Conserving your legacy: managing hardwood forests in uncertain times

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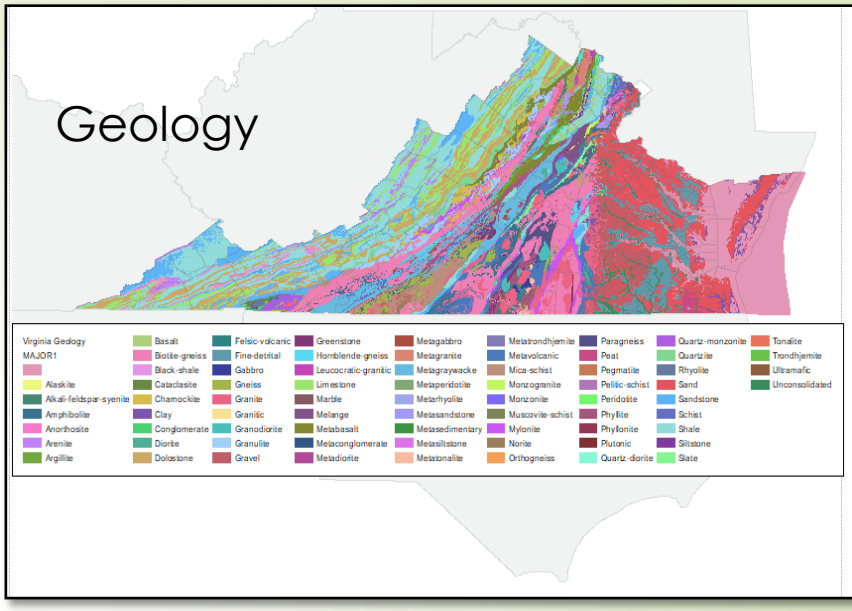
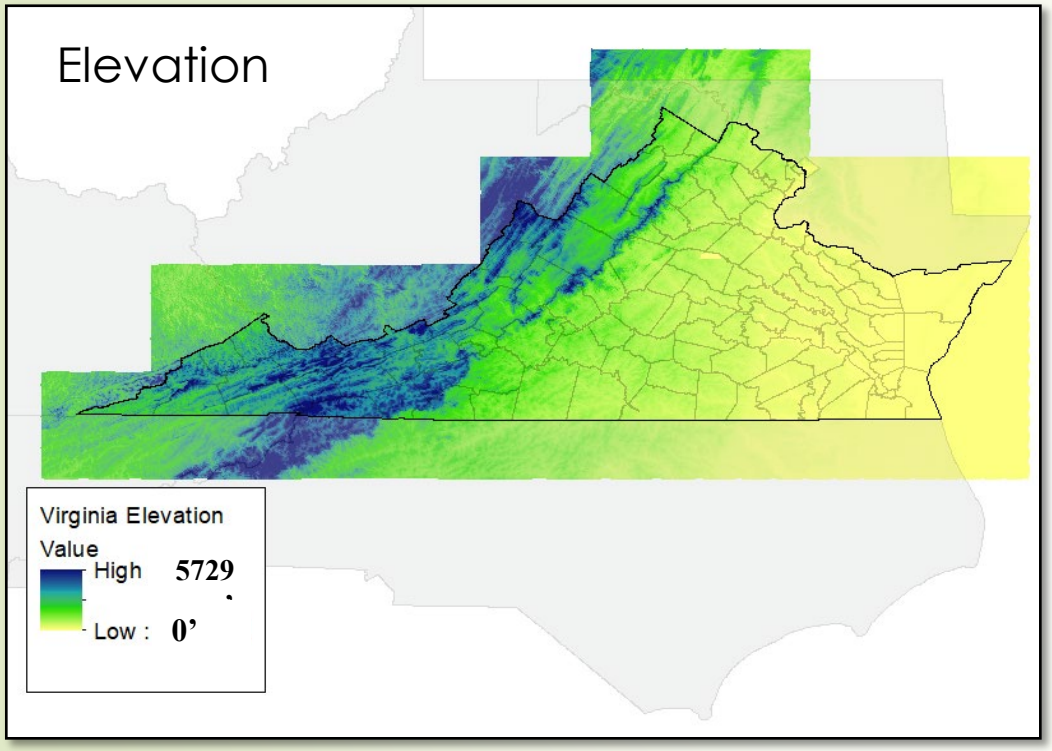
Presentation roadmap

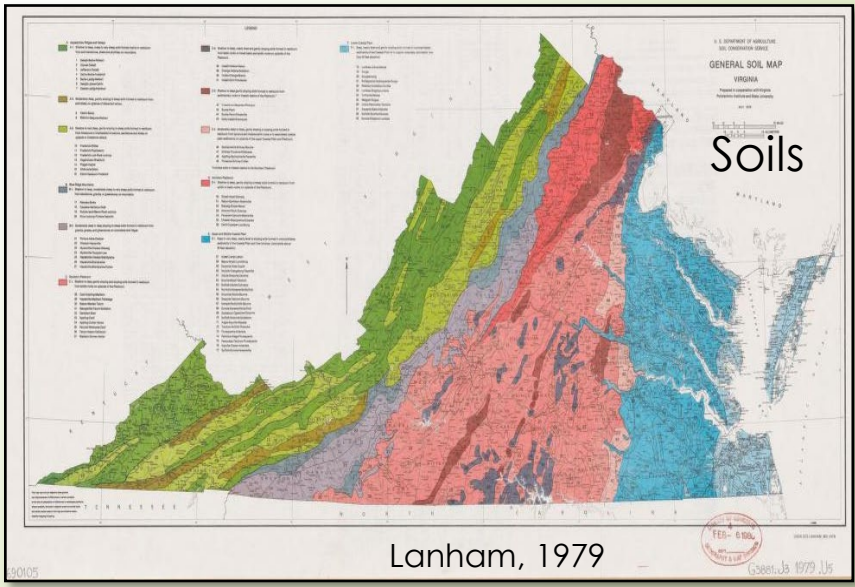
1. Physical/environmental setting of Virginia's hardwood forests
2. Land-use legacies & current forest conditions: a look at Virginia's hardwood forests
3. Ecological and economic values
4. Future threats to the health and productivity of upland hardwoods
5. Management for future conditions

Physical environment

Geology, soils, elevation

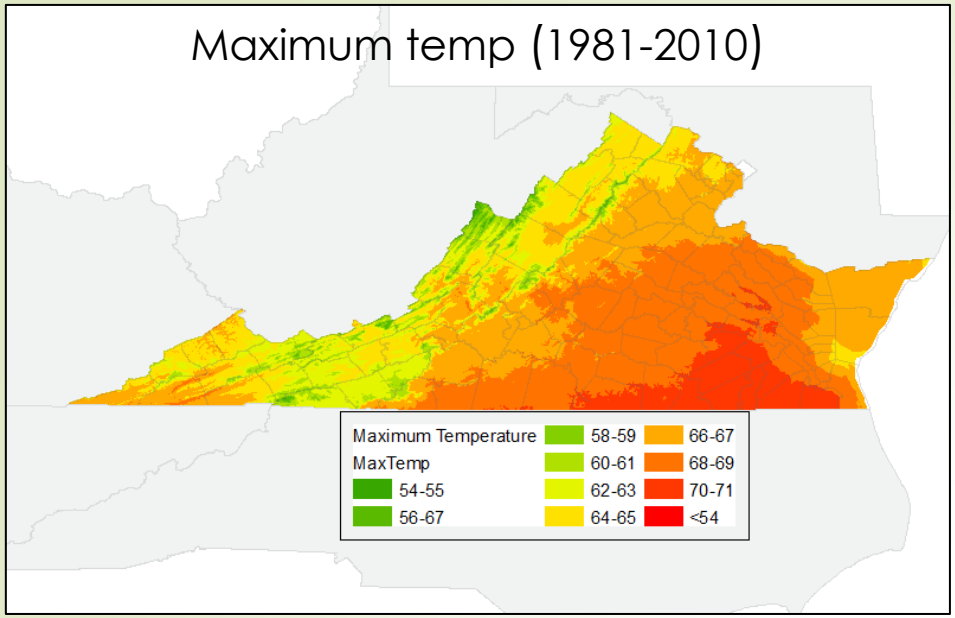


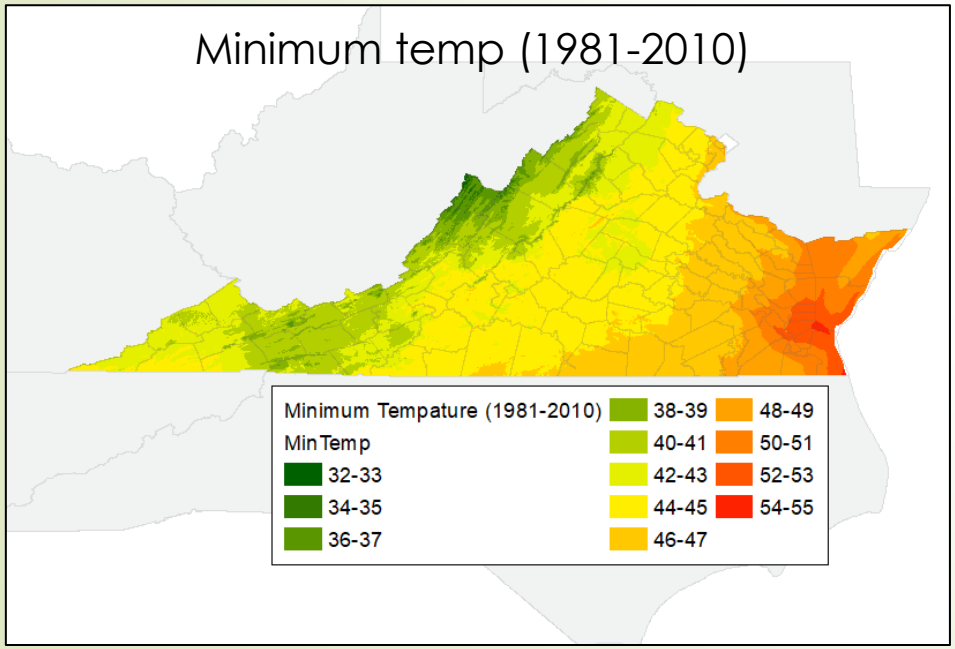


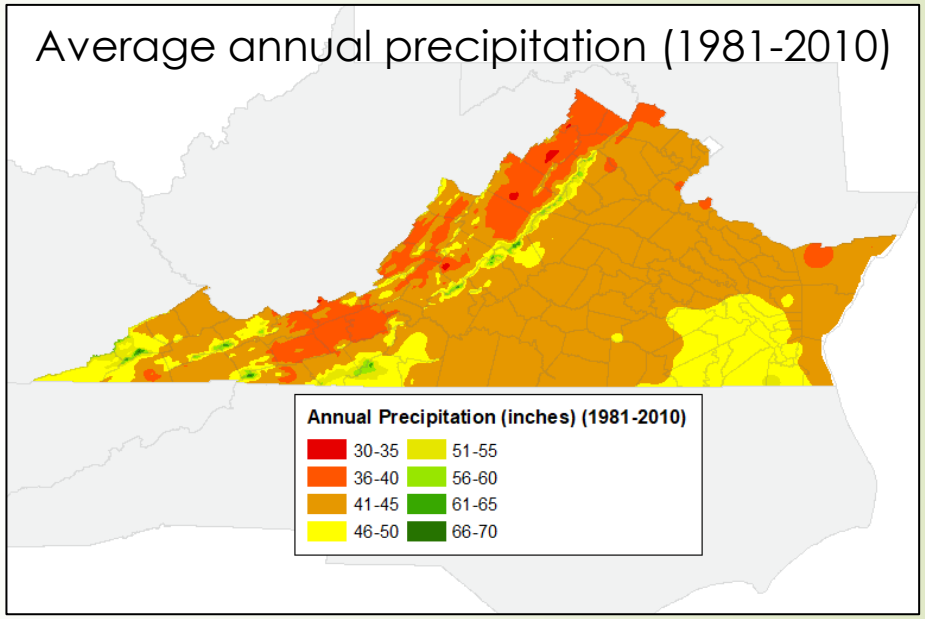


- Geology, varying erosion rates, and chemical characteristics of different rock types has produced diversity in landforms and soils
- Diverse topography ~0' at the coast to 5,729' (Mt Rogers) in the western mountains

Climate

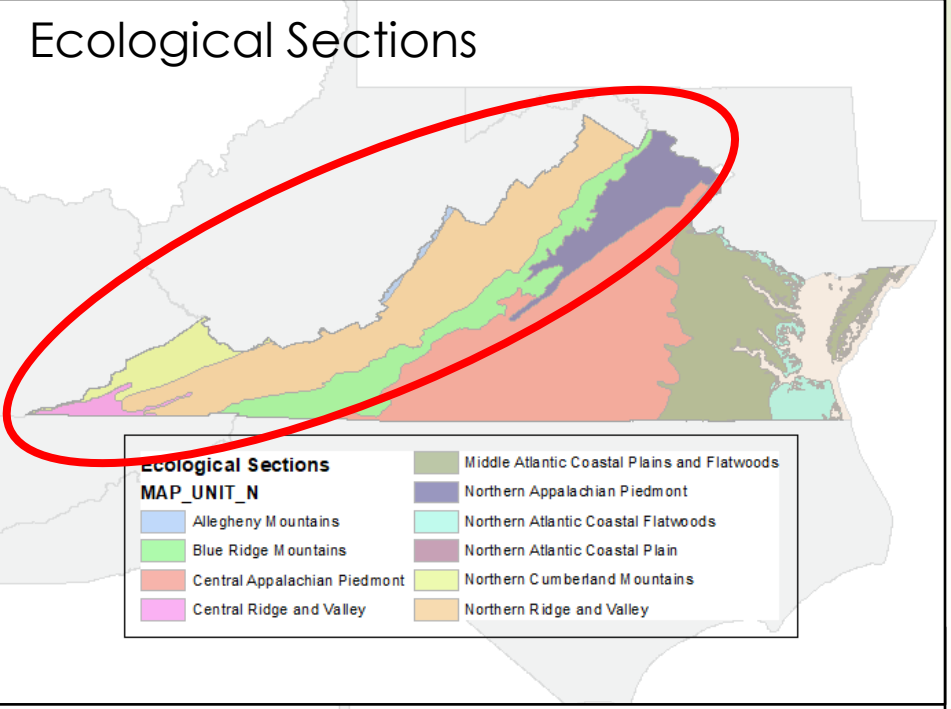




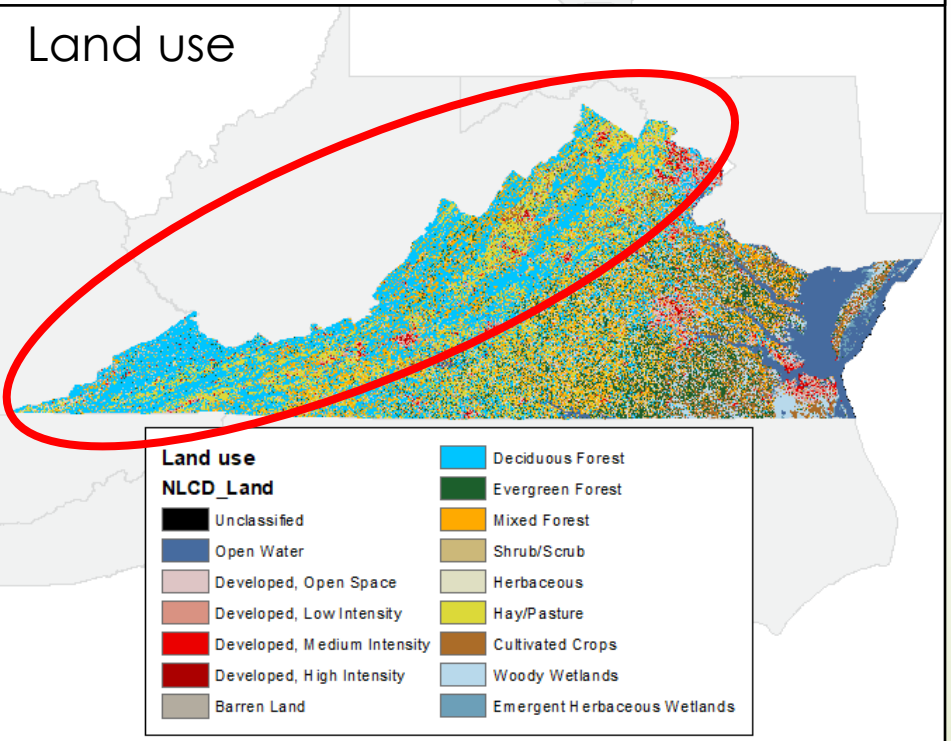


- Diversity in topography from the coast to the mountains influences temperature & precipitation.
  - Every 1000' increase in elevation = 3.6 °F decrease in temperature

