Looking at Forest Carbon from Multiple Dimensions: Evaluating Tradeoffs and Opportunities to Forest Carbon Management

THE UNIVERSITY OF VERMONT FORESTRY

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Photo: Duane Cross

Photo: Les Benedict

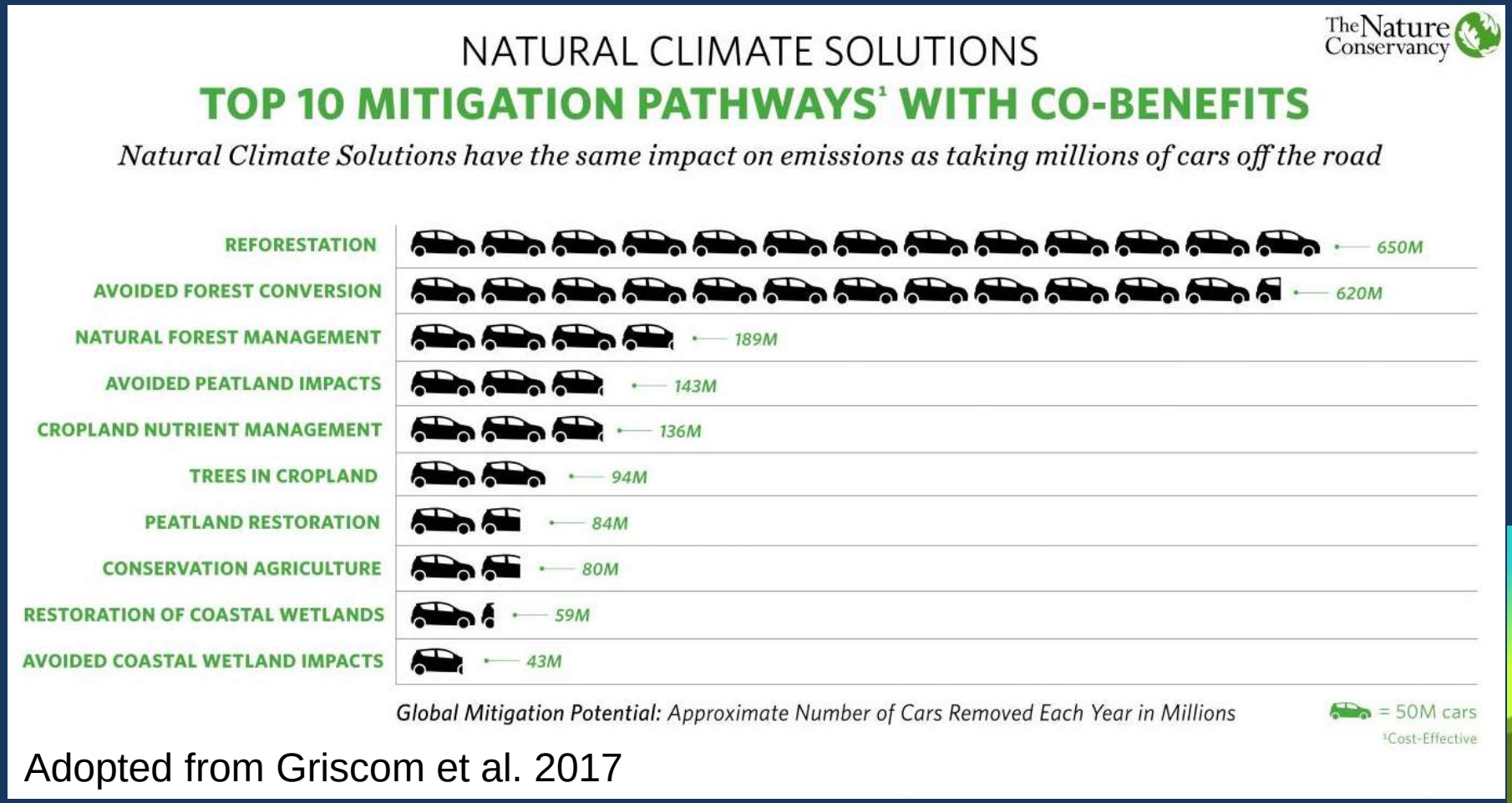
Seeking of balance from forests

"It should now be apparent that there is no inherent harmony among the various major objectives sought in managing forests."

D.M. Smith. 1962. The Practice of Silviculture, 7th Edition.

Seeking maximum carbon benefit from forests

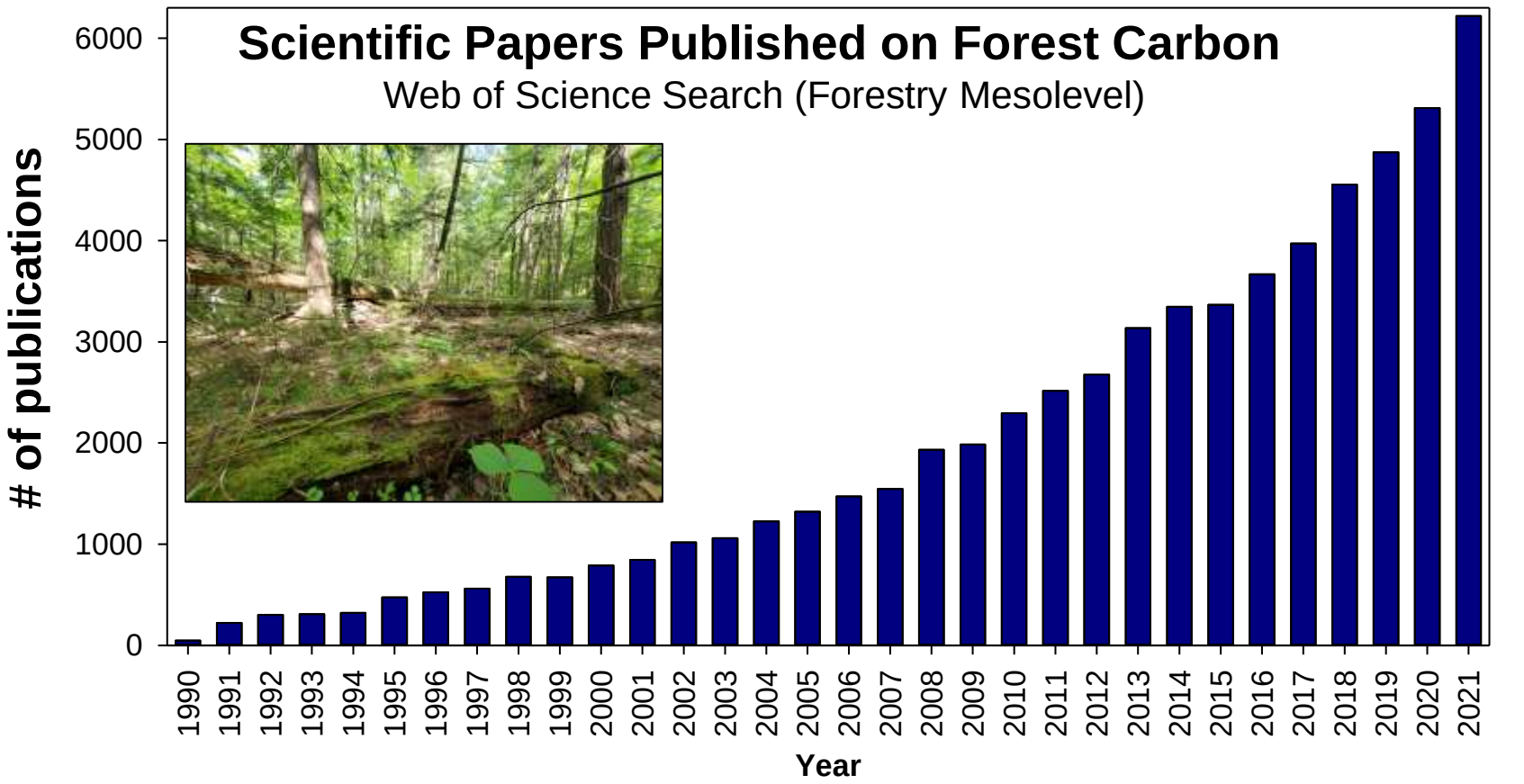
Urgency of climate crisis has broadened awareness and interest in role forests play in capturing and storing carbon



Adopted from Griscom et al. 2017

Seeking maximum carbon benefit from forests

Recent Interest in Scientific Community



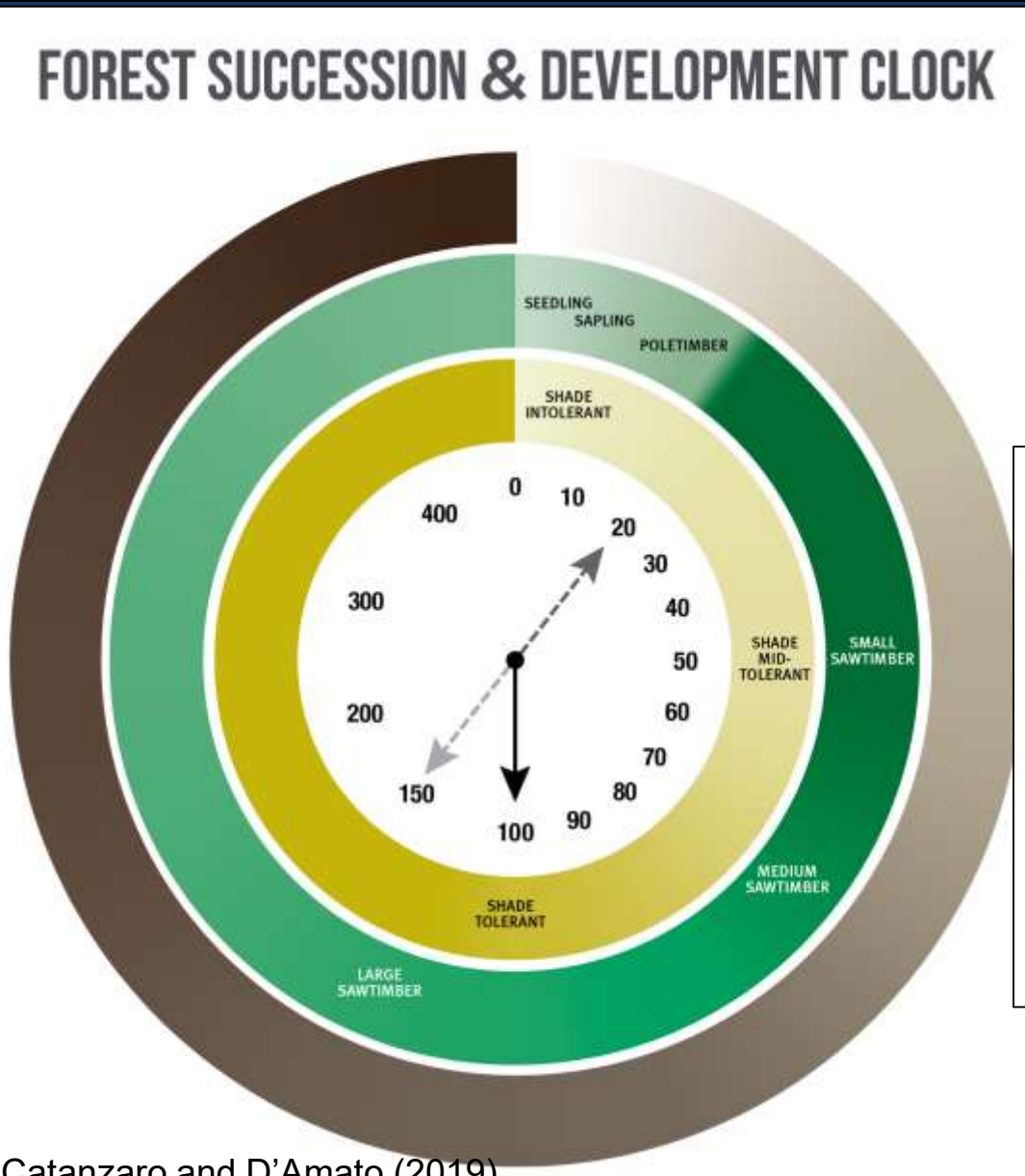
Recent Public Interest

Photo: Missoula Current

Photo: Douglas Hook

Tradeoffs and Opportunities with Carbon

Forest Conditions Providing Highest C Storage



Catanzaro and D'Amato (2019)

