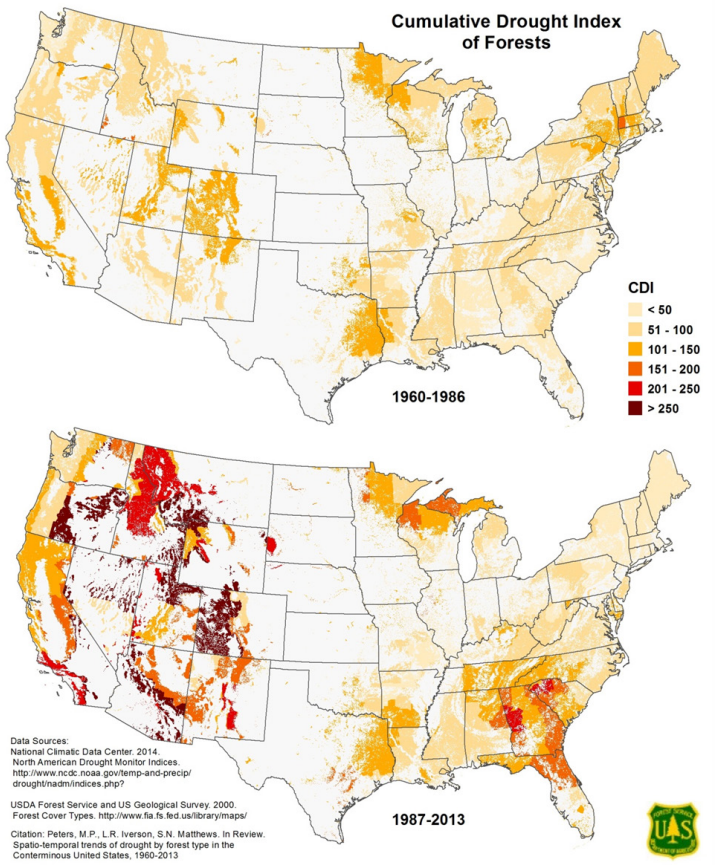
Image: American Forest Foundation

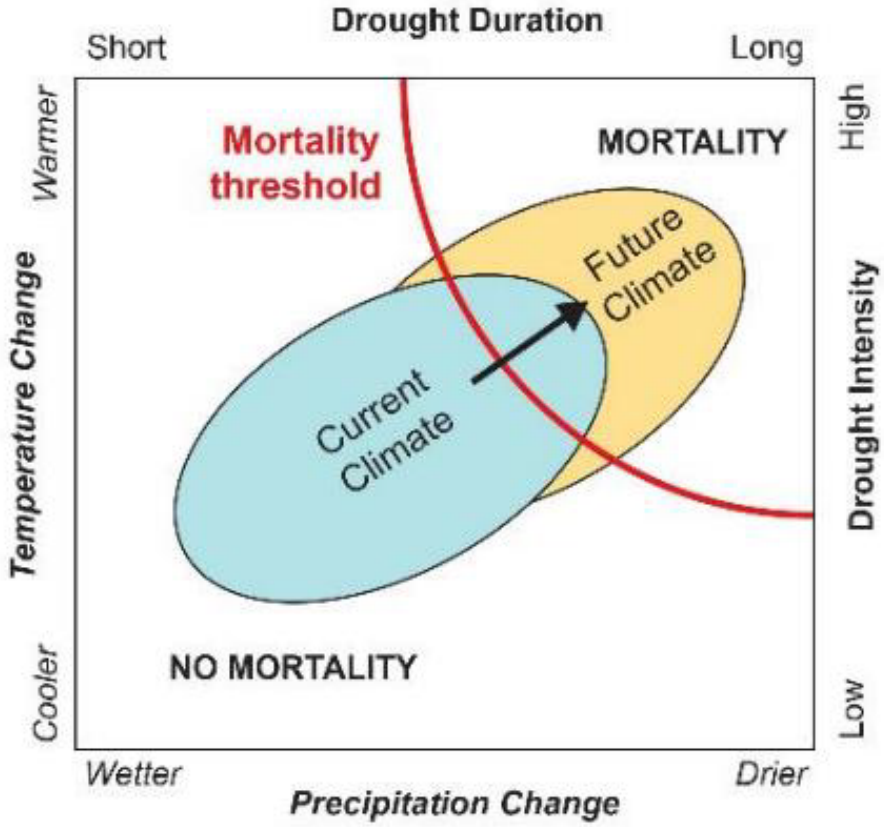
Effects on Forests

SHIFTING SEASONS | **SHIFTING STRESSORS** | SHIFTING SPECIES

Climate change exacerbates many ecosystem stressors.

Warmer temperatures drive moisture deficits.



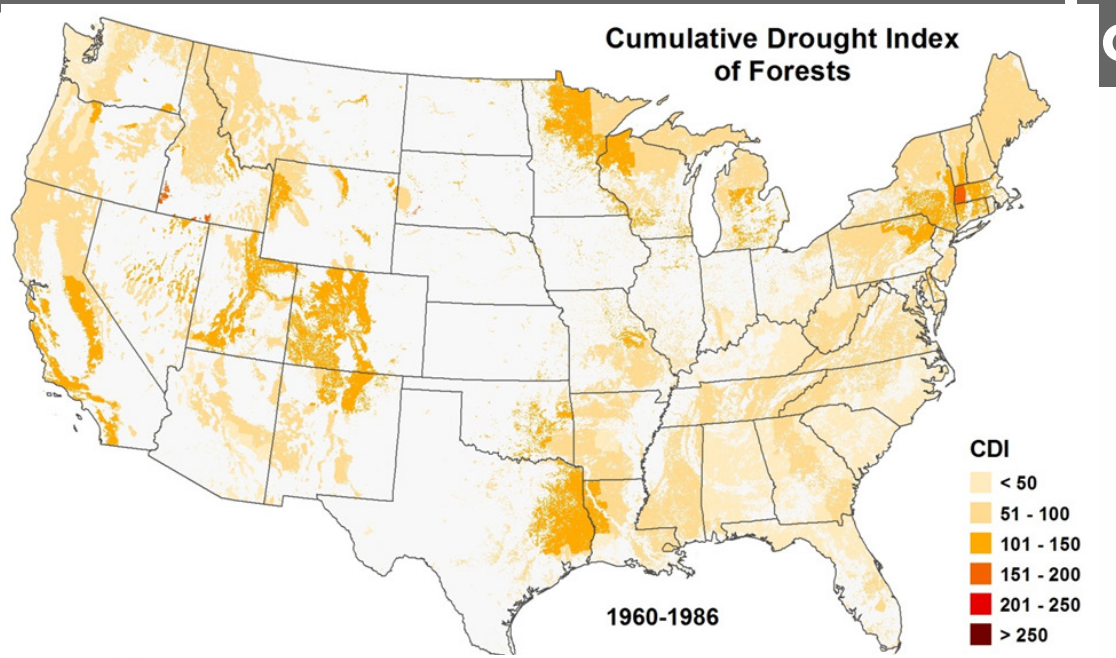


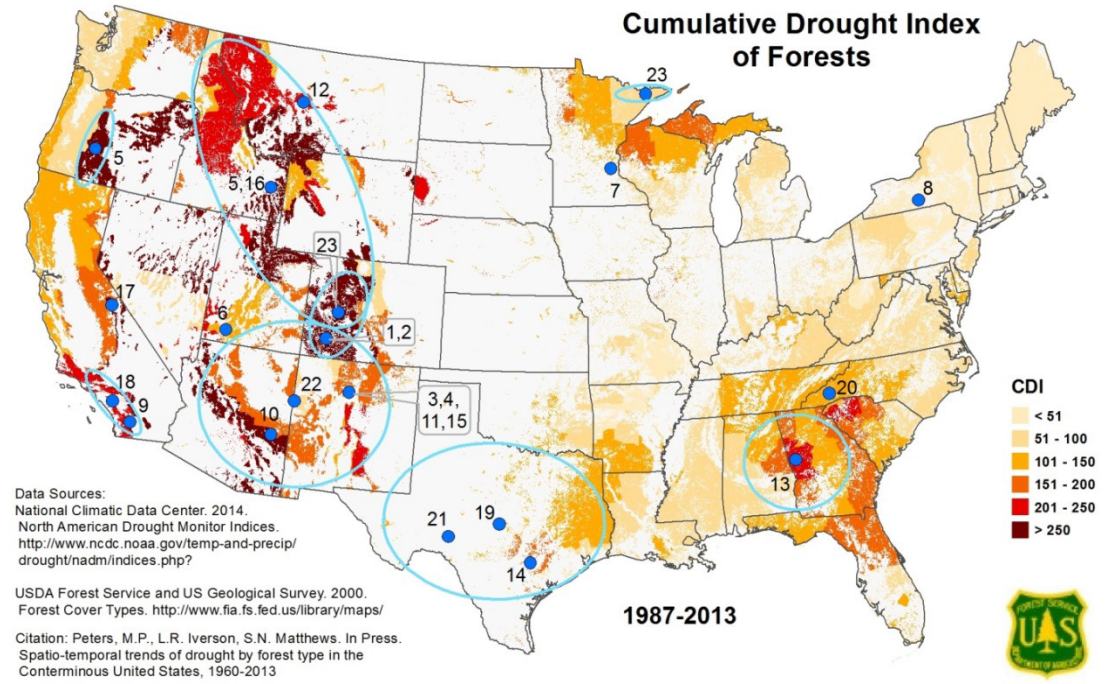
Images: NCA 2014, USGCRP TSU 2017, Clark et al. 2016, Peters et al. 2015

These changes are having impact on ecosystems.

Not just increases in temperature but variability in conditions and other persistent change are influencing forest health

Clark et al. 2016, Peters et al. 2015



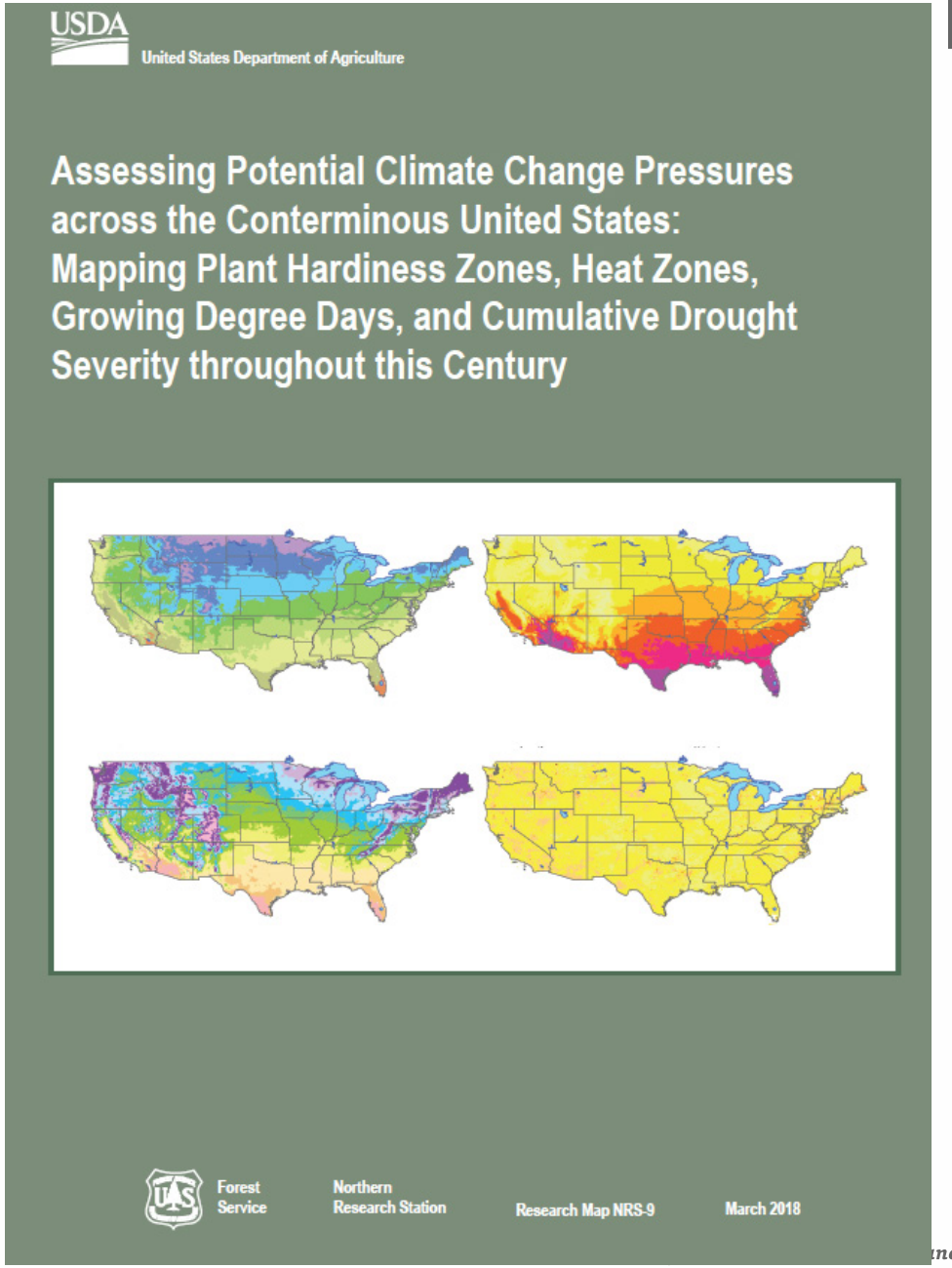


Climate indices of change

- Capture current and potential future conditions
- Key variables that capture stress and growth indicators in plants
- Complementary to species models

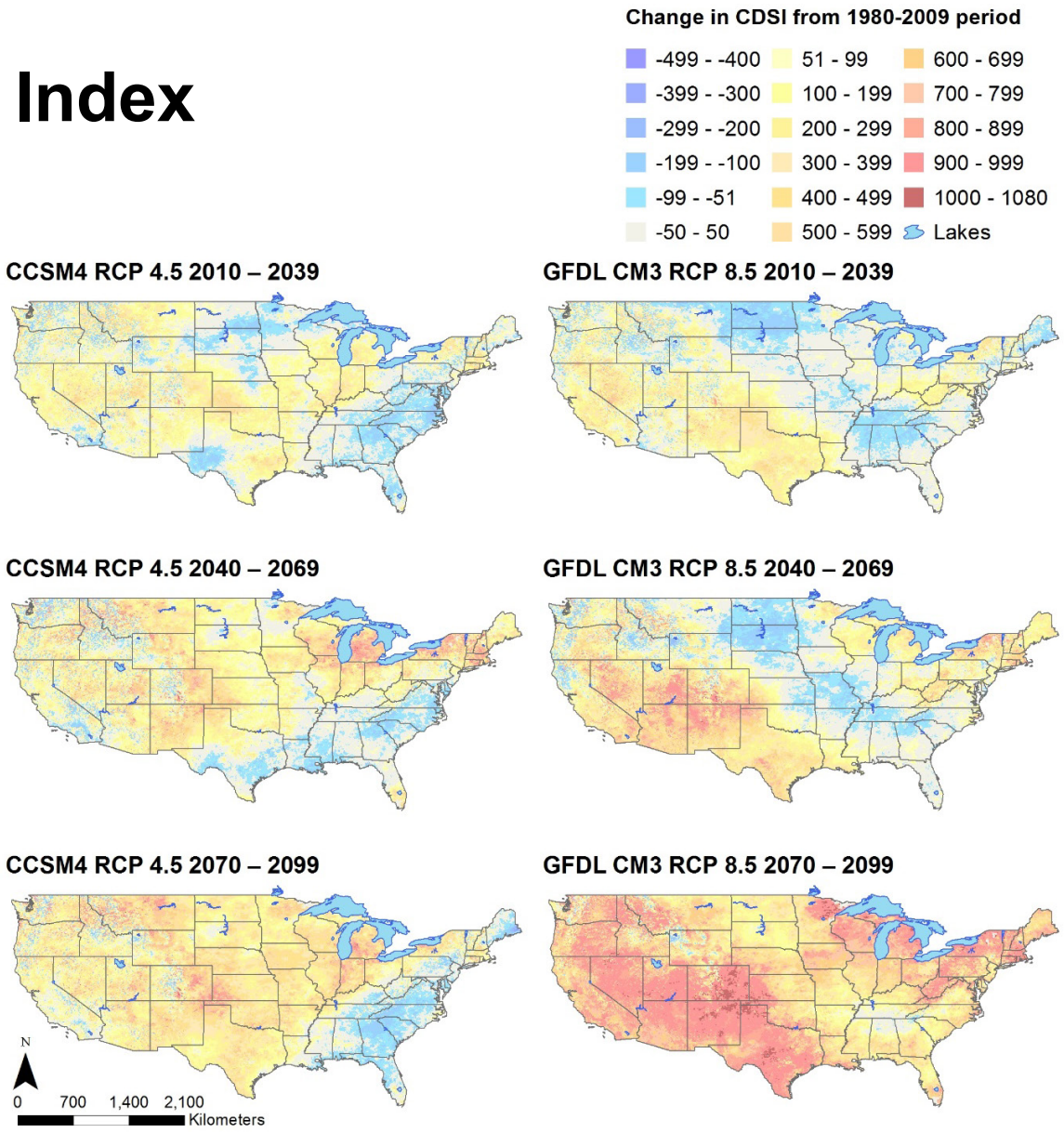
www.nrs.fs.fed.us/pubs/55870

(Matthews et al. 2018)