Ecological Sections

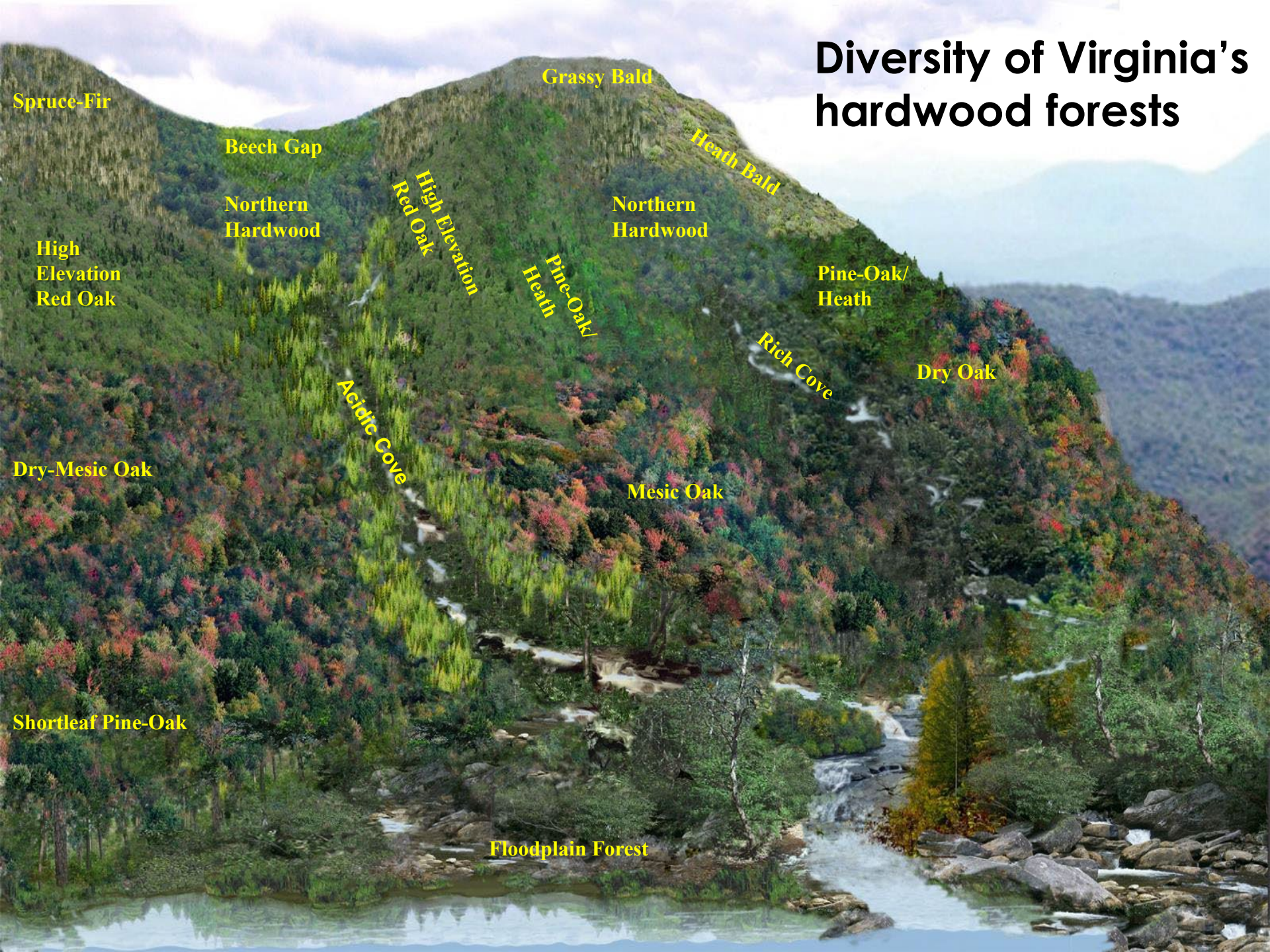


Land use



Ecological variability

- Diversity in physical characteristics produces a highly diverse landscape
- 10 distinct ecological sections in Virginia
- 6 ecological sections where hardwood forests dominate *(light blue on the land-use map)*
  - Allegheny Mts; Blue Ridge Mtns; Central Ridge & Valley; Northern Ridge & Valley; Northern Cumberland Mtns; Northern Appalachian Piedmont
  - ~7.54 million acres of forestland in these 6 ecological sections
- Area is dominated by deciduous forests


Diversity of Virginia's hardwood forests
Spruce-Fir
Grassy Bald
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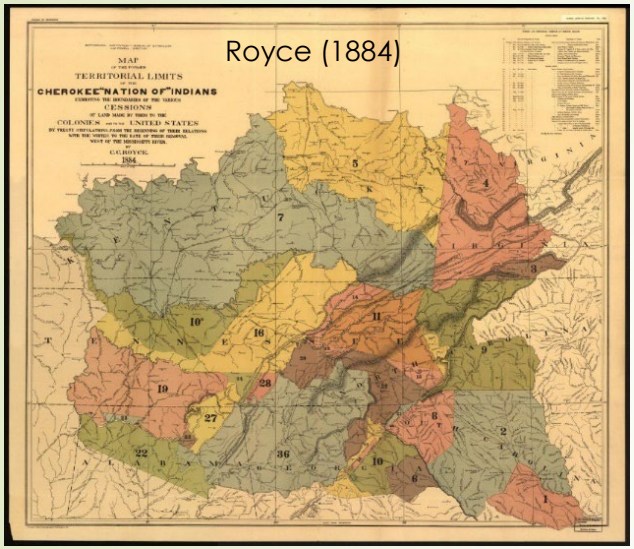
Pine-Oak/ Heath
Pine-Oak/ Heath
Rich Cove
Dry Oak
Acidic Cove
Dry-Mesic Oak
Mesic Oak
Shortleaf Pine-Oak
Floodplain Forest

Past land use

More than the physical environment:

Before we understand how to best manage today's forests, we have to understand their past

The southern Appalachians: Thousands of years of disturbance

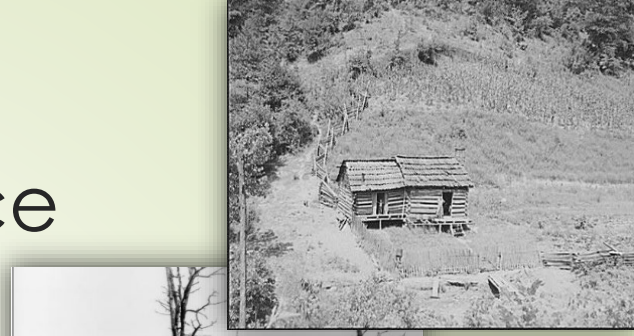


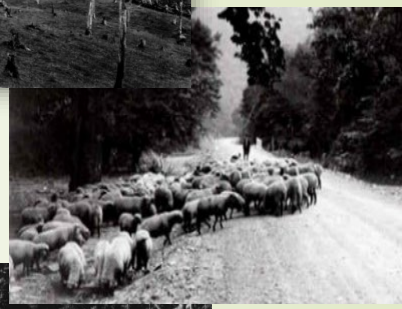
An artist's impression of Town Creek, a South Appalachian Mississippian culture town with ceremonial mound in NC, ancestors of the Cherokee people. https://www.nps.gov/liri/learn/historyculture/cherokee-people.htm

- Woodland Era (3,000 BCE - 1,000 CE) and Mississippian Culture/Era (1,000 CE to 1500 CE)
- Time period when humans began to have a major impact on the landscape
  - Well established, ***permanent large*** settlements with complex social systems and hierarchies
  - Agriculture was widespread & advanced, with domestication & propagation of numerous plant species
- Use of fire was extensive
  - Attract and/or drive game (vigorous re-sprouting)
  - Clear land (along with tree girdling) for village and agriculture sites
  - Communication and facilitate travel
  - Promote berry production
  - Control insects and facilitate nut/mast collection

The southern Appalachians: Thousands of years of disturbance

- Contact with European explorers occurred in 1500s and started the depopulation of Indigenous Peoples
- European settlement began in late 1700s
- Subsistence
  - Typical landscape: 20% pasture, 25% cultivated, 45% forest
  - Culture of woods-burning continued and increased, with fire sometimes much more frequent, intense, and widespread across the landscape
  - Document from NC records an average family used 15 cords of fuelwood per year, not including wood for construction, fence posts, etc.
- Iron furnaces in the 1800s relied upon local forests, often consuming the equivalent of 1-acre of forest each day of production

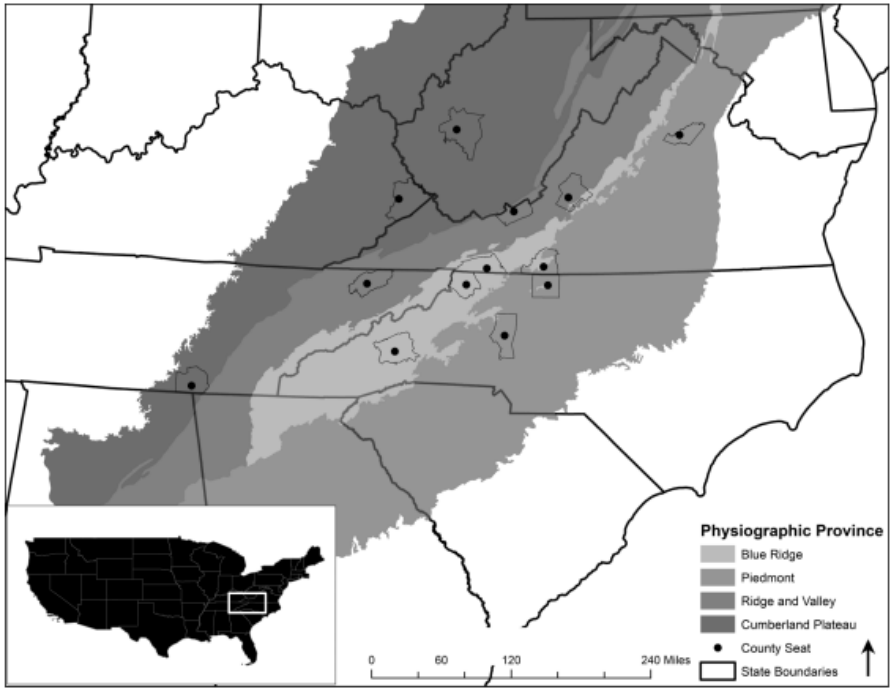




Common name	Stems recorded
White oak	**9,701**
Black oak	**2,314**
Hickory	**2,127**
Chestnut	**2,100**
Beech	**2,056**
Red oak	**1,558**
Pine	**1,511**
Yellow-poplar	1,271
Scarlet oak	1,260
Sugar maple	987
Post oak	925
Dogwood	808
Red maple	691
Chestnut oak	646
Blackgum	606
Ash	564
Black walnut	428
Basswood	401
Buckeye	336
Locust	286
Sourwood	233

Witness trees records

- Common witness trees reported in land surveys from 1734 to 1830 in 13 counties in the southern Appalachian Mountains (Copenheaver and Keyser, 2016)



A change in the disturbance regime

Eastern TN State University

Southern Appalachian brook trout foundation

- In the late 1800s and into the early 1900s began a period of unregulated timber extraction.
- In 1908, it was estimated that in western NC, 50% of forestland was owned by large companies, and 86% of the acreage in the Blue Ridge Mountains was either cleared, burned, or both.
- Fires were more intense fires set by Indigenous Peoples before European settlement and those used by early European settlers

Result: Cutover and degraded forests (*The Lands Nobody Wanted*)

- Cutover and degraded land was abandoned
- Subsistence living transitioned after industrialization
- A portion of land was purchased by the federal government and became NFS lands
- Keystone species (American chestnut) functionally eliminated from forests
  - Up to 1 out of every 4 canopy trees
- Forests recovered iare the oak and hickory forests that dominate the present-day landscape
- Fire suppression became the norm, as the culture of woods-burning was eliminated

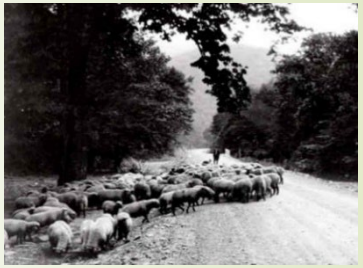
Loss of keystone species: American chestnut

Native American burning & management

European settlement - land clearing for pasture & agriculture, continued use of fire