Amount of on-site **carbon storage** increases as forests age

Sequestration continues, but stand-level rates decline with age

LEGEND

0–400 Age of the forest in years

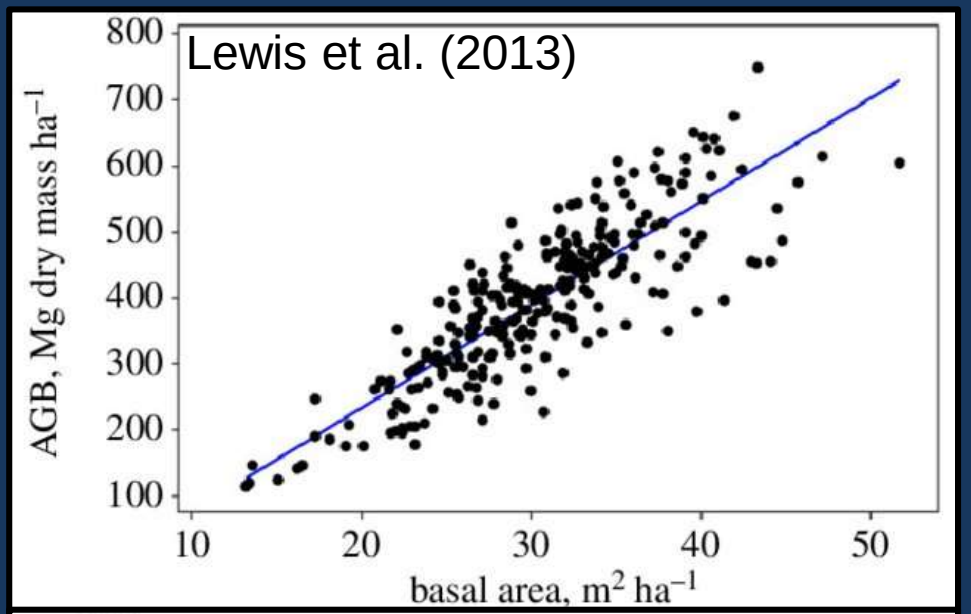
Changes in carbon storage over time. The darker the brown, the more carbon storage.

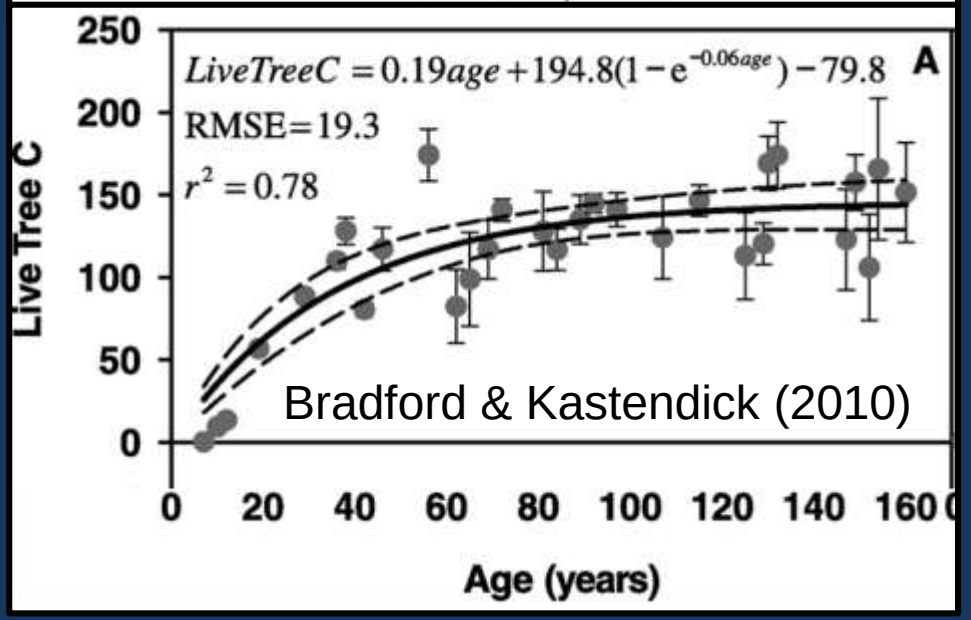
Changes in carbon sequestration over time. The darker the green, the more forest level carbon sequestration.

Changes in tree species shade tolerance over time. The darker the yellow, the more likely shade-tolerant trees (e.g., hemlock, sugar maple, and beech) are to be competitive.

Forest Conditions Providing Highest C Storage

- **General structural conditions associated with high carbon storage include:**
  - High overall live tree stocking
  - High large tree stocking
  - Abundant deadwood
  - High structural complexity





Values & Functions Provided by High Storage

- **Many values and functions associated with later successional forests are satisfied by stands with high carbon storage:**
  - Breeding habitat for bird species associated with mature forests
  - Cultural and spiritual values tied to old trees and late-seral flora
  - Water storage
  - Thermal buffering
  - Habitat for dispersal limited taxa
  - Multiple recovery and developmental pathways (in complex, old forests)

Wood et al. (2013)

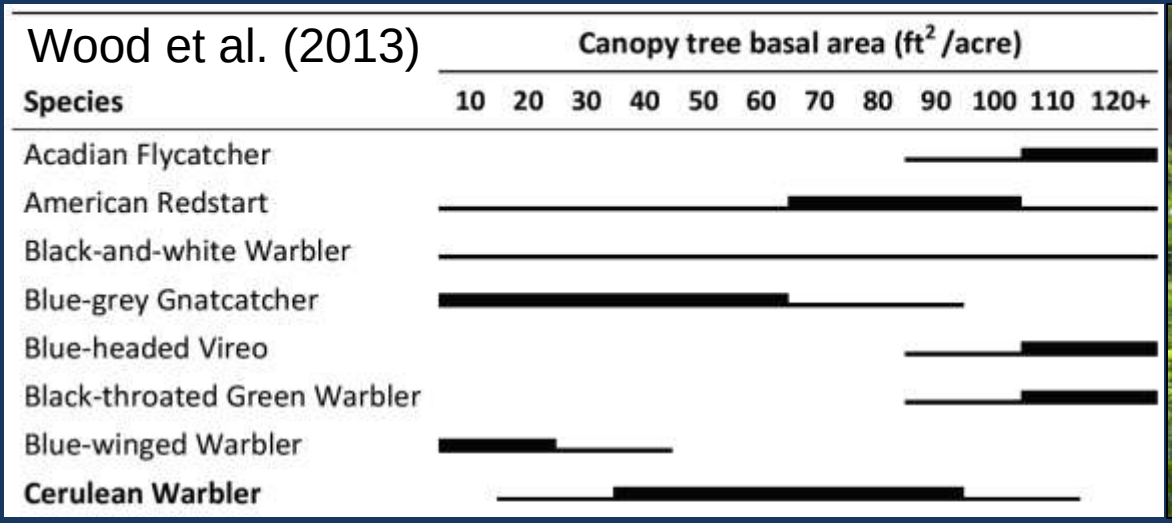



Photo: Bryant DeRoy

Values & Functions Provided by High Storage

- Higher carbon stocks do not automatically equate to high ecological complexity (or old-growth conditions)

Economically (not ecologically) mature
High carbon density, low complexity

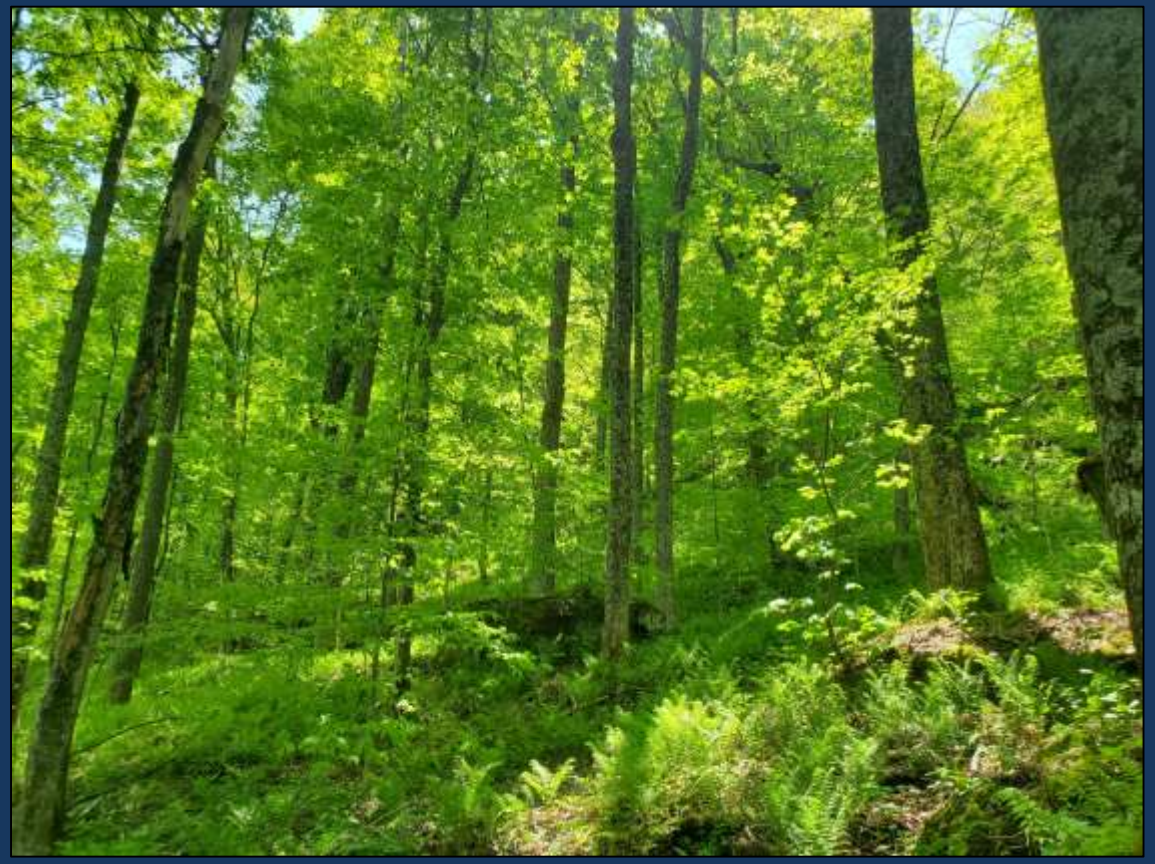
≠

Old-growth forests
Highest carbon density, high complexity

≠

Evaluating Tradeoffs with High Carbon Stocking

- What values, species, and functions are not supported by high carbon stocking conditions emphasized by recent policy and incentivized by offsets?



