How to Increase the Resiliency of Your Woodlot in the Face of Climate Change & *Close Encounters of the Third Kind!*

Prof. Christian Messier, *Université du Québec à Montréal (UQAM) et (UQO), Chaire de recherche du Canada sur la resilience des forêts, Institut des Sciences de la Forêt Tempérée (ISFORT)*

Overview of the talk

- The tree, a complex being
- Uncertainties and threats
- New concepts in ecology & forestry
- How to increase the resilience of your woodlot?

Overview of the talk

- ***The tree, a complex being***
- Uncertainties and threats
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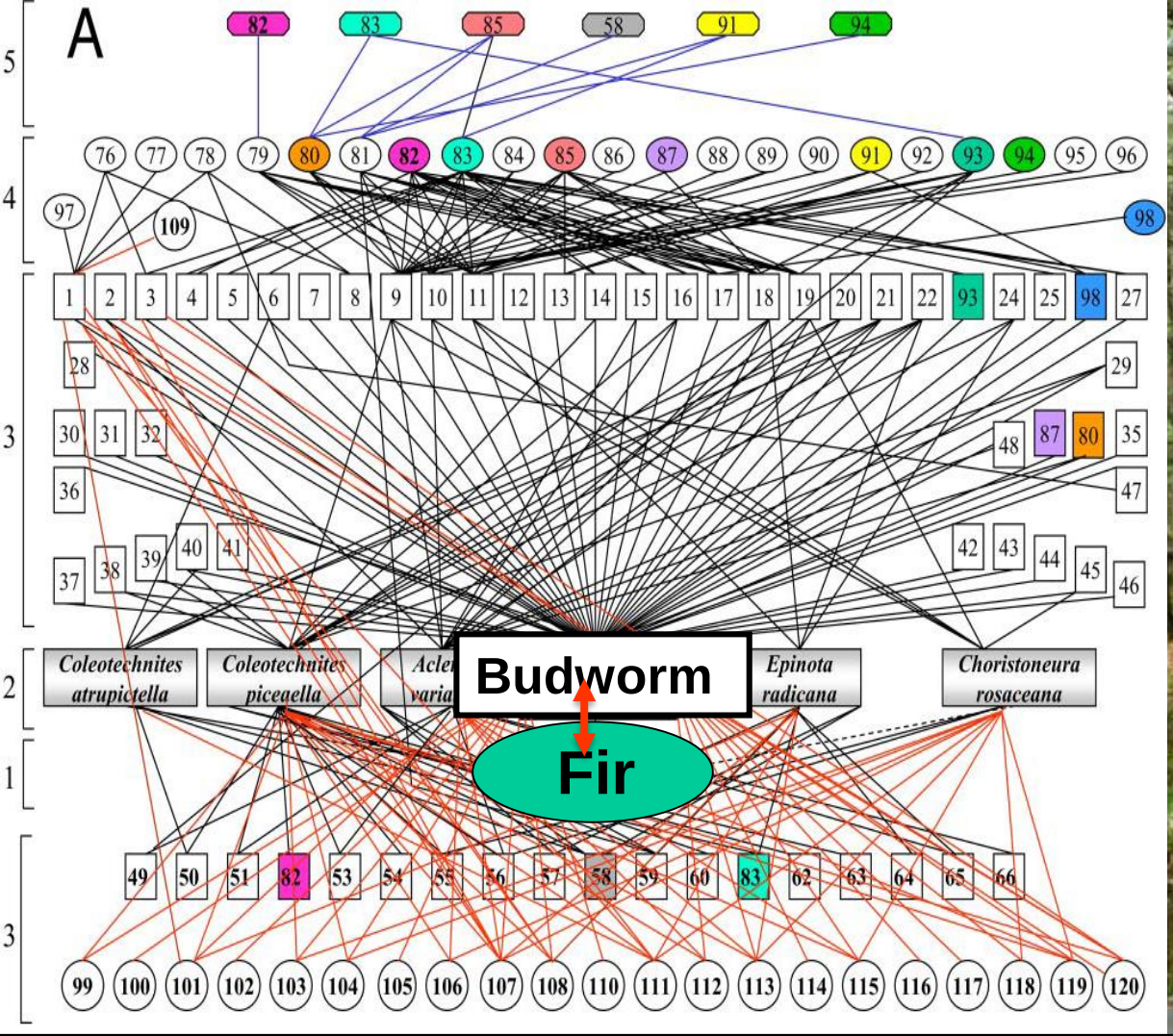
Trees are complex and social beings

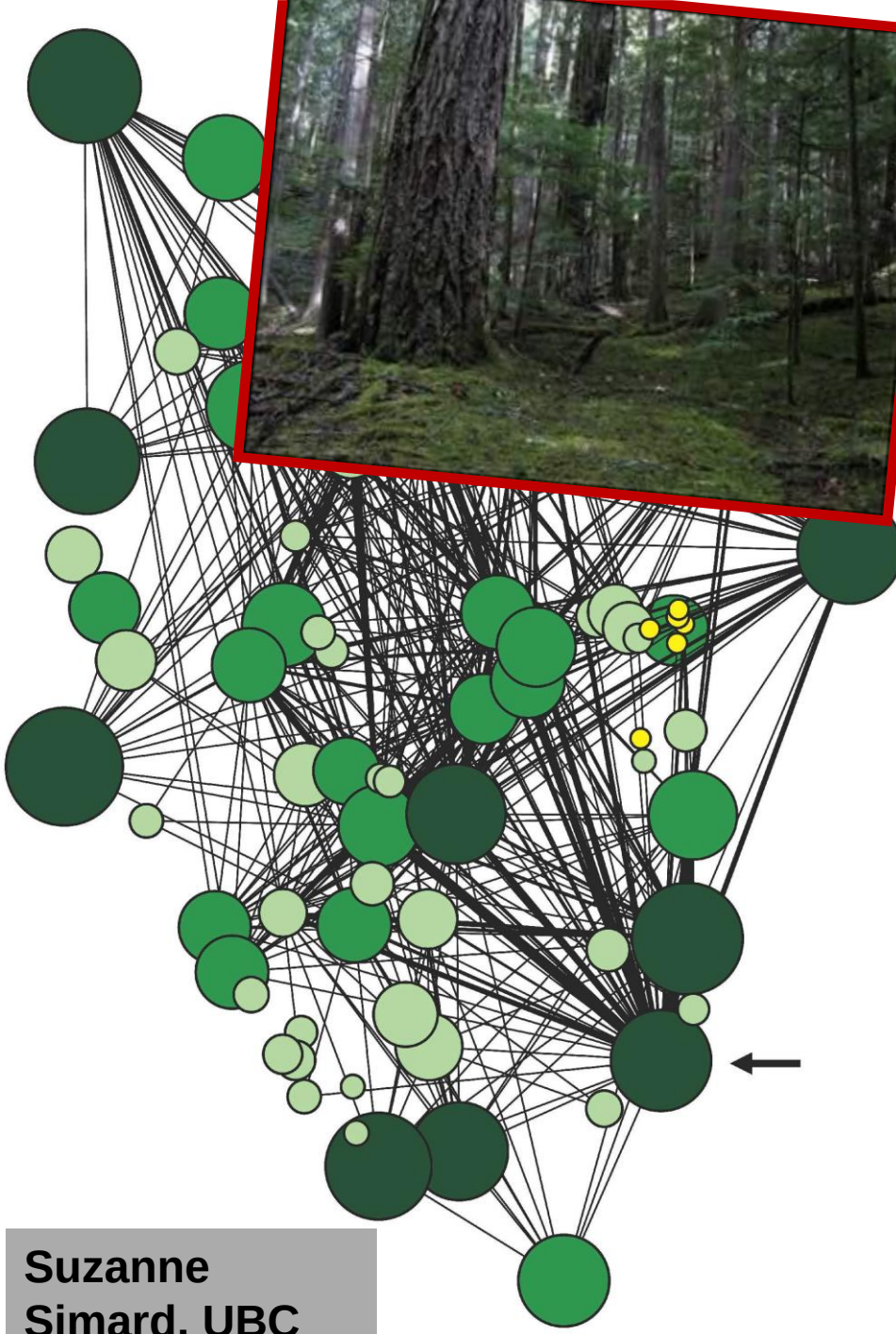


Aggregated food web of the Balsam fir: ***1 host plant, 6 herbivores, 66 primary parasitoids and 21 primary entomopathogens, 23 secondary parasitoids and 1 secondary entomopathogen, and 6 tertiary parasitoids*.**

From Eveleigh et al. 2007. *Proceedings of the National Academy of Science*

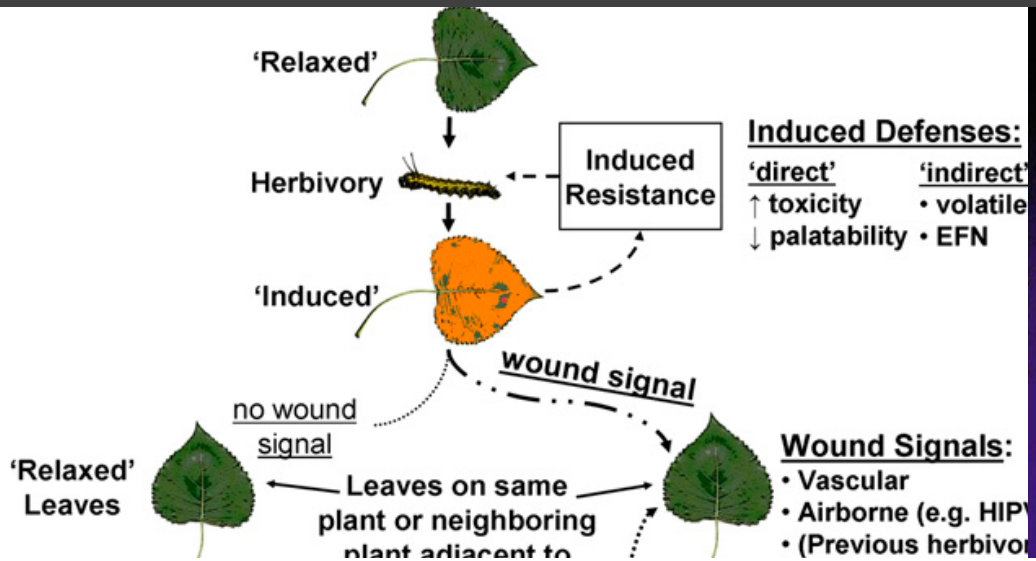
They do trade

Annie Desrochers, UQAT



Suzanne Simard, UBC

They exchange information!