Cumulative Drought Severity Index

- Over much of the US, droughts will intensify in second half of this century.
- **Even with more precipitation, more drought in many area *such as* Ohio**



www.nrs.fs.fed.us/pubs/55870

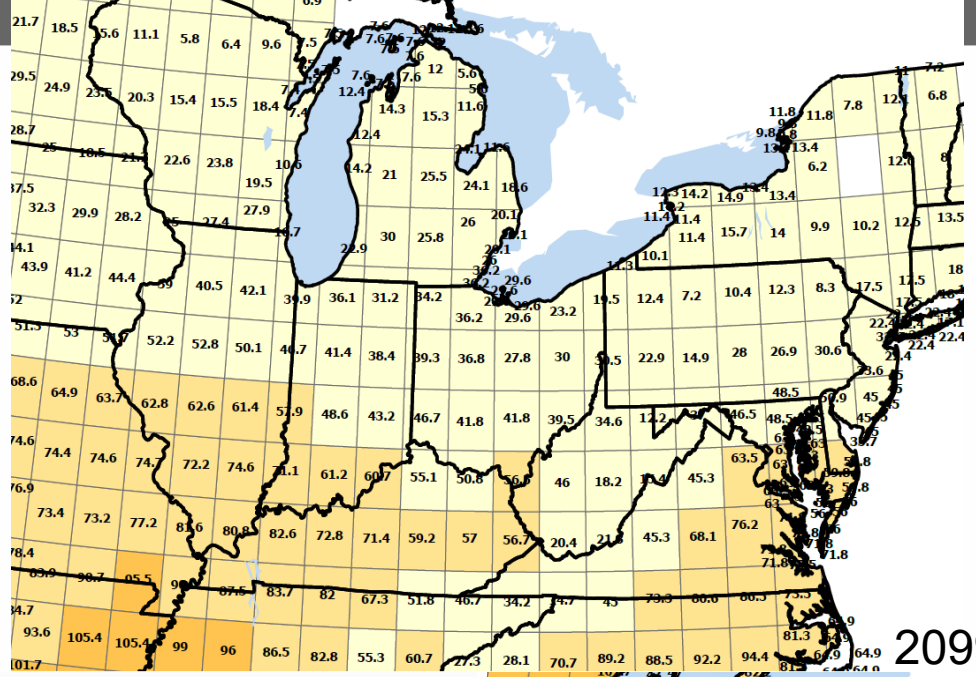
CFAES

Heat Index

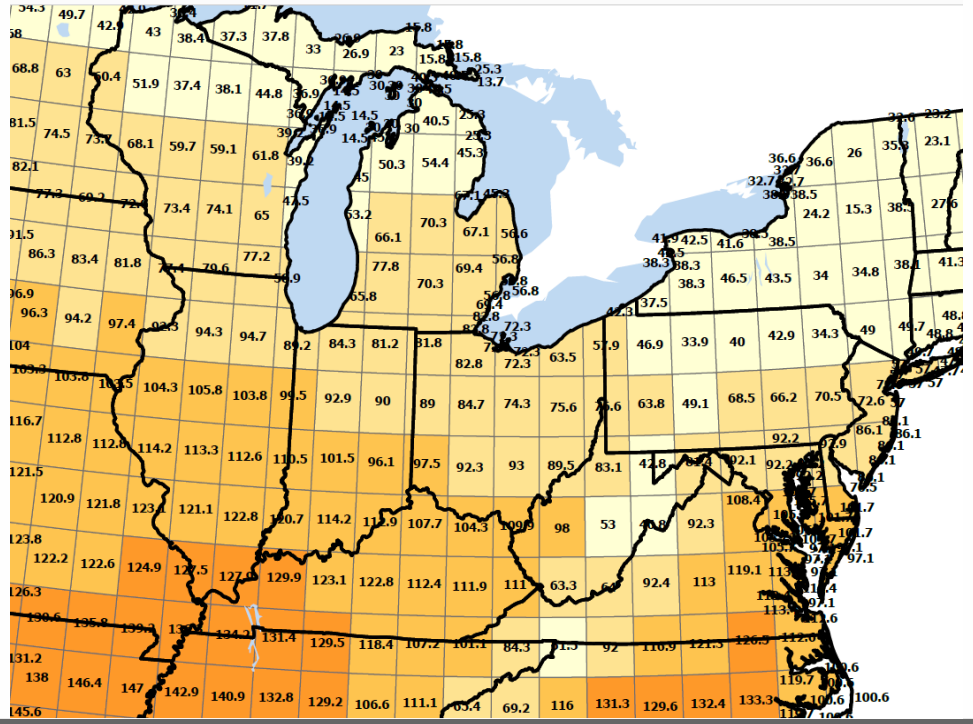
2009

Days over 86F

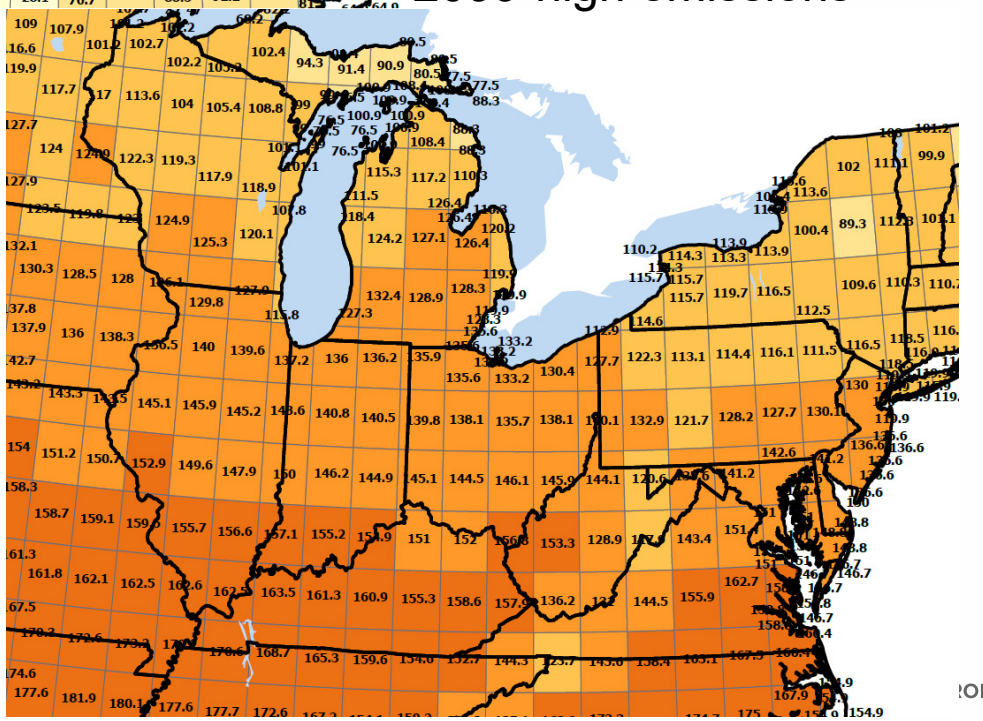
- ≤55
- ≤95
- ≤124
- ≤152
- ≤185
- ≤225
- ≤280



2099-low emissions



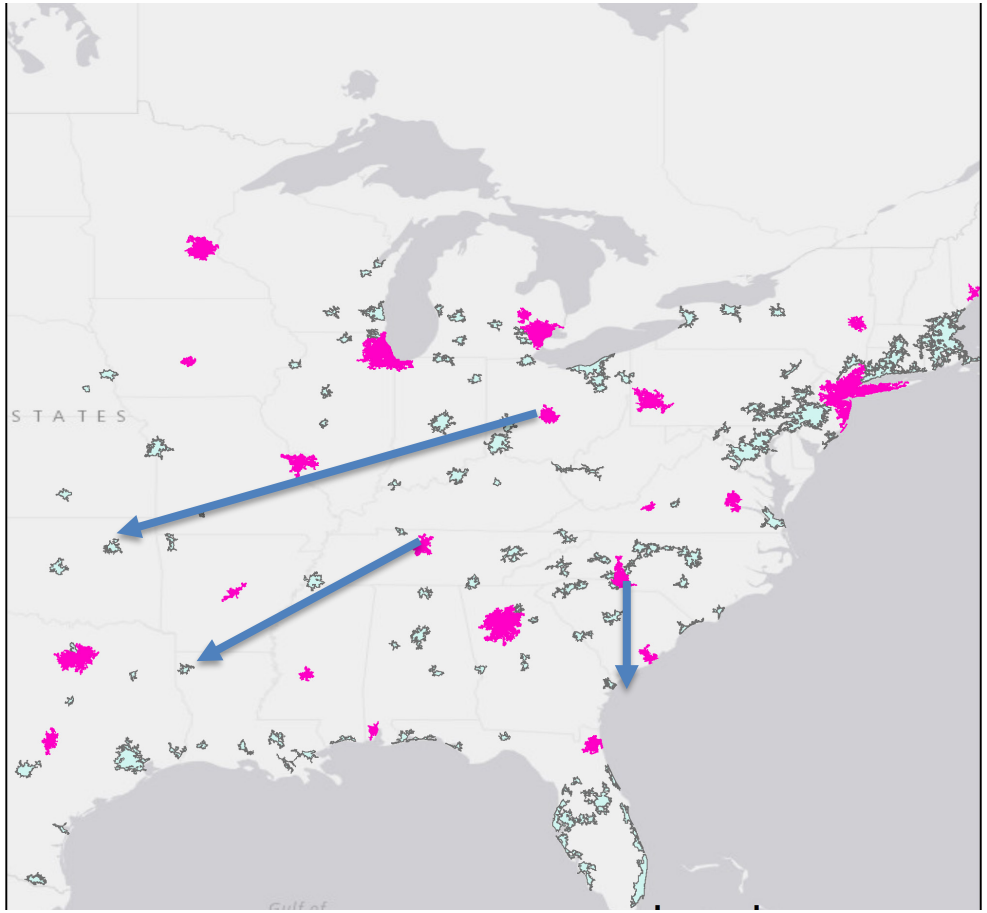
2099-high emissions



For SE Ohio that is almost double even under lower emissions and up to 100 more days under higher emissions

Climate analogs (Adams et al. In Pred)

- Sigma dissimilarity standardizes climatic distance according to historic interannual variability.
- Based on same 7 variables as used in the Atlas
- Calculated for each urban area for the year 2100 under RCP 8.5.



Climate change along with other drivers can have multiplicative influence on forest ecosystems

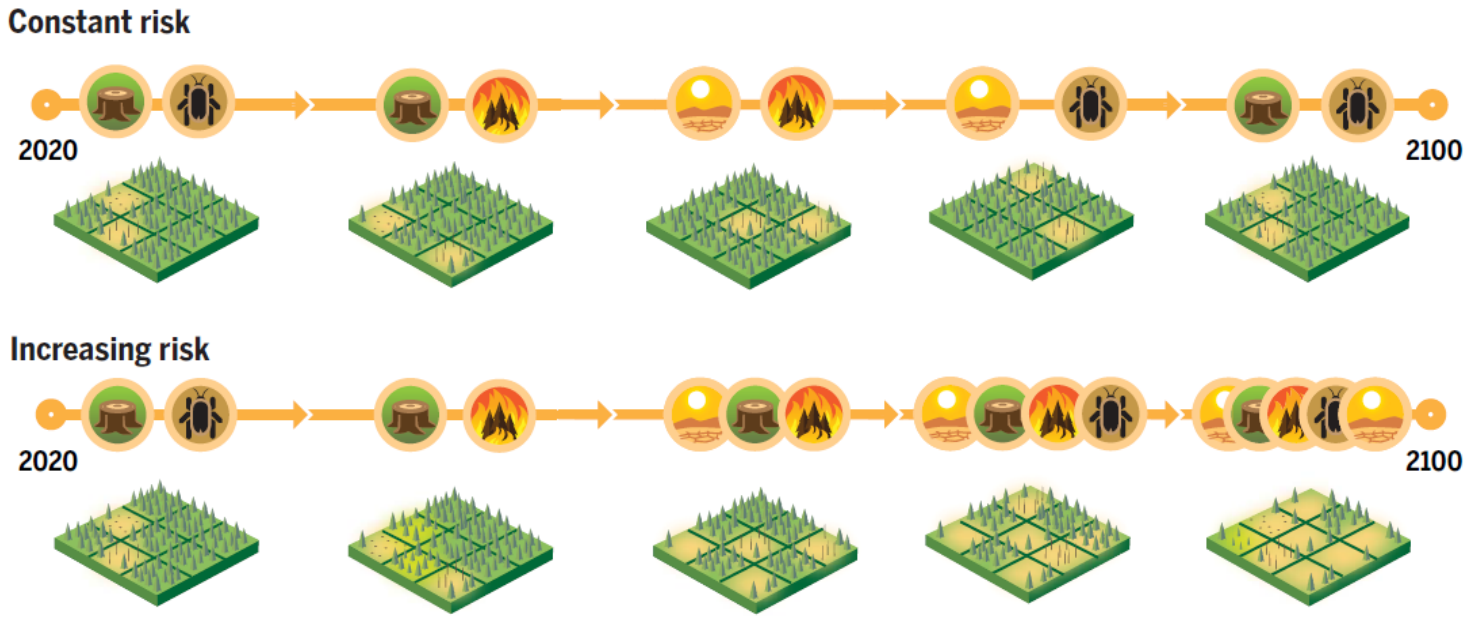


Fig. 3. Increasing climate-driven disturbance risk over time has major impacts on forest carbon. Conceptual diagram of stationary or constant (**Top**) versus nonstationary or increasing (**Bottom**) permanence risks from disturbance at a landscape scale in a changing climate. Disturbance events are illustrated in the circles and include fire, drought, biotic agents, and human disturbance.

