habitat
LA NATURE À L'ŒUVRE

Menaces, incertitudes et approches possibles pour augmenter la résilience de nos forêts

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

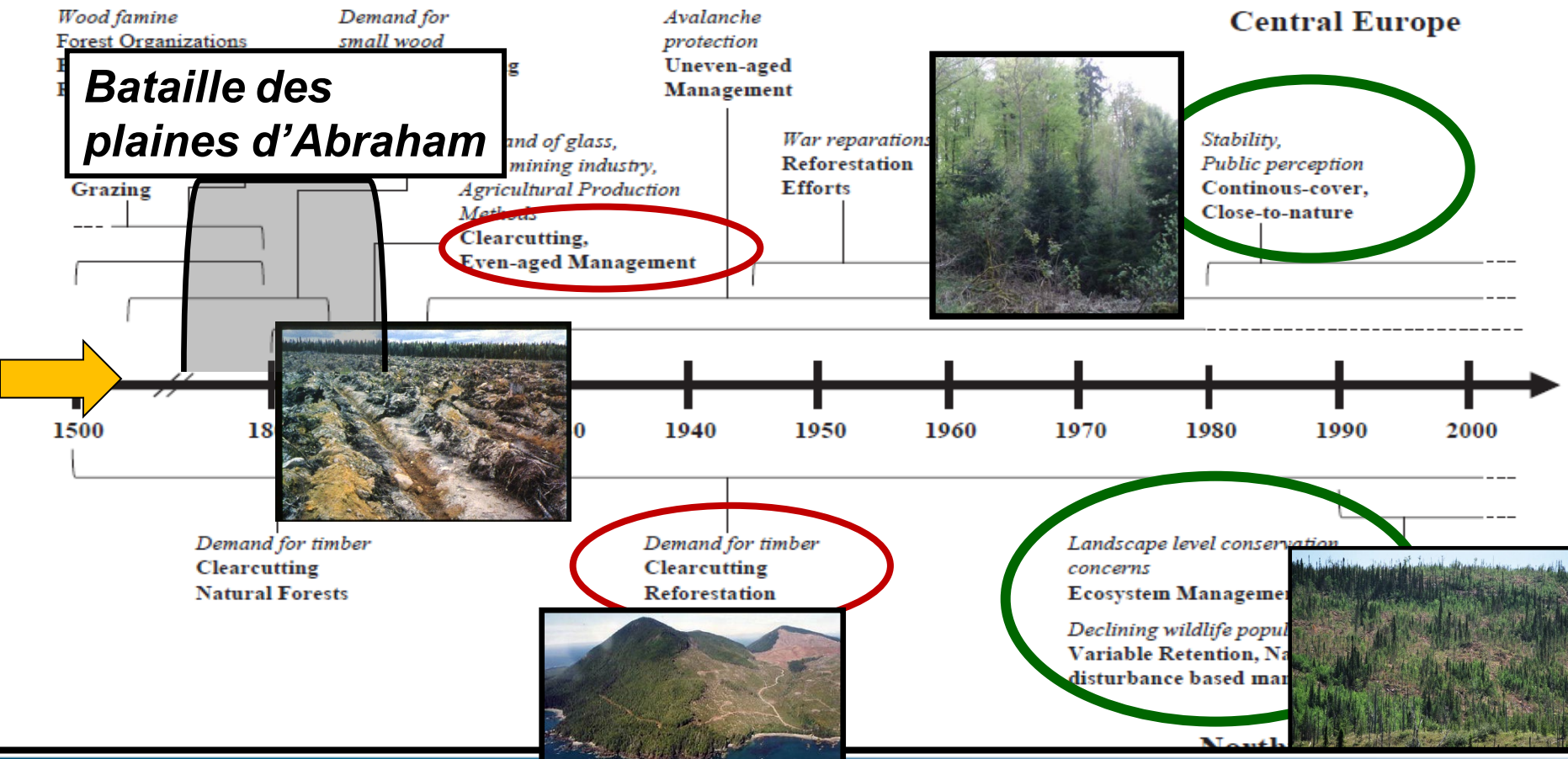
cef
Centre d'étude de la forêt

Plan de la présentation

- La foresterie et ses fantômes
- La forêt menacée
- Quelques nouveaux concepts intéressants
- Pour une foresterie de résilience

Évolution de la foresterie

Bataille des plaines d'Abraham



POLICY PERSPECTIVES Con ters September/October 2015, 8(5), 368–377

From Management to Stewardship: Viewing Forests As Complex Adaptive Systems in an Uncertain World

C. Messier[1,2], K. Puettmann[3], R. Chazdon[4], K.P. Andersson[5], V.A. Angers[6], L. Brotons[7], E. Filotas[8,9], R. Tittler[10], L. Parrott[11], & S.A. Levin[12]

Coupe avec protection de la régénération

Aménagement forestier au Québec aujourd'hui

Coupe avec rétention

Coupe partielle

Coupe de jardinage

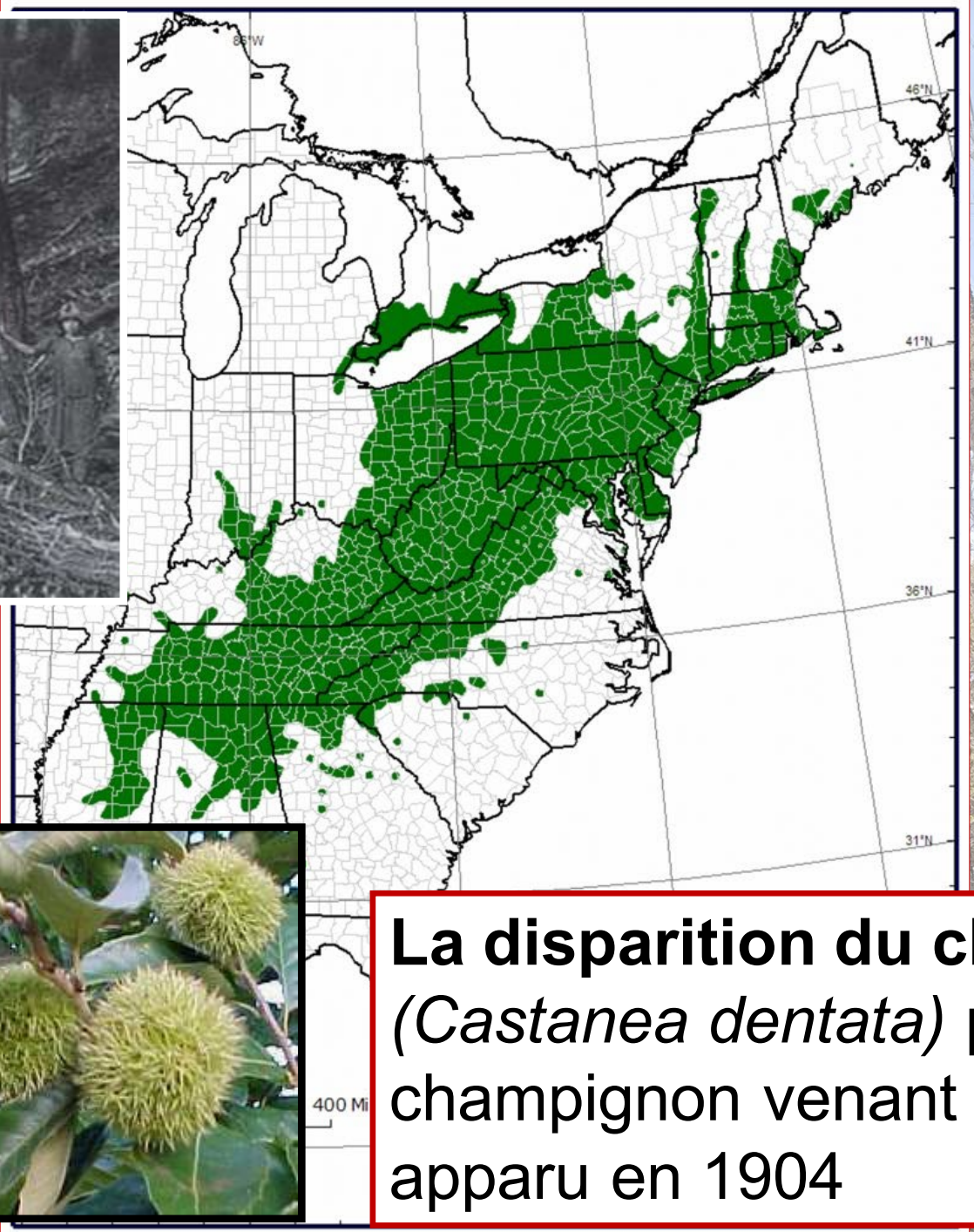
Plantations mono-spécifiqes

La foresterie a toujours visé à simplifier la forêt pour maximiser certains services. Est-ce toujours la bonne approche?

Plan de la présentation

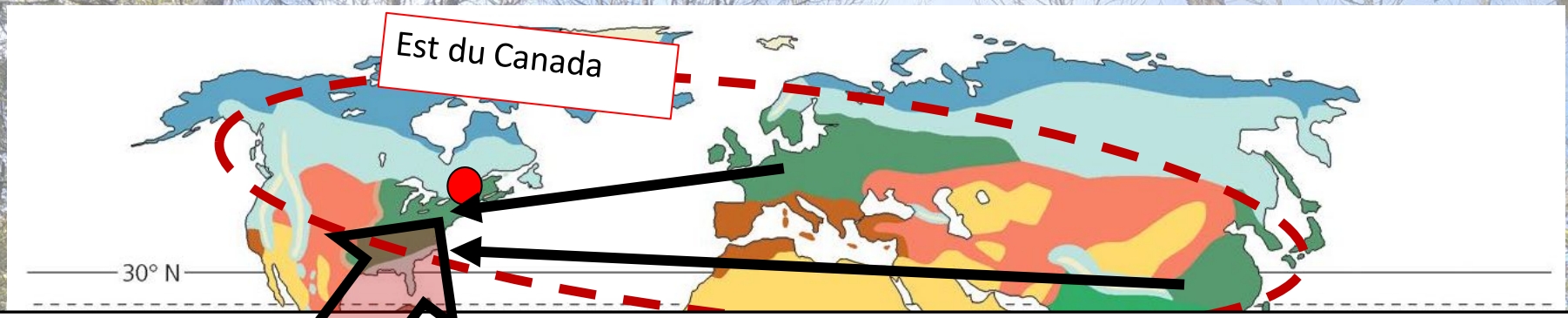
- La foresterie et ses fantômes
- **La forêt menacée**
- Quelques nouveaux concepts interessants
- Pour une foresterie de Résilience

La forêt menacée



La disparition du chataîgner *(Castanea dentata)* par un champignon venant d'Asie apparu en 1904

La menace des insectes et maladies exotiques



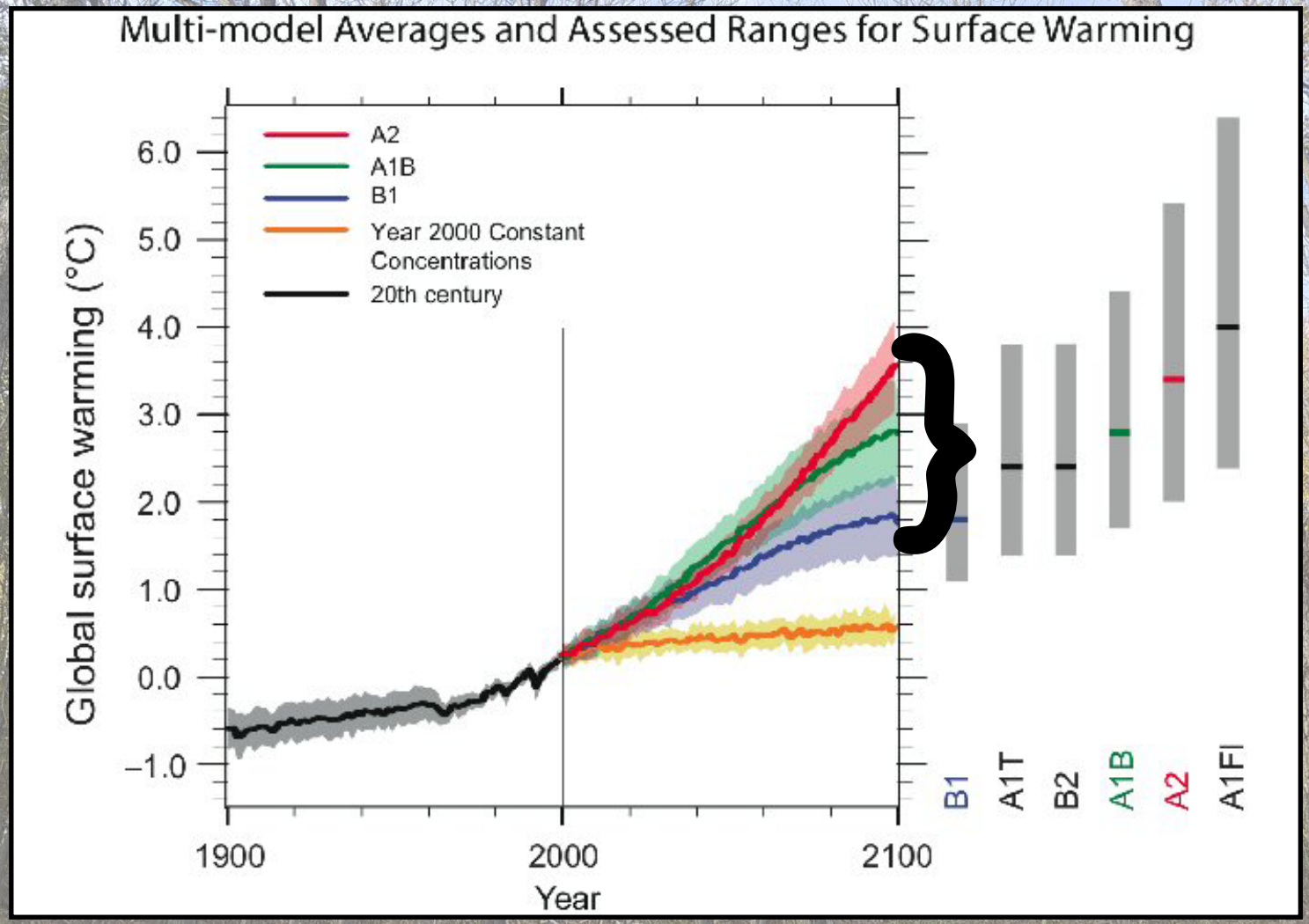
Ecological Applications, 26(5), 2016, pp. 1437–1455

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]

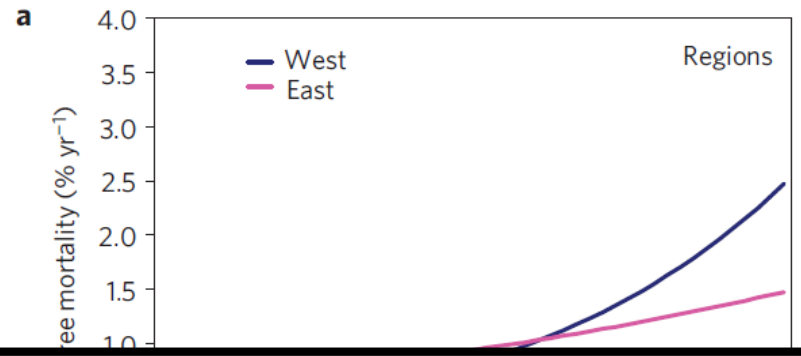
Plus de 25 insectes et maladies exotiques sont présents et risquent de fortement affecter plus de 30 espèces d'arbres du Québec dans les 50 prochaines années

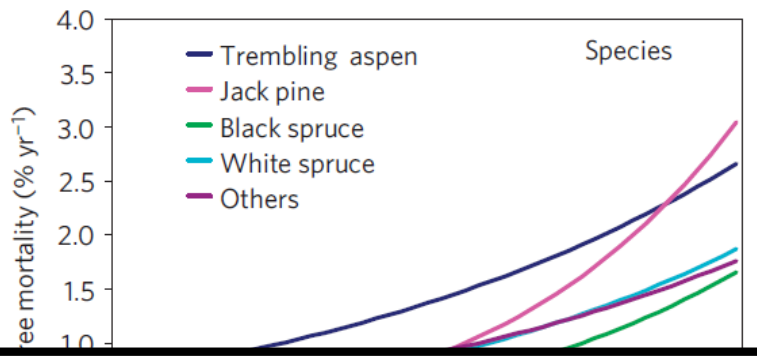
Le réchauffement climatique



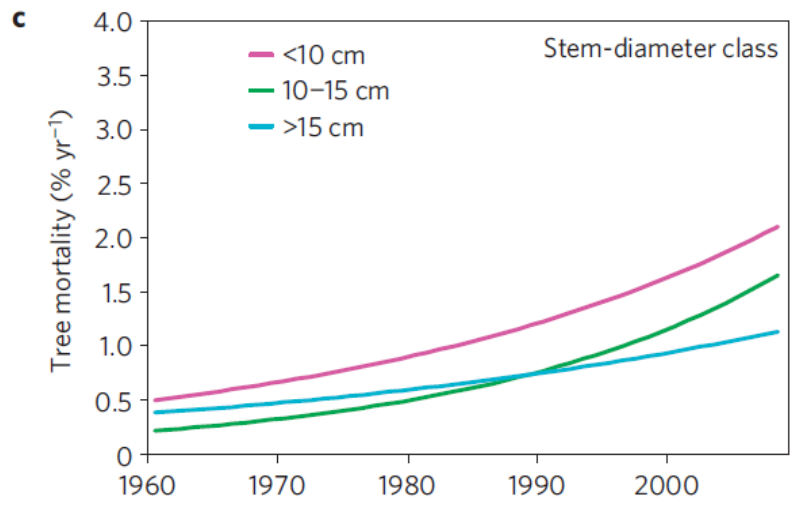
nature climate change

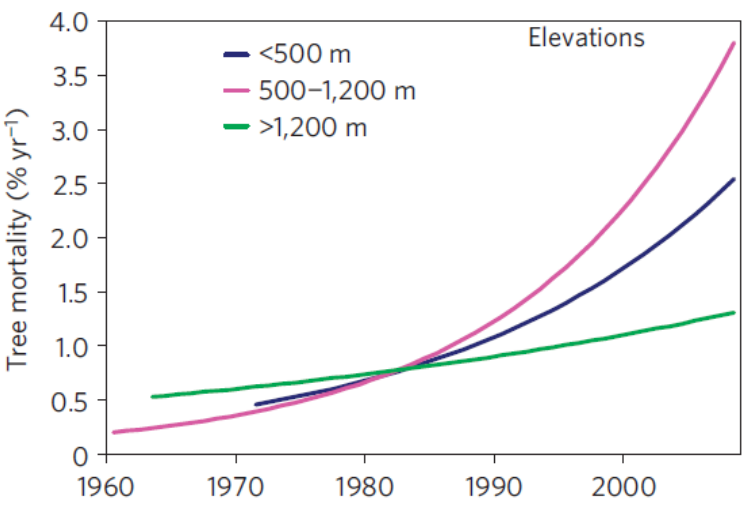
LETTERS





Le taux de mortalité des arbres est en augmentation PARTOUT au Canada et pour TOUTES les espèces depuis les années 70-80





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 REVIEWS

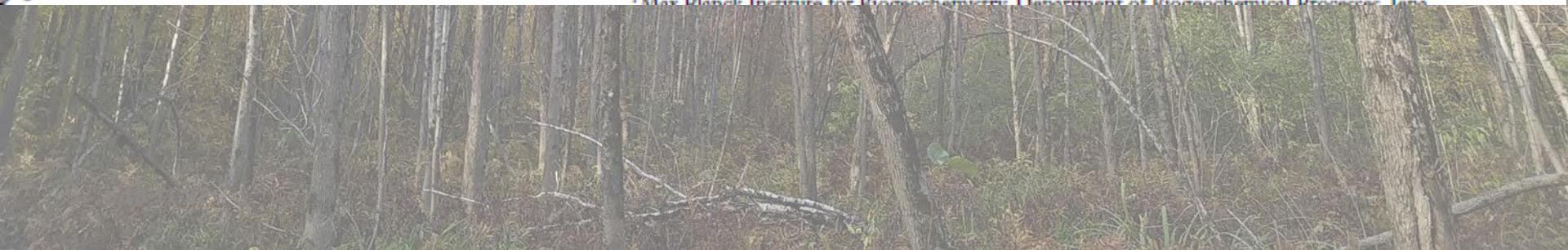
Annual Review of Plant Biology

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

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

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



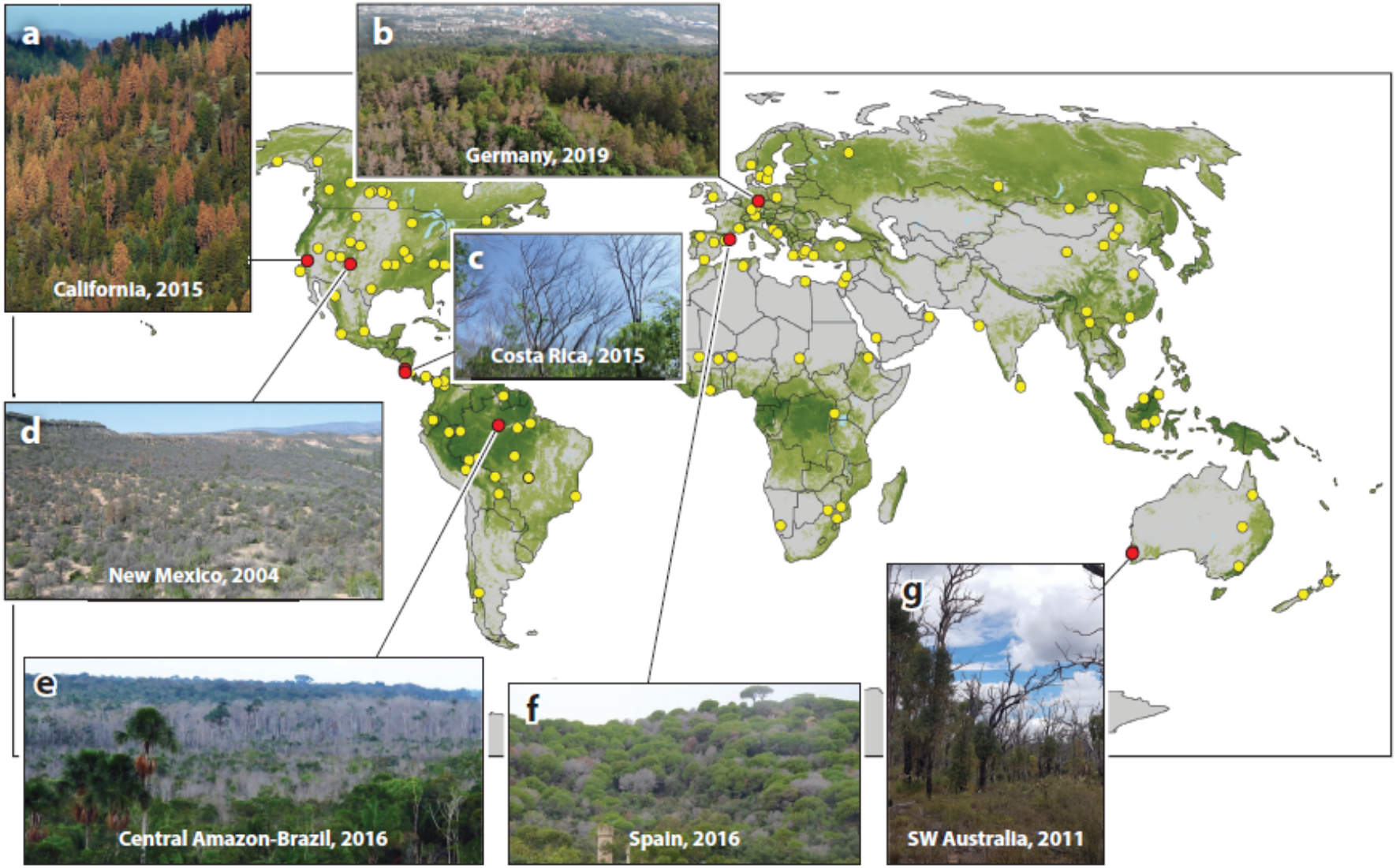


Figure 1

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]

