habitat
LA NATURE À L'ŒUVRE

Natural solutions to the climate and biodiversity crises in our forests

Prof. Christian Messier, ing. f., *Université du Québec à Montréal (UQAM) et (UQO), Chaire du Canada sur la résilience des forêts face aux changements globaux et Chaire HQ sur le contrôle de la croissance des arbres*

Institut des Sciences de la Forêt tempérée

UQÀM Université du Québec à Montréal

UQO

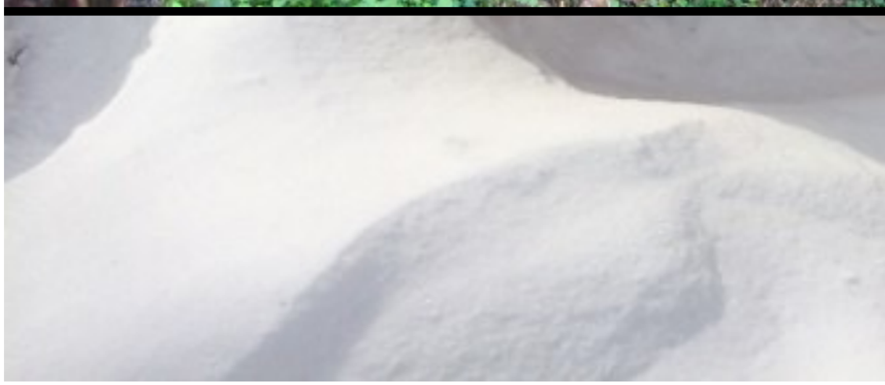
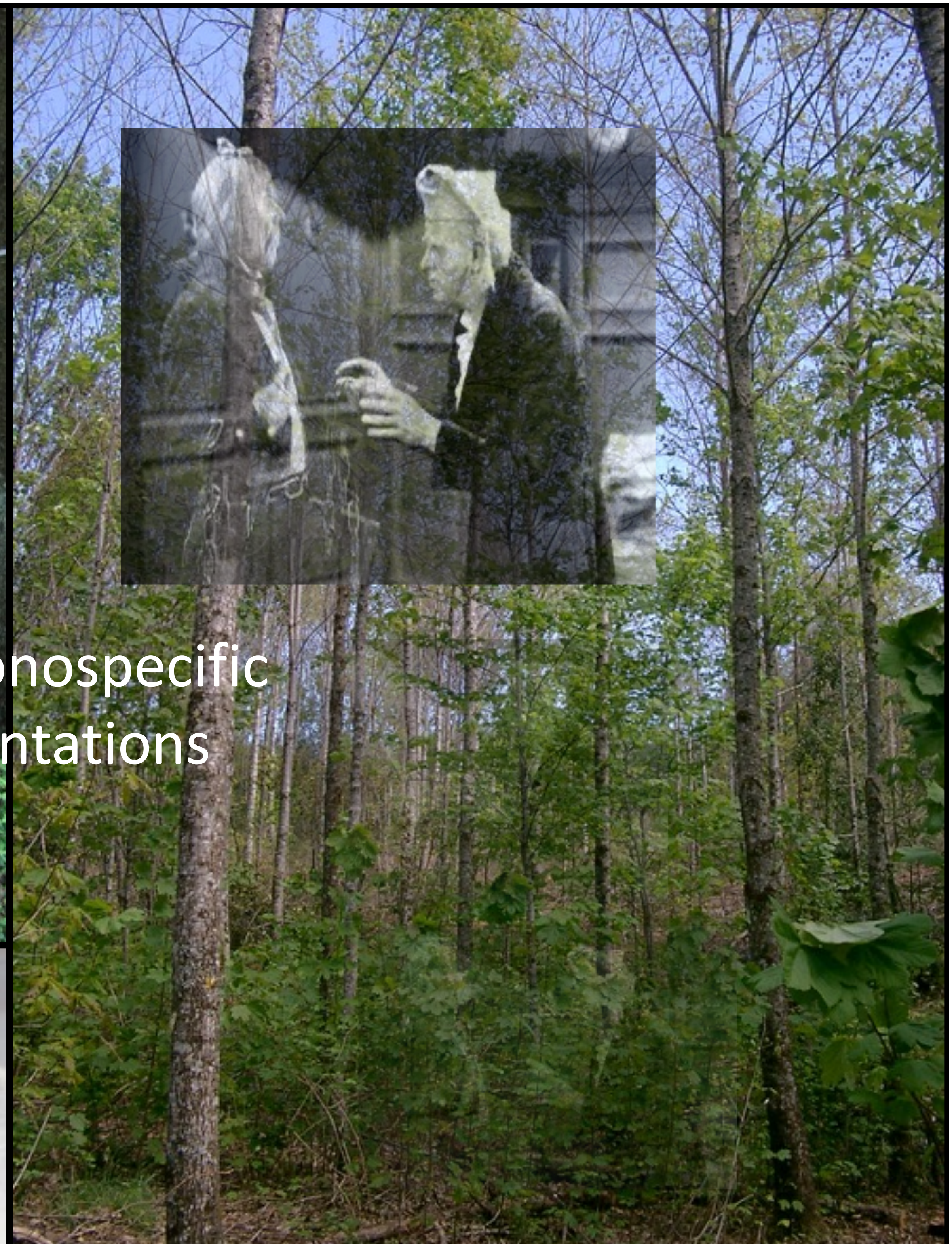
cef Centre d'étude de la forêt

Presentation Plan

- Forestry and its ghosts
- The threatened forest
- Some interesting new concepts
- For a forestry of resilience

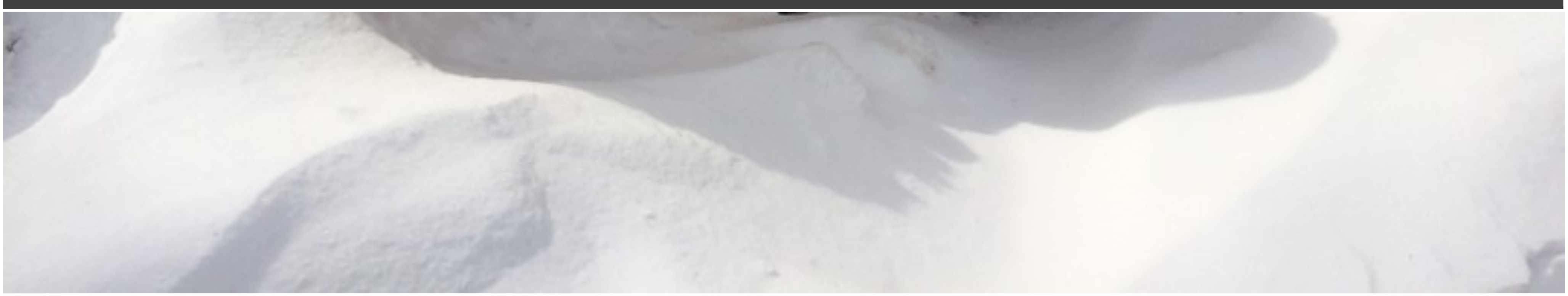
Forest management in Quebec today

Gardening cut

Monospecific plantations

Forestry has always aimed to simplify the forest to maximize certain services. Is this still the right approach?



Presentation Plan

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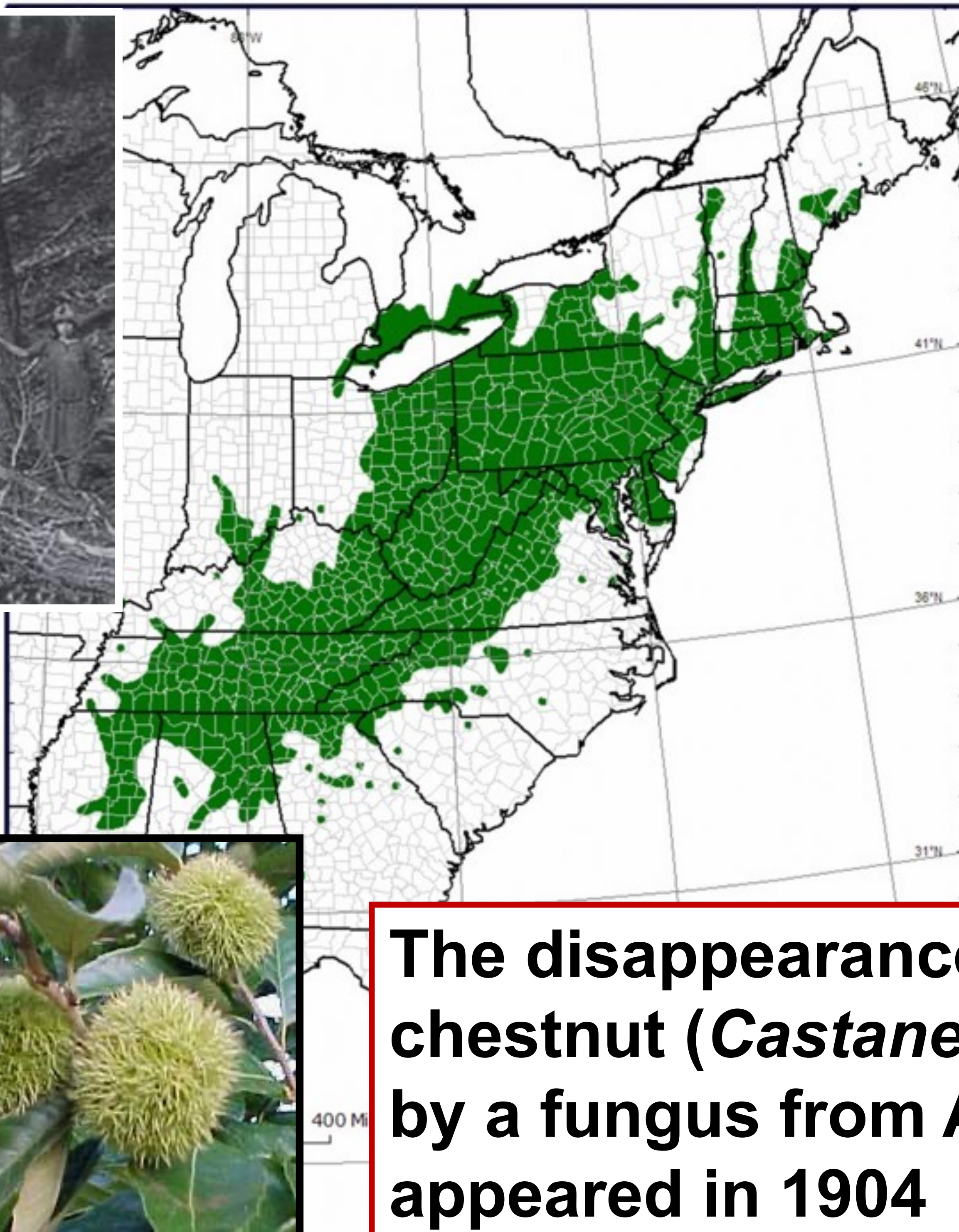
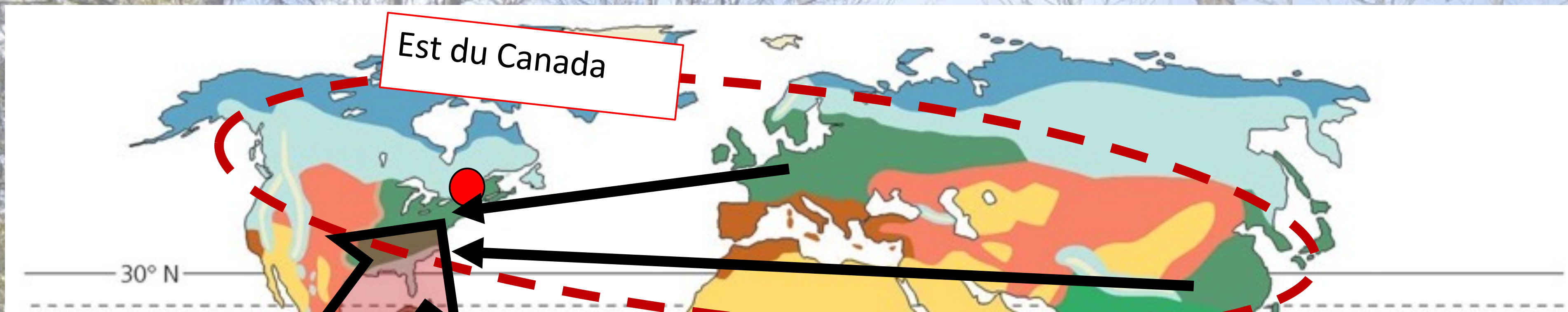
The threatened forest



The disappearance of the chestnut (*Castanea dentata*) by a fungus from Asia that appeared in 1904

