Boreal forest succession: understanding how disturbances are interacting is key

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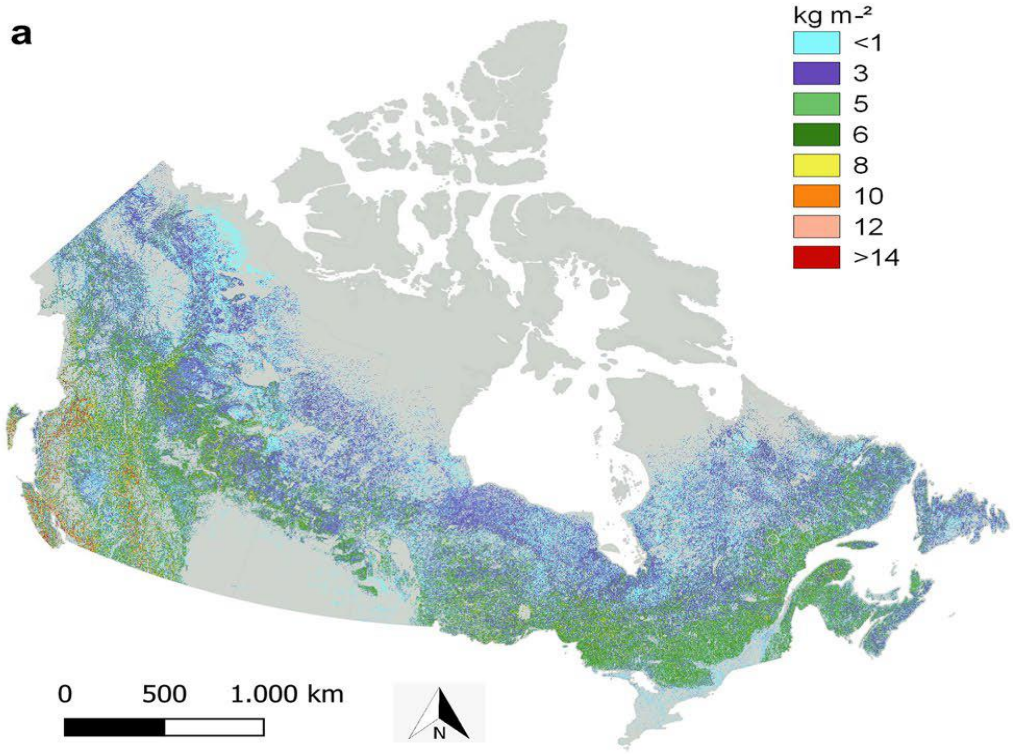
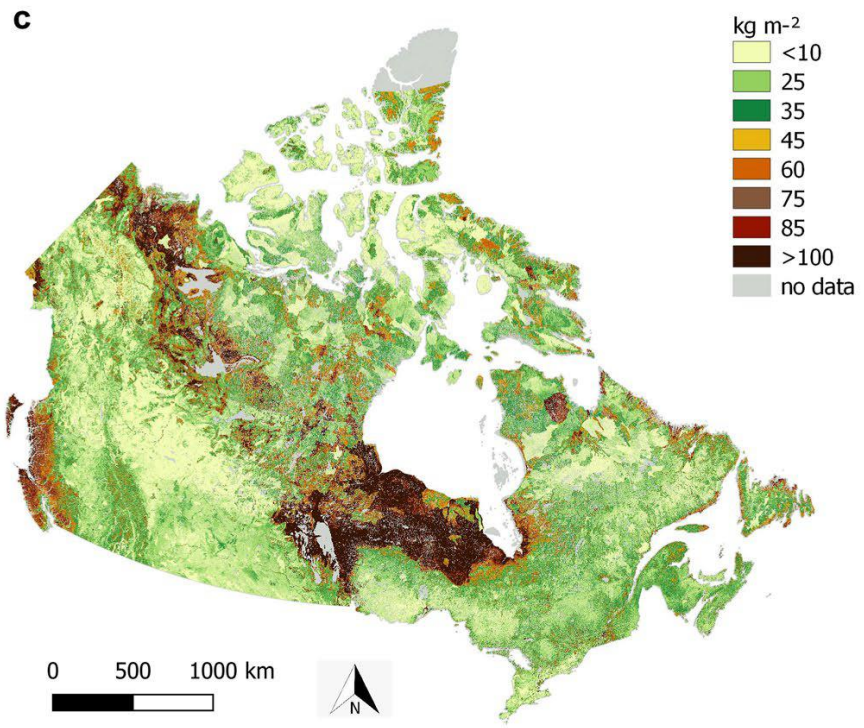
Canadian forest ecosystems: carbon





