A Global Perspective on Temperate Old-Growth Forest Ecology, Conservation, and Restoration

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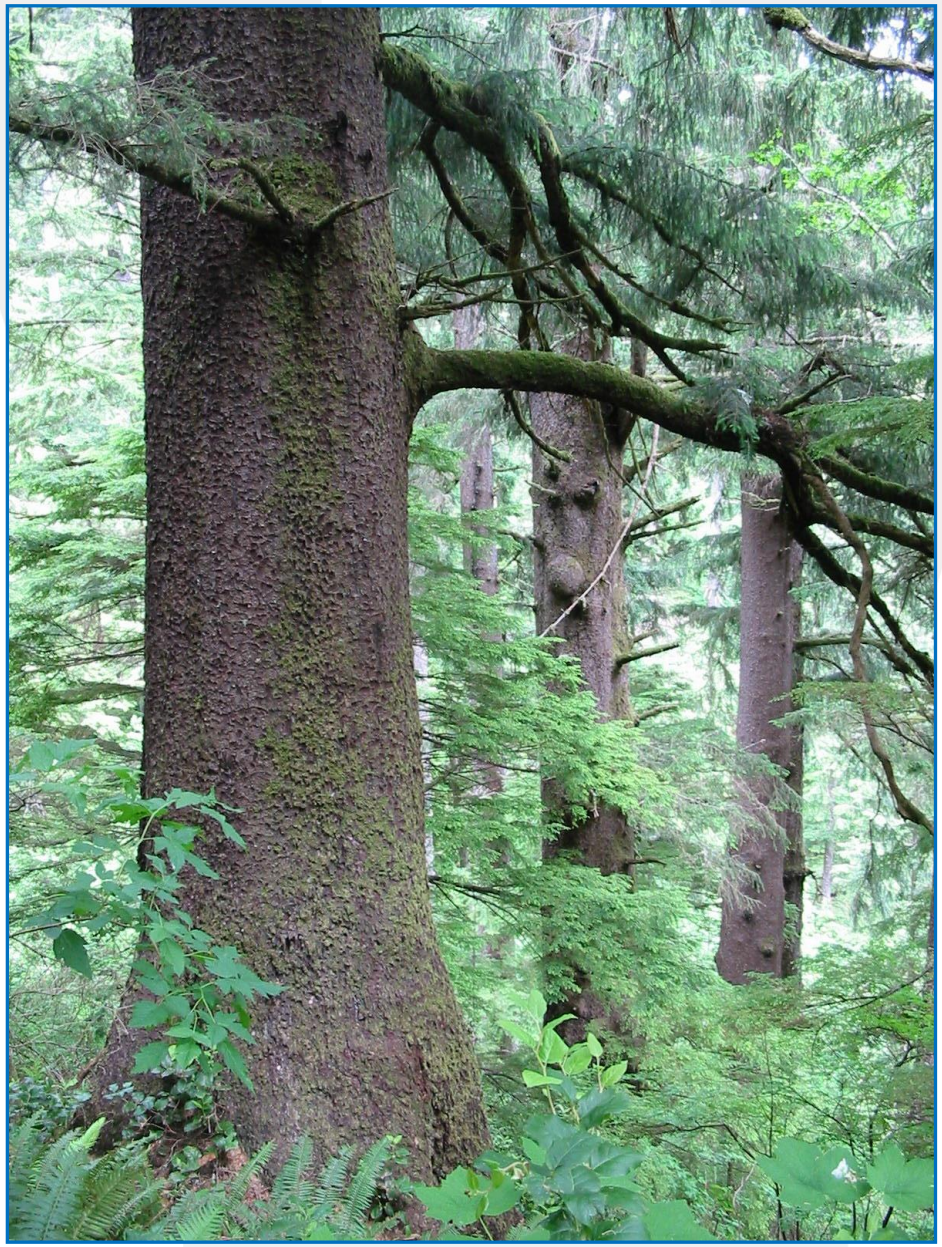

Photo credit: W.S. Keeton

Let’s talk about old-growth forests:

1. What have we learned?
2. Commonality and variability around the world
3. Inventory and conservation in the U.S. and Europe
4. Restoration and adaptation in the face of global change

Photo credit: W.S. Keeton

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We tend to romanticize old-growth, looking for iconic forests

Old-growth hemlock-hardwood forest, High Peaks Wilderness, Adirondack State Park, NY

Photo credit: W.S. Keeton

What have we learned? Commonality and variability Inventory and conservation Restoration and adaptation

"Contemporary ecology paints a different picture… we have to recalibrate…the retrained eye sees the messy consequence of disturbance as complexity…"

- Keeton and Barton. 2018. In: Barton and Keeton (eds.). Ecology and Recovery of Eastern Old-Growth Forests. Island Press

What have we learned? Commonality and variability Inventory and conservation Restoration and adaptation

One Pathway of Forest Development Following Partial Disturbance

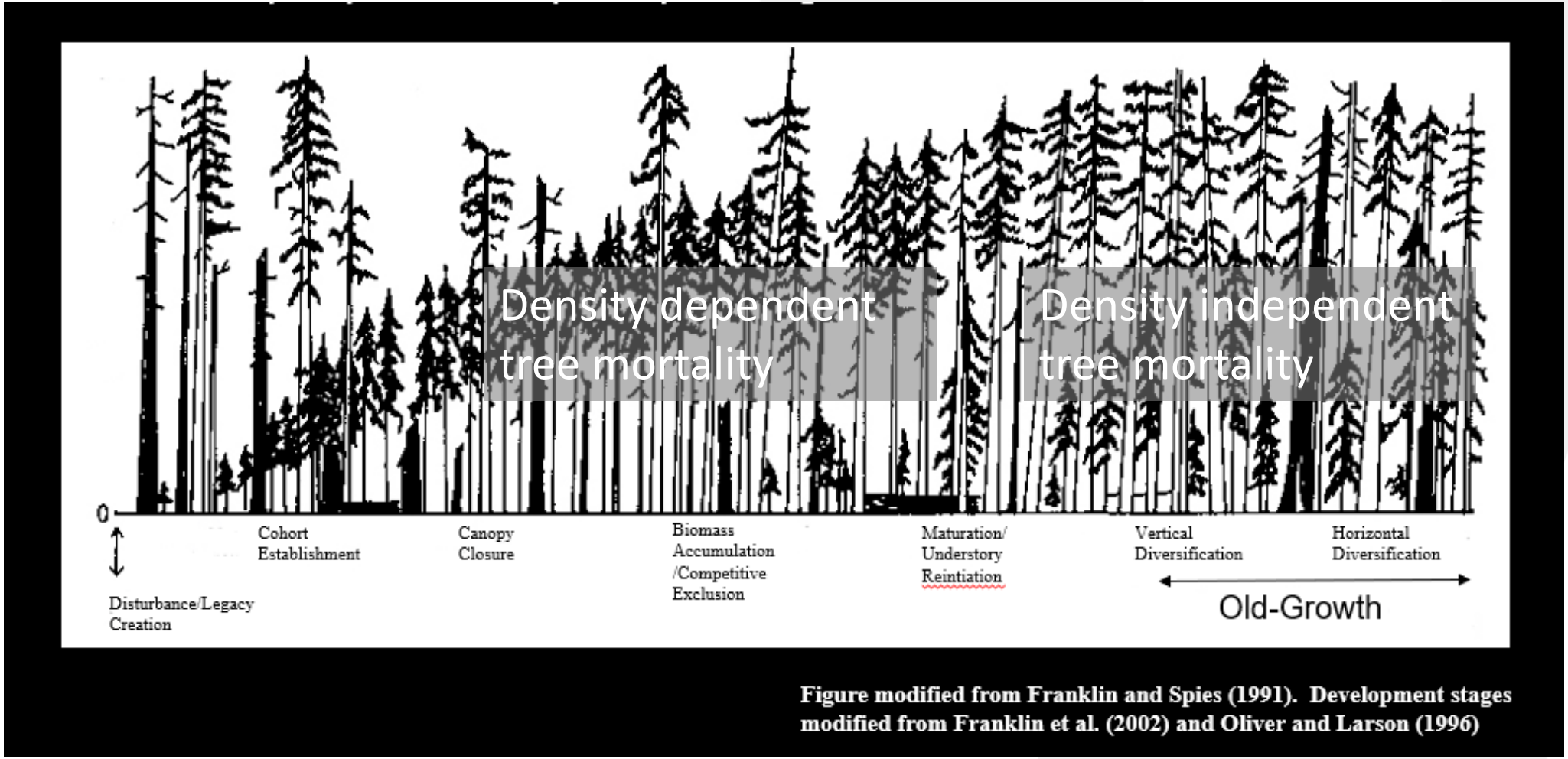
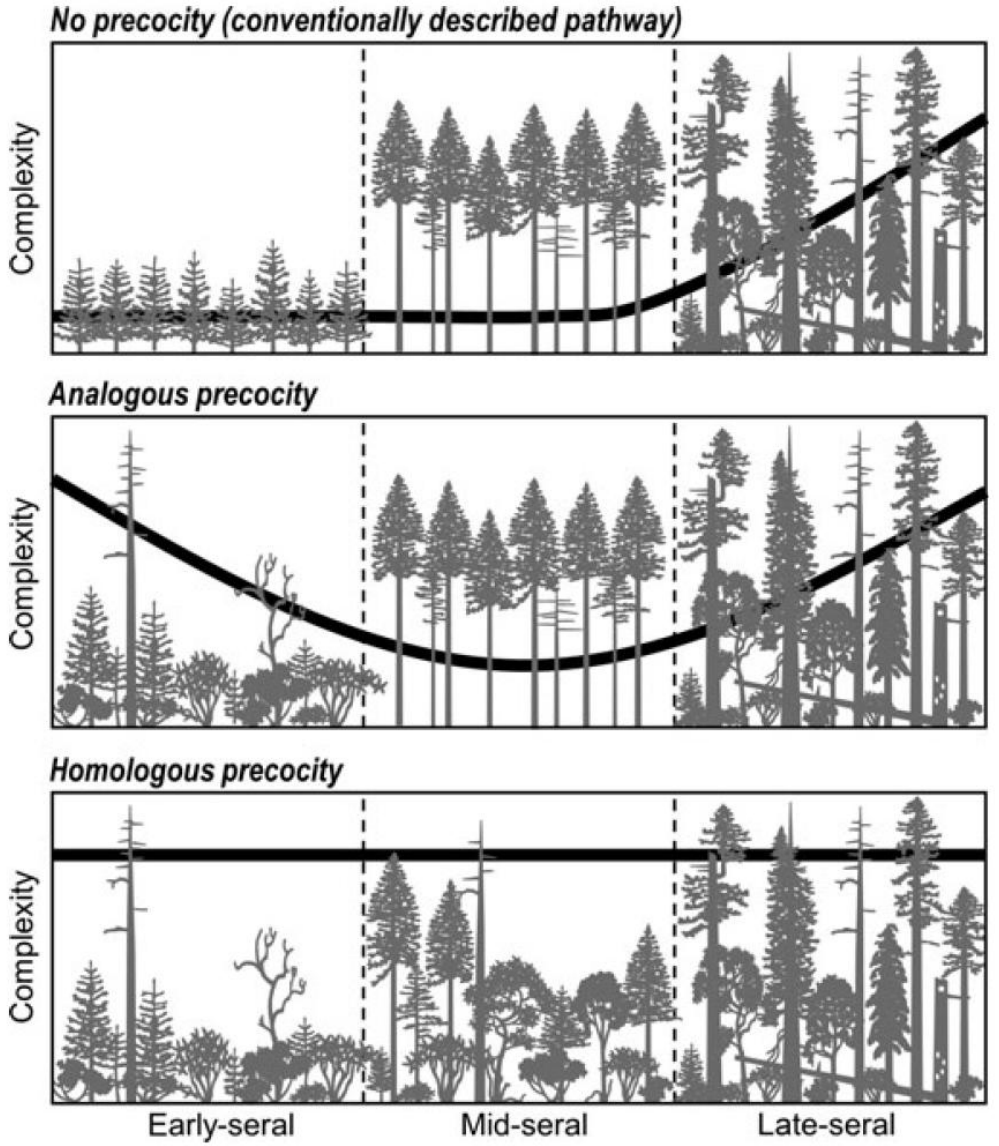


Figure modified from Franklin and Spies (1991). Development stages modified from Franklin et al. (2002) and Oliver and Larson (1996)

Three alternate pathways of stand development, with associated structural complexity

From Donato et al. 2012. Journal of Vegetation Science



PROCEEDINGS B

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Natural disturbance impacts on trade-offs and co-benefits of forest biodiversity and carbon

Martin Mikoláš[1], Marek Svitok[1,2], Radek Bače[1], Garrett W. Meigs[3], William S. Keeton[4], Heather Keith[5], Arne Buechling[1], Volodymyr Trotsiuk[1,6], Daniel Kozák[1], Kurt Bollmann[6], Krešimir Begovič[1], Vojtěch Čada[1], Oleh Chaskovskyy[7], Dheeraj Ralhan[1], Martin Dušátko[1], Matej Ferenčík[1], Michal Frankovič[1], Rhiannon Gloor[1], Jeňýk Hofmeister[1], Pavel Janda[1],

Research

Cite this article: Mikoláš M *et al.* 2021 Natural disturbance impacts on trade-offs and co-benefits of forest biodiversity and carbon.