The threat of exotic insects and diseases



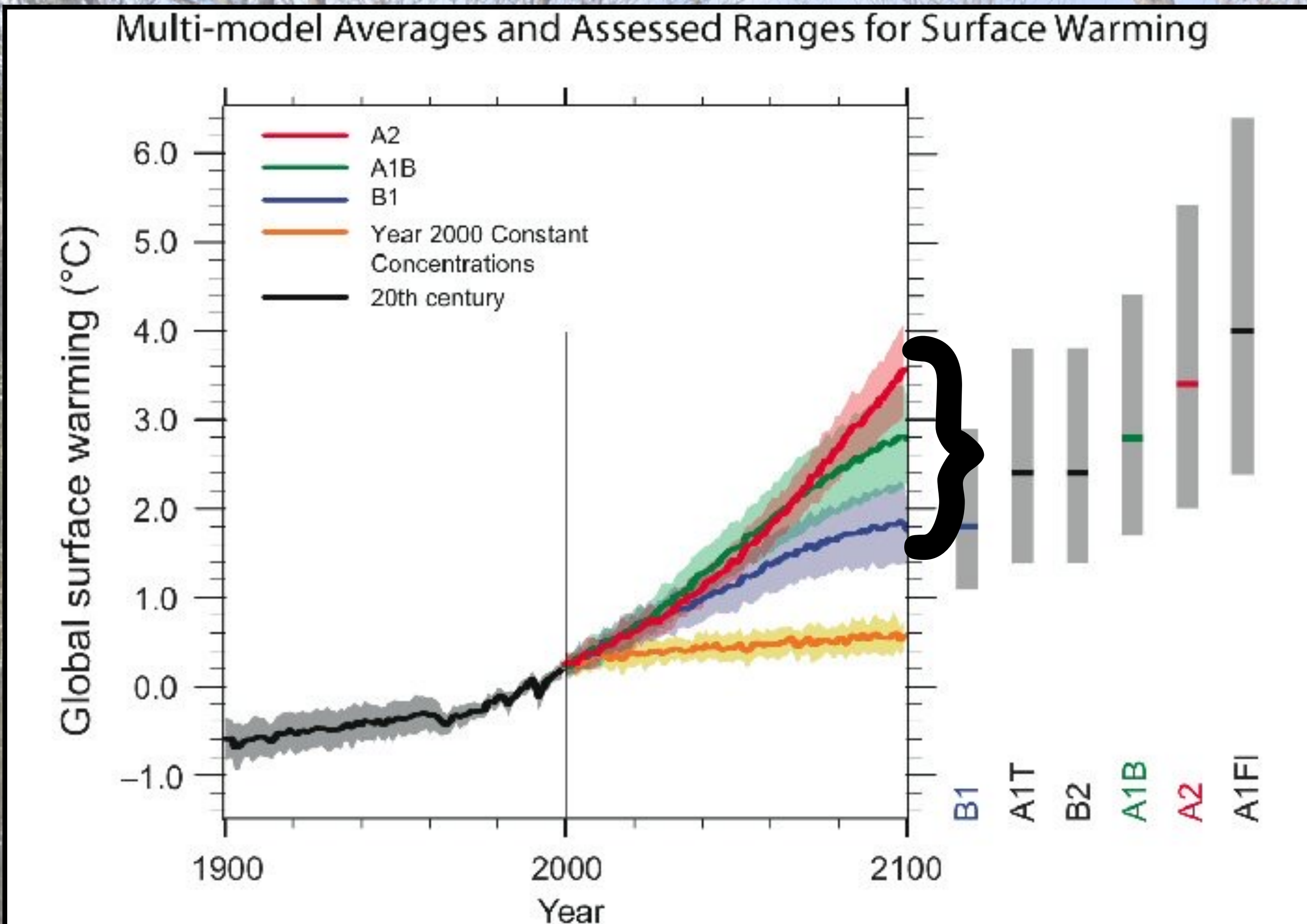
Ecological Applications, 26(5), 2016, pp. 1437–1455

Nonnative forest insects and pathogens in the United States: Impacts and policy options

Gary M. Lovett,[1,12] Marissa Weiss,[2,3] Andrew M. Liebhold,[4] Thomas P. Holmes,[5] Brian Leung,[6] Kathy Fallon Lambert,[2,3] David A. Orwig,[3] Faith T. Campbell,[7] Jonathan Rosenthal,[8] Deborah G. McCullough,[9] Radka Wildova,[8] Matthew P. Ayres,[10] Charles D. Canham,[1] David R. Foster,[3] Shannon L. LaDeau,[1] and Troy Weldy[11]

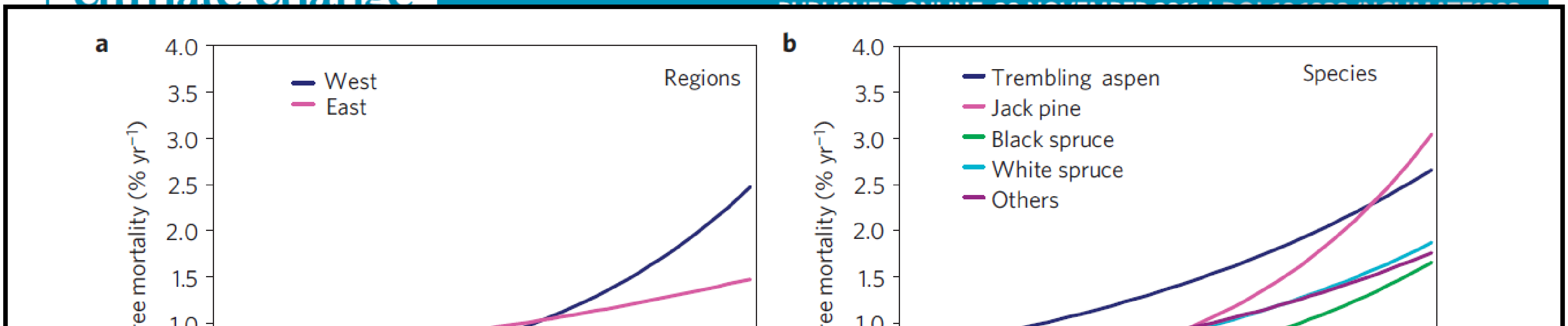
More than 25 exotic insects and diseases are present and may strongly affect more than 30 tree species in Quebec in the next 50 years

Global warming

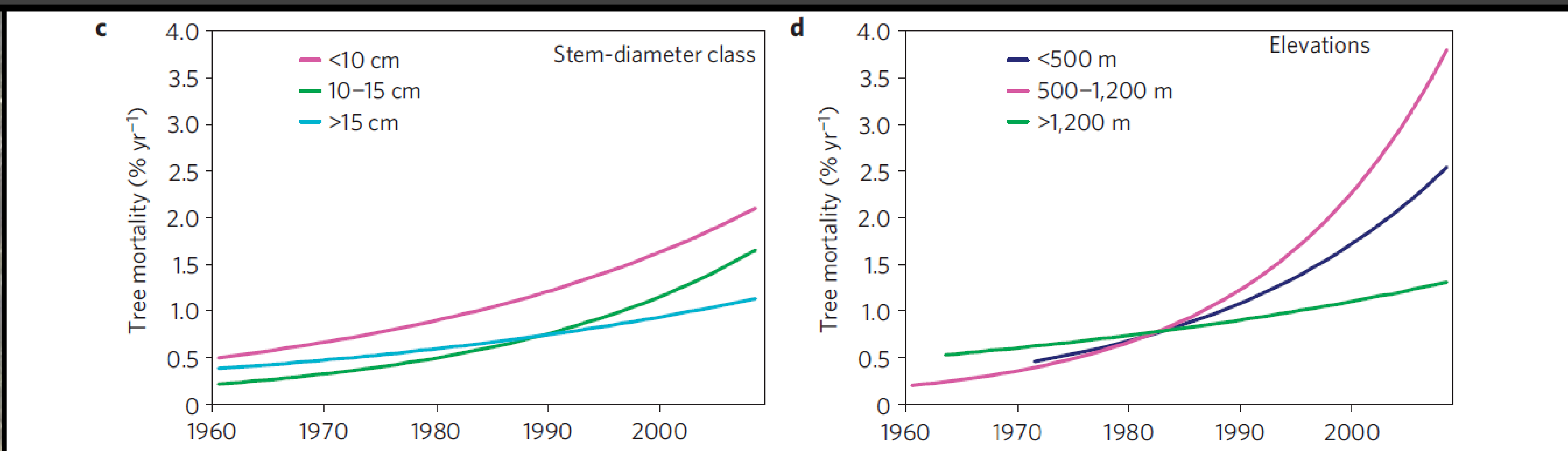


nature
climate change

LETTERS



Tree mortality rates have been increasing EVERYWHERE in Canada and for ALL species since the 1970s and 1980s



represent, respectively, Canada's boreal and hemiboreal regions. Of these plots, 70 were located in western Canada including Alberta (AB), Saskatchewan (SK) and Manitoba (MB), and 26 were located in eastern Canada including Ontario (ON) and Quebec (QC).

Annual Review of Plant Biology

Climate Change Risks to Global Forest Health: Emergence of Unexpected Events of Elevated Tree Mortality Worldwide

Annu. Rev. Plant Biol. 2022. 73:673–702

Henrik Hartmann,[1] Ana Bastos,[2] Adrian J. Das,[3] Adriane Esquivel-Muelbert,[4,5] William M. Hammond,[6] Jordi Martínez-Vilalta,[7,8] Nate G. McDowell,[9,10] Jennifer S. Powers,[11] Thomas A.M. Pugh,[4,5,12] Katinka X. Ruthrof,[13,14] and Craig D. Allen[15]

[1]Max Planck Institute for Biogeochemistry, Department of Biogeochemical Processes, Jena

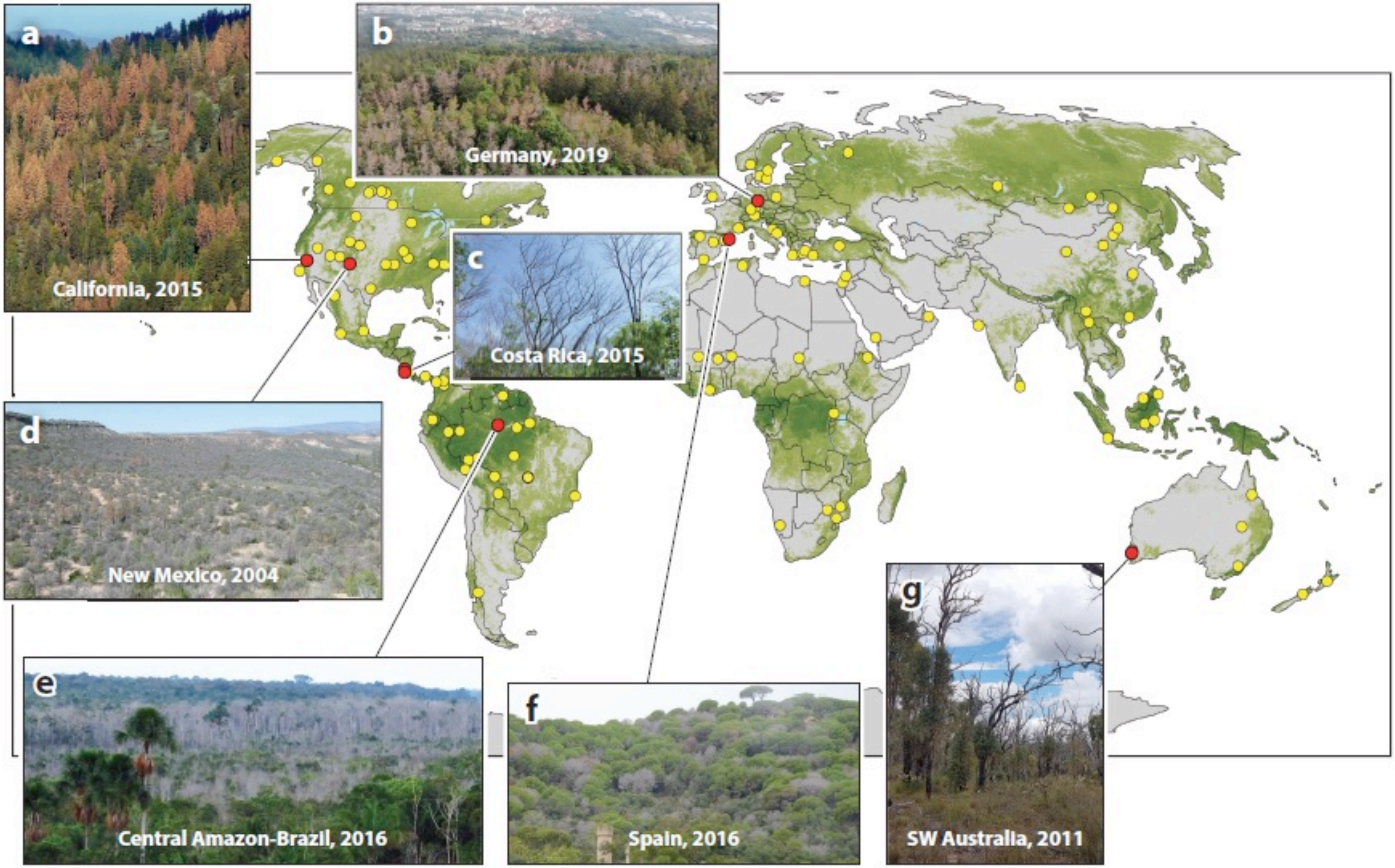


Figure 1

Published observations of elevated tree mortality in response to drought and heat (*yellow dots*). These documented observations have been presented in References 9, 10, 72, and 78. Locations of selected mortality events presented here as case studies are indicated by red dots and illustrated by inset photos. The forest cover shown here is adapted with permission from the canopy height map of Reference 142, with only canopies 5 m or taller plotted and taller canopies in increasingly darker green. (*a*) Dying *Pinus* and *Abies* in California; photo provided by Nate Stephenson. (*b*) *Pinus sylvestris* mortality in a matrix of living *Fraxinus excelsior* in Germany; photo provided by Henrik Hartmann. (*c*) Photo taken in 2017 of ongoing mortality after 2015 drought in Costa Rica; photo provided by

Received: 1 August 2022 | Revised: 8 November 2022 | Accepted: 11 November 2022
DOI: 10.1111/gcb.16531

Global Change Biology WILEY

RESEARCH ARTICLE

Significant increase in natural disturbance impacts on European forests since 1950