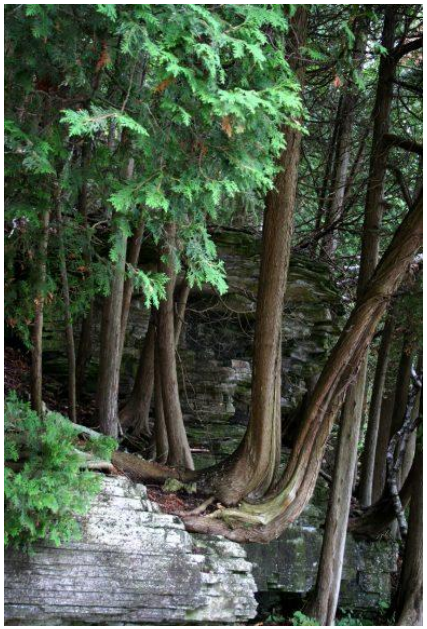
Live plants = 18.3 Pg C, ~6%

Soil Organic C (1 m) = 306 Pg C, ~20%

Soothe et al. 2022. Large soil carbon storage in terrestrial ecosystems of Canada. Global Biogeochemical Cycles, 36(2)

Canadian Forest Ecosystems: biodiversity

Canadian Forest Ecosystems: biodiversity

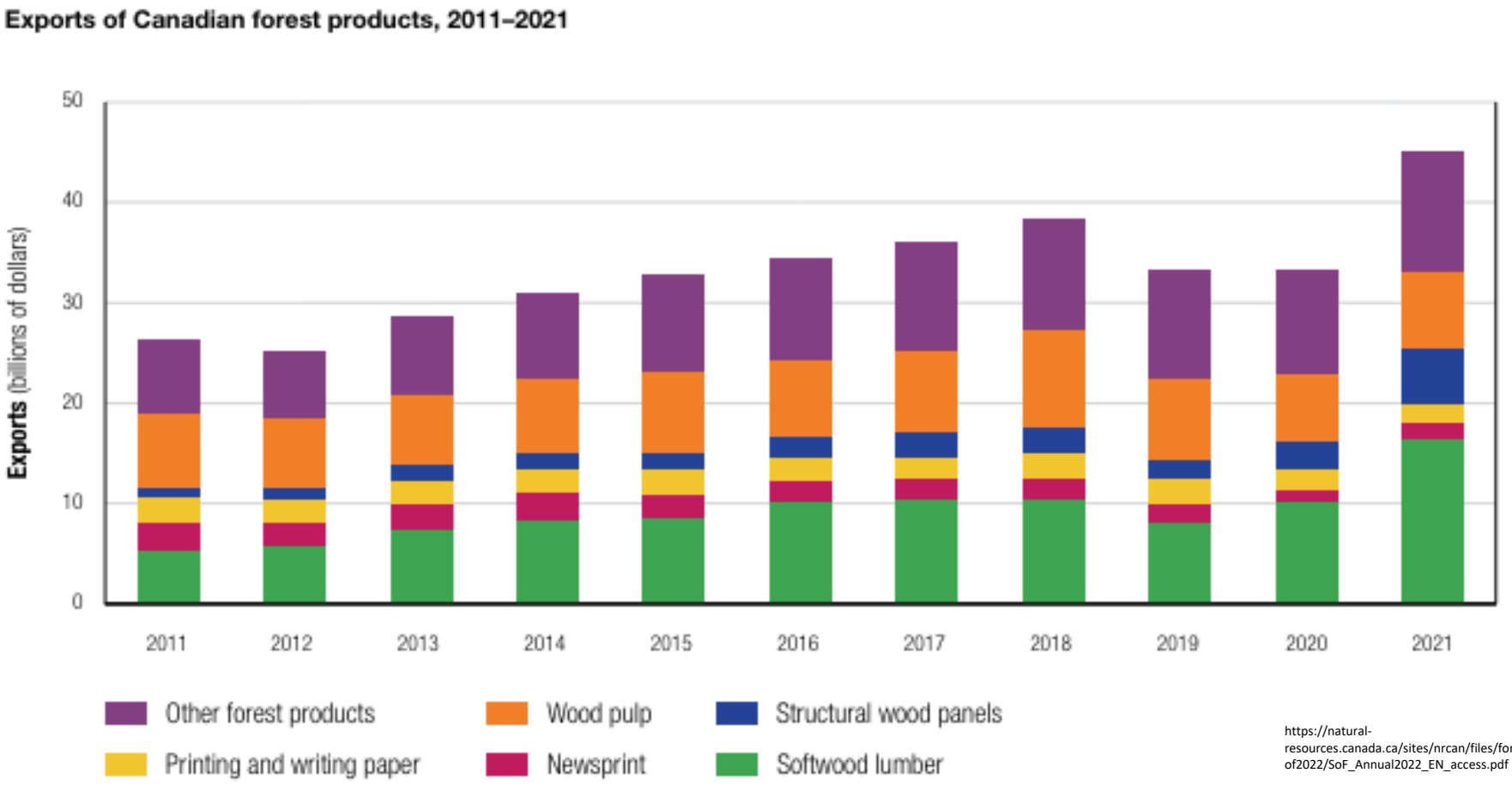


24% of world's boreal forest
Habitat for ~ 80, 000 species