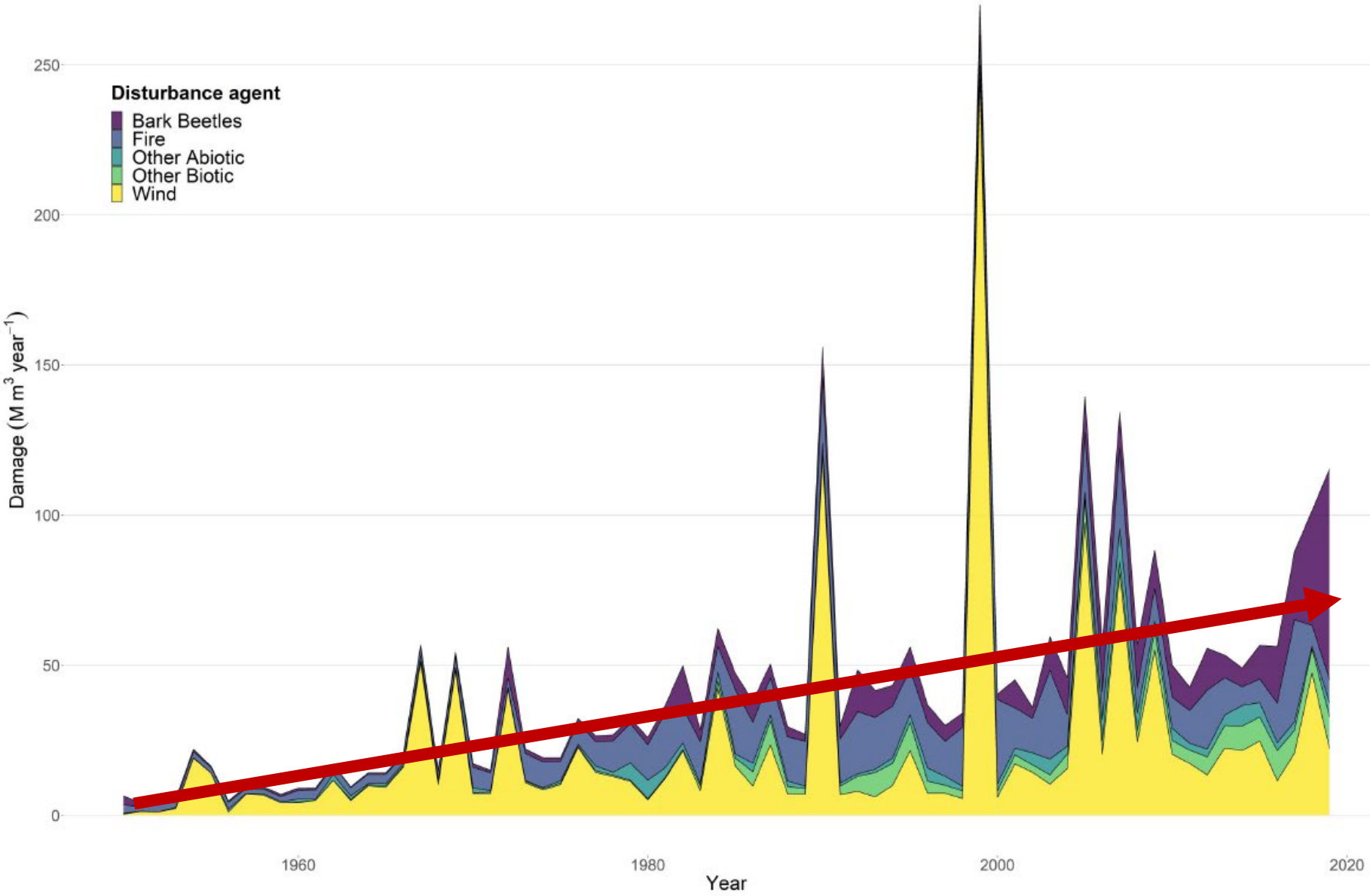


FIGURE 3 Total reported damage caused by natural disturbance in Europe between 1950 and 2019.

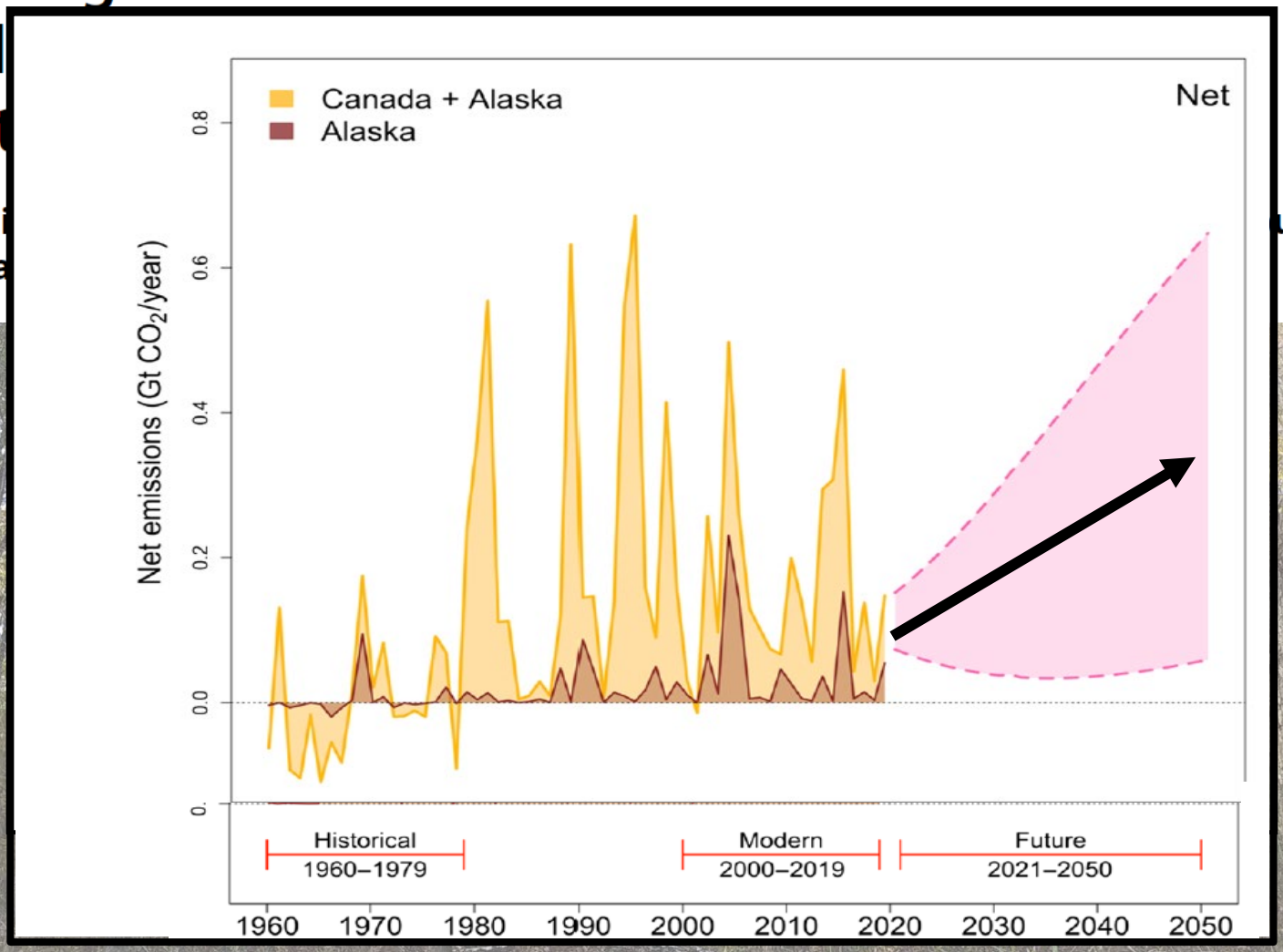
SCIENCE ADVANCES | RESEARCH ARTICLE

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.

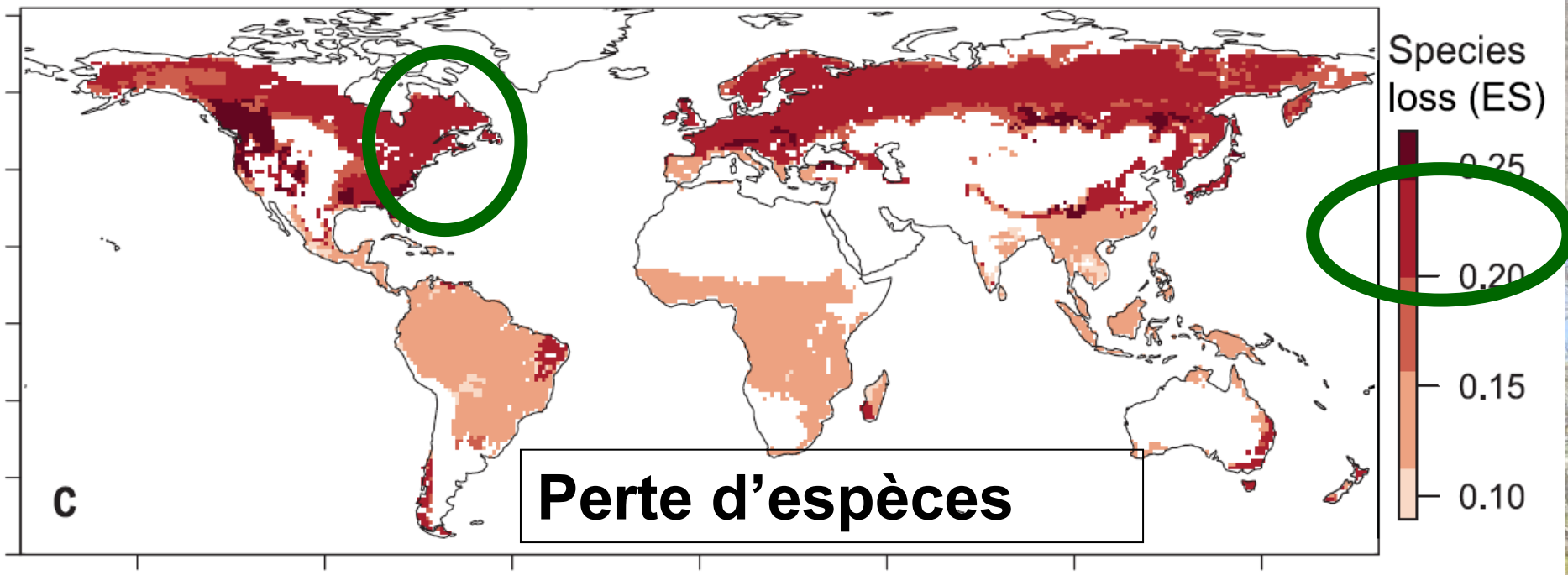


Fig. 2. Global forest risk estimates from climate envelope approaches. (C) Risk of loss in species richness [quantified as an effect size (ES) of –1 × log(DSpeciesRichnesshighcc-mitigation/ DSRbaseline)] where higher numbers indicate more risk of species loss) in the 2070s in a high climate change (RCP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

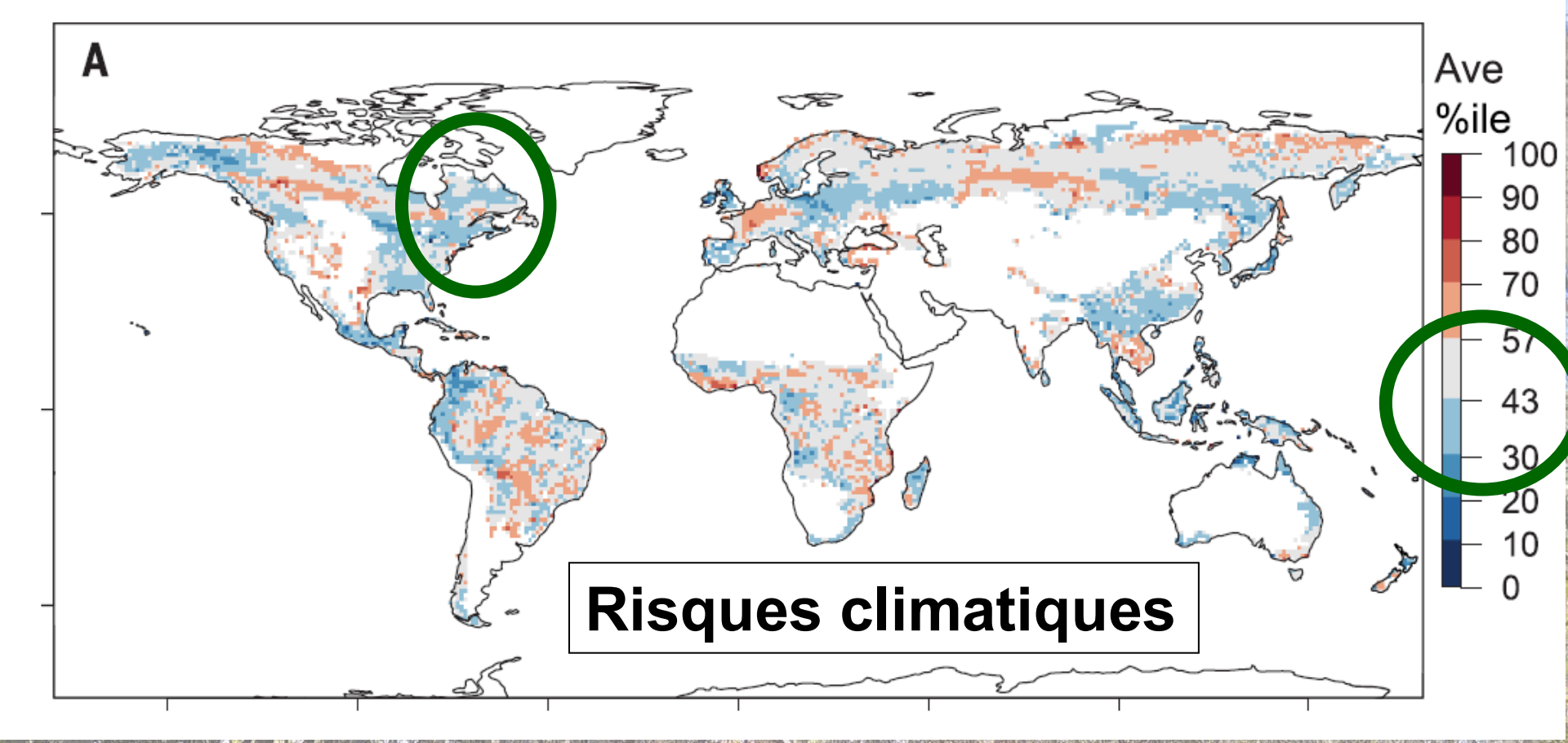
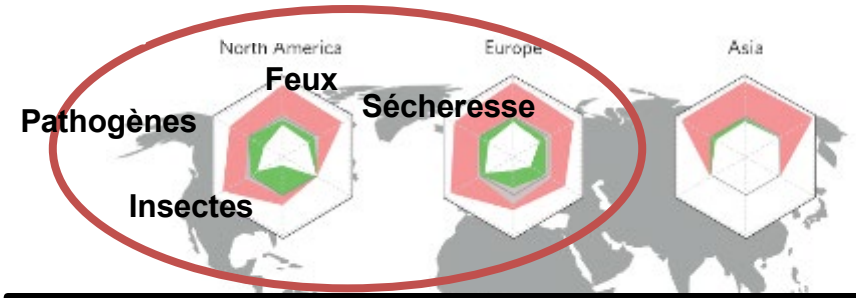
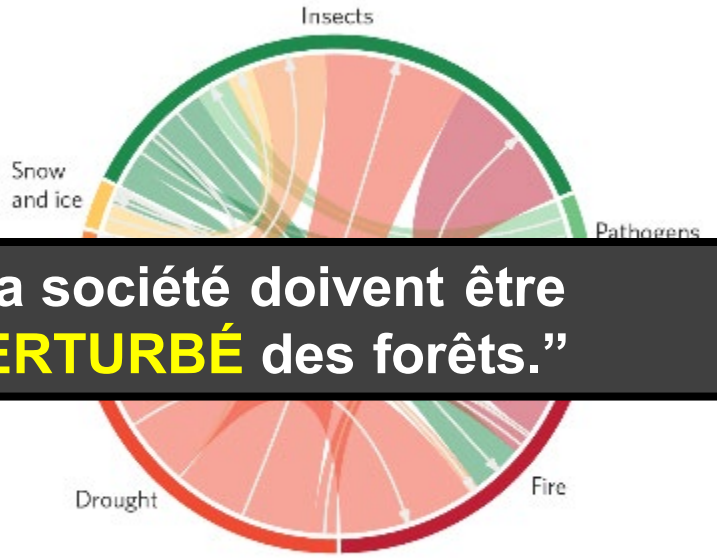


Fig. 4. Comparisons and syntheses across different climate risk axes.
(**A**) Average percentile of risk combined across all metrics where 0%ile is lowest climate risk and 100%ile is highest climate risk, averaged across all datasets that covered a given grid cell.

Intensification des perturbations forestières et interactions avec le changement climatique





"Nous concluons que les écosystèmes et la société doivent être préparés à un avenir DE PLUS EN PLUS PERTURBÉ des forêts."