Marco Patacca[1,2] | Marcus Lindner[3] | Manuel Esteban Lucas-Borja[4] | Thomas Cordonnier[5] | Gal Fidej[6] | Barry Gardiner[7,8] | Ylva Hauf[9] | Gediminas Jasinevičius[10] | Sophie Labonne[5] | Edgaras Linkevičius[11] | Mats Mahnken[9,12] | Slobodan Milanovic[13,14] | Gert-Jan Nabuurs[1,2] | Thomas A. Nagel[6] | Laura Nikinmaa[3,15] | Momchil Panyatov[16] | Roman Bercak[17] | Rupert Seidl[18,19] | Masa Zorana Ostrogović Sever[20] | Jaroslaw Socha[21] | Dominik Thom[16,22] | Dijana Vuletic[20] | Sergey Zudin[3] | Mart-Jan Schelhaas[1]

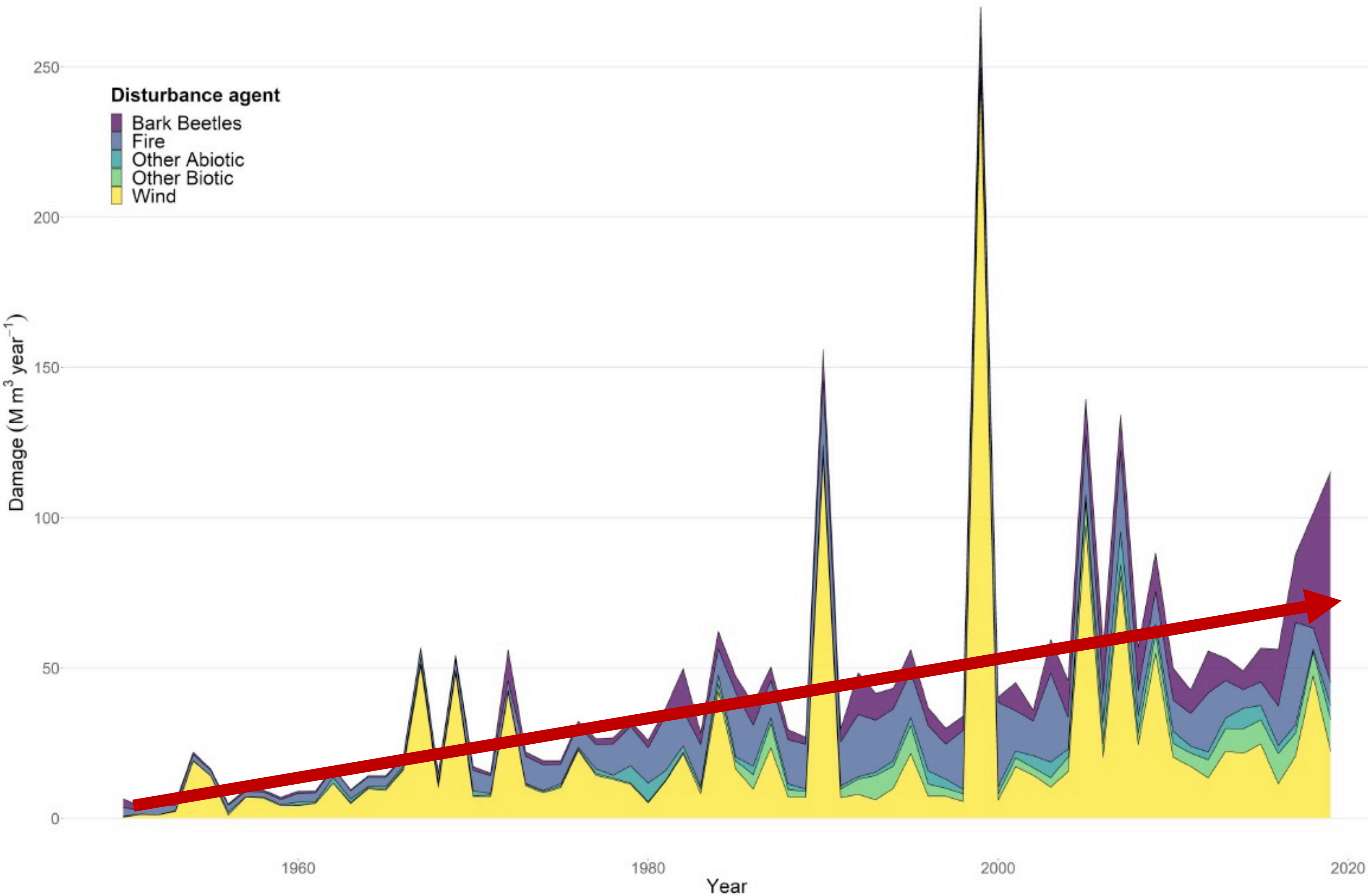


FIGURE 3 Total reported damage caused by natural disturbance in Europe between 1950 and 2019.

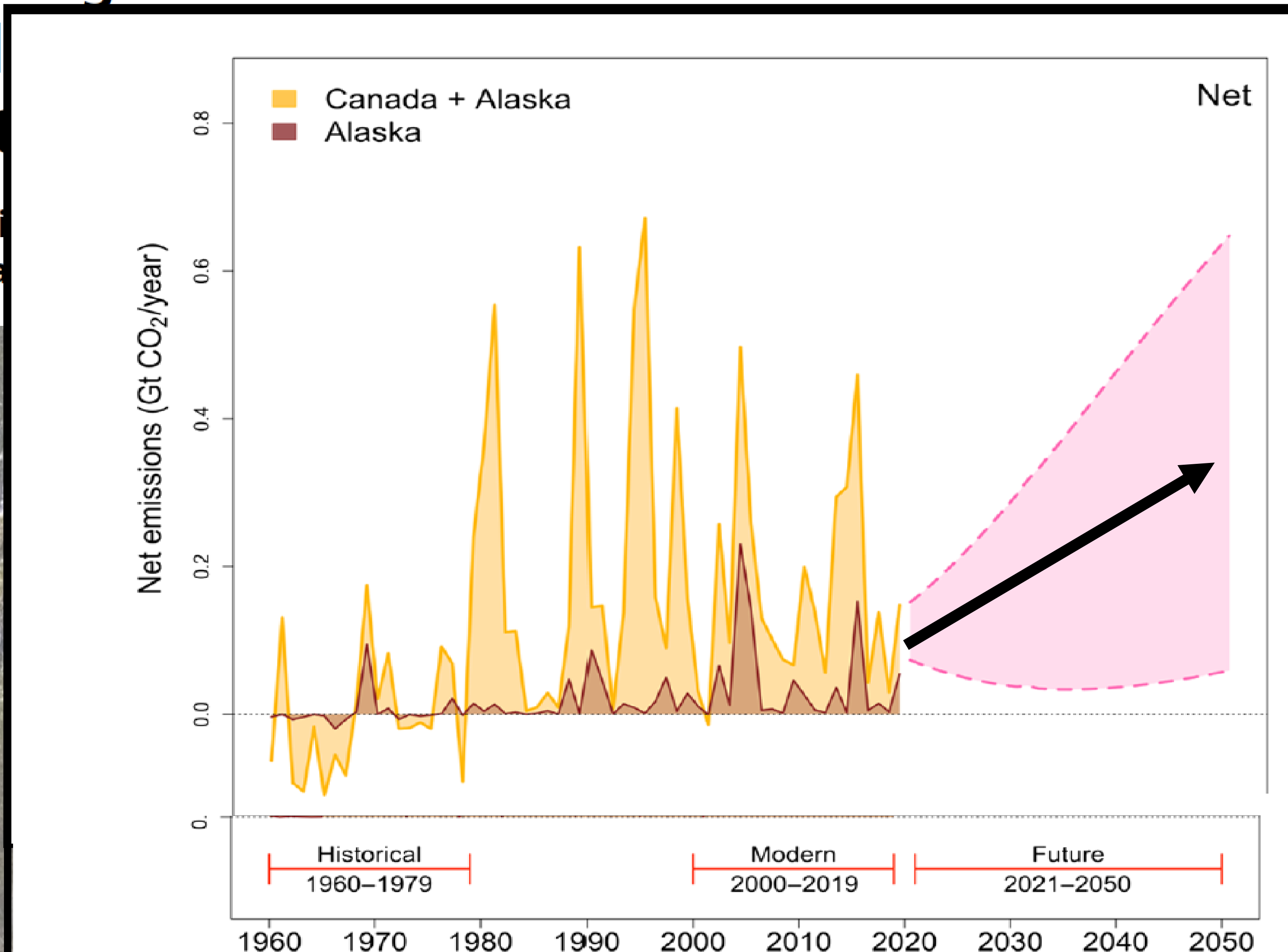
SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

Phillips *et al.*, *Sci. Adv.* **8**, eabl7161 (2022) 27 April 2022

Escalating carbon emissions from North American boreal potent

Carly A. Phi ubarak[4],
James T. Ra



REPORT

Anderegg *et al.*, *Science* **377**, 1099–1103 (2022)

FOREST ECOLOGY

A climate risk analysis of Earth's forests in the 21st century

William R. L. Anderegg[1,2]*, Chao Wu[1,2], Nezha Acil[3,4], Nuno Carvalhais[5,6], Thomas A. M. Pugh[3,4,7], Jon P. Sadler[3,4], Rupert Seidl[8,9]

Earth's forests harbor extensive biodiversity and are currently a major carbon sink. Forest conservation and restoration can help mitigate climate change; however, climate change could fundamentally imperil forests in many regions and undermine their ability to provide such mitigation. The extent of climate risks facing forests has not been synthesized globally nor have different approaches to quantifying forest climate risks been systematically compared. We combine outputs from multiple mechanistic and empirical approaches to modeling carbon, biodiversity, and disturbance risks to conduct a synthetic climate risk analysis for Earth's forests in the 21st century. Despite large uncertainty in most regions we find that some forests are consistently at higher risk, including southern boreal forests and those in western North America and parts of the Amazon.

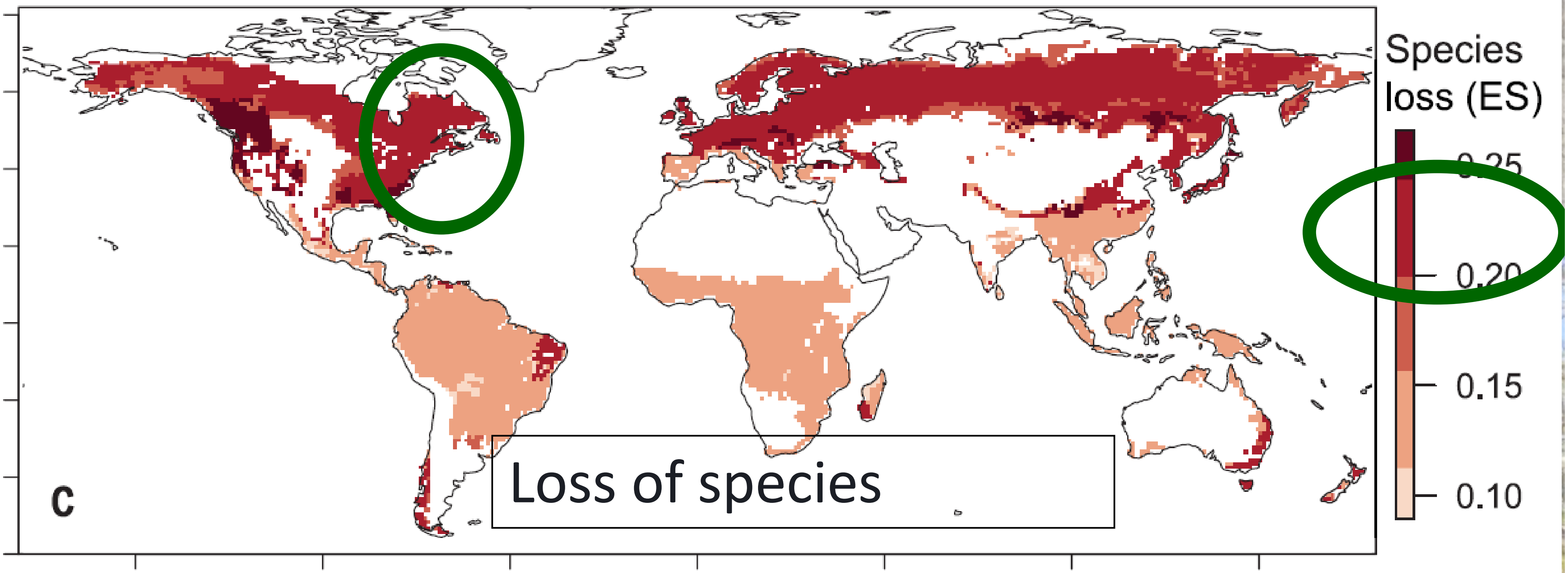


Fig. 2. Global forest risk estimates from climate envelope approaches. (C) Risk of loss in species richness [quantified as an effect size (ES) of –1 × log(DSpeciesRichnesshighcc-mitigation/ DSRbaseline)] where higher numbers indicate more risk of species loss) in the 2070s in a high climate change (RCP 8.5) scenario from Mori et al. 2021 (21).