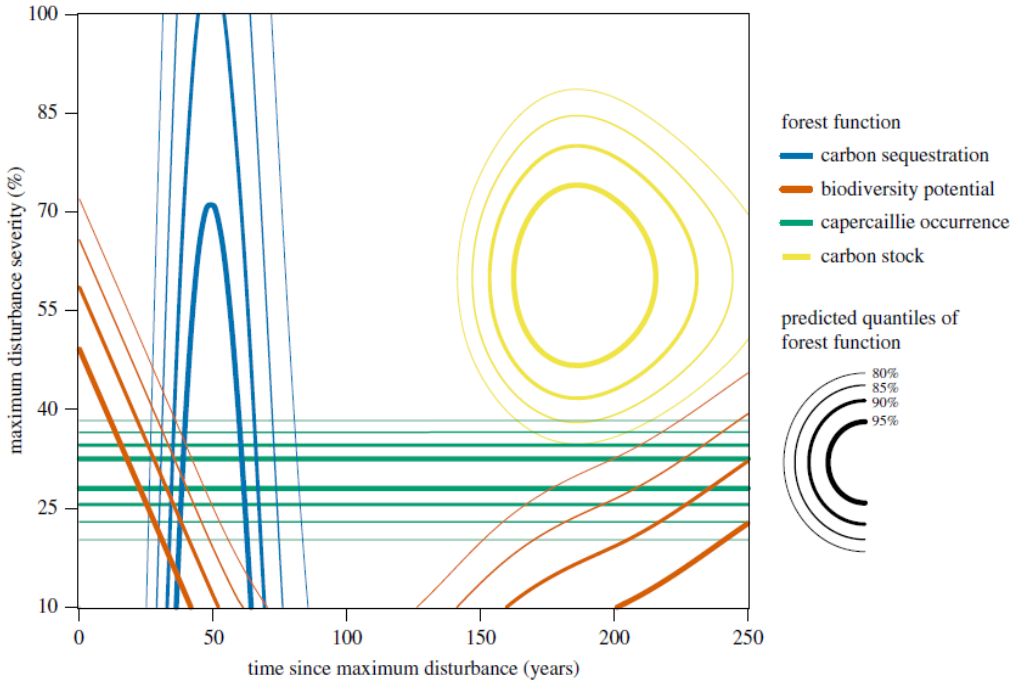
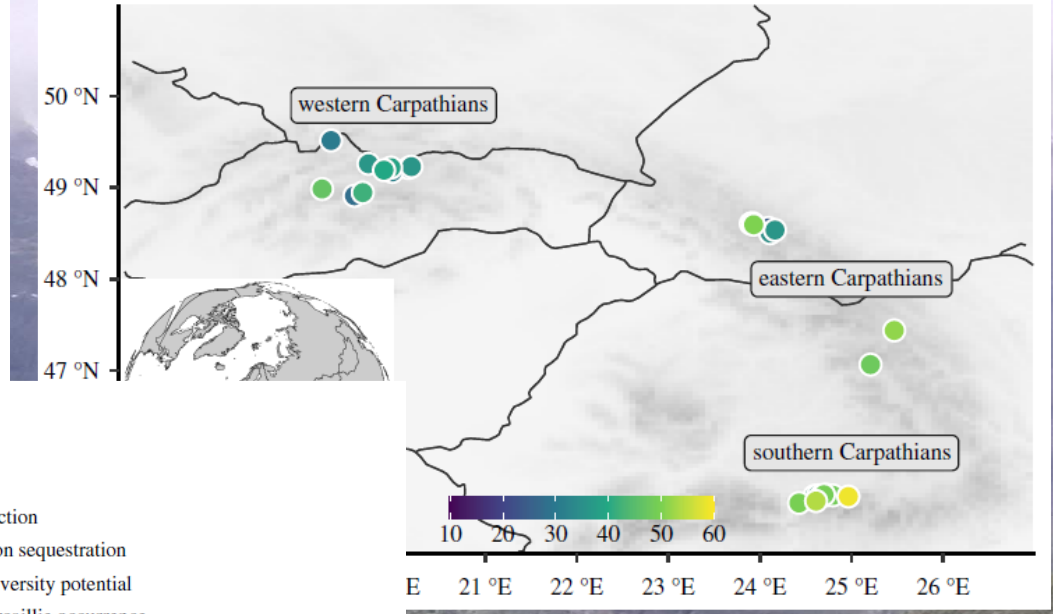


Figure 2. Maxima of forest functions along the gradients of maximum disturbance severity and time since that event. Isolines represent upper percentiles (greater than 80%) of GAMM-predicted values of the forest functions.



The Koprova Valley in the High Tatra Range (Carpathian Mountains) in the Slovak Republic: a primary forest landscape shaped by centuries of superimposed natural disturbances

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What have we learned? Commonality and variability Inventory and conservation Restoration and adaptation

Old-Growth Riparian Forests

Strong effects on:

- Large wood loading
- Stream geomorphology
- Light regimes and in-stream productivity
- Nutrient processing and retention
- Flood resilience
- In-stream carbon storage

See papers by: Keeton et al. (2007), Warren et al. (2009), Bechtold et al. 2016), Warren et al. 2016, Keeton et al. 2017, Peters-Collaer and Keeton (2025)

Old-growth forests are a global ecosystem formation across the temperate biome in both northern and southern hemispheres



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journal homepage: www.elsevier.com/locate/foreco

Review

Commonality and variability in the structural attributes of moist temperate old-growth forests: A global review

Sabina Burrascano [a], William S. Keeton [b], Francesco M. Sabatini [a,*], Carlo Blasi [a]

Global Review of Moist Temperate Old-Growth Forest Structure (Burrascano, Keeton et al. 2013)

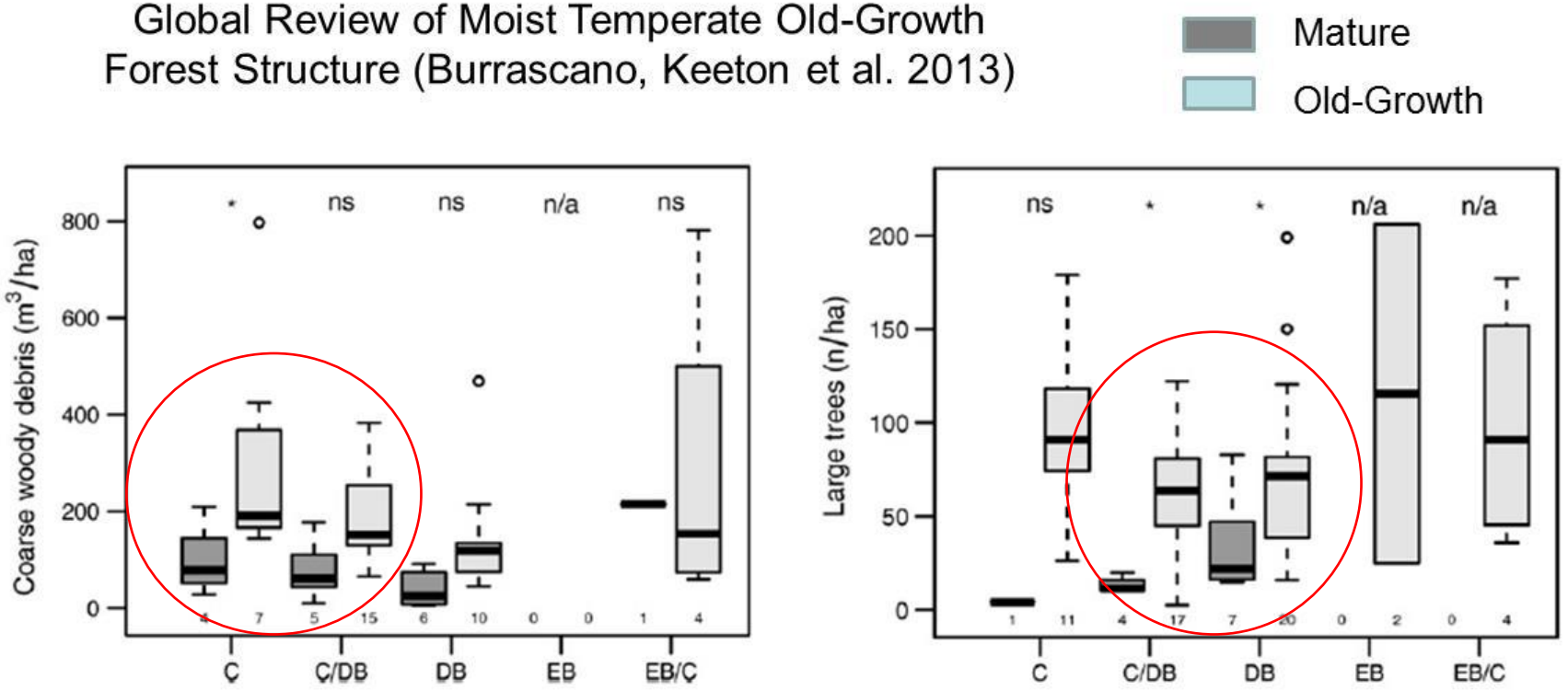

Figure explanation:

- Boxplots of data distribution for forest types (C – conifer, DB – deciduous broadleaf, EB – evergreen broadleaf, C/DB – mixed conifer/deciduous broadleaf, EB/C – mixed evergreen broadleaf/conifer).
- The median, first and third quartiles, and whiskers (corresponding to 1.5 times the inter-quartile distance) are reported. Empty circles represent outliers.
- Sample size is reported at the bottom of each box.
- Monte-Carlo two-sided significance levels are at the top (n/a: no test was possible; ns: not significant.