Fire suppression & exclusion

Structure & composition



Domestic grazing

Source: American Memory online photographic collection, Library of Congress

Wood utilization: subsistence living

Land abandonment

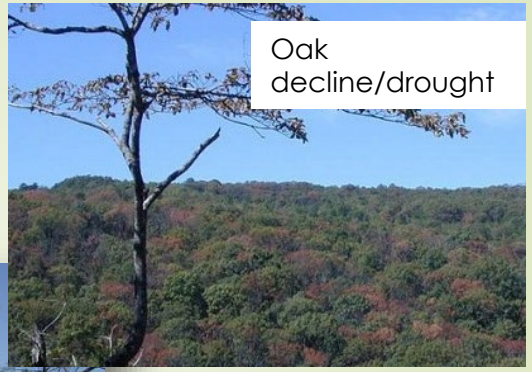
Exploitive logging/wildfires

Photo: Southern Appalachian brook trout foundation

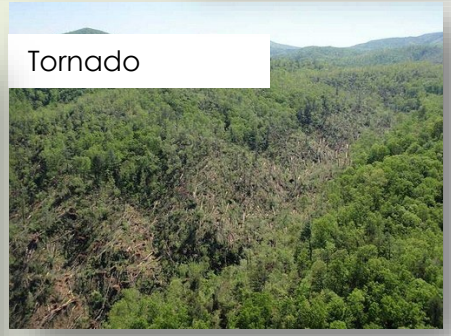
Charcoal production


Wind


Ice storm


Oak decline/drought


Ice damage

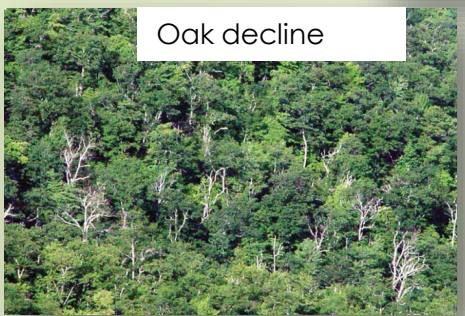

Tornado


Landslide, NC


Microburst

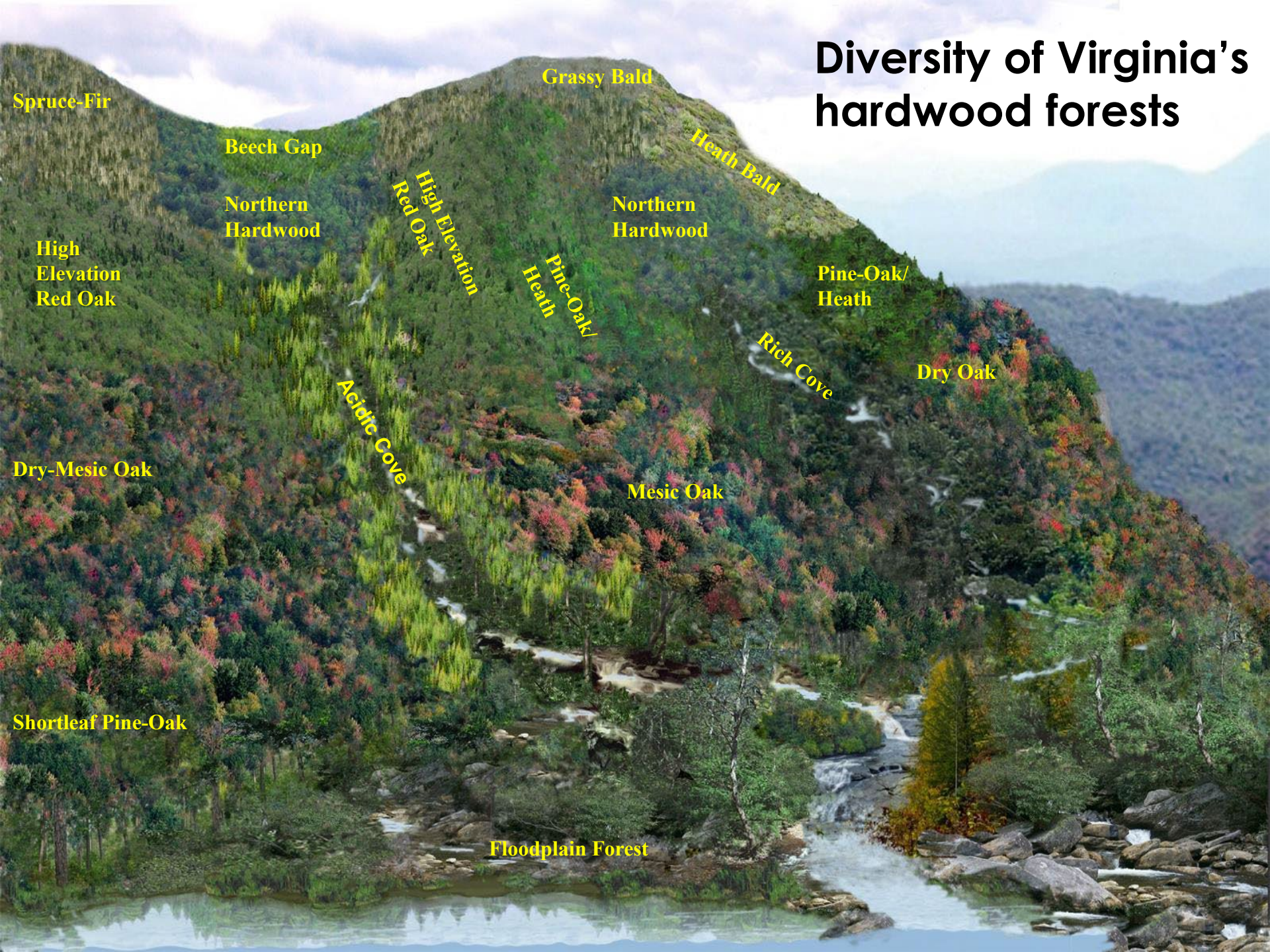

Wind


Background gap/phase


Oak decline


Ice damage


Wildfire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Mesic Oak
Shortleaf Pine-Oak
Floodplain Forest

Table mountain pine/pitch pine

Mixed oak/pine

Dry (xeric) oak

Dry-mesic oak

Mesic oak

Rich cove

Acidic cove

High elevation red oak - © DCR-DNH, Gary P. Fleming

Northern hardwood

Spruce/fir

Young forest

Oak savanna

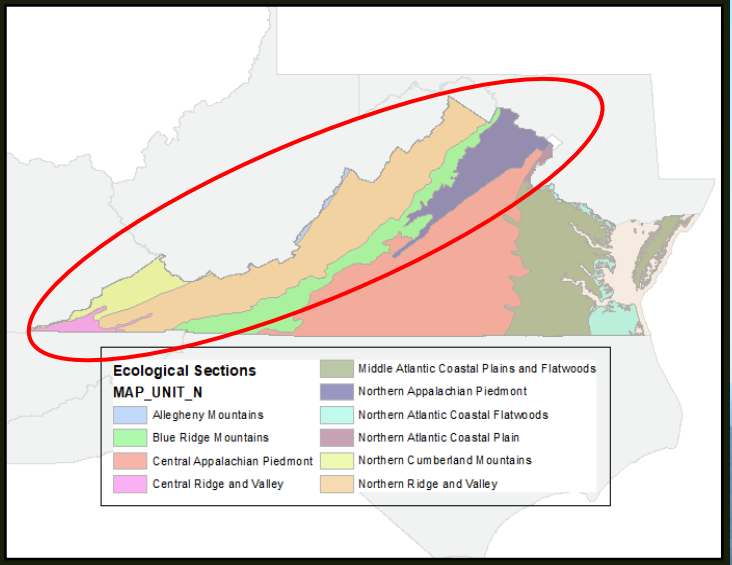
Mature, open oak woodland

Mature, closed oak woodland

Mature-open understory oak forest

Mature-closed oak forest

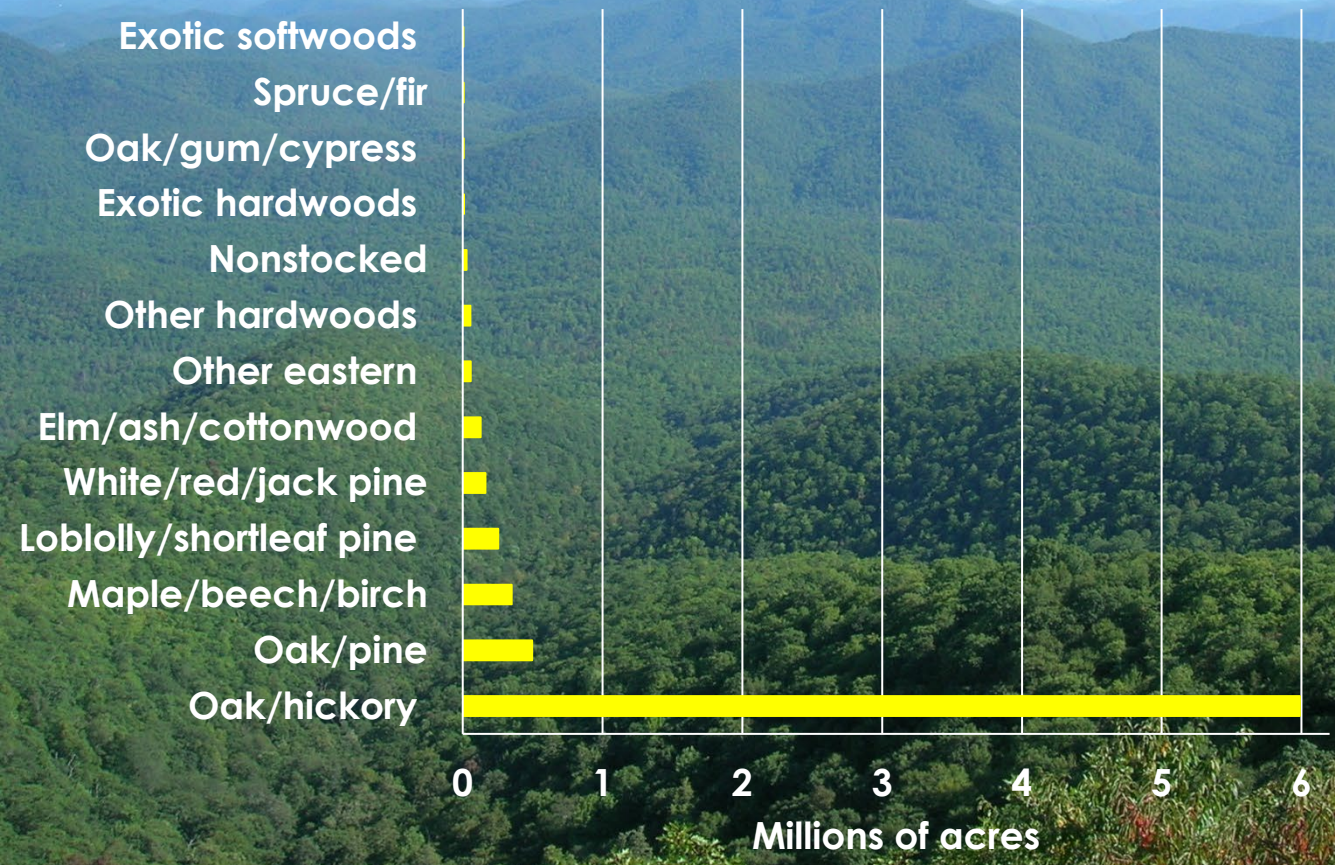
Mixed-mesophytic



Current forest conditions

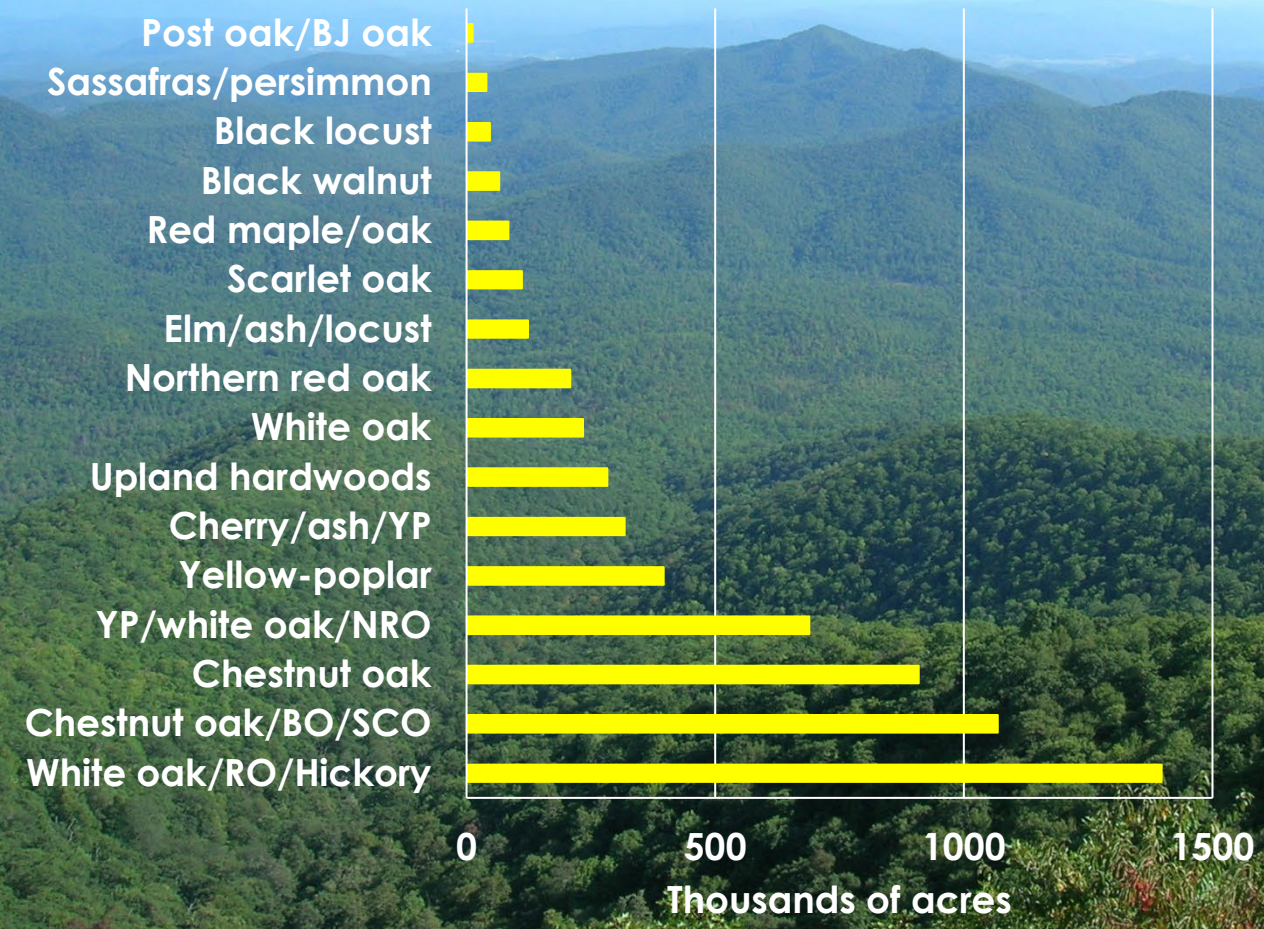
Virginia

Forest type groups in Virginia



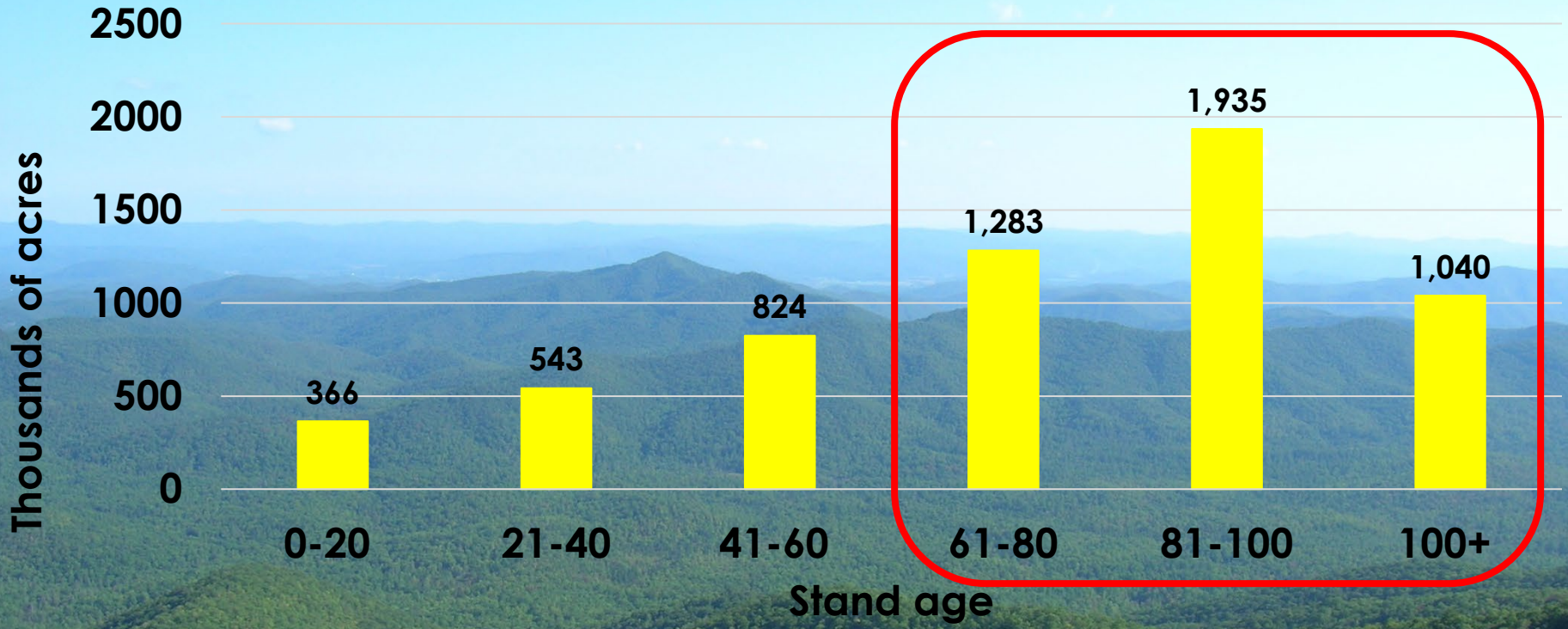
- Oak/hickory group comprises **79%** of forestland in the 6 ecological sections dominated by hardwoods
- The next most abundance forest type is oak/pine, but this represents only **7%** of the forestland in the region