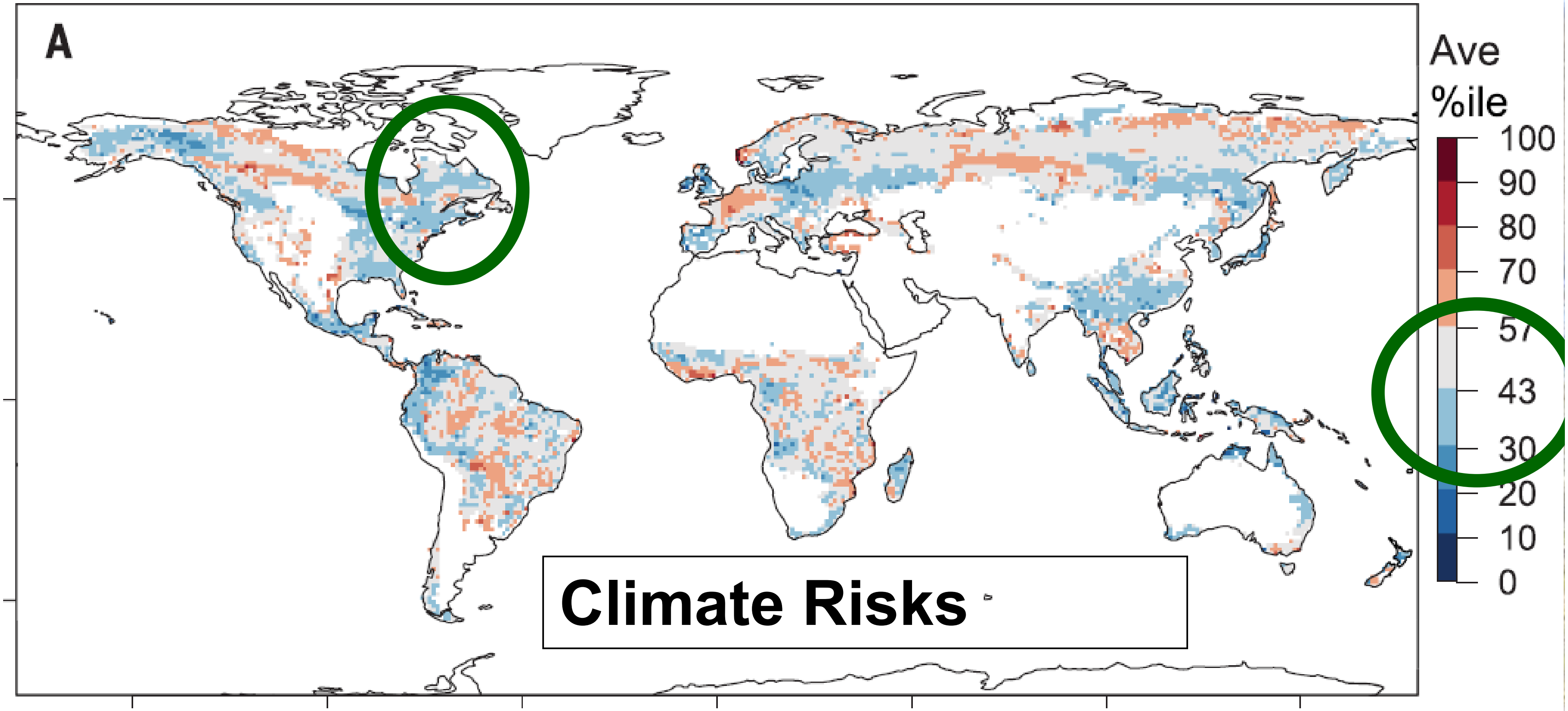
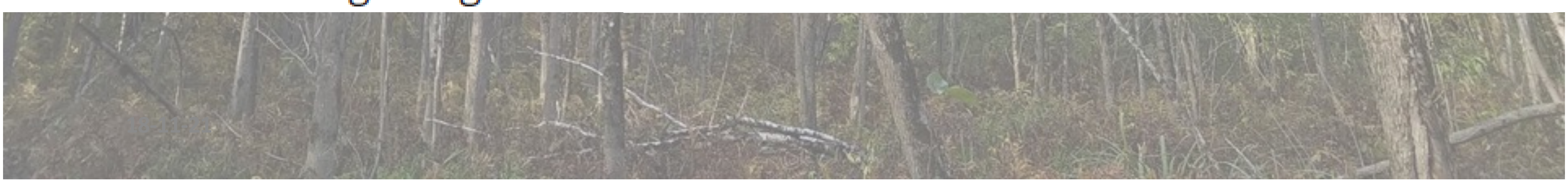
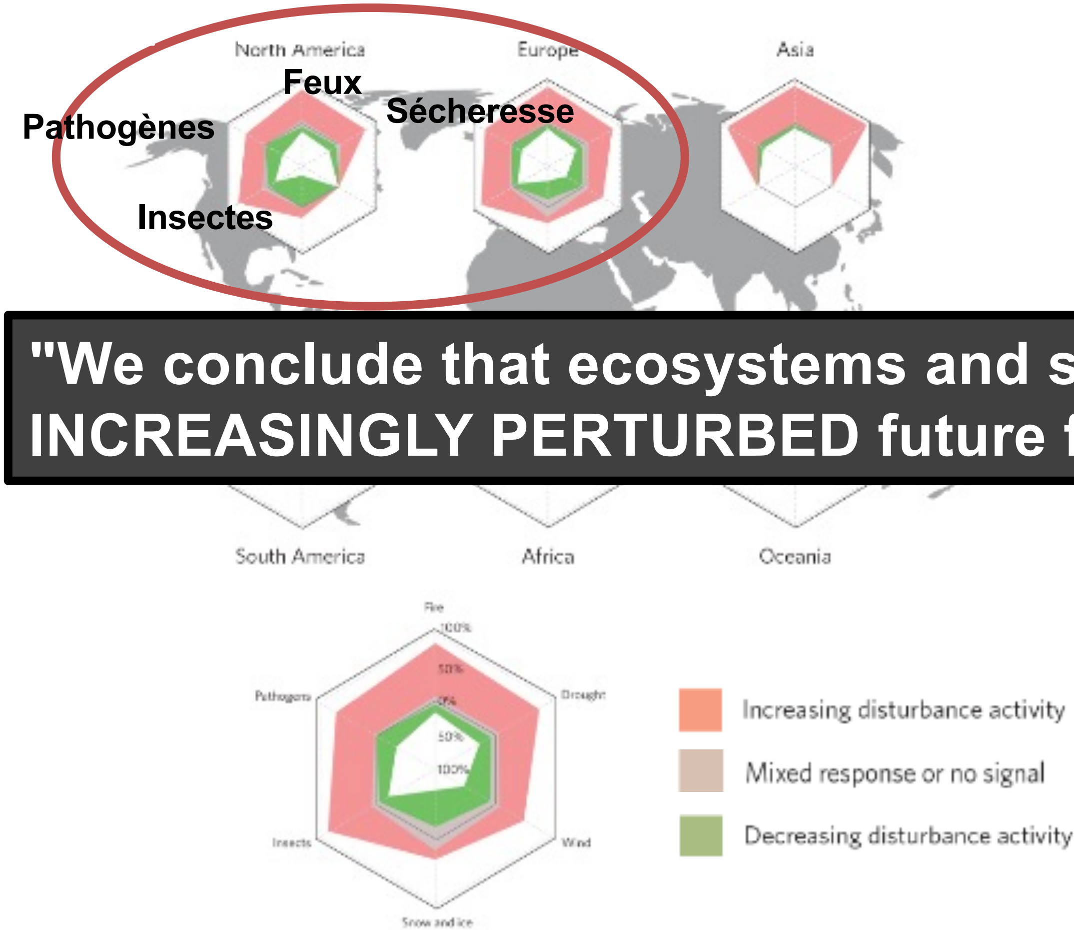
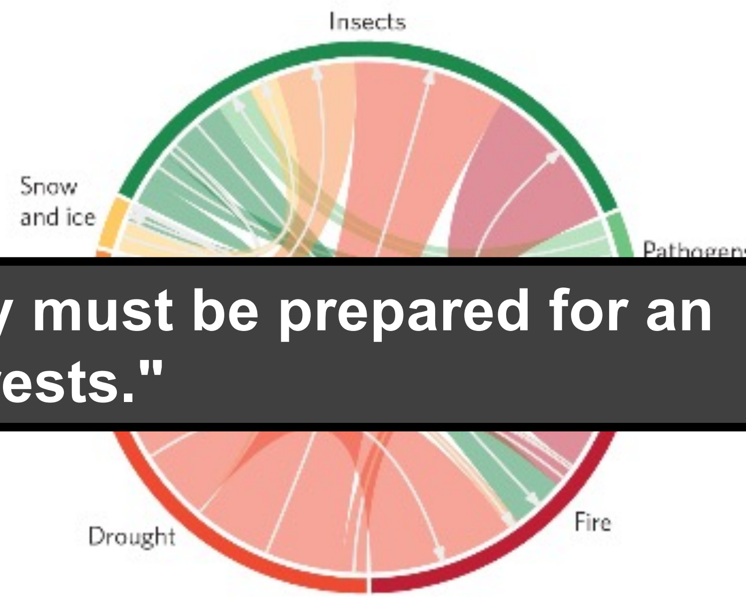


Fig. 4. Comparisons and syntheses across different climate risk axes.
(**A**) Average percentile of risk combined across all metrics where 0%ile is lowest climate risk and 100%ile is highest climate risk, averaged across all datasets that covered a given grid cell.



Intensification of forest disturbances and interactions with climate change





"We conclude that ecosystems and society must be prepared for an INCREASINGLY PERTURBED future for forests."

Seidl et al. 2018. Nat. Clim. Change

We are entering a period of "high turbulence and uncertainty”. **Are there any solutions?**

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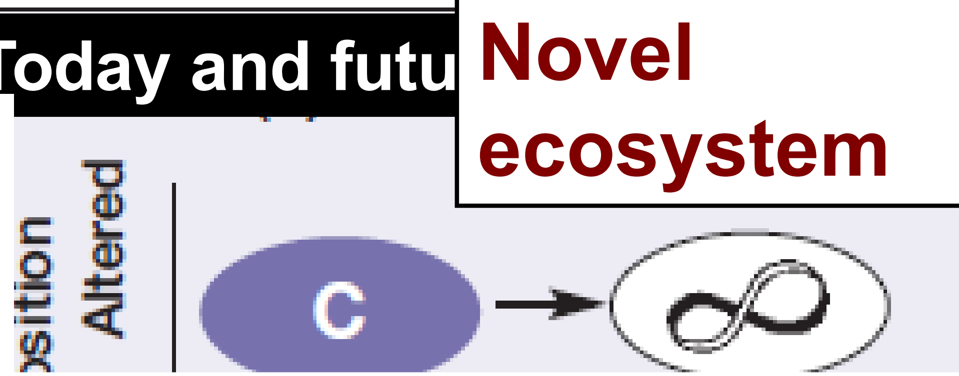
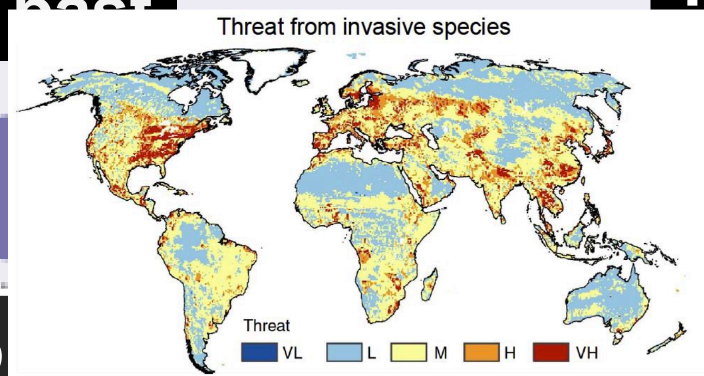
Concept of a new ecosystem

Management of novel ecosystems: are novel approaches required?

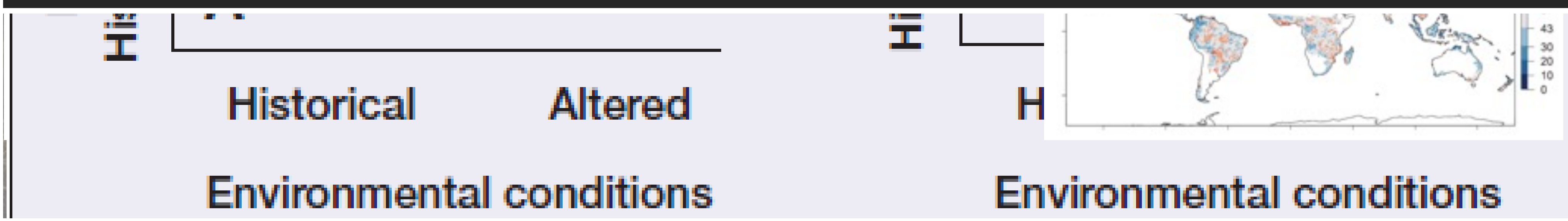
Timothy R Seastedt[1*], Richard J Hobbs[2], and Katharine N Suding[3]



Novel ecosystem



- *We sho... ...restry interventions only on our knowledge of the past, but ALSO on the changing and uncertain future conditions.*



Reconciling Conflicting Paradigms of Biodiversity Conservation: Human Intervention and Rewilding

December 2019 / Vol. 69 No. 12 • BioScience 997

- ***We must increasingly consider INTERVENING to maintain the services we want even in our protected areas.***

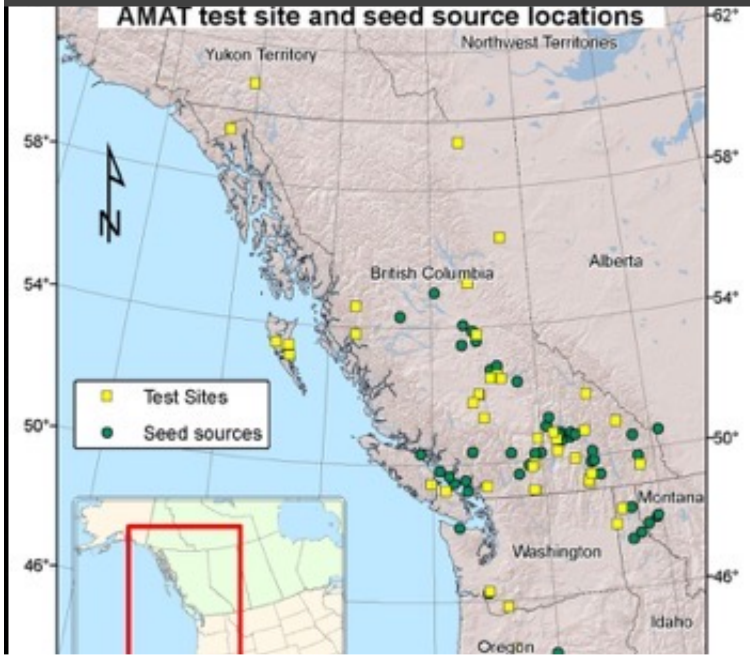
Ecological Science in the Twenty-first Century

BioScience • June 2011 / Vol. 61 No. 6

RICHARD J. HOBBS, LAUREN M. HALLETT, PAUL R. EHRLICH, AND HAROLD A. MOONEY

Rapid, extensive, and ongoing environmental change increasingly demands that humans intervene in ecosystems to maintain or restore ecosystem services and biodiversity. At the same time, the basic principles and tenets of restoration ecology and conservation biology are being debated and

Concept of assisted migration



- ***We can adapt our forests for the future by ENRICHING their genetic (provenance) and specific (new species) composition.***

climate, one forester in British Columbia is already doing it. **Emma Marris** reports.