Update on Plant Defense Priming against Herbivores

Plant Defense Priming against Herbivores: Getting Ready for a Different Battle[1]

Christopher J. Frost*, Mark C. Mescher, John E. Carlson, and Consuelo M. De Moraes

Center for Chemical Ecology (C.J.F., M.C.M., J.E.C., C.M.D.M.), Department of Entomology (C.J.F., M.C.M., C.M.D.M.), and School of Forest Resources (C.J.F., J.E.C.), Pennsylvania State University, University Park, Pennsylvania 16802

Plants have evolved various strategies to defend themselves against herbivores and pathogens. Although some of these strategies are constitutive, i.e. present at all times, others are induced only in response to

environmental cue that reliably indicates an increased probability of encountering a biotic stress, but a primed state may also persist as a residual effect following an initial exposure to the stress. For example, the classic

As us, they live better with a diverse microbiome

doi:10.1038/nature22399

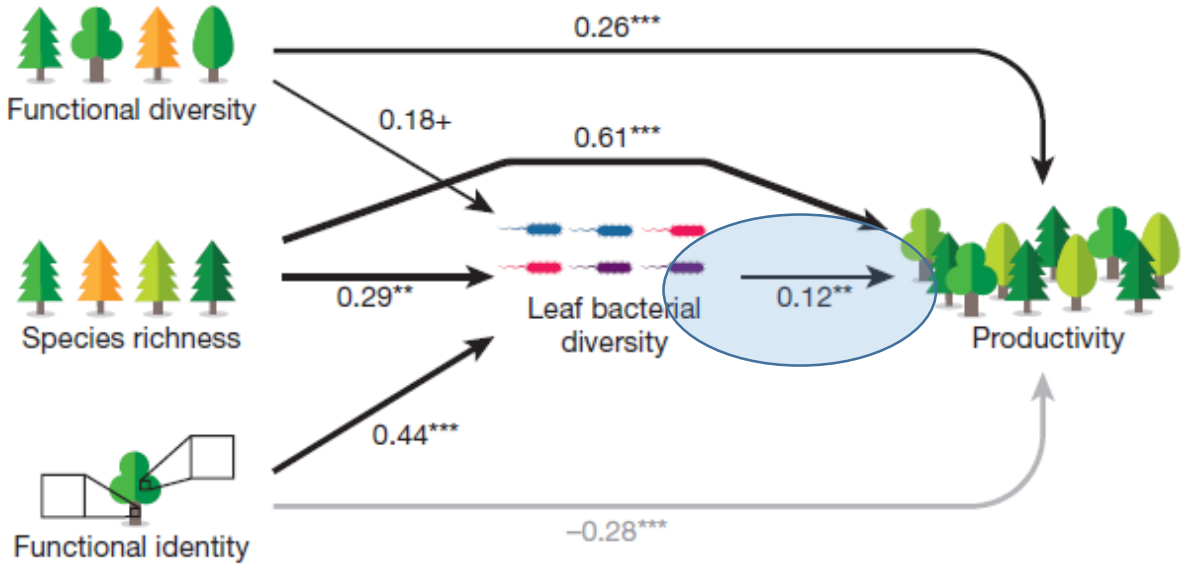


Figure 2 | Structural equation model of plant diversity and identity explaining leaf bacterial diversity and plant community productivity.

Overview of the talk

- The tree, a complex being
- ***Uncertainties and threats***
- New concepts in ecology & forestry
- How to increase the resilience of your woodlot?

Changing & uncertain environmental and socio-economic conditions

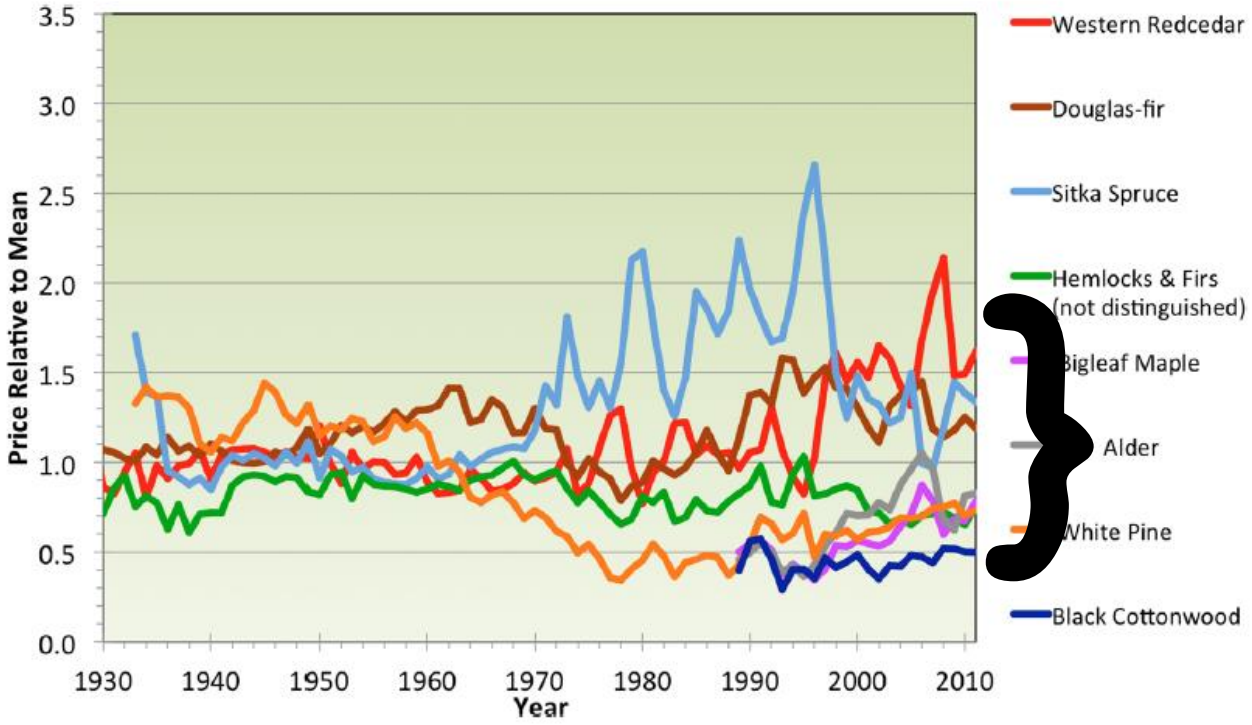
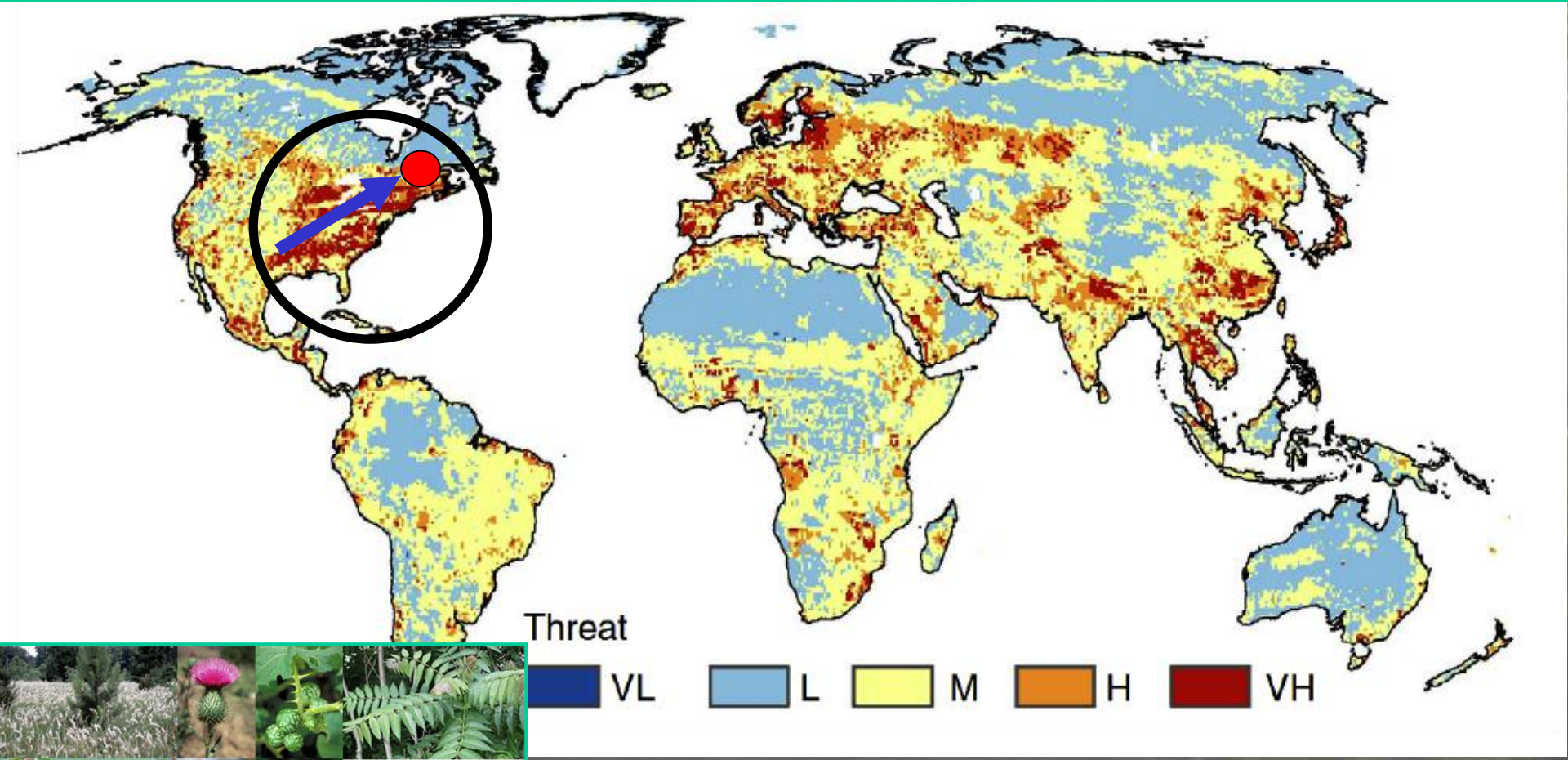
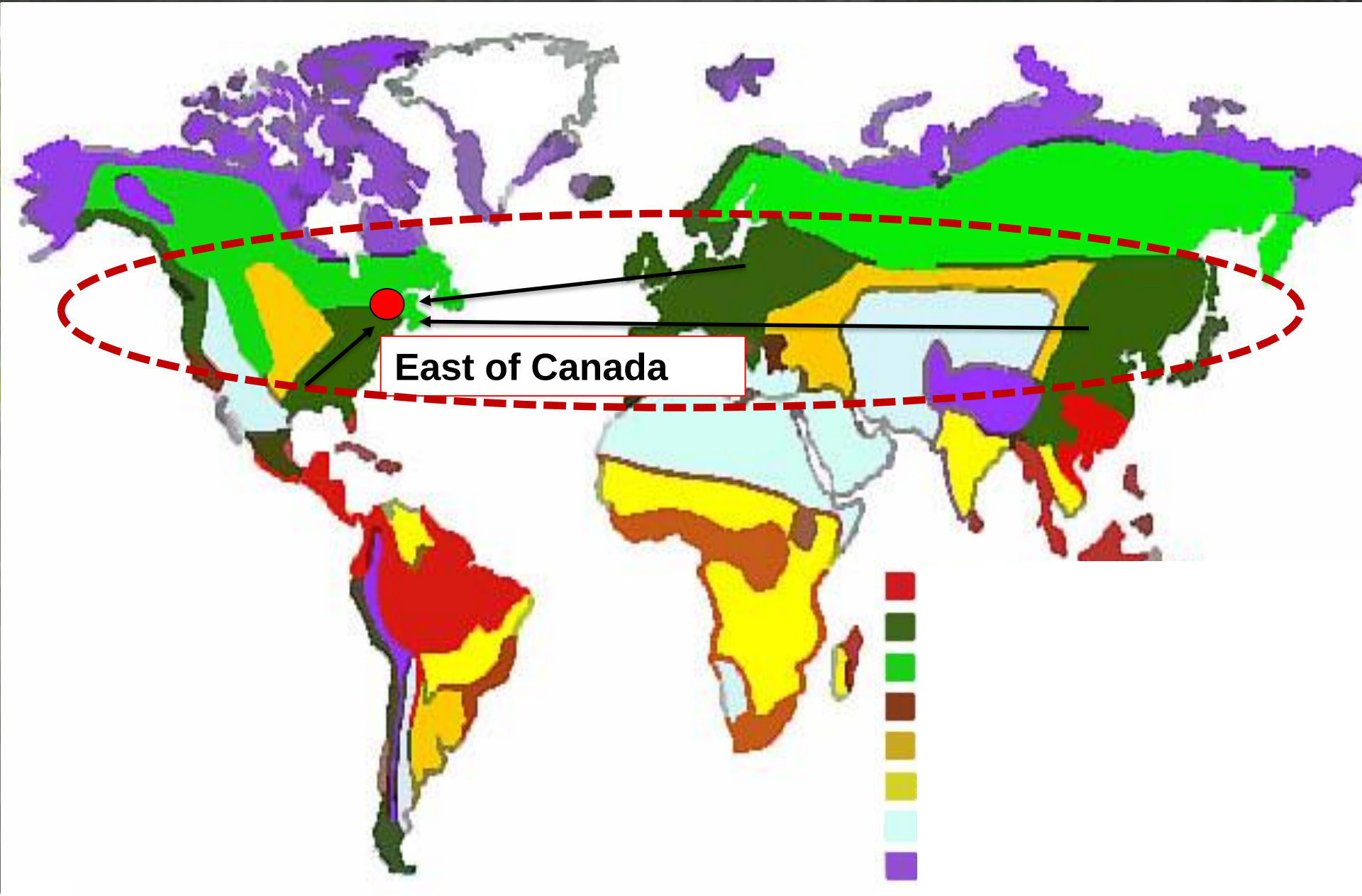