https://www.canada.ca/en/environment-climate-change/services/biodiversity/national-biodiversity-strategy/milestone-document.html

Formenti, S., Peace, A., Eyles, C., Lee, R. and Waldron, J.W., 2022. Fractures in the Niagara Escarpment in Ontario, Canada: distribution, connectivity, and geohazard implications. *Geological Magazine*, *159*(11-12), pp.1936-1951.

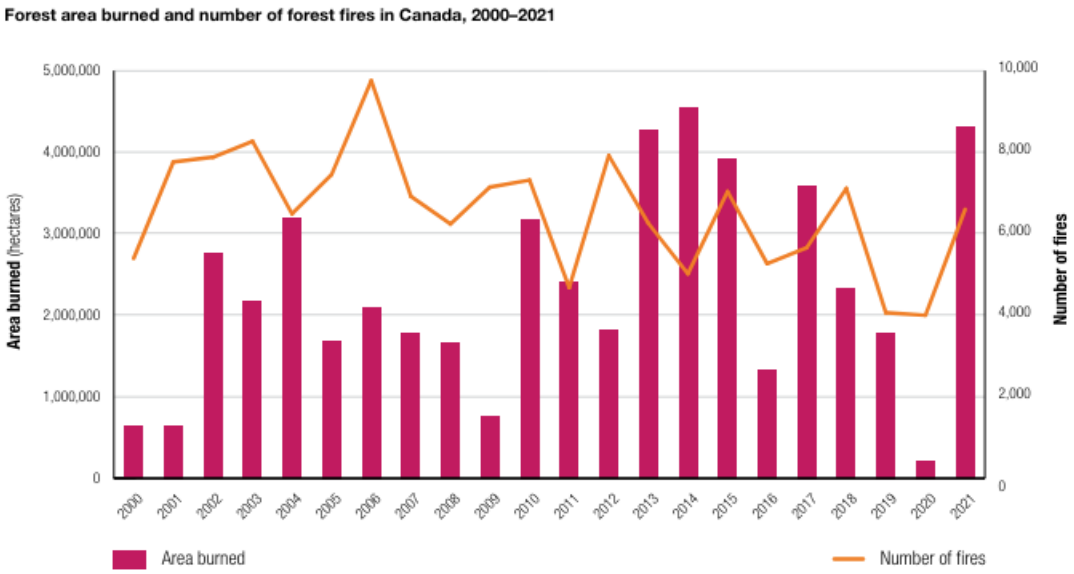
Canadian Forest Ecosystems: timber supply