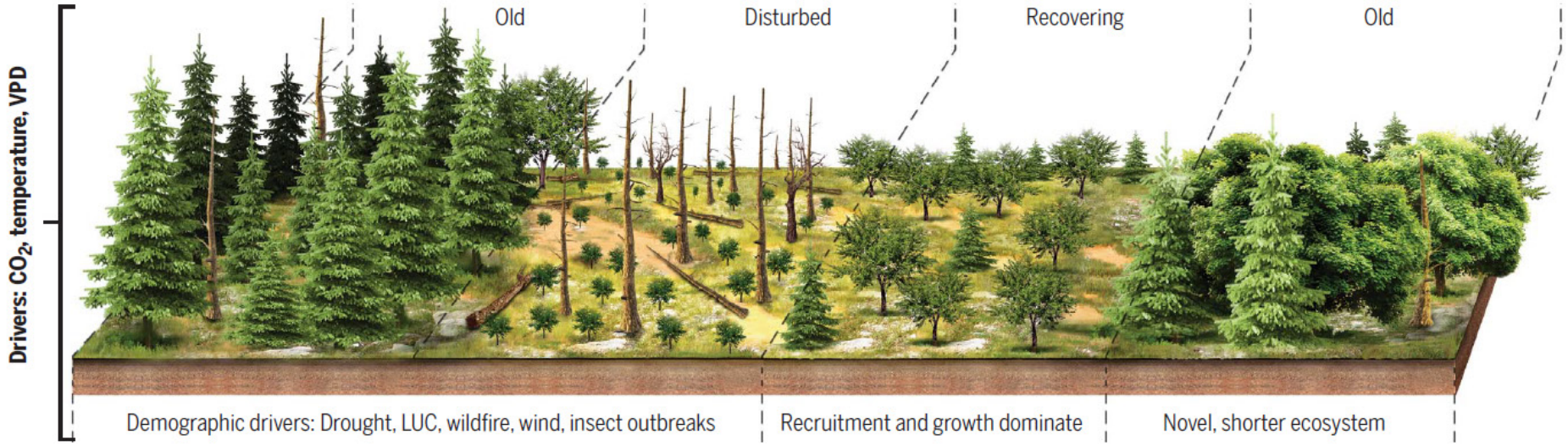
ILLUSTRATION: DAVID MEIKLE

Anderegg *et al.*, *Science* **368**, eaaz7005 (2020) 19 June 2020

4 of 9

With change in forest dynamics the emergence of novel conditions

- Such shifts will influence wildlife and other taxa dependent on these ecosystems



From McDowell et al. 2020 Science

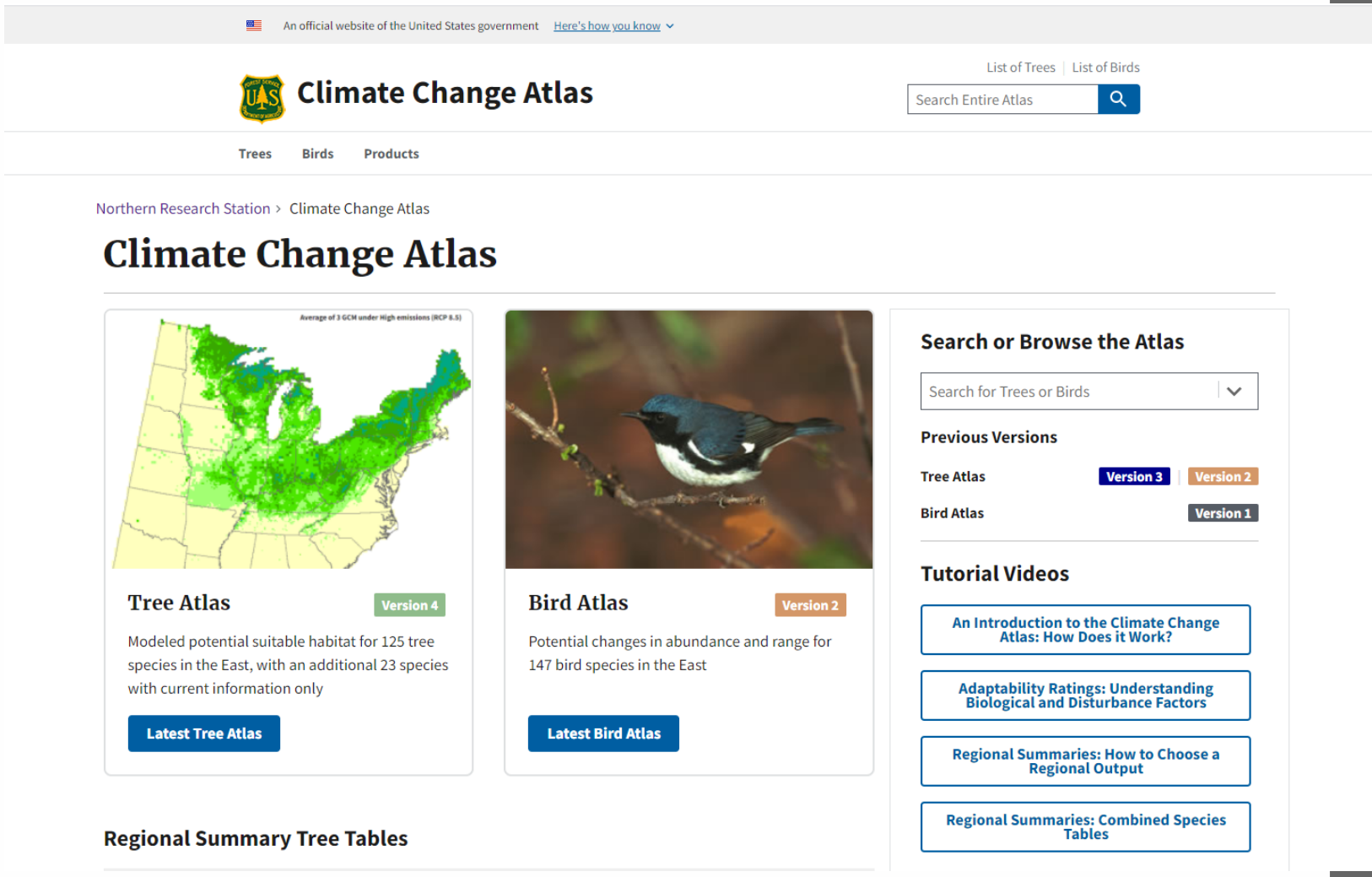
Climate Change Atlas

Atlas Components:

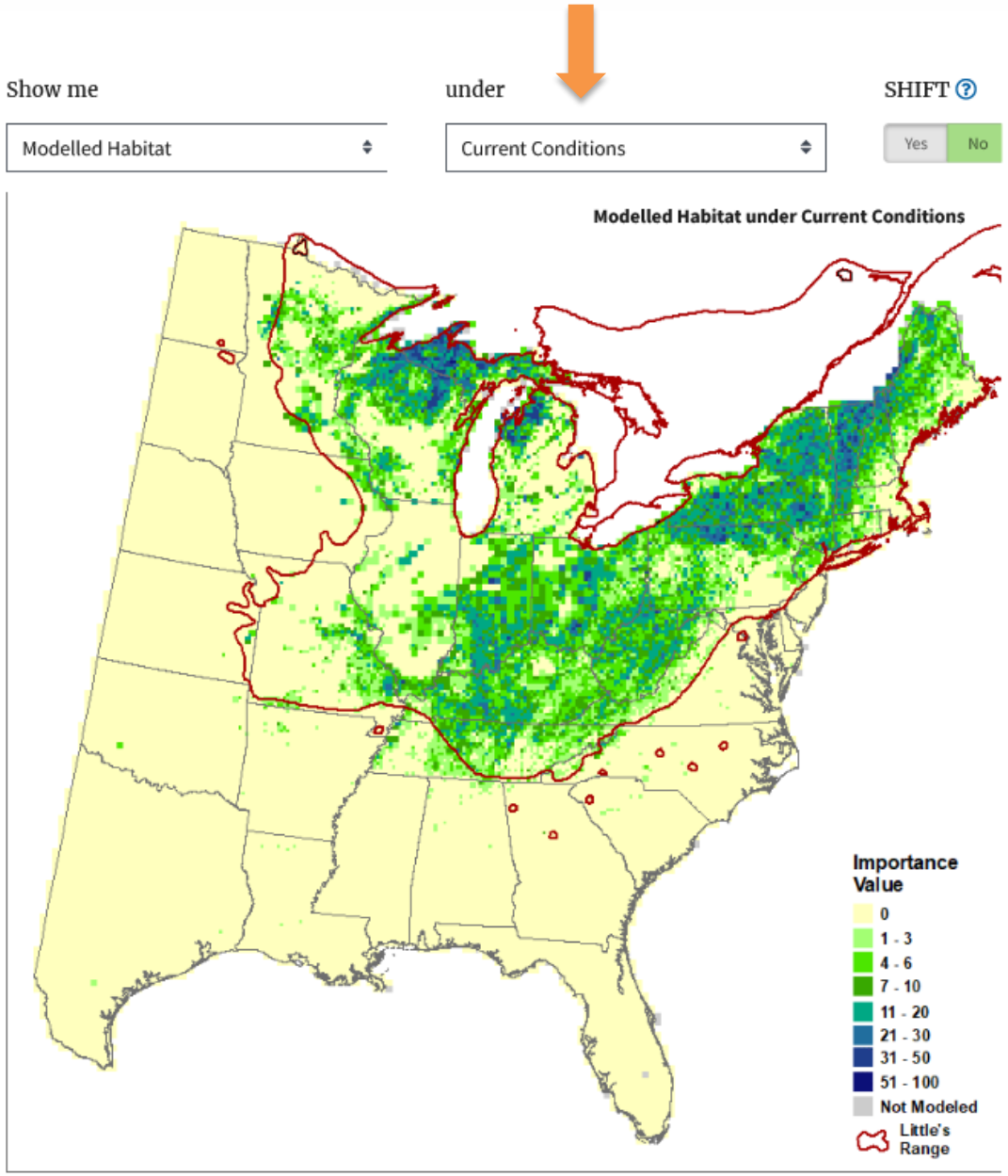
- DISTRIB = Habitat suitability model
- Adaptability ratings = species traits not included in models
- SHIFT = Colonization likelihood model

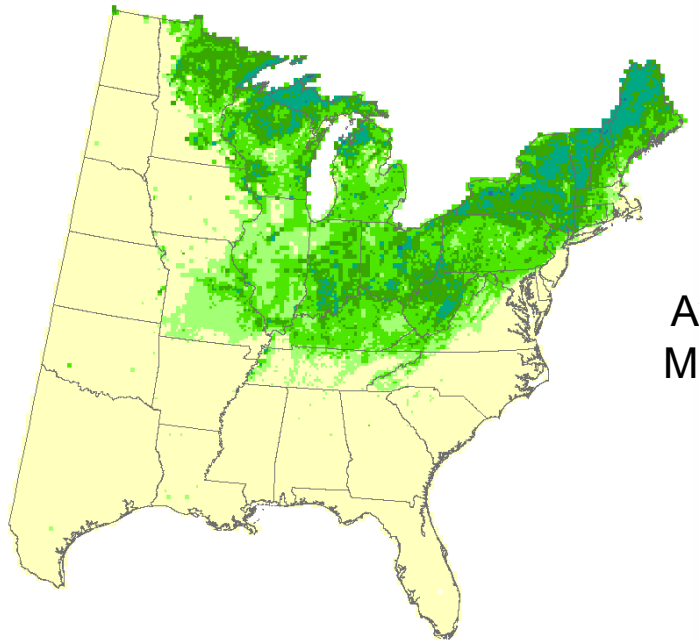
New version 4!

www.fs.fed.us/nrs/atlas

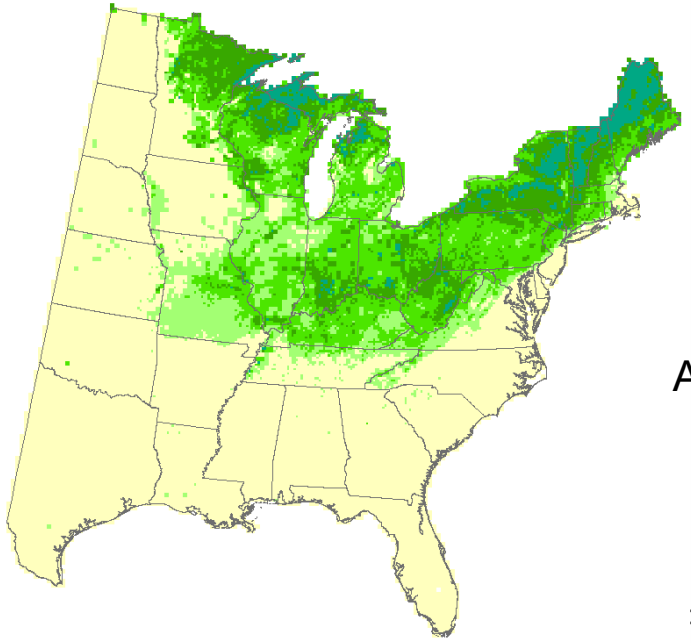


Sugar Maple





Average of 3 climate models
Medium emissions (RCP 4.5)

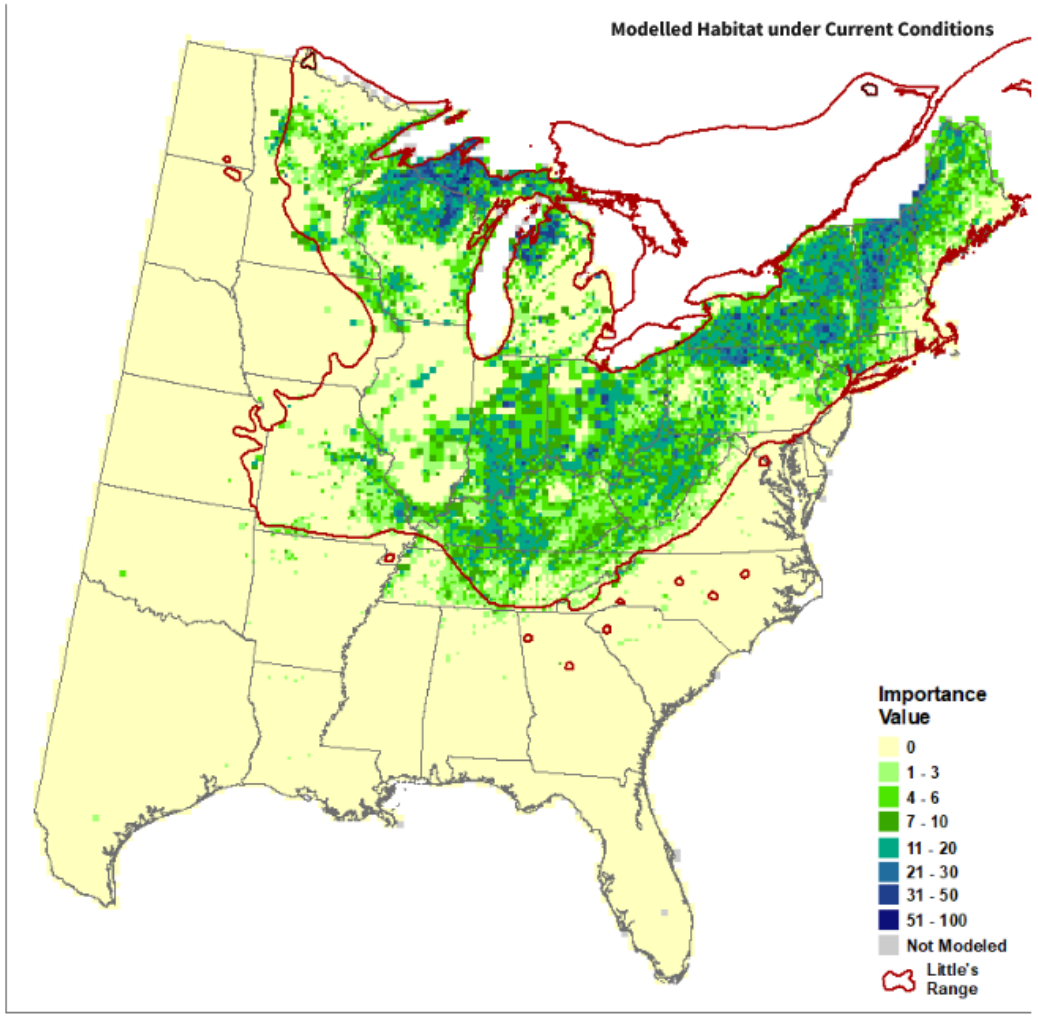


Average of 3 climate models
High emissions (RCP 8.5)