Fig. 6. Fluctuations in the relative price of logs for coastal tree species in British Columbia, Canada. Bigleaf maple, red alder and black cottonwood did not have marketable values prior to 1990. British Columbia Ministry of Forests, Lands and Natural Resource Operations, Timber Pricing Branch, *unpublished data*.

Threats from exotic pests and diseases



Biomes of the world



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]

Table 1. Eighteen nonnative forest insects and pathogens in North America with current or potential future high impacts.

Common name	Scientific name	Pathway	Hosts	Impacts	Geographic region at risk
Established species with high impact					
Chestnut blight	*Cryphonectria parasitica* (Murrill) Barr.	live plants	American chestnut, chinkapin	chestnuts	eastern deciduous forest
White pine blister rust	*Cronartium ribicola* J. C. Fisch	live plants	five-needle pines (section Quinquefolia in genus *Pinus*)	western	continent-wide; greatest impacts in West
Phytophthora dieback	*Phytophthora cinnamomi* Rands	unknown	many hosts including American chestnut, white oak, shortlea pine, and Fraser fir, fruit trees	e trees	continent-wide
Port-Orford-cedar root disease	*Phytophthora lateralis* Tucker & Milbrath	probably live plants	Port-Orford cedar	virtually eliminated host from lower	Klamath Mountains, California and Oregon
Beech bark disease (scale insect + fungus)	*Cryptococcus fagisuga* Lindinger + *Nectria coccinea* var. *faginata* (Pers.) Fr.	live plants	American beech	h; often of root	deciduous forests of East and Midwest
European gypsy moth	*Lymantria dispar dispar* L.	deliberate introduc-tion	many hosts includes oaks, aspen, willow, and birch	oliations sts	deciduous forests of East and Midwest
Hemlock woolly adelgid	*Adelges tsugae* Annand	live plants	Eastern and Carolina hemlock	cted stands	Appalachians, Northeast and upper Midwest

Châtaigner

Pin blanc

Chêne blanc

Hêtre

Tous les feuillus

Pruche

Sudden oak death	*Phytophthora ramorum* S. Werres, A.W.A.M. de Cock	live plants	>100 spp., especially tanoak [illegible] several western oak specie[illegible] some eastern oaks vulnera[illegible]	[illegible]uccumb, while [illegible]or impacts	Coastal California and Oregon; could potentially spread to eastern forests
Redbay ambrosia beetle + fungus (laurel wilt disease)	*Xyleborus glabratus* Eichhoff + *Raffaelea lauricola* Harrington and Fraedrich	wood packaging	numerous probable hosts including redbay and pondberry & pondspice shrubs;	predicted >90% reduction in redbay basal area within 15 yr (25 yr after first detected)	eastern deciduous forests; greatest impacts in southeastern coastal plain
Emerald ash borer	*Agrilus planipennis* Fairmaire	wood packaging	all North American ash spec[illegible]	[illegible] some species [illegible] limited resistance	eastern deciduous forest; riparian areas in Great Plains and West, landscape plantings continent-wide
Dutch elm disease	*Ophiostoma ulmi* (Buisman) Nannf. & *O. novo-ulmi* Brasier; vectored by several insects including *Scolytus multistriatus* and *S. schevyrewi*	wood products	American elm; other native elms, e.g., red or slippery are more resistant	[illegible] areas; elms [illegible]uced in [illegible]iparian woodlands	continent-wide
Butternut canker	*Sirococcus clavigignenti-juglan-dacearum* N. B. Niar, Kostichka & Kuntz	unknown	butternut (white walnut)	[illegible]ernut; over [illegible]ternut in the [illegible]	deciduous forests of Northeast and Midwest
Balsam woolly adelgid	*Adelges piceae* Ratzeburg	live plants	most true fir species (*Abies*) North Americ[illegible]	[illegible] firs; severe [illegible]r on Southern [illegible]ountaintops and [illegible]s	Northeast; Southern Appalachians; Northwest

Chênes

Frênes

Orme

Noyer

Should we worry?

(continued)

TABLE 1 Continued

Common name	Scientific name	Pathway	Hosts	Impacts	Geographic region at risk
Established, potential for significant effects in the future					
Asian longhorned beetle	*Anoplophora glabripennis* Motschulsky	wood packaging	woody vegetation in 15 fam[illegible] especially maples, elms, a[illegible] willows	[illegible] in both urban [illegible]; eradication being attempted	continent-wide deciduous forests
Winter moth	*Operophtera brumata* L.	unknown	many species including oak[illegible] maples, cherries	[illegible] southeast-	Eastern deciduous forest
Polyphagous shot hole borer and fusarium fungus	*Euwallacea (sp. un-known) + Fusarium euwallacea*	unknown	>200 species attacked by in[illegible] >100 support the fungus; hosts killed include box elder, bigleaf maple, coast live oak	[illegible] nerable	Southern California hardwood forests, riparian and urban; potentially in Southeast
European woodwasp	*Sirex noctilio*	probably wood packaging	many pine species	[illegible]f pines in [illegible]e; modest impacts so far in United States	all ecosystems with hard pines: Southeast, Great Lakes States, western United States
Not yet established					
Asian gypsy moth & hybrids	*Lymantria dispar asiatica* Vinuskovkij	ship super-structures	>600 species, including common deciduous and coniferous trees	could have more severe impacts than European gypsy moth since has wider host range and females fly	continent-wide

Erable

Cerisiers, Érables et chênes

Pins

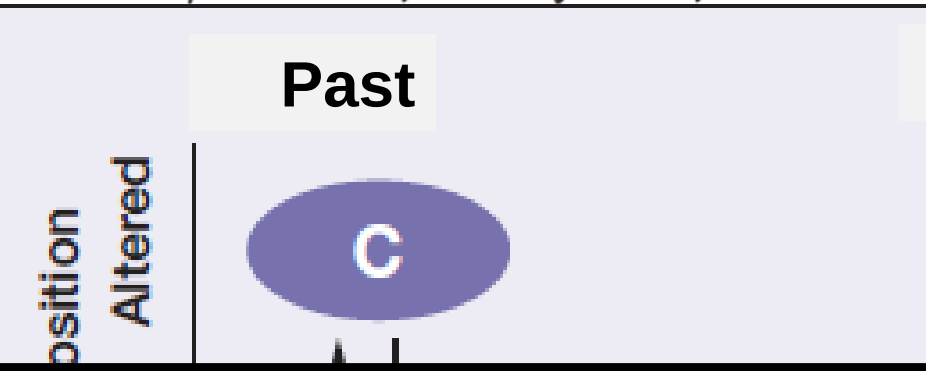
Overview of the talk

- The tree, a complex being
- Uncertainties and threats
- **New concepts in ecology & forestry**
- How to increase the resilience of your woodlot?

Novel ecosystems

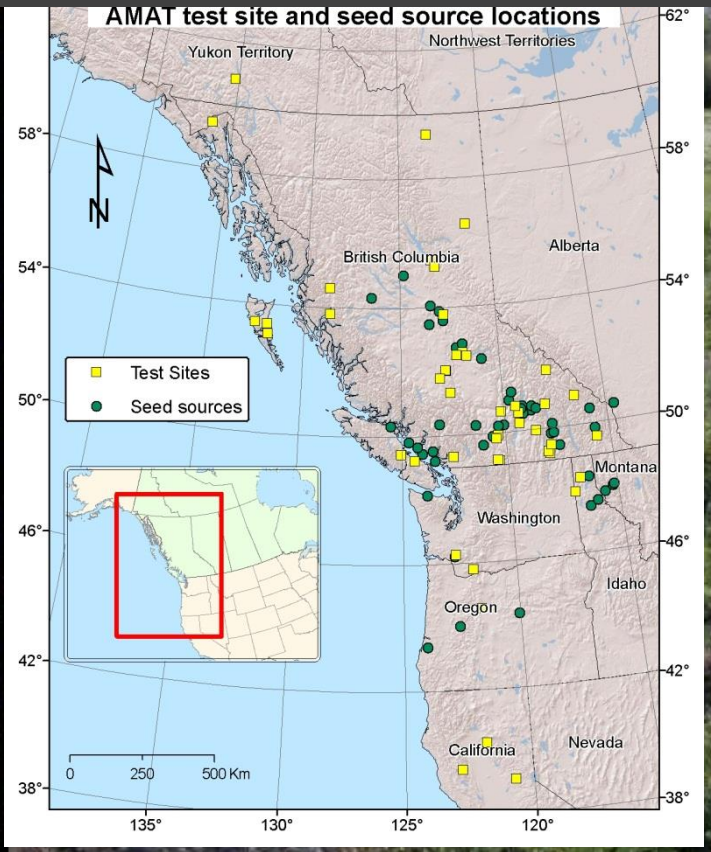
Management of novel ecosystems: are novel approaches required?