South America Africa Oceania

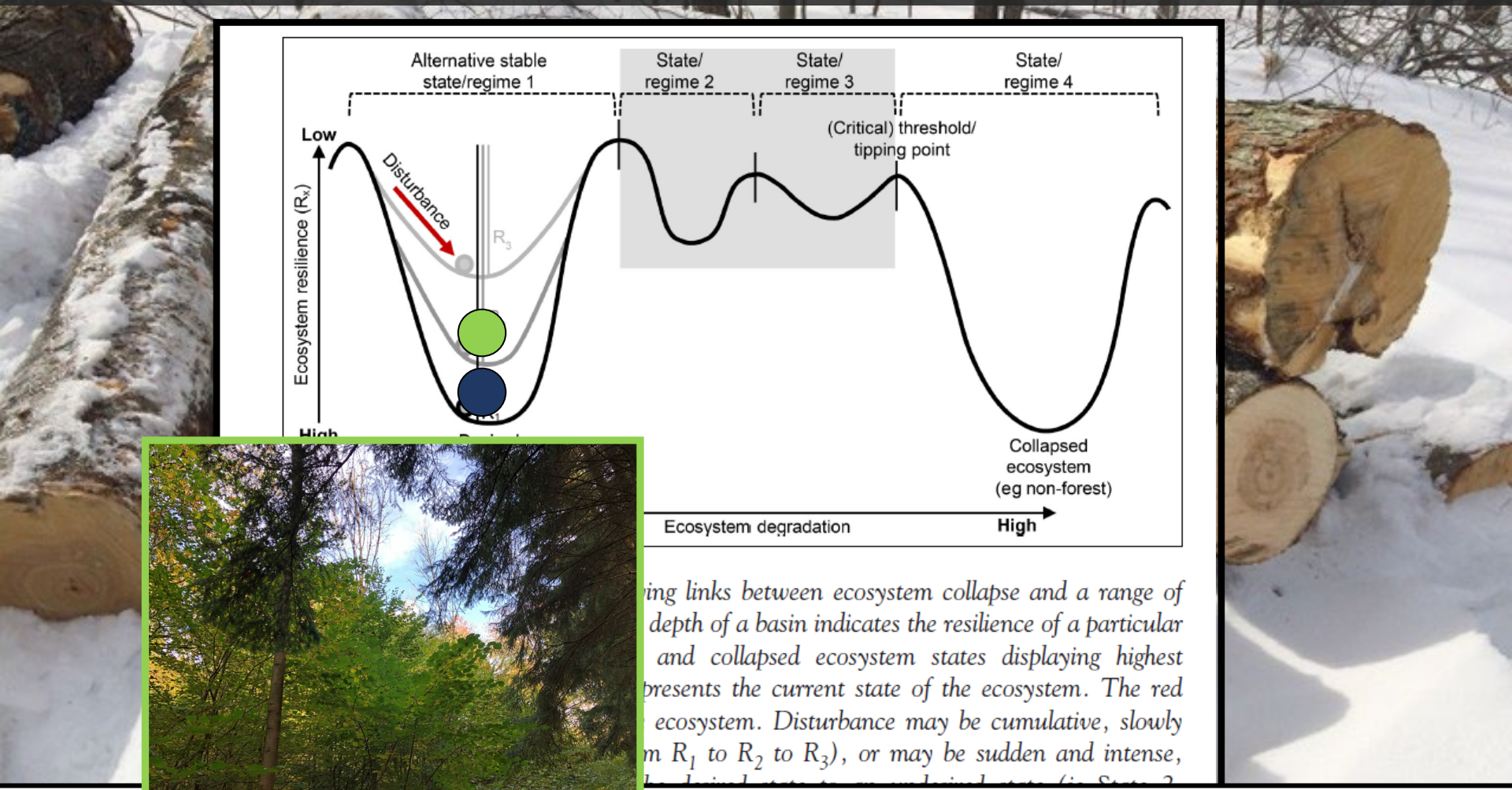
Increasing disturbance activity

Mixed response or no signal

Decreasing disturbance activity

Seidl et al. 2018. Nat. Clim. Change

Effondrement de nos écosystèmes forestiers



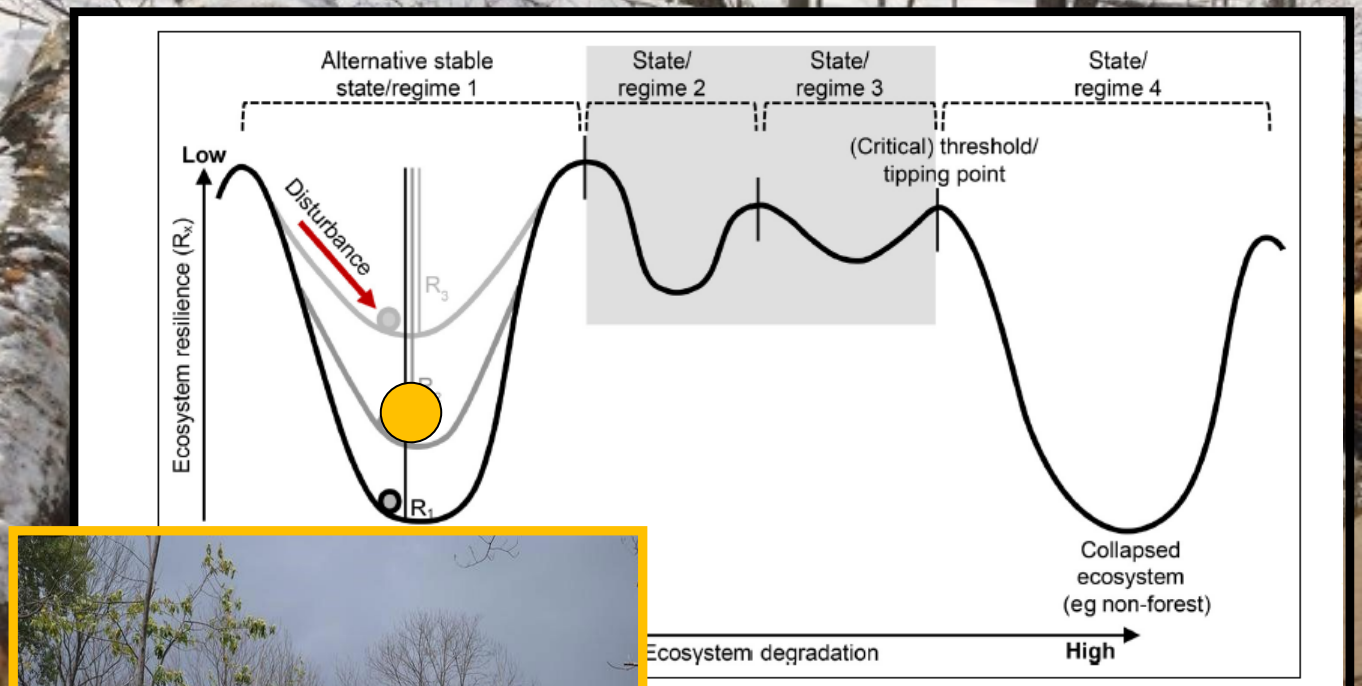
ing links between ecosystem collapse and a range of depth of a basin indicates the resilience of a particular and collapsed ecosystem states displaying highest presents the current state of the ecosystem. The red ecosystem. Disturbance may be cumulative, slowly m R_1 to R_2 to R_3), or may be sudden and intense,

Avoiding ecosystem collapse in managed forest ecosystems

David Lindenmayer[1*], Christian Messier[2,3], and Chloe Sato[1]

Front Ecol Environ 2016; 14(10): 561–568, doi:10.1002/fee.1434

Effondrement de nos écosystèmes forestiers



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CONCEPTS AND QUESTIONS

561

Avoiding ecosystem collapse in managed forest ecosystems

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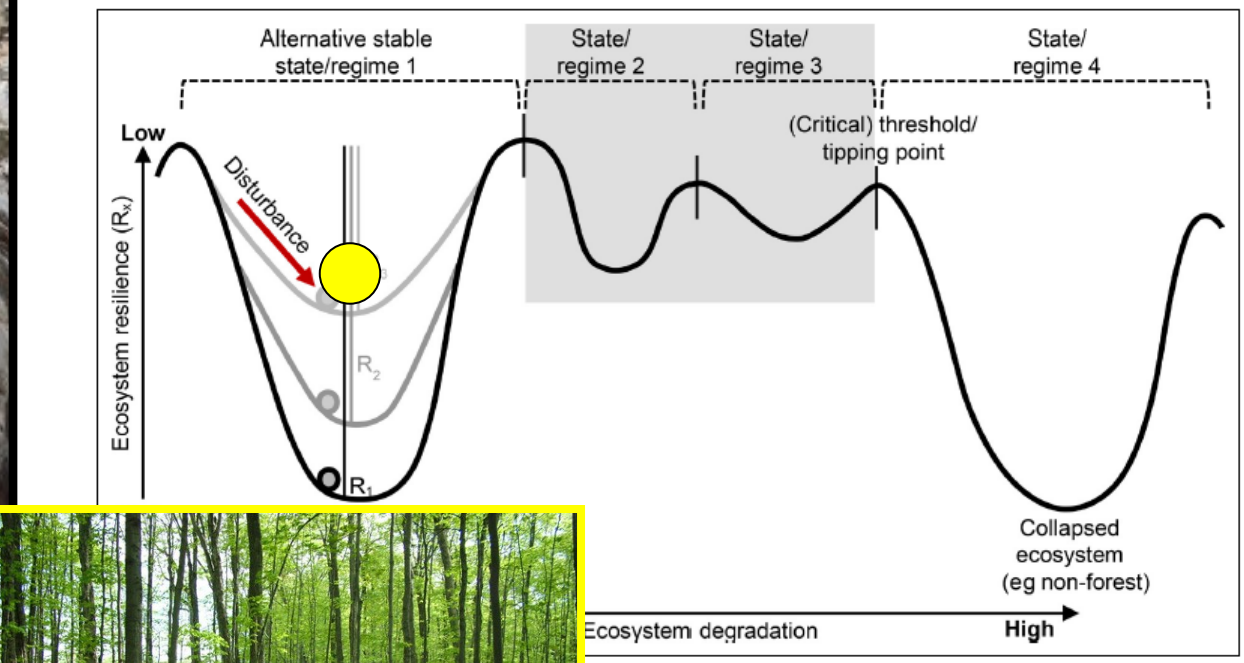

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CONCEPTS AND QUESTIONS

561

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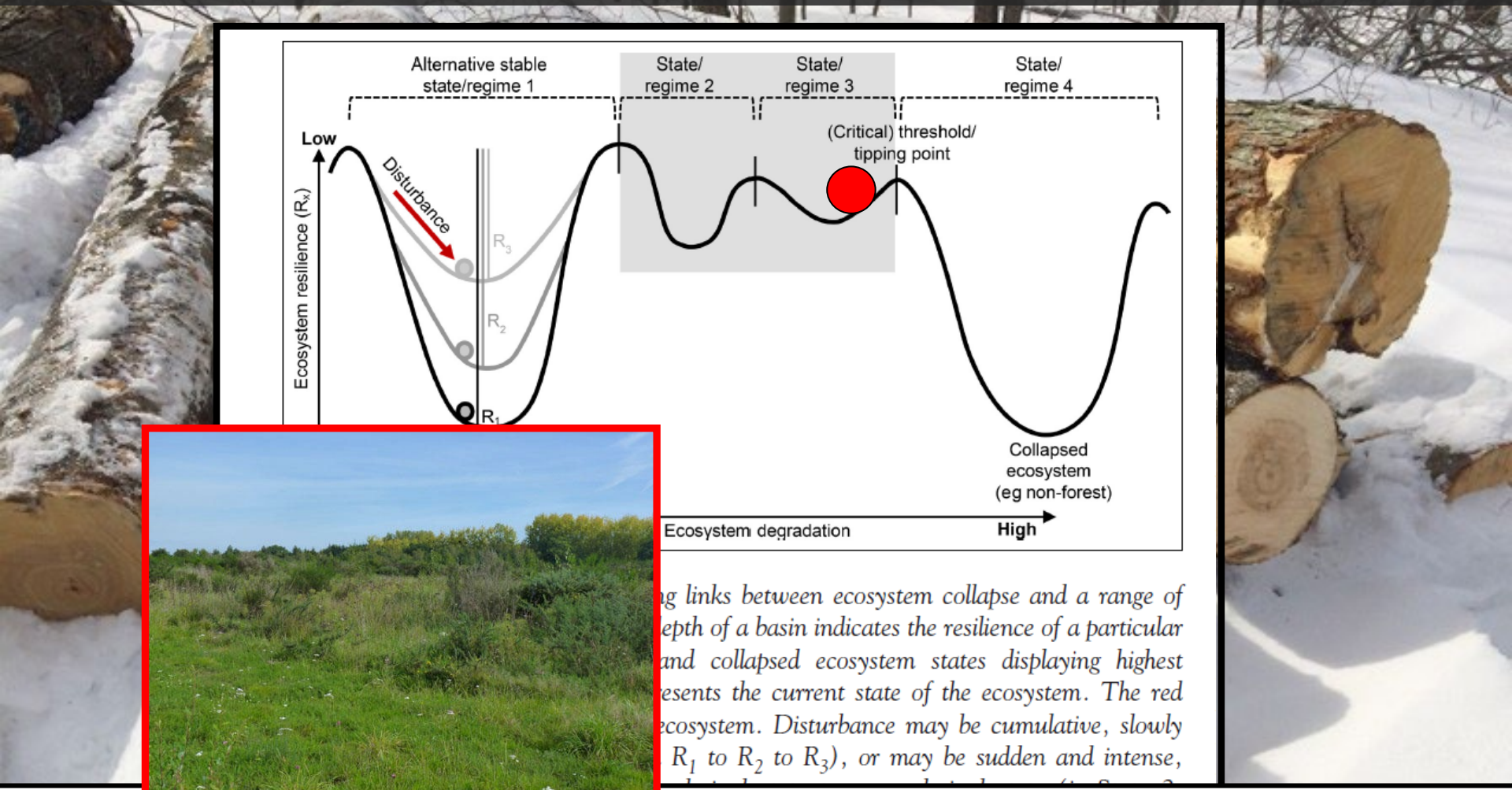

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Avoiding ecosystem collapse in managed forest ecosystems

David Lindenmayer[1*], Christian Messier[2,3], and Chloe Sato[1]

Front Ecol Environ 2016; 14(10): 561–568, doi:10.1002/fee.1434

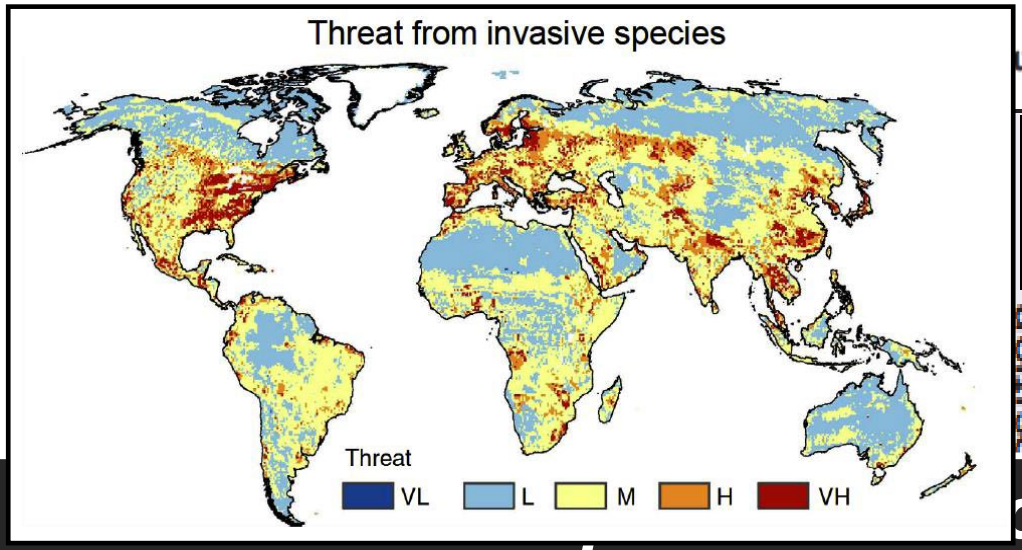
On rentre dans une zone de “haute turbulence et d’incertitude”, y-a-t’il des solutions?

Plan de la présentation

- La foresterie et ses fantômes
- La forêt menacée
- **Des nouveaux concepts interessants**
- Pour une foresterie de résilience

Concept de nouvel écosystème

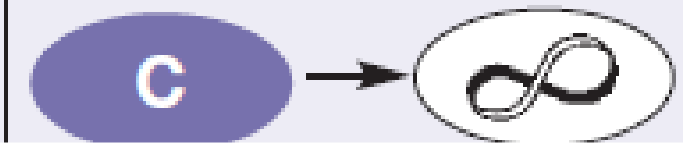
Management of novel ecosystems: are novel approaches required?



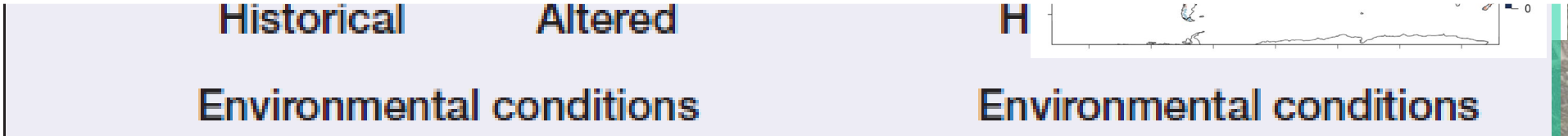
uding[3]

Aujourd'hui & demain

Nouvel écosystème



*os interventions forestières seulement sur nos connaissances du passé, mais **AUSSI selon les conditions futures changeantes et incertaines***



Reconciling Conflicting Paradigms of Biodiversity Conservation: Human Intervention and Rewilding

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

- ***On doit considérer de plus en plus INTERVENIR pour maintenir les services que l'on désire même dans nos aires protégées***

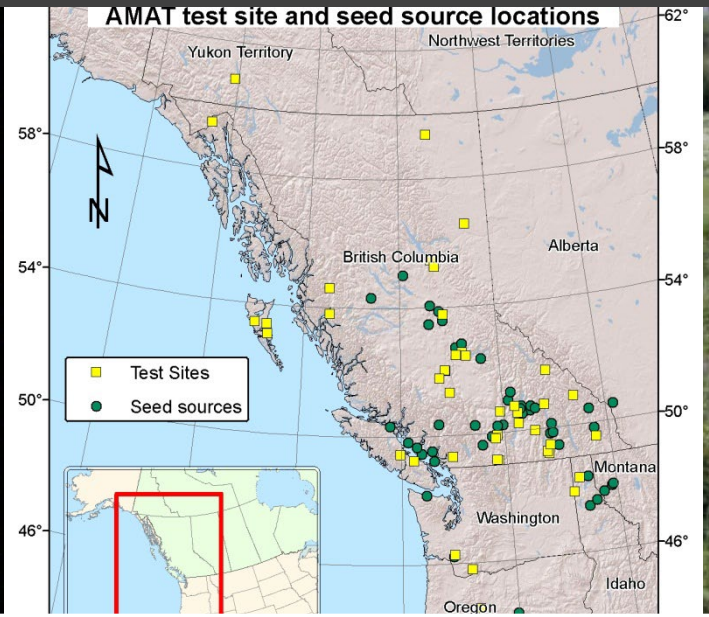
Ecological Science in the Twenty-first Century

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 de migration assistée



- ***On peut adapter nos forêts pour le future en <u>ENRICHISSANT</u> la composition <u>génétique</u> (provenance) et spécifique (<u>nouvelles espèces</u>) de celles-ci***

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

t 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

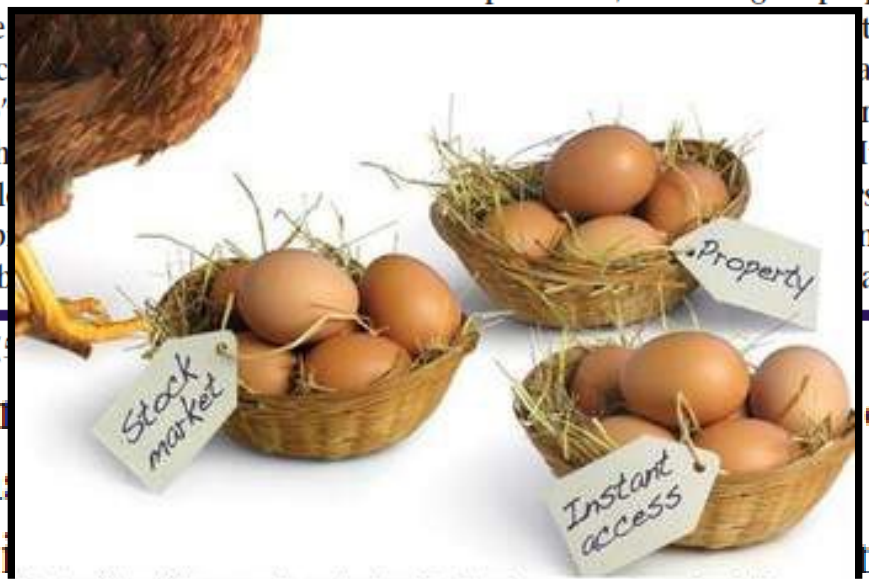
important trees and moving them south, forcing them to endure a warmer climate, quickly simu-

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 t 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 diversifi-
cation across a integrity
and productivi ng term.

- ***Comme pour vos investissements, on peut DIVERSIFIER intelligemment les espèces d'arbres dans nos forêt pour réduire les risques***

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

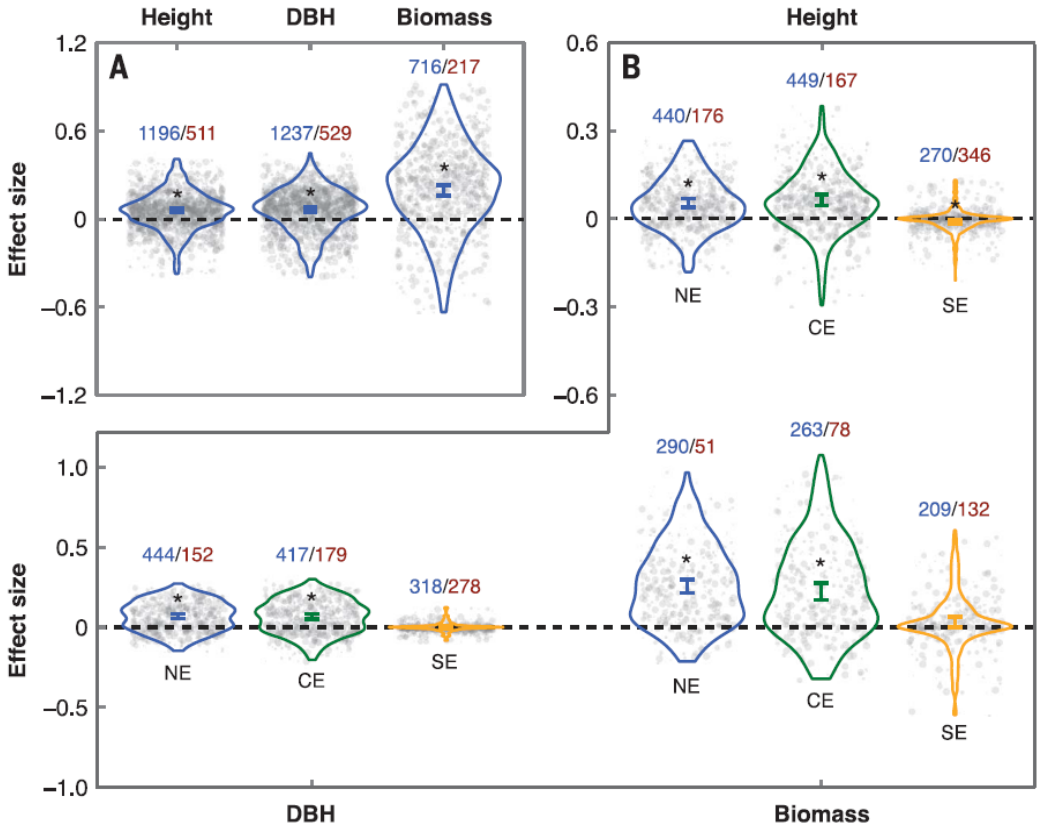
For the sake of resilience and multifunctionality, let's diversify planted forests!