Diversity of forest types categorized as oak/hickory



- High diversity of forest types lumped into that oak/hickory group
  - 23%:WO/RO/HICKORY
  - 18%: CO/BO/SCO
  - 15%: CO
  - 12: YP/WO/NRO

Age of oak/hickory forests in Virginia

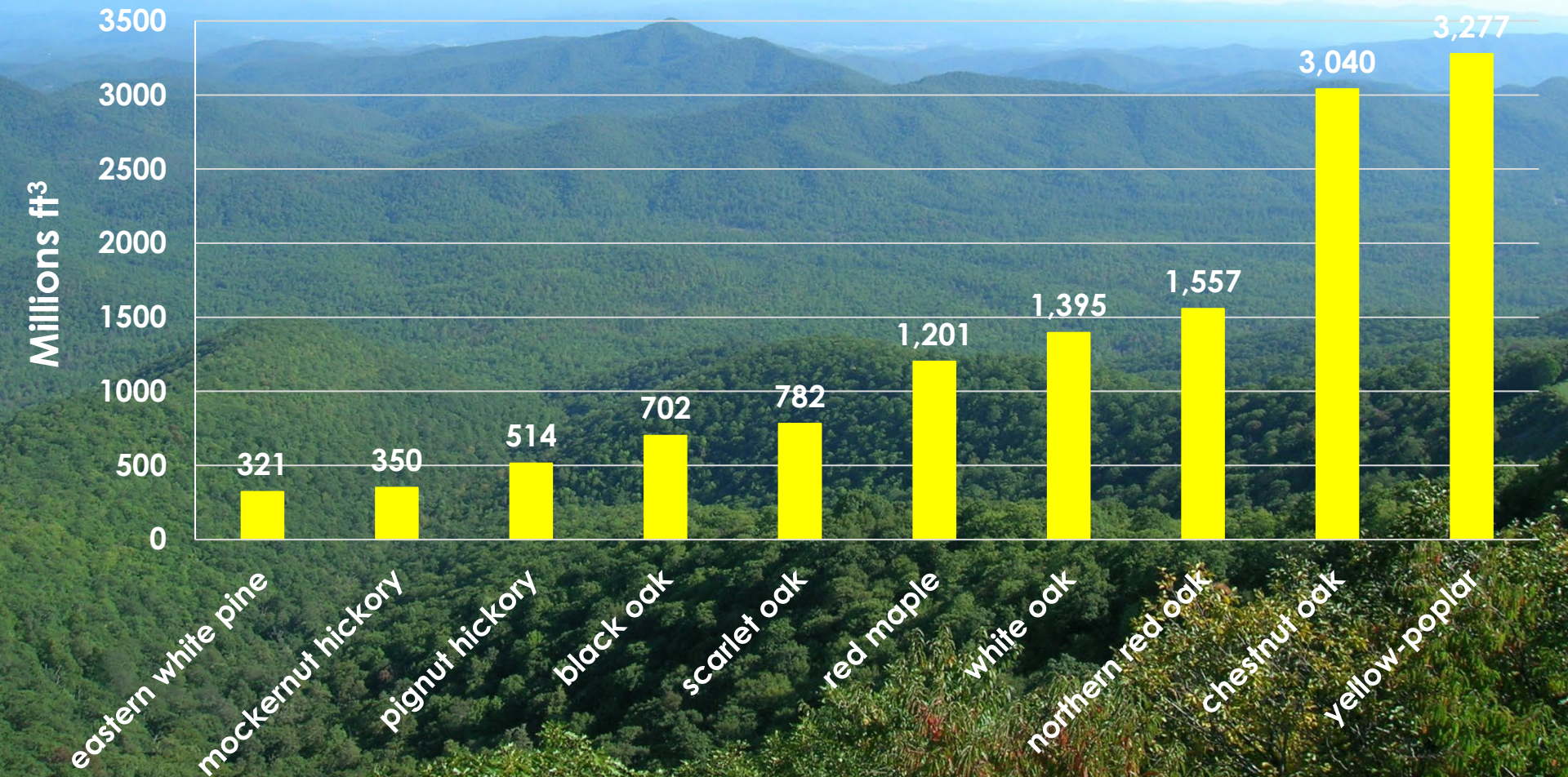


Hardwood forests in Virginia are skewed towards the older age classes

- 6 % of forestland is <20 yrs
- 71% of forestland is ≥60 yrs
- 49% of forestland is ≥80 yrs

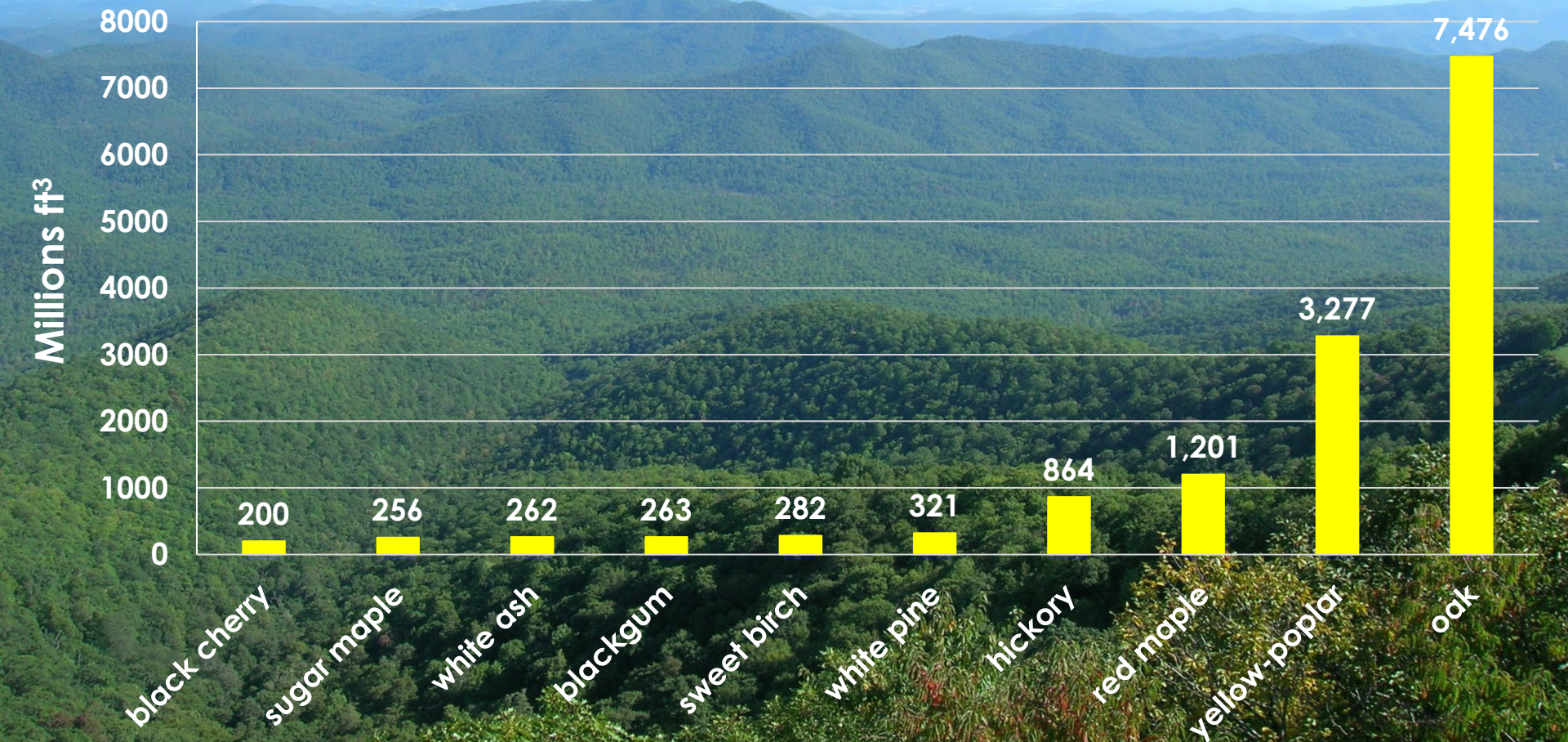
Net merchantable volume in oak/hickory forests: live trees ≥5”

- Species by species basis, yellow-poplar dominates in terms of volume

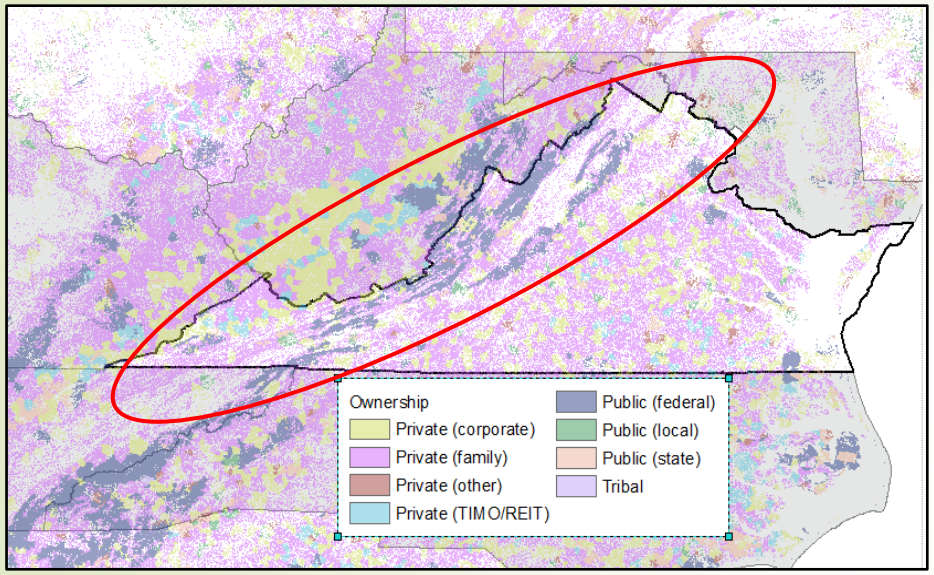


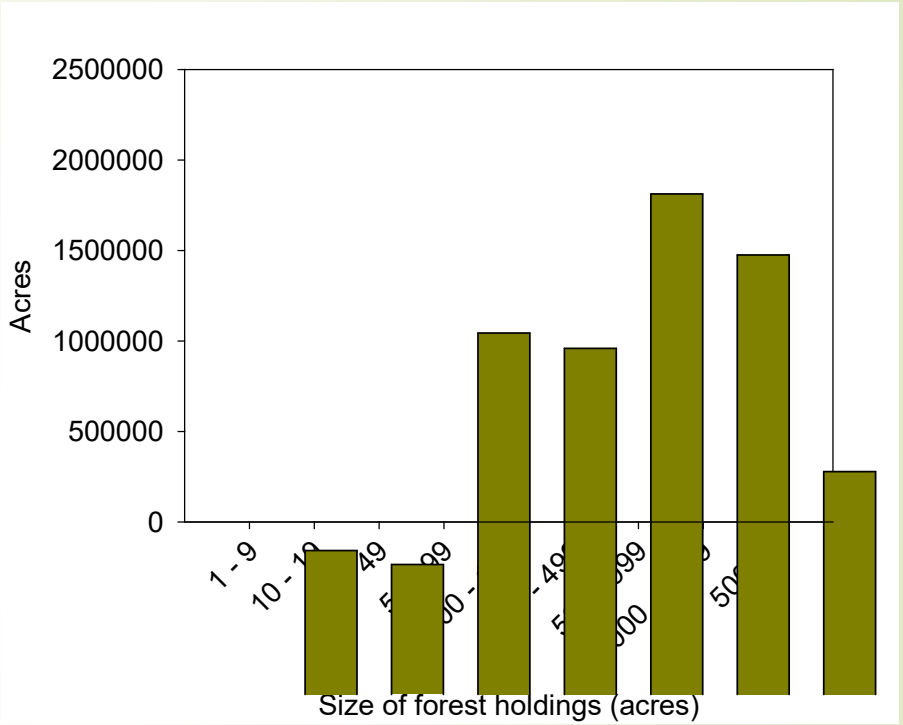
Net merchantable volume in oak/hickory forests: live trees ≥5”

- Oak species combined constitute 7476 million ft^3; double that of yellow-poplar
- Hickory species combined constitute 865 million ft^3



Forest ownership patterns





- National Forest System: 22%
- Other federal: 3%
- State & local: 4%
- **Private: 70%**

Source: USFS Forest Inventory & Analysis

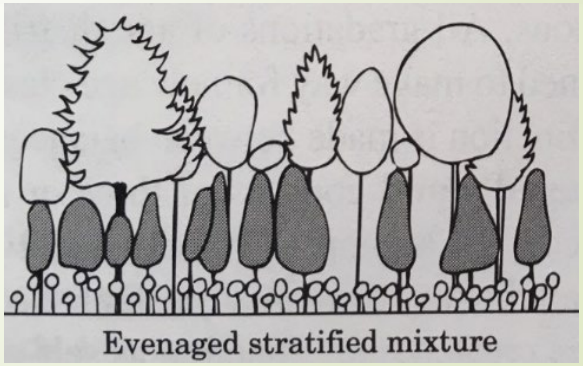
<u>Private land (family) in Virginia</u>

- 42% own <99 acres
- 28% own 100 – 999 acres
- 8% own ≥1000 acres

Source: National Woodland Owners Survey (https://ffrc.shinyapps.io/NWOSdashboard/)

Contemporary forests: Structure

- Virginia hardwood forests are, at a landscape level, closed-canopied (with multiple canopy layers), mature and even-aged forests
  - Tree density is greater in current vs pre-settlement forests = loss of open canopy and open understory conditions
  - Average tree size is smaller in current vs pre-settlement forests
- Current structure is a legacy of past land use and current disturbance regime
- Intermediate severity/frequency disturbances that were associated with European settlement are, for the most part, missing
- Large gap-creating disturbances are rare



Lack the diversity in forest structures across the landscape that used to be present prior to land abandonment