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



- *One needs to plan ou*
  not only on past con
  on future, changing a
  uncertain conditions

Assisted tree migration



- ***One need to start adapting our forest for the future conditions by modifying their genetic and specific composition***

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-

Epigenetic concept in trees

Ecology and Evolution

Open Access

Epigenetic regulation of adaptive responses of forest tree species to the environment

Katharina Bräutigam[1], Kelly J. Vining[2], Clément Lafon-Placette[3], Carl G. Fossdal[4], Marie Mirouze[5], José Gutiérrez Marcos[6], Silvia Fluch[7], Mario Fernández Fraga[8], M. Ángeles Guevara[9,10], Dolores Abarca[11], Øystein Johnsen[12], Stéphane Maury[3], Steven H. Strauss[2], [14], Carmen Díaz-Sala[11] & María-Teresa Cervera[9,10]

n, Department of Cell & Systems Biology, University of Toronto, Toronto, ON M5S 3B2, Canada
State University, Corvallis, OR 97331-5752, USA

Ecology and Evolution 2013; 3(2): 399–415

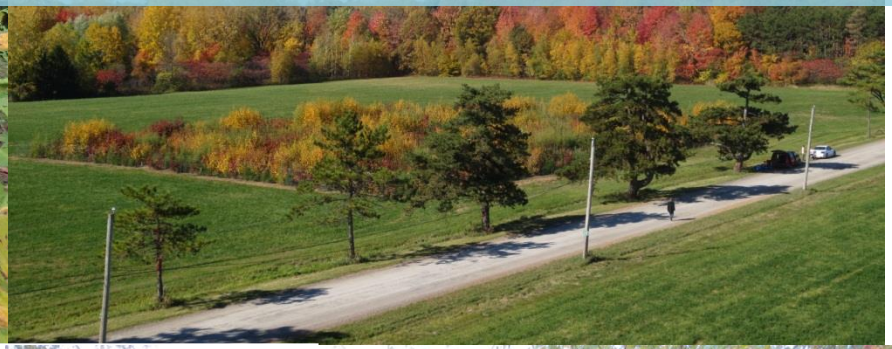
doi: 10.1002/ece3.461

Abstract

- ***One should conserve natural regeneration of species that we believe maladapted to future climatic conditions because this regeneration MIGHT BE BETTER ADAPTED THAN WE THINK***

Complementarity concepts in forests

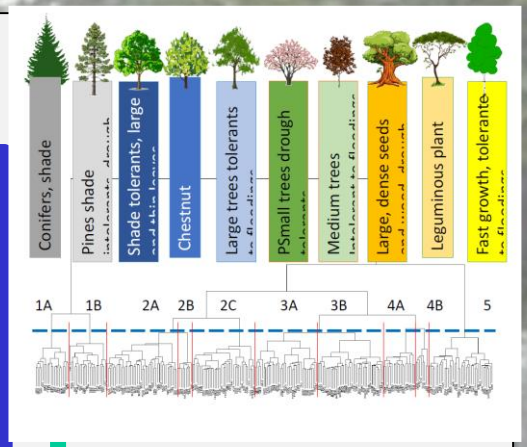
IDENT: Mixed tree species experiments



- 12 indigeneous & 7 exotics
- Mixed of 1, 2, 4 and 12 species
- Gradient of functional diversity
- 14 000 trees

High functional diversity

Low functional diversity



Group 1a

Acer saccharum

Acer rubrum

Functional diversity: 0,10

Group 2a

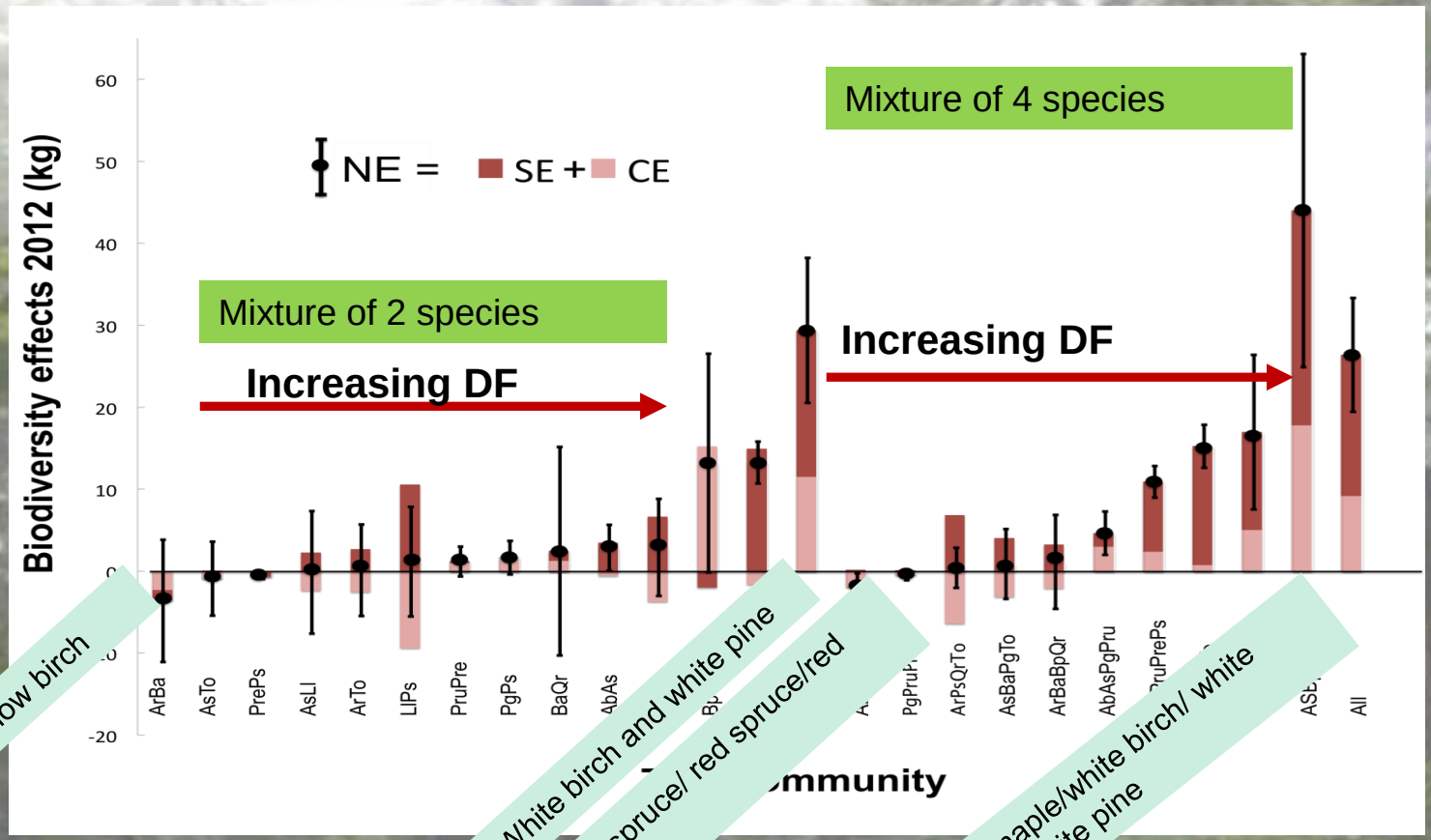
Picea glauca

Abies balsamea

Functional diversity: 0,08

Functional diversity: 0,29

Functional diversity: 0,23



- ***Maintaining biodiversed tree communities is ADVANTAGEOUS***

Overview of the talk

- The tree, a complex being
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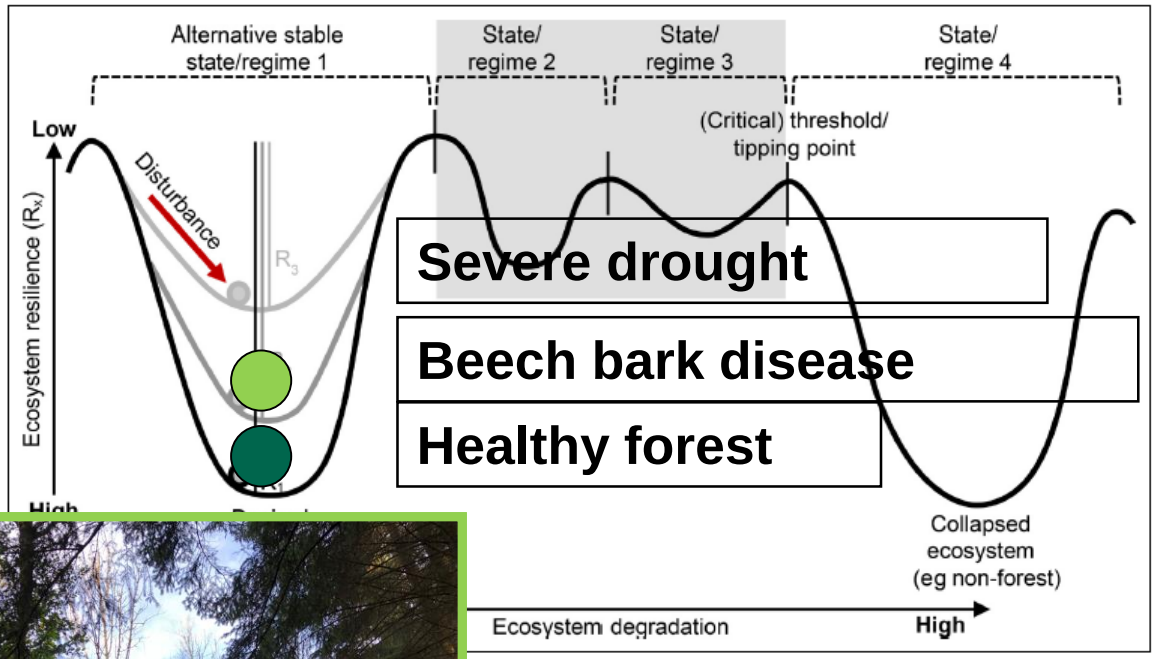
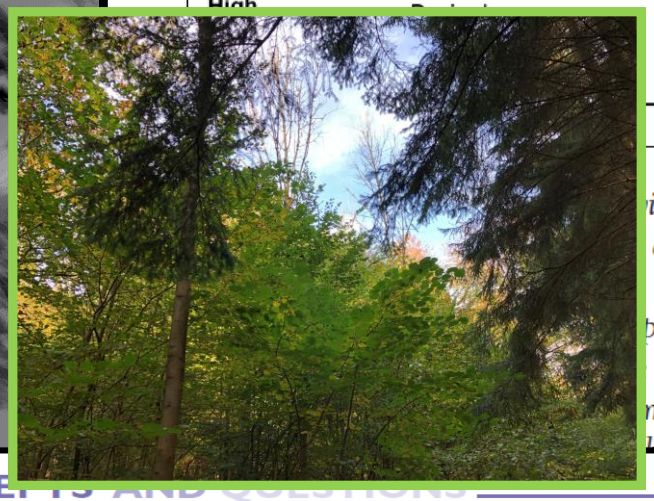
- ***How to increase the resilience of your woodlot?***

- What is resilience?