Species Dependent on Young & Woodland Habitats

- Restoration or maintenance early successional forest or woodland conditions reduces overstory live tree densities to sustain declining, threatened, and endangered taxa

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ESSAY

Identifying trade-offs and opportunities for forest carbon and wildlife using a climate change adaptation lens

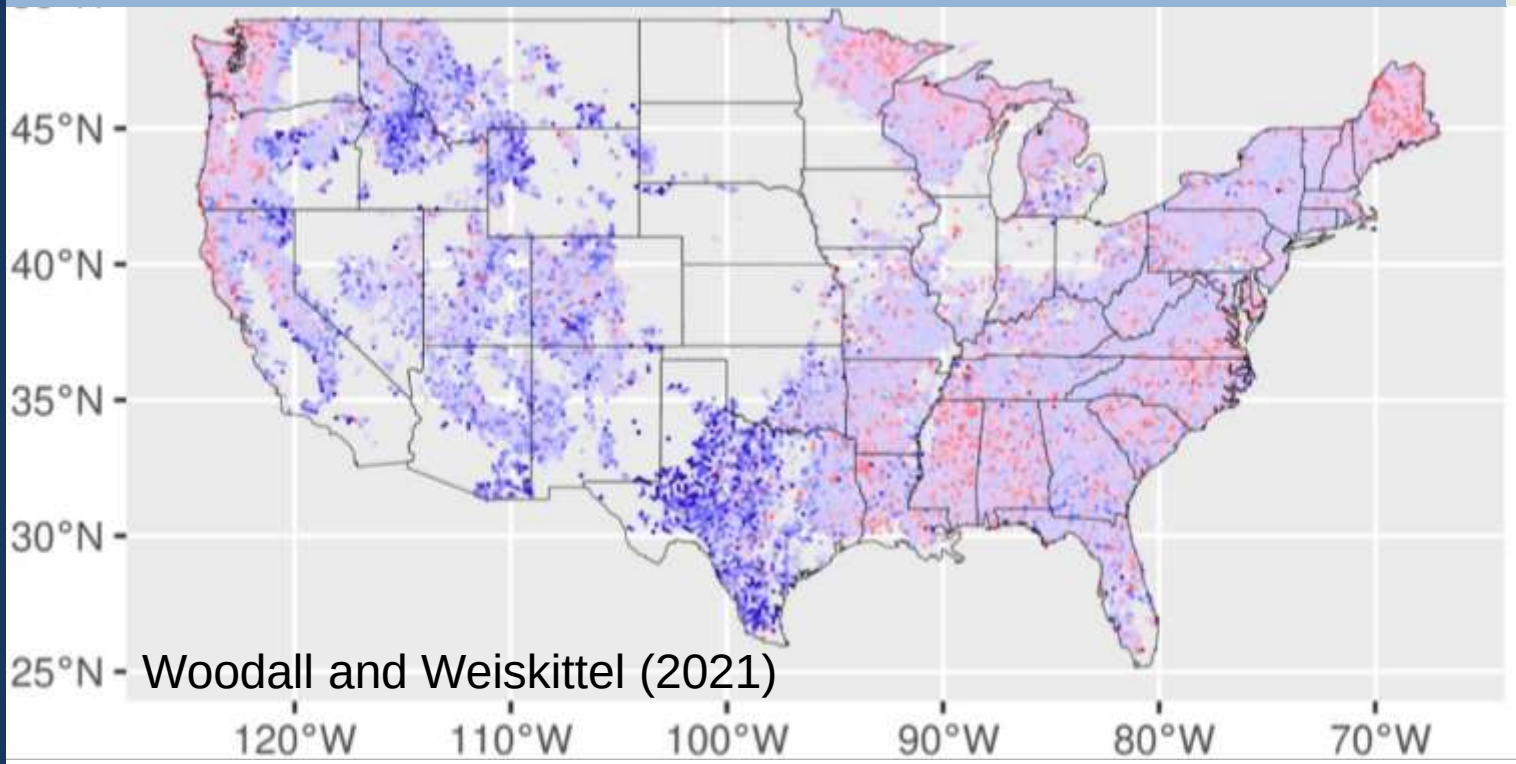
Caitlin E. Littlefield[1] | Anthony W. D'Amato[2]

Habitat to be restored and maintained	Habitat quality for focal species	Stand-level carbon storage in trees	Habitat and wildlife species diversity	Risk of carbon release from severe disturbance	Enhanced resilience and adaptive capacity
Early successional n. hardwoods	↑	↓	↑	↓	↑
Tallgrass aspen parklands	↑	↓ *	↑	↓	↑
Oak savanna	↑	↓ *	↑	↓	↑
Pitch pine-scrub oak barrens	↑	↓	↑	↓	↑
	Stand-level effects		Landscape-level effects		

Stock Size versus Stock Resilience

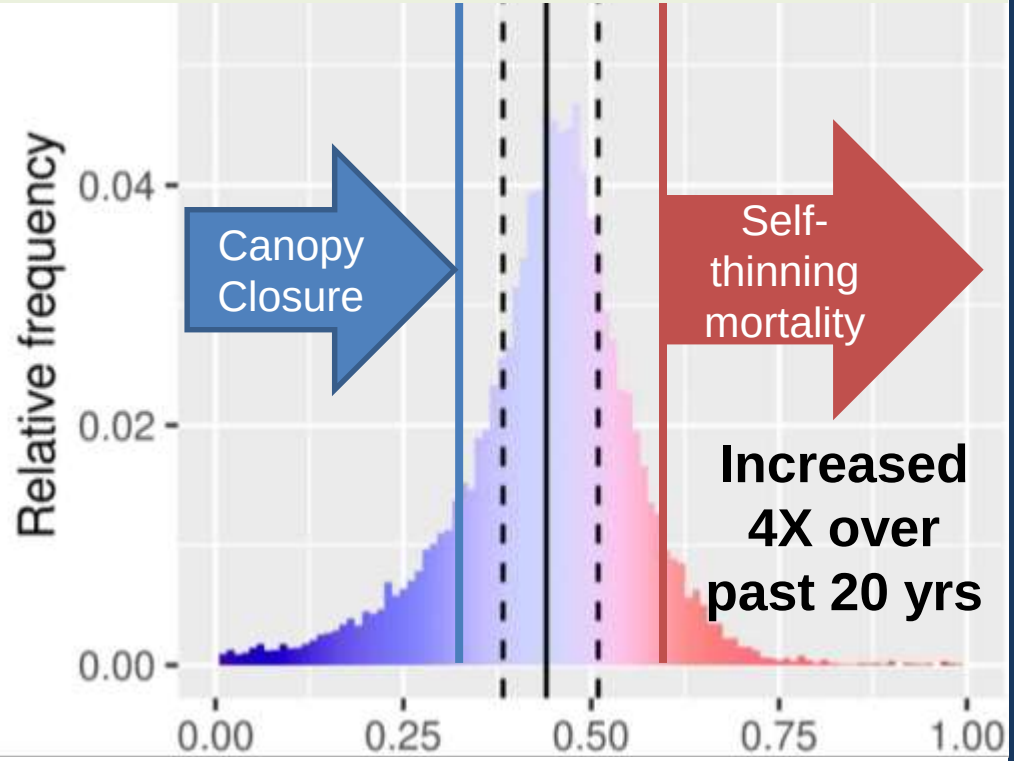
- Long-term stability of forest carbon benefits requires consideration of factors conferring resilience in dynamic systems
  - Many carbon stocks in vulnerable state due to high live-tree stocking and absence of complexity

Relative density of forests across conterminous US



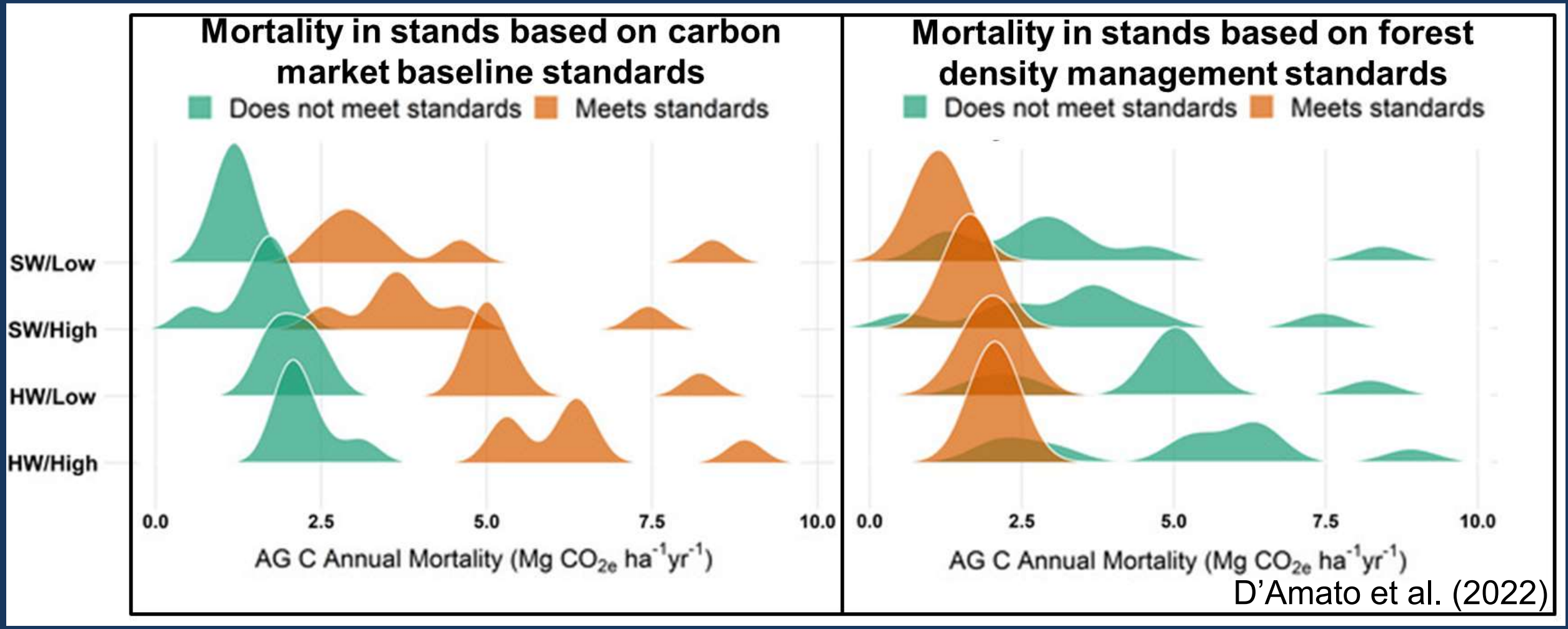
Woodall and Weiskittel (2021)