At a research station in the Okanagan valley in British Columbia, a few kilo-

and premature. Plants moved by humans may become invasive in their new haunts or just fail

important trees and moving them south, forcing them to endure a warmer climate, quickly simu-

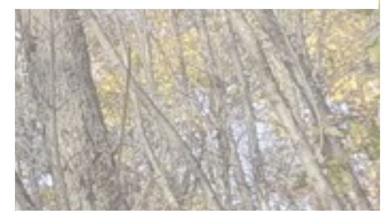
The portfolio concept in ecology and evolution

Daniel E Schindler[1*], Jonathan B Armstrong[2], and Thomas E Reed[3]

Biological systems have similarities to efficient financial portfolios; the emergent properties of aggregate systems are often less volatile … tistical averaging across the dynamics of system c… ach other through time and space. The "portfolio"… nt insights into how ecosystems are organized, h… It also helps identify appropriate scales for devel… s an approach that does not rely on prescriptive p… nts a framework for managing risk from inevitab… and or anticipate.

Front Ecol Environ 2015; 13(

certain emerge… diversification across a… integrity and productivi… ng term.



- ***As for investments, we can intelligently DIVERSIFY the species of trees in our forest to reduce the risks.***

Received: 28 January 2021 | Revised: 20 June 2021 | Accepted: 5 July 2021

DOI: 10.1111/conl.12829

Conservation Letters
A journal of the Society for Conservation Biology
Open Access

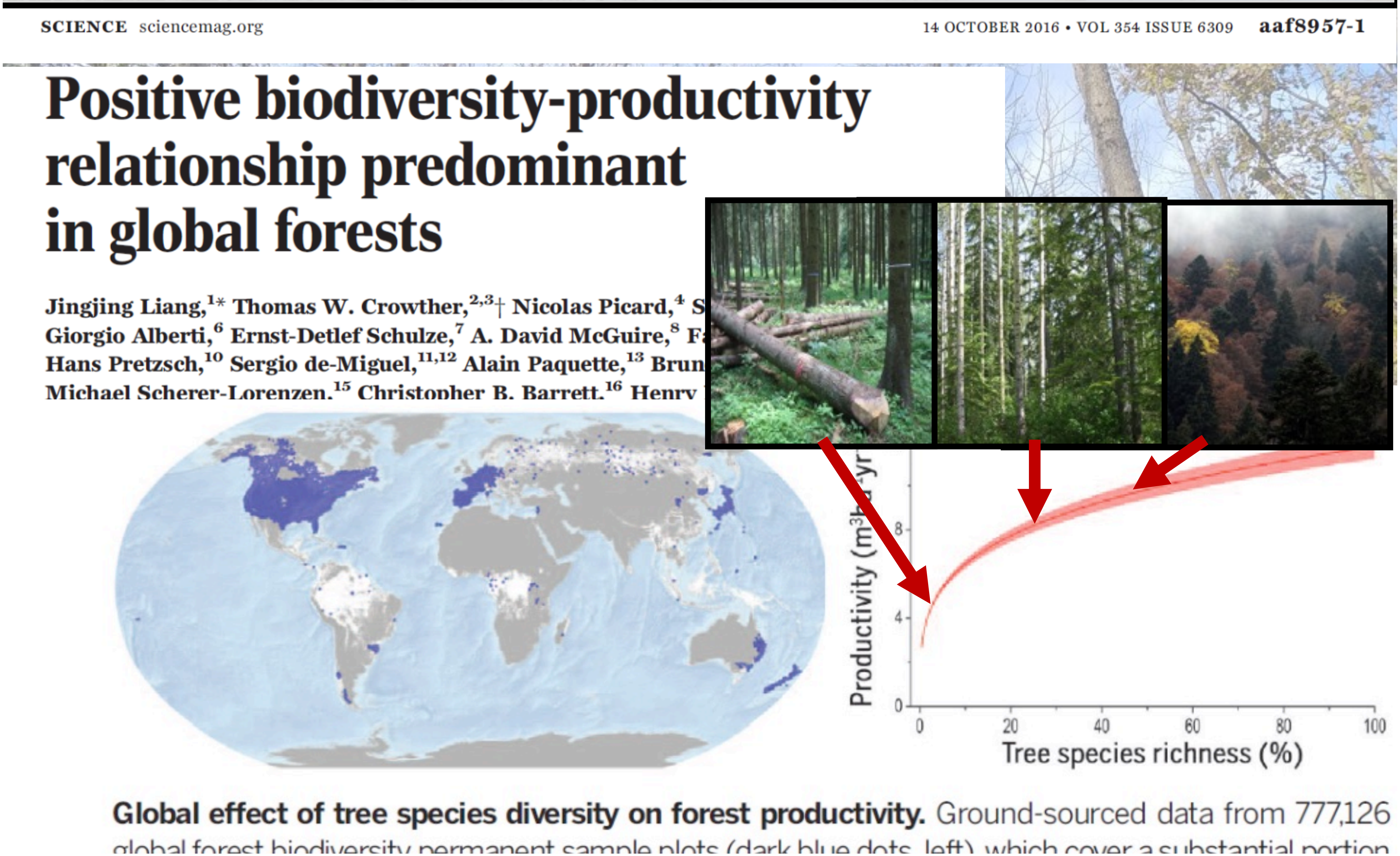
WILEY

PERSPECTIVE

For the sake of resilience and multifunctionality, let's diversify planted forests!

- *By diversifying our plantations, we reduce susceptibility to disturbances and increase the production of ecosystem services*

The effect of tree species diversity on productivity

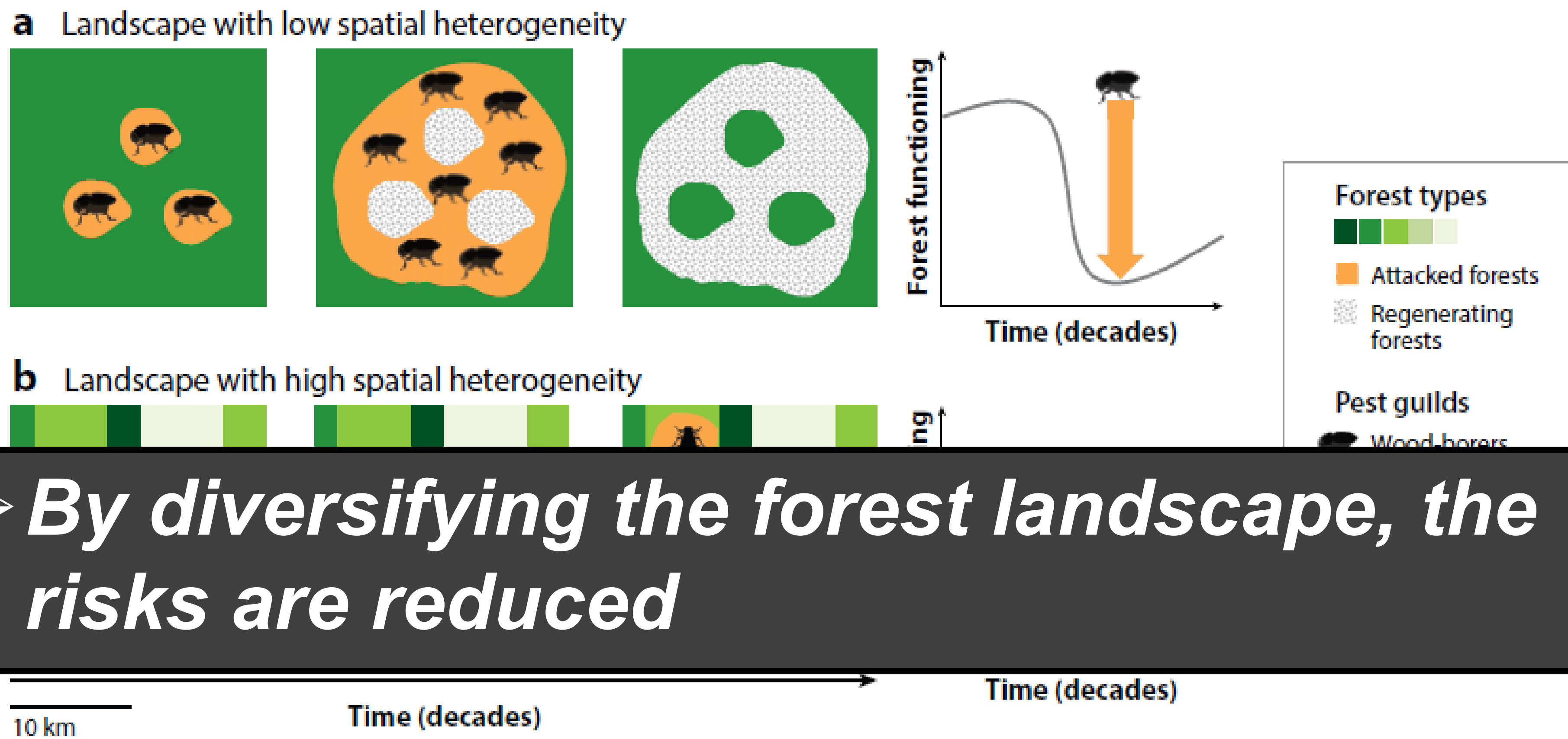

SCIENCE sciencemag.org 14 OCTOBER 2016 • VOL 354 ISSUE 6309 aaf8957-1

Positive biodiversity-productivity relationship predominant in global forests

Jingjing Liang,[1]* Thomas W. Crowther,[2,3]† Nicolas Picard,[4] S
Giorgio Alberti,[6] Ernst-Detlef Schulze,[7] A. David McGuire,[8] F
Hans Pretzsch,[10] Sergio de-Miguel,[11,12] Alain Paquette,[13] Brun
Michael Scherer-Lorenzen,[15] Christopher B. Barrett,[16] Henry

Global effect of tree species diversity on forest productivity. Ground-sourced data from 777,126 global forest biodiversity permanent sample plots (dark blue dots, left), which cover a substantial portion

Annu. Rev. Entomol. 2022. 67:181–99

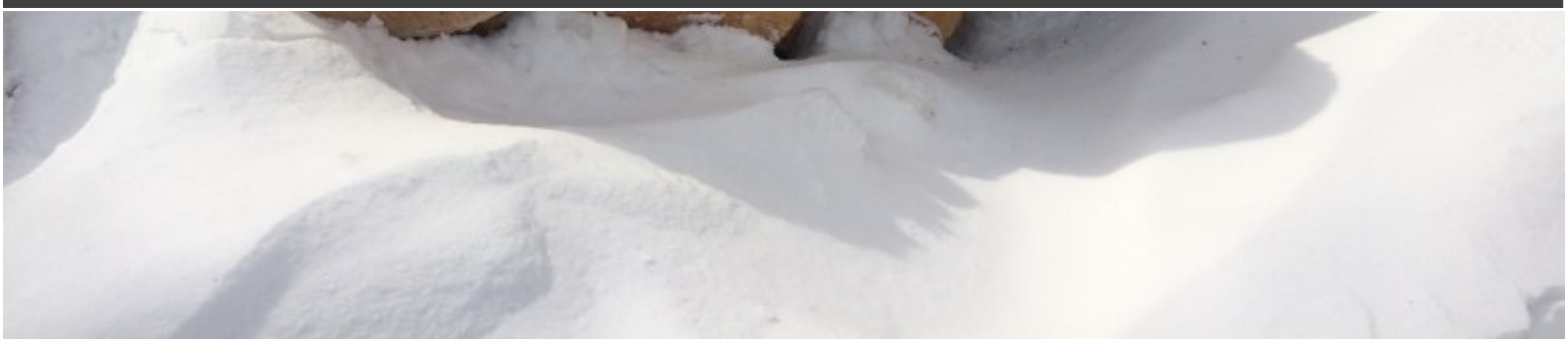


➢ ***By diversifying the forest landscape, the risks are reduced***

Figure 2

Expected effects of landscape heterogeneity on insect damage. (*a*) In highly homogeneous landscapes dominated by single tree species, there are high chances of large outbreaks causing quick pulses in forest biomass, while (*b*) in heterogeneous landscapes with multiple forest types, insect disturbances are expected to be smaller and shorter, maintaining higher stability in ecosystem functioning at a large spatial scale.

OK, but how do we apply it in the field?



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What is resilience?

The ability of a system to withstand, rapidly recover from, or adapt to one or more disturbances or stresses so that the system retains its structure and functions. (adapted from Gunderson & Holling 2002).