Resilience: **Capacity to *recover* quickly or to *adapt* following one or many disturbances or stress so to maintain the functionality and services of the ecosystem (adapted from Gunderson & Holling 2002).**

Resilience & collapse





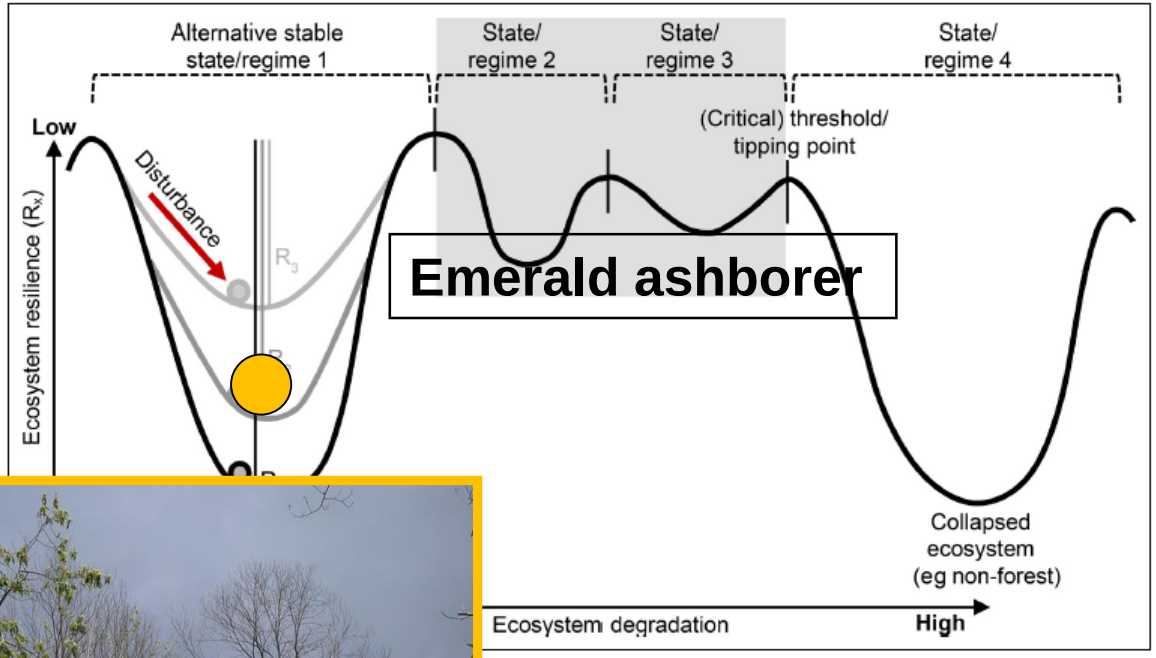
ing links between ecosystem collapse and a range of depth of a basin indicates the resilience of a particular and collapsed ecosystem states displaying highest presents the current state of the ecosystem. The red ecosystem. Disturbance may be cumulative, slowly m R_1 to R_2 to R_3), or may be sudden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

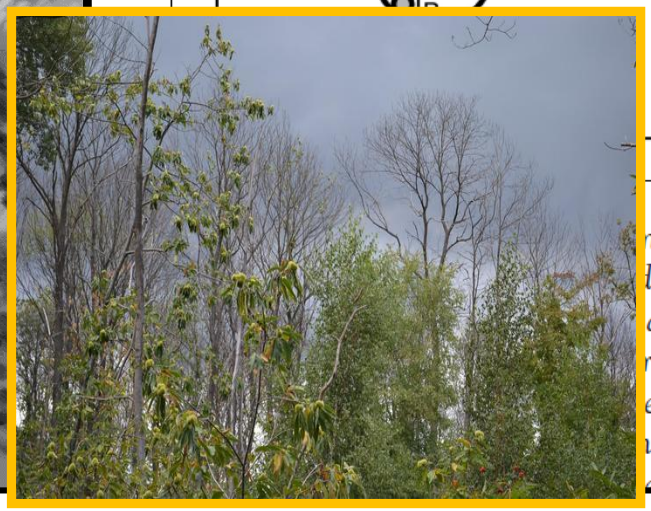
Avoiding ecosystem collapse in managed forest ecosystems

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

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

Résilience et effondrement





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CONCEPTS AND QUESTIONS

Avoiding ecosystem collapse in managed forest ecosystems

561

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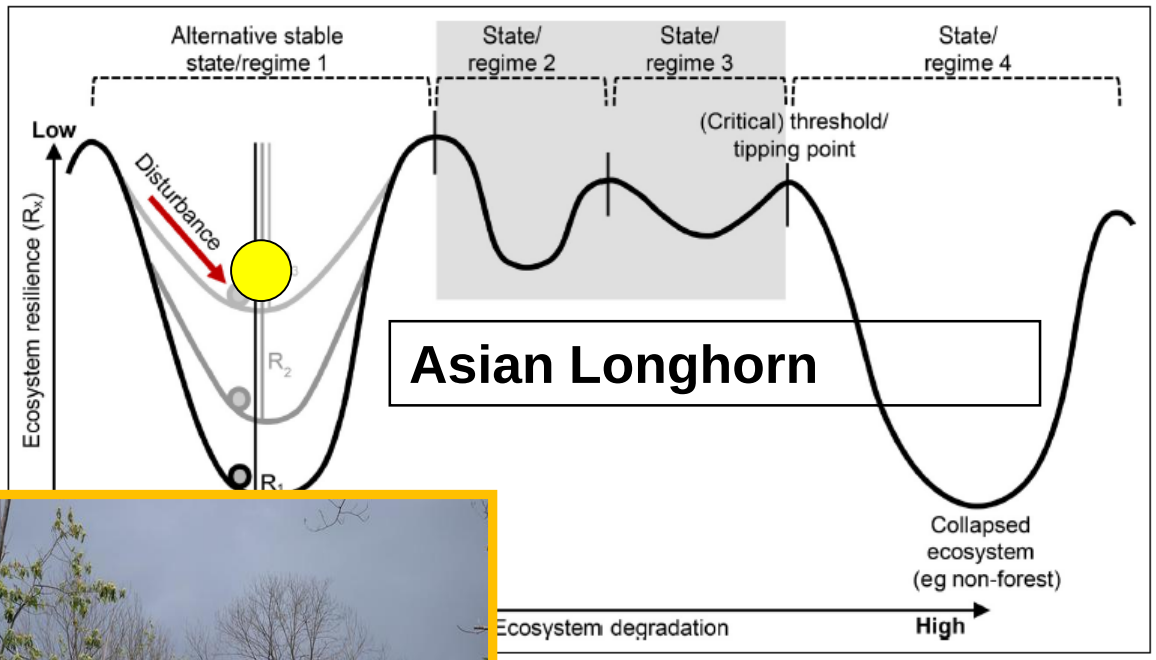
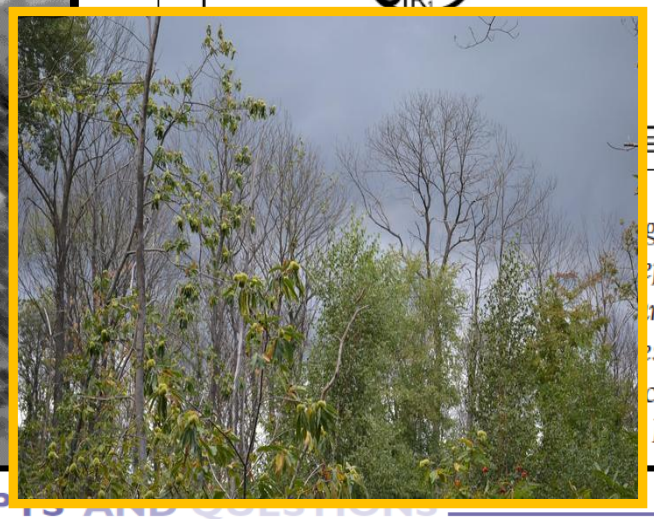
Resilience & collapse



Asian Longhorn



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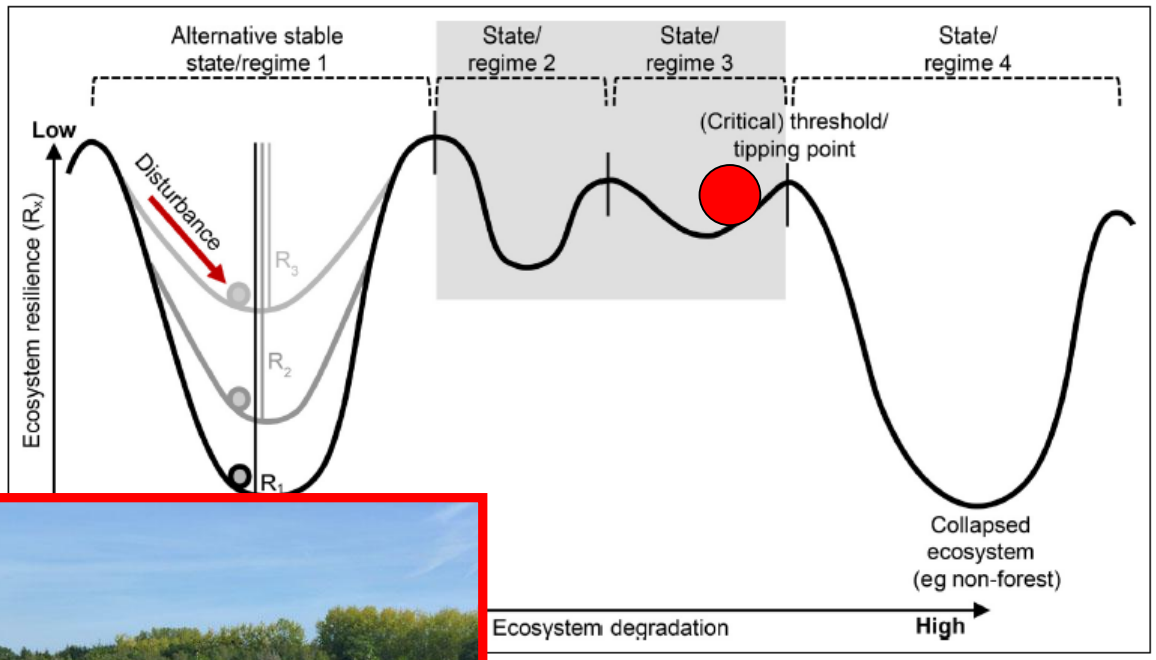
Resilience & collapse