Relative frequency of stocking conditions



Stock Size versus Stock resilience

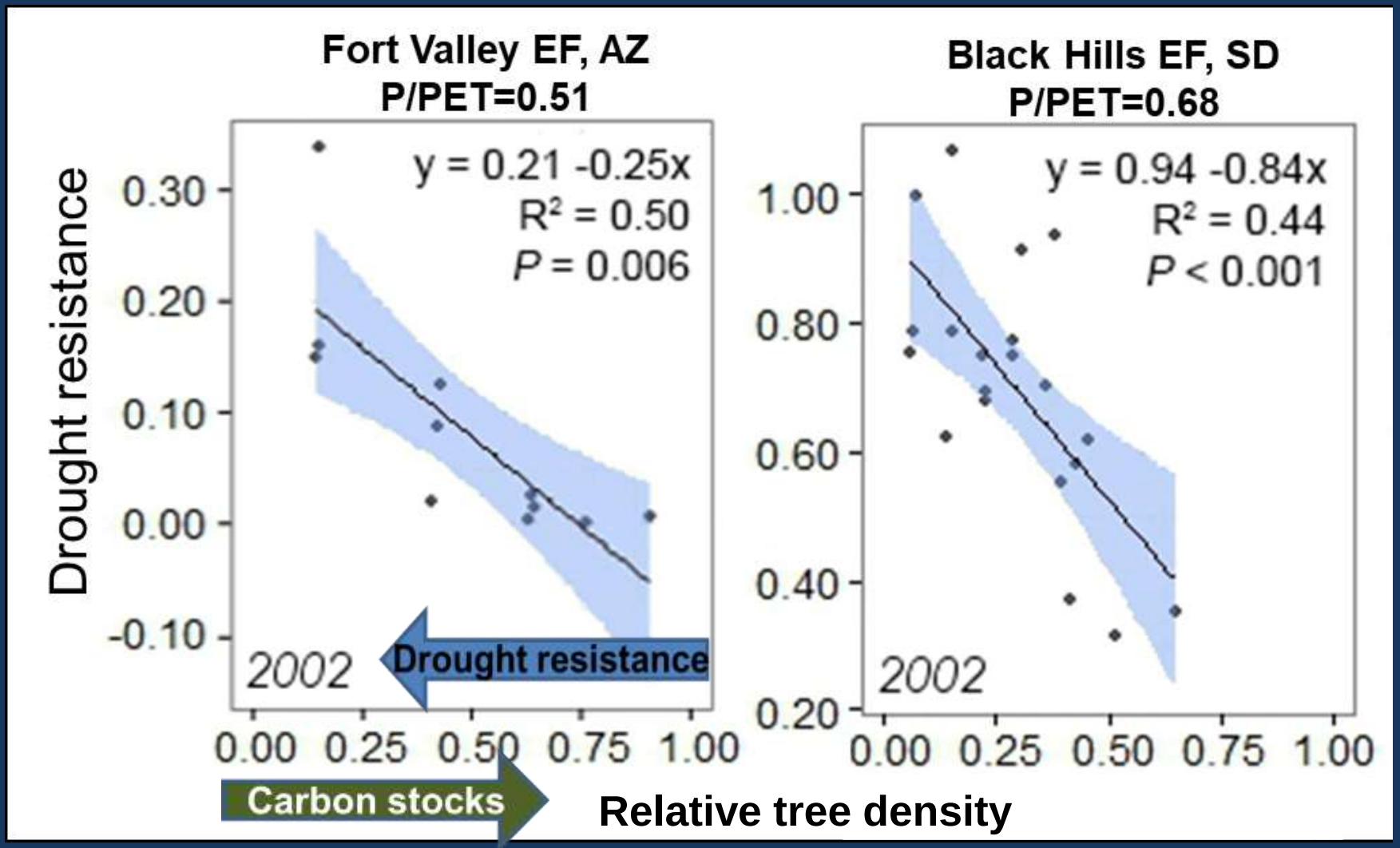
- High carbon stocks incentivized by carbon market baseline standards may encourage forest densities more vulnerable to carbon losses to mortality



D'Amato et al. (2022)

Stock Size versus Stock Resilience

Density management to reduce drought impacts



Bottero et al. (2017)

Stock Size versus Stock Resilience

Restoration of woodland conditions and fire represents tradeoff between short-term loss and long-term resilience

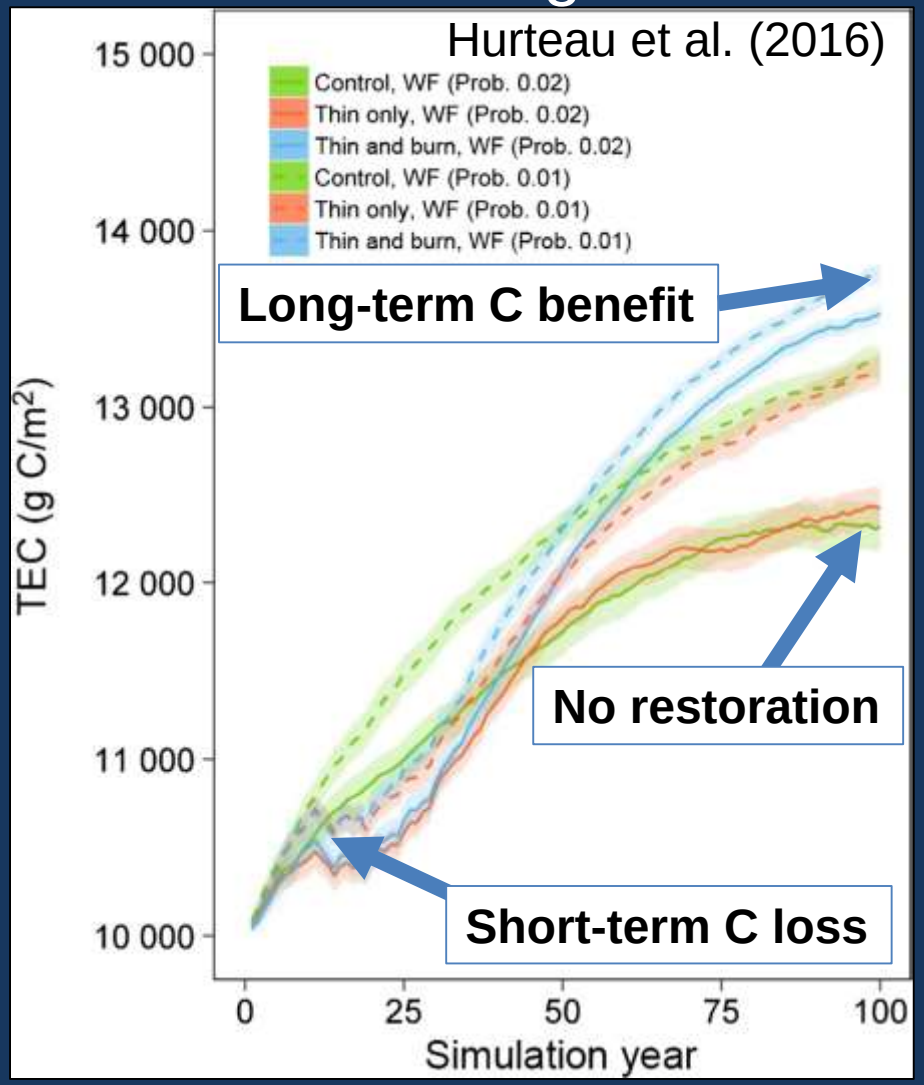
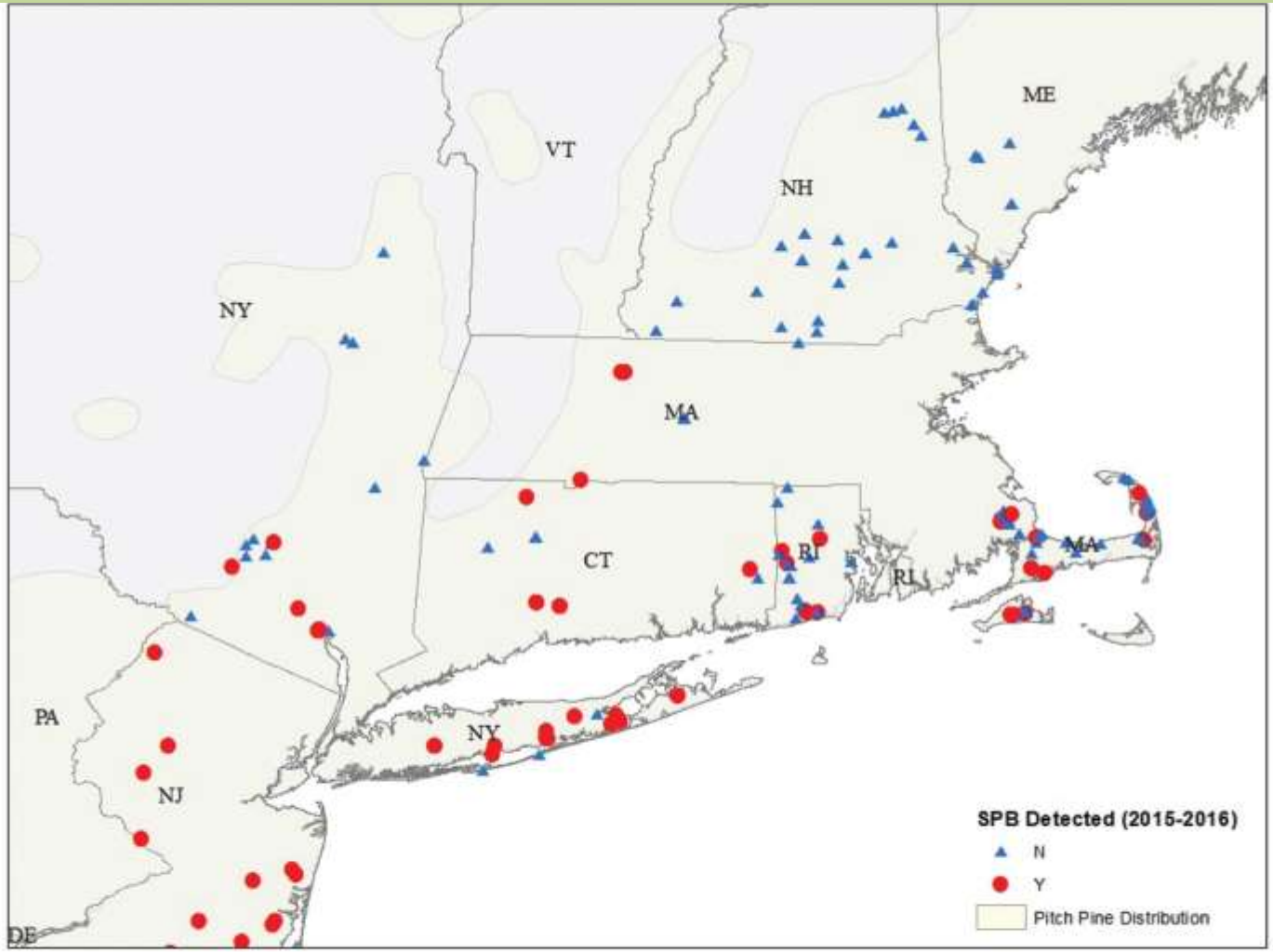