THE SOLUTION: by diversifying INTELLIGENTLY and EFFECTIVELY

Reversing the relationship
WOOD FOREST ➡ INDUSTRY

Until now, the "wood" industry has conditioned the simplification of the forest: a typical TOP-DOWN approach

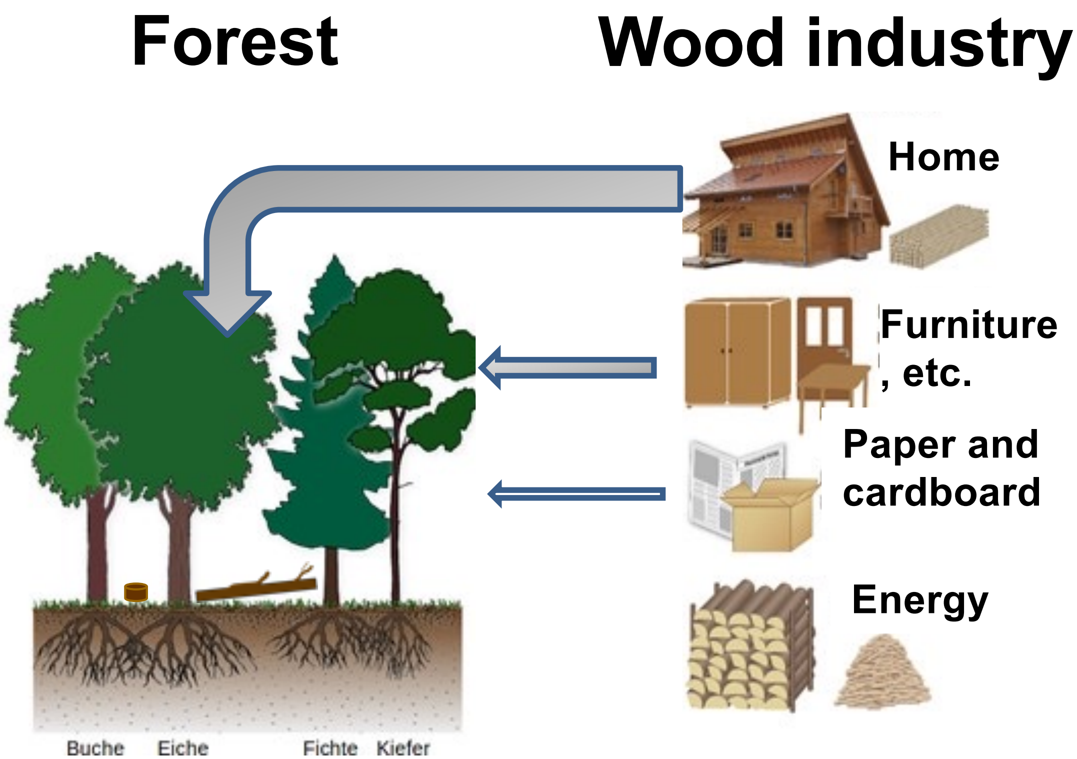


Photo: Hafner

Reversing the relationship
WOOD INDUSTRY ⟵ FOREST

In the future, the need a MORE DIVERSIFIED RESILIENT forest that will condition the "wood" industry: a typical BOTTOM-UP approach of an Adaptive Complex System

Forest   Wood industry

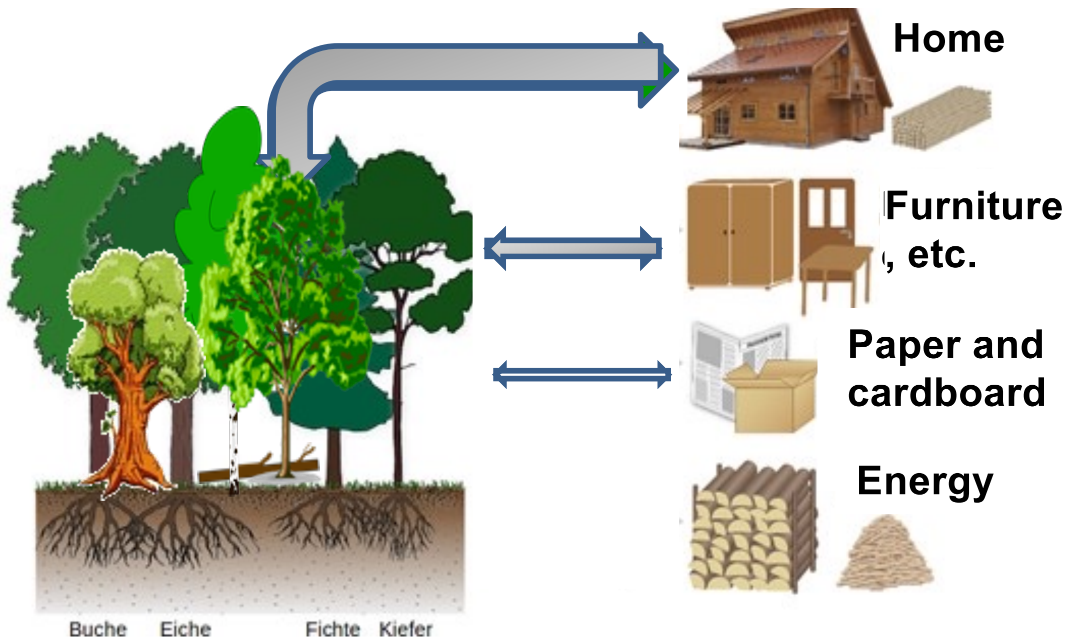


Photo: Hafner

Diversity and functional connectivity are promoted

Messier *et al. Forest Ecosystems* (2019) 6:21
https://doi.org/10.1186/s40663-019-0166-2

Forest Ecosystems

DISCUSSION

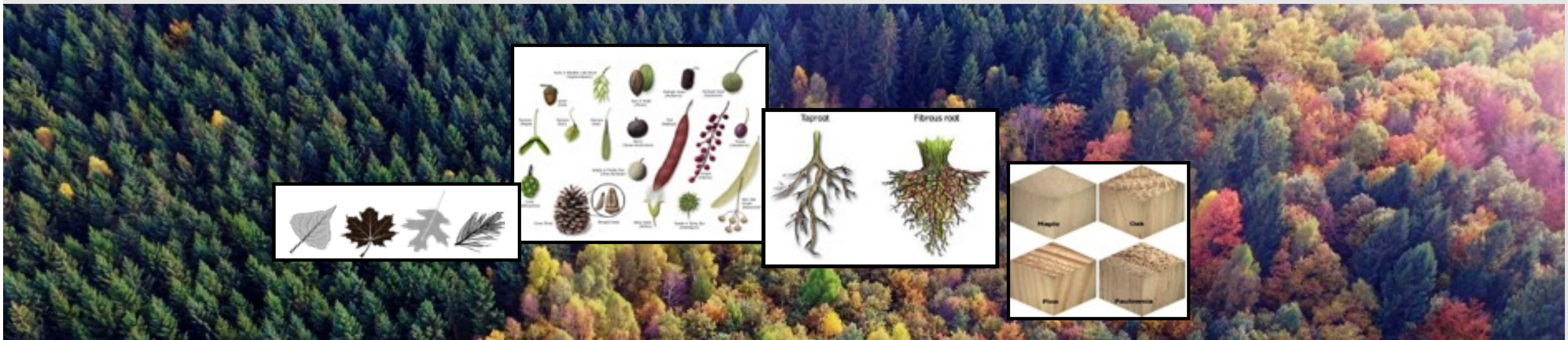
Messier *et al. Forest Ecosystems* (2019) 6:21
https://doi.org/10.1186/s40663-019-0166-2

Open Access

The functional complex network approach to foster forest resilience to global changes

Christian Messier[1,2*], Jürgen Bauhus[3], Frederik Doyon[1], Fanny Maure[2], Rita Sousa-Silva[1], Philippe Nolet[1], Marco Mina[2,4], Núria Aquilué[2], Marie-Josée Fortin[5] and Klaus Puettmann[6]

FUNCTIONAL TRAIT DIVERSITY: A better way to characterize tree diversity



- ***Or how different species ACT in the ecosystem and REACT to disturbances***

- Properties of the leaves
- Dispersal method
- Rooting depth
- Type of mycorrhizae
- Density of the wood
- Bark thickness
- Germination capacity

GROUPING TREE SPECIES INTO FUNCTIONAL GROUPS: to help diversify effectively

Urban Forestry & Urban Greening 62 (2021) 127157

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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

ELSEVIER

Short communication

Praise for diversity: A functional approach to reduce risks in urban forests

Alain Paquette [a,*], Rita Sousa-Silva [a], Fanny Maure [a], Elyssa Cameron [a], Michaël Belluau [a], Christian Messier [a,b]

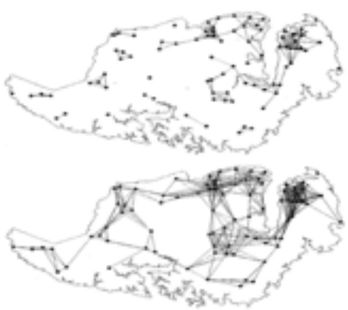
FUNCTIONAL CONNECTIVITY AND CENTRALITY: a way to optimize our intervention

FUNCTIONAL CONNECTIVITY: The potential level of exchange of tree propagules (measured in terms of functional traits that can be transferred) between stands and forest properties

CENTRALITY: The level of influence or connectivity of nodes in a network. It is used to determine the most influential nodes.

Complex network

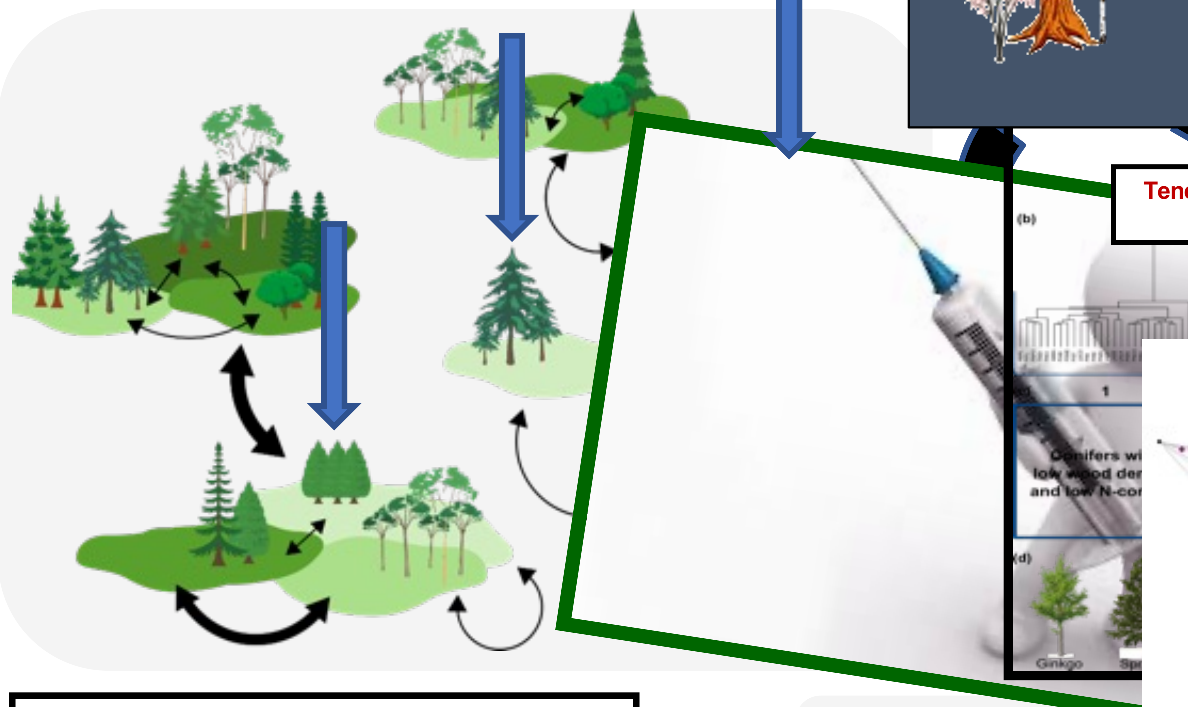
Connectivity



Bunn *et al.* 2000

Here is an example

Before the intervention



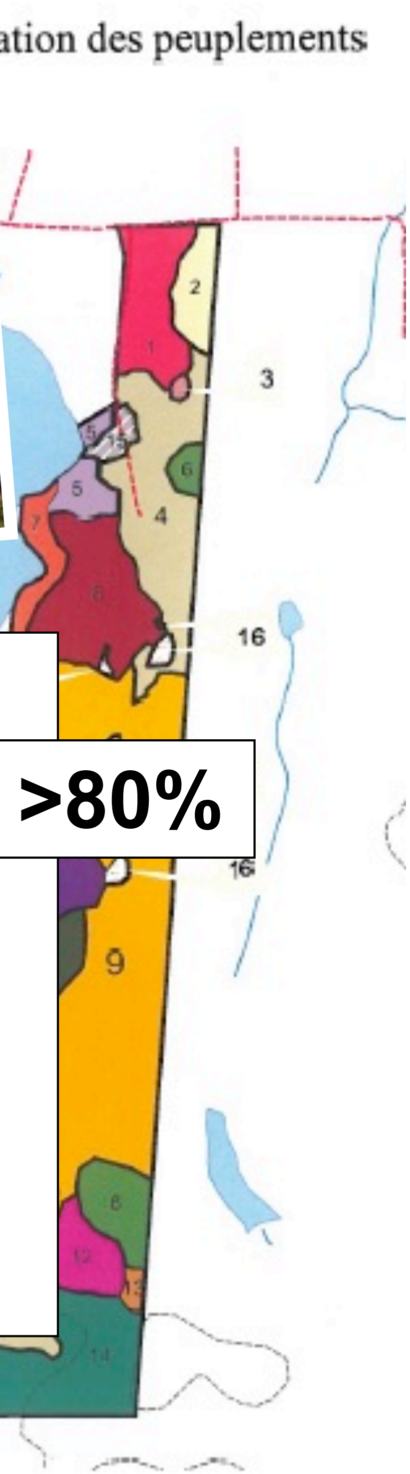
After the intervention

Diversité fonctionnel

Faible Forte

Diversité Fonctionnelle = 2,7
Connectivité Fonctionnelle = 1,8

(4) We plant/foster the regeneration of missing functional groups



Fir
Poplar
Sugar maple
Red maple
Yellow birch
White birch
Basswood
Hemlock
Autumn cherry
White Pine
Red Oak

