Vulnerability Assessment

- Series of reports for **natural resource professionals**
- Focus on **tree species and forest ecosystems**
- Examine a **range** of future climates
- Evaluate **key ecosystem vulnerabilities** to climate change
- Does **not make recommendations** or assess vulnerability to changes in mgmt., land use, policy

Reports, Summaries and StoryMaps: 
[www.forestadaptation.org/vulnerability-assessment](http://www.forestadaptation.org/vulnerability-assessment)
Vulnerability Assessment

- Current Forest Condition
- Observed Climate Change
- Future Climate Change
- Climate Change Impacts on Forests
- Forest Ecosystem Vulnerability
- Implications for Forest Management

Climate Change Tree Atlas: suitable habitat

LINKAGES: species establishment

LANDIS: productivity and composition

https://tinyurl.com/EVAS-MAR
Future Modeling Introduction

We used climate data that was downscaled by ATM OS/K. Hayhoe

Three time periods
  2010 to 2039
  2040 to 2069
  2070 to 2099

7.5-mile grid

Annual and Seasonal changes

Temperature: Mean, Minimum, Maximum

Precipitation

Stoner et al. 2012
Projected Annual Temperature

PCM B1 and GFDL A1FI diverge more as time progresses.

Similar patterns across seasons.
Projected Changes in Annual Temperature

2010-2039

- PCM B1: 0.9 °F
- GFDL A1FI: 1.9 °F

2040-2069

- PCM B1: 1.8 °F
- GFDL A1FI: 5.2 °F

2070-2099

- PCM B1: 2.2 °F
- GFDL A1FI: 7.6 °F
Projected Annual Precipitation

**GFDL A1FI: 2070-2099**
- 2.6 in

**PCM B1: 2070-2099**
- 2.1 in
Seasonal Precipitation 2070-2099

PCM B1

Winter

0.6 in

Spring

0.3 in

GFDL A1FI

2.1 in

1.5 in
Seasonal Precipitation 2070-2099

**PCM B1**
- **Summer**: Increase of 1.6 in
- **Fall**: Decrease of 0.5 in

**GFDL A1FI**
- **Summer**: Decrease of 2.3 in
- **Fall**: Increase of 1.3 in
Extreme Temperatures

Coldest Days

Hottest Days

RCP 2.6

RCP 8.5

NCA 2014
What does this mean for forests?
Projected decreases in snow fall, cover, and depth

- 20-50% decrease in Days with Snowfall
- 20-50% decrease in amount
- Greatest loss in December/January

https://nelson.wisc.edu/ccr/resources/dynamical-downscaling/index.php
Projected decreases in snowfall, cover, and depth

- 20-50% decreases in snowfall
- Greatest loss in December/January

Decreased snowpack

- Increased soil freeze-thaw cycles can damage roots and alter soil processes

What may be at risk: The ability to do winter timber harvest when it is preferred to prevent damage to forest soils and residual forest; tree species sensitive to soil freeze-thaw
Shorter Winter (More Rain)

More rain
- Warmer temperatures
- Increased precipitation
- Extreme rain events

Earlier peak stream flows
- Flashiness and episodic high flows may increase

More rain
- Warmer temperatures
- Increased precipitation
- Extreme rain events

Earlier peak stream flows
- Flashiness and episodic high flows may increase

What may be at risk: Increased erosion/sedimentation on susceptible sites; culvert washouts and road damage from extreme events; aquatic habitats and species
Longer Growing Season

Warmer temps result in longer growing seasons
- Evidence of phenological shifts
- Projected to increase 3-7+ more weeks

Longer period for plant growth

What may be at risk: Early bud break and frost damage from increased freeze-thaw cycles

Changes in Forest Composition

Many northern/boreal species are projected to decline in the region—contract to more northerly and higher-elevation locations.