Photo: ODF

Photo: B. Quester

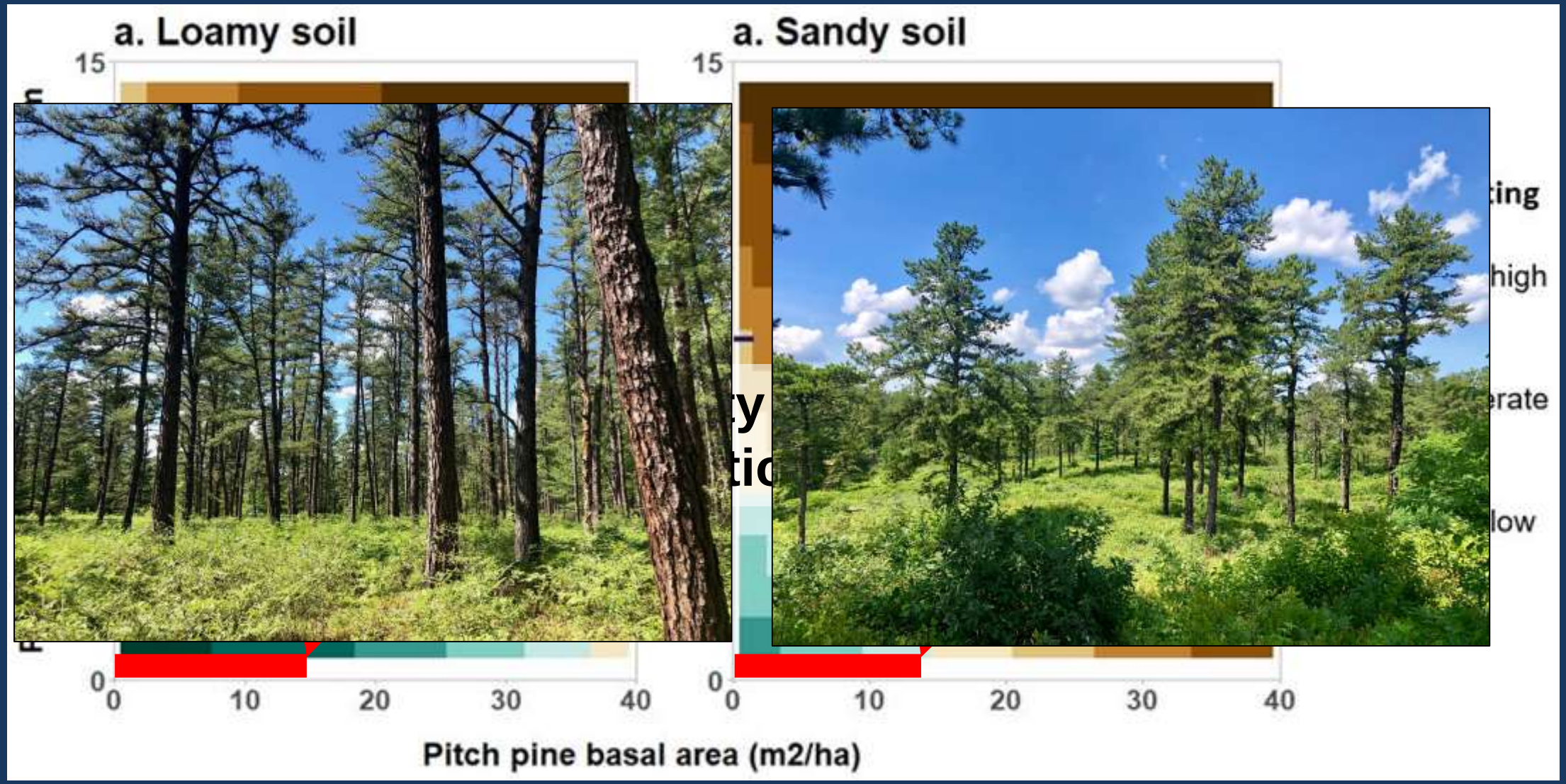
Stock Size versus Stock resilience

Southern pine beetle (SPB) detection in northeastern pine barrens (2015-2016)



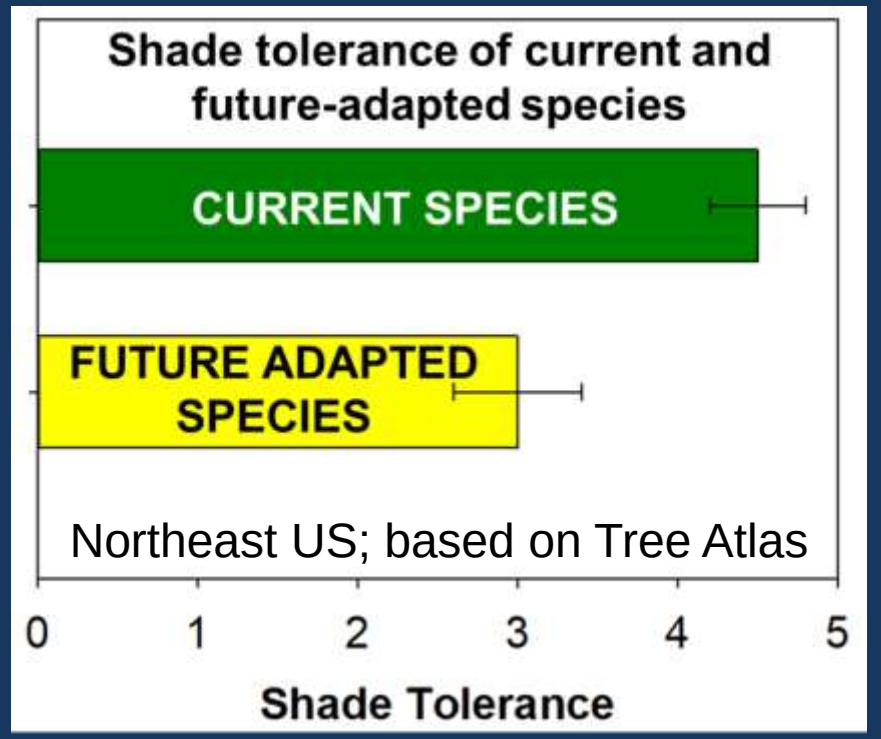
Stock Size versus Stock Resilience

SPB Hazard Rating Model (Jamison et al. 2022)



Stock Size versus Adaptation Options

- Many strategies for increasing adaptive capacity entail restoring and/or increasing the structural and compositional complexity of forest simplified by past land use
- Increasingly include regeneration of “future-adapted species”
  - Most are large gap specialists (not high carbon stock specialists)