$\}$ >80%

40 ha

Application : iForUrb

Application: *iForêt*

This tool makes it possible to determine:

The functional diversity of stands
Functional connectivity between stands
The level of vulnerability
of your
The leve m
services

It sugge
where t
maximiz t
the lowe

Groups 2, 3 & 4

Forest Ecology and Management 481 (2021) 118692

Contents lists available at ScienceDirect

Forest Ecology and Management

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

A simple-to-use management approach to boost adaptive capacity of forests to global uncertainty

Núria Aquilué [a,b,*], Christian Messier [a,c], Kyle T. Martins [d], Véronique Dumais-Lalonde [d], Marco Mina [a]

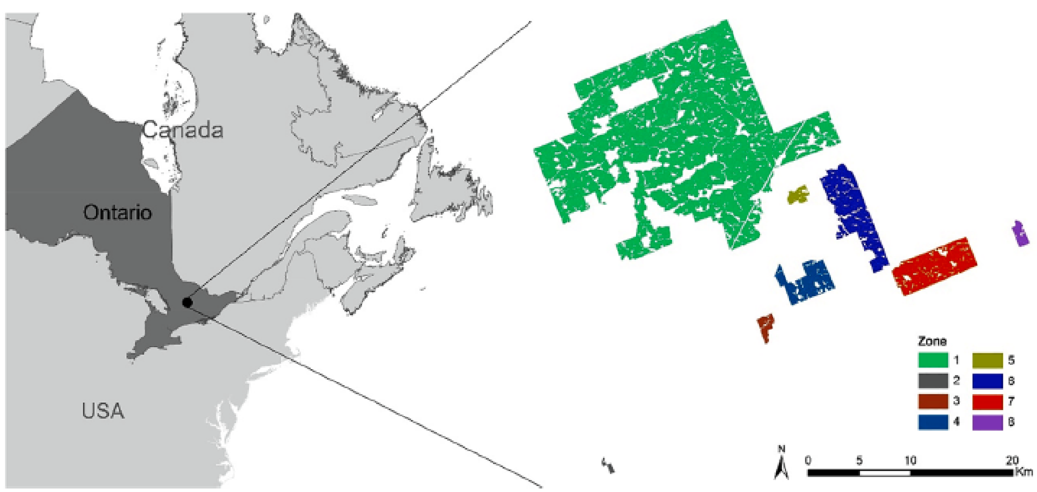
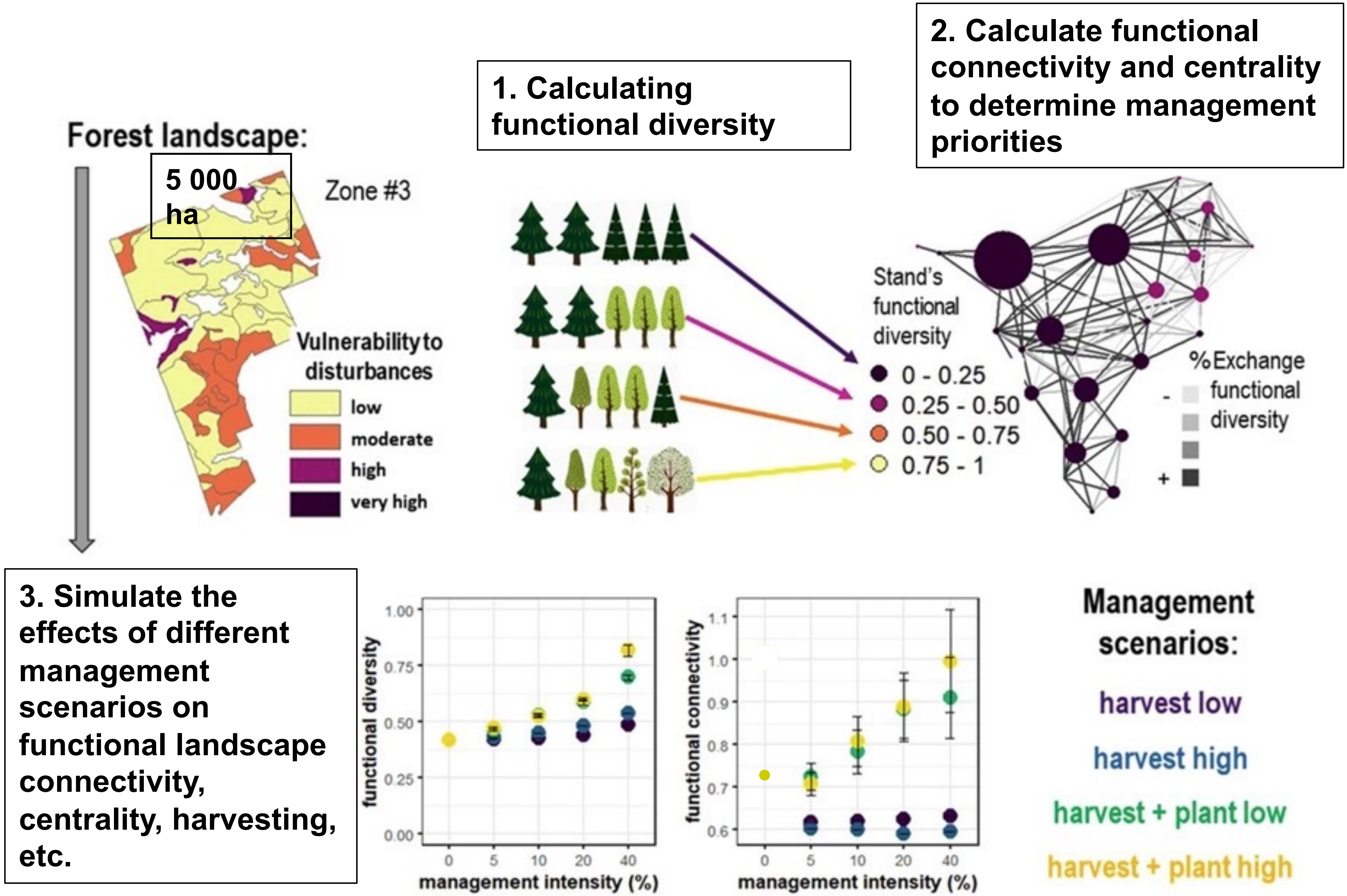


Fig. 1. . Geographic location of the Haliburton Forest in Ontario, Canada (left panel) and the eight forest zones in the Haliburton Forest (right panel).



Forest landscape:
5 000 ha
Zone #3
Vulnerability to disturbances
low
moderate
high
very high
1. Calculating functional diversity
Stand's functional diversity
0 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1
2. Calculate functional connectivity and centrality to determine management priorities
% Exchange functional diversity
-
+
3. Simulate the effects of different management scenarios on functional landscape connectivity, centrality, harvesting, etc.
functional diversity
1.00
0.75
0.50
0.25
0.00
0
5
10
20
40
management intensity (%)
functional connectivity
1.1
1.0
0.9
0.8
0.7
0.6
0
5
10
20
40
management intensity (%)
Management scenarios:
harvest low
harvest high
harvest + plant low
harvest + plant high

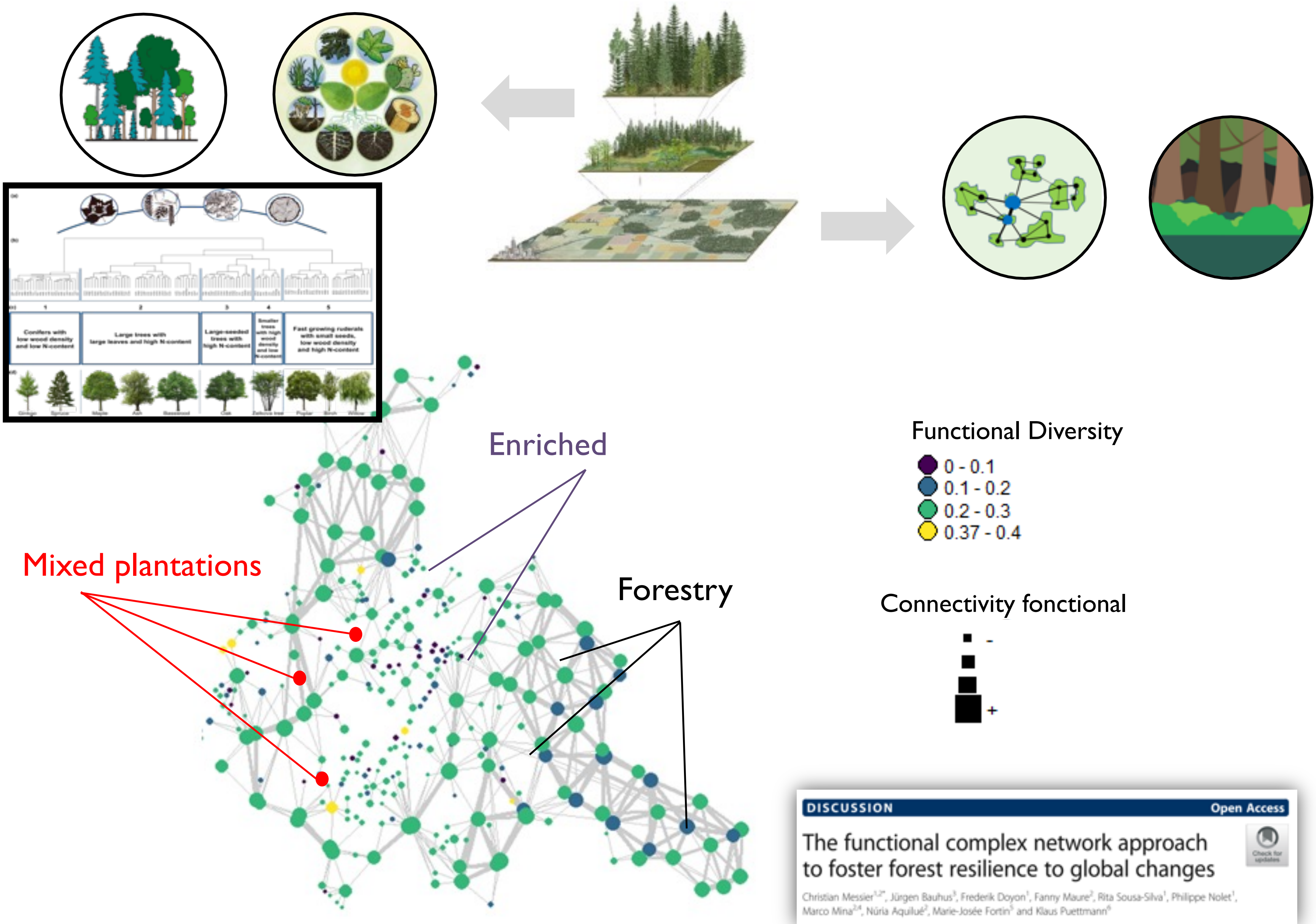
Received: 21 January 2022 | Revised: 21 January 2022 | Accepted: 19 March 2022
DOI: 10.1111/gcb.16197

Global Change Biology WILEY

RESEARCH ARTICLE

Managing for the unexpected: Building resilient forest landscapes to cope with global change

Marco Mina[1,2] | Christian Messier[1,3] | Matthew J. Duveneck[4,5] | Marie-Josée Fortin[6] | Núria Aquilué[1,7]