- **Spatial variability is <u>THE</u> defining characteristic**
- **Old-growth structure in dynamic systems is an emergent property**

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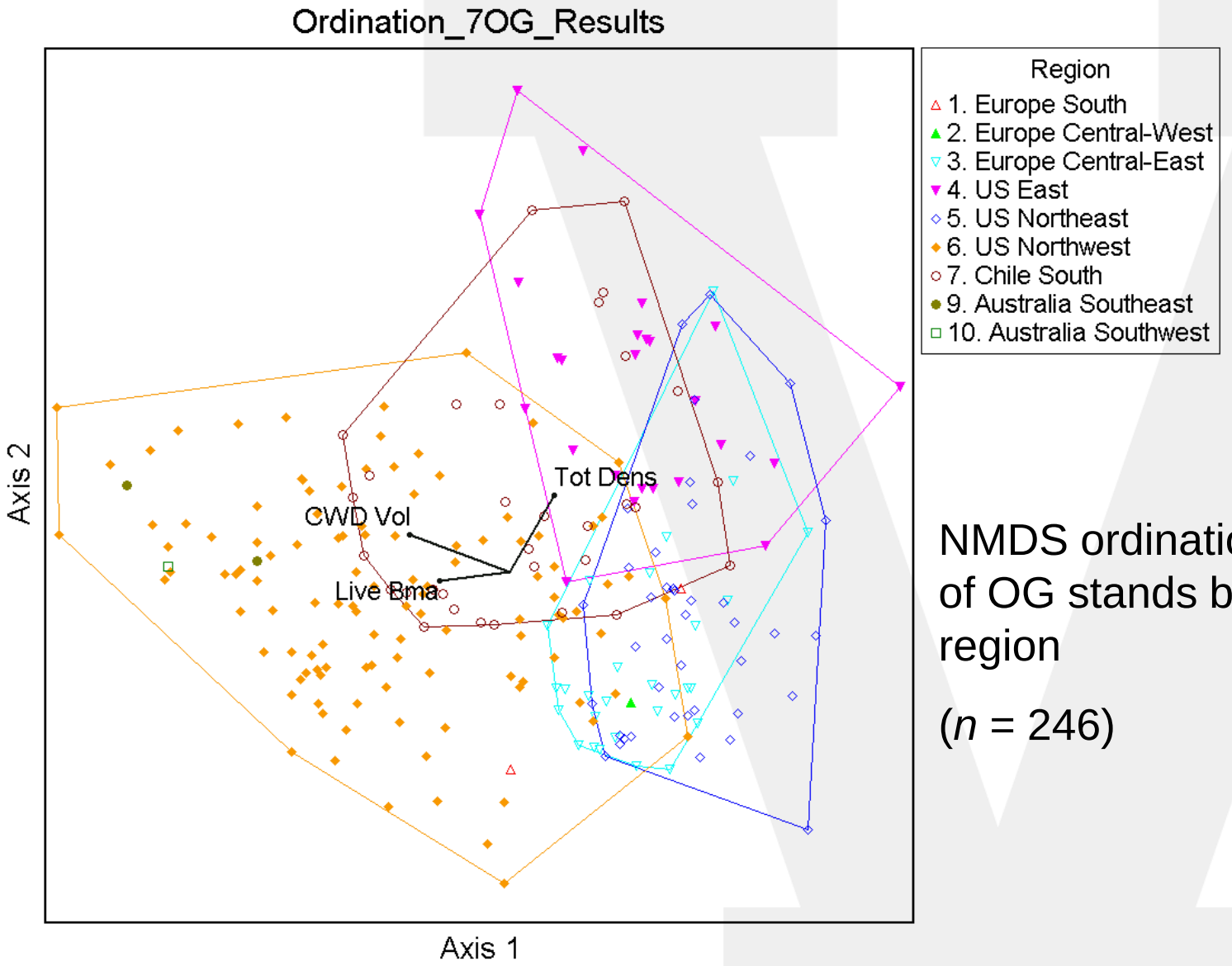
Old-growth forests in different regions exhibit structural similarities and differences.

The US Northeast and Central/Eastern Europe are the most similar in our dataset

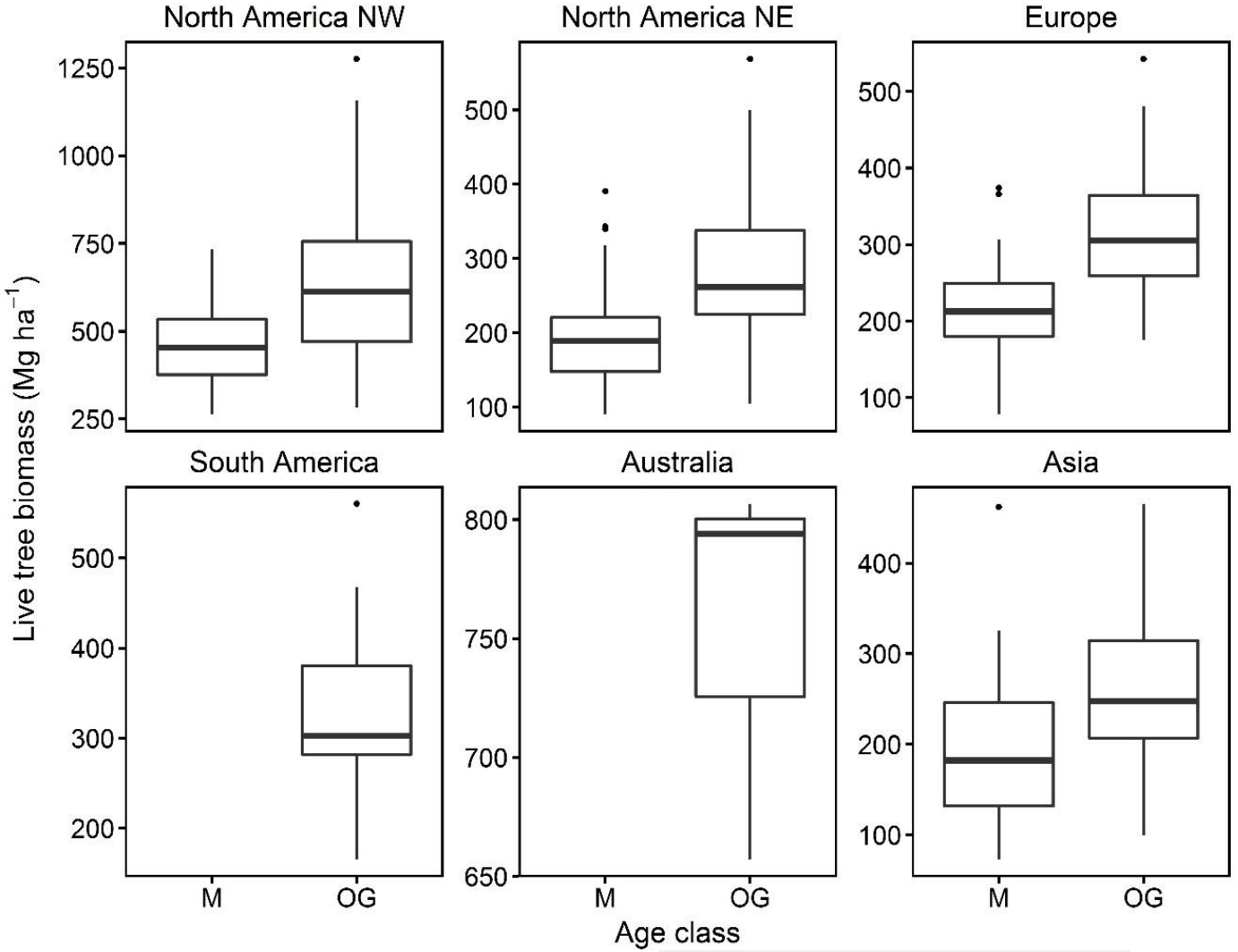


NMDS ordination of OG stands by region

(*n* = 246)

Commonality in old-growth structure globally?

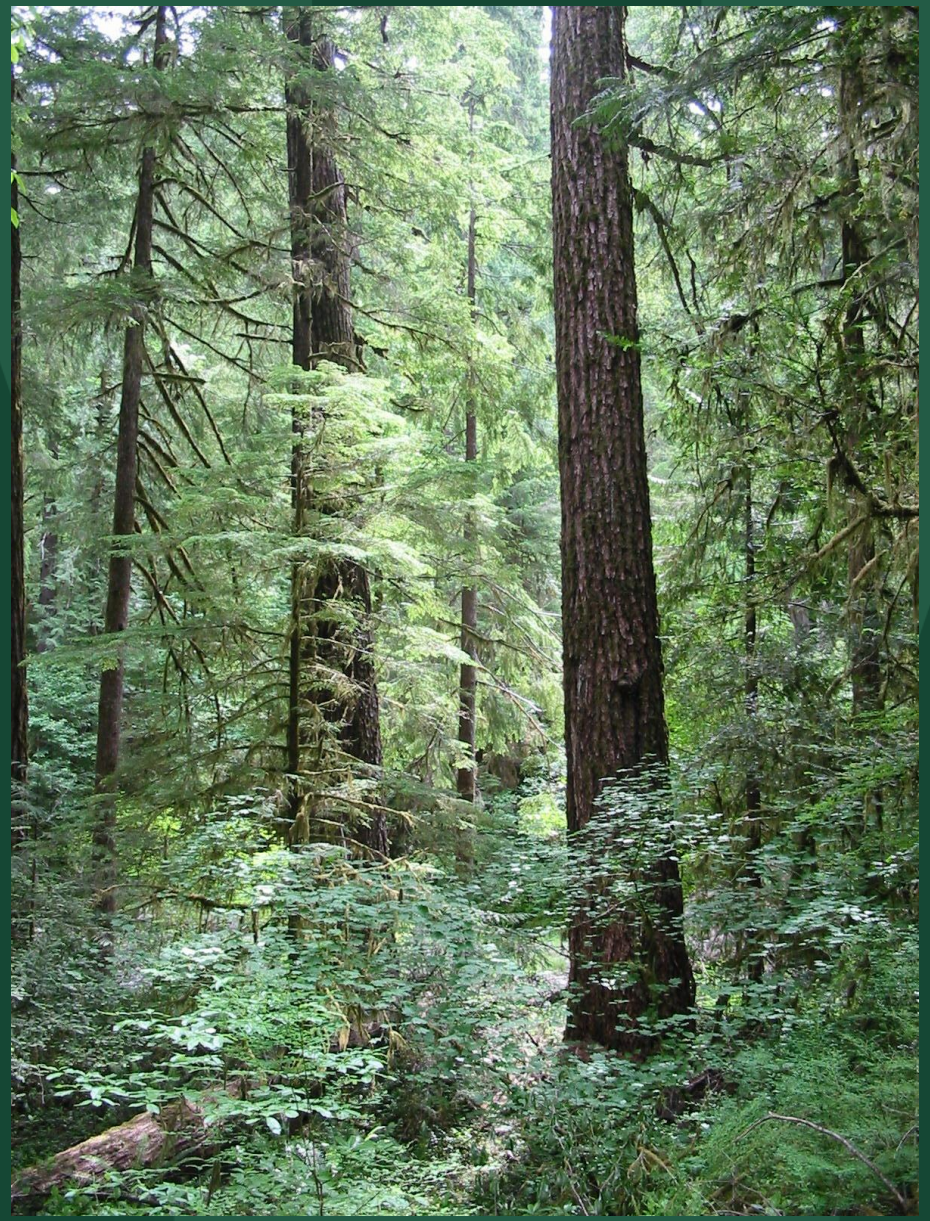
- Old-growth values often higher than mature forest
- BUT high degree of variability within and among systems



M = Mature
OG = Old-growth

n = 501 sites

U.S. Pacific Northwest

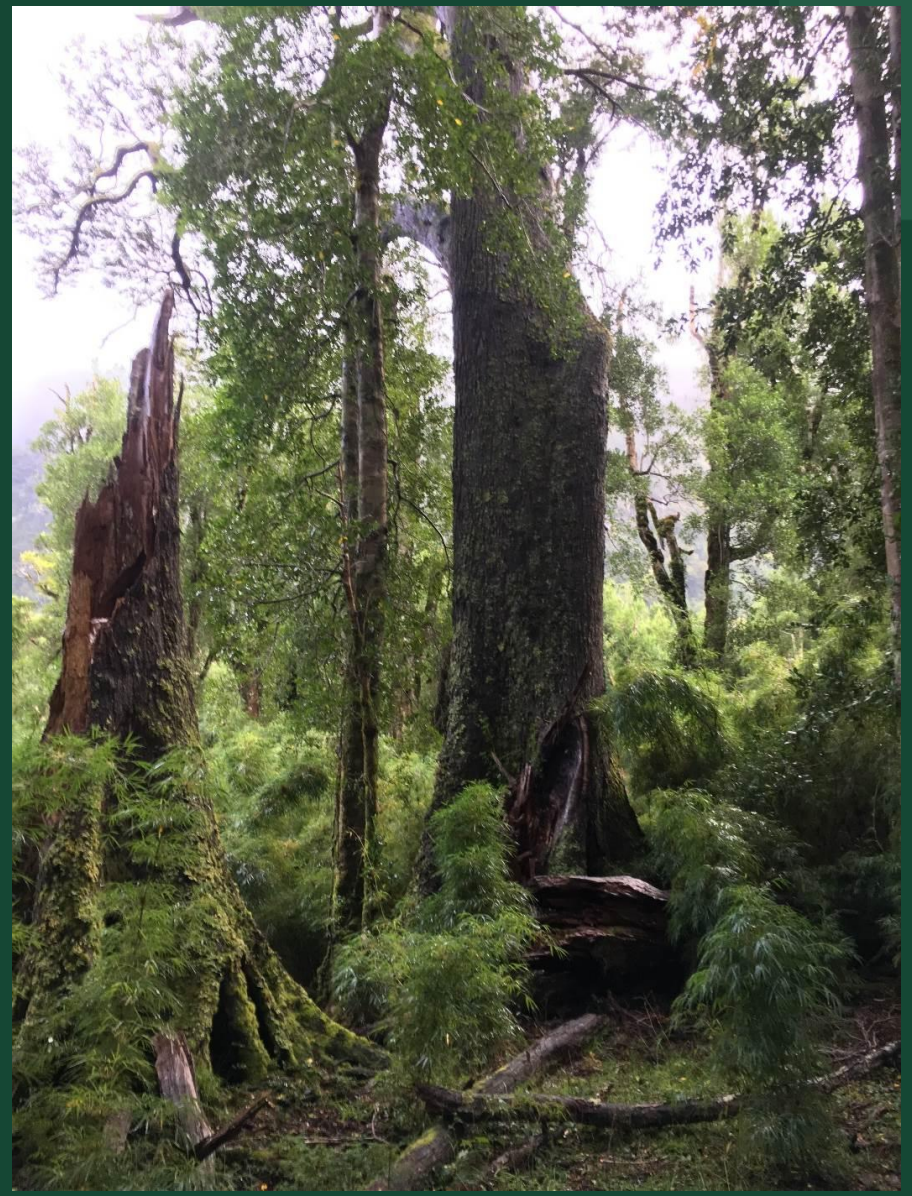


What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Bhutan, Central Himalayan Mountains