- *En **diversifiant** nos plantations, on **diminue** la susceptibilité aux perturbations et on **augmente** la production des services écosystémiques*

Feng *et al.*, *Science* **376**, 865–868 (2022)

Multispecies forest plantations outyield monocultures across a broad range of conditions

Yuhao Feng[1], Bernhard Schmid[1,2], Michel Loreau[3], David I. Forrester[4,5], Songlin Fei[6], Jianxiao Zhu[7], Zhiyao Tang[1], Jiangling Zhu[1], Pubin Hong[1], Chengjun Ji[1], Yue Shi[8], Haojie Su[1], Xinyu Xiong[1], Jian Xiao[1], Shaopeng Wang[1]*, Jingyun Fang[1,9]*

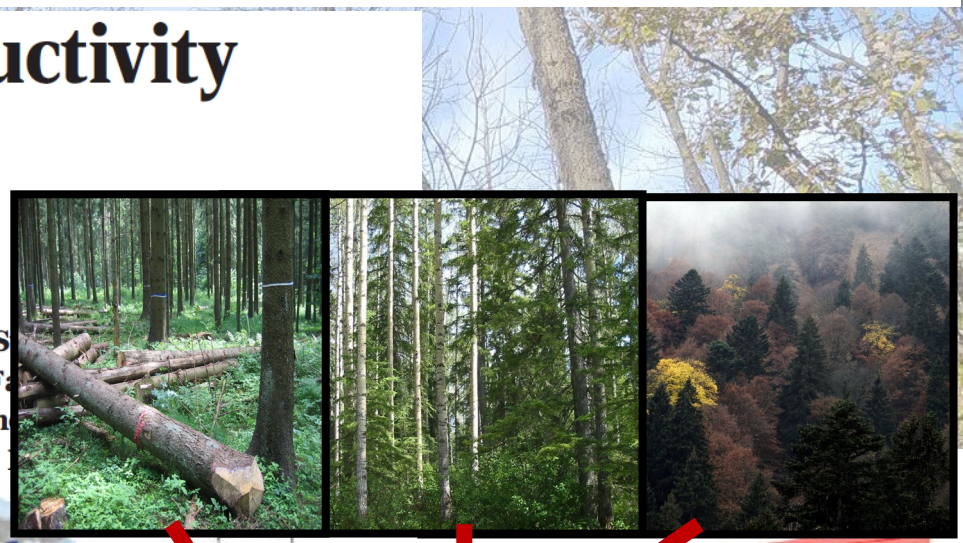


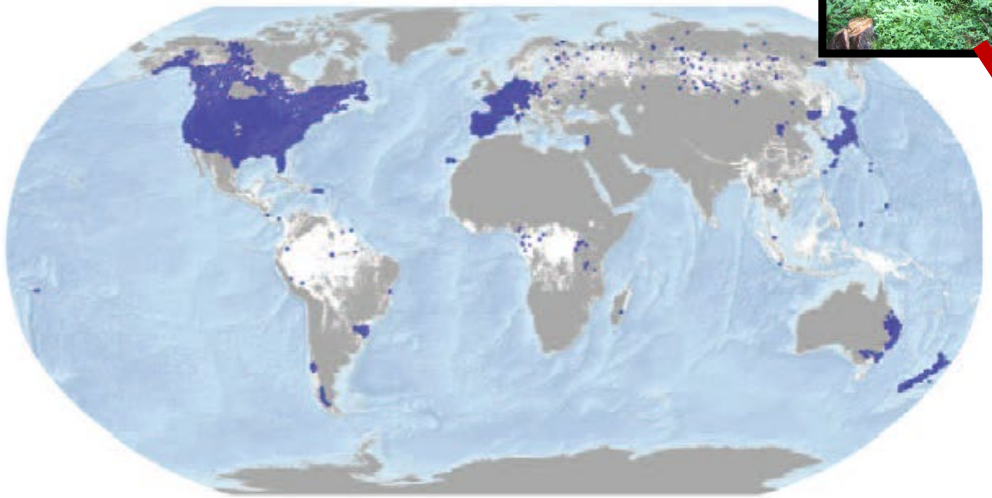
L'effet de la diversité des espèces d'arbres sur la productivité

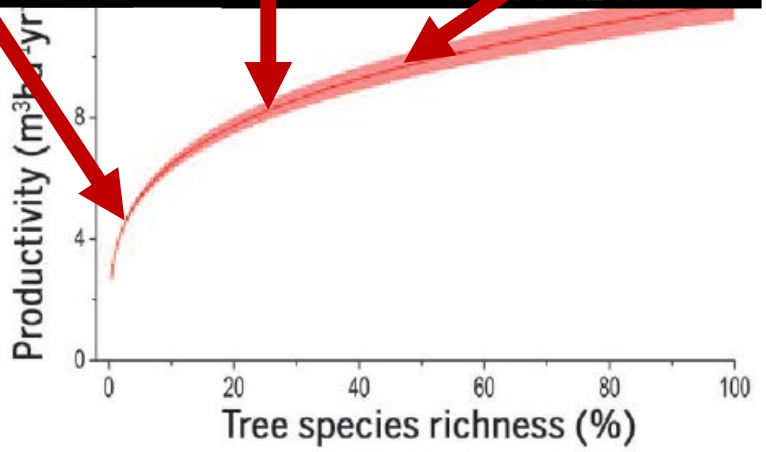
SCIENCE sciencemag.org 14 OCTOBER 2016 • VOL 354 ISSUE 6309 aaf8957-1

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







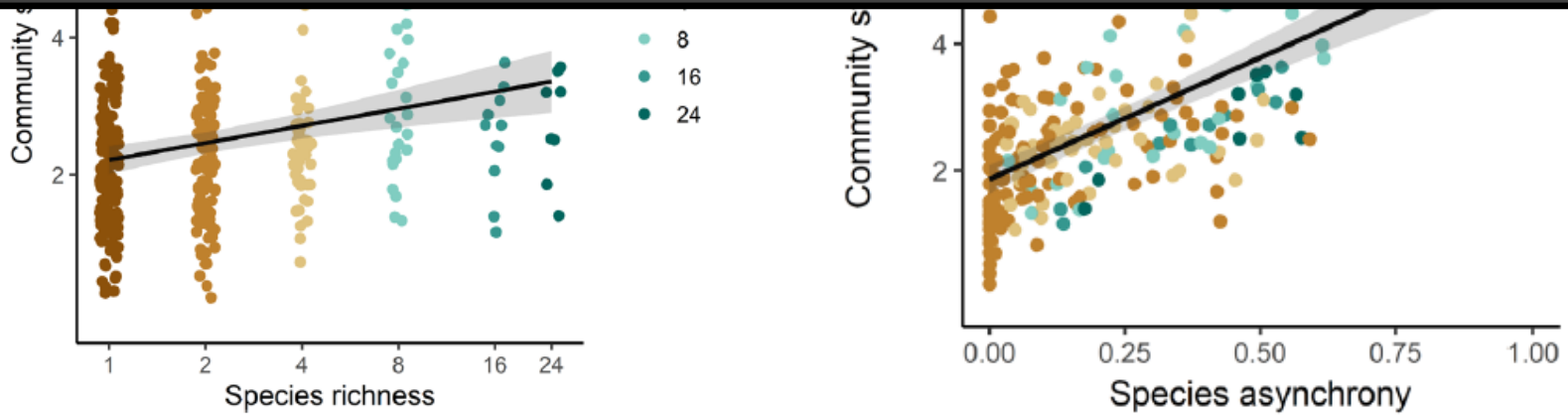
Global effect of tree species diversity on forest productivity. Ground-sourced data from 777,126 global forest biodiversity permanent sample plots (dark blue dots, left), which cover a substantial portion

ECOLOGY

Species richness stabilizes productivity via asynchrony and drought-tolerance diversity in a large-scale tree biodiversity experiment

Florian Schnabel[1,2]*†, Xiaojuan Liu[3]*†, Matthias Kunz[4]*, Kathryn E. Barry[1,2,5], Franca J. Bongers[3], Helge Bruelheide[1,6], Andreas Fichtner[7], Werner Härdtle[7], Shan Li[3], Claas-Thido Pfaff[1,2], Bernhard Schmid[8], Julia A. Schwarz[9], Zhiyao Tang[10], Bo Yang[11], Jürgen Bauhus[9], Goddert von Oheimb[1,4], Keping Ma[3], Christian Wirth[1,2,12]

➢ *Il est important d'avoir des espèces **fonctionnellement différentes** pour maximiser la résilience*



Received: 11 May 2019 | Revised: 29 July 2019 | Accepted: 4 August 2019

DOI: 10.1111/gcb.14792

PRIMARY RESEARCH ARTICLE

Global Change Biology WILEY

Drivers of productivity and its temporal stability in a tropical tree diversity experiment

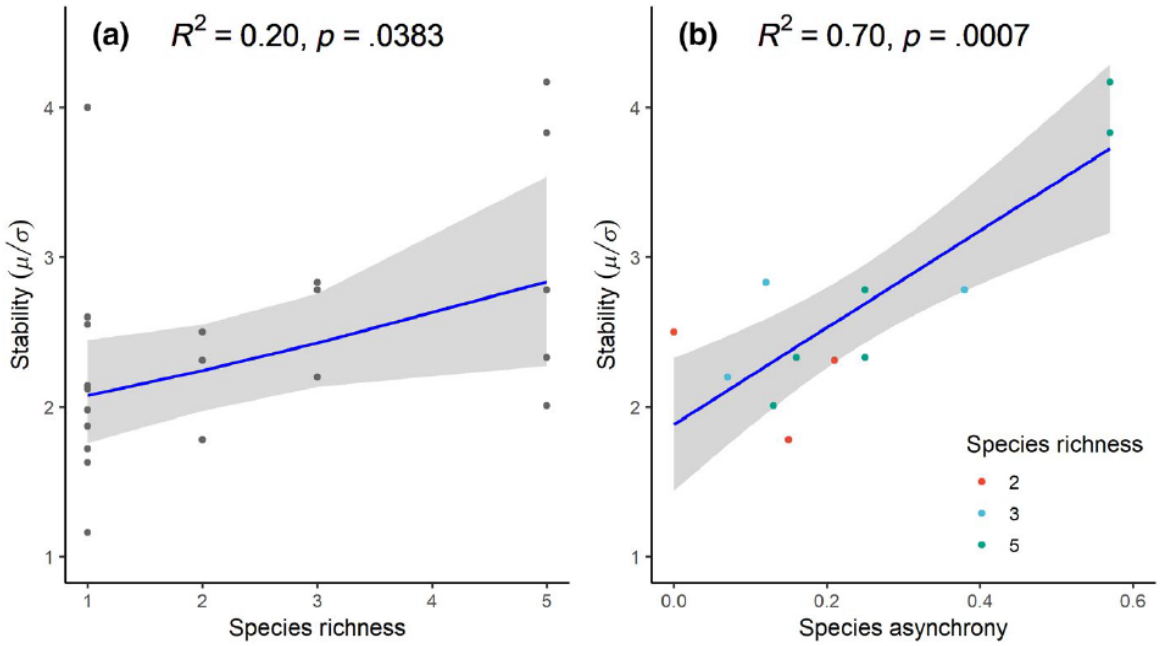
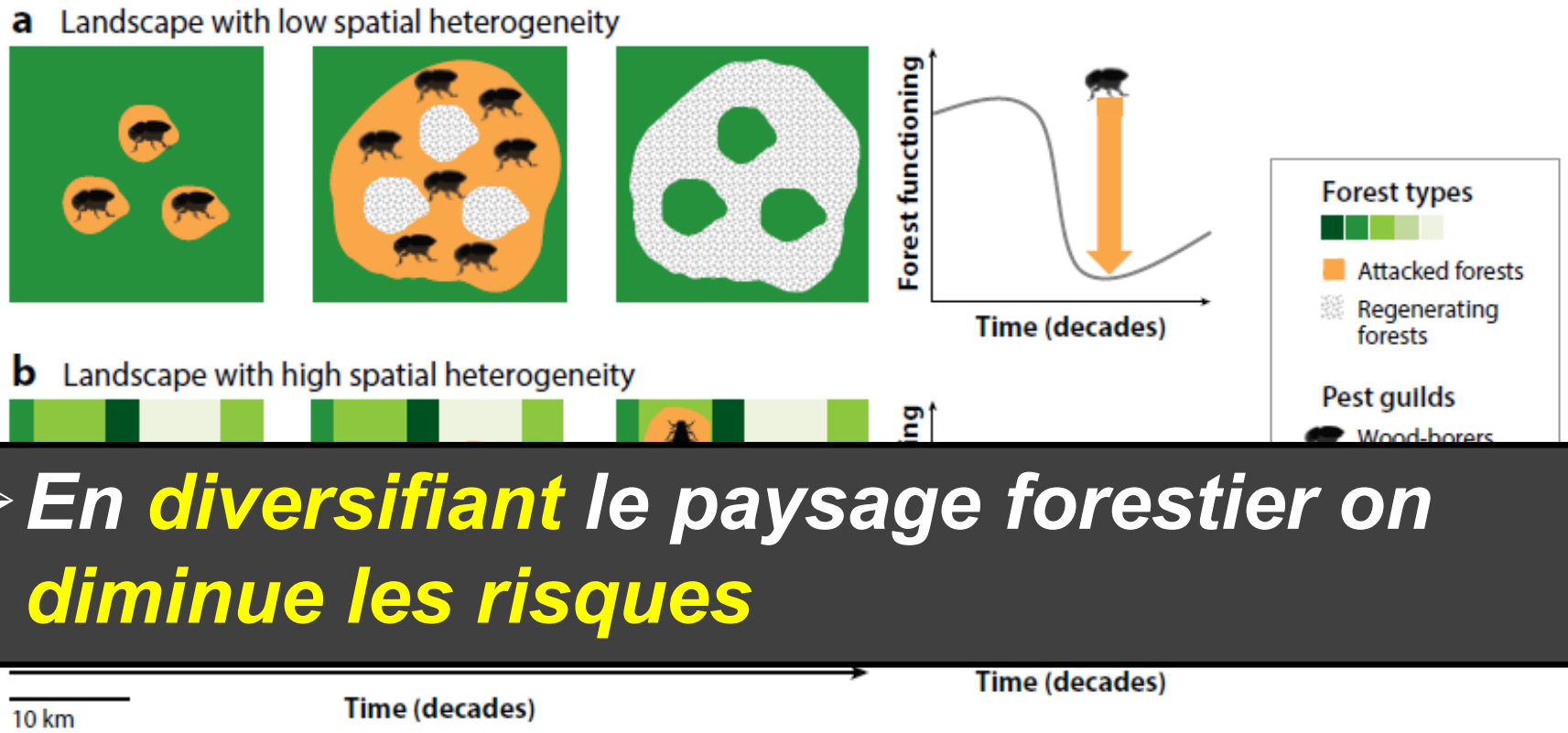


FIGURE 5 Temporal stability of community productivity as a function of species richness (a) and species asynchrony (b). Stability and species asynchrony were calculated with Equations (4) and (5) respectively. For (a) fitted values were back transformed from a log-scale to match the original values per plot (grey points). For (b) points represent values per plot and colours the respective species richness. The grey-shaded areas show a 95% confidence interval for the fitted models

ANNUAL REVIEWS

Annu. Rev. Entomol. 2022. 67:181–99



➢ *En diversifiant le paysage forestier on diminue les risques*

Figure 2

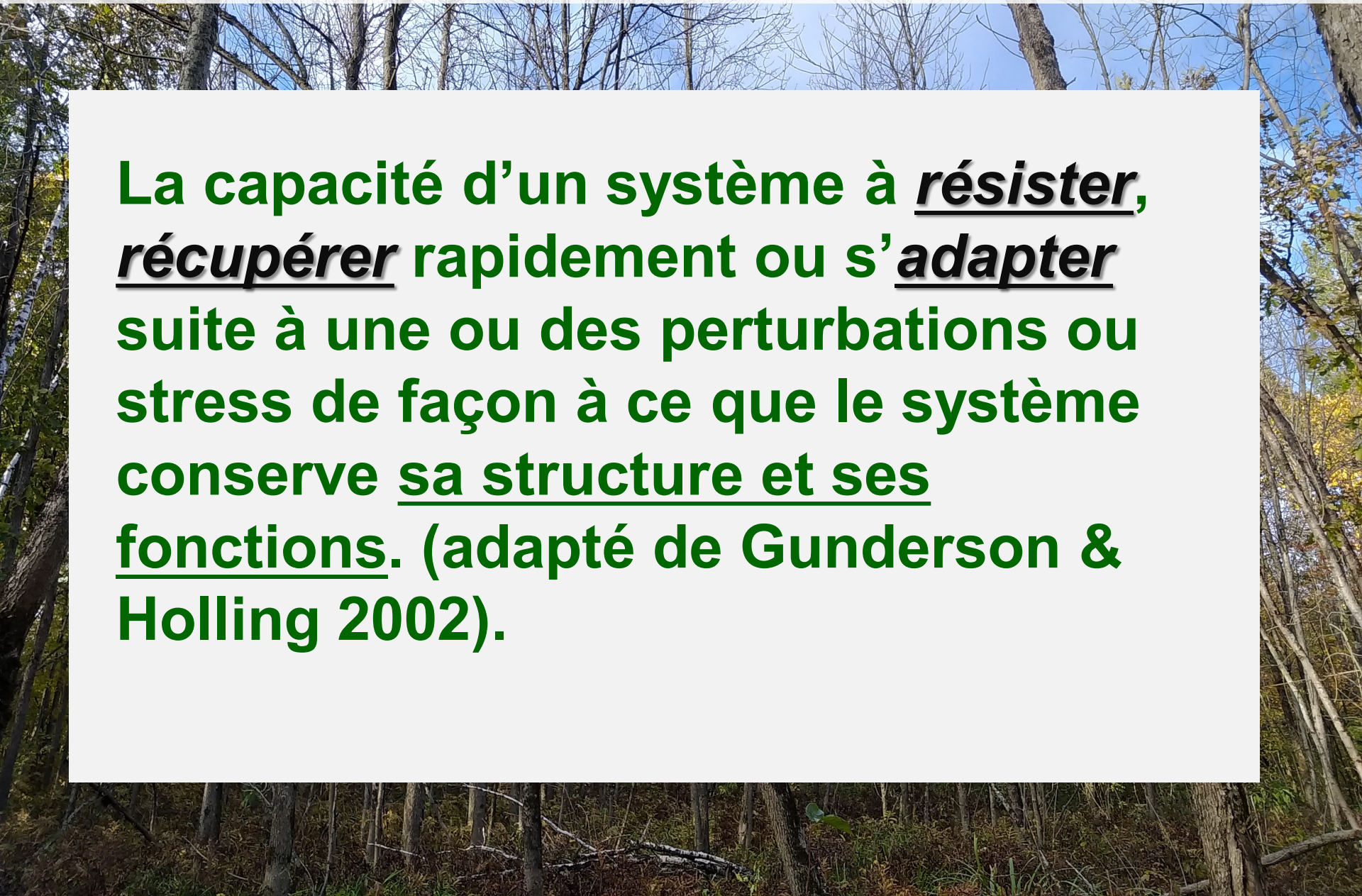
Expected effects of landscape heterogeneity on insect damage. (*a*) In highly homogeneous landscapes dominated by single tree species, there are high chances of large outbreaks causing quick pulses in forest biomass, while (*b*) in heterogeneous landscapes with multiple forest types, insect disturbances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

Ouf, ok, mais on fait comment sur le terrain?

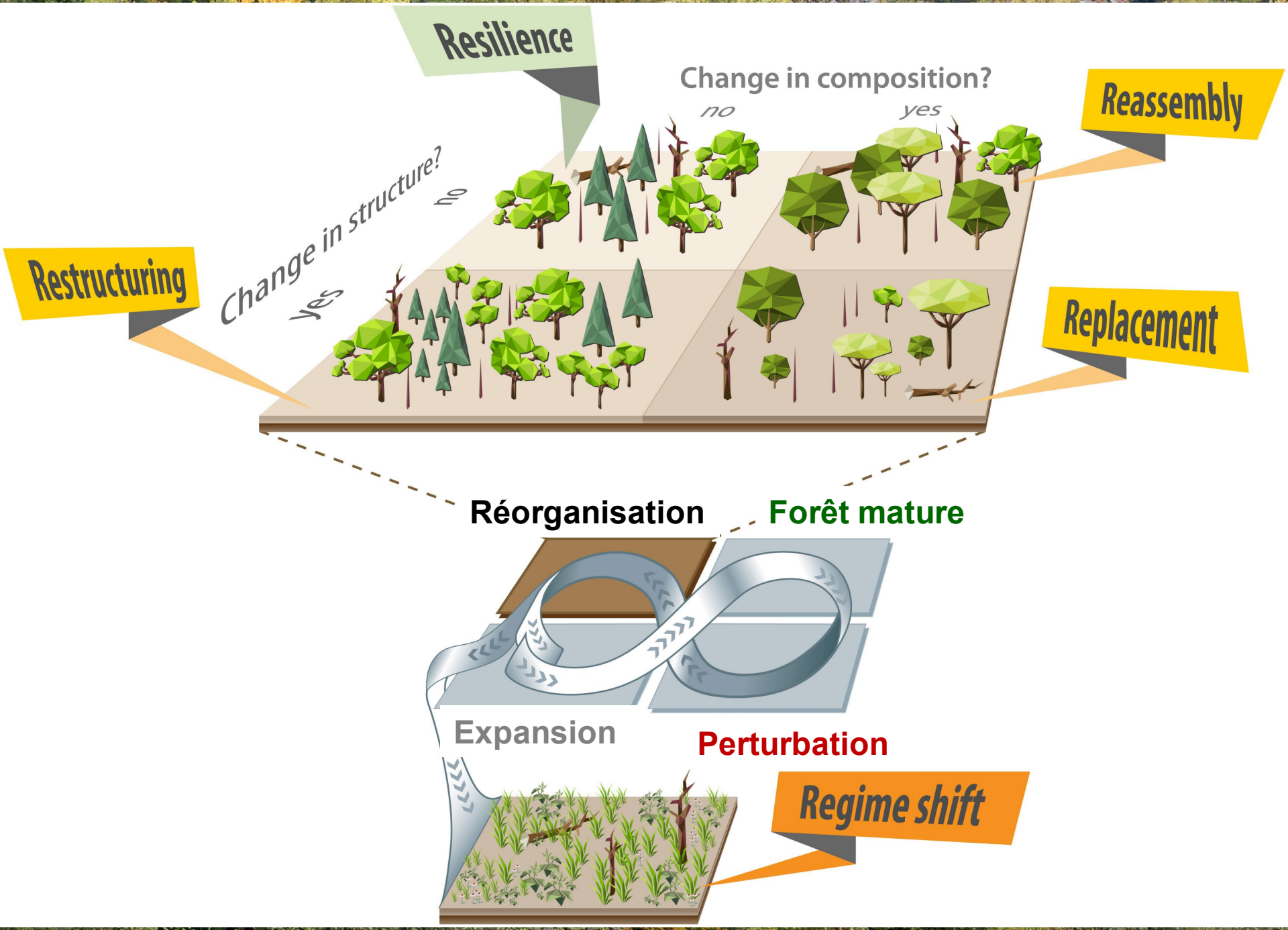
Plan de la présentation

- La foresterie et ses fantômes
- La forêt menacée
- Des nouveaux concepts interessants
- **Pour une foresterie de résilience**

Qu’est-ce que la résilience?