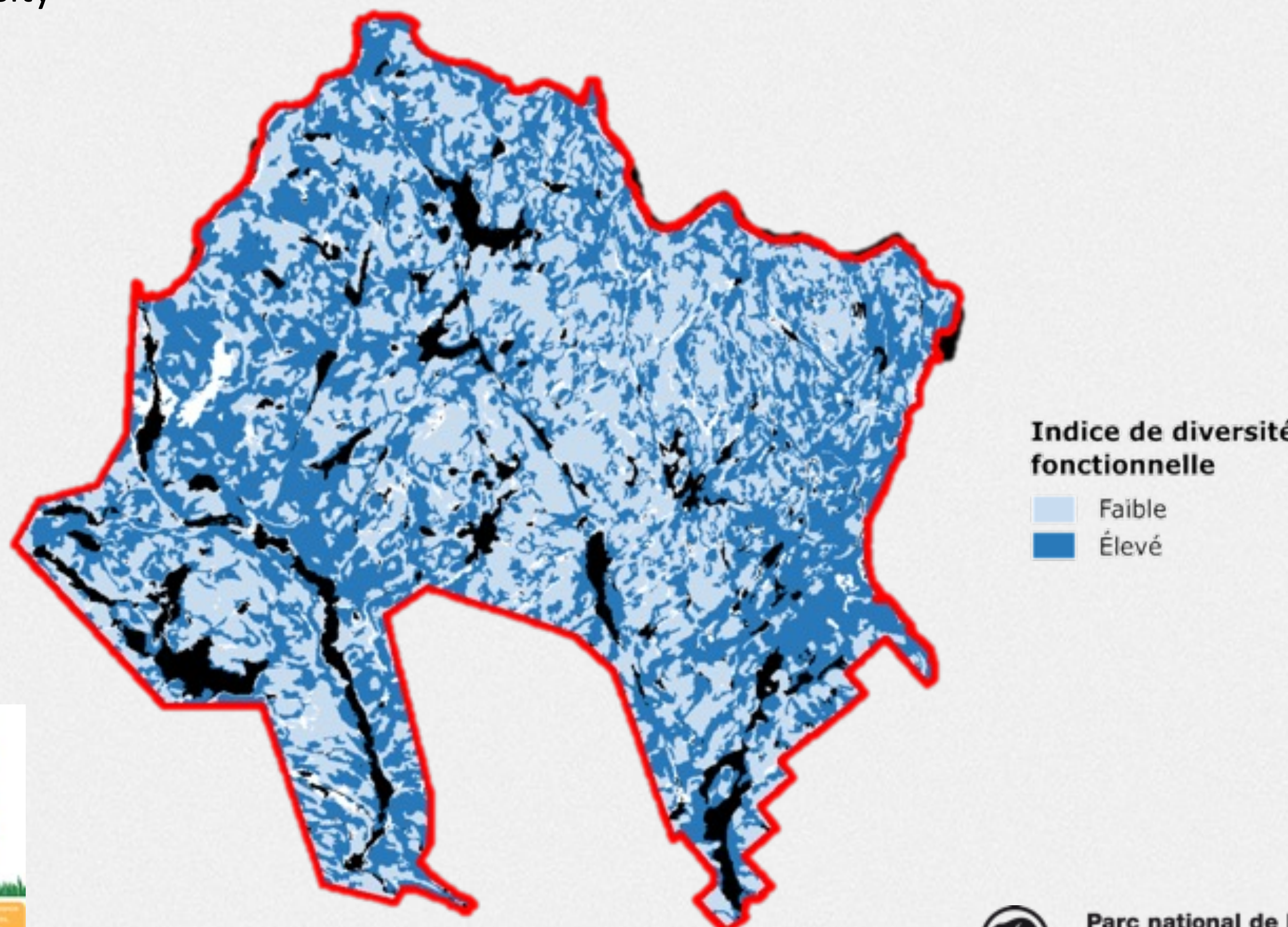


Conifers with low wood density and low N-content
Large trees with large leaves and high N-content
Large-seeded trees with high N-content
Smaller trees with high wood density and low N-content
Fast growing ruderals with small seeds, low wood density and high N-content
Enriched
Mixed plantations
Forestry
Functional Diversity
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.37 - 0.4
Connectivity fonctional
-
+
DISCUSSION
Open Access
The functional complex network approach to foster forest resilience to global changes
Christian Messier, Jürgen Bauhus, Frederik Doyon, Fanny Maure, Rita Sousa-Silva, Philippe Nolet, Marco Mina, Núria Aquilué, Marie-Josée Fortin and Klaus Puettmann

Assessment of functional diversity La Mauricie National Park

habitat
LA NATURE À L'ŒUVRE

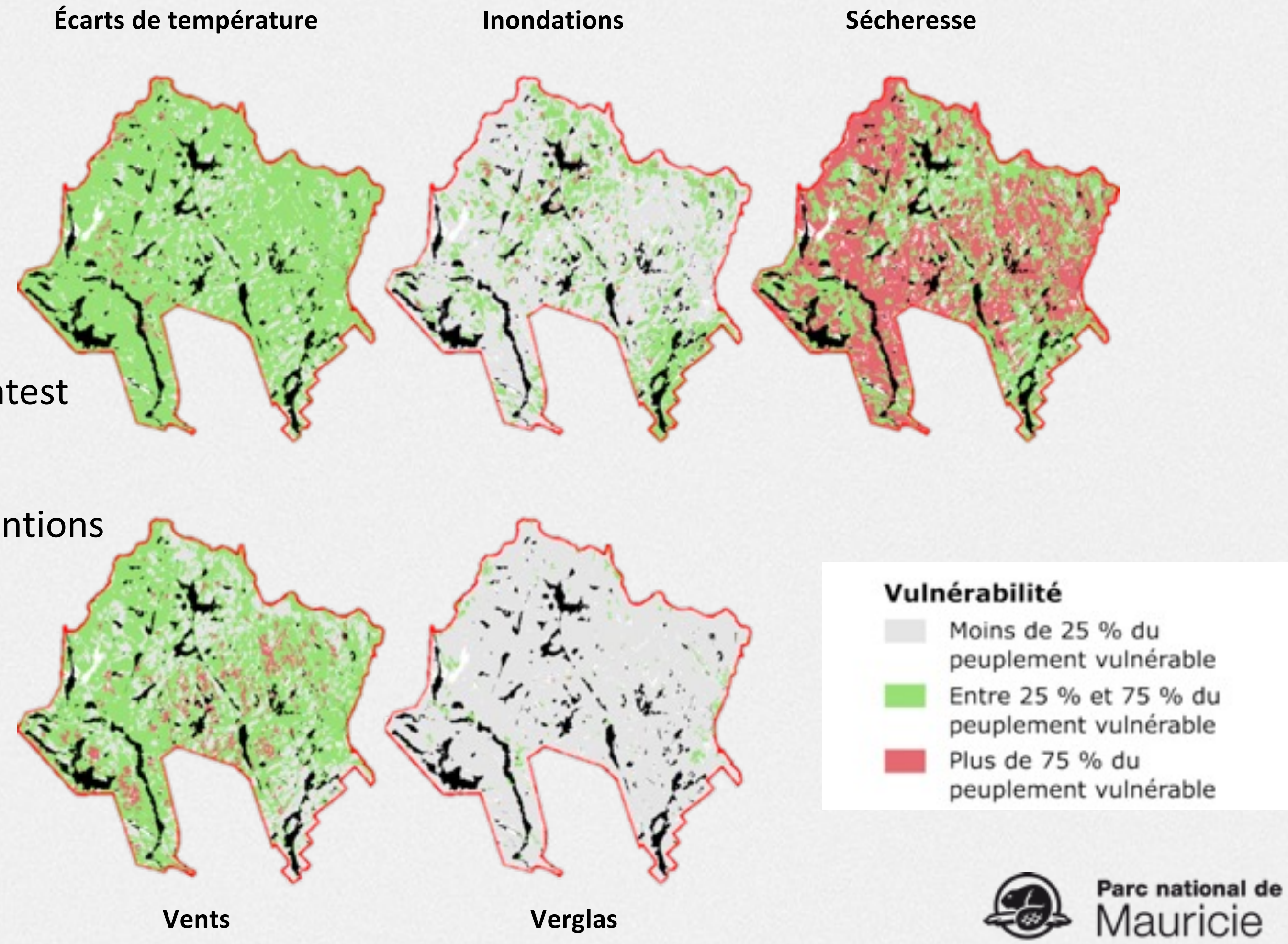
- Distribution of the functional diversity of forest stands
- Identification of priority sectors for diversification interventions
- Recommendations to promote diversification



Parc national de la Mauricie

Vulnerabilities to abiotic threats
La Mauricie National Park

- Identification of threats of greatest concern
- Guide to diversification interventions

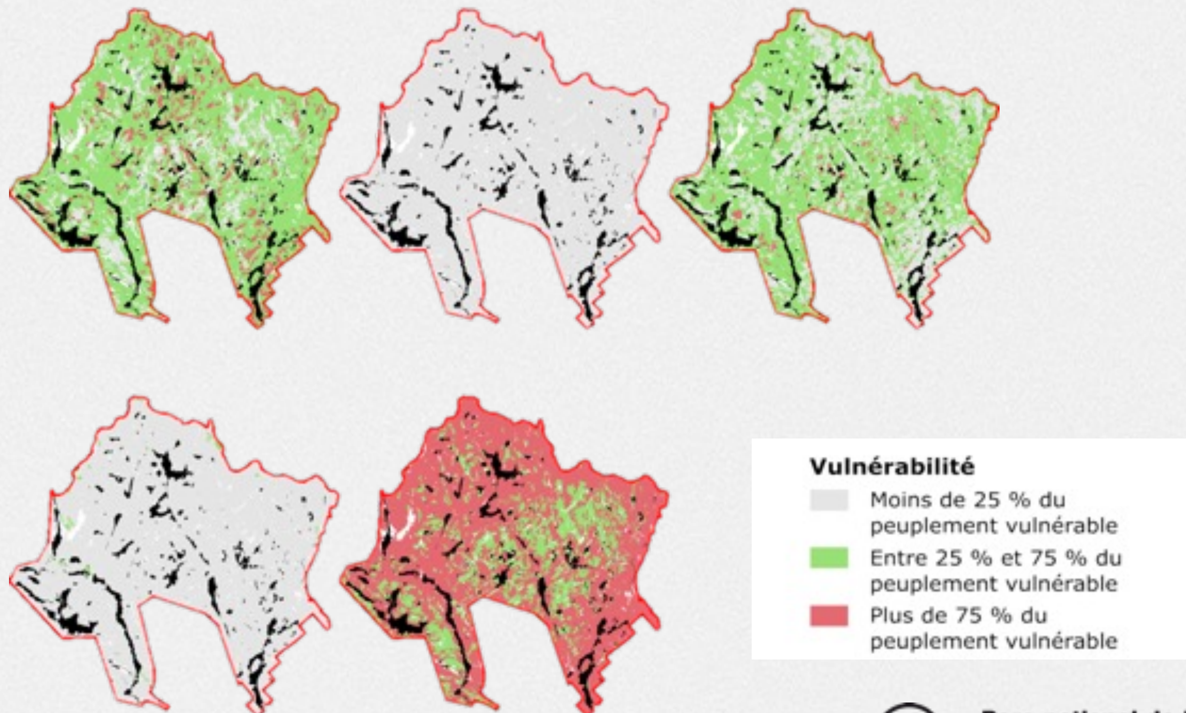


Parc national de la Mauricie

Vulnerabilities to biotic threats
La Mauricie National Park

- ➢ Identification of threats of greatest concern
- ➢ Guide to diversification interventions

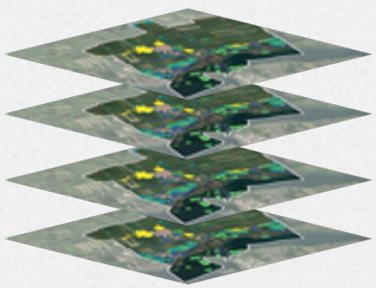
Longicorne asiatique | **Maladie corticale du hêtre** | **Puceron lanigère du sapin**

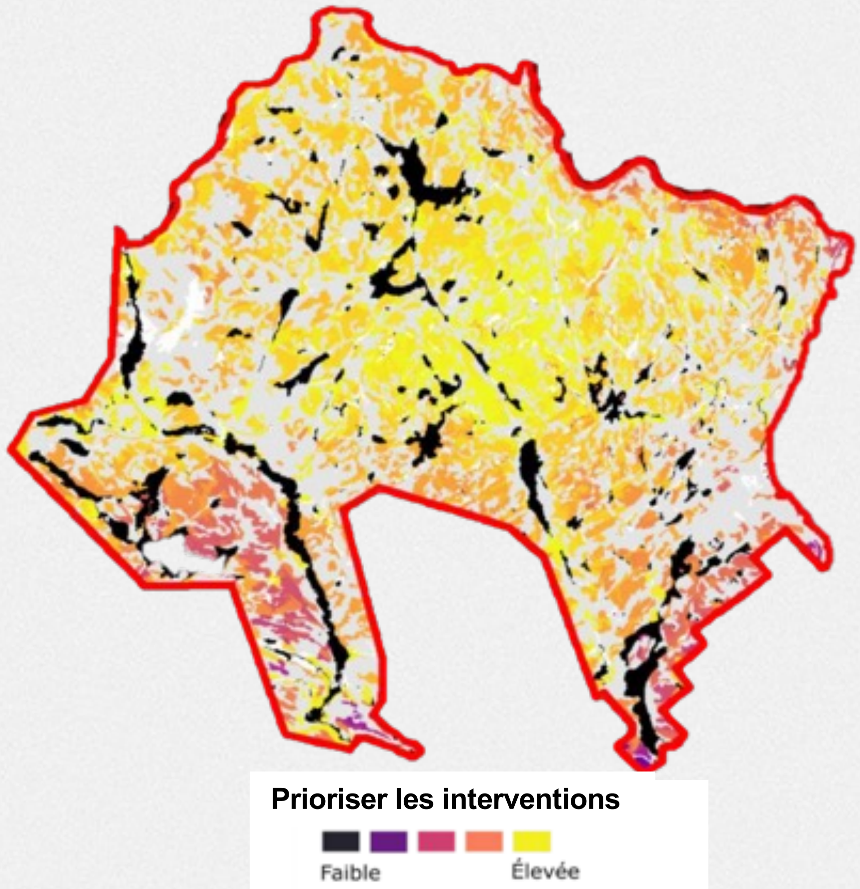


Rouille vésiculeuse du pin blanc | **Spongieuse asiatique**

Parc national de la Mauricie

Identification of vulnerable sectors
La Mauricie National Park





- Anticipate impacts on the landscape and ecological connectivity
- Prioritize interventions in the sectors :
  - the least diverse
  - the most vulnerable

Parc national de la Mauricie

A « Marshall » Plan for Quebec forests

- Do not plant or promote ONLY species considered commercial today
- The species present locally may not be well adapted or diversified enough to face future climatic and biotic rigors and uncertainties
- THE PAST IS NO LONGER A GUARANTEE OF THE FUTURE
- NO MORE PLANTING MONOCULTURES
- Favour species that are diversified in terms of their functioning
- Think wood and carbon, biodiversity, key species, water, mental health, resilience, stability, etc.
- 1+1 = 3 OR EVEN 5: OUR BEST ALLY...DIVERSITY
- We must think globally and act locally

Thank you!