What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Patagonia, Chile



What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Carpathian Mountains, Ukraine

What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

The stone pine forests of the Kôprová Valley in the High Tatra Range of the Carpathians, Slovak Republic

What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Eucalyptus regnans (mountain ash). Queensland, Australia

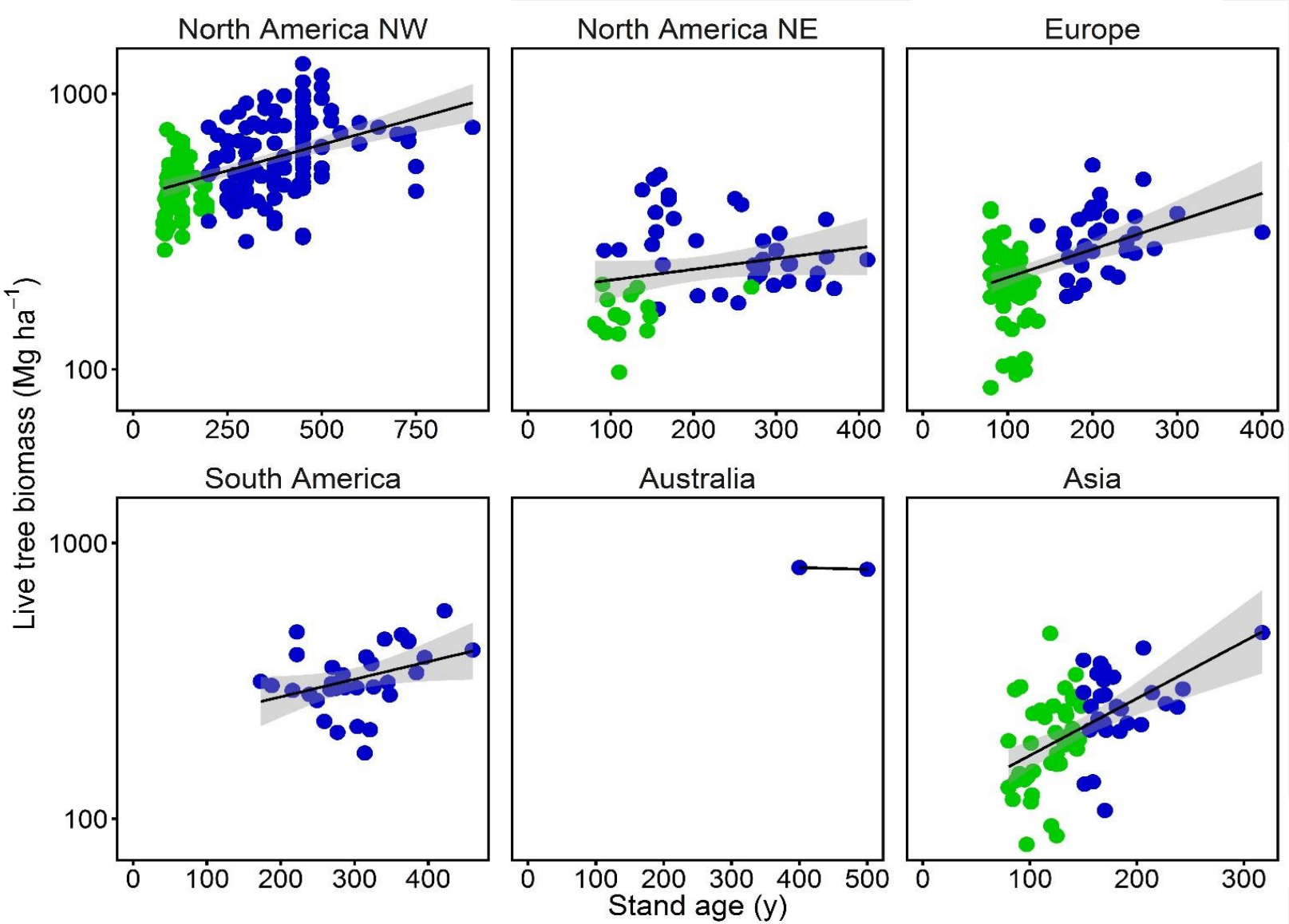
What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Northern-hardwood-conifer forests. Northeastern U.S.

What have we learned? **Commonality and variability** Inventory and conservation Restoration and adaptation

Overall, carbon storage in older forests tends to be high globally, despite:

- Multiple sources of variability, including productivity
- Dynamics associated with disturbances, and
- Multiple pathways of carbon accumulation



U.S.

vs.

Europe

The Washington Post
Democracy Dies in Darkness

U.S. has inventoried old-growth forests. Will protection be next?

The report is the federal government's first estimate of America's oldest trees. Environmentalists hope it is a step for protecting them from logging.

By Anna Phillips

April 20, 2023 at 5:00 a.m. EDT

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Biden-Harris Administration Proposes First-of-its Kind National Forest Plan Amendment to Conserve and Steward Old Growth Forests

Action is next step in the Forest Service's work under President Biden's Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies

WASHINGTON, Dec. 19, 2023 – Today, consistent with direction from President Biden in Executive Order 14072 to conserve and restore old and mature forests, the U.S. Department of Agriculture announced a proposal to amend all 128 forest land management plans to conserve

Press Release
Release No. 0254.23

Contact: USDA Press

European Commission

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Biodiversity strategy for 2030

The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030, and contains specific actions and commitments.

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GENERAL GUIDELINES

Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests

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What have we learned? Commonality and variability **Inventory and conservation** Restoration and adaptation

Alternate methodologies in the U.S.:

Multivariate. From Woodall et al. (2023). National inventory of mature and old-growth forests

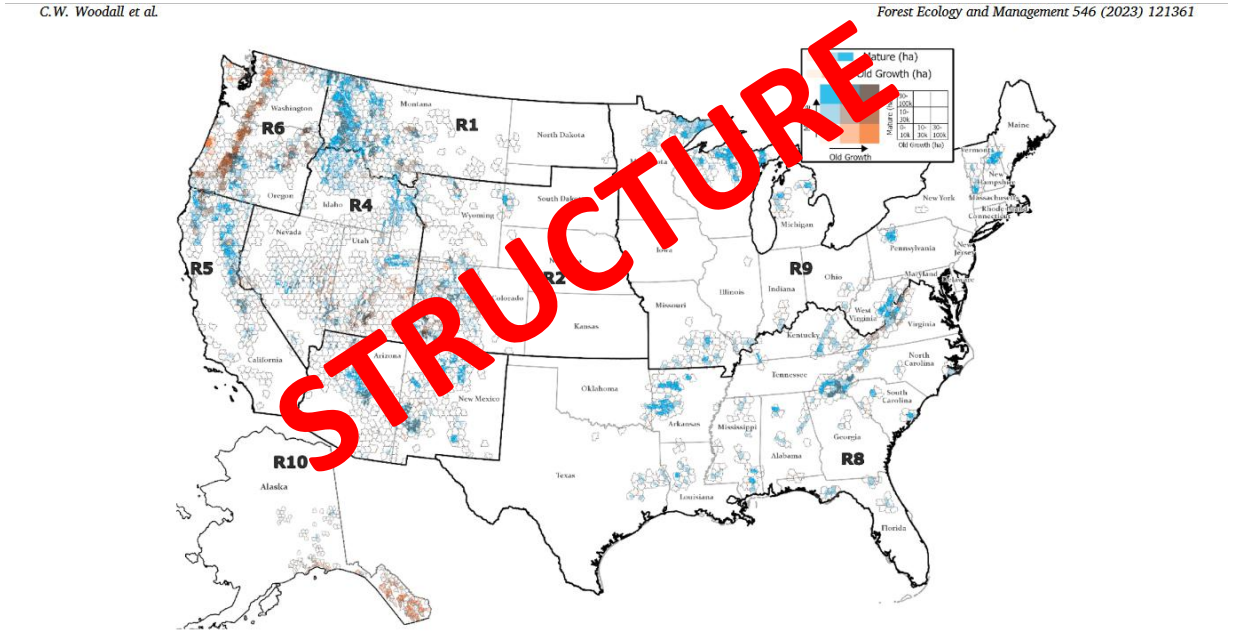


Fig. 5. Bivariate map of mature and old-growth proportion of area (low, medium, high) by fireshed for USFS/BLM forested land area, coterminous and coastal AK, US.

Classification based on carbon accumulation by forest type for the United States. From: Barnet, Aplet, and Belote (2023).