Many species common farther south are expected to see increased and new habitat within the region.
Changes in Forest Composition

Current Habitat

Low Emissions

High Emissions

Black Cherry: Decline
2070-2099

fs.fed.us/nrs/atlas
Changes in Forest Composition

Southern Red Oak: Increase 2070-2099

fs.fed.us/nrs/atlas
Changes in Forest Composition

![Forest Composition Diagram](https://tinyurl.com/Mid-Atlantic-Species)
### More Tree Atlas Results

#### Potential “losers”
- American beech
- Balsam fir
- Black maple
- Eastern hemlock
- Eastern white pine
- Northern white-cedar

#### Potential “winners”
- Black walnut
- Chinkapin oak
- Eastern redcedar
- Flowering dogwood
- Pin oak
- Post oak
- Scarlet oak
- Shagbark hickory
- Southern red oak
- Sycamore

#### Mixed model results
- Cucumber tree
- Silver maple
- Sourwood
- Table Mountain pine
- Tulip tree

#### New habitat under GFDL
- Black hickory
- Cedar elm
- Laurel oak
- Longleaf pine
- Ohio buckeye
- Overcup oak
- Shumard oak
- Slash pine
- Sugarberry
- Turkey oak
Changes in Forest Composition

CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES
CENTRAL APPALACHIANS

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.

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.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>ADDITIONAL CONSIDERATIONS - 10 MOST COMMON SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAY DECREASE</td>
<td></td>
</tr>
<tr>
<td>American basswood</td>
<td>Tolerates shade, susceptible to fire</td>
</tr>
<tr>
<td>American elm</td>
<td>Grow on a variety of sites, susceptible to Dutch elm disease</td>
</tr>
<tr>
<td>Black cherry</td>
<td>Susceptible to Insect pests and disease, somewhat drought tolerant</td>
</tr>
<tr>
<td>Black locust</td>
<td>Early-successional colonizer, susceptible to insect pests</td>
</tr>
<tr>
<td>Chestnut oak</td>
<td>Establishes from seed or sprout, adapted to fire</td>
</tr>
<tr>
<td>Eastern white pine</td>
<td>Good disperser, but susceptible to drought and insects</td>
</tr>
<tr>
<td>Flowering dogwood</td>
<td>Shade tolerant</td>
</tr>
<tr>
<td>Red maple</td>
<td>Competitive colonizer on diverse sites, tolerant of disturbance</td>
</tr>
<tr>
<td>Sassafras</td>
<td>Early-successional colonizer, susceptible to fire and drought</td>
</tr>
<tr>
<td>Scarlet oak</td>
<td>Establishes from seed or sprout, susceptible to fire and disease</td>
</tr>
<tr>
<td>Slippery elm</td>
<td>Shade-tolerant, susceptible to disease and fire and topkill</td>
</tr>
<tr>
<td>Sugar maple</td>
<td>Grows across a variety of sites, tolerates shade</td>
</tr>
<tr>
<td>Sweet chestnut</td>
<td>Susceptible to drought, fire topkill, and insects</td>
</tr>
<tr>
<td>Tulip tree</td>
<td>Competitive colonizer tolerant of diverse sites</td>
</tr>
<tr>
<td>White ash</td>
<td>Emerald ash borer causes mortality</td>
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<td>Black oak</td>
<td>Drought tolerant, susceptible to insect pests and diseases</td>
</tr>
<tr>
<td>Black walnut</td>
<td>Good disperser, but intolerant of shade and drought</td>
</tr>
<tr>
<td>Balsam Fir</td>
<td>Drought and shade tolerant, competitive in a range of site conditions</td>
</tr>
<tr>
<td>Eastern hop hornbeam</td>
<td>Grows across a variety of sites, tolerates shade</td>
</tr>
<tr>
<td>Mockernut hickory</td>
<td>Susceptible to fire topkill</td>
</tr>
<tr>
<td>Serviceberry</td>
<td>Competitive colonizer, susceptible to drought</td>
</tr>
<tr>
<td>Virginia pine</td>
<td>Irresistant to shade and pollution</td>
</tr>
<tr>
<td>White oak</td>
<td>Fire-adapted, grows on a variety of sites</td>
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</tbody>
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www.forestadaptation.org

Forestadaptation.org
Changes in Forest Composition

**CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES**

**Coastal Plain (Subregion 6)**

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**CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES**

**Piedmont (Subregion 5)**

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**CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES**

**Ridge and Valley (Subregion 4)**

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**FORESTADAPTATION.ORG**
Many common tree species are projected to have reduced suitability in the future.

Changes will occur slowly—not instant dieback.

Mature and established trees should fare better.

Immense lags to occupy habitats.

Critical factors: competition, management, & disturbance.