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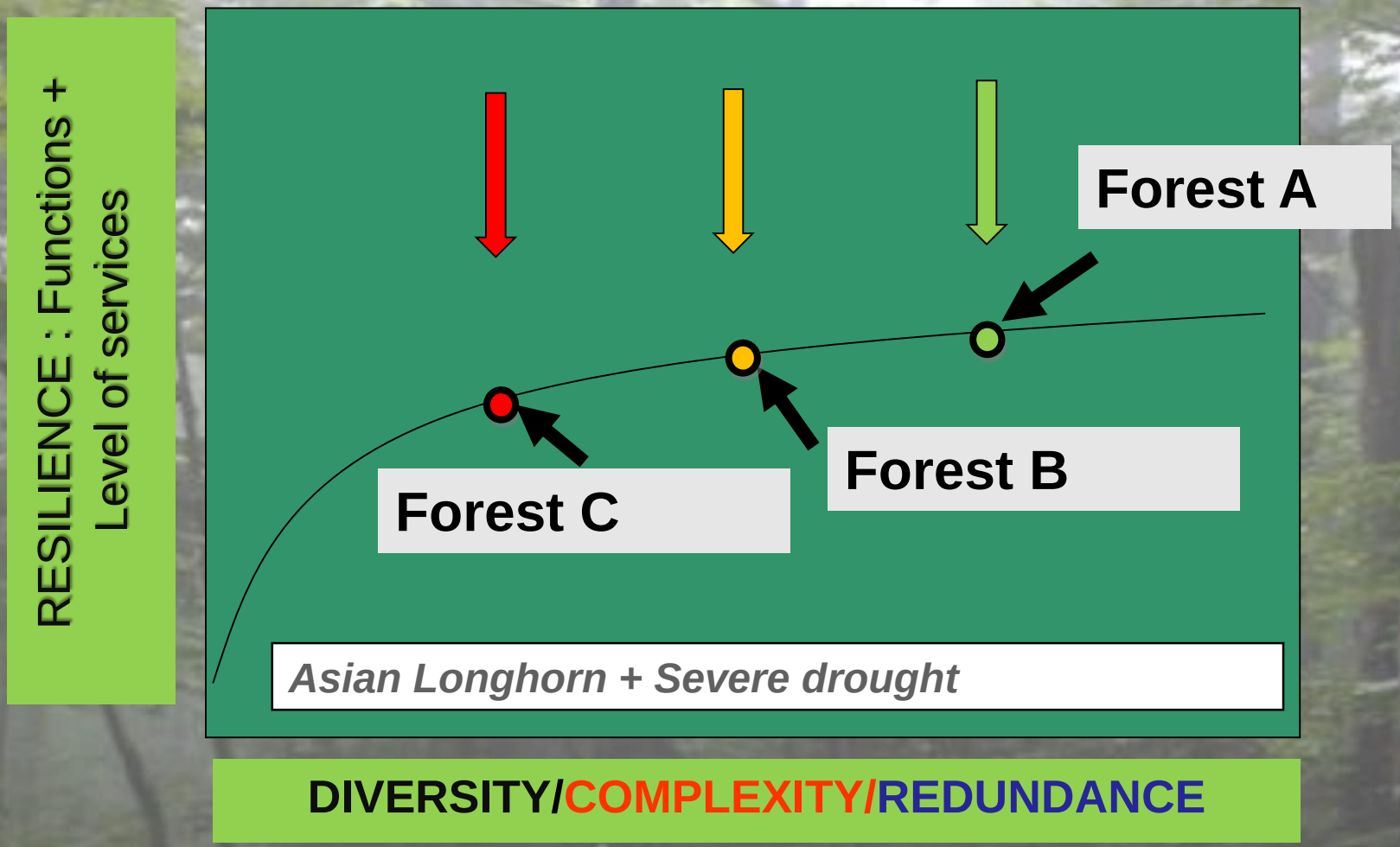
RESILIENCE



Adapted from: *Loreau, M., S. Naeem, and P. Inchausti, eds. 2002. Biodiversity and ecosystem functioning: synthesis and perspectives. Oxford, UK: Oxford University Press.*

- **But, what can we do to help maintain or increase the resilience of our forest?**

  - **Diversify « intelligently » in relation to known and unknown threats using a functional diversity approach**

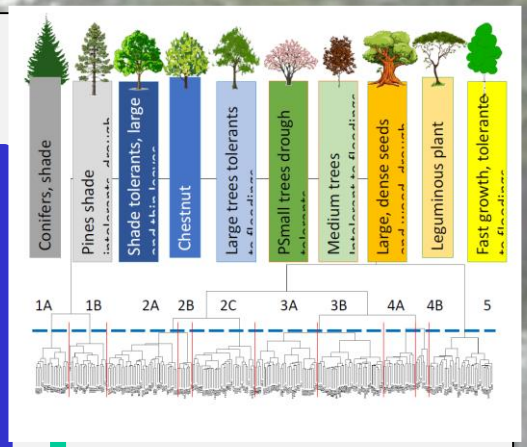
➢ Using Functional DIVERSITY <u>instead of species diversity</u>

- Specific leaf area (SLA)
- Type of seed dispersal
- Rooting depth

- Mycorrhizal type
- Wood density
- Bark thickness
- Ability to resprout

High functional diversity

Low functional diversity



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Acer saccharum

Acer rubrum

Functional diversity: 0,10

Group 2a

Picea glauca

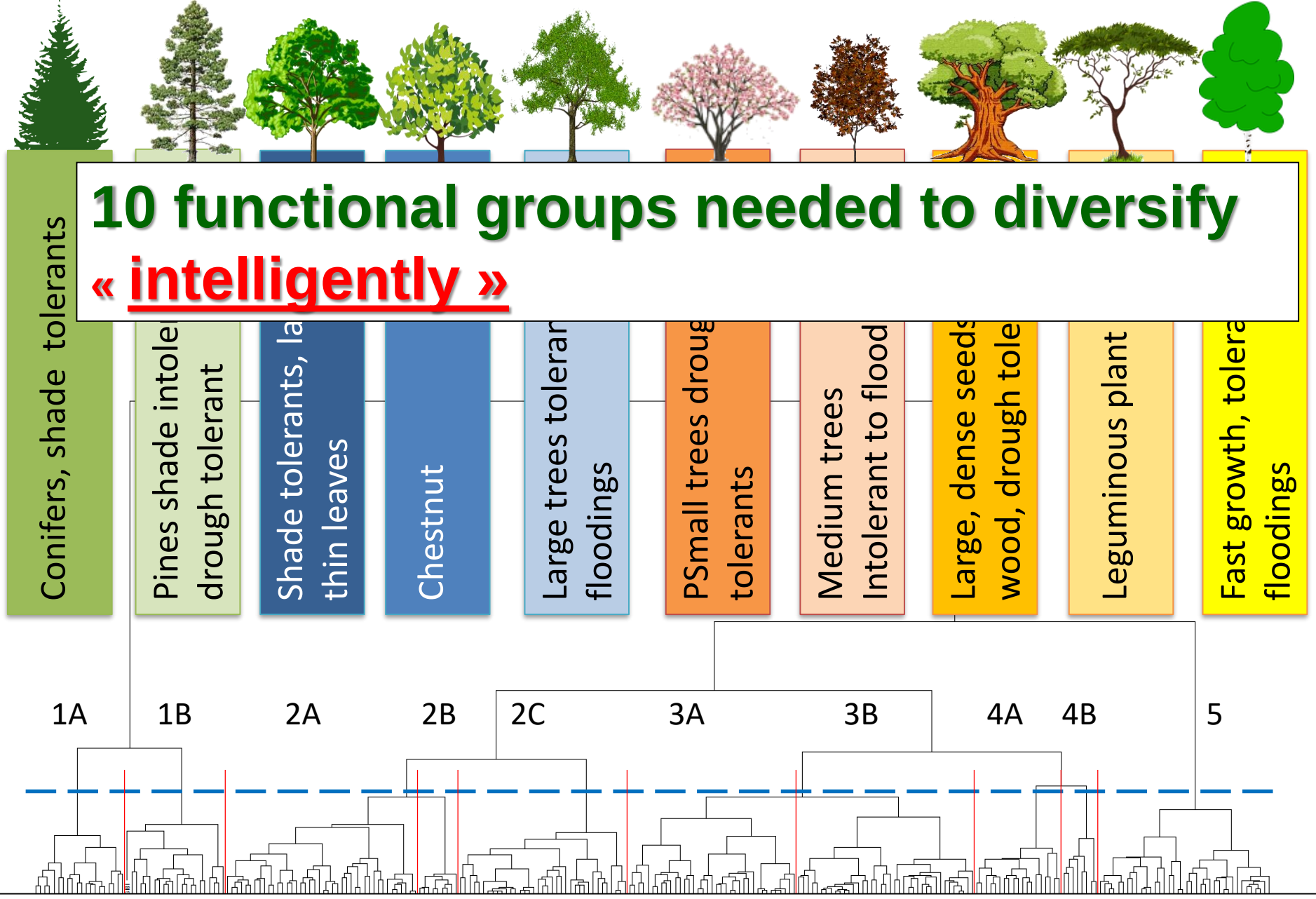
Abies balsamea

Functional diversity: 0,08

Functional diversity: 0,29

Functional diversity: 0,23

10 functional groups needed to diversify « intelligently »



Paquette, Alain, 2016, Augmentation de la canopée et de la résilience de la forêt urbaine de la région métropolitaine de Montréal. Sous la direction de Cornelia Garbe, Jour de la Terre, et du Comité de reboisement de la CMM. Montréal, Octobre 2016.

- **But, what can we do to help maintain or increase the resilience of our forest?**

  - Diversify « intelligently » in relation to known and unknown threats using a functional diversity approach

  - **Use a network approach to optimize your intervention at the landscape scale**

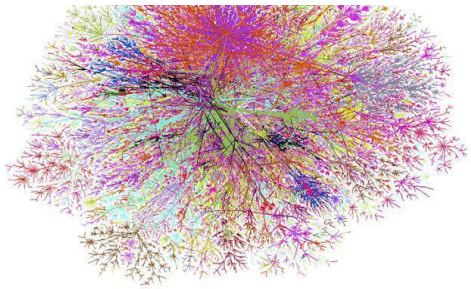
➢ Using Complex NETWORK

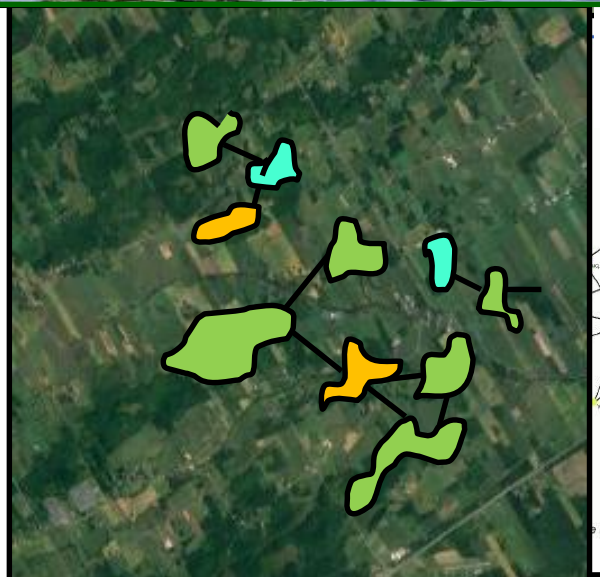
CONNECTIVITY: Level of effective connection among forest stands