La capacité d’un système à ***résister***, ***récupérer*** rapidement ou s’***adapter*** suite à une ou des perturbations ou stress de façon à ce que le système conserve sa structure et ses fonctions. (adapté de Gunderson & Holling 2002).


Resilience
Change in composition?
no
yes
Reassembly
Change in structure?
no
yes
Restructuring
Replacement
Réorganisation
Forêt mature
Expansion
Perturbation
Regime shift

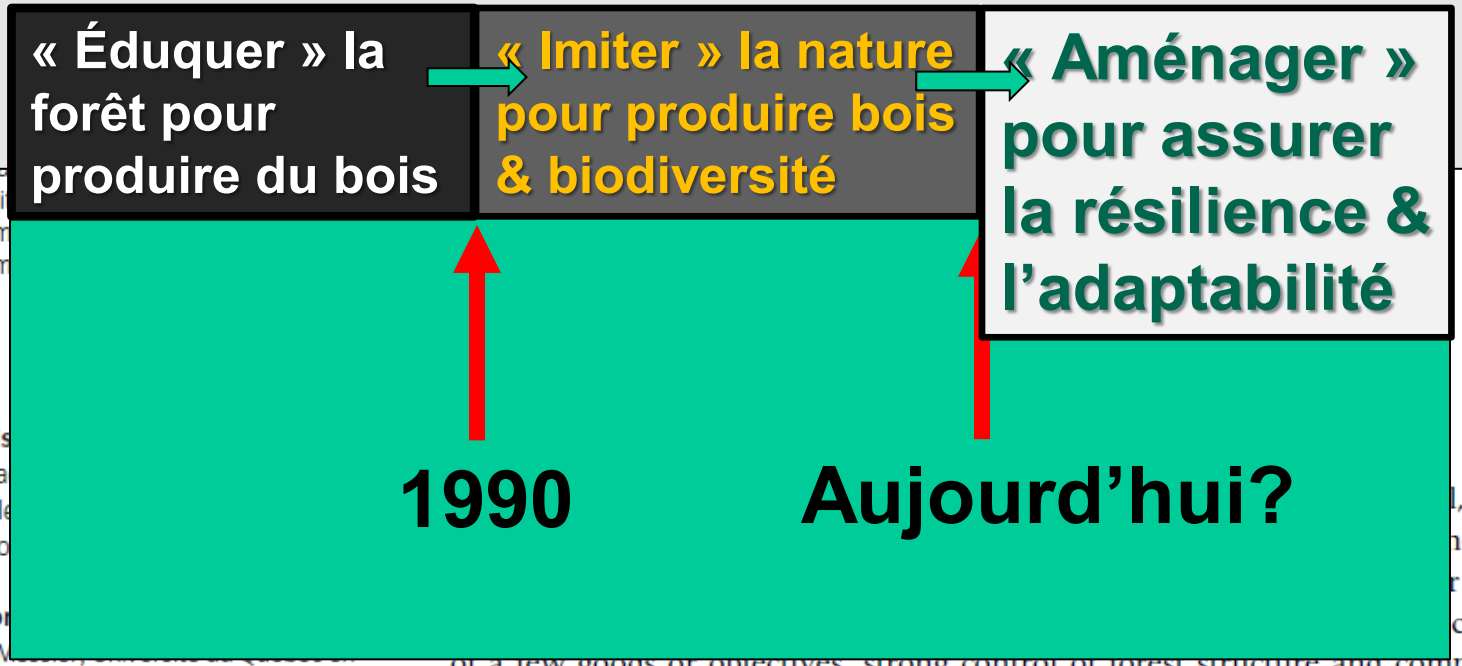
LA SOLUTION: en *diversifiant* INTELLIGEMMENT et EFFICACEMENT

Conservation Letters
A journal of the Society for Conservation Biology
Open Access
POLICY PERSPECTIVES
Conservation Letters, September/October 2015, 8(5), 368–377

From Management to Stewardship: Viewing Forests As Complex Adaptive Systems in an Uncertain World

C. Messier[1,2], K. Puettmann[3], R. Chazdon[4], K.P. Andersson[5], V.A. Angers[6], L. Brotons[7], E. Filotas[8,9], R. Tittler[10], L. Parrott[11], & S.A. Levin[12]

La « rééducation » du forestier



[10] Universi
[11] Departm
[12] Departm

Keywords
Complex a
sustainable
socioecolo

Correspon
Christian M
Outaouais, Département des Sciences

l, po-
novel
r un-
ction

of a few goods or objectives, strong control of forest structure and composition, and most importantly the absence of a global scientific framework and

Inverser la relation
INDUSTRIE DU BOIS ➡ FORÊT

Jusqu'à présent, l'industrie du « bois » a conditionné la simplification de la forêt: une approche typique TOP-DOWN

La forêt **L'industrie du bois**

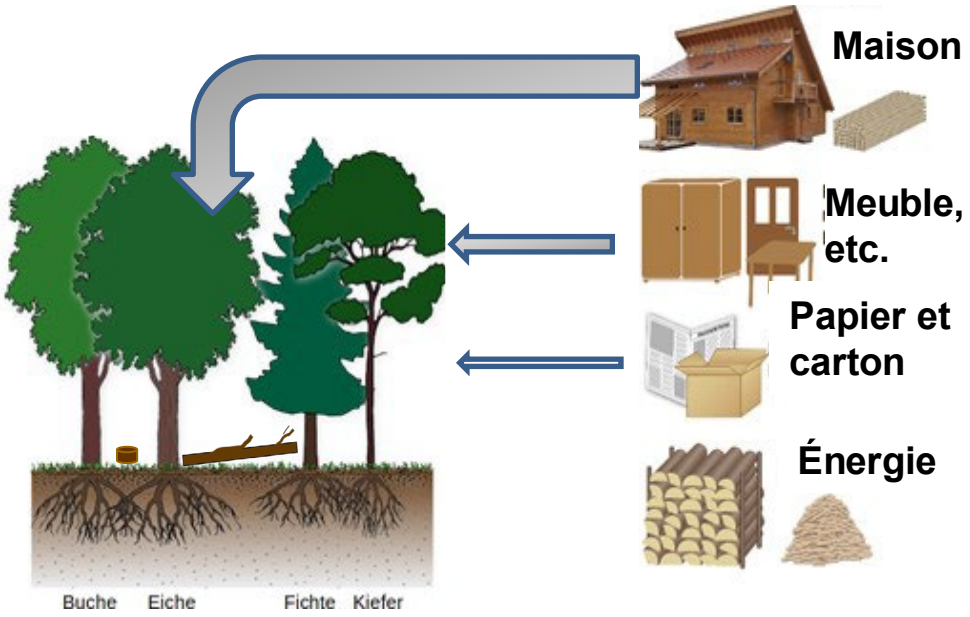
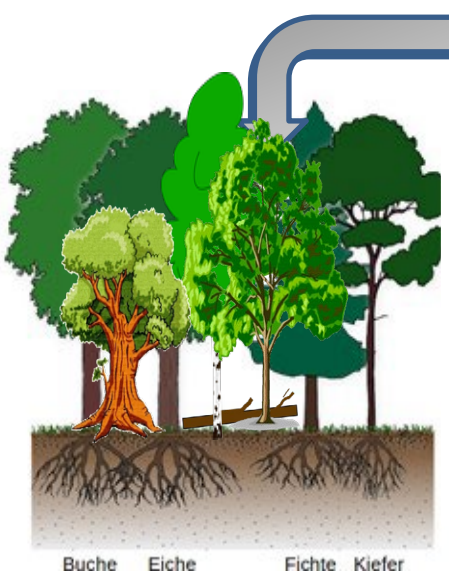


Photo: Hafner

Inverser la relation
INDUSTRIE DU BOIS ⟸ FORÊT

À l'avenir, la nécessité d'une forêt *RÉSILIENTE PLUS DIVERSIFIÉE* conditionnera l'industrie du « bois » : une approche BOTTOM-UP typique d'un Système Complexe Adaptative

La forêt



L'industrie du bois

Photo: Hafner

On *favorise* la diversité et connectivité fonctionnelle

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

Forest Ecosystems

DISCUSSION

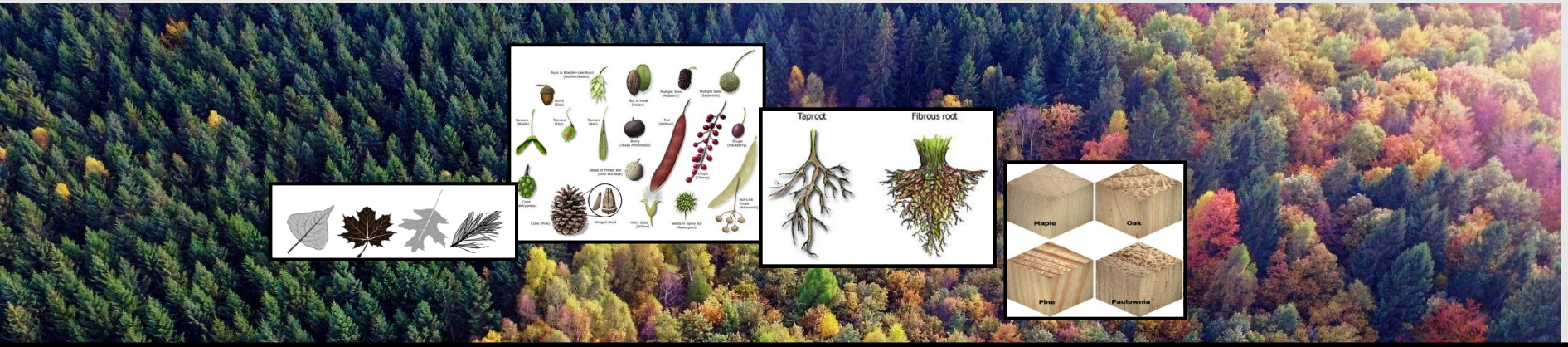
Messier *et al. Forest Ecosystems* (2019) 6:21
https://doi.org/10.1186/s40663-019-0166-2

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]

DIVERSITÉ DES TRAITS FONCTIONNELS: Une meilleure façon de caractériser la diversité des arbres



➢ ***Ou comment différentes espèces AGISSENT dans l'écosystème et RÉAGISSENT aux perturbations***

- ❖ Propriétés des feuilles
- ❖ Méthode de dispersion
- ❖ Profondeur d'enracinement

- ❖ Type de mycorhizes
- ❖ Densité du bois
- ❖ Épaisseur de l'écorce
- ❖ Capacité de germination

REGROUPER LES ESPÈCES D'ARBRES EN GROUPES FONCTIONNELS:

pour aider à diversifier efficacement

Urban Forestry & Urban Greening 62 (2021) 127157

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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

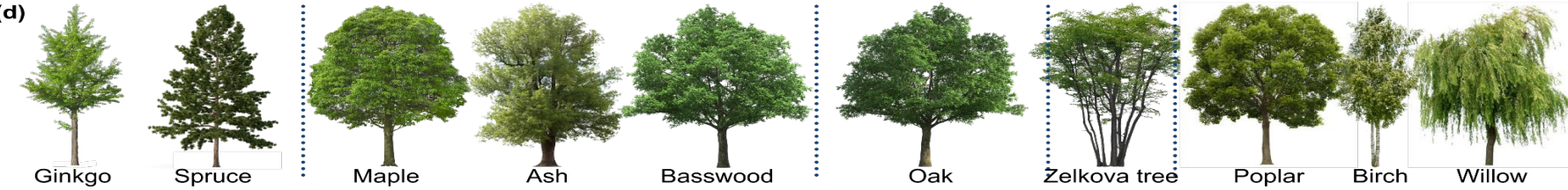
Short communication

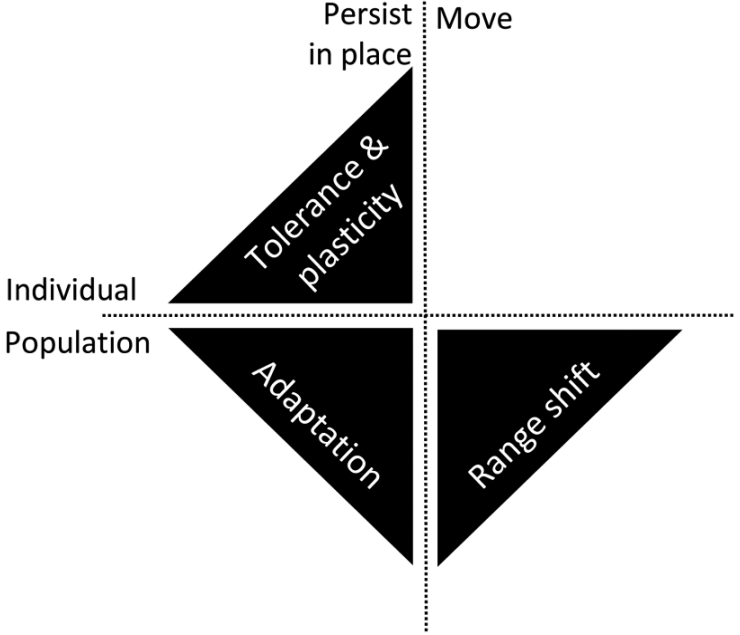
Praise for diversity: A functional approach to reduce risks in urban forests

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

and low N-content | high N-content | and low N-content | and high N-content

(d)





Strategy	Mechanism	Scale	*Main traits*
PERSIST IN PLACE (Section 2.)			
Via tolerance			
- Drought (2.1.)			
Avoidance	Efficiency of water uptake	Ind.	*Rooting depth*
	Mitigation of water loss	Ind.	*Stomatal sensitivity, Leaf mass area, Xylem conductance*
Resistance	Resistance to cavitation	Ind.	*Index of xylem resistance to embolism*
Recovery	Resumption of water transport	Ind.	*Xylem recovery capacity?*
	Vegetative reproduction	Pop.	*Resprouting ability*
- Change in temperature regime (2.2.)			
	Mitigation of heat-related physiological impacts	Ind.	*Heat shock proteins induction?*
	Morphological plasticity	Ind.	*Branching pattern variability*
	Accelerated phenology	Ind.	*Bud burst timing*
- Change in fire regime (2.3.)			
Resistance	Mechanical and architectural protection	Ind.	*Bark thickness, Height to live crown*
	Fuel potential	Ind.	*Leaf and bark flammability*

Table 1

CONNECTIVITÉ FONCTIONNELLE ET CENTRALITÉ : *une façon d'optimiser notre intervention*

CONNECTIVITÉ FONCTIONNELLE: Niveau possible d'échange de propagules d'arbres (mesuré en termes de traits fonctionnels qui peuvent être transférés) entre les peuplements et les propriétés forestières

CENTRALITÉ: Le niveau d'influence ou de connectivité des nœuds dans un réseau. Il permet de déterminer les nœuds les plus influents.

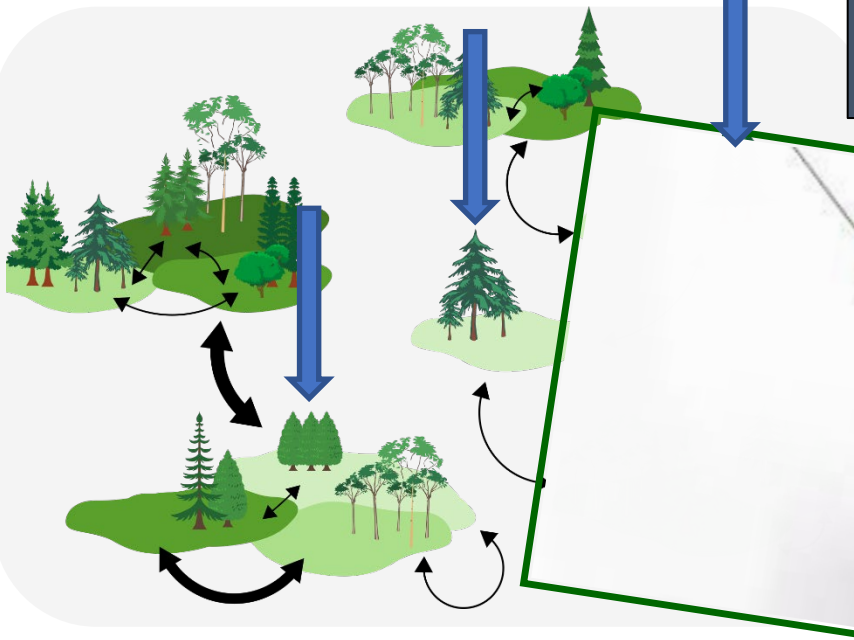
Complex network

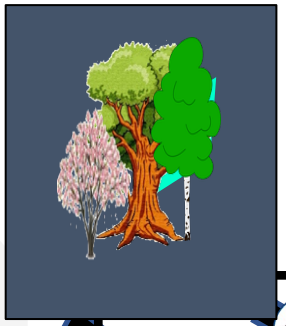
Connectivity

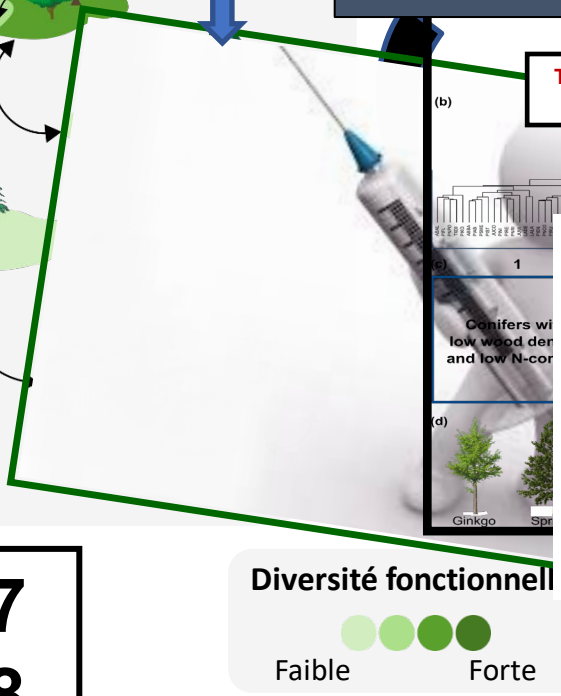
Bunn *et al.* 2000

Voici un exemple

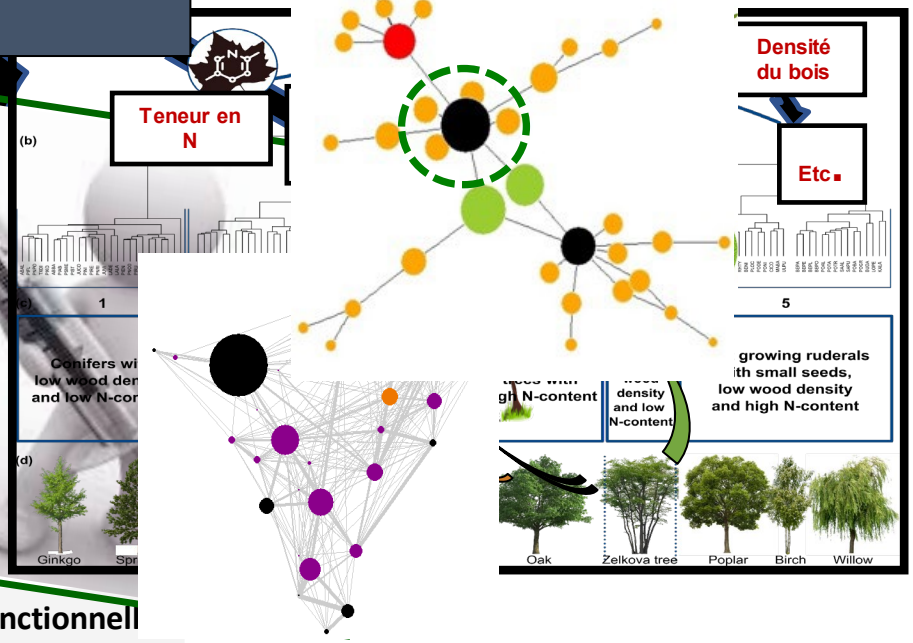
Avant intervention







Après intervention



Diversité fonctionnelle

Faible Forte

Diversité **F**onctionnelle = 2,7

Connectivité **F**onctionnelle = 1,8

(4) On plante/favorise la régénération de groupes fonctionnels manquants

Localisation des peuplements

CARTOGRAPHIE
Numéro de la carte forestière : 31 G15 NO
Échelle : 1 cm : 80 m 1 po : 667 pi

Sapin
Peupliers
Érable à sucre
Érable rouge
Bouleau jaune
} >80%
Bouleau blanc
Tilleul
Pruche
Cerisier d'automne
Pin blanc
Chêne rouge