**Risk may be greatest:**
- Location is relatively near the southern extent of species range
- Trees are projected to decline and located on a marginal site
- Forest is composed of few species, esp. those projected to decline
- Something is “missing” from the ecosystem
- Other factors cause additional stress
Interactions make all the difference.

- Chronic stress
- Disturbances
- Invasive species
- Insect pests
- Forest diseases

Image: Bartlett Tree Experts
Extreme Weather Events

Extreme events may become more frequent or severe

- Heavy precipitation
- Flooding
- Ice storms
- Heat waves/droughts
- Wind storms
- Hurricanes

“Events” are not well modeled

What may be at risk: Depends greatly on site conditions and susceptibility to different types of disturbance
Interactions: Wildfire

Future climate conditions suggest increased risk of fire.

Wildfire may increase:
- Warmer/drier summers
- Increased stress or mortality from less suitable conditions
- Shift toward fire-associated species like oaks and pines

Wildfire may not change:
- Spring/early summer moisture
- Current regeneration of more mesic species
- Spatial patterns of land use and fragmentation
- Fire suppression

What may be at risk: Fire-dependent forests or areas of tree mortality when fire is not suppressed.

Clark et al. 2014, Guyette et al. 2014
Interactions: Forest Health

Increased damage from forest insects & diseases

**Indirect:** Stress from other impacts increases susceptibility

**Direct:**
- Pests migrating northward
- Decreased probability of cold lethal temperatures
- Accelerated lifecycles

Risk may be greatest: Presence of host species; pest is nearby; other factors reduce that forest vigor

Interactions: Invasive Plants

Increased habitat for many noxious plants

**Indirect:** Stress or disturbance from other impacts can affect the potential for invasion or success

**Direct:**
- Expanded ranges under warmer conditions
- Increased competitiveness from ability of some plants to take advantage of elevated CO₂

**Risk may be greatest:** Presence of invasive species nearby; other factors that reduce forest/understory vigor

Ecosystem Vulnerability
Vulnerability Process

Place-based, model-informed, expert driven, transparent

Modified from Swanston and Janowiak 2012
# Mid-Atlantic Vulnerability Ratings

<table>
<thead>
<tr>
<th>Forest community</th>
<th>Potential impacts</th>
<th>Adaptive capacity</th>
<th>Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montane Spruce-Fir</td>
<td>Negative</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Northern Hardwood</td>
<td>Moderate-Negative</td>
<td>Moderate</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>Central Oak-Pine</td>
<td>Moderate-Positive</td>
<td>Moderate-High</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Woodland, Glades, and Barrens</td>
<td>Positive</td>
<td>Moderate-High</td>
<td>Low</td>
</tr>
<tr>
<td>Lowland and Riparian Hardwood</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Lowland Conifer</td>
<td>Negative</td>
<td>Moderate-Low</td>
<td>High</td>
</tr>
<tr>
<td>Coastal Plain Swamp</td>
<td>Moderate</td>
<td>Moderate-High</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Coastal Plain Tidal Swamp</td>
<td>Moderate-Negative</td>
<td>Moderate-Low</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>Coastal Plain Oak-Pine-Hardwood</td>
<td>Moderate-Positive</td>
<td>High</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Coastal Plain Pine-Oak Barrens</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Coastal Plain Maritime Forest</td>
<td>Negative</td>
<td>Moderate-Low</td>
<td>High</td>
</tr>
</tbody>
</table>
High Vulnerability: Lowland Conifer

- Changes in hydrologic regime: floods and droughts
- Tree susceptibility to insect infestations may increase as trees become moisture-stressed
- Most species projected to decline, including balsam fir, black ash, black spruce, eastern hemlock, eastern white pine, red spruce, tamarack, and northern white-cedar
- As the keystone conifers decline, the identity of this forest community may be severely compromised
Low Vulnerability: Woodland, glades, barrens

- Exist in the hottest, driest, and most exposed sites
- Warmer, drier summers are likely to increase the risk of drought and fire in these locations, which could help maintain open conditions
- Most dominant species are projected to increase or remain stable, including eastern redcedar, eastern redbud, hackberry, northern red oak, pignut hickory, pitch pine, scrub oak, Virginia pine, and white oak.
Story Map: Mid-Atlantic Forests & CC

Online Now! https://tinyurl.com/MAstorymap
Questions???