CENTRALITY: Importance and number of stands with strong connectivity

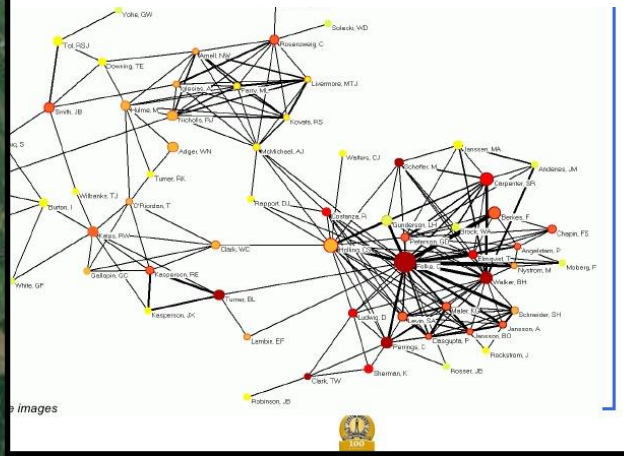
MODULARITY: Level of structural and/or functional discontinuity among stands

The internet





Network of colleagues in the internet



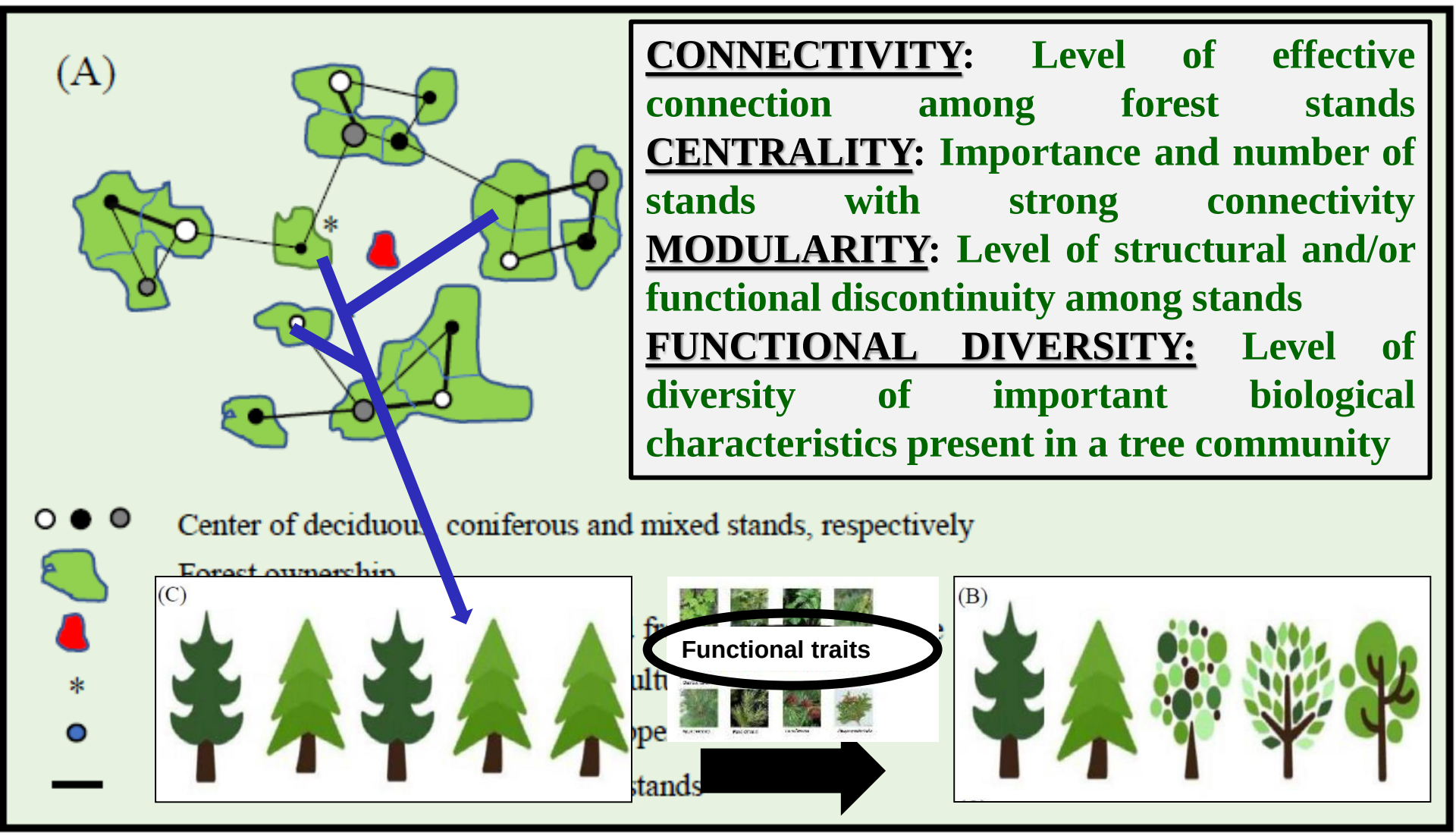
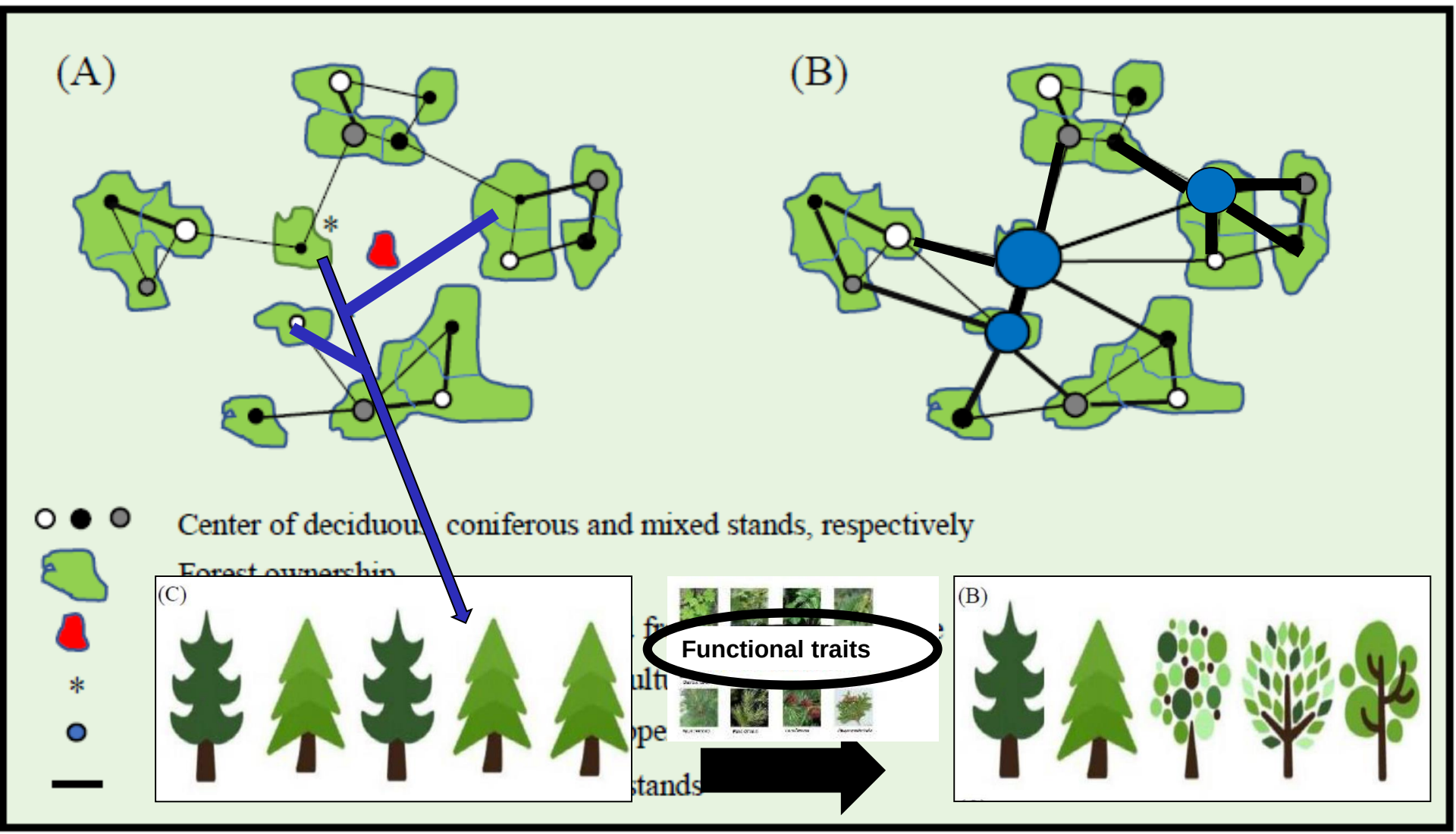


Figure 5. Schematic representation of the analysis of a fictitious forest landscape before (A) and after (B) targeted silvicultural interventions. Three attributes related to the resilience of the territory are represented: the functional diversity (related to the average size of the dots), connectivity (related to the total number and the average thickness of the links between dots), and centrality (related to the average number of links per dot).



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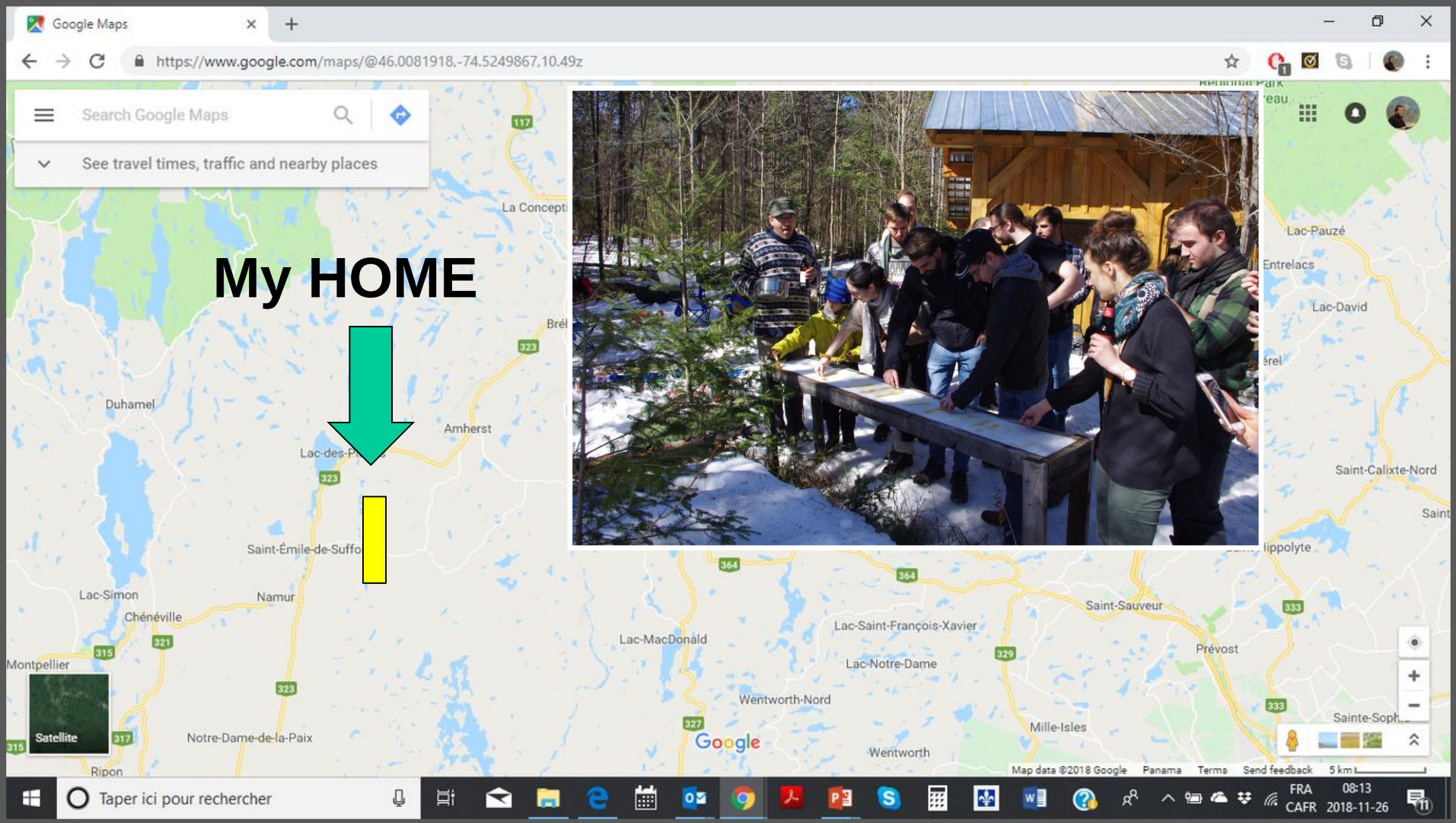
In short