Young forest

Oak savanna

Mature, open oak woodland

Mature, closed oak woodland

Mature-open understory oak forest

Mature-closed oak forest

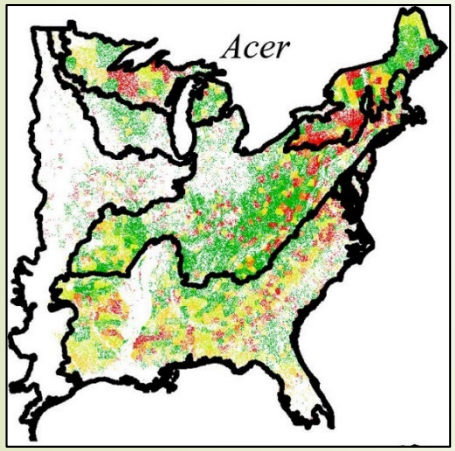
Mixed-mesophytic

Most of the hardwood forests are here

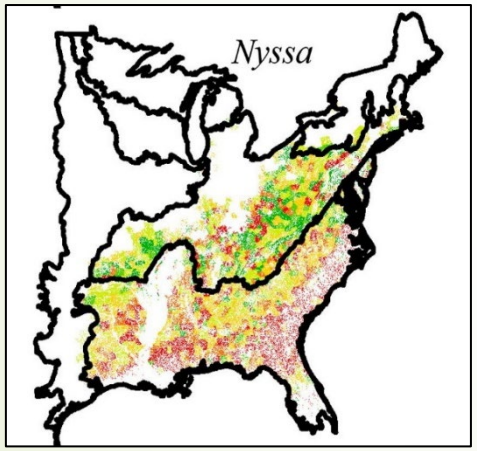
Contemporary forests: **Composition**

Changes in species importance (1980-2015); *Knott et al. 2019*

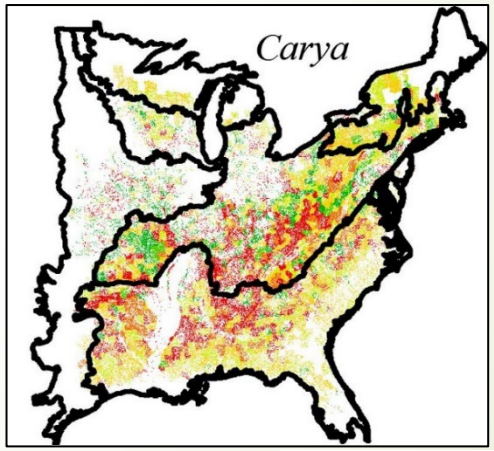
Maple



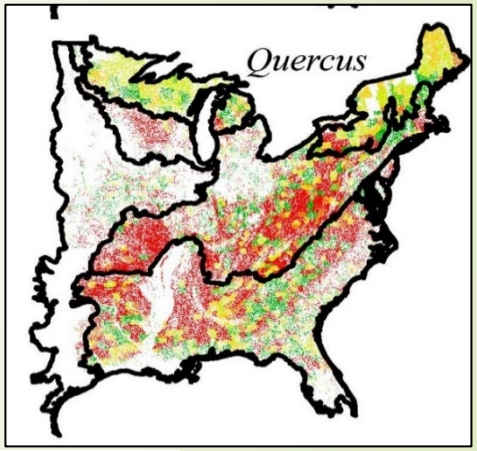
Gum



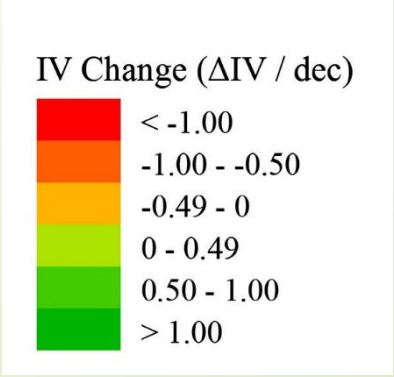
Hickory



Oak

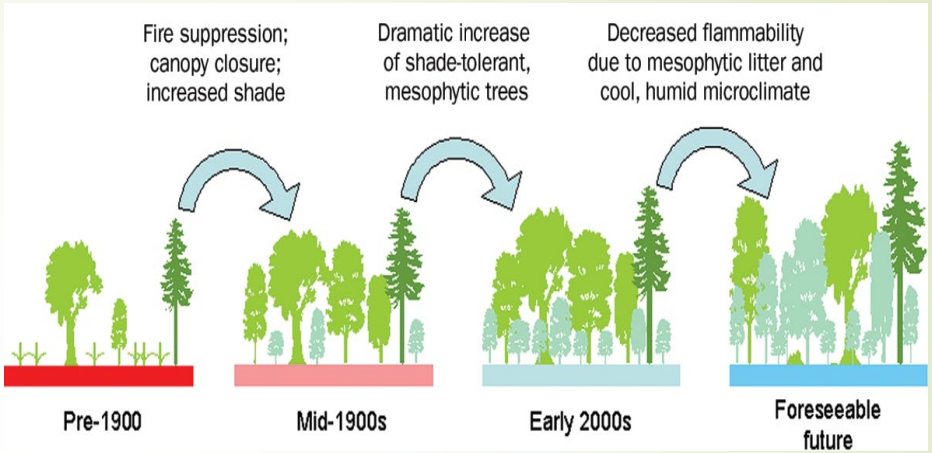


Changes correspond to an increase in shade tolerant species and concurrent decrease in fire tolerance across the landscape

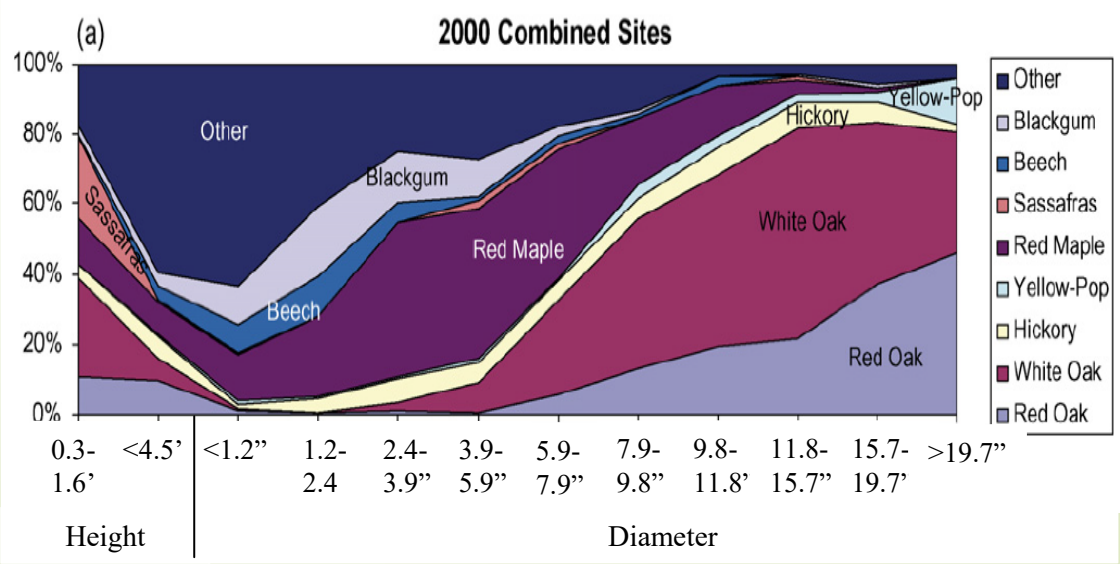


Contemporary forests: Composition

- Oaks still dominate; however, there has been a steady decrease in the abundance and relative importance of oak (and fire-tolerant pines)
- Composition of the oak component has changed relative to pre-settlement
  - In many areas, NRO, SCO, CO increased due to loss of chestnut and exploitive harvesting
- Species composition of the understory is markedly different than the overstory implying oak forests are largely successional (mesophication)



Nowacki and Abrams 2008



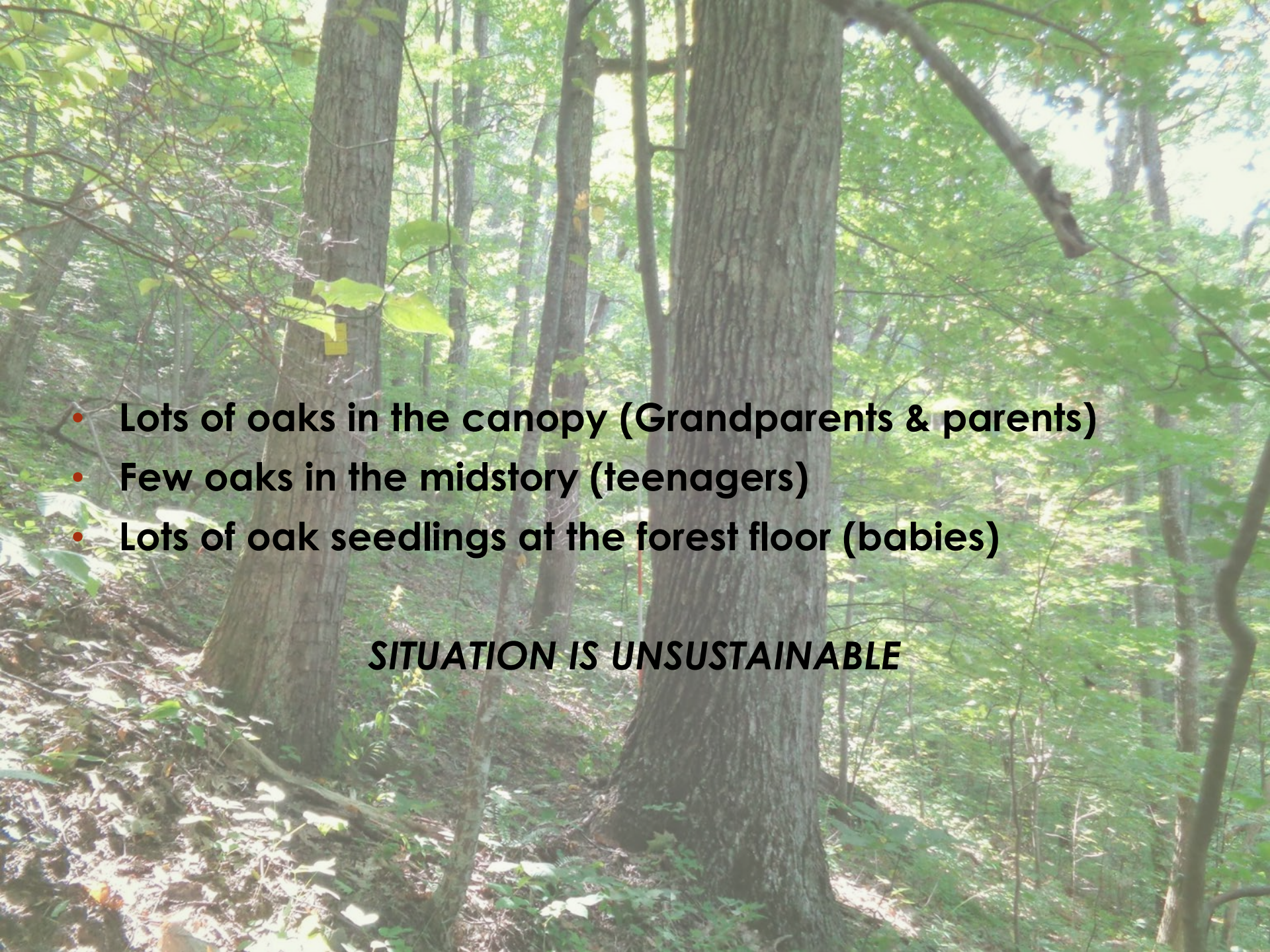
Iverson et al. 2008 – southern Ohio

Species abundance

Number of trees by species

Species	>5”
Virginia pine	27,237,893
Sugar maple	29,186,814
Pignut hickory	30,759,283
Scarlet oak	37,772,206
Northern red oak	39,900,015
White oak	52,445,694
White pine	55,282,303
Red maple	88,747,491
Yellow-poplar	106,473,655
Chestnut oak	**124,941,086**

Species	>1”
Pignut hickory	94,025,077
White oak	95,487,673
Sourwood	103,297,544
Sweet birch	109,276,570
Sugar maple	149,020,302
White pine	154,880,767
Chestnut oak	232,750,011
Yellow-poplar	**294,952,507**
Blackgum	**357,032,900**
Red maple	**553,086,105**

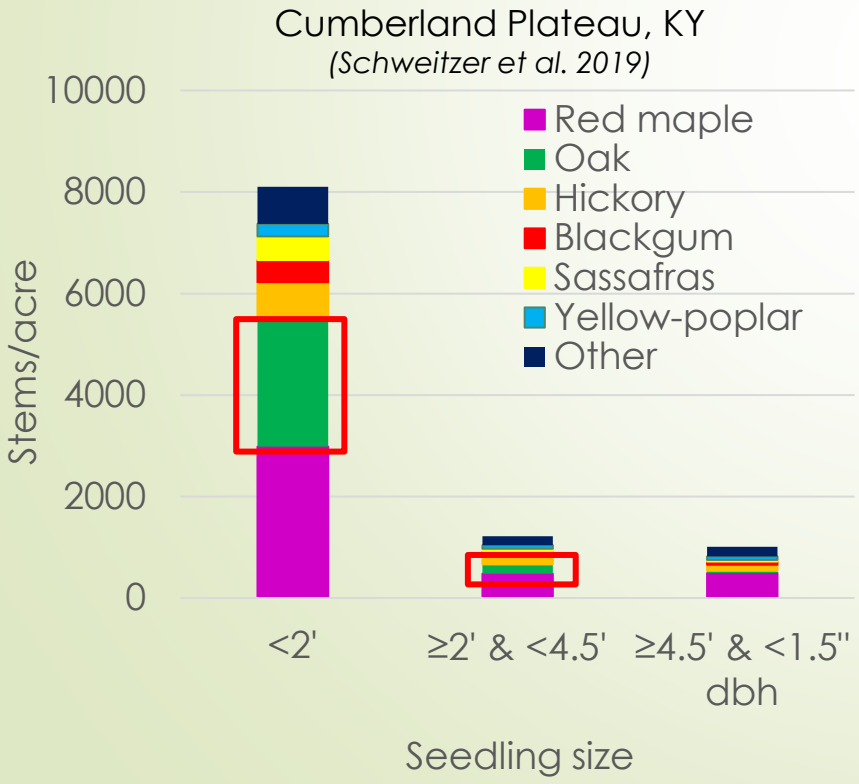


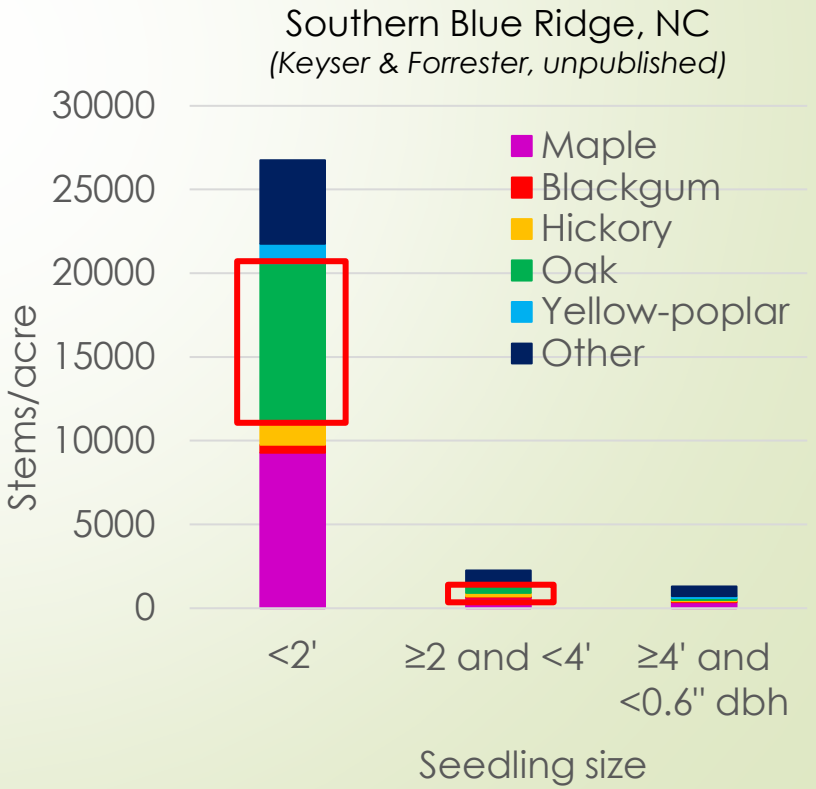
- Lots of oaks in the canopy (Grandparents & parents)
- Few oaks in the midstory (teenagers)
- Lots of oak seedlings at the forest floor (babies)

SITUATION IS UNSUSTAINABLE

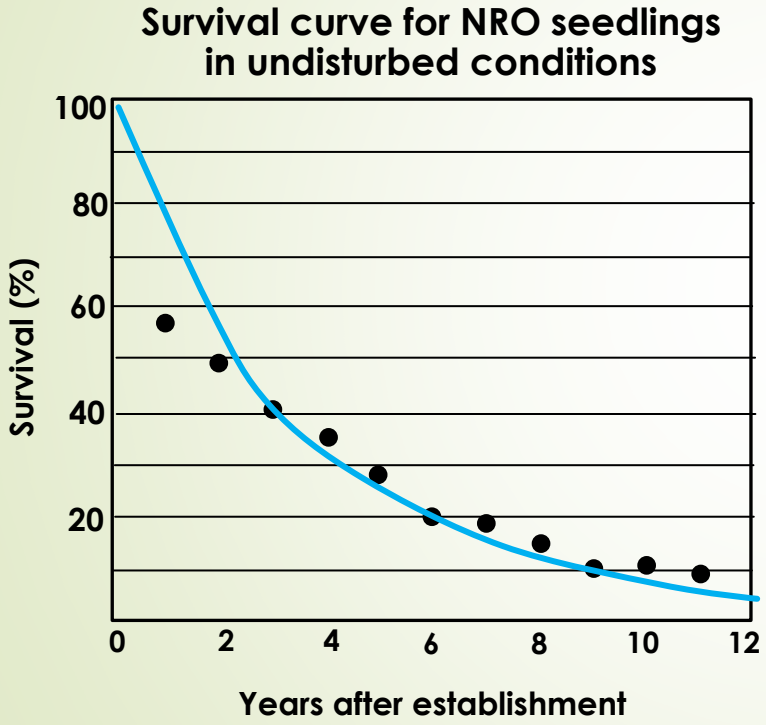
What's the problem?