40 ha

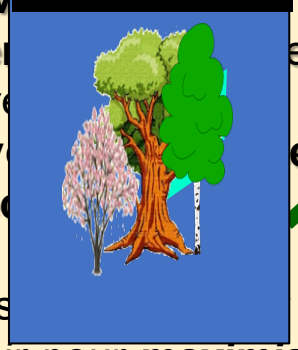
Application: *iForêt*

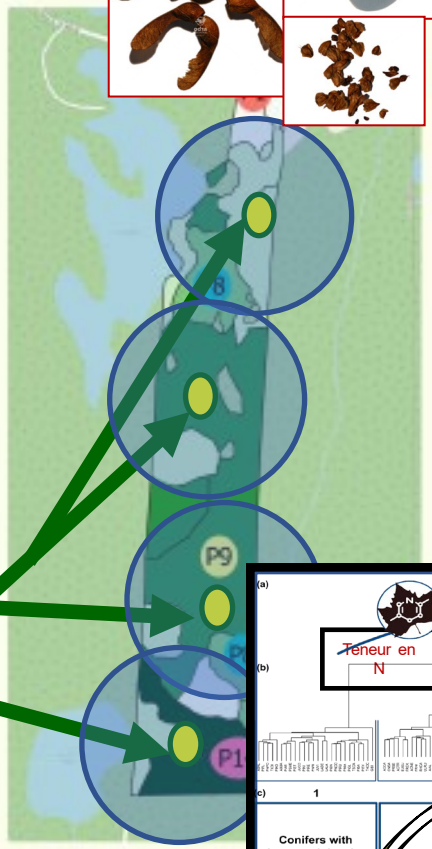
Cet outil permet de déterminer:

- **La diversité fonctionnelle** des peuplements
- **La connectivité fonctionnelle** entre les peuple
- **Le niv vulné** e forêt/re
- Le niv es **des éc**

Il propos **où** *intervenir pour* ***maximiser la résilience*** *au moindre coût.*

Groupes 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]

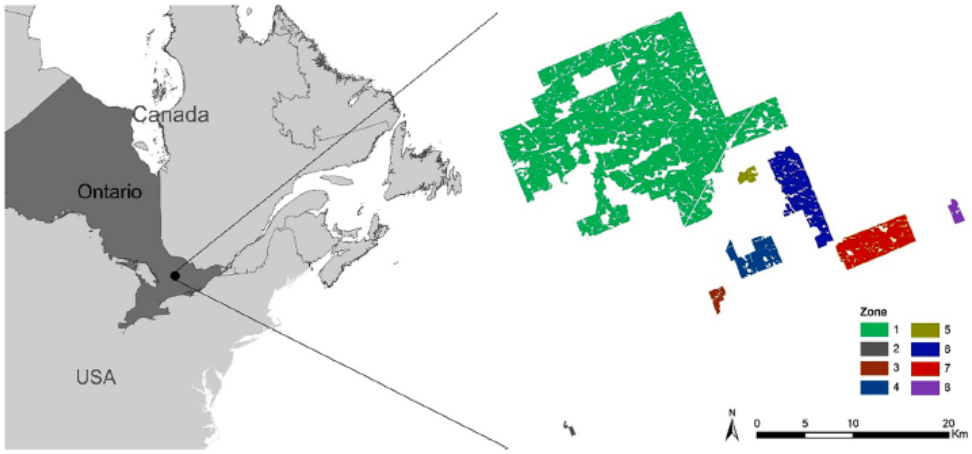
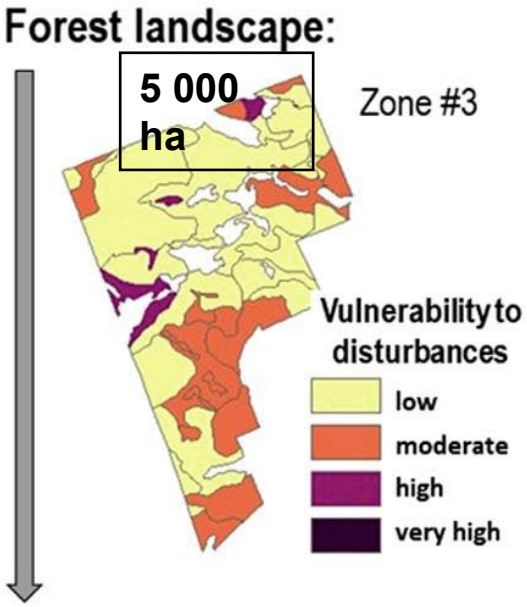
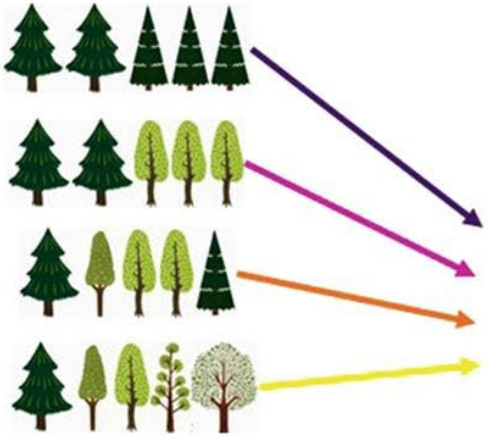


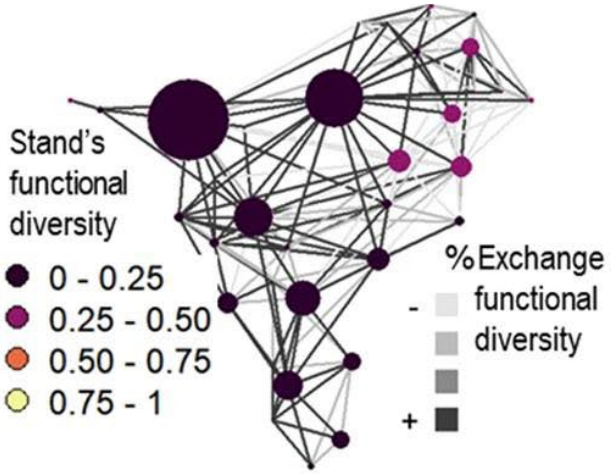
Fig. 1. . Geographic location of the Haliburton Forest in Ontario, Canada (left panel) and the eight forest zones in the Haliburton Forest (right panel).

1. Calculer la *diversité fonctionnelle*

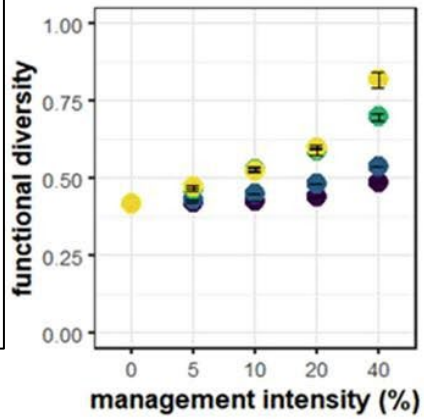
2. Calculer la *connectivité fonctionnelle* et la *centralité* pour déterminer les priorités de gestion

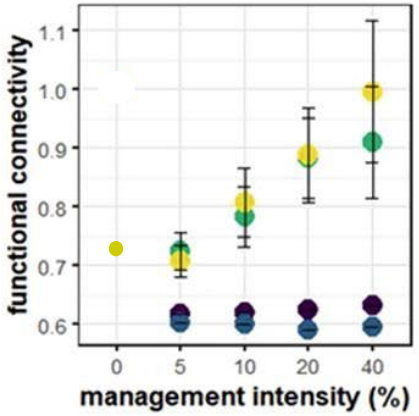






3. Simuler les effets de *différents scénarios* de gestion sur la *connectivité fonctionnelle* du paysage, la *centralité*, *la récolte*, etc.





Management scenarios:

harvest low

harvest high

harvest + plant low

harvest + plant high

Received: 21 January 2022 | Revised: 21 January 2022 | Accepted: 19 March 2022

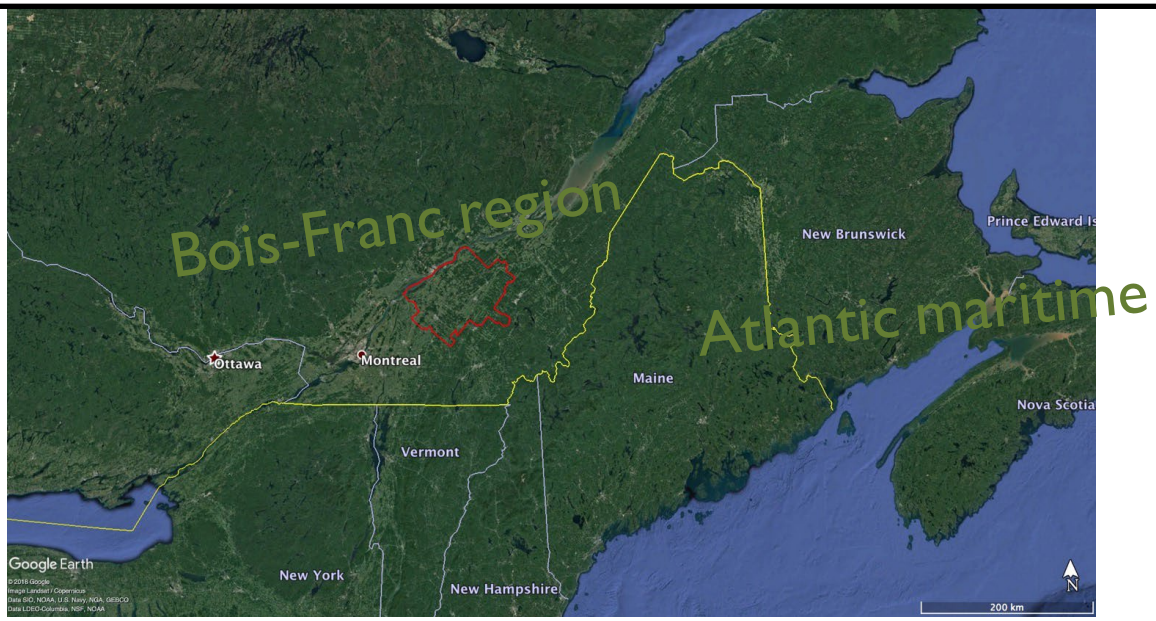
DOI: 10.1111/gcb.16197

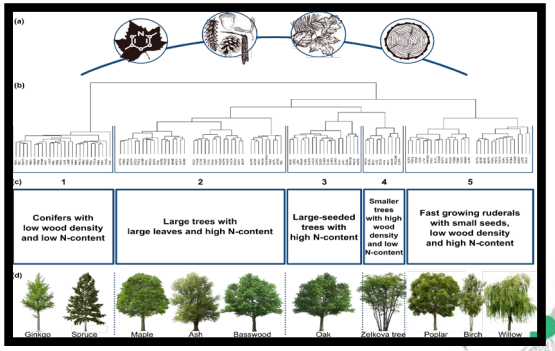
Global Change Biology WILEY

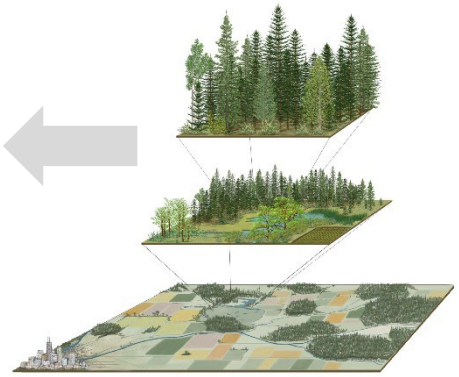
RESEARCH ARTICLE

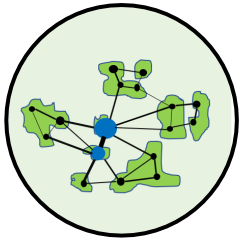
Managing for the unexpected: Building resilient forest landscapes to cope with global change

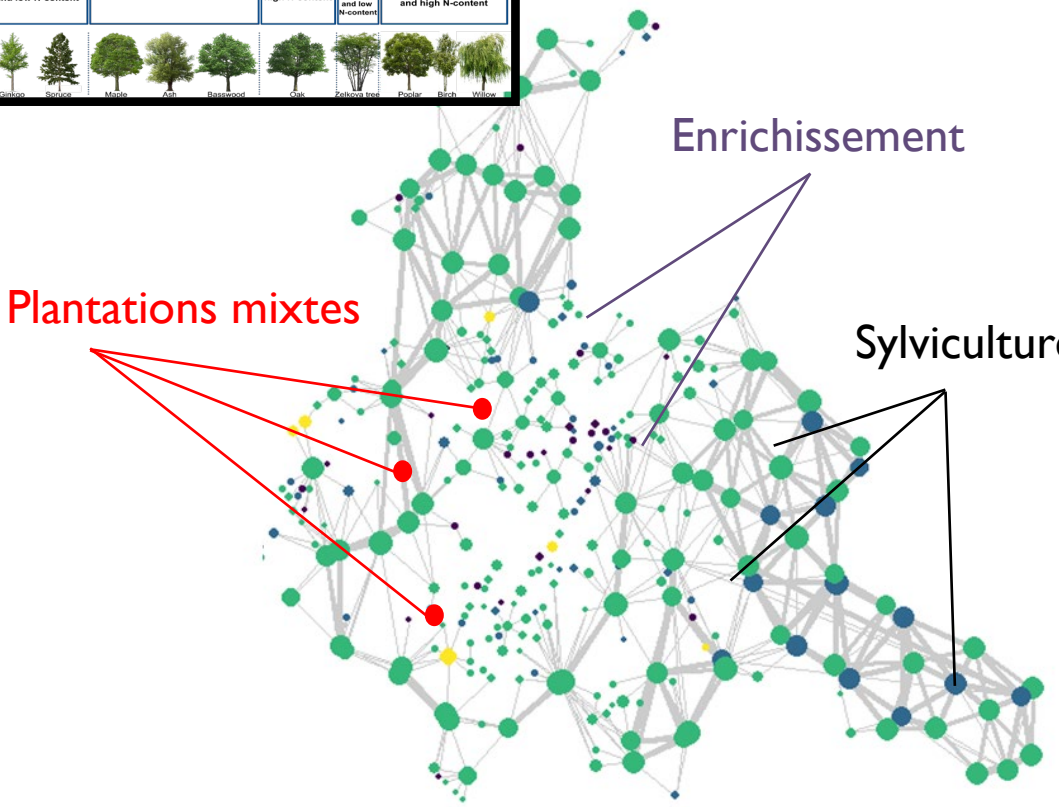
Marco Mina[1,2] | Christian Messier[1,3] | Matthew J. Duveneck[4,5] | Marie-Josée Fortin[6] | Núria Aquilué[1,7]











Functional Diversity

Connectivity fonctional

DISCUSSION 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]

Christian Messier
UQAM/UQO

Nuria Aquilué
UQAM/UQO

Marco Mina
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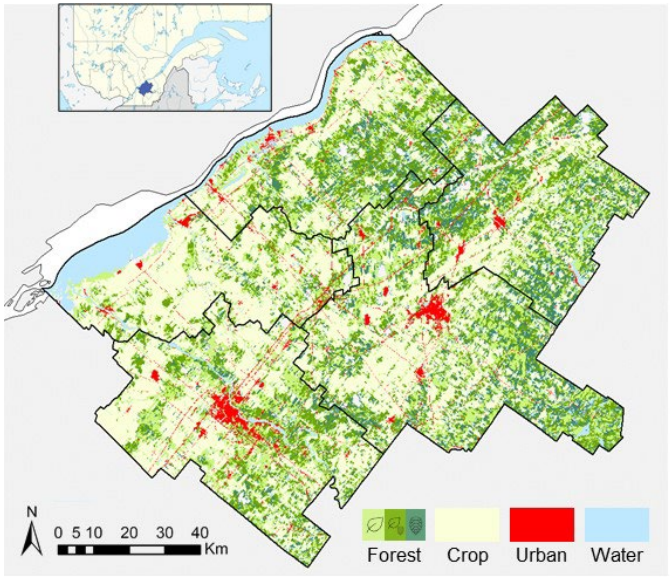
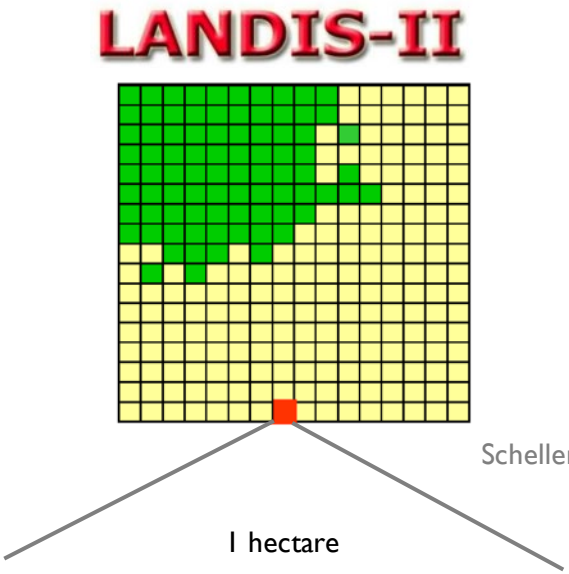
LANDIS-II

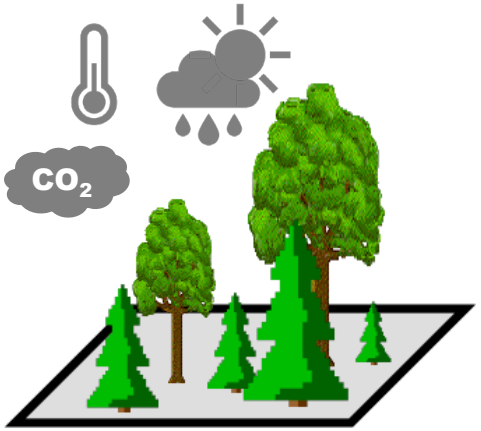
Centre-du-Quebec



Mina *et al.* (2021) *Ecol Appl*

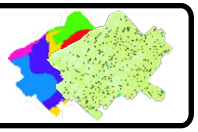


Scheller *et al.* (2007)

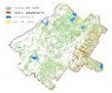


de Brujin *et al.* (2014)

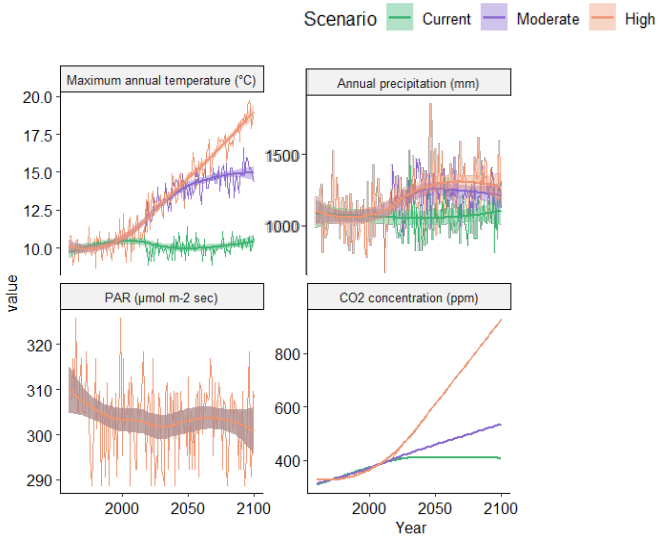
Modélisation du paysage forestier – conception expérimentale

Model initialization 

Model calibration 

Current silvicultural practices (BAU management) 

Climate Change Scenarios

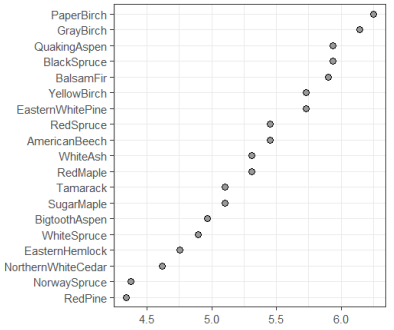


Disturbance Scenario

Random press disturbances

- *Adaptability Scores*
- Weighting factor *future relevance by disturbance type*
- *Vulnerability index* by species

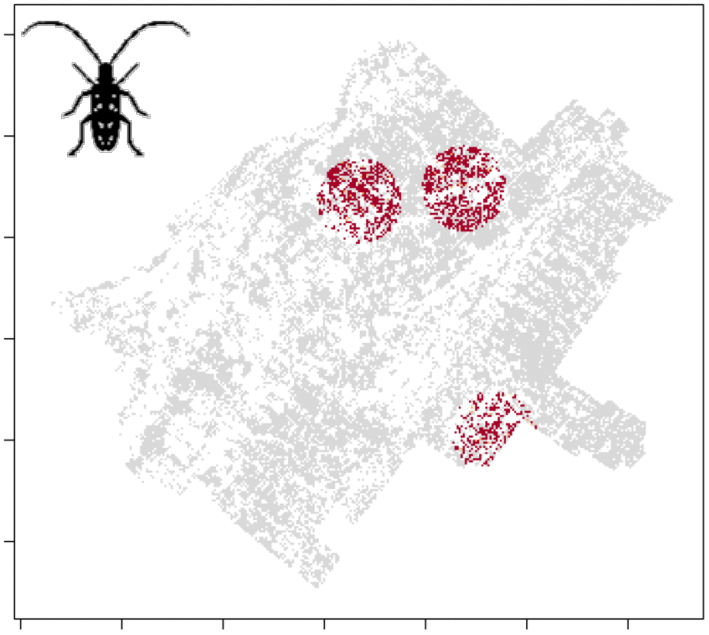
0 = LESS VULNERABLE
10 = MORE VULNERABLE