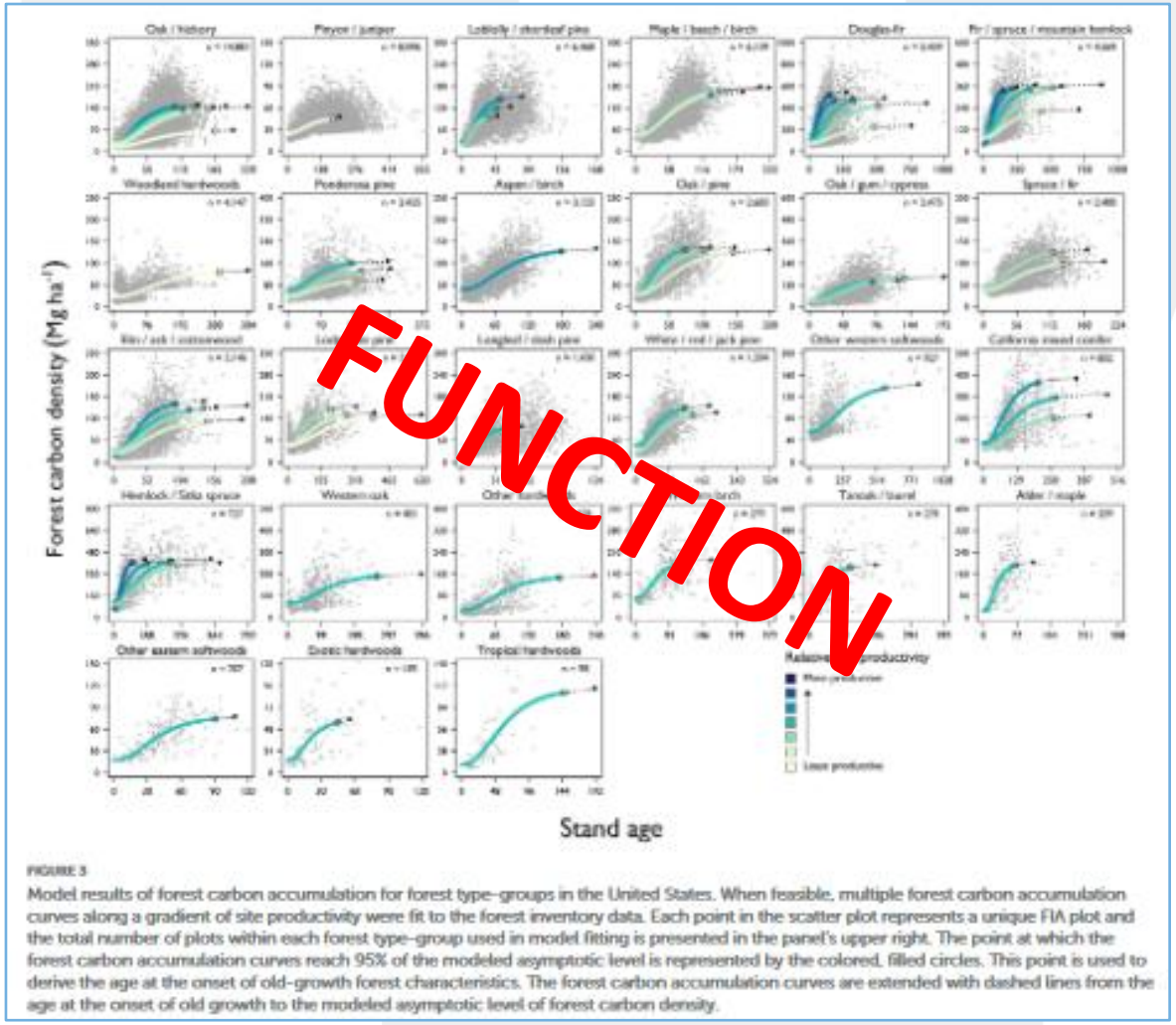


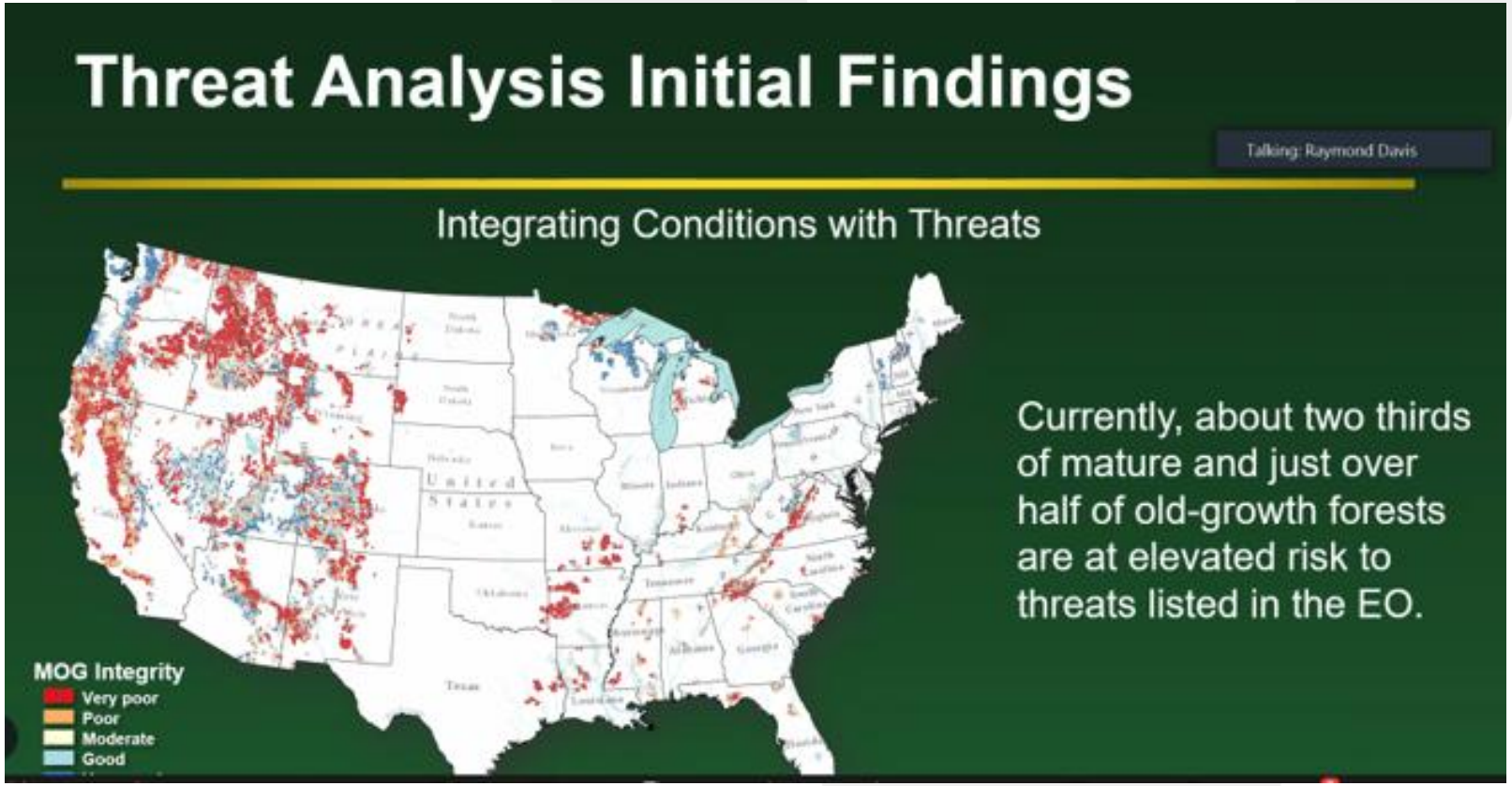
FIGURE 3
Model results of forest carbon accumulation for forest type–groups in the United States. When feasible, multiple forest carbon accumulation curves along a gradient of site productivity were fit to the forest inventory data. Each point in the scatter plot represents a unique FIA plot and the total number of plots within each forest type–group used in model fitting is presented in the panel's upper right. The point at which the forest carbon accumulation curves reach 95% of the modeled asymptotic level is represented by the colored, filled circles. This point is used to derive the age at the onset of old-growth forest characteristics. The forest carbon accumulation curves are extended with dashed lines from the age at the onset of old growth to the modeled asymptotic level of forest carbon density.

Conserving old-growth forests will require more than just protected areas

Existing old-growth forests are threatened by:

- Forest fires
- Drought
- Insects
- Rural housing development.

All of these threats are projected to increase in the future.



USDA Threat Analysis of Mature and Old-Growth Forests. 2023

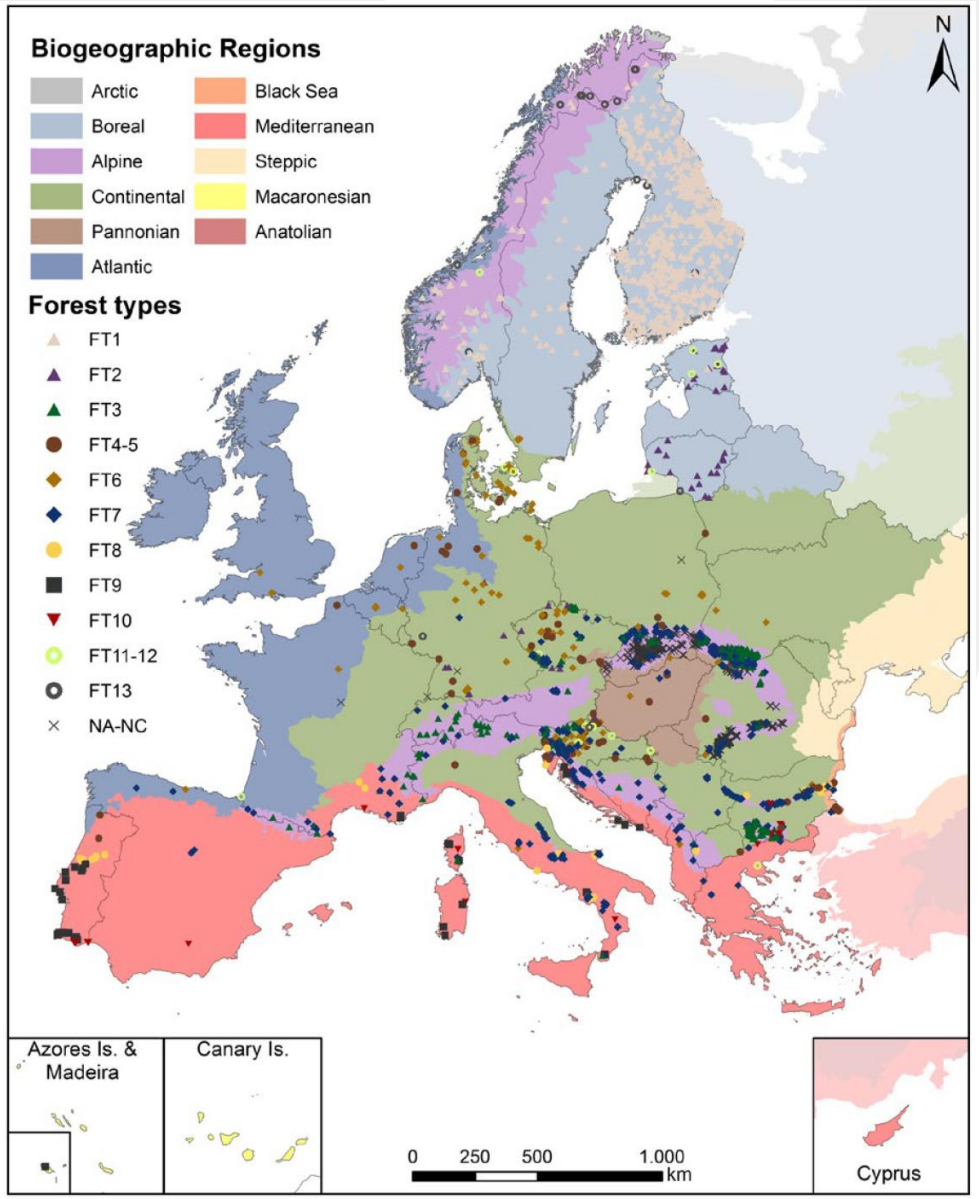
Received: 20 September 2017 | Accepted: 19 April 2018
DOI: 10.1111/ddi.12778

BIODIVERSITY REVIEW

WILEY Diversity and Distributions

Where are Europe's last primary forests?

Francesco Maria Sabatini[1] | Sabina Burrascano[2] | William S. Keeton[3] | Christian Levers[1] | Marcus Lindner[4] | Florian Pötzschner[1] | Pieter Johannes Verkerk[5] | Jürgen Bauhus[6] | Erik Buchwald[7] | Oleh Chaskovsky[8] | Nicolas Debaive[9] | Ferenc Horváth[10] | Matteo Garbarino[11] | Nikolaos Grigoriadis[12] | Fabio Lombardi[13] | Inês Marques Duarte[14] | Peter Meyer[15] | Rein Midteng[16] | Stjepan Mikac[17] | Martin Mikoláš[18] | Renzo Motta[11] | Gintautas Mozgeris[19] | Leónia Nunes[14,20] | Momchil Panayotov[21] | Peter Ódor[10] | Alejandro Ruete[22] | Bojan Simovski[23] | Jonas Stillhard[24] | Miroslav Svoboda[18] | Jerzy Szwagrzyk[25] | Olli-Pekka Tikkanen[26] | Roman Volosyanchuk[27] | Tomas Vrska[28] | Tzvetan Zlatanov[29] | Tobias Kuemmerle[1]



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What have we learned? Commonality and variability **Inventory and conservation** Restoration and adaptation

Map:

Modeled (predicted) areas likely to have high concentrations of primary forests

Remnant stands and patches are highly fragmented

Findings:

1.4 million ha of primary forest in 32 countries (estimated)