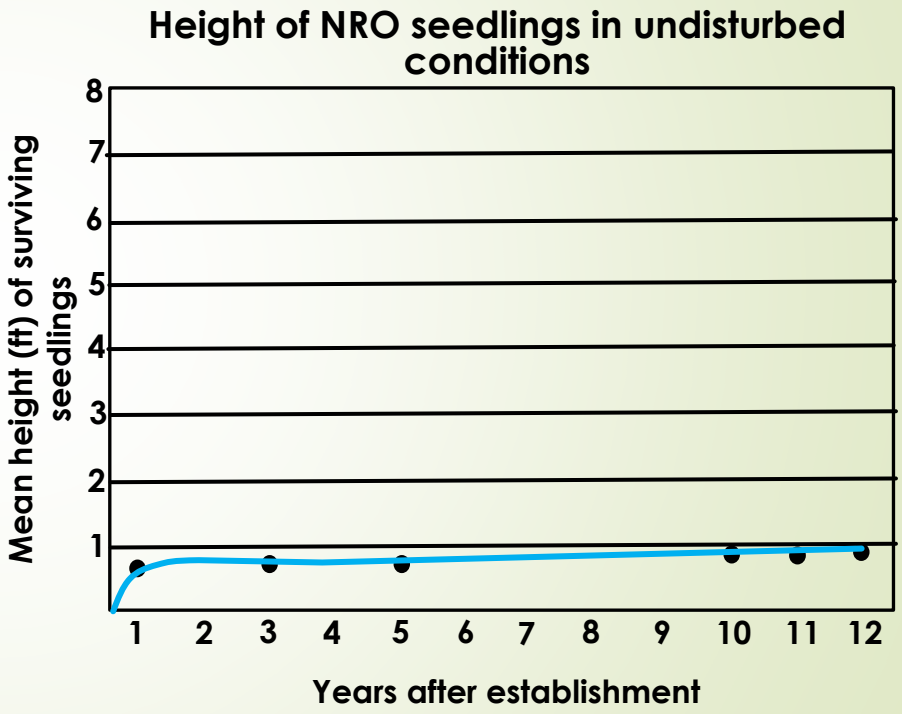
- The problem is related to how well oak seedlings compete with the 100+ species that co-exist with them to eventually reach the forest canopy and replace those canopy/mature oaks when they die.
- We have lots of baby oaks





What happens to small oak seedlings? (Loftis 1983)

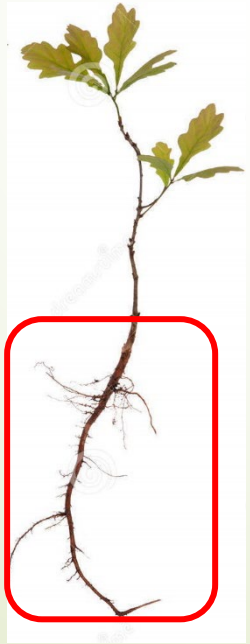


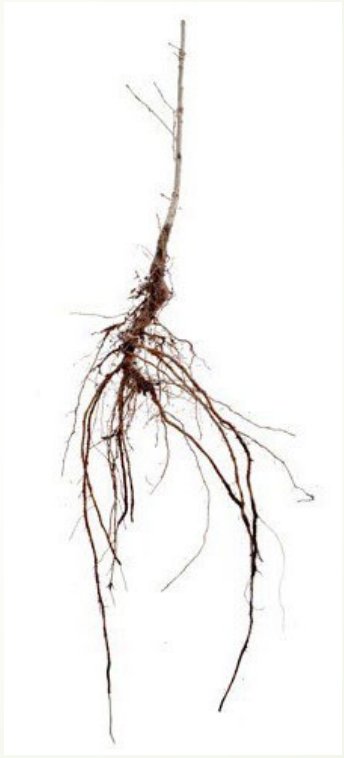


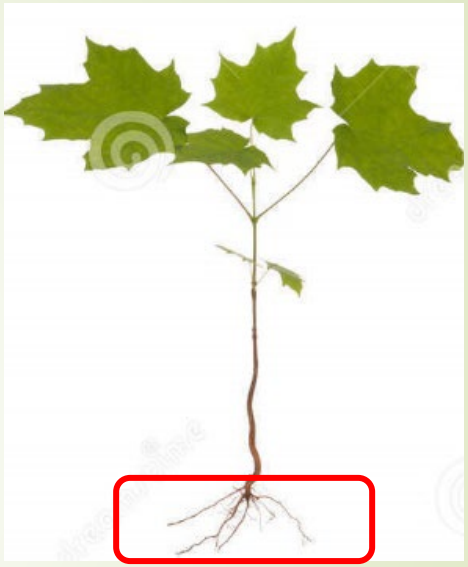
Growth strategy of oak seedlings

The oak seedling at the bottom has a stem at least 3/8-inch in diameter and a fibrous root system that help insure survival

Photo © University of Minnesota Extension

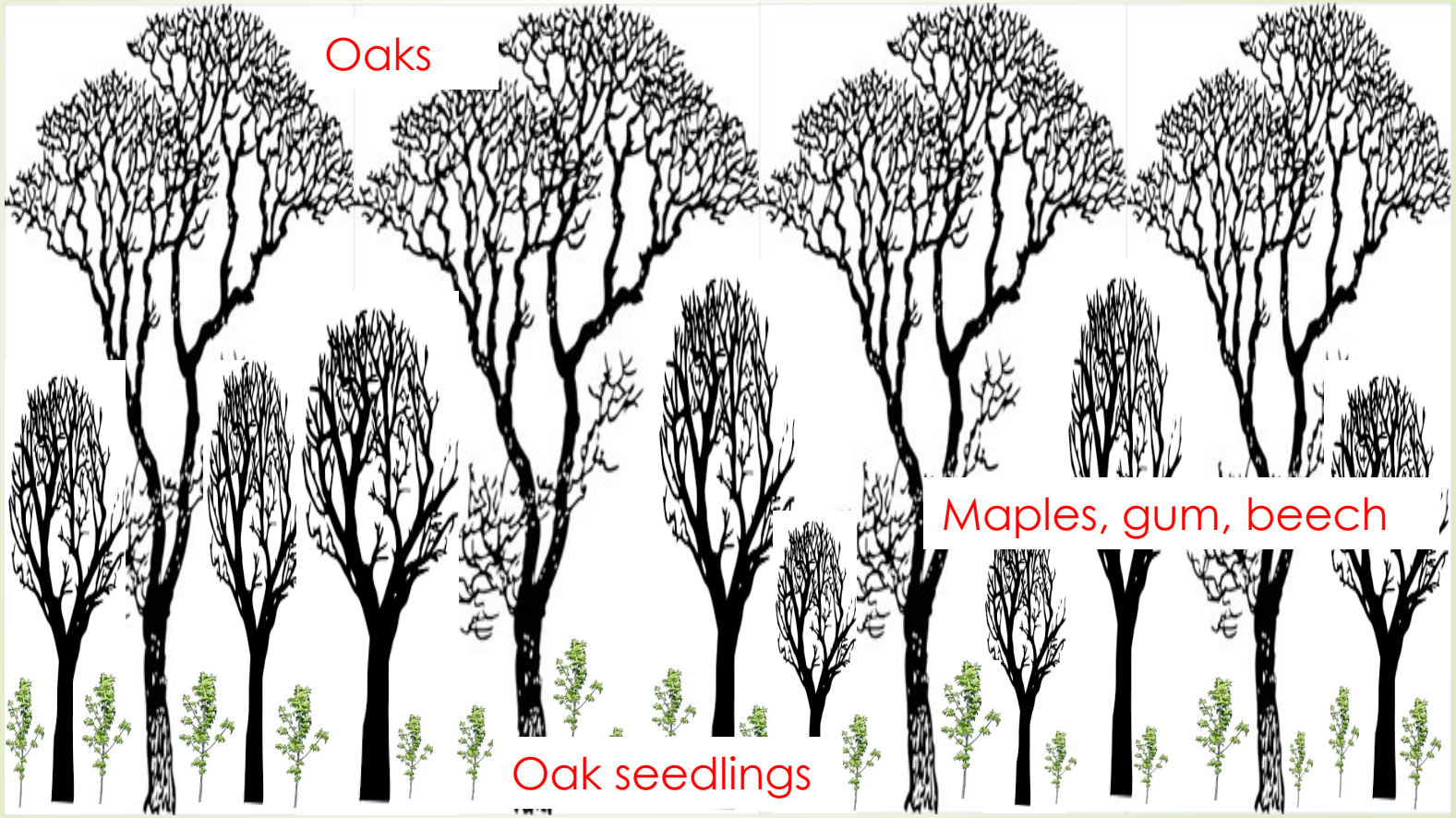






Closed-canopy, mature forest

High light



Low light

<10% PAR (2-3%)

Oak regeneration potential
(likelihood of growing into the canopy)

ZERO

LOW

BETTER

EVEN BETTER (stump sprout, but large/old oaks rarely sprout)

BEST!!!!
(stems ~≥4.5')

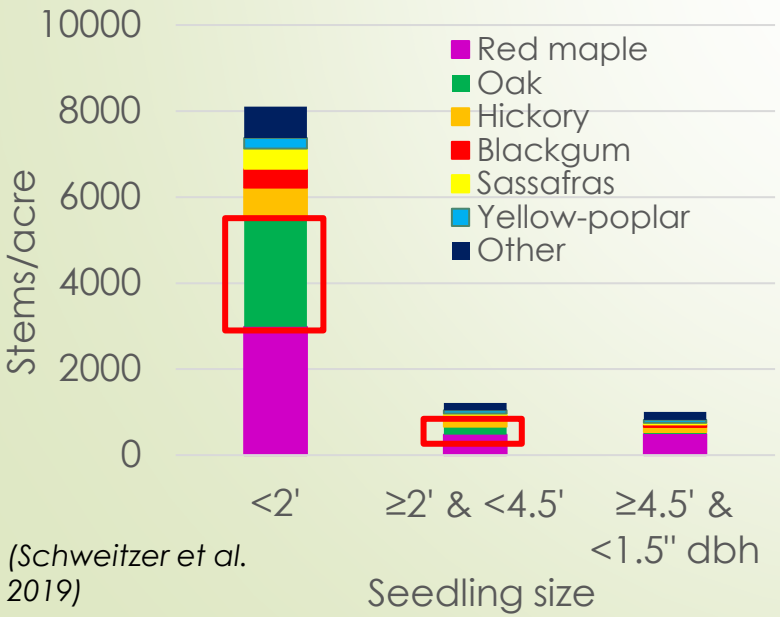
Probability of successful regeneration

Small-scale disturbance

Schliemann & Bockheim 2011

~320 ft^2

~1500 ft^2



(Schweitzer et al. 2019)

Species composition – small-scale disturbance

Data from Hutchinson et al. 2012

Without management, the sustainability of current oak forests is uncertain

BAY JOURNAL

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Oaks are dying at record rates across Chesapeake region

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TOP STORY

Mystery disease and drought is killing Iowa's white oaks

ERIN JORDAN The Gazette Nov 7, 2022 Updated Dec 12, 2022 0

Naturalist's Notebook

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Threats to the Tree of Life

Magnificent, strong and once thriving in Appalachian forests, oaks now struggle to regenerate. As deadly diseases spread in other regions, a new alliance is emerging to protect this key species.

Eliza Laubach | December 16, 2019 | No Comments

JOURNAL ARTICLE

Threats to Oaks in the Eastern United States: Perceptions and Expectations of Experts FREE

Anna O Conrad ✉, Ellen V Crocker, Xiaoshu Li, William R Thomas, Thomas O Ochuodho, Thomas P Holmes, C Dana Nelson

Journal of Forestry, Volume 118, Issue 1, January 2020, Pages 14–27,
https://doi.org/10.1093/jofore/fvz056
Published: 28 November 2019 **Article history** ▾

The Washington Post

Democracy Dies in Darkness

D.C., Md. & Va. The District Maryland Virginia Crime & Public Safety Local Education Obituaries Transportation Capital Weather Ga

LOCAL

Across the Mid-Atlantic, giant oak trees are dying

By Alisa Tang

November 25, 2021 at 4:00 a.m. EST

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NEWSROOM: TEXAS A&M FOREST SERVICE CONFIRMS INCREASE OF POST OAK MORTALITY IN TEXAS

Oct. 20, 2016 — COLLEGE STATION, Texas — Post oak trees across the state are facing higher mortality rates in both

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Gypsy Moths On The Decline — For Now — But Damage Is Already Done

03:44

American Forests

Initiatives & Projects

Bringing Back White Oaks

Conserving and restoring the East Coast's most important tree

Barr Announces Formation of Congressional White Oak Caucus

April 8, 2022

Washington, D.C.– Today, U.S. Congressmen Andy Barr (R-KY), Steve Cohen (D-TN), Scott DesJarlais (R-TN) and Ami Bera (D-CA) announced the creation of the

radio IQ | wvtf MUSIC Virginia's Public Radio

News

Virginia oaks in danger

RADIO IQ | By Sandy Hausman

Published November 7, 2022 at 5:46 PM EST

▶ LISTEN • 3:26

CONSERVATION & SUSTAINABILITY

PrairieFarmer

Why are white oak trees dying?

Tree Talk: A new disease is moving into Illinois from Missouri, and it's rapidly killing white oak trees.