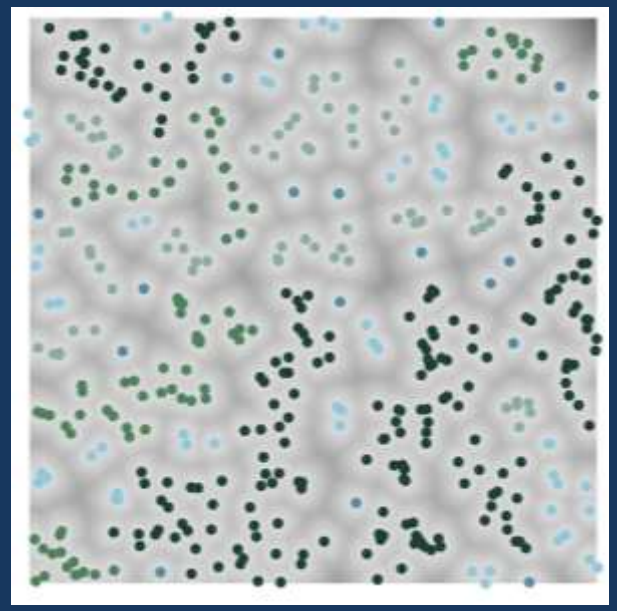
Stock Size versus Adaptation Options

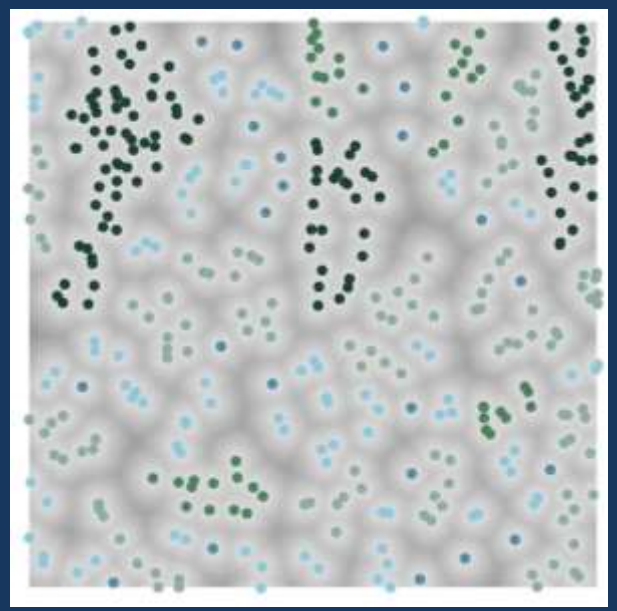
Accept

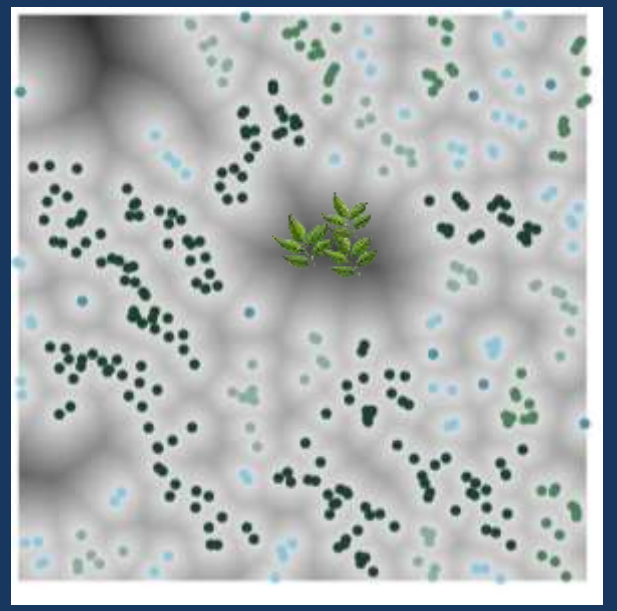
Resistance

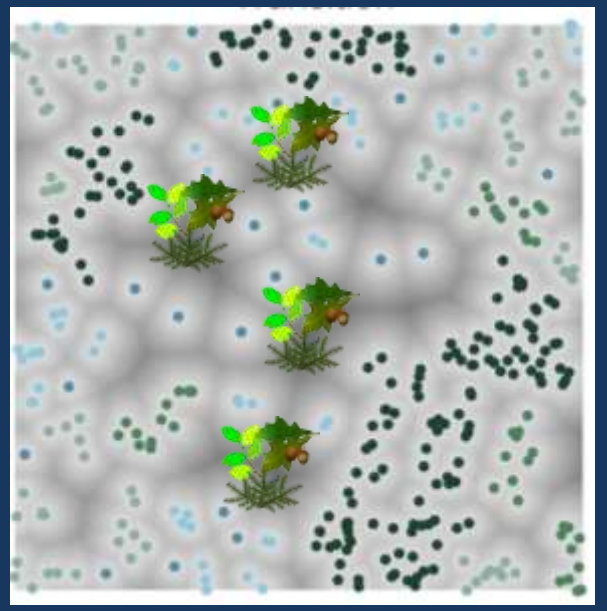
Resilience

Transition







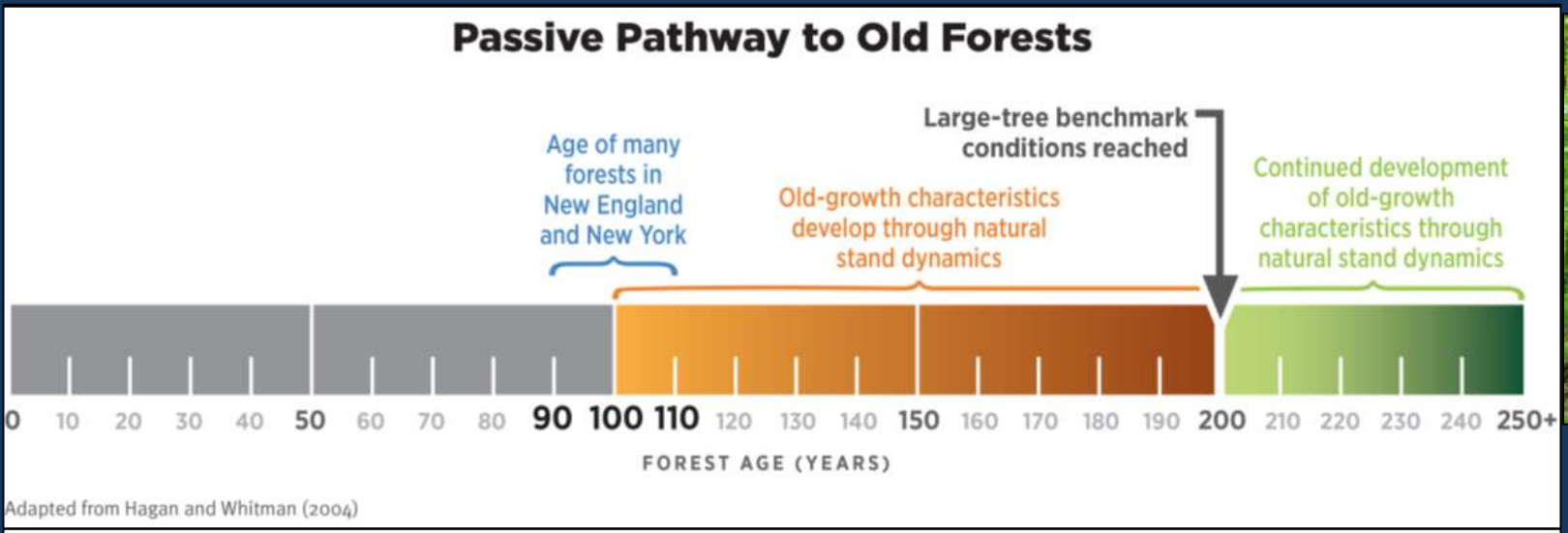


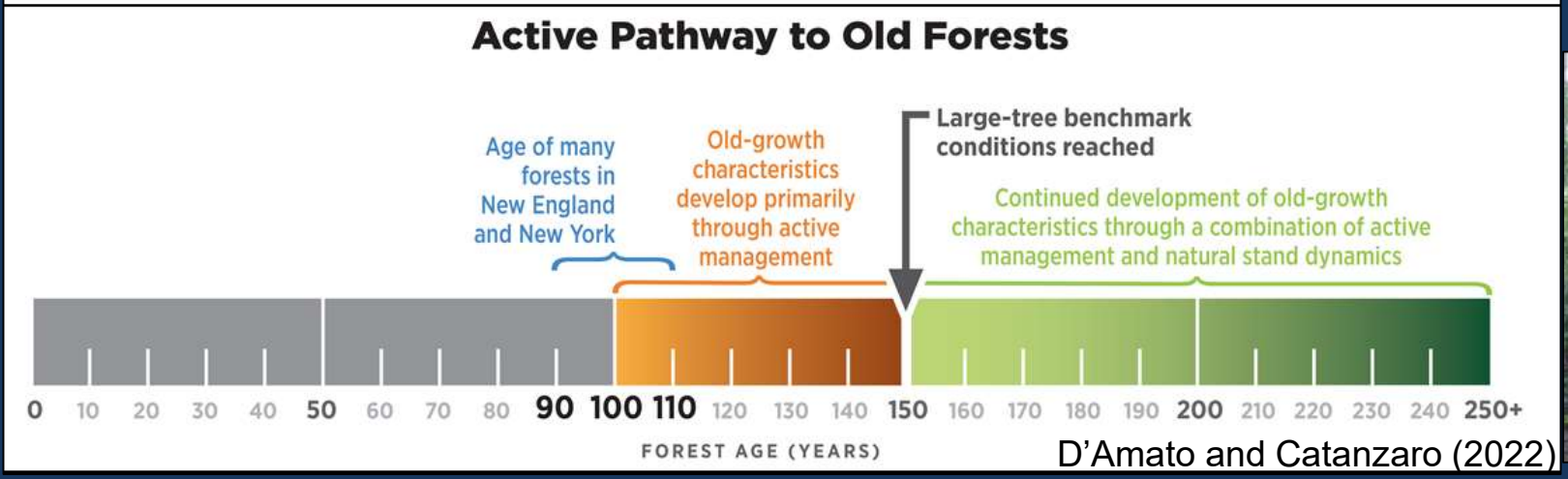
2.5-acre stem-mapped plots

Wikle and D'Amato (in press)

Additional Ecological and Cultural Considerations

Emphasis on preserving “mature stands” for carbon may reduce options for actively restoring old-growth forest characteristics and old forest benefits

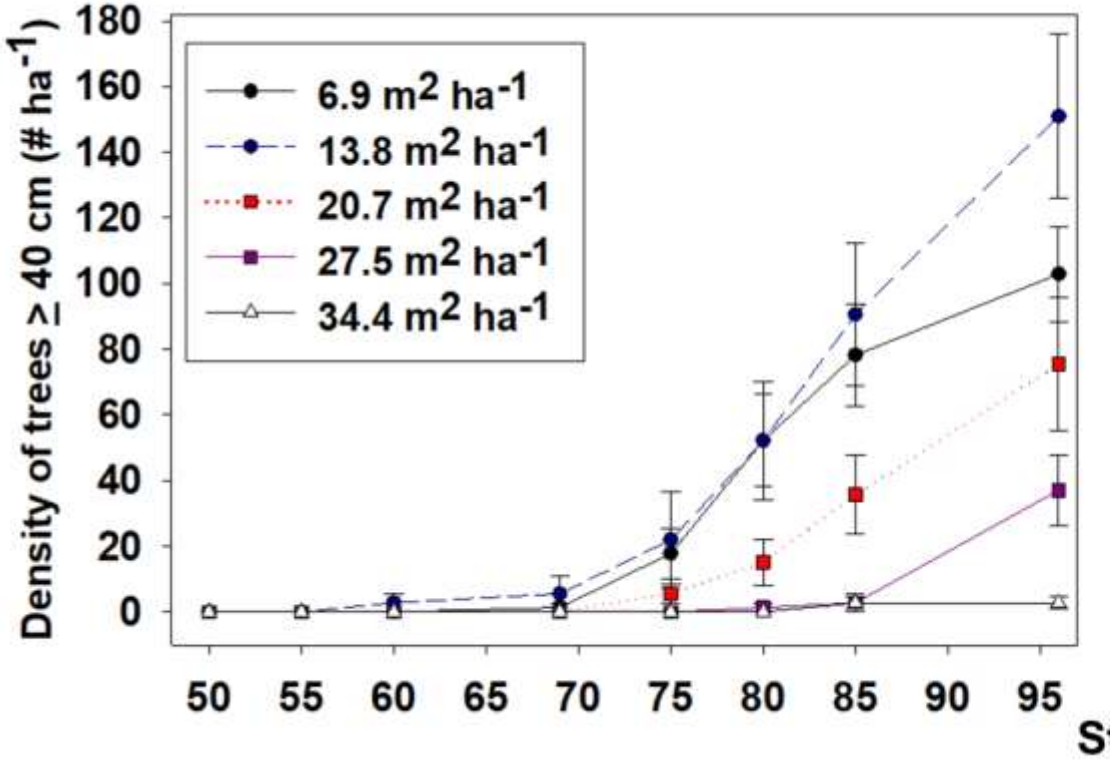




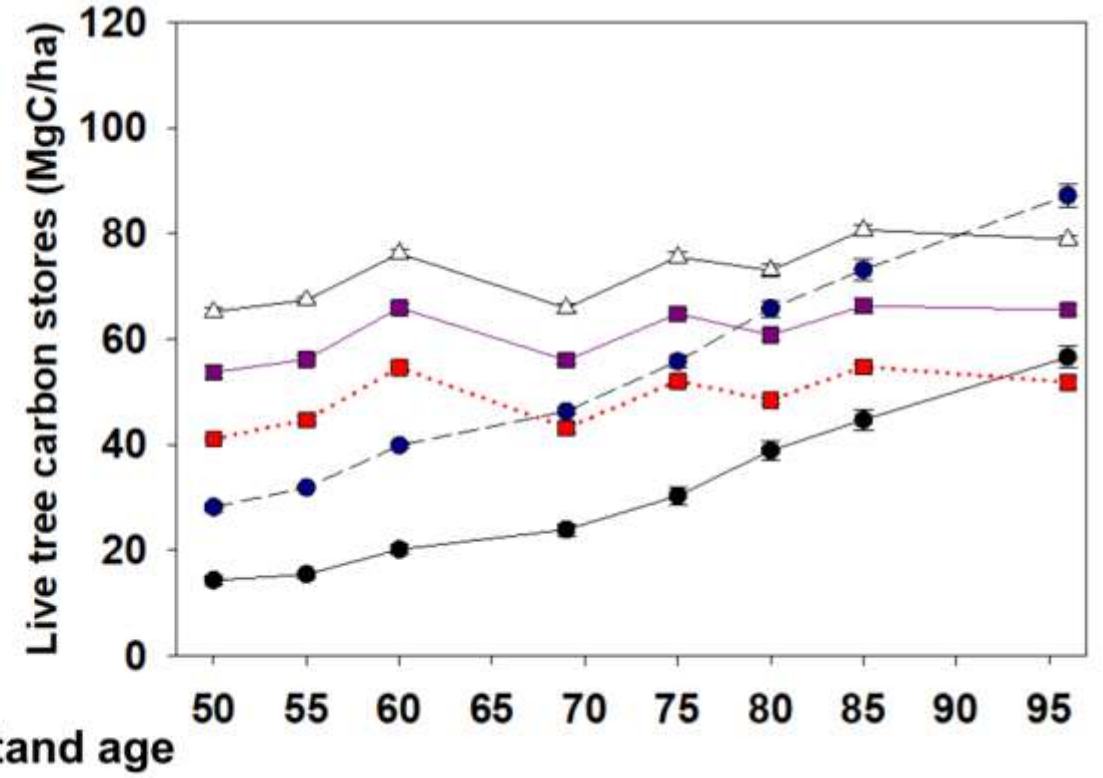
D’Amato and Catanzaro (2022)