Sugar Maple

CFAES

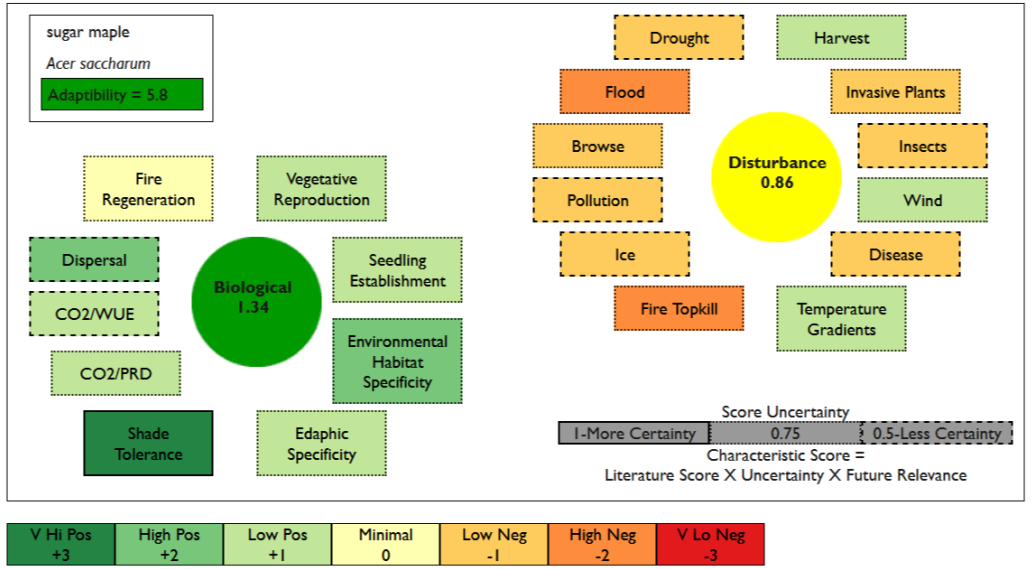
Show me: Modelled Habitat | under: Current Conditions | SHIFT: Yes / No



Cautions | Model Info | FAQ

Interpretation

Sugar maple is widely
dense, and with high I
2/3 of the Eastern US.
abundance across the
pine, red maple and sv
adaptable although ur
other stresses, it woul
our earlier models whi
habitat decline in the s
change, the species is
modestly, so we rate it
cope, and to be a gooc
SHIFT).



RCP 4.5 SHIFT | R

V Hi Pos +3	High Pos +2	Low Pos +1	Minimal 0	Low Neg -1	High Neg -2	V Lo Neg -3

Climate Change Adaptability

5.8	0.86
1.34	●

MODFACs

What traits will impact sugar maple's ability to adapt to climate change, and in what way?:

Primary Positive Traits

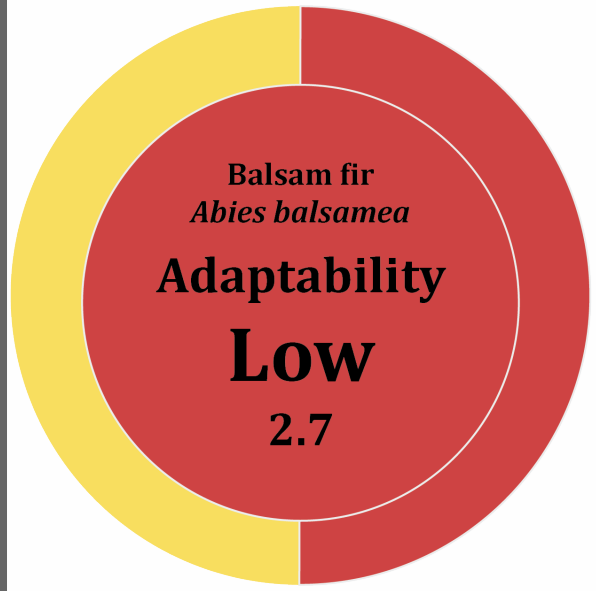
Shade tolerance | Environment habitat specificity

Primary Negative Traits

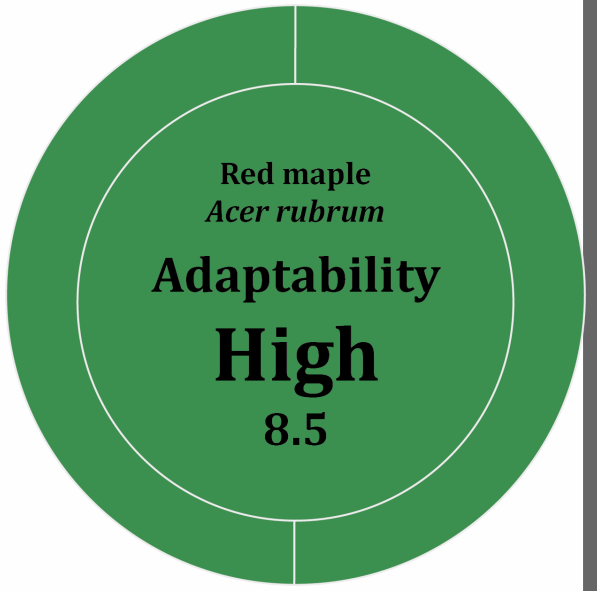
CFAES

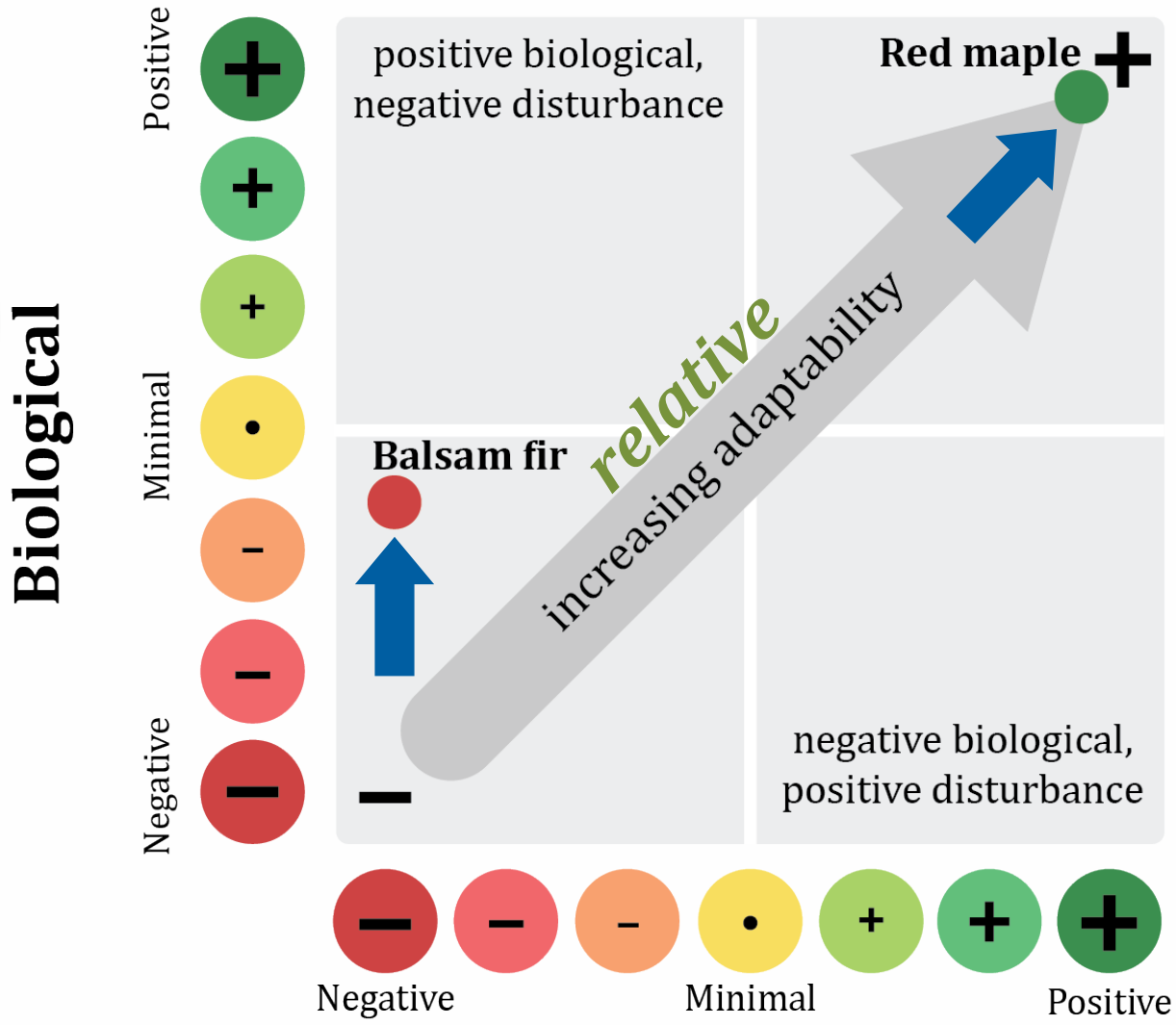
Adaptability

Balsam fir



Red maple



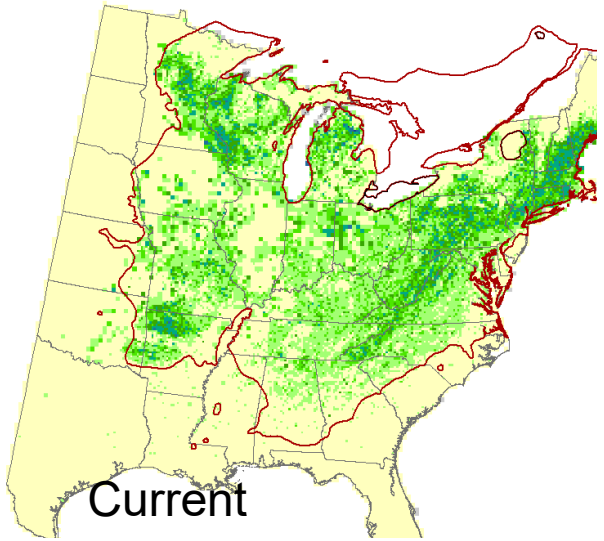


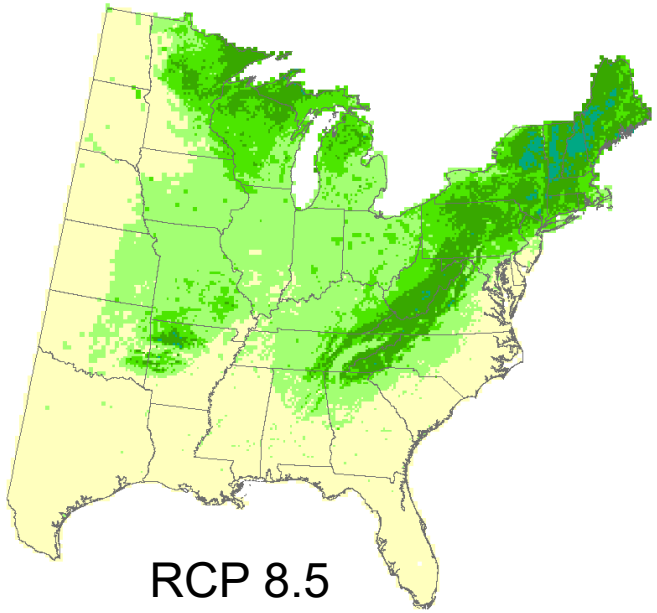
SHIFT example: Northern Red Oak

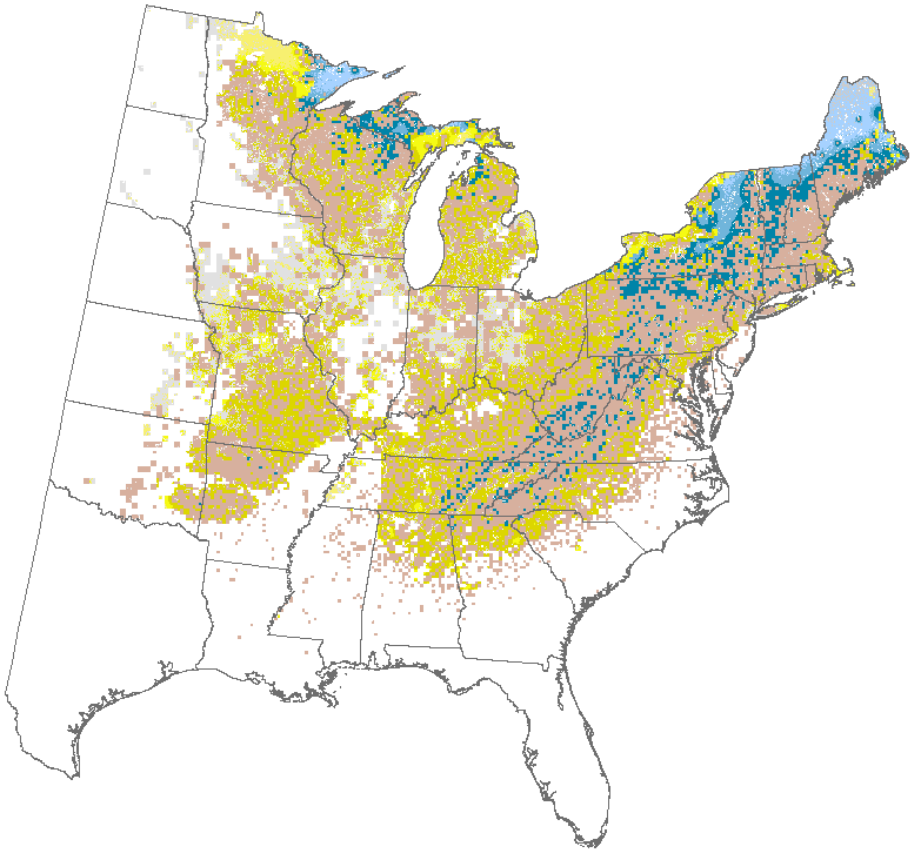
Northern Red Oak temporal mismatch current and projected future habitat

New tree atlas quantifies colonization likelihood by 2100 (Prasad et al. 2016).

Intersection of SHIFT and DISTRIB II gives clearer picture of mismatch between how much climate is projected to change and how far trees may move on their own.







Colonization is limited to range margins and infill (Blue) which is derived from habitat quality (HC) and colonization likelihood (CL)

How are the Atlas data being used?