89% have some protection, but only 46% are strictly protected

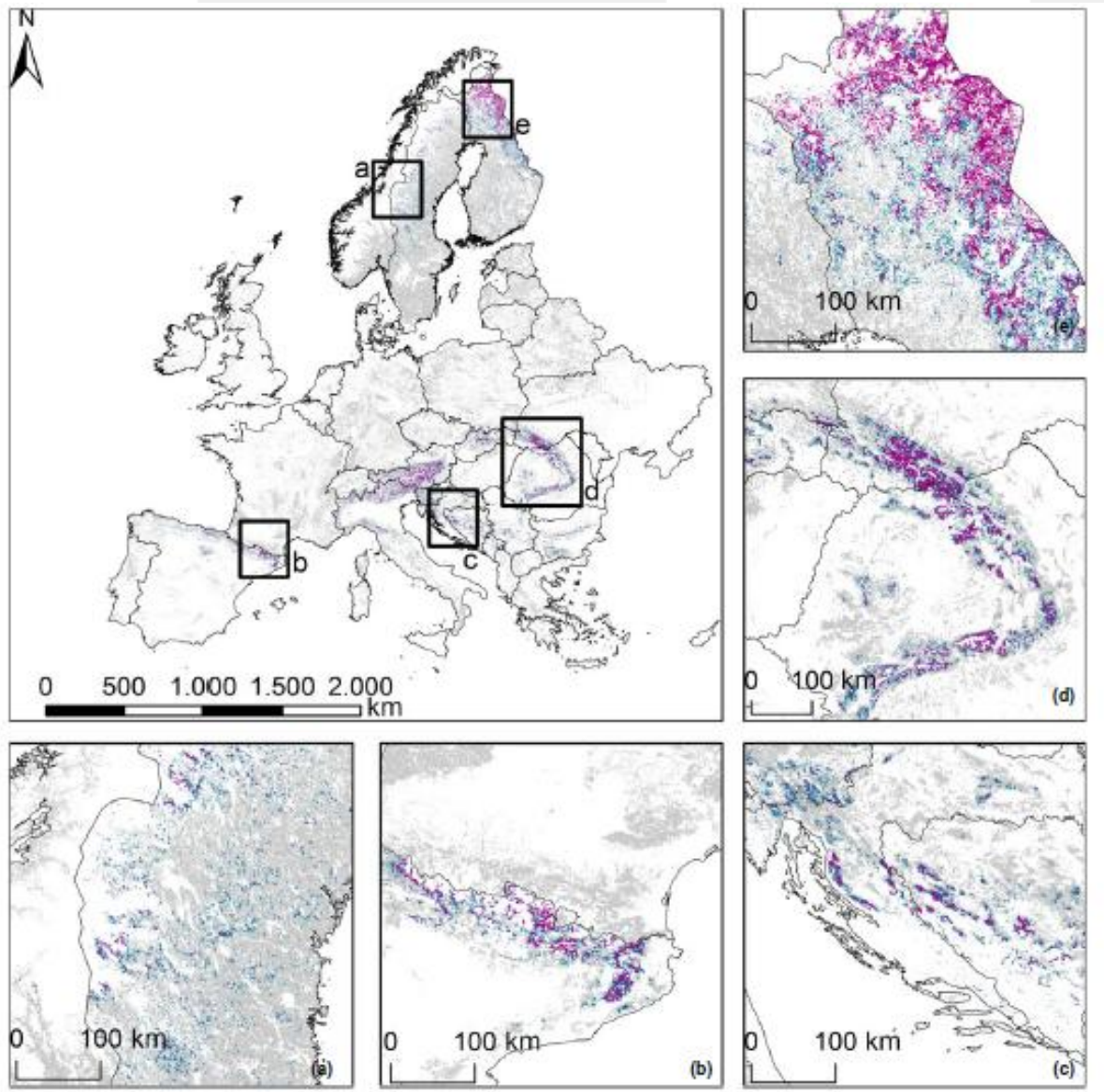


FIGURE 5 Areas with the highest likelihood of occurrence of primary forest in Europe at a 1 × 1 km resolution. The top-ranking 5% pixels were highlighted in purple and the 90–95th percentile in blue. Forests are reported in grey and follow Gallaun et al. (2010)

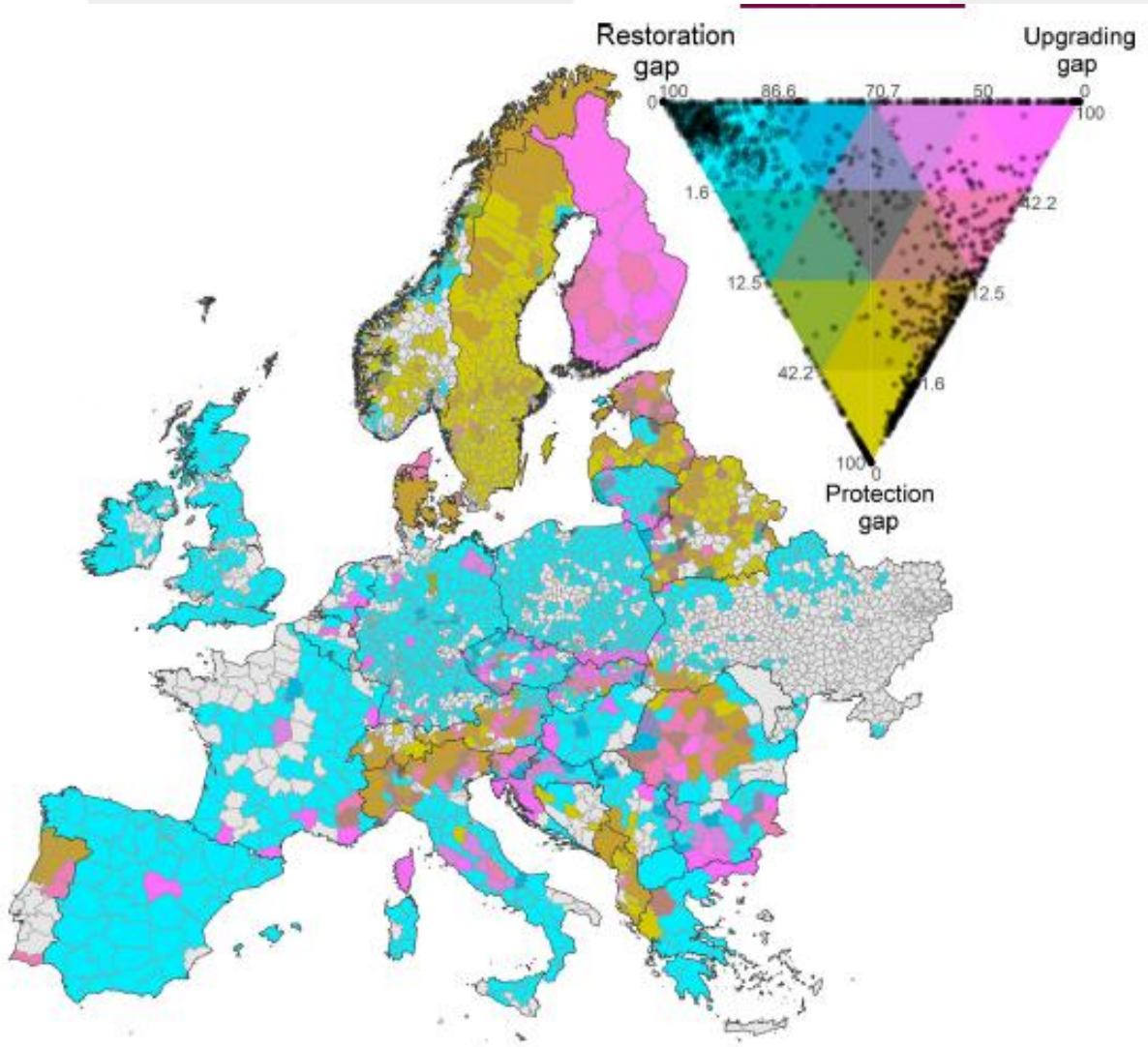
Sabatini, Keeton, Lindner et al. 2020. Protection gaps and restoration opportunities for primary forests in Europe. Diversity and Distributions

Where are the restoration and protection gaps?

A modest 1% expansion of protected areas would protect all remaining old-growth in Europe – 0.3% of land area

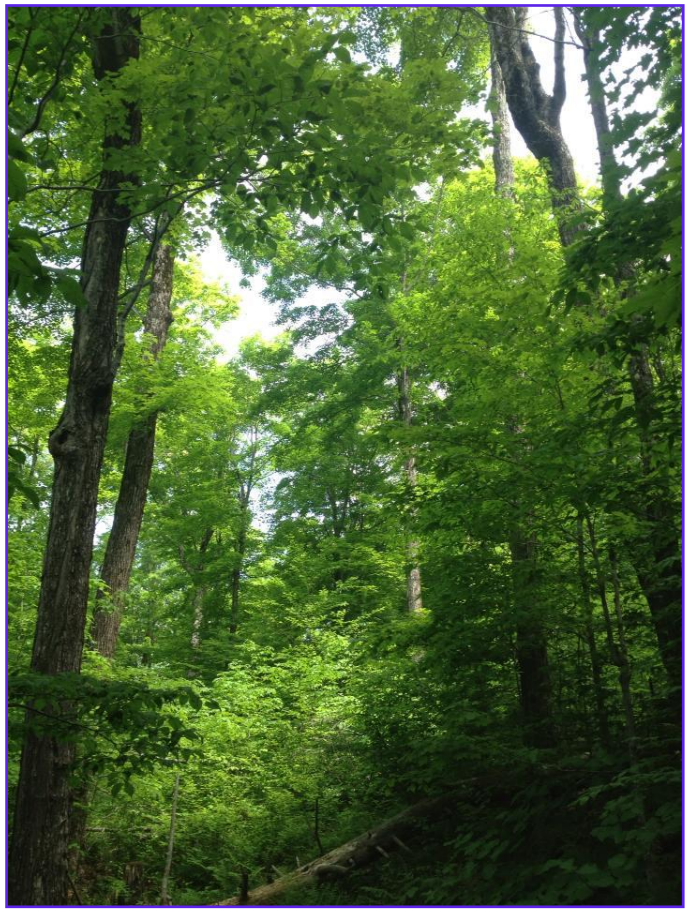
EU Biodiversity Strategy for 2030 recognizes need to protect and restore old-growth and to increase complexity in managed forests

But how can we restore old-growth forests? Passive management only, or can silvicultural restoration help?



Question:

Would closer emulation of natural forest dynamics help restore old-growth characteristics and complexity in both protected and managed forests?



Mixed-species “Close-to-Nature” silviculture in Bohemia, Czech Republic

Structural Complexity Enhancement, Vermont, USA

Restoration Treatments to Accelerate Forest Stand Development in the PNW

For stem-exclusion stage, Douglas-fir stands with limited shade tolerant seed sources:

Step 1. Variable density, thinning-from-below the canopy

Step 2. Underplanting of shade tolerant conifers

Photo credit: Jerry F. Franklin

Fuels treatment and prescribed burning will be central to old-growth restoration in drier, fire-dependent forest ecosystems

Lowland old-growth pine – savanna; Longleaf and Slash pines

Upland clayhill old-growth pine savanna - woodland

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Experimental Old-growth Restoration in Northern Hardwood-Conifers (e.g. Keeton 2006, Ford and Keeton 2017, Keeton et. al 2018)

- Long-term study
- Testing effects of natural disturbance-based silvicultural treatments on development of late-successional forest structure and function
- Initiated in 2001
- Treatments in 2003
- Outcomes monitored to present