- **One needs to evaluate the *FUNCTIONAL DIVERSITY* of each stand/patch**
- **One then calculates *connectivity, centrality and modularity* at the lanscape scale using complex network**
- **One determines the stands/patches that are more *central* to focus our forestry interventions**
  - **One favours and/or plants those tree species having the most important/missing functional traits**
  - **One makes sure to have redundancy**

How do we do that in REAL LIFE?



LES CONSEILLERS FORESTIERS DE L'OUTAOUAIS

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

Localisation des peuplements

fir
Poplars
Sugar maple
Red maple
Yellow birch

} >80%

40 ha

iForUrb:woodlot

NOMBRE DE GROUPES FONCTIONNELS PRÉSENTS AU SEIN DE LA FORÊT ÉTUDIÉE
4/5

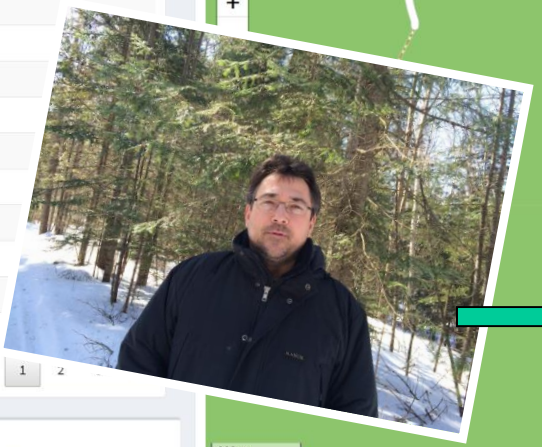
INDICE DE DIVERSITÉ FONCTIONNELLE DE LA FORÊT ÉTUDIÉE
3,24/5

ÉVALUATION DE L'INDICE DE DIVERSITÉ FONCTIONNELLE
Intermédiaire

Afficher 10 éléments Rechercher :

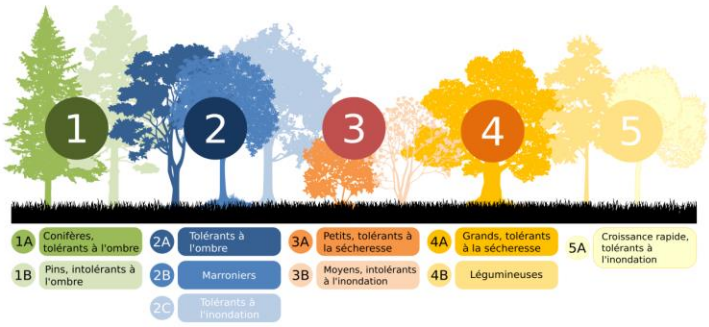
	Peuplement	Diversité	Priorité	Superficie (ha)
1	P1	1,68	Élevée	1,8
2	P10	2,11	Faible	1,5
3	P11	3,07	Faible	1,8
4	P12	1,38	Faible	1,2
5	P13	2,53	Faible	0,2
6	P14	3,69	Faible	3,9
7	P2	1,53	Élevée	0,9
8	P3	2	Élevée	0,1
9	P4	1,99	Faible	6,2
10	P5	2,99	Moyenne	0,7

Affichage de l'élément 1 à 10 sur 14 éléments Précédent 1 2



Sélectionnez la couche géospatiale à illustrer

Nombre de groupes fonctionnels Indice de diversité fonctionnelle Indice de priorités



Sélectionnez le(s) peuplements(s) à illustrer

Sélectionnez le nombre de groupes ou sous-groupes à illustrer

5 groupes fonctionnels 10 sous-groupes fonctionnels

eco²urb

INDICE DE DIVERSITÉ FONCTIONNELLE DE LA FORÊT ÉTUDIÉE

3,24/5

ÉVALUATION DE L'INDICE DE DIVERSITÉ FONCTIONNELLE

Intermédiaire

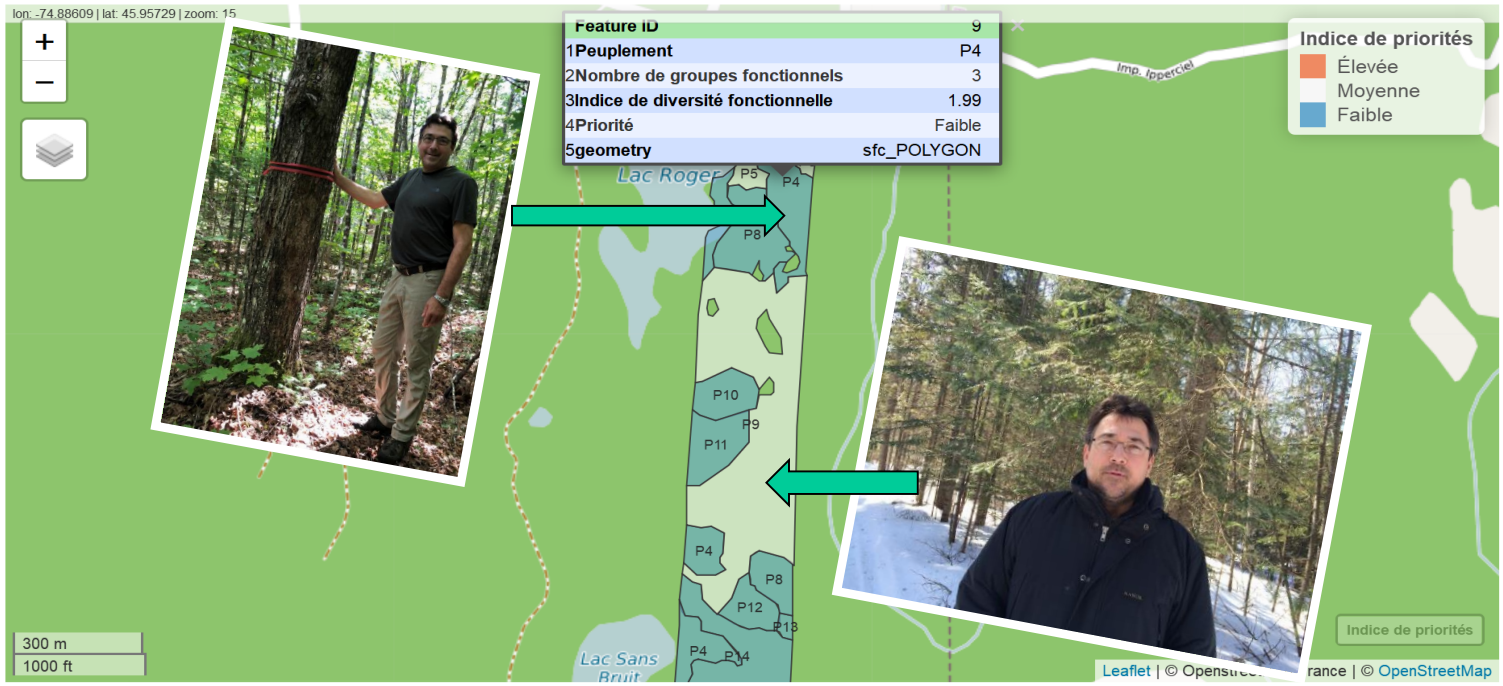
ercher :

Superficie (ha)
1,8
1,5
1,8
1,2
0,2
3,9
0,9
0,1
6,2
0,7

cédent 1 2 Suivant

Sélectionnez la couche géospatiale à illustrer

Nombre de groupes fonctionnels | Indice de diversité fonctionnelle | Indice de priorités

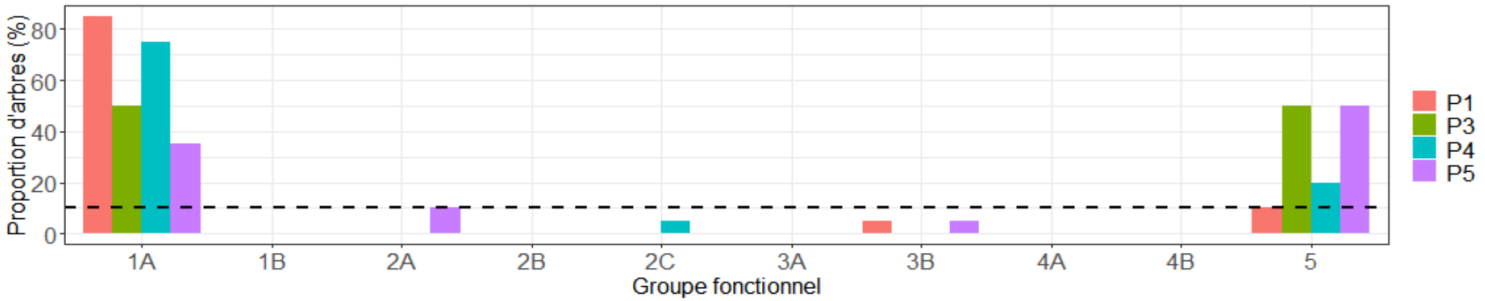


érants esse
5A Croissance rapide, tolérants à l'inondation
uses

Sélectionnez le(s) peuplements(s) à illustrer

Sélectionnez le nombre de groupes ou sous-groupes à illustrer

5 groupes fonctionnels | 10 sous-groupes fonctionnels



- Hornbeam
- Hackberry
- Other oaks
- Catalpa
- Hickory
- Other pines

fir
Poplars
Sugar maple
Red maple
Yellow birch
White birch
Linden
Tsuga
Cherry
White pine
Red oak

} >80%


Thanks/
Merci