- Climate Change Response Framework
- Ecosystem Vulnerability Assessments
- Combined species outputs provides new view
  - 1 x 1° example

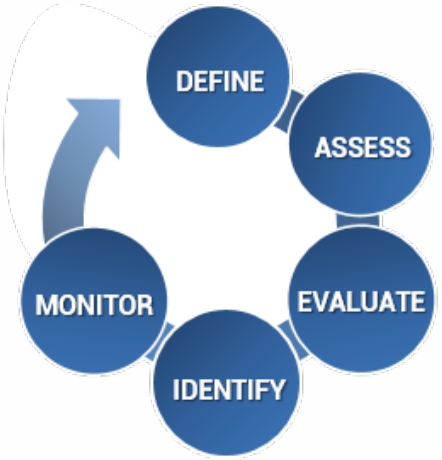
NORTHERN INSTITUTE OF APPLIED CLIMATE SCIENCE

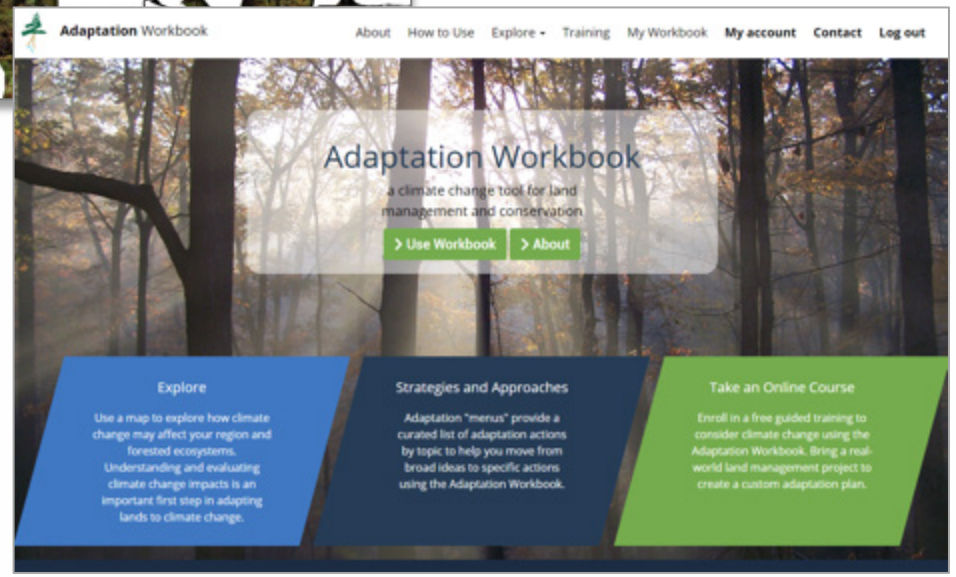
Chartered by USDA Forest Service, universities, non-profit, and tribal conservation organizations

Adaptation Resources

A flexible workbook and menu to address diverse needs

- Designed for a variety of land owners with diverse goals
- Does not make recommendations
- Includes:
  - Adaptation Workbook
  - Adaptation strategies for different resource areas (menus)





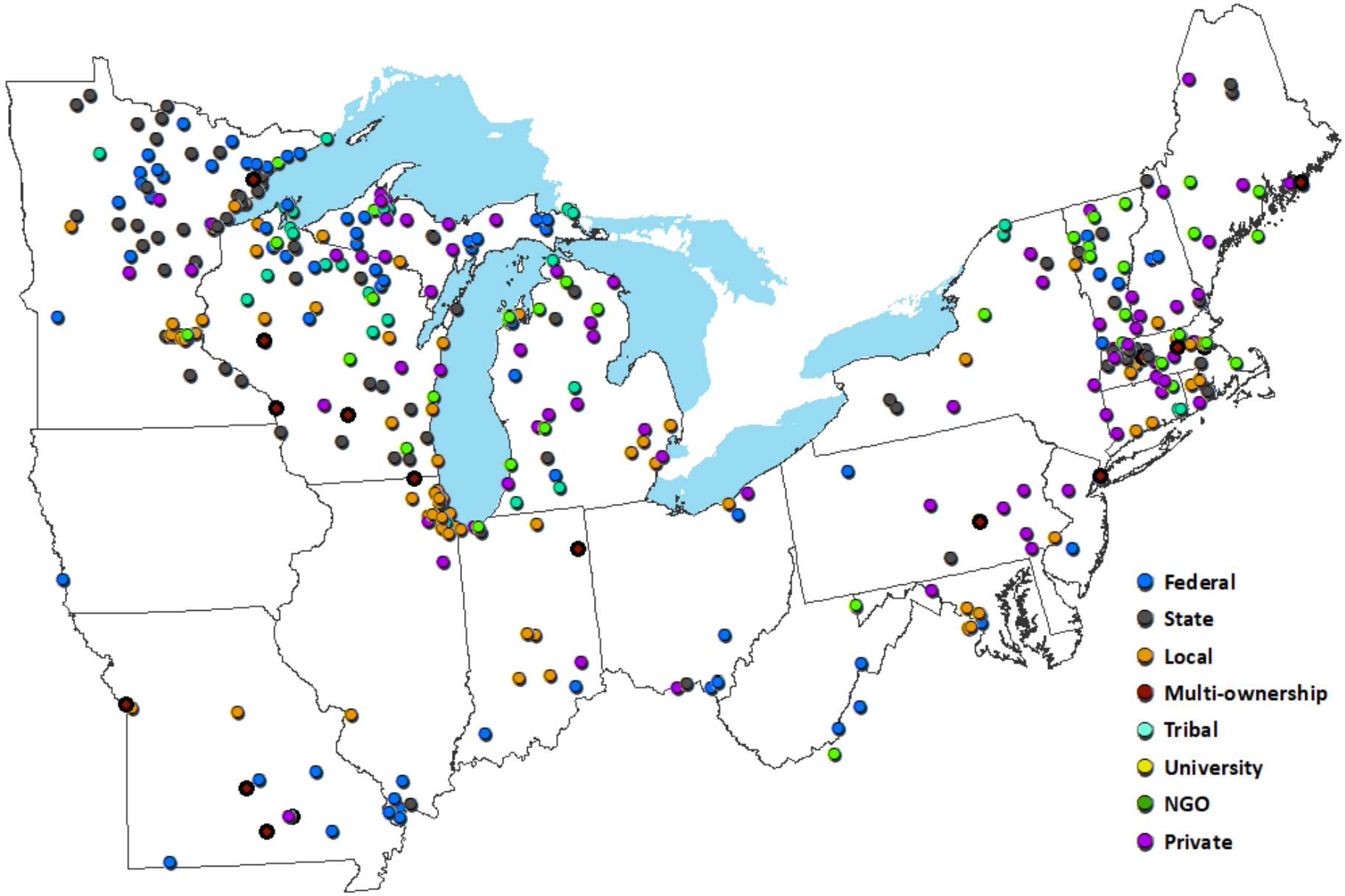
Swanston et al. 2016 (2nd edition); www.treesearch.fs.fed.us/pubs/52760; www.adaptationworkbook.org

Adaptation Demonstrations

CFAES

Real-world examples of climate-informed forest management.

Nearly 500 projects have used the Adaptation Workbook to consider climate change and identify adaptation actions.



Another example of how these data are being used: Climate Change Response Framework -NIACS

Audience: Land managers

Scope: Forest ecosystems

Vulnerability of:

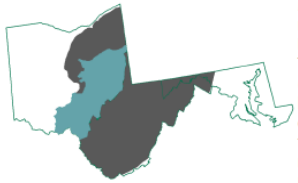
- Tree species
- Forest/natural communities
- Does not make recommendations

Central Appalachians Region

CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

CENTRAL APPALACHIANS SOUTHEAST OHIO

The region's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Central Appalachians (Butler et al. 2015). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full assessment.



Remember that models are just tools, and they're not perfect. Model projections don't account for some factors that could be modified by climate change, like droughts, wildfire activity , and invasive species. If a species is rare or confined to a small area, Tree Atlas results may be less reliable. These factors, and others (see table below), could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

TREE SPECIES INFORMATION:

This assessment uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with two forest impact models (Tree Atlas and LANDIS) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the assessment. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
MAY DECREASE	
American beech	Susceptible to beech bark disease, extremely shade tolerant
American elm	Grows on a variety of sites, Affected by Dutch elm disease
Bigtooth aspen	Early-sucessional colonizer, susceptible to drought
Black cherry	Susceptible to insects and fire, somewhat drought-tolerant
Black locust	Early-successional colonizer, susceptible to insect pests
Black walnut	Good disperser, but intolerant of shade and drought
Chestnut oak	Establishes from seed or sprout, adapted to fire
Eastern white pine	Good disperser, but susceptible to drought and insects
Flowering dogwood	Shade tolerant
Pawpaw	Shade tolerant; susceptible to drought
Red maple	Competitive colonizer in diverse sites, disturbance-adapted
Sassafras	Early-successional colonizer, susceptible to fire topkill
Slippery elm	Shade-tolerant, susceptible to disease and fire topkill
Sugar maple	Grows across a variety of sites, tolerates shade
Tulip tree	Competitive colonizer tolerant of diverse sites
White ash	Emerald ash borer causes mortality

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
NO CHANGE	
American hornbeam	Tolerates shade, susceptible to fire and drought
MIXED MODEL RESULTS	
Scarlet oak	Establishes from seed or sprout, susceptible to fire and disease
Silver maple	Early-successional colonizer, susceptible to fire topkill and drought
MAY INCREASE	
Black oak	Drought tolerant, susceptible to insect pests and diseases
Blackgum	Shade tolerant, fire adapted
Eastern hophornbeam	Grows across a variety of sites, tolerates shade
Eastern redcedar	Drought tolerant, shade intolerant, susceptible to fire and insects
Mockernut hickory	Susceptible to fire topkill
Northern red oak	Sus
Pignut hickory	Sus
Shagbark hickory	Sus
Sourwood	Con
Virginia pine	Into
White oak	Fire

NIACS Northern Institute of Applied Climate Science

www.forestadaptation.org

Forest ecosystem used in this assessment	NatureServe ecological systems represented by the forest ecosystems used in this assessment	FIA forest-type groups	Common tree species in forest ecosystem
Dry/mesic oak forest	Northeastern interior dry/mesic oak forest Central and southern Appalachian montane oak forest Southern Appalachian oak forest	oak/hickory, oak/pine, white/red/jack pine, aspen/birch	white oak, black oak, northern red oak, scarlet oak, red maple, pignut hickory, mockernut hickory, shagbark hickory, sugar maple, chestnut oak, sweet birch, American beech, blackgum, tulip tree, white ash

Dry Oak and Oak/Pine Forest and Woodland

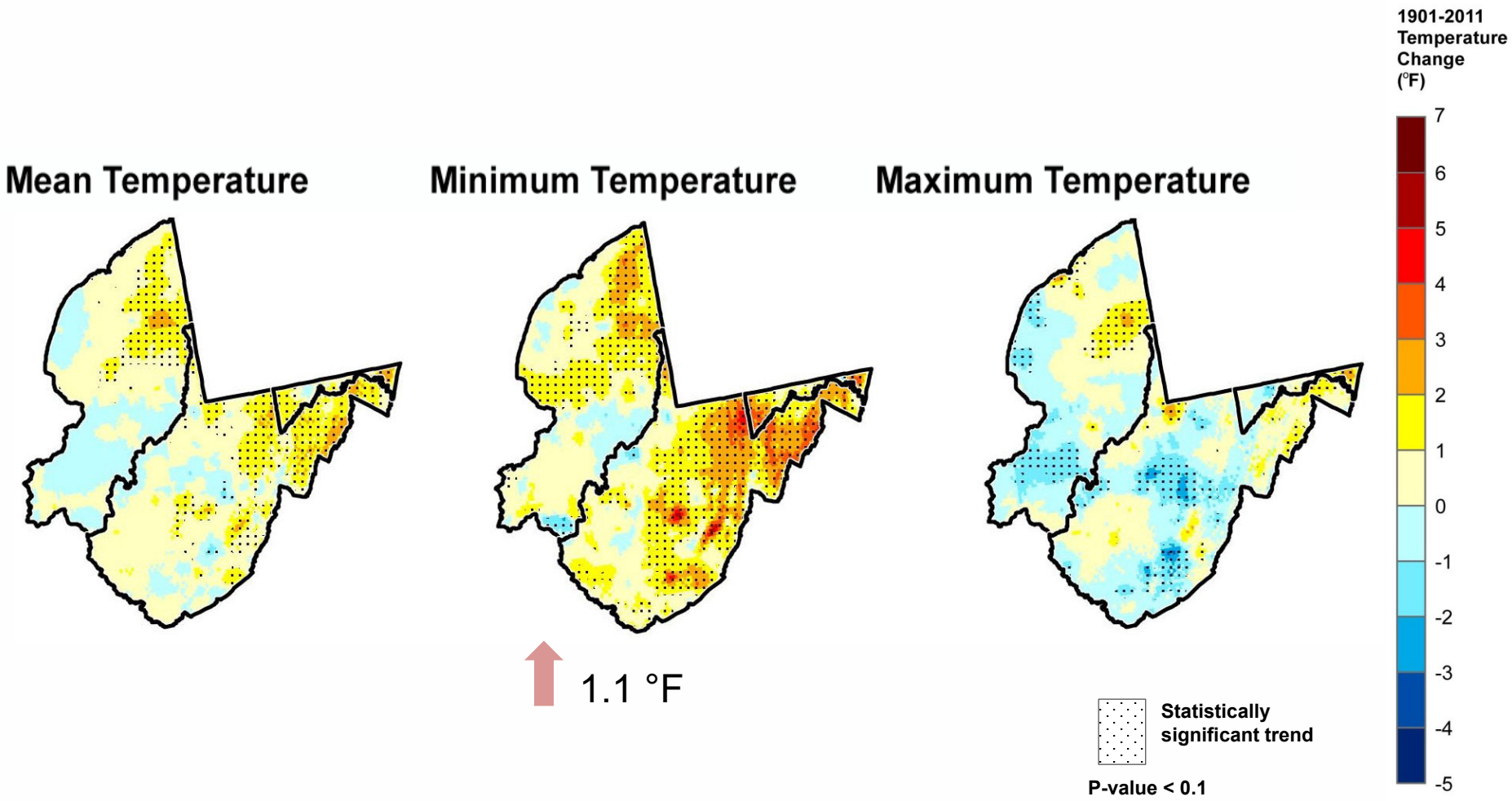
Low Vulnerability (medium evidence, medium-high agreement)

This ecosystem is the most resilient to heat and drought, with many of the species currently doing well, and projected to do well under future climate. Periodic conditions that limit regeneration may be buffered by oak's ability to resprout. Increased drought and fire are likely to benefit this ecosystem, discourage invasive species, and maintain an open structure that promotes oak and pine regeneration.