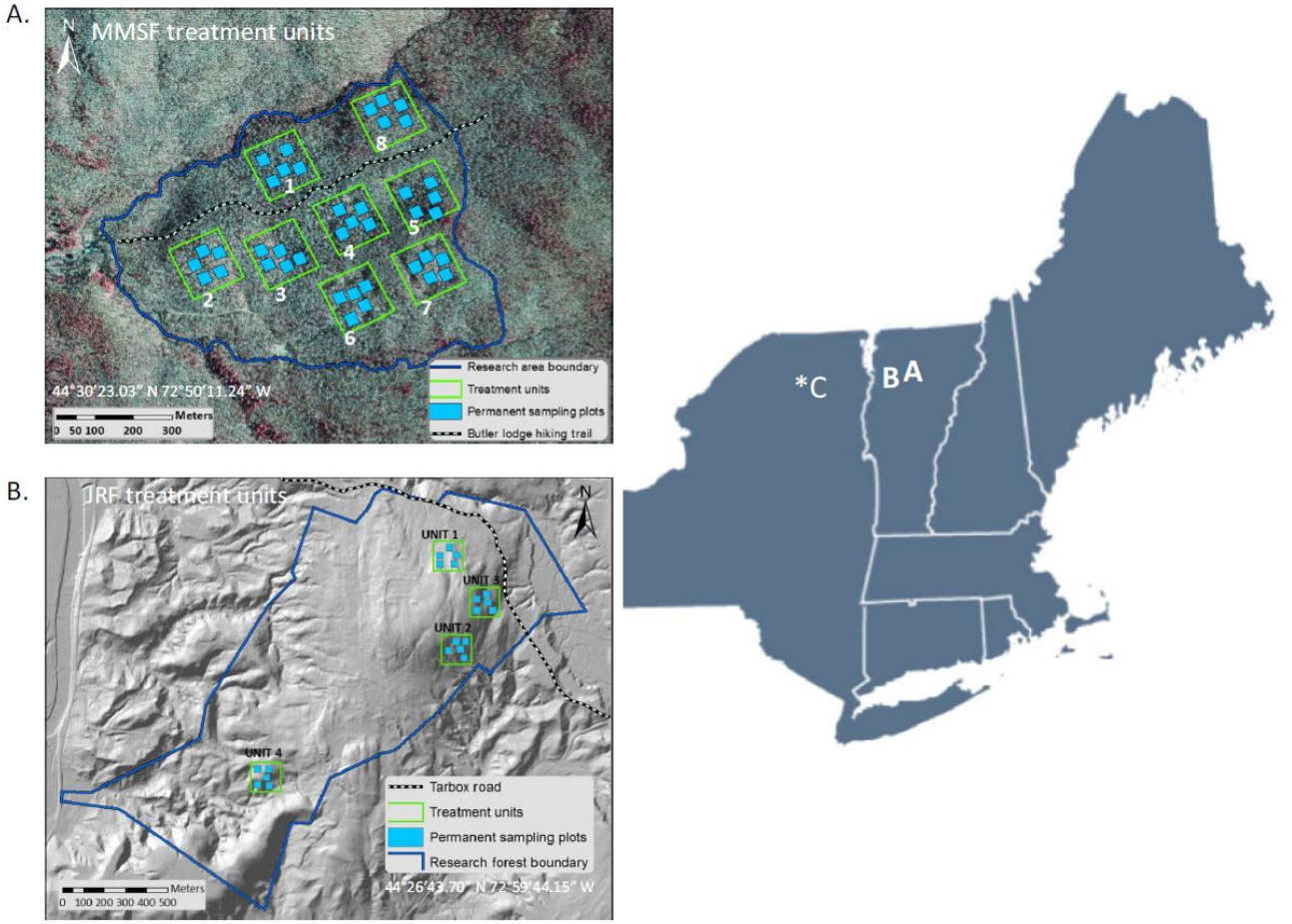
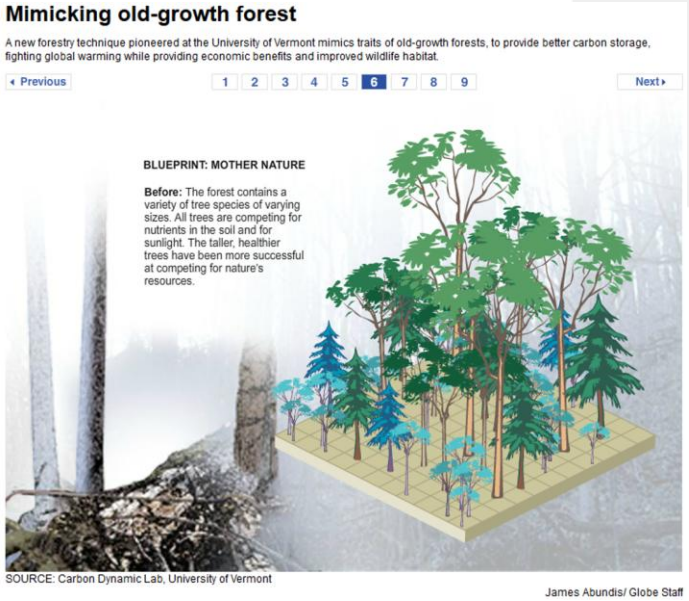


Fig. 1. Regional map with locations of the three project study areas: (A) Mount Mansfield State Forest (MMSF), (B) Jericho Research Forest (JRF), and (C) Forest Ecosystem Research Demonstration Area (FERDA). Also shown are treatment unit layout maps for the MMSF (A) and JRF (B) study areas. Mansfield treatment manipulations: units 1 and 8, control; 2–3, structural complexity enhancement (SCE); 4–5, single-tree selection; 6–7, group selection. Jericho manipulations: 1 and 4, control; 2–3, SCE. *FERDA Treatment Units (44°25′59.6″ N 74°20′36.4″ W).

Learning from the developmental dynamics of old-growth forests

Applying this knowledge to managed stands



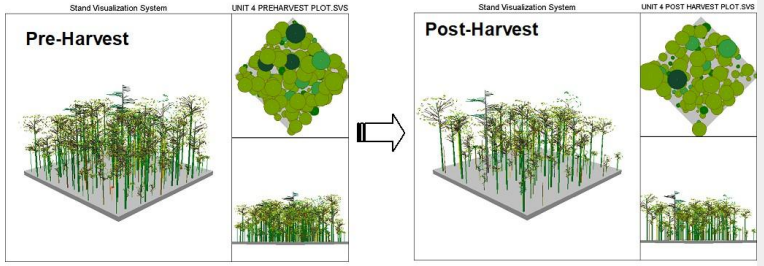
SOURCE: Carbon Dynamic Lab, University of Vermont

James Abundis/ Globe Staff

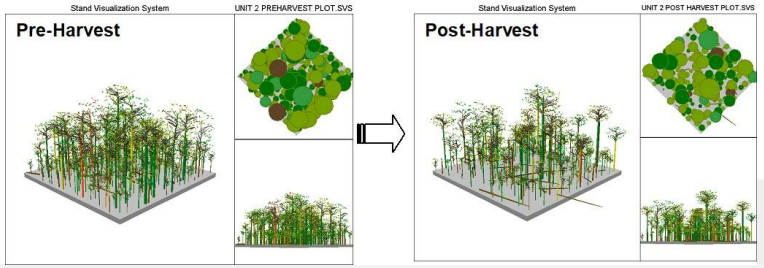
SOURCE: Carbon Dynamic Lab, University of Vermont

SOURCE: Carbon Dynamic Lab, University of Vermont

Single-Tree Selection



Structural Complexity Enhancement



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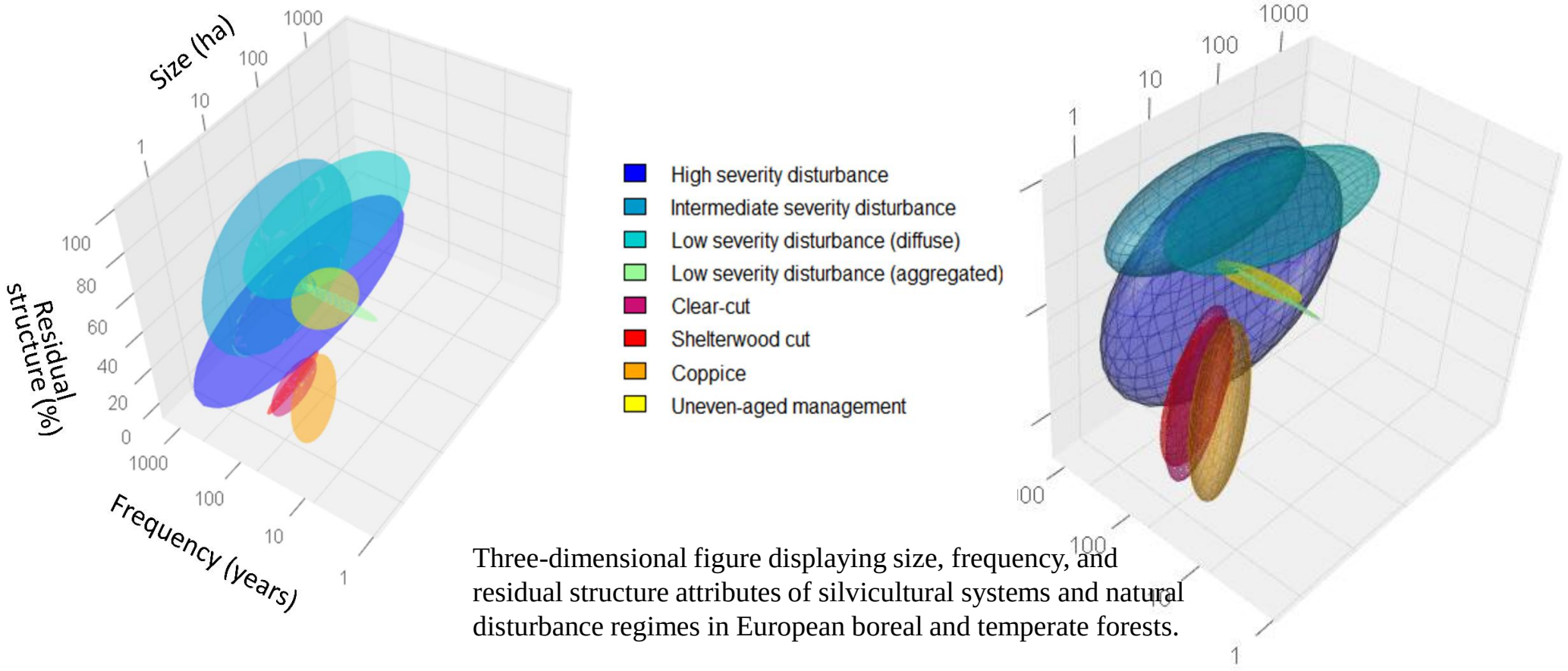
A “Comparability Index” to guide Natural Dynamics Silviculture in Europe



Three-dimensional figure displaying size, frequency, and residual structure attributes of silvicultural systems and natural disturbance regimes in European boreal and temperate forests.

From: Aszalos, Thom…Keeton et al. 2022. Ecological Applications.

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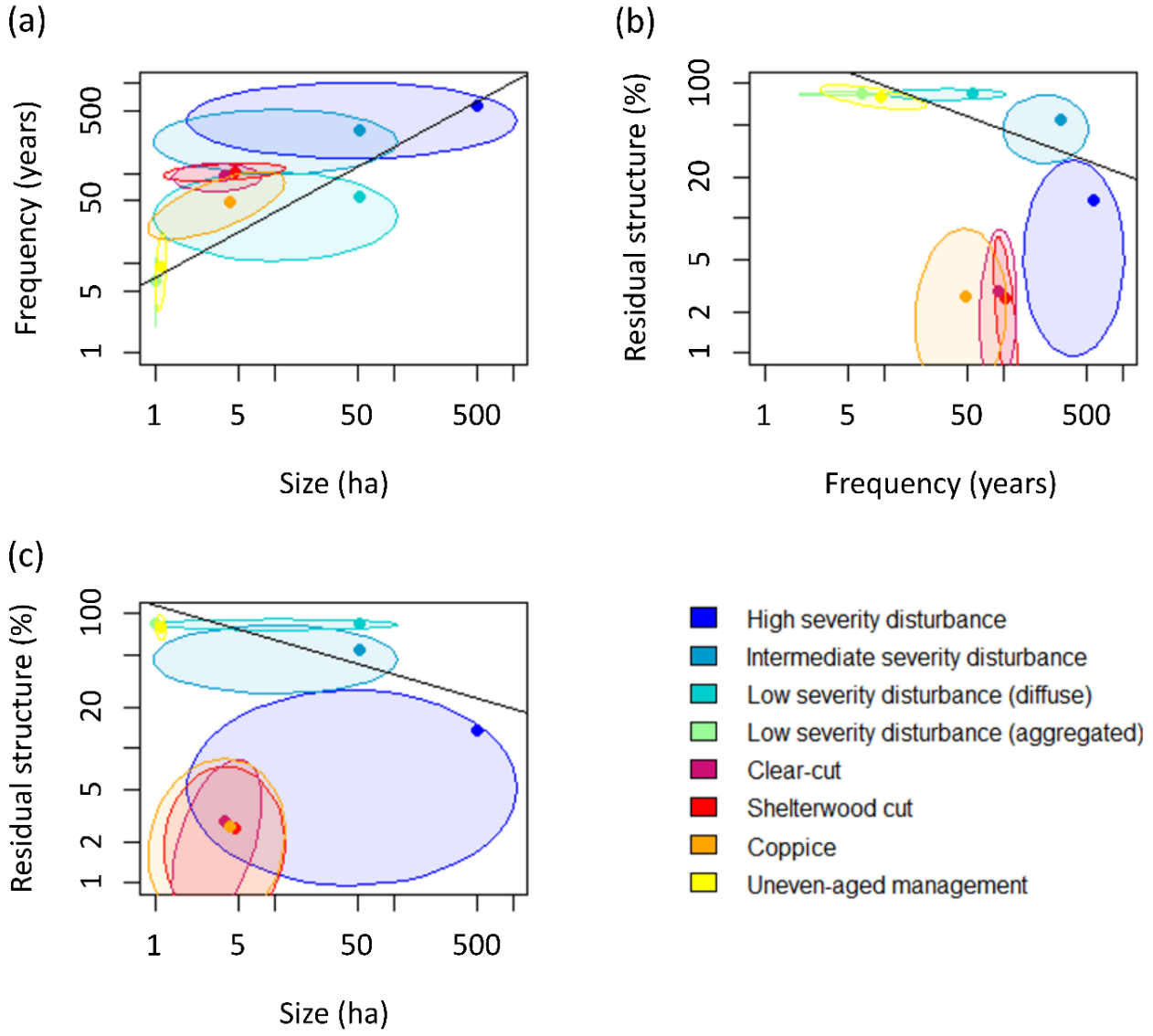
A *"Comparability Index"* for European forests

Size, frequency, and residual structure attributes for natural disturbance regimes and silvicultural systems in Europe.