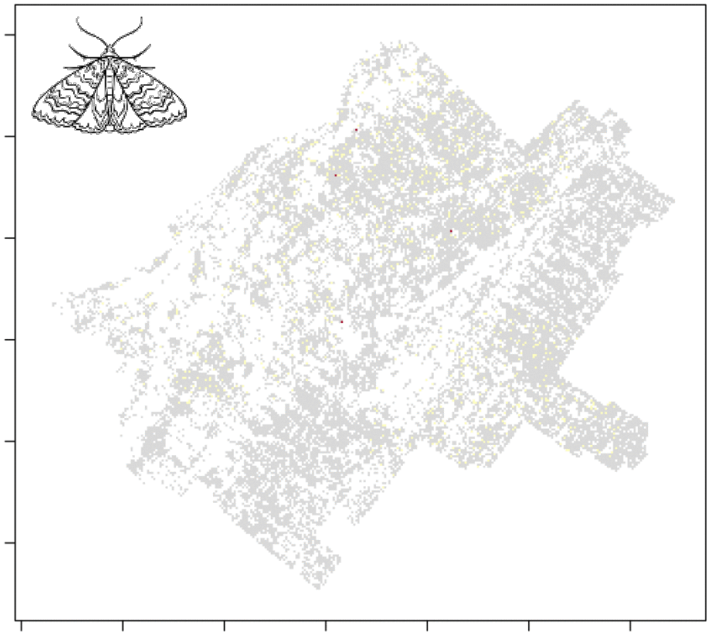
Climate Change Tree Atlas; Matthews et al. 2011

Mina *et al.* in prep

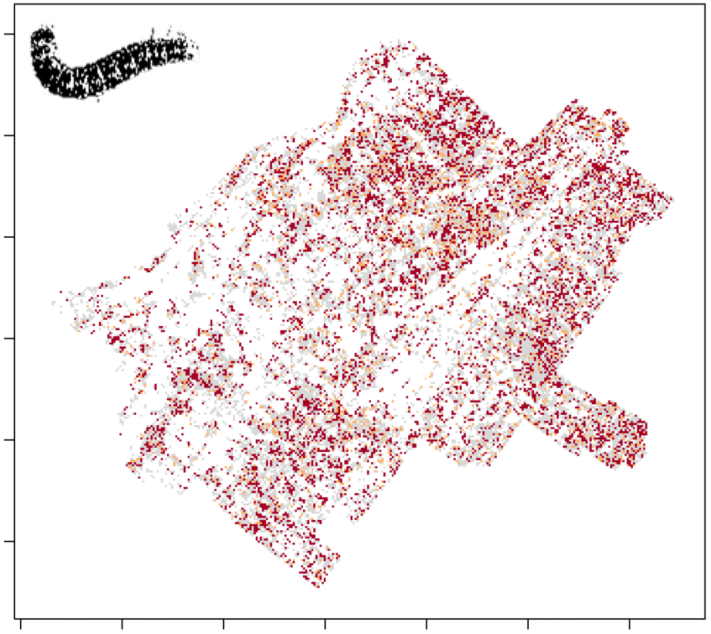
AsianLonghornedBeetle_Severity_30



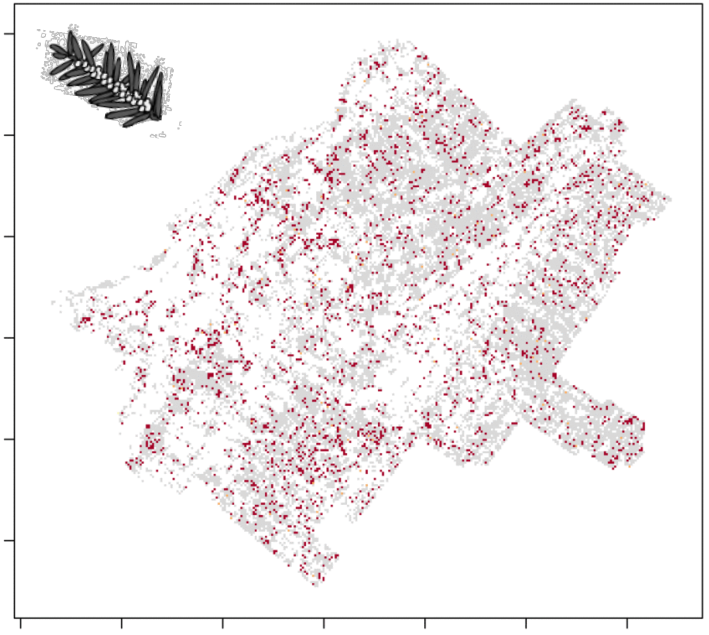
GypsyMoth_Severity_20



SpruceBudWorm_Severity_40



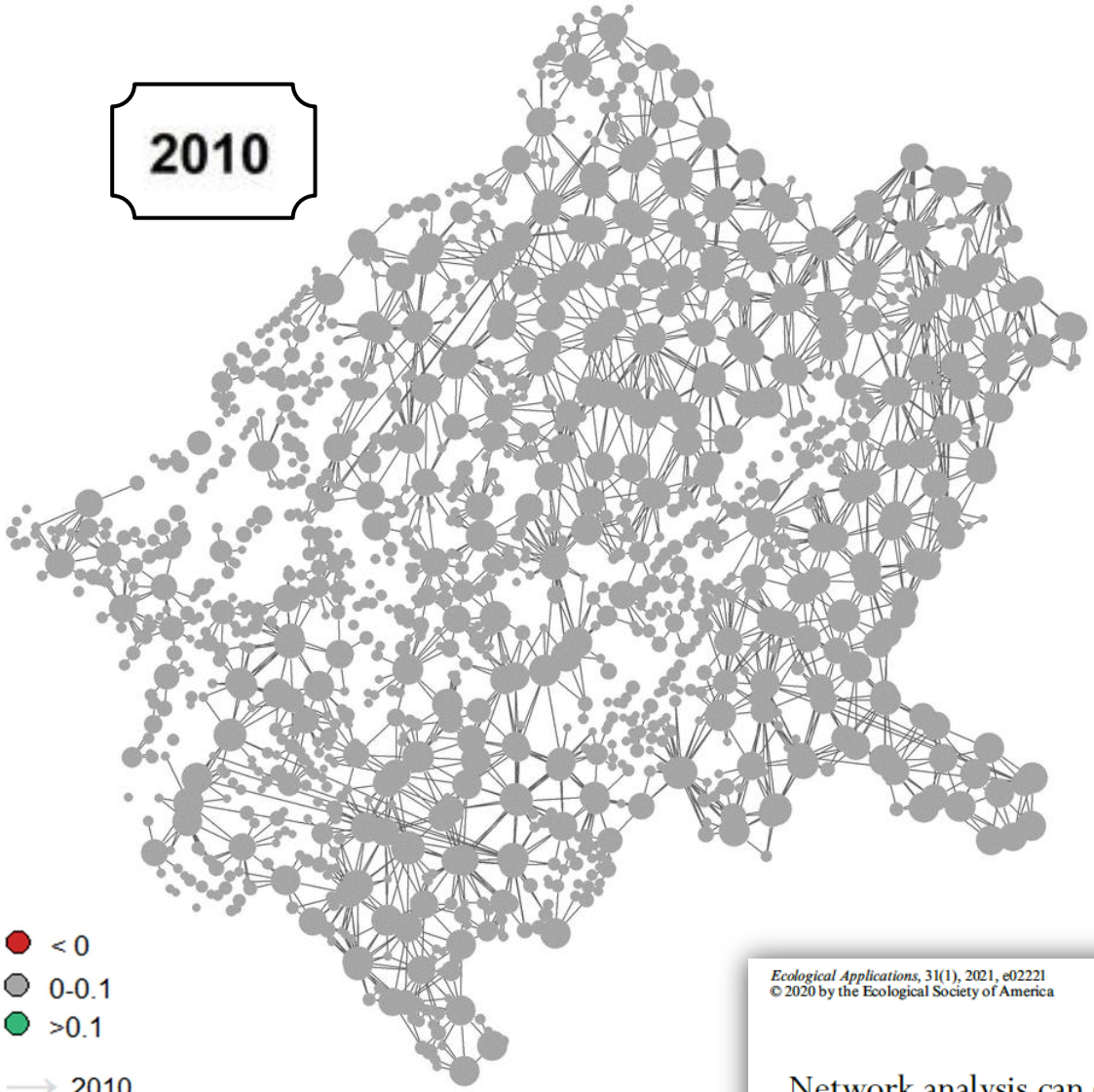
HemlockWoollyAdelgid_Severity_30

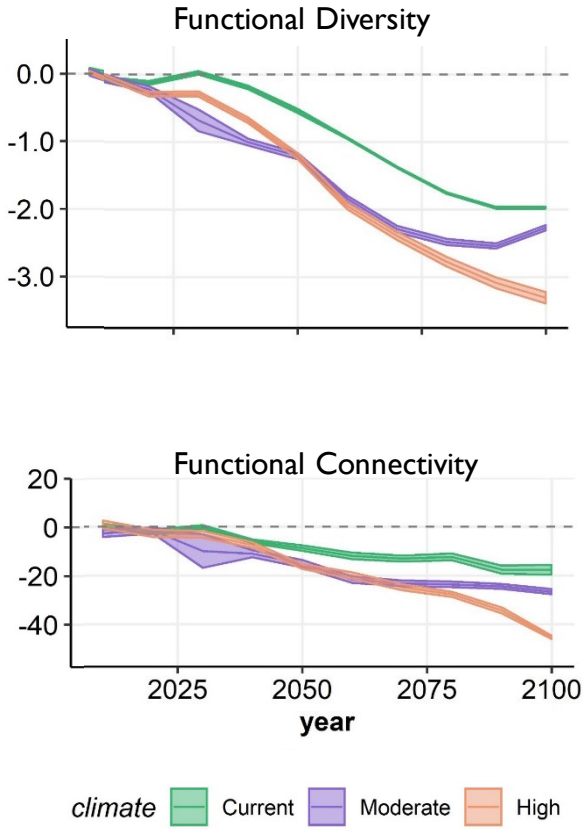


Severity

NonDist
Low
Medium
High

CURRENT MANAGEMENT with CLIMATE CHANGE





Ecological Applications, 31(1), 2021, e02221

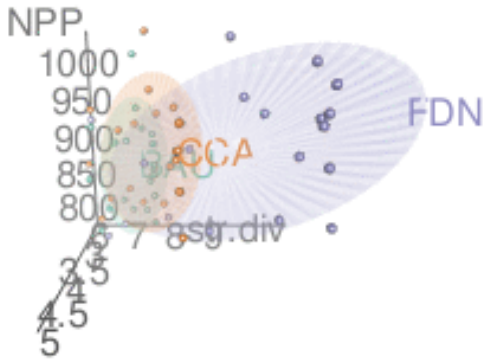
Network analysis can guide resilience-based management in forest landscapes under global change

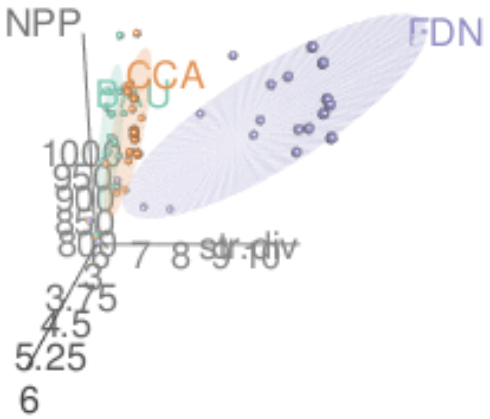
Marco Mina [1,7] Christian Messier, [1,2] Matthew Duveneck, [3,4] Marie-Josée Fortin, [5] and Núria Aquilué [1,6]

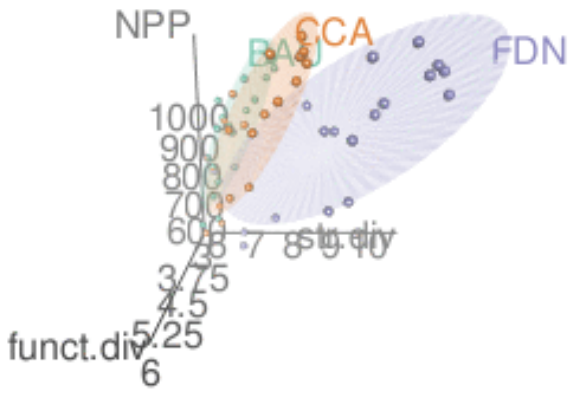
RÉSILIENCE ÉCOLOGIQUE

BAU: On continue comme on fait maintenant
CCA: On favorise des espèces adaptées aux CC
FDN: On maximise la diversité et connectivité fonctionnelles

RCP4.5 PAS D'INSECTES	RCP8.5 INSECTES ACTUELS	RCP8.5 DR INSECTES ACTUELS ET À VENIR

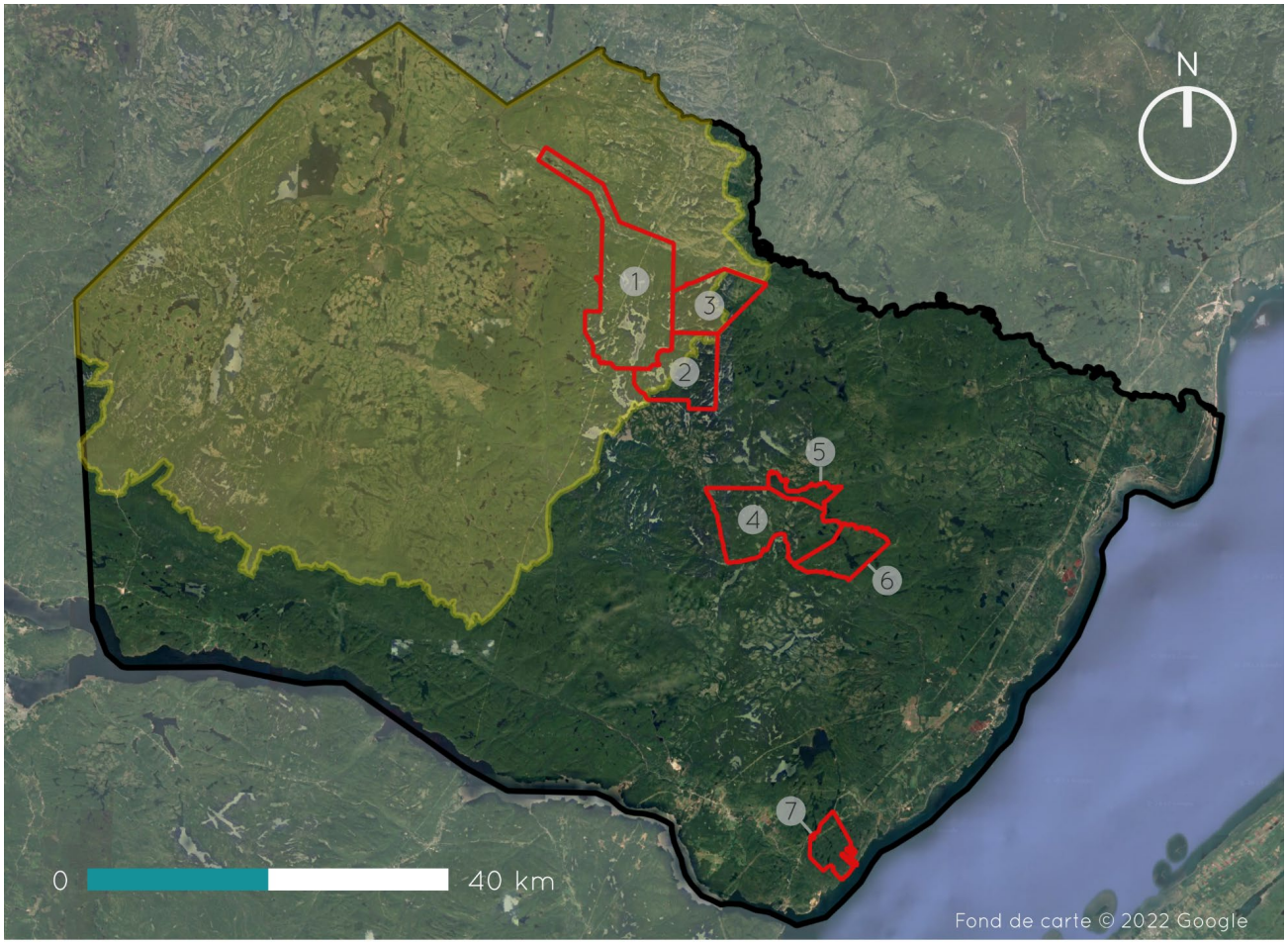






- « BUSINESS AS USUAL » permet un certain stockage du carbone, mais CCA et FDN performent mieux pour la diversité fonctionnelle et la connectivité - et la résilience globale à long terme, ***particulièrement FDN***!

Territoire d'étude



Zone d'étude d'Essipit

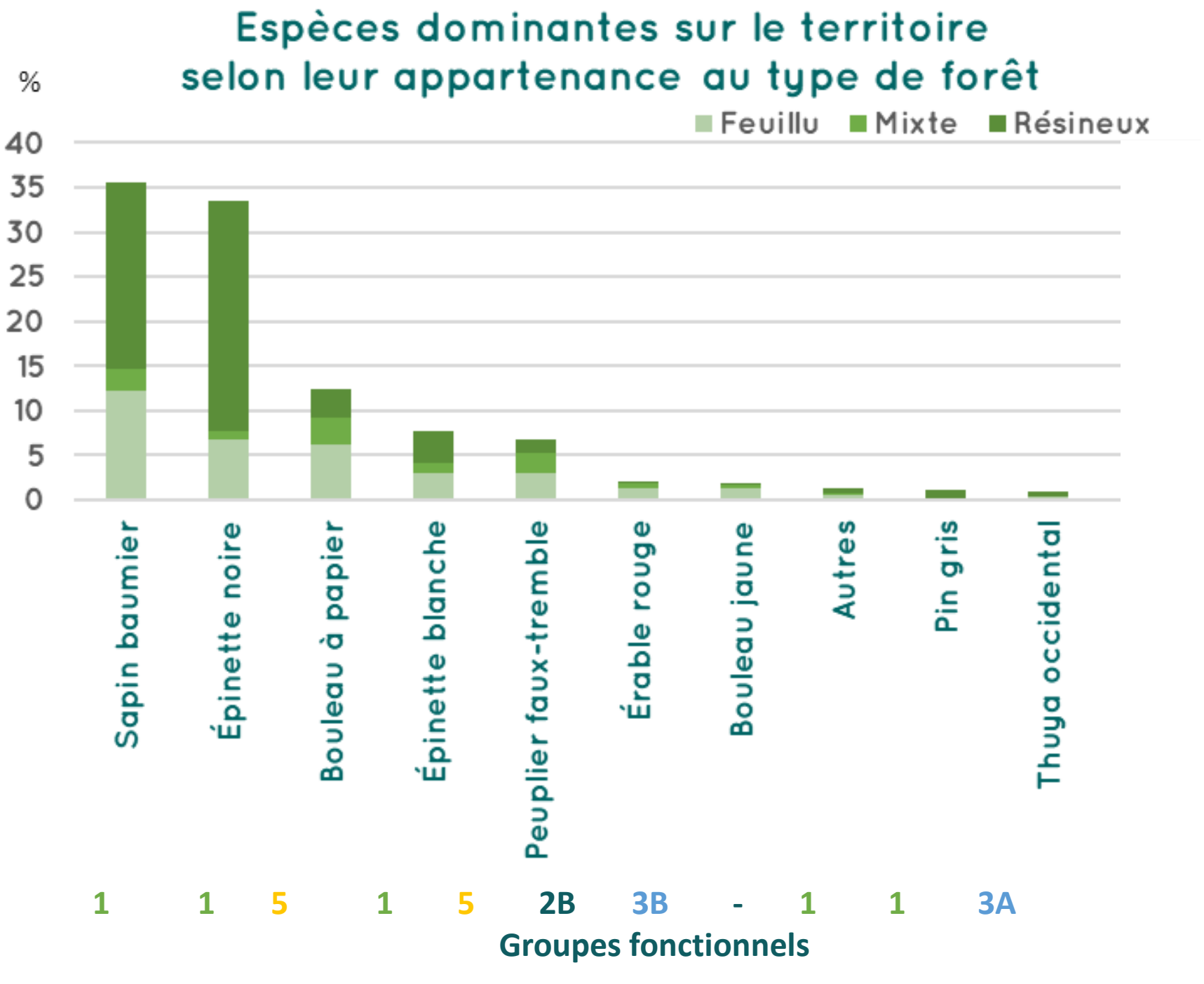
Territoires d'application du plan d'aménagement forestier