Fredric Miller

March 15, 2019

3 Min Read

WILDLIFE & NATURE

For Better and Worse: Statewide Oak Tree Mortality Changes Rhode Island's Landscape

By Cynthia Drummond / ecoRI News contributor | June 3, 2021 | Share

JOURNAL ARTICLE EDITOR'S CHOICE

The Drought Response of Eastern US Oaks in the Context of Their Declining Abundance FREE

Kimberly Novick ✉, Insu Jo, Loïc D'Orangeville, Michael Benson, Tsun Fung Au, Mallory Barnes, Sander Denham, Songlin Fei, Kelly Heilman, Taehee Hwang, Tara Keyser, Justin Maxwell, Chelcy Miniat, Jason McLachlan, Neil Pederson, Lixin Wang, Jeffrey D Wood, Richard P Phillips

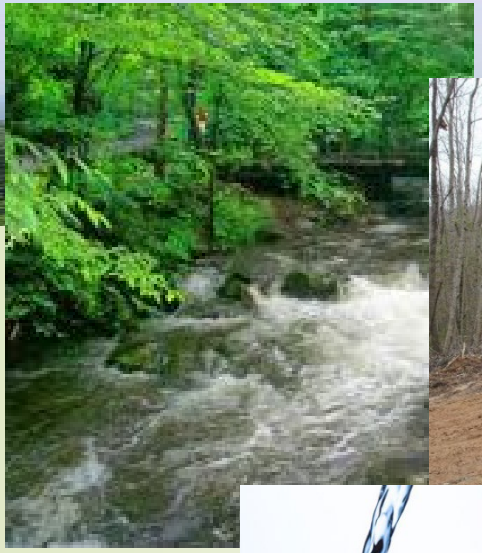
BioScience, Volume 72, Issue 4, April 2022, Pages 333–346,
https://doi.org/10.1093/biosci/biab135
Published: 25 January 2022

Ecosystem services

Ecosystem service: the benefits people obtain from nature

1. Provisioning: Material from an ecosystem
2. Regulating: Benefits obtained by moderation of ecosystem processes
3. Supporting: Services that maintain fundamental ecosystem processes
4. Cultural: Non-material benefits

Provisioning services



Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org.

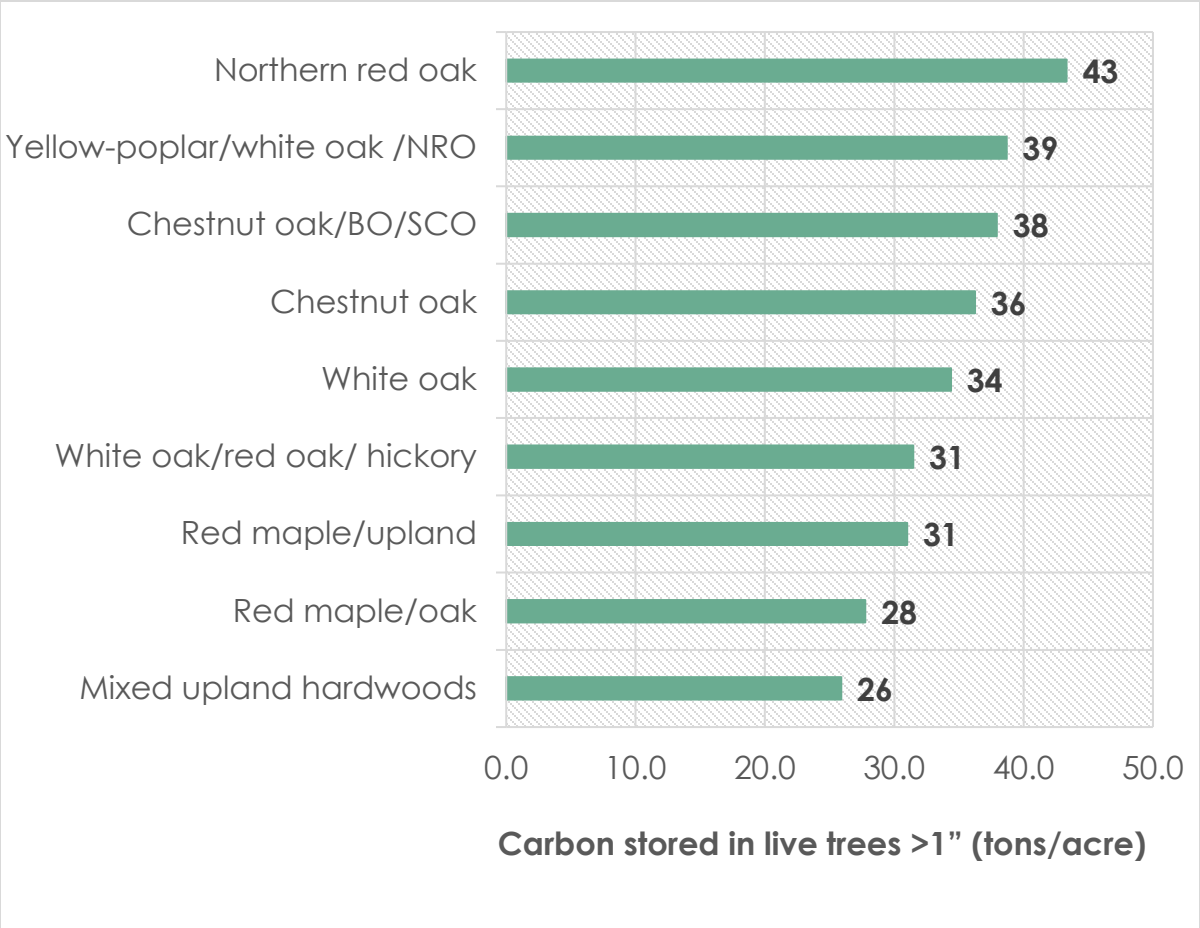
- High-quality hardwood sawtimber
- Fuel wood
- Non-timber forest products
- Medicinal products
- Human food resources
- **Water:** Forests in the Southeast deliver surface drinking water to 48.7 million people, with streams from the southern Appalachian region alone providing water supplies to 10 million people (major urban centers)

Provisioning services

- **Water:** Forests in the Southeast deliver surface drinking water to 48.7 million people
- Streams from the southern Appalachian region alone providing water supplies to 10 million people (major urban centers)
- After accounting for climate, the process of mesophication reduced annual water yield in western NC watersheds by as much as 18% (Caldwell et al. 2016)

Regulating services

- **Carbon sequestration & storage**
- Species composition influences air quality (Mushinski et al. 2019)
  - Forests dominated by maple & yellow-poplar release reactive nitrogen oxides (cause smog, respiratory problems); Arbuscular mycorrhizal
  - Forests dominated oaks absorb reactive nitrogen oxides; Ectomycorrhizal
- Water quality (purification)
- Pollination
- Flood control

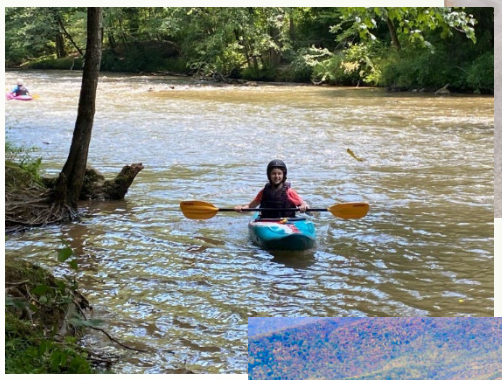


Supporting services

- **Wildlife habitat: Acorns are considered a keystone forest food resource: >90 wildlife species rely on or benefit from acorns as food resource**
- **Bark texture, leaf structure, and leaf chemistry support arthropod populations which enhances bird diversity and abundance**
- Oak leaf litter stabilizes species interactions in woodland ponds (Rubbo and Kiesecker 2004) leading to higher success of amphibians (wood frogs)
- Nutrient cycling (Alexander and Arthur 2014)
- Reduced forest flammability
- Biodiversity: Appalachian hardwood forests are the most complex and diverse outside of the tropics (flora and/or fauna)

Cultural services

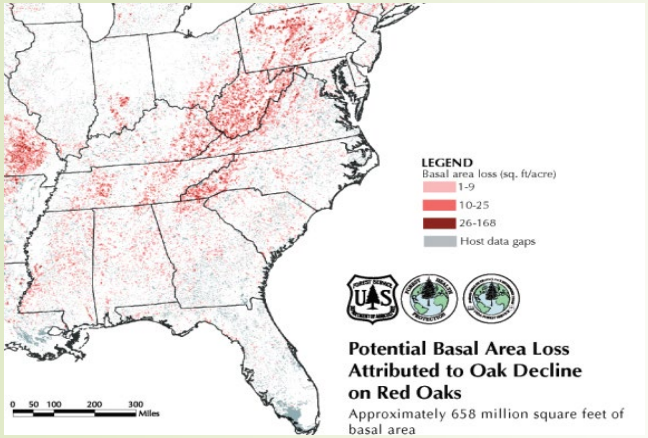
- Recreation
- Tourism
- Spirituality
- Artistic inspiration/appreciation



Blue Ridge Mountain Sunset: Julie Brugh Riffey

Photo: Transylvania times

Current and future forest threats: **Oak decline**



USDA FS, FHTET 2008-06

- Disease complex that affects **old oak trees**, predominantly in the red oak group (scarlet, black, northern red oak)
- Most common on dry sites, but occurs across the landscape
- An inciting factor, such as drought, frost, or defoliation from native and non-native insects, causes stress
- Insect (two-lined chestnut borer) and diseases(shoestring fungus) that normally do not cause harm to healthy trees invade and eventually kill the tree

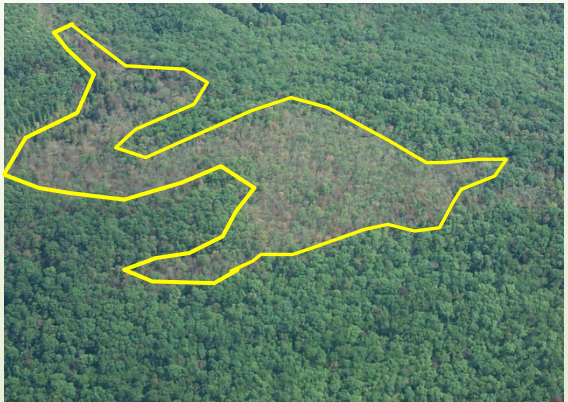


Photo: Martin Spetich, USDA FS, SRS

Current and future forest threats: **Spongy moth**

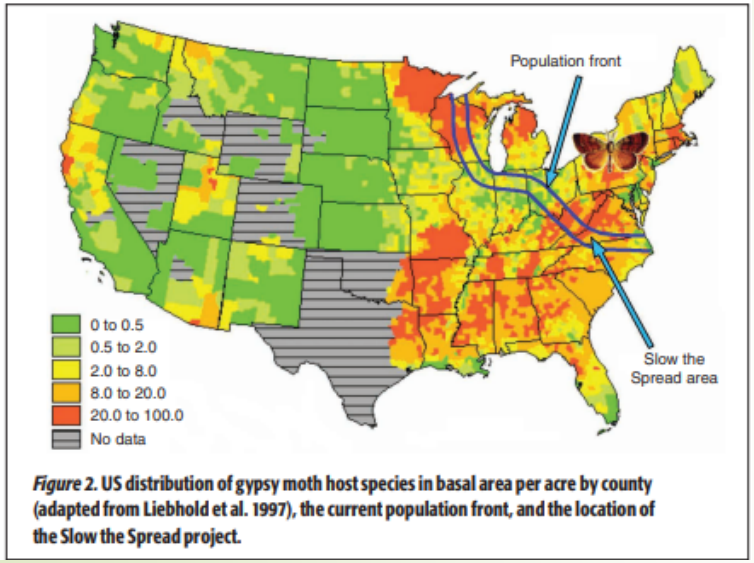


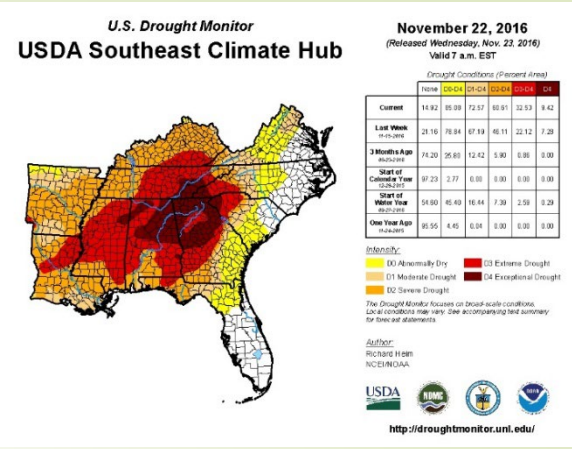
***Figure* 2. US distribution of gypsy moth host species in basal area per acre by county (adapted from Liebhold et al. 1997), the current population front, and the location of the Slow the Spread project.**

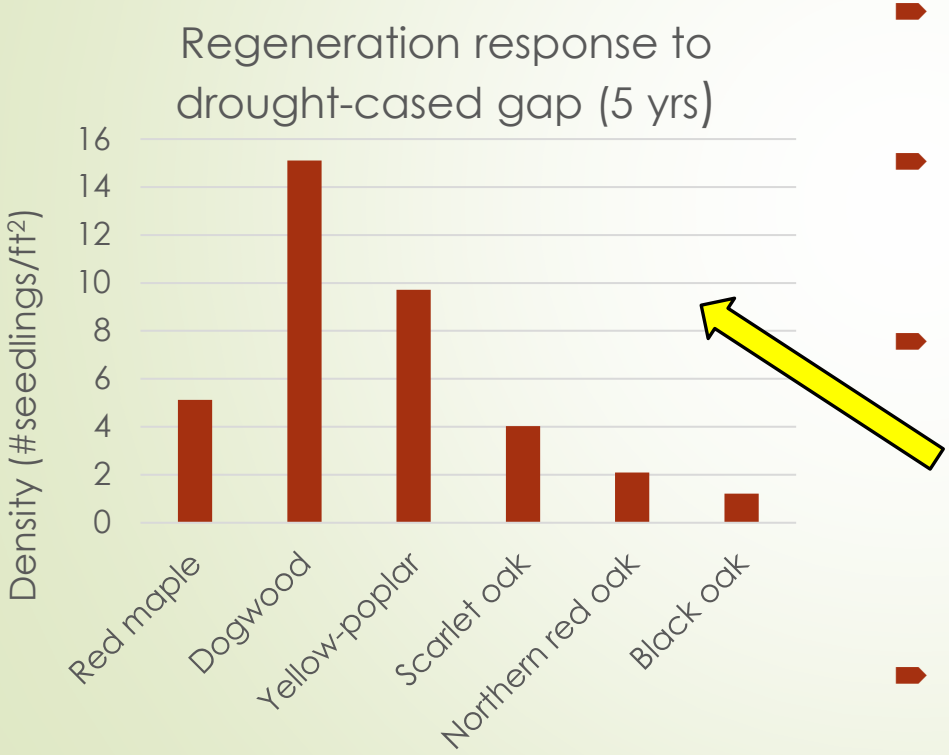
Sharov et al. 2002

Gypsy moth defoliation in northern Virginia circa 1991;
M.E. Robinson - USDA Forest Service;
UGA0000004b

- Introduced to US in 1869
- Host trees are numerous, but guess what?? Oaks are one of its favorite snacks (red oaks may be preferred over white oaks (Foss & Rieske 2003)
  - Resistant species include less desirable hardwoods, like red maple, sugar maple, and yellow-poplar
- Repeated defoliation can lead to death or weaken trees and start the disease spiral (oak decline) that can lead to death
- Defoliation of oak canopy results in an increase in growth and recruitment of understory red maple