Dots indicate the centroids of natural disturbance types and silvicultural systems.

The **Comparability Index** is based on the centroids of all the natural disturbance types assessed.

From Aszalos, Thom…Keeton et al. 2022. Ecological Applications



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Applying the Comparability Index: Example

Does “Close-To-Nature”silviculture promote old forest characteristics?

Works well for:

- Gap processes
- Natural regeneration
- Conversion to site-endemic, mixed species composition
- Redevelopment of vertical structure

Needs further modification for:

- Large legacy trees
- Standing dead trees
- Large downed logs
- Tip-up mounds
- Spatial complexity within stands
- Diversification at landscape scales → resilience to disturbance
- Adaptation to climate change

Close-to-Nature silvicultural demonstration at the Klokocna Forest, Czech Republic

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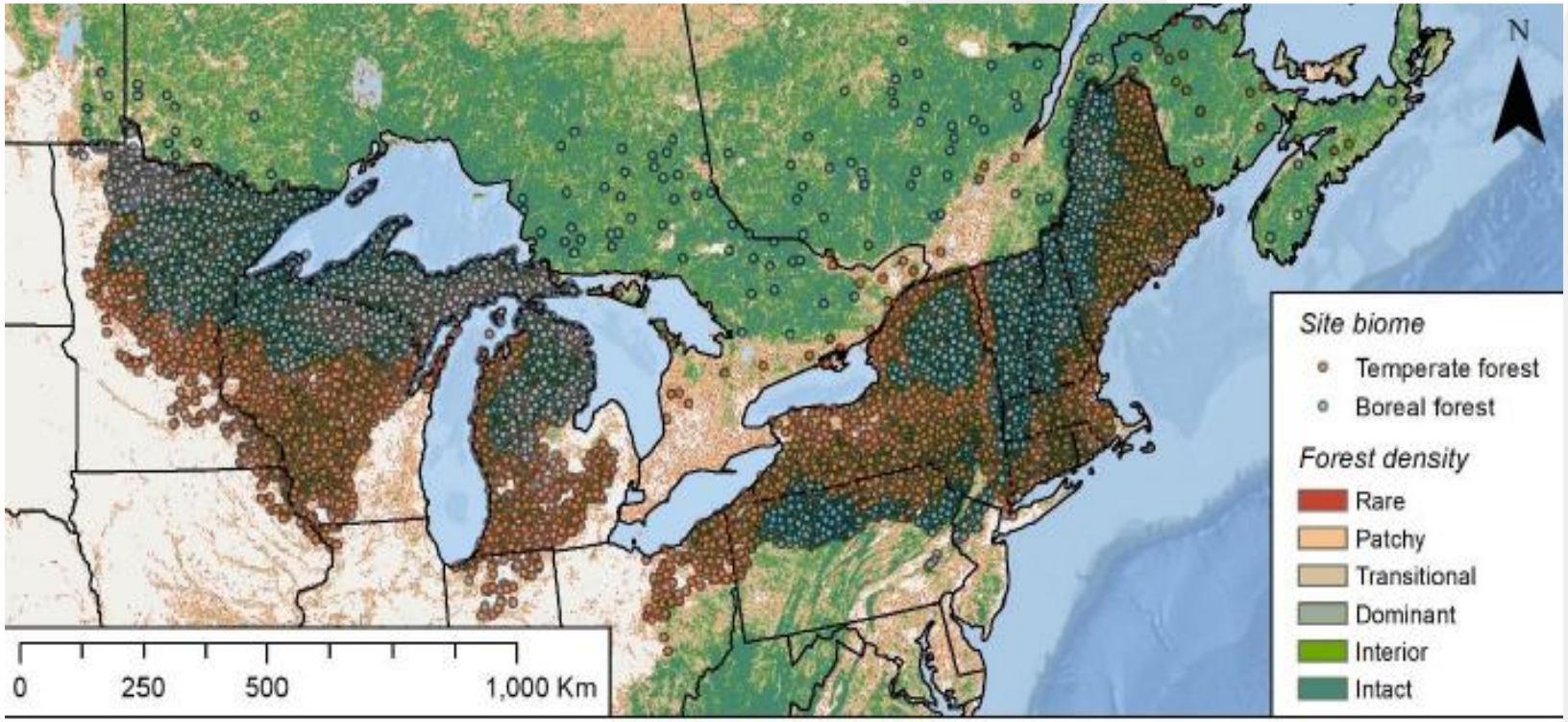
What about Adaptation?

The services that old-growth forests provide may be more resilient to climate change

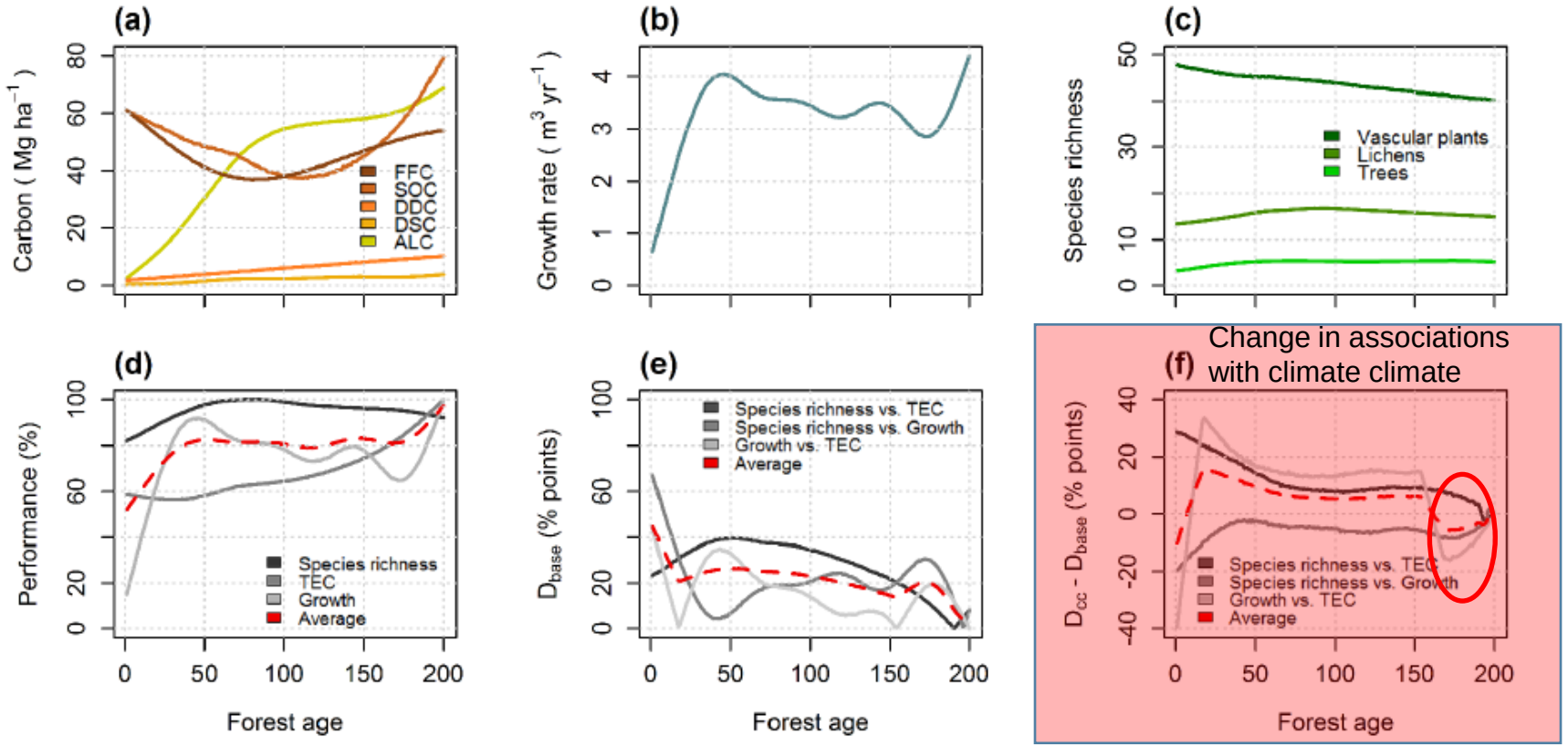
"Services" and biodiversity:

- Relative to forest age
- Relative to one another
- With climate change

Thom…Keeton et al. 2019. Global Change Biology



The services that old-growth forests provide may be more resilient to climate change



Thom…Keeton et al. 2019. Global Change Biology

Old-growth silviculture as adaptive management

- Old-growth will be different in the future → boundary conditions will change
- But "dynamic" restoration is one element of adaptive mgt.
- Resistance: e.g. below-canopy microclimate buffering
- Resilience: e.g. functional trait diversity, genetic and evolutionary potential

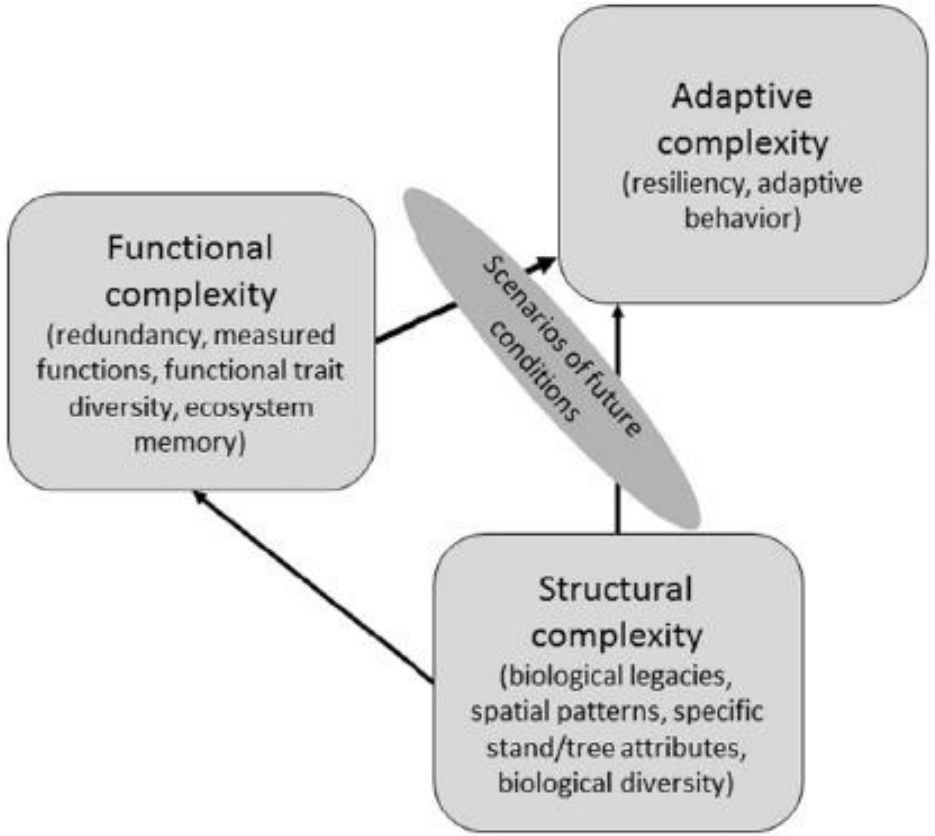


Fig. 1. Conceptual diagram illustrating the relationship between different conceptions of complexity that could be used to analyze or design silviculture treatments.

Figure from Fahey…Keeton… et al. 2017.

Closing Thoughts:

1. Structure in old-growth temperate forests is highly variable, but provides services of universal value

2. Inventories of remaining old-growth vary among regions, as does degree of protection

3. Option for active restoration of structural and functional characteristics of old-growth temperate forests

4. Conservation and management of old-growth systems as an element of adaptive management in the face of climate change

Andes Mtns., Patagonia, Chile

THANK YOU!

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- U.S. Fulbright Scholarship Program
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