Zone d'intérêt des caribous

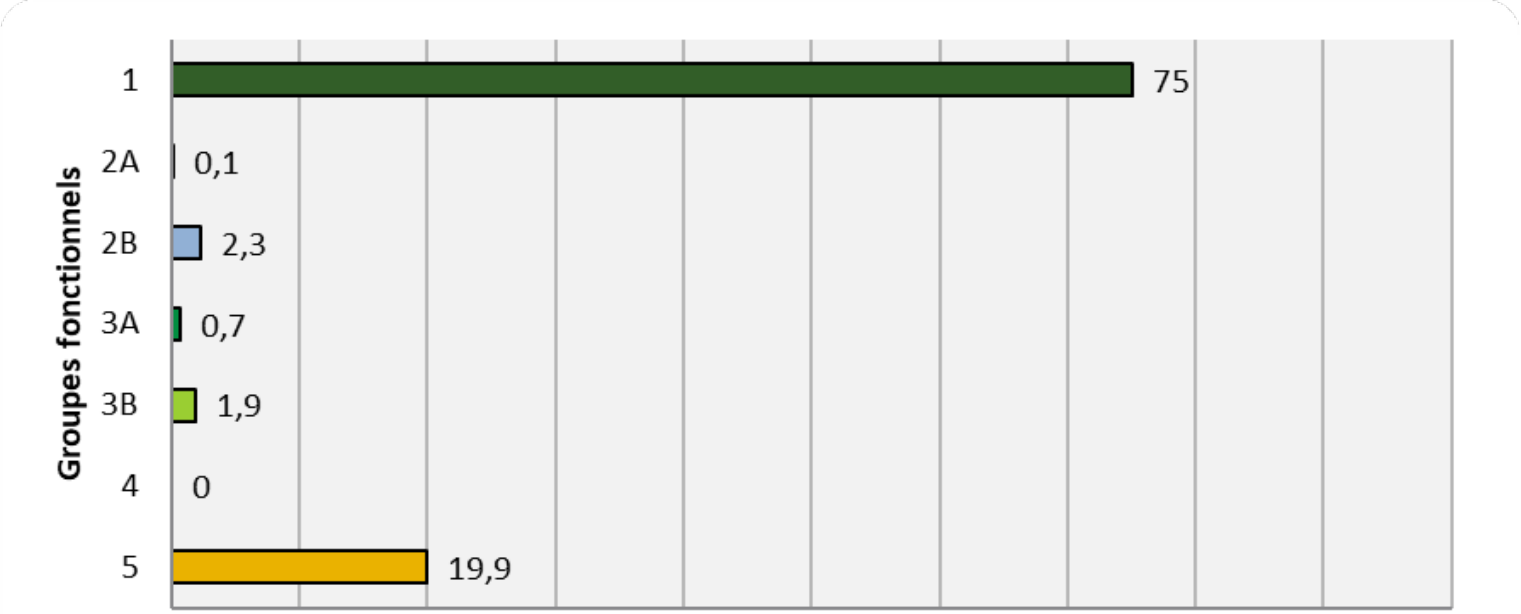
1 - Domaine du Lac des Coeurs
2 - Domaine sportif du Lac Loup
3 - Club Chasse et Pêche Ste-Anne-de-Porneuf
4 - Club Claire
5 - Agrandissement Club Claire
6 - Domaine du Lac Bernier
7 - Pourvoirie des Lacs à Jimmy

habitat
LA NATURE À L'ŒUVRE

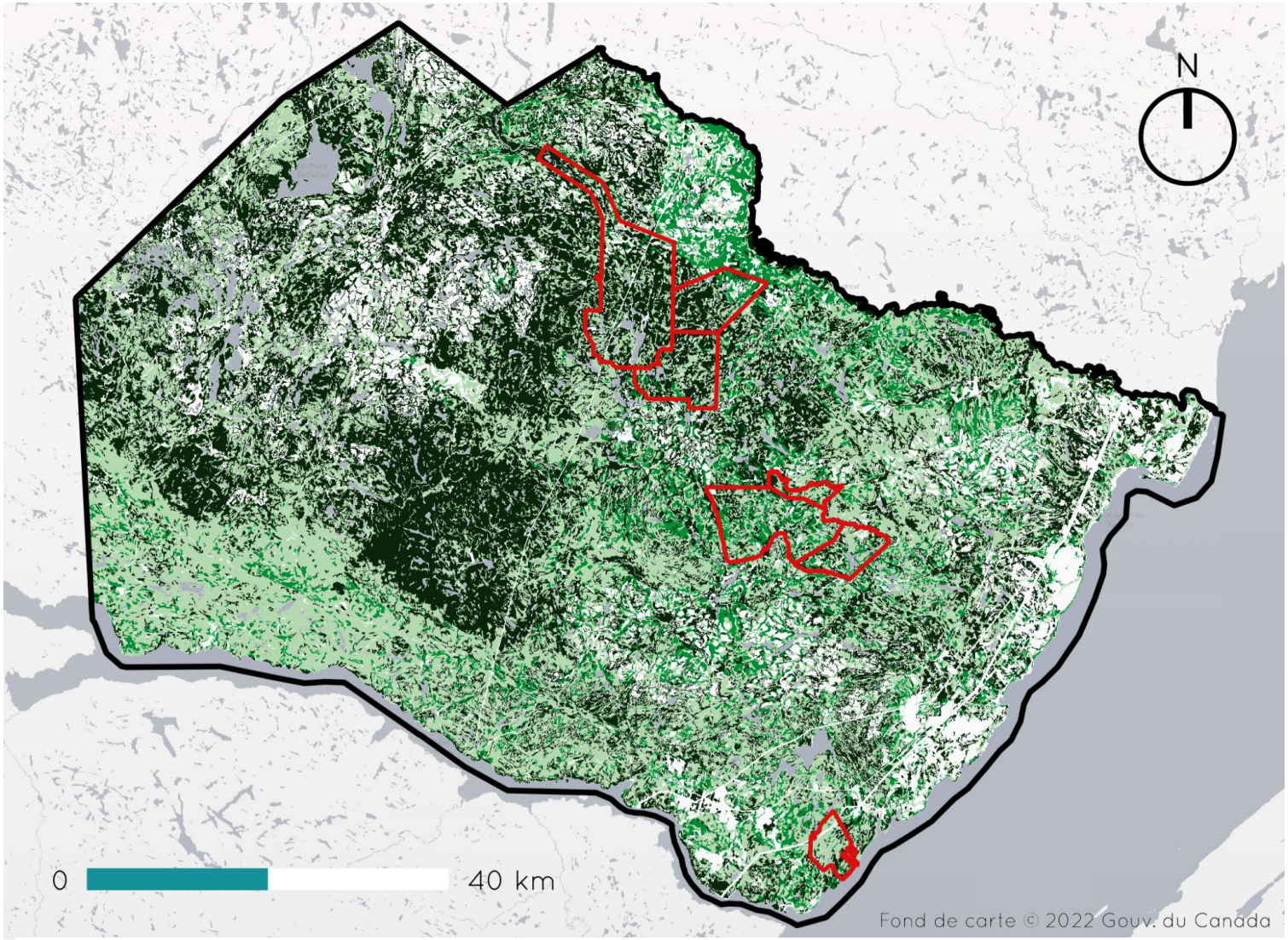
Diversité fonctionnelle


Espèces dominantes sur le territoire
selon leur appartenance au type de forêt
%
Feuillu
Mixte
Résineux
40
35
30
25
20
15
10
5
0
Sapin baumier
Épinette noire
Bouleau à papier
Épinette blanche
Peuplier faux-tremble
Érable rouge
Bouleau jaune
Autres
Pin gris
Thuya occidental
1
1
5
1
5
2B
3B
-
1
1
3A
Groupes fonctionnels

Diversité fonctionnelle
sur le territoire d'Essipit



Types de couvert forestier

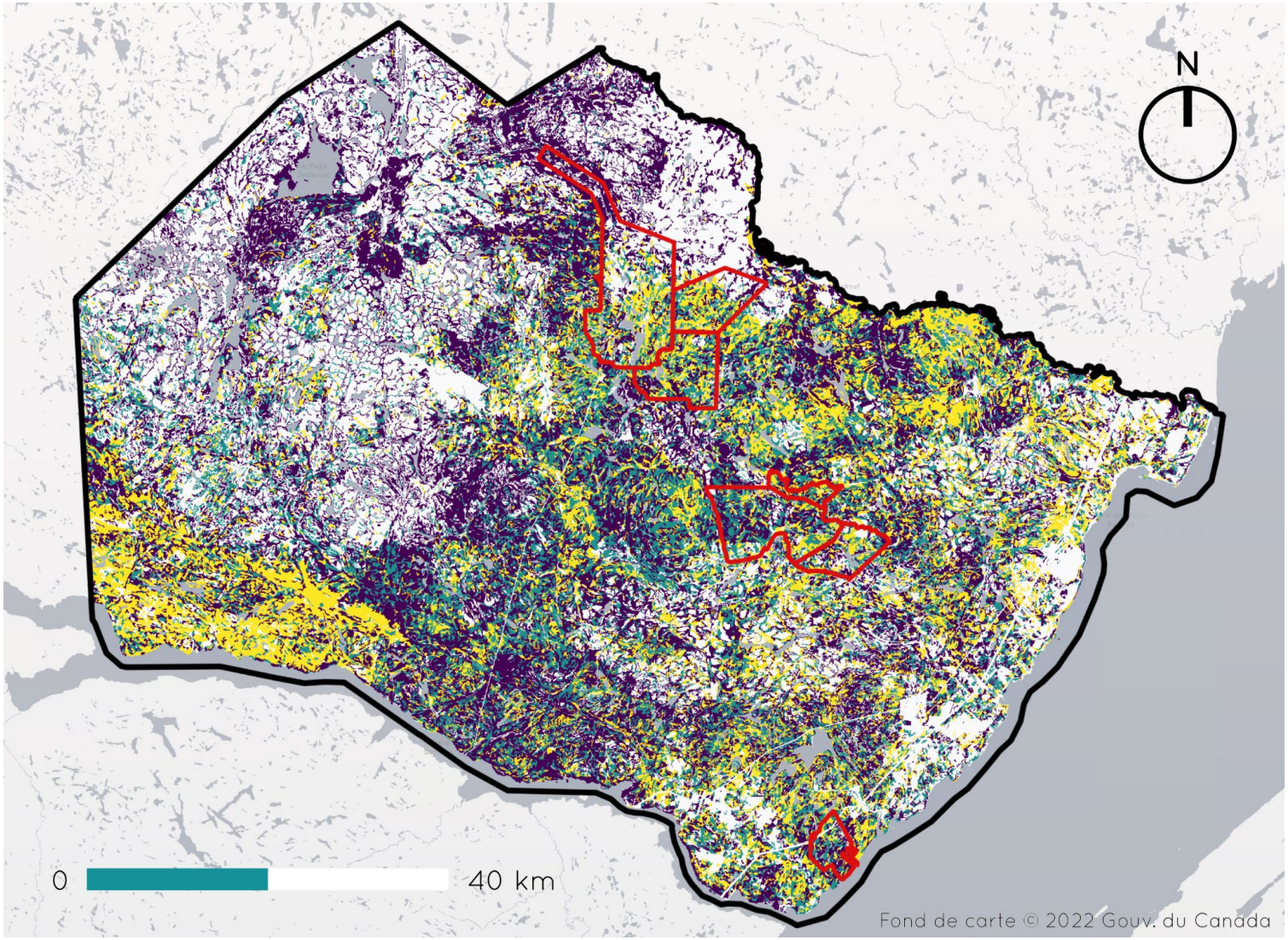


Types de peuplements forestiers

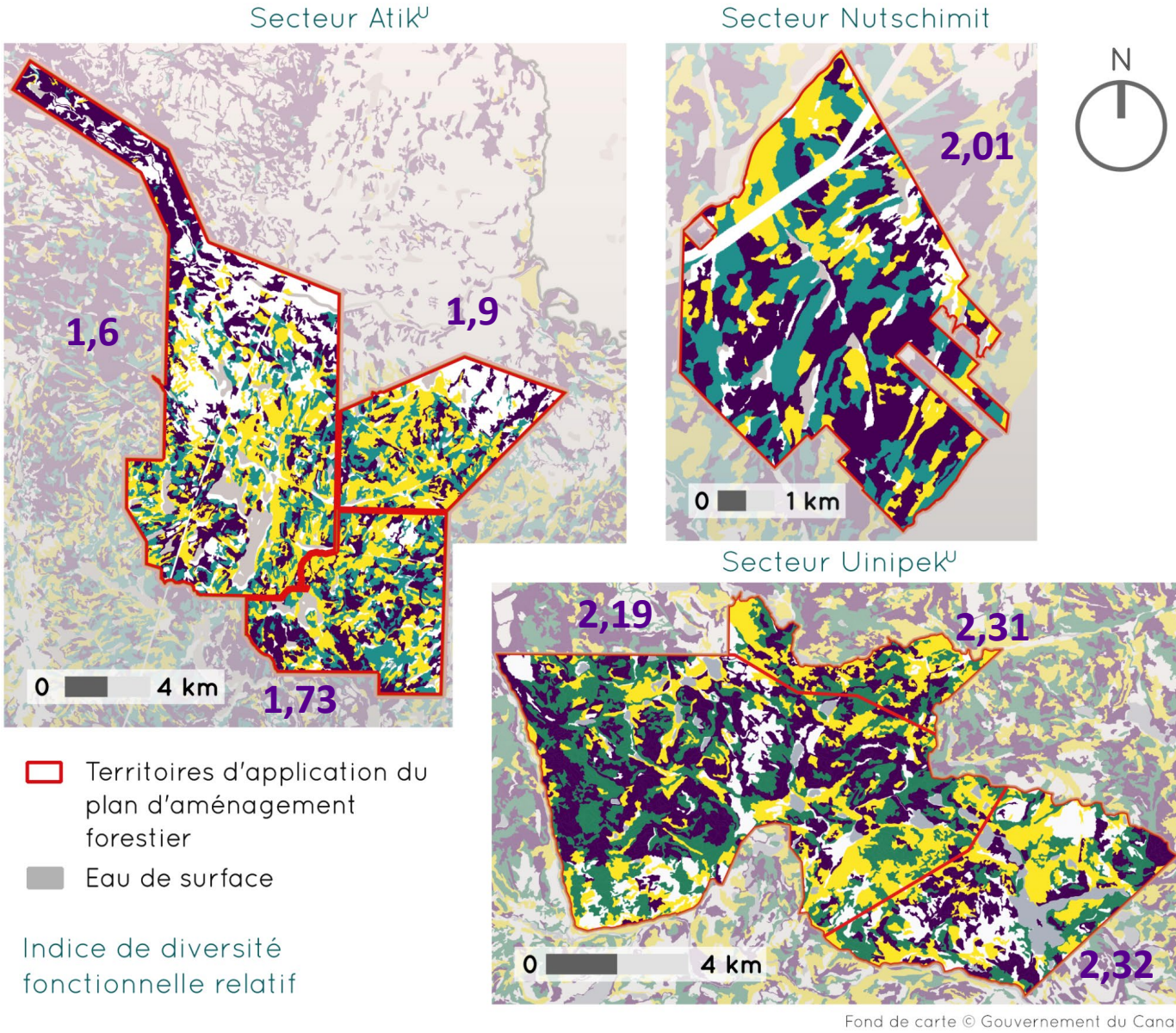
- Résineux (49,4 %)
- Mixtes (38,7 %)
- Feuillus (11,8 %)

- Zone d'étude d'Essipit
- Territoires d'application du plan d'aménagement forestier
- Eau de surface

Indice de diversité fonctionnelle relatif aux types de couvert forestier



Indice de diversité fonctionnelle relatif aux types de couvert forestier



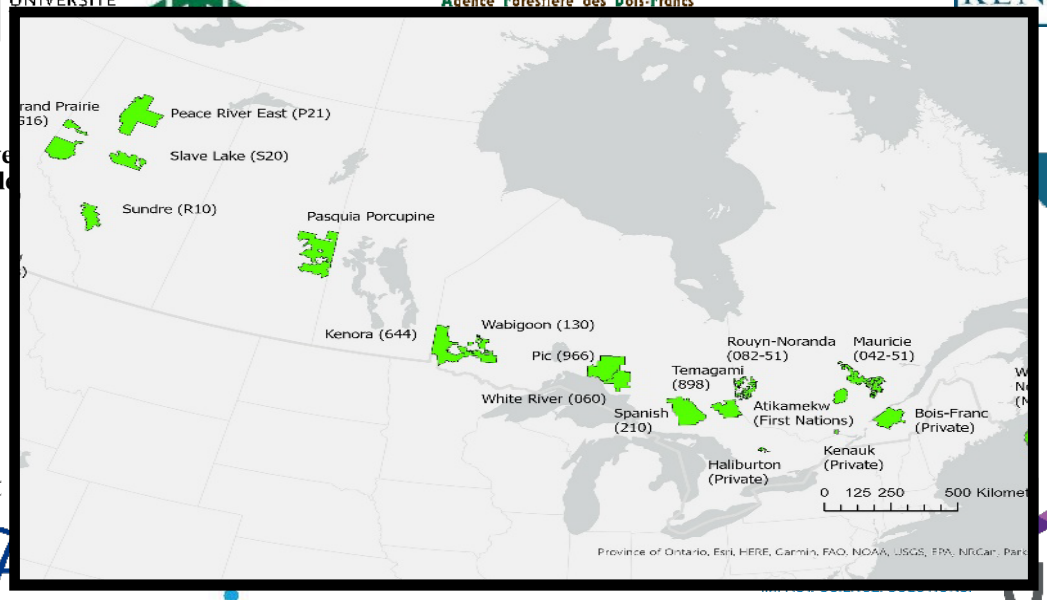
Vulnérabilités

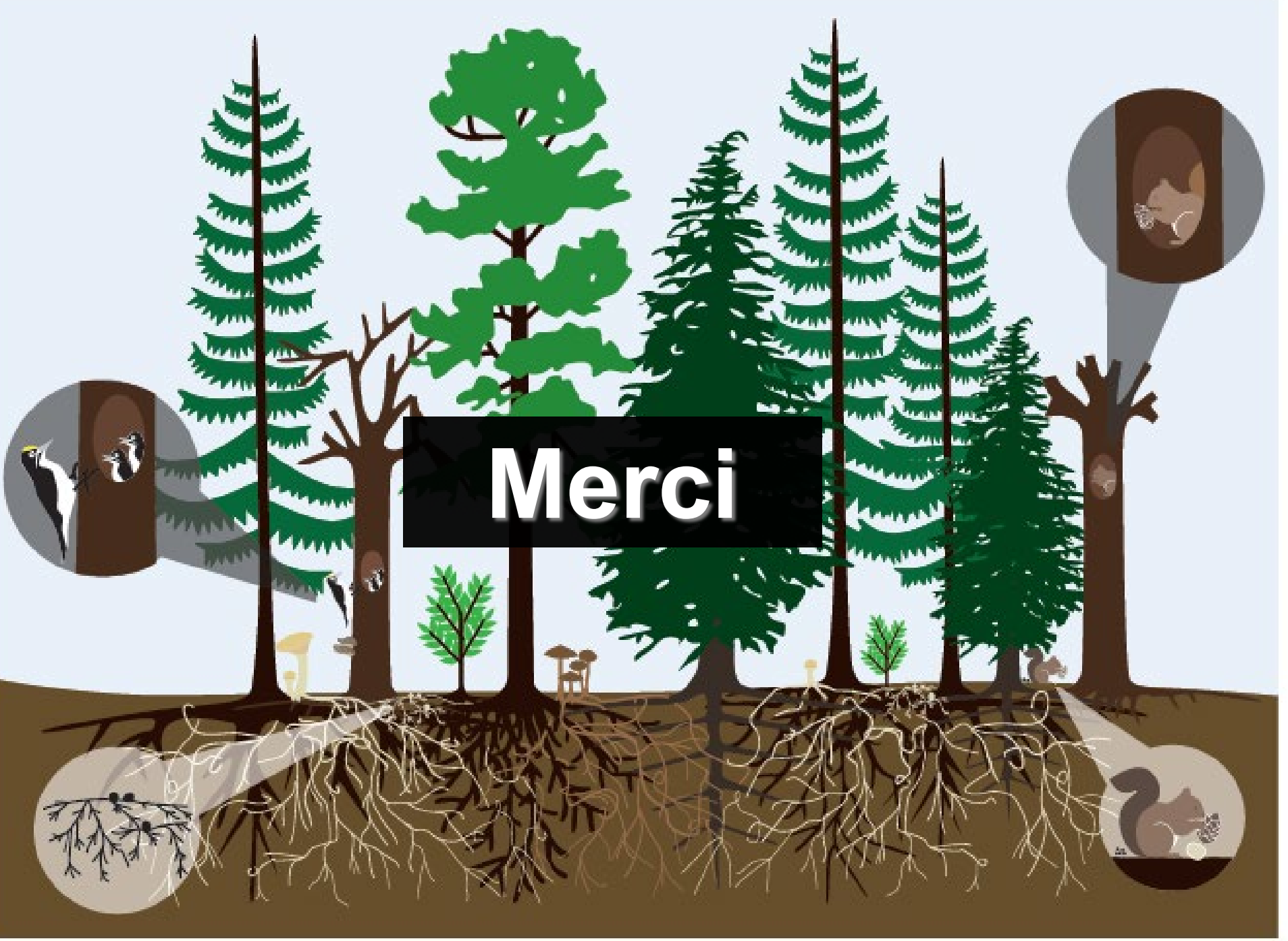
Vulnérabilité des espèces face aux menaces

Les espèces les plus abondantes sur le territoire d'Essipit		Menaces climatiques associée	Menaces biotiques associée
Abies balsamea	**Sapin baumier**	Sécheresse, vent, gradients de température	Puceron lanigère du sapin, Spongieuse asiatique
Picea mariana	**Épinette noire**	Sécheresse, Verglas, Vent	NA
Betula papyrifera	**Bouleau à papier**	Sécheresse, Gradients de température	Spongieuse asiatique, Spongieuse européenne, Longicorne asiatique
Picea glauca	**Épinette blanche**	-	NA
Populus tremuloides	**Peuplier faux-tremble**	Sécheresse, Verglas, Vent	Spongieuse asiatique, Spongieuse européenne, Longicorne asiatique
Acer rubrum	**Érable rouge**	Sécheresse	Champignon fusarium et scolyte, Spongieuse asiatique Longicorne asiatique, Phalène brumeuse
Betula alleghaniensis	**Bouleau jaune**	Gradients de température, sécheresse	Spongieuse asiatique, Spongieuse européenne Longicorne asiatique
Pinus banksiana	**Pin gris**	-	guêpe perce-bois, Spongieuse asiatique
Thuja occidentalis	**Thuya occidental**	Sécheresse	Spongieuse asiatique

Un plan « Marshall » pour la forêt Québécoise

- **Ne plus planter ou favoriser QUE des espèces considérées commerciales aujourd'hui**
- **Les espèces présentes localement ne sont peut-être pas bien adaptées ou assez diversifiées pour affronter les rigueurs et incertitudes climatiques et biotiques futures**
- ***LE PASSÉ N'EST PLUS GARANT DU FUTUR***
- ***NE PLUS PLANTER DES MONOCULTURES***
- **Favoriser des espèces diversifiés au niveau de leur fonctionnement**
- **Penser bois et carbone, biodiversité, espèces clés, eau, santé mentale, résilience, stabilité, etc.**
- ***1+1 = 3 OU MÊME 5: NOTRE MEILLEURE ALLIÉE…LA DIVERSITÉ***
- **Il faut penser globalement et agir localement**


Peace River East (P21)
Slave Lake (S20)
Sundre (R10)
Pasquia Porcupine
Kenora (644)
Wabigoon (130)
Pic (966)
White River (060)
Spanish (210)
Temagami (898)
Rouyn-Noranda (082-51)
Mauricie (042-51)
Atikamekw (First Nations)
Bois-Franc (Private)
Kenauk (Private)
Haliburton (Private)
0 125 250 500 Kilomet


Merci