Additional Ecological and Cultural Considerations

Development of large trees



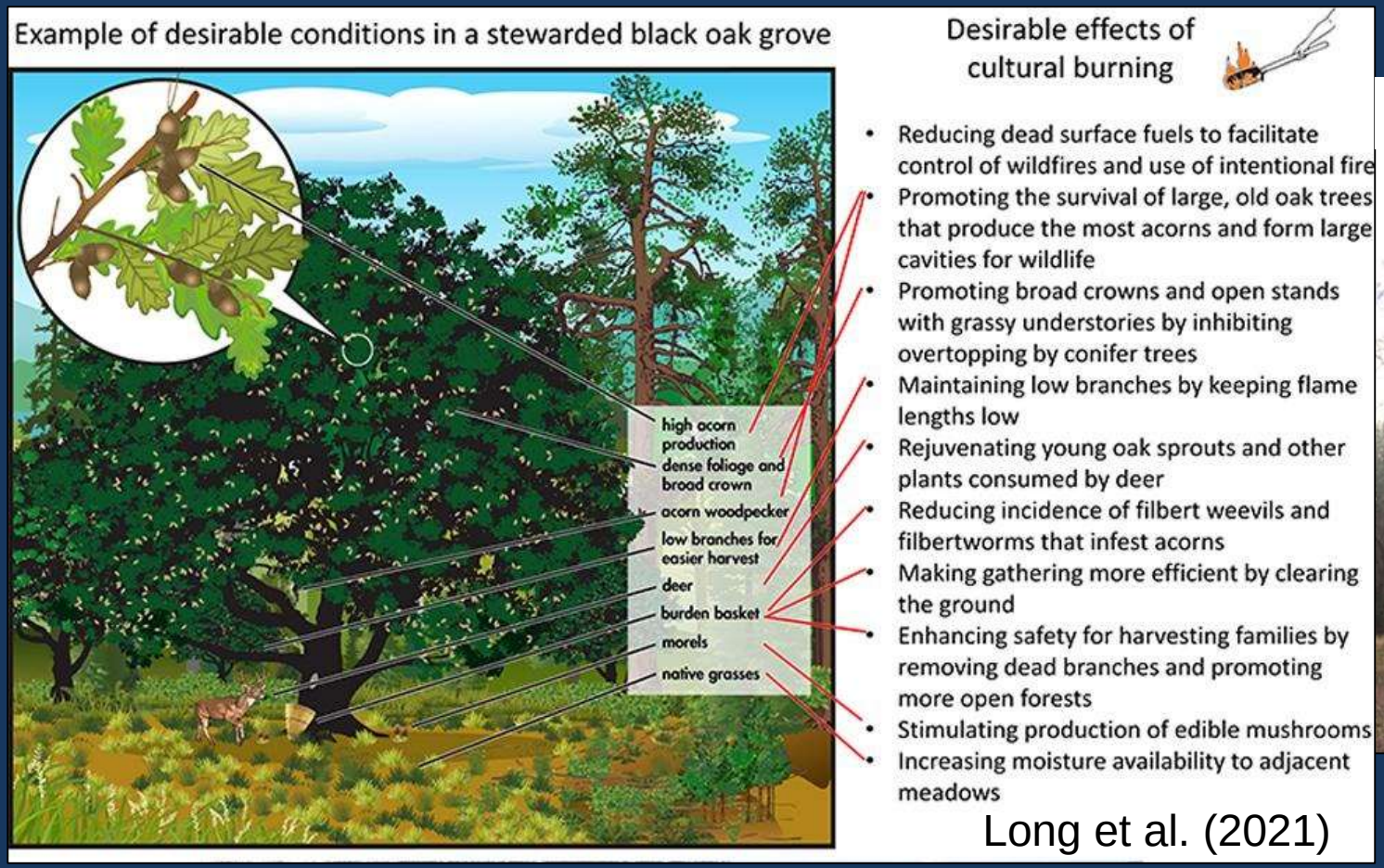
Development of aboveground C stocks



D'Amato et al. 2011

Additional Ecological and Cultural Considerations

- Honoring and applying Indigenous burning practices to address current threats, conserve biocultural diversity, and maintain traditional knowledge, values, and goods should supersede singular carbon stock focus

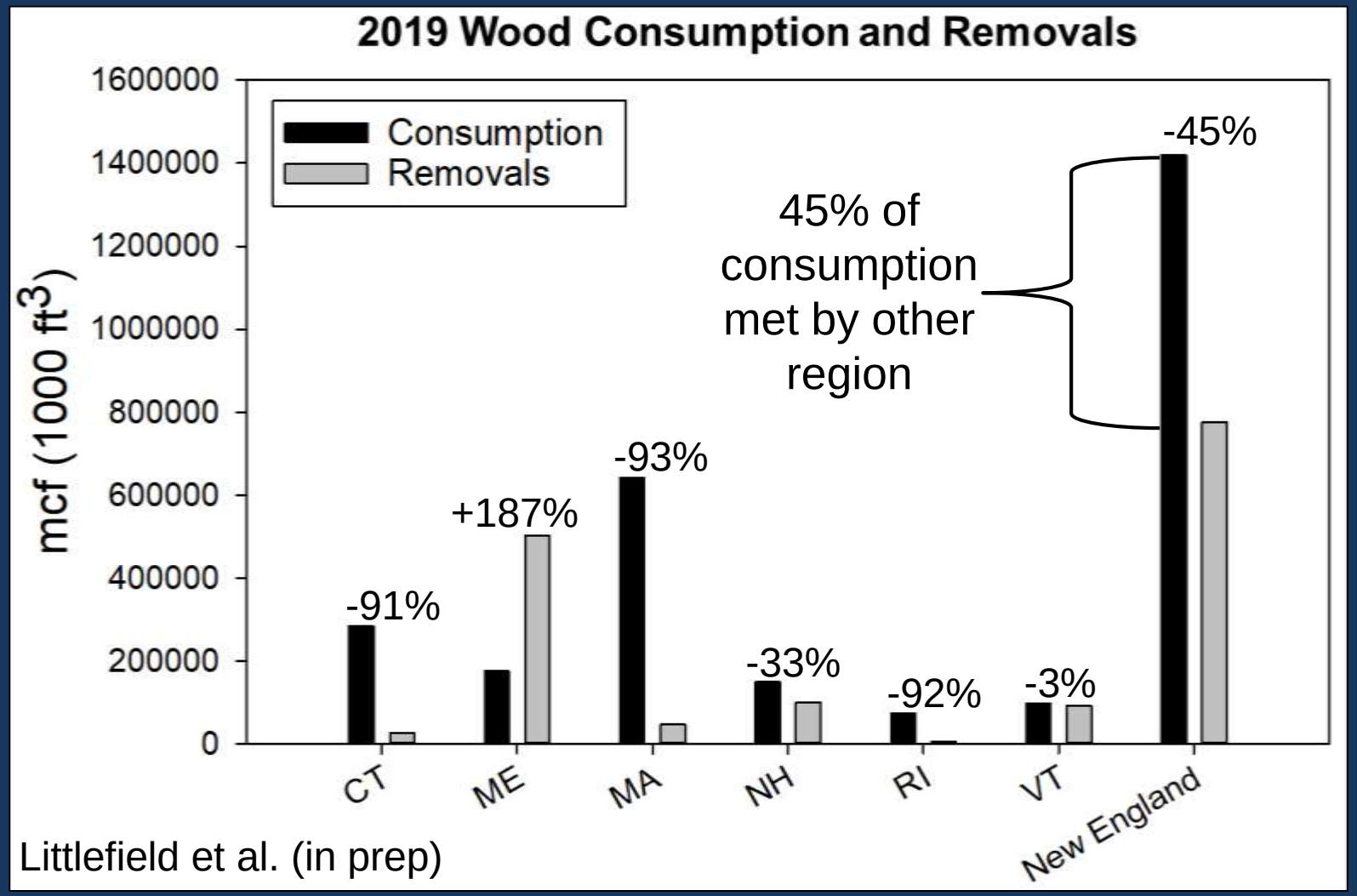


Tribal cultural burn in blue oak woodland

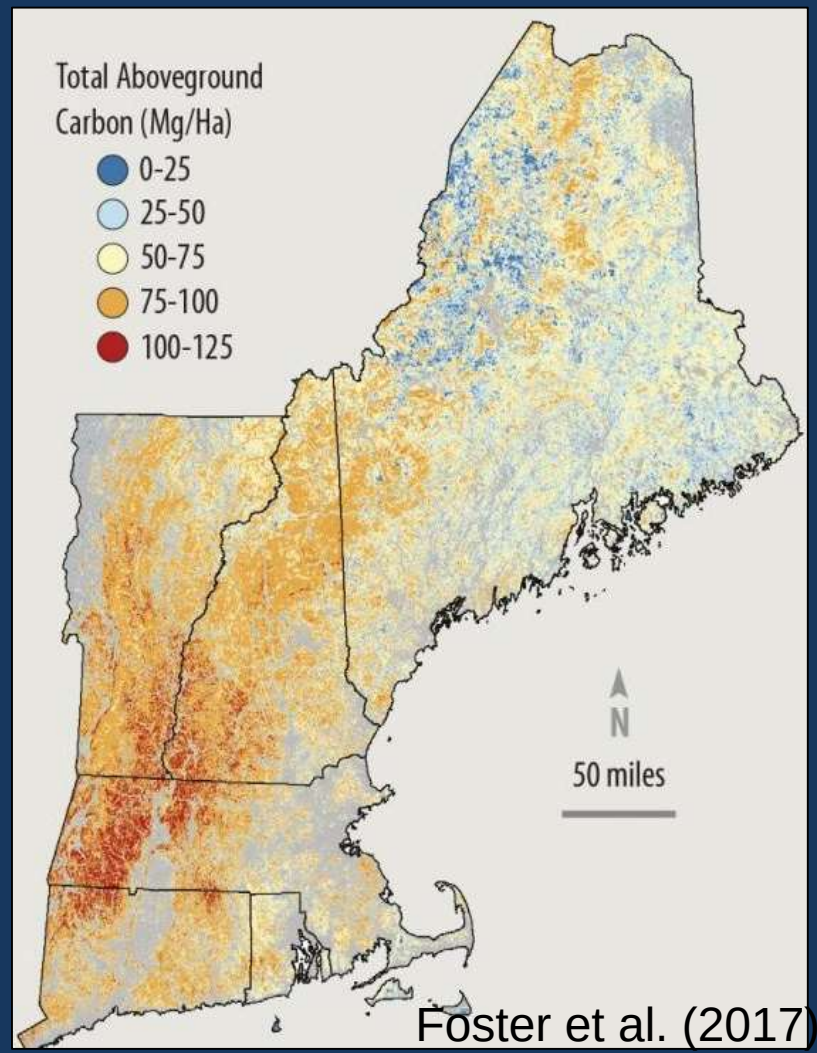
Local Carbon versus Local Consumption

The Illusion of Proforestation?