(Butler et al. 2016)

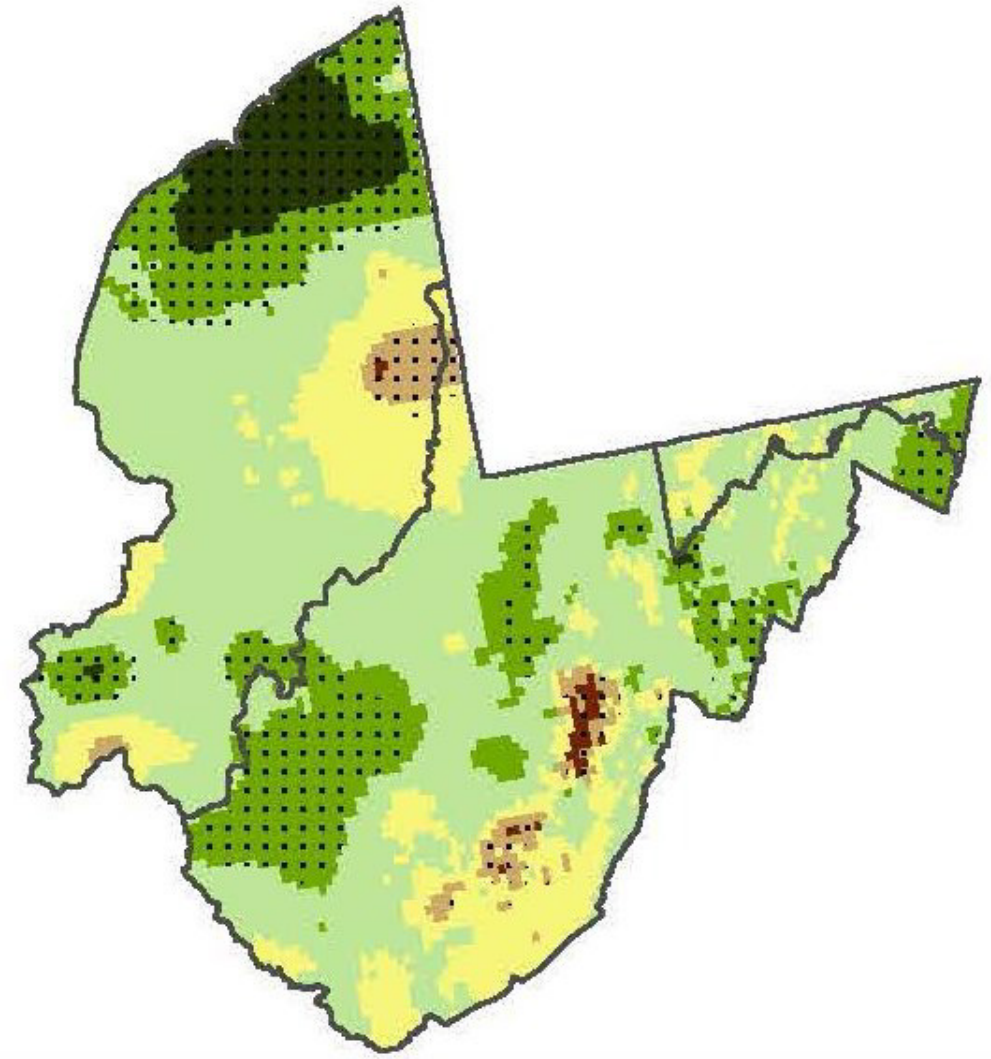
CFAES

Observed Annual Temperatures



www.climatewizard.org

Observed Annual Precipitation



1901-2011
Change in
Precipitation (in)

4
2
1
0
-1
-2
-4

Statistically
significant trend
P-value <
0.1

www.climatewizard.org

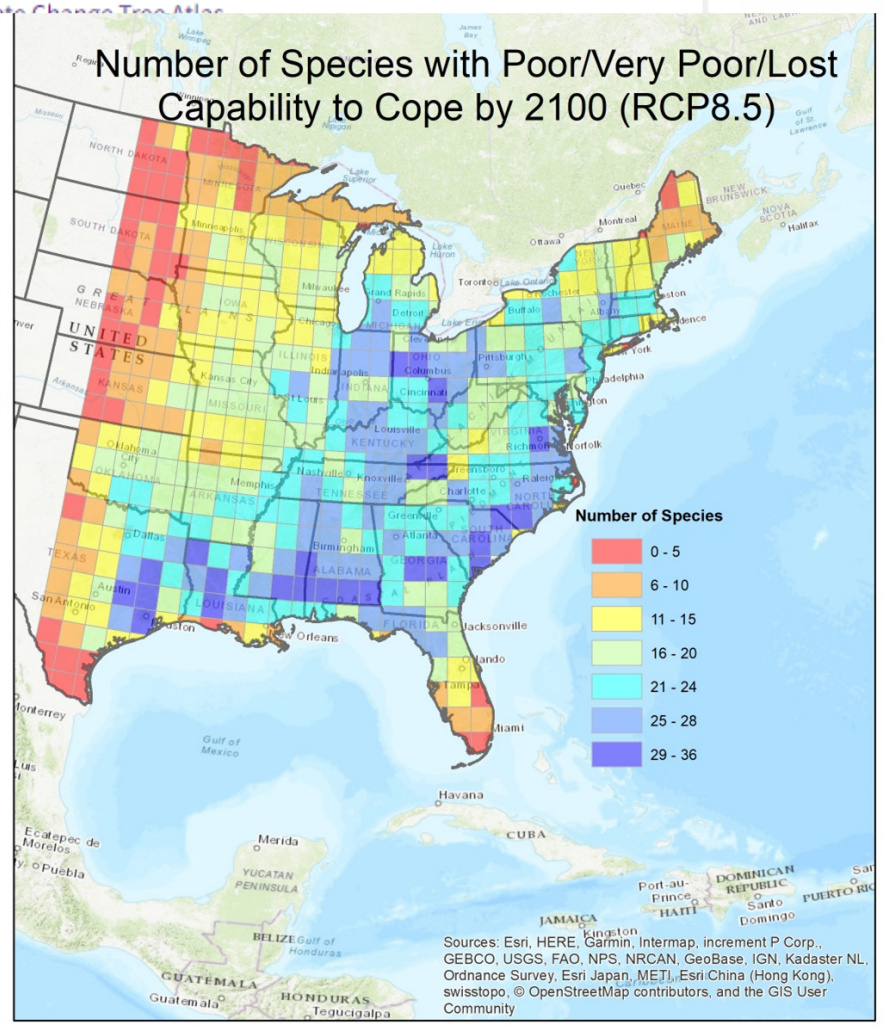
Regional Summary Tree Tables

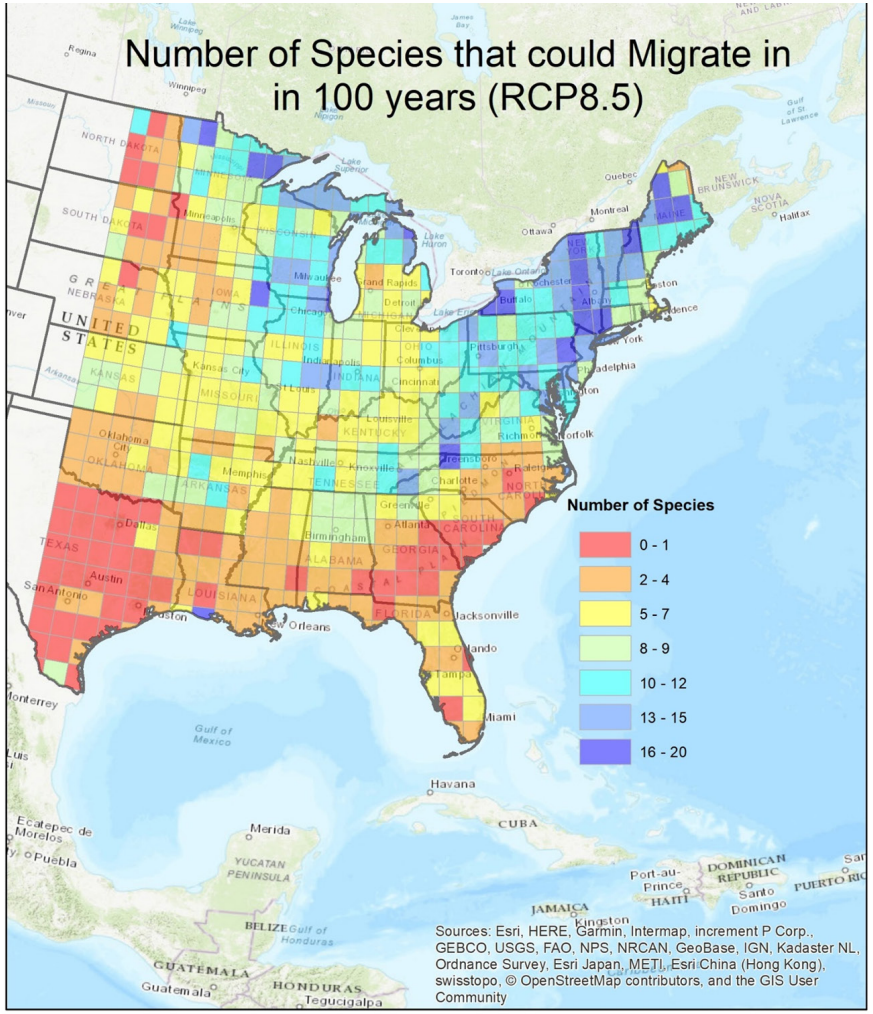
Current and Potential Future Habitat, Capability, and Migration −

Summaries for tree species are available for a variety of geographies, in both PDF and Excel format. These summaries are based on Version 4 of the Climate Change Tree Atlas

- National Forest Summaries
- National Park Summaries
- HUC6 Watersheds
- Ecoregional Vulnerability Assessments (EV
- USDA Forest Service EcoMap 2007 Sections

- Enable managers/publics to understand potential changes in tree species for each particular area
- *(Iverson et al. 2019)*



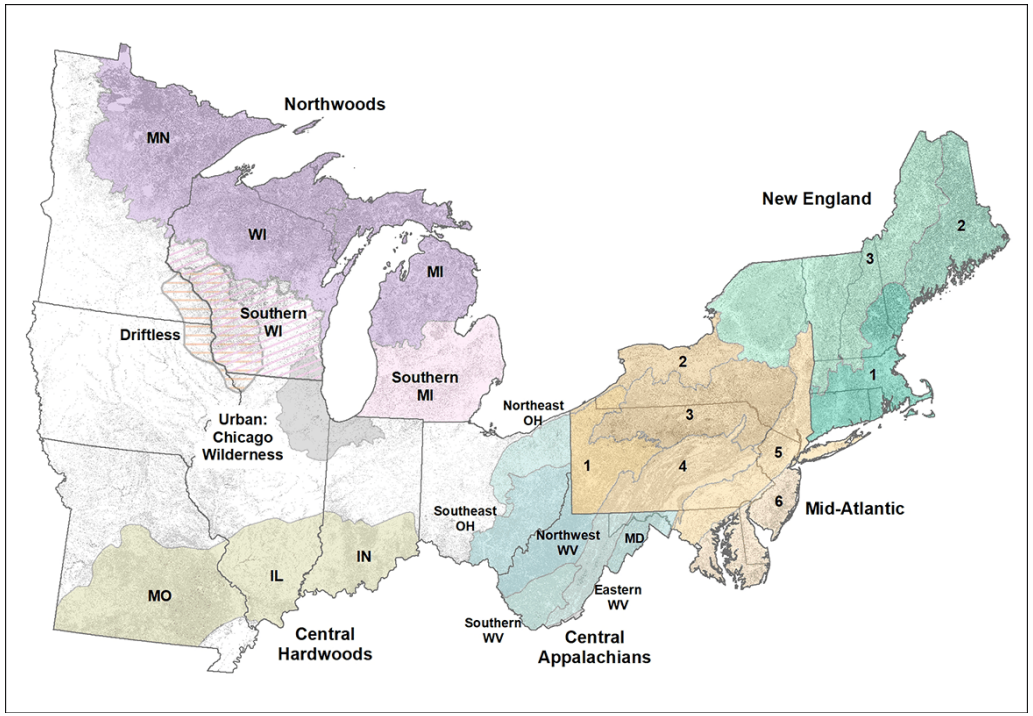


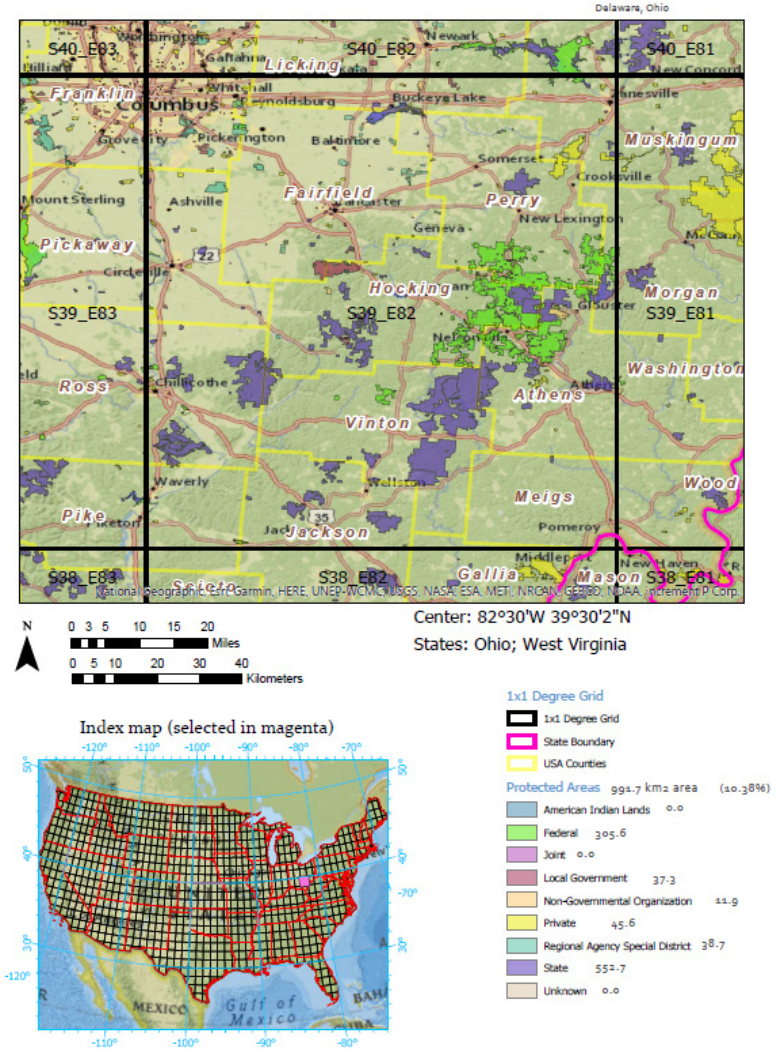
Regional Summary Tree Tables

Current and Potential Future Habitat, Capability, and Migration −

Summaries for tree species are available for a variety of geographies, in both PDF and Excel format. These summaries are based on Version 4 of the Climate Change Tree Atlas

- National Forest Summaries
- National Park Summaries
- HUC6 Watersheds
- Ecoregional Vulnerability Assessments (EVAS)
- USDA Forest Service EcoMap 2007 Sections
- National Climate Assessment (NCA) 2016 Regional Summaries
- 1 x 1 ° Grid Summaries
- Eastern United States
- Urban Areas





Consider overall patterns of climate change

CentralApps seOH

NIACS EVAS Region
Climate Change Atlas Tree Species
Current and Potential Future Habitat, Capability, and Migration

Landscape Change Research (
Iverson, Peters, Prasad, Matt
USFS Northern Research St
Delawar

	sq. km	sq. mi	FIA Plots
Area of Region	30,856	11,914	870

Species Information

The columns below provide breif summaries of the species associated with the region and described in the table on the next pages.