Current and future forest threats: **Drought**



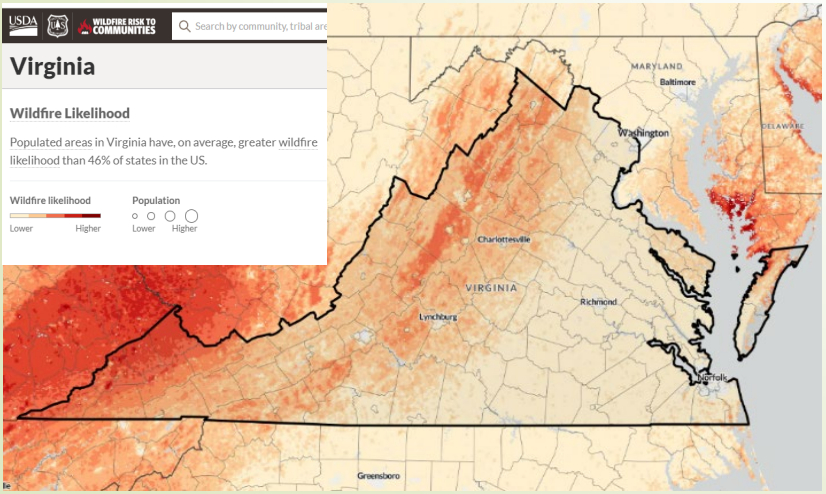


Clinton et al. 1994

- Oaks are considered drought tolerant
  - Red oaks < white oaks
- Drought often sets the stage for insect and disease outbreaks that lead to mortality in the long-term
- Drought-caused gaps are small, allowing shade-tolerant species (maple) to respond more so than oaks, but shade-intolerants (yellow-poplar) can also establish and dominate over oaks in the understory
- Season of drought; length of drought (micro-droughts); frequency of droughts will all affect growth and mortality – all forecasted to increase in the future

Current and future forest threats: **Wildfire**

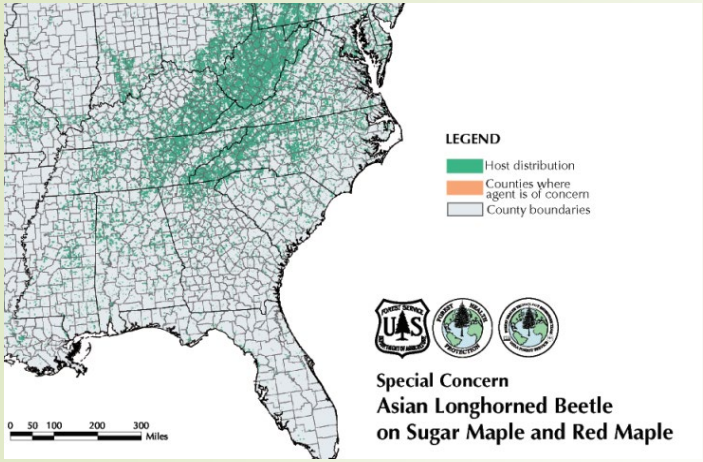
Chimney Tops 2 Fire: NPS photo by Warren Bielenbert



Wildfirerisk.org

- The occurrence, severity, and extent of wildfire is forecasted to increase, even in the relatively mesic eastern US
- Depending on severity, wildfire can result in immediate and delayed mortality of the canopy
- Following the 2016 wildfires, mortality in one watershed averaged (Caldwell et al. 2020):
  - 61% for mesic species <8" dbh
  - 51% for xeric species <8" dbh
  - 19% for mesic species >8" dbh
  - 9% for xeric species >8" dbh
- When wildfire occurs without previous burning (prescribed fire) or other management, stands may transition more quickly to red maple and/or yellow-poplar
- Small oak seedlings may sprout but are quickly overtopped by resprouting mesic species

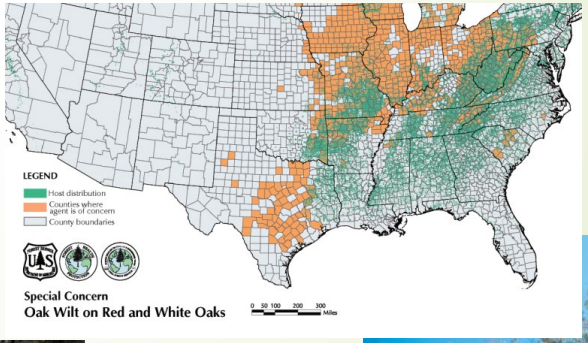
Current and future forest threats



USDA FS, FHTET 2007-06

- Oak wilt**
- Emerald ash borer
- Asian longhorned beetle (like red maple, but bugs are not great forest managers)
- Invasive plant species (the list is long…….)
- Markets for forest products

Asian longhorned beetle: *Thomas B. Denholm, NJ Dept Ag, Bugwood.org*



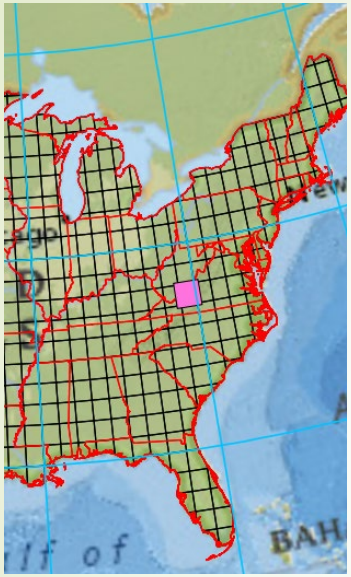
Oak wilt: *Joseph O'Brien, USDA FS, Bugwood.org*

Conserve your forest legacy: Management to prepare for forest threats

- Forest management for resilience instead of resistance
- Resistance: Ability of an ecosystem to withstand the negative impacts of a disturbance (***Resistance is futile***…..)
- **Resilience: Ability of an ecosystem to recovery after experiencing disturbance**
  - Accepting disturbance is going to happen, but trying to recover from the impacts of the disturbance




Management to promote resilience: **species preference**



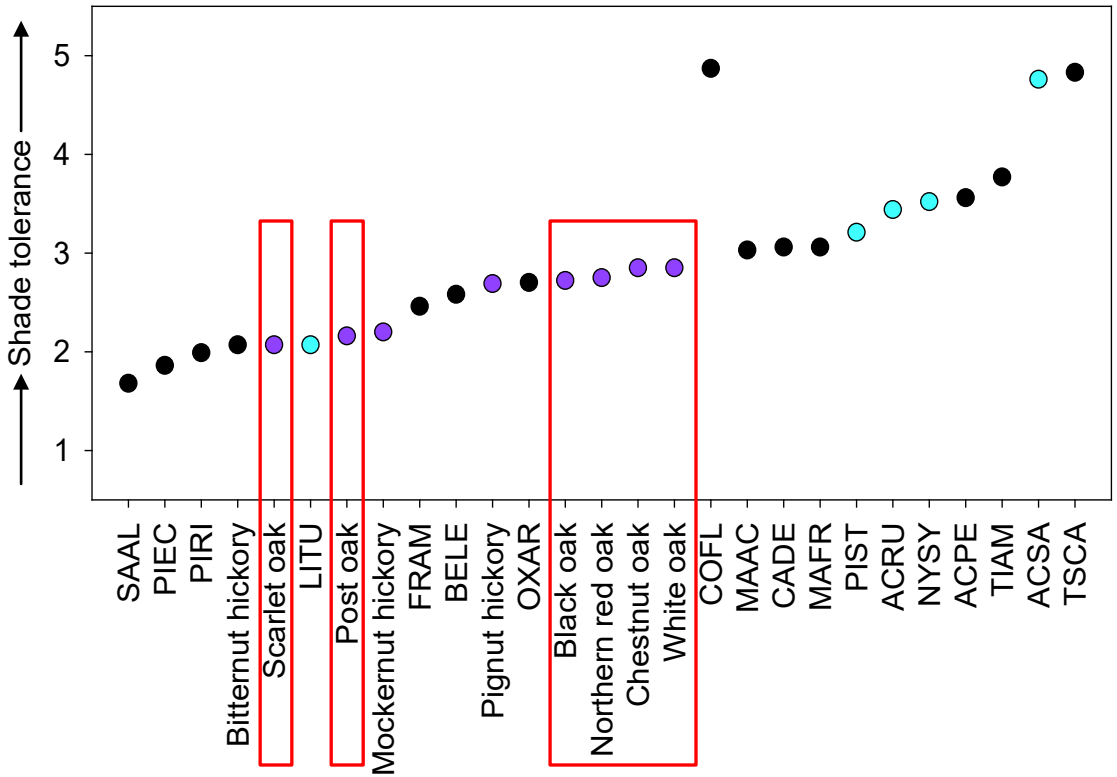
- Habitat quality for may decrease (orange) or increase (green), and new habitat (brown) may emerge
- For the most part, oaks are 'winners' in a warmer/drier climate

https://www.fs.usda.gov/nrs/atlas/tree

Species	Current abundance	Change in potential habitat	Ability to cope w/ climate change
Scarlet oak	Abundant	Sm. dec.	Fair
White pine	Abundant	Sm. dec.	Fair
Cucumbertree	Common	No change	Fair
Sweet birch	Common	No change	Poor
Fraser magnolia	Rare	No change	Very Poor
Striped maple	Rare	Sm. dec.	Very Poor
Chestnut oak	Abundant	Sm. dec.	Good
White oak	Abundant	Sm. inc.	Very Good
Black oak	Common	Sm. inc.	Good
Northern red oak	Abundant	Sm. inc.	Very Good
Mockernut hickory	Common	Lg. inc.	Very Good
Red maple	Abundant	Sm. dec.	Good
Blackgum	Common	Sm. inc.	Very Good
Yellow-poplar	Abundant	Sm. dec.	Good
Southern red oak	Rare	Lg. inc.	Good
Shortleaf pine	Rare	Lg. inc.	Good
Post oak	Rare	Lg. inc.	Good
Blackjack oak	Absent	New habitat	New habitat (IN)
Winged elm	Absent	New habitat	New habitat (M)
Water oak	Absent	New habitat	New habitat (M)
Shumard oak	Absent	New habitat	New habitat (M)
Pecan	Absent	New habitat	New habitat (M)

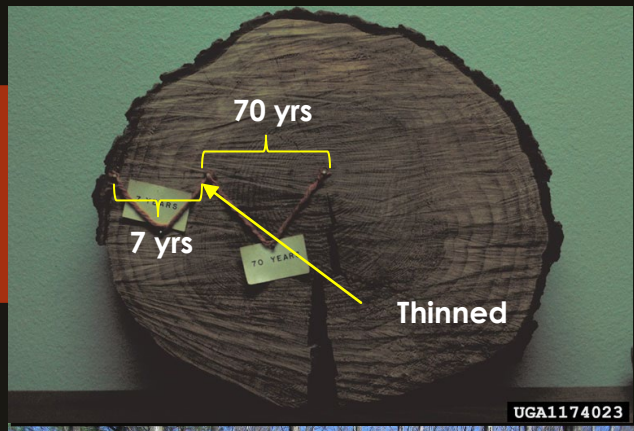
Management for oaks

- Manage for light
- Oaks are mid-tolerant of shade
- Seedlings need light to grow into large seedlings that can grow into the canopy after disturbance



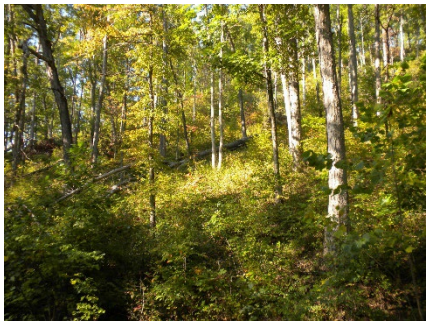
Management for oaks: **Thinning**

- Improves the vigor and value of an existing forest stands
- Increase individual tree growth which decreases the time need to become merchantable ($)
- Stimulates the forest understory = browse
- Promote crown development = increased acorn production
- Opportunity to improve species composition and select species that are more resilient to disturbances/threats
- Increase resiliency to drought
- Increase tree vigor = increased ability to withstand defoliation (spongy moth)
- Increase light and stimulates the growth of oak seedlings



Management for oaks: **Prescribed fire**

- Not just one time, but a regime (every 2 – 7 years)
- Reduce hazardous fuels & future wildlife hazard (litter/duff/shrubs)
- Depending on frequency & severity, reduce tree density & increase light
- With repeated burning, reduce maple/gum seedlings & promote oak seedling growth
- Stimulate the forest understory = soft mass production (berries), pollinator habitat (bees & butterflies), amount & quality of browse)
- Create snags and cavities (wildlife habitat)
- Risks: loss of volume, decrease in tree grade ($$)
  - 54 forests across Indiana, researchers found only a 10% loss of sawtimber volume and only 3% of trees had a decrease in grade



Management for oaks: **Midstory removal**

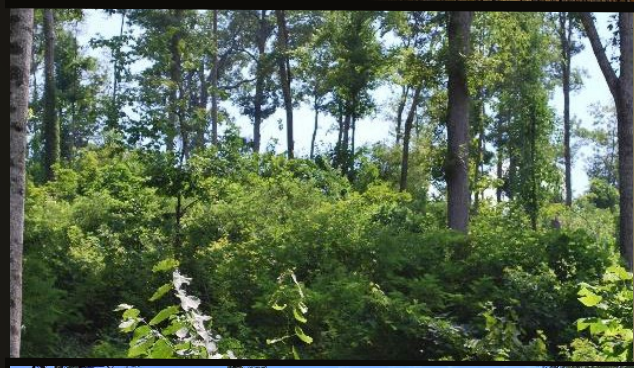
- Designed to increase light in the understory and increase the growth of oak seedlings
- Non-commercial treatment; usually chemical treatment/removal of smaller diameter, undesirable species (maple, blackgum, beech, etc.) below the main canopy
  - Hack 'N Squirt used to reduce/eliminate sprouting that would be prolific if mechanically felled

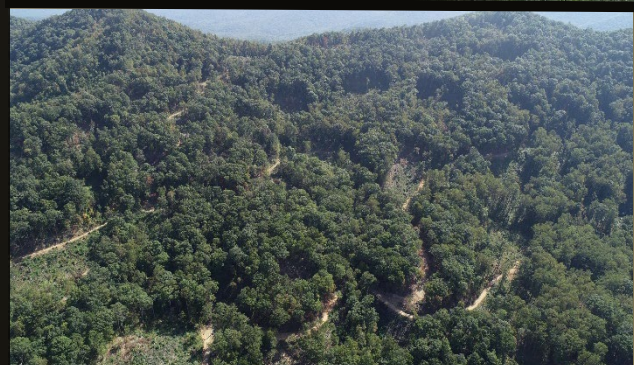
Photo: Kentucky Woodlands Magazine, Jeff Stringer

Photo: Kentucky Woodlands Magazine, Jeff Stringer

Management for oaks: **Regeneration harvests**

- Creates and releases a new age cohort
- Multiple benefits:
  - Create wildlife habitat (deer, turkey, grouse, neotropical migratory birds) and open conditions lacking across the landscape
  - Create forests that are younger and maybe more resilient to disturbances
- Multiple methods to regenerate:
- Gaps (group selection), expanding gaps (Femelschlag)
- Shelterwood (cuts of different intensities at different times)
  - Begin a 10–15-year shelterwood sequence whereby harvesting is done in steps in order to promote oak seedling growth *before* the canopy trees are removed/harvested

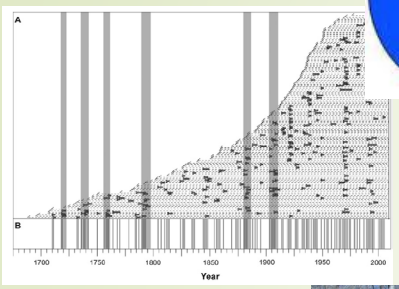


Indigenous Peoples – burning & other land uses

European settlement pasture, agriculture, fuel; girdling & fire

Loss of keystone species

Domestic grazing



Lack of disturban
(Hart et al. 2012

Iron furnaces

Fire suppression

Land aban

Indiscriminate logging/wildfires

Wood utilization - subsistence

Questions