- Local carbon preservation, Global wood consumption

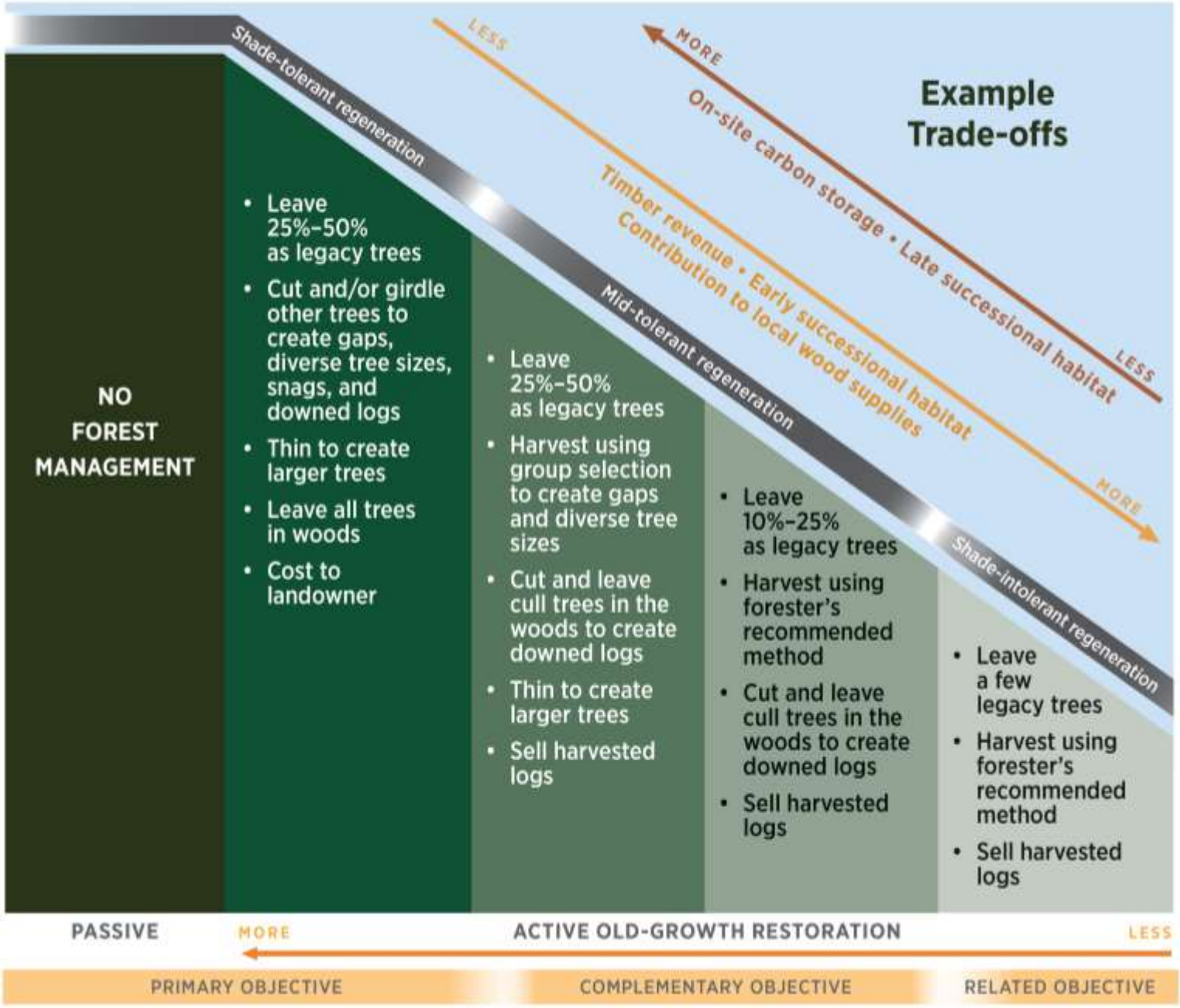


Littlefield et al. (in prep)



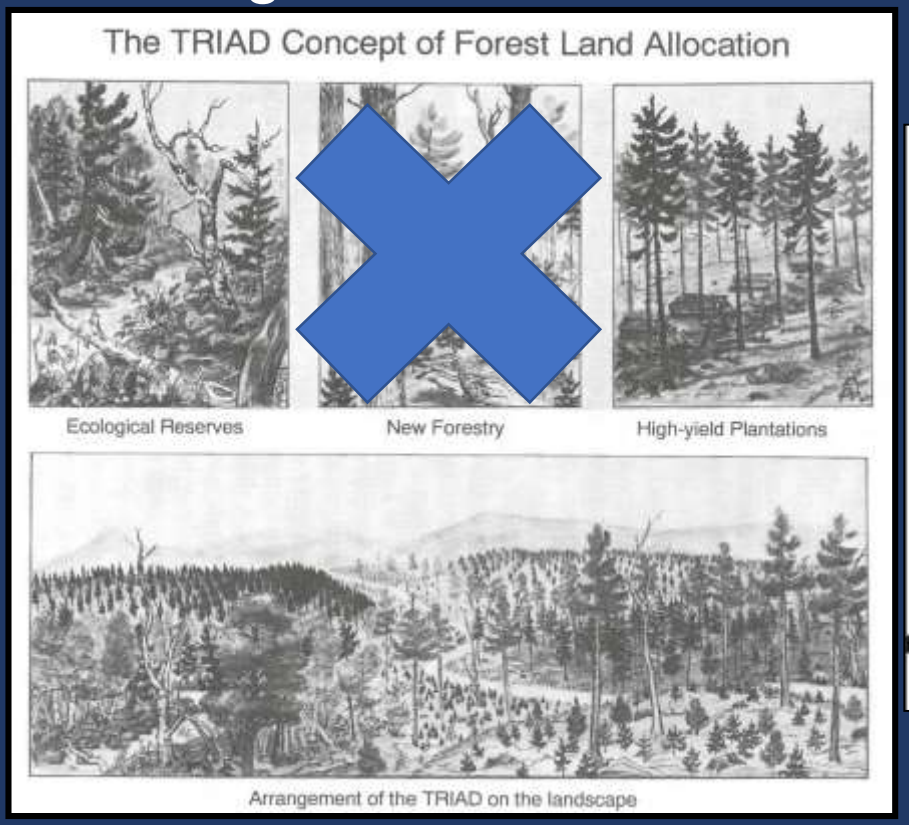
Foster et al. (2017)

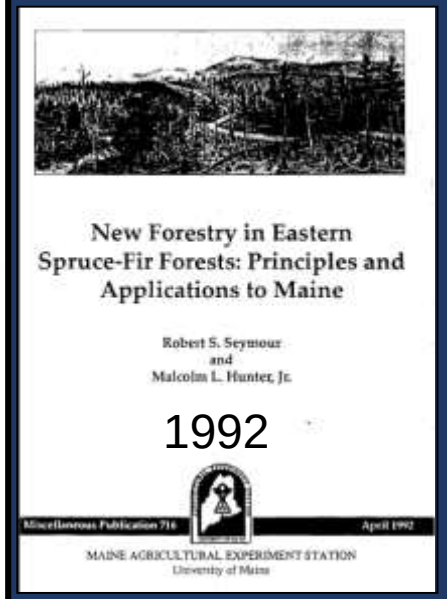
Gradient of old-growth restoration strategies



Attempting Balance: Landscape Mosaics

- We can’t satisfying all objectives in every forest stand (something recognized decades ago in relation to biodiversity conservation)
- Current emphasis on local preservation for carbon and outsized reliance on wood from plantations is removing key middle ground for adaptive and ecological silviculture to meet diverse objectives

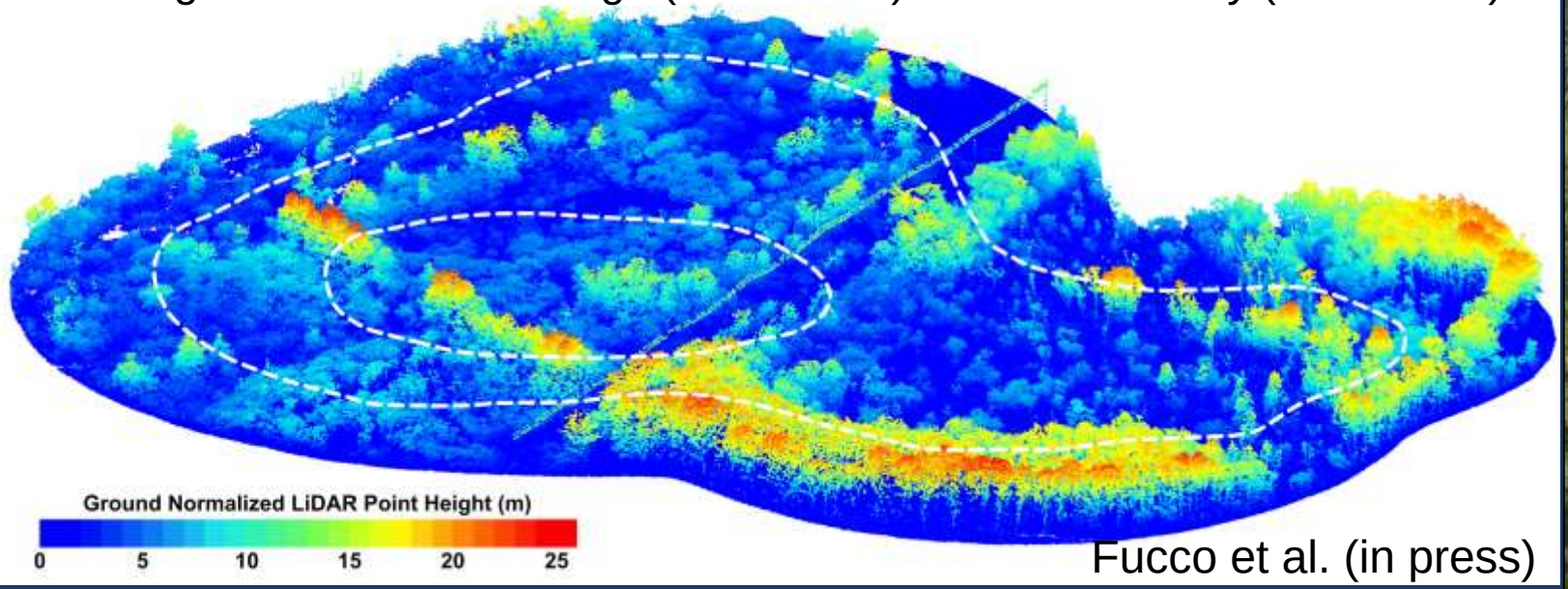




Attempting Balance: Landscape Mosaics

- Conservation and management approaches that emphasize diverse and ecologically complex landscape conditions are critical for maintaining mosaic that sustains species, processes, and values over the long-term
- Landscape balance (vs. bifurcation) requires an improved public understanding of critical role management plays in supporting cultural values, wildlife, carbon, and adaptation

Blue-winged warbler home range (outer circle) and core territory (inner circle)



Fucco et al. (in press)

Photo: L. Kopacki

Conclusions

- Emphasis on tradeoffs, but many co-benefits exist with forest carbon management and adaptation if approached through the multi-objective lens historically used for forest stewardship
- Climate change is a global issue. Need to account for impacts of efforts to maximize carbon in one's backyard (or state) while continuing to consume wood products at current rates
  - Locally embrace passive and adaptive strategies for resilient, equitable forest carbon

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NECASC Northeast Climate Adaptation Science Center

NIACS Northern Institute of Applied Climate Science

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FORESTS, PARKS & RECREATION VERMONT

The Nature Conservancy

USDA NIFA United States Department of Agriculture National Institute of Food and Agriculture

Vermont Land Trust