Genus	Species
Ash	4
Hickory	5
Maple	6
Oak	11
Pine	7
Other	47
	80

Abundance	
Abundant	5
Common	29
Rare	46
Absent	23
	103

Model Reliability		Adaptability
High	21	27
Medium	31	52
Low	40	18
FIA	12	
	104	97

Potential Change in Habitat Suitability	Scenario RCP45	Scenario RCP85
Increase	18	21
No Change	12	12
Decrease	38	35
New	12	14
Unknown	24	22
	104	104

Capability to Cope or Persist	Scenario RCP45	Scenario RCP85
Very Good	6	7
Good	13	21
Fair	16	5
Poor	9	13
Very Poor	23	21
FIA Only	5	5
Unknown	12	10
	84	82

Migration Potential	SHIFT RCP45	SHIFT RCP85
Likely	1	1
Infill	9	10
Migrate	4	7
	14	18

Potential Changes in Climate Variables

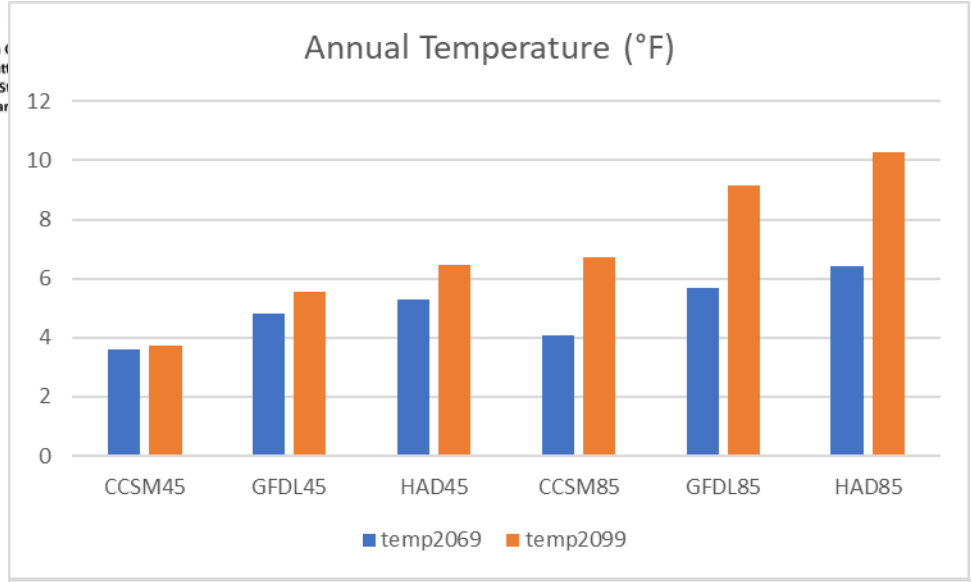
Temperature (°F)

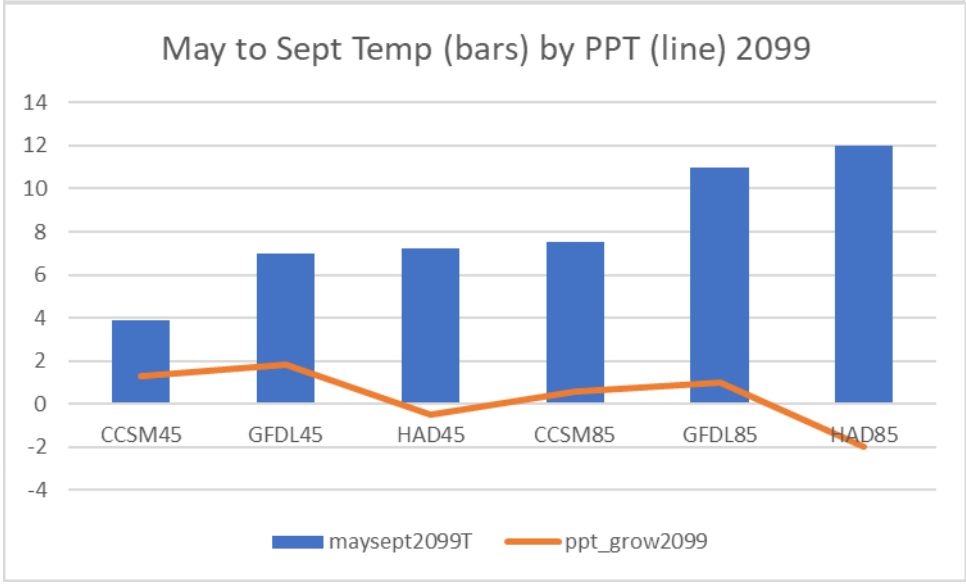
	Scenario	2009	2039	2069	2099
Annual Average	CCSM45	48.6	50.1	52.2	52.4
	CCSM85	48.6	50.6	52.7	55.4
	GFDL45	48.6	51.0	53.5	54.2
	GFDL85	48.6	51.4	54.3	57.8
	HAD45	48.6	51.0	53.9	55.1
	HAD85	48.6	51.3	55.1	58.9
Growing Season May—Sep	CCSM45	62.0	63.5	65.5	65.9
	CCSM85	62.0	64.0	66.2	69.6
	GFDL45	62.0	64.7	67.9	69.0
	GFDL85	62.0	65.4	69.1	73.0
	HAD45	62.0	64.9	67.6	69.3
	HAD85	62.0	65.0	69.9	74.0
Coldest Month Average	CCSM45	27.7	29.0	30.4	30.8
	CCSM85	27.7	30.0	30.9	32.3
	GFDL45	27.7	30.7	31.3	31.9
	GFDL85	27.7	30.3	31.2	32.2
	HAD45	27.7	28.4	30.6	30.7
	HAD85	27.7	29.3	31.0	32.9
Warmest Month Average	CCSM45	66.6	68.1	69.2	69.6
	CCSM85	66.6	68.7	70.1	71.9
	GFDL45	66.6	69.3	71.2	72.0
	GFDL85	66.6	70.2	72.4	74.6
	HAD45	66.6	69.8	72.0	73.1
	HAD85	66.6	70.9	74.4	77.0

Precipitation (in)

	Scenario	2009	2039	2069	2099
Annual Total	CCSM45	33.6	35.7	36.3	37.2
	CCSM85	33.6	35.8	37.0	39.4
	GFDL45	33.6	37.0	38.4	40.0
	GFDL85	33.6	34.9	39.1	40.8
	HAD45	33.6	34.8	35.1	34.8
	HAD85	33.6	34.9	32.5	35.3
Growing Season May—Sep	CCSM45	15.8	16.7	16.6	17.1
	CCSM85	15.8	15.9	16.2	16.4
	GFDL45	15.8	17.3	16.9	17.6
	GFDL85	15.8	15.8	16.5	16.8
	HAD45	15.8	16.8	14.5	15.3
	HAD85	15.8	15.9	13.2	13.9

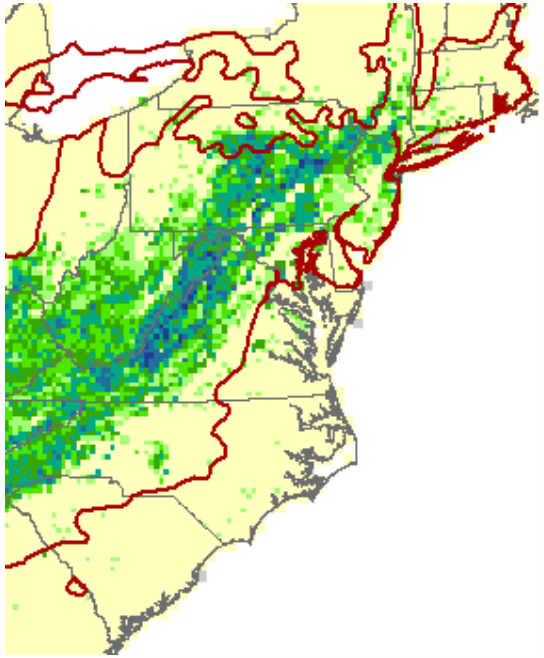
NOTE: For the six climate variables, four 30-year periods are used to indicate six potential future trajectories. The period ending in 2009 is based on modeled observations from the PRISM Climate Group and the three future periods were obtained from the NASA NEX-DCP30 dataset. Future climate projections from three models under two emission scenarios show estimates of each climate variable within the region. The three models are CCSM4, GFDL CM3, and HadGEM2-ES and the emission scenarios are the 4.5 and 8.5 RCP. The average value for the region is reported, even though locations within the region may vary substantially based on latitude, elevation, land-use, or other factors.

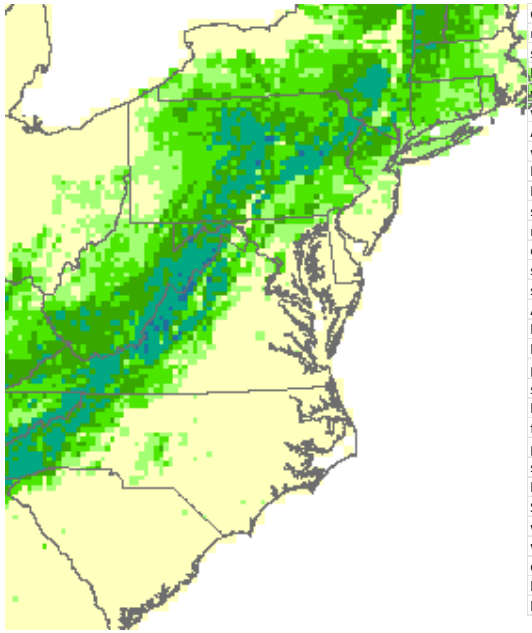




Common Name	Scientific Name	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO	
red maple	Acer rubrum	WDH	High	82	1144.1	11.3	Lg. dec.	Lg. dec.	High	Abundant	Good	Good				1
sugar maple	Acer saccharum	WDH	High	70.4	1021.4	10.1	Sm. dec.	Sm. dec.	High	Abundant	Good	Good				1
black cherry	Prunus serotina	WDL	Medium	74.8	906.5	9.8	Lg. dec.	Lg. dec.	Low	Abundant	Poor	Poor				0
yellow-poplar	Liriodendron tulipifera	WDH	High	67.3	861.7	10.6	Sm. dec.	Lg. dec.	High	Abundant	Good	Good				1
white oak	Quercus alba	WDH	Medium	61	592.9	7.5	Sm. inc.	No change	High	Abundant	Very Good	Very Good				1
American elm	Ulmus americana	WDH	Medium	66.8	490.5	5.7	Sm. dec.	No change								
white ash	Fraxinus americana	WDL	Medium	63.9	428.4	5.3	No change	No change								
black locust	Robinia pseudoacacia	NDH	Low	45.9	398.2	6.7	Lg. dec.	Sm. dec.								
black oak	Quercus velutina	WDH	High	55	318.5	4.6	Sm. inc.	Lg. inc.								
sassafras	Sassafras albidum	WSL	Low	58.8	316.9	4.4	No change	Sm. dec.								
northern red oak	Quercus rubra	WDH	Medium	54.4	297.8	4.1	No change	No change								
chestnut oak	Quercus prinus	NDH	High	27.7	261.7	7.1	Sm. dec.	Sm. dec.								
slippery elm	Ulmus rubra	WSL	Low	55.3	235.1	3.3	No change	No change								
shagbark hickory	Carya ovata	WSL	Medium	50.1	233.3	3.9	No change	Sm. dec.	Medium	Common	Fair	Poor				1
American beech	Fagus grandifolia	WDH	High	44.8	220.5	4.0	No change	Sm. dec.	Medium	Common	Fair	Poor				1
black walnut	Juglans nigra	WDH	Low	39	203.4	4.3	Sm. inc.	Sm. inc.	Medium	Common	Good	Good				1
bigtooth aspen	Populus grandidentata	NSL	Medium	27.3	174.4	5.9	Lg. dec.	Lg. dec.	Medium	Common	Poor	Poor				0
pignut hickory	Carya glabra	WDL	Medium	39.4	170.9	3.3	Sm. inc.	Sm. inc.	Medium	Common	Good	Good				1
sycamore	Platanus occidentalis	NSL	Low	27.2	170.8	4.7	Sm. inc.	Sm. inc.	Medium	Common	Good	Good				1
blackgum	Nyssa sylvatica	WDL	Medium	43.7	159.9	3.0	Sm. inc.	Sm. inc.	High	Common	Very Good	Very Good				1
florida maple	Acer barbatum	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat		Migrate +		3
pecan	Carya illinoinensis	NSH	Low	0	0	0	New Habitat	New Habitat	Low	Absent	New Habitat	New Habitat		Migrate ++		3
sugarberry	Celtis laevigata	NDH	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat	Migrate +	Migrate ++		3
blackjack oak	Quercus marilandica	NSL	Medium	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate ++		3
Shumard oak	Quercus shumardii	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +		3
winged elm	Ulmus alata	WDL	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat	Migrate +	Migrate ++		3
water oak	Quercus nigra	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat		Migrate +		3
cittamwood/gum bumelia	Sideroxylon lanuginosum ssp	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat				3
black hickory	Carya texana	NDL	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat				3
bluejack oak	Quercus incana	NSL	Low	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat				3

104 total species reported on
80 species present now according to plots
~35 decline and 20 increase in habitat by 20%
~13 species could have new habitat by 2100
6 species could migrate in within 100 yrs

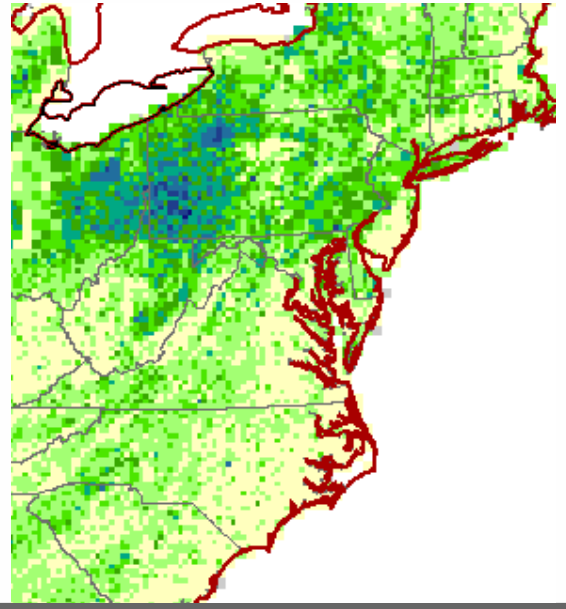


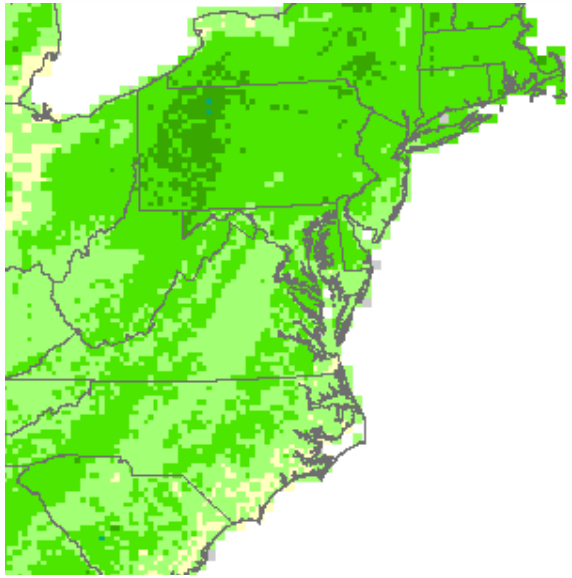


Common Name	Scientific Name	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO
red maple	Acer rubrum	WDH	High	82	1144.1	11.3	Lg. dec.	Lg. dec.	High	Abundant	Good	Good			1
sugar maple	Acer saccharum	WDH	High	70.4	1021.4	10.1	Sm. dec.	Sm. dec.	High	Abundant	Good	Good			1
black cherry	Prunus serotina	WDL	Medium	74.8	906.5	9.8	Lg. dec.	Lg. dec.	Low	Abundant	Poor	Poor			0
yellow-poplar	Liriodendron tulipifera	WDH	High	67.3	861.7	10.6	Sm. dec.	Lg. dec.	High	Abundant	Good	Good			1
white oak	Quercus alba	WDH	Medium	61	592.9	7.5	Sm. inc.	No change	High	Abundant	Very Good	Very Good			1
American elm	Ulmus americana	WDH	Medium	66.8	490.5	5.7	Sm. dec.	No change	Medium	Common	Poor	Fair			1
white ash	Fraxinus americana	WDL	Medium	63.9	428.4	5.3	No change	No change	Low	Common	Poor	Poor			0
black locust	Robinia pseudoacacia	NDH	Low	45.9	398.2	6.7	Lg. dec.	Sm. dec.	Medium	Common	Poor	Poor			0
black oak	Quercus velutina	WDH	High	55	318.5	4.6	Sm. inc.	Lg. inc.	Medium	Common	Good	Very Good			1
sassafras	Sassafras albidum	WSL	Low	58.8	316.9	4.4	No change	Sm. dec.	Medium	Common	Fair	Poor			1
northern red oak	Quercus rubra	WDH	Medium	54.4	297.8	4.1	No change	No change	High	Common	Good	Good			1
chestnut oak	Quercus prinus	NDH	High	27.7	261.7	7.1	Sm. dec.	Sm. dec.	High	Common	Fair	Fair			1
slippery elm	Ulmus rubra	WSL	Low	55.3	235.1	3.3	No change	No change	Medium	Common	Fair	Fair			1
shagbark hickory	Carya ovata	WSL	Medium	50.1	233.3	3.9	No change	Sm. dec.	Medium	Common	Fair	Poor			1
American beech	Fagus grandifolia	WDH	High	44.8	220.5	4.0	No change	Sm. dec.	Medium	Common	Fair	Poor			1
black walnut	Juglans nigra	WDH	Low	39	203.4	4.3	Sm. inc.	Sm. inc.	Medium	Common	Good	Good			1
bigtooth aspen	Populus grandidentata	NSL	Medium	27.3	174.4	5.9	Lg. dec.	Lg. dec.	Medium	Common	Poor	Poor			0
pignut hickory	Carya glabra	WDL	Medium	39.4	170.9	3.3	Sm. inc.	Sm. inc.	Medium	Common	Good	Good			1
sycamore	Platanus occidentalis	NSL	Low	27.2	170.8	4.7	Sm. inc.	Sm. inc.	Medium	Common	Good	Good			1
blackgum	Nyssa sylvatica	WDL	Medium	43.7	159.9	3.0	Sm. inc.	Sm. inc.	High	Common	Very Good	Very Good			1
florida maple	Acer barbatum	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat		Migrate +	3
pecan	Carya illinoinensis	NSH	Low	0	0	0	New Habitat	New Habitat	Low	Absent	New Habitat	New Habitat		Migrate ++	3
sugarberry	Celtis laevigata	NDH	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat	Migrate +	Migrate ++	3
blackjack oak	Quercus marilandica	NSL	Medium	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate ++	3
Shumard oak	Quercus shumardii	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +	3
winged elm	Ulmus alata	WDL	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat	Migrate +	Migrate ++	3
water oak	Quercus nigra	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat		Migrate +	3
cittamwood/gum bumelia	Sideroxylon lanuginosum ssp	NSL	Low	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat			3
black hickory	Carya texana	NDL	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3
bluejack oak	Quercus incana	NSL	Low	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3

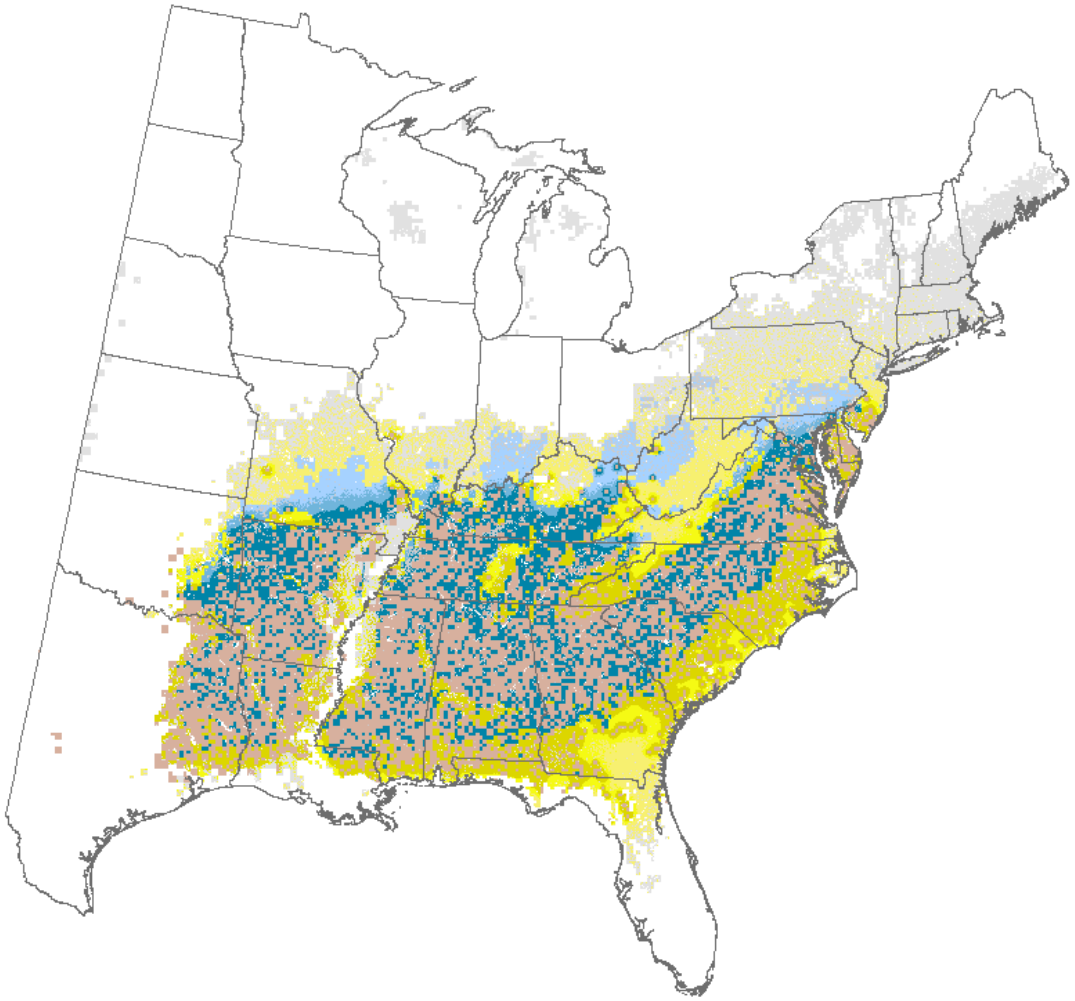
Chestnut Oak
Current and habitat 8.5

Black Cherry
Current and habitat 8.5





Southern Red Oak and example of potential migration

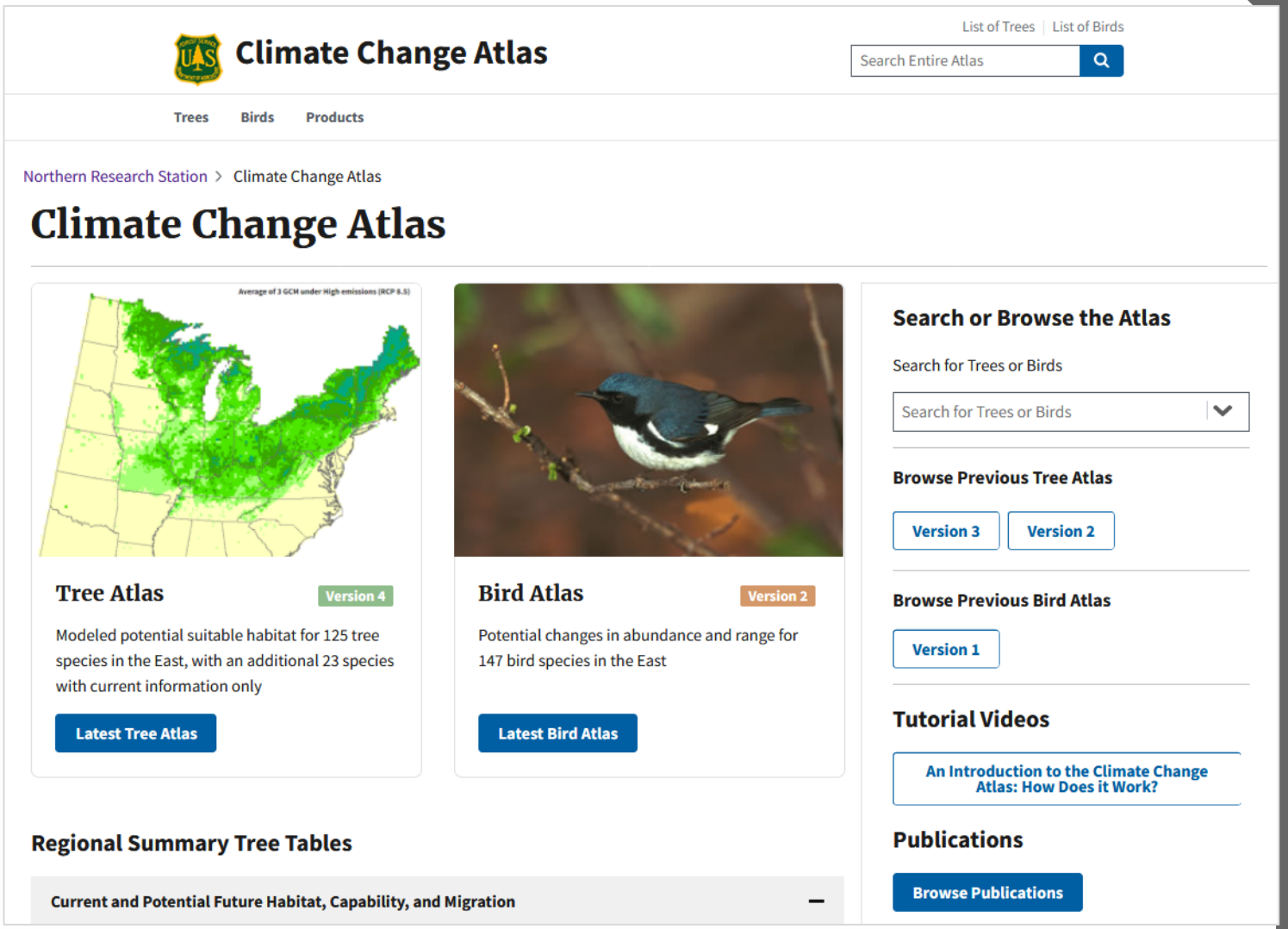


Common Name	Scientific	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO	N
chestnut oak	Quercus p	NDH	High	65.1	1601.0	17.6	Sm. dec.	Sm. dec.	High	Abundant	Good	Good			1	1
yellow-poplar	Liriodend	WDH	High	62.5	1107.4	11.6	Sm. dec.	Lg. dec.	High	Abundant	Good	Good			1	2
white oak	Quercus a	WDH	Medium	72.1	904.1	7.8	No change	No change	High	Abundant	Very Good	Very Good			1	3
red maple	Acer rubr	WDH	High	84.6	844.8	7.0	No change	Sm. dec.	High	Abundant	Very Good	Good			1	4
Virginia pine	Pinus virg	NDH	High	54.8	551.3	6.4	No change	Sm. dec.	Medium	Abundant	Good	Fair			1	5
northern red oak	Quercus r	WDH	Medium	64.5	532.0	6.0	Sm. inc.	Sm. inc.	High	Abundant	Very Good	Very Good			1	6
blackgum	Nyssa syl	WDL	Medium	71.4	467.2	4.5	No change	No change	High	Common	Good	Good			1	7
scarlet oak	Quercus c	WDL	Medium	50.6	419.3	5.0	Sm. dec.	Sm. dec.	Medium	Common	Poor	Poor			0	8
eastern redcedar	Juniperus	WDH	Medium	37.4	380.2	6.6	Lg. inc.	Lg. inc.	Medium	Common	Very Good	Very Good			1	9
black oak	Quercus v	WDH	High	56.5	374.8	4.8	Sm. inc.	Sm. inc.	Medium	Common	Good	Good			1	10
black locust	Robinia p	NDH	Low	57.9	359.1	4.6	Sm. dec.	No change	Medium	Common	Poor	Fair			1	11
pignut hickory	Carya glat	WDL	Medium	71.6	346.4	3.4	No change	Sm. dec.	Medium	Common	Fair	Poor			1	12
eastern white pine	Pinus stro	WDH	High	36.1	342.5	7.9	Sm. dec.	Sm. dec.	Low	Common	Poor	Poor			0	13
black cherry	Prunus se	WDL	Medium	43.5	307.9	4.9	No change	No change	Low	Common	Poor	Poor			0	14
loblolly pine	Pinus tae	WDH	High	7.3	298.1	16.4	No change	Sm. inc.	Medium	Common	Fair	Good	Infill +	Infill ++	1	15
white ash	Fraxinus a	WDL	Medium	52.6	250.3	3.6	No change	Sm. inc.	Low	Common	Poor	Fair			1	16
mockernut hickory	Carya alba	WDL	Medium	44.1	219.2	3.9	Sm. inc.	Lg. inc.	High	Common	Very Good	Very Good			1	17
ailanthus	Ailanthus	NSL	FIA	36.3	209.0	4.6	Unknown	Unknown	NA	Common	NNIS	NNIS			0	18
sweet birch	Betula le	NDH	High	36.2	179.7	4.1	Sm. dec.	Lg. dec.	Low	Common	Poor	Very Poor			0	19
longleaf pine	Pinus pal	NSH	Medium	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habitat		Migrate +	3	72
northern white-cedar	Thuja occ	WSH	High	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habitat			3	73
florida maple	Acer barb	NSL	Low	0	0	0	New Habi	New Habi	High	Absent	New Habi	New Habi	Migrate +	Migrate +	3	74
yellow buckeye	Aesculus	NSL	Low	0	0	0	New Habi	New Habi	Low	Absent	New Habi	New Habi	Migrate +		3	75
pecan	Carya illin	NSH	Low	0	0	0	New Habi	New Habi	Low	Absent	New Habi	New Habitat		Migrate +	3	76
black hickory	Carya tex	NDL	High	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habitat			0	77
sugarberry	Celtis lae	NDH	Medium	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habi	Migrate +	Migrate ++	3	78
American holly	Ilex opac	NSL	Medium	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habi	Likely +	Likely +	3	79
mountain or Fraser m	Magnolia	NSL	Low	0	0	0	New Habi	New Habi	Low	Absent	New Habi	New Habitat			0	80
overcup oak	Quercus l	NSL	Medium	0	0	0	New Habi	New Habi	Low	Absent	New Habi	New Habitat		Migrate +	3	81
water oak	Quercus r	WDH	High	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habi	Migrate +	Migrate ++	3	82
Shumard oak	Quercus s	NSL	Low	0	0	0	New Habi	New Habi	High	Absent	New Habi	New Habitat			3	83
bluejack oak	Quercus i	NSL	Low	0	0	0	New Habi	New Habi	Medium	Absent	New Habi	New Habitat		Migrate +	3	84

Thank you!

- Climate change is altering the distribution and dynamics of forest tree and bird species
- Models can help us anticipate changes and devise management strategies.

Questions?



www.fs.fed.us/nrs/atlas