https://natural-resources.canada.ca/sites/nrcan/files/forest/sof2022/SoF_Annual2022_EN_access.pdf

One of the world's largest exporter of wood products

Canadian Forest Ecosystems: disturbances & climate change



https://natural-resources.canada.ca/sites/nrcan/files/forest/sof2022/SoF_Annual2022_EN_access.pdf

Climate change in Canada's boreal forest region [1]

- **1961-1990: 0.6 ^{o}C**
- **2071-2100: 4.3-5.7 ^{o}C**

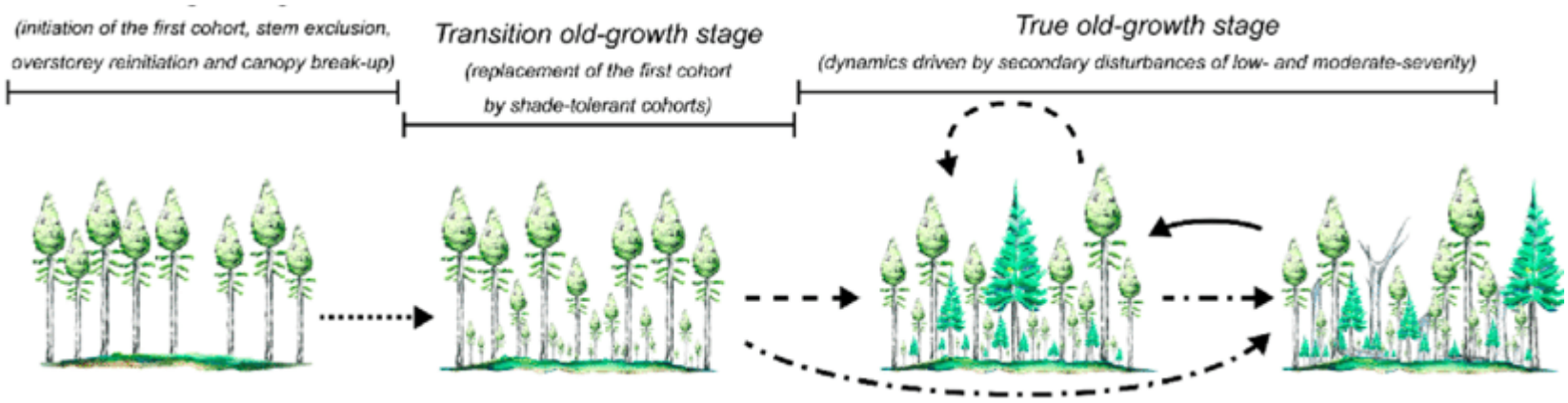
Climate change introduces enormous uncertainty in predicting vegetation changes

[1] Price et al. 2013. Anticipating the consequences of climate change for Canada's boreal forest ecosystem. Environ. Rev. 21:322-365.

Boreal Forest Succession

- **Forest succession**

  A dynamic process of progressive compositional development of ecological communities of species following natural or anthropogenic disturbance.



Martin, M., Krause, C., Fenton, N.J. and Morin, H., 2020. Unveiling the diversity of tree growth patterns in boreal old-growth forests reveals the richness of their dynamics. *Forests*, *11*(3), p.252.

Potential	Reality
Predict future vegetation structure and composition i.e. carbon, biodiversity, timber	**Limited understanding and limited ability to predict**

Boreal Forest Succession

- **Objective**

  Study forest succession dynamics in Boreal North America i.e. clarify advances in knowledge and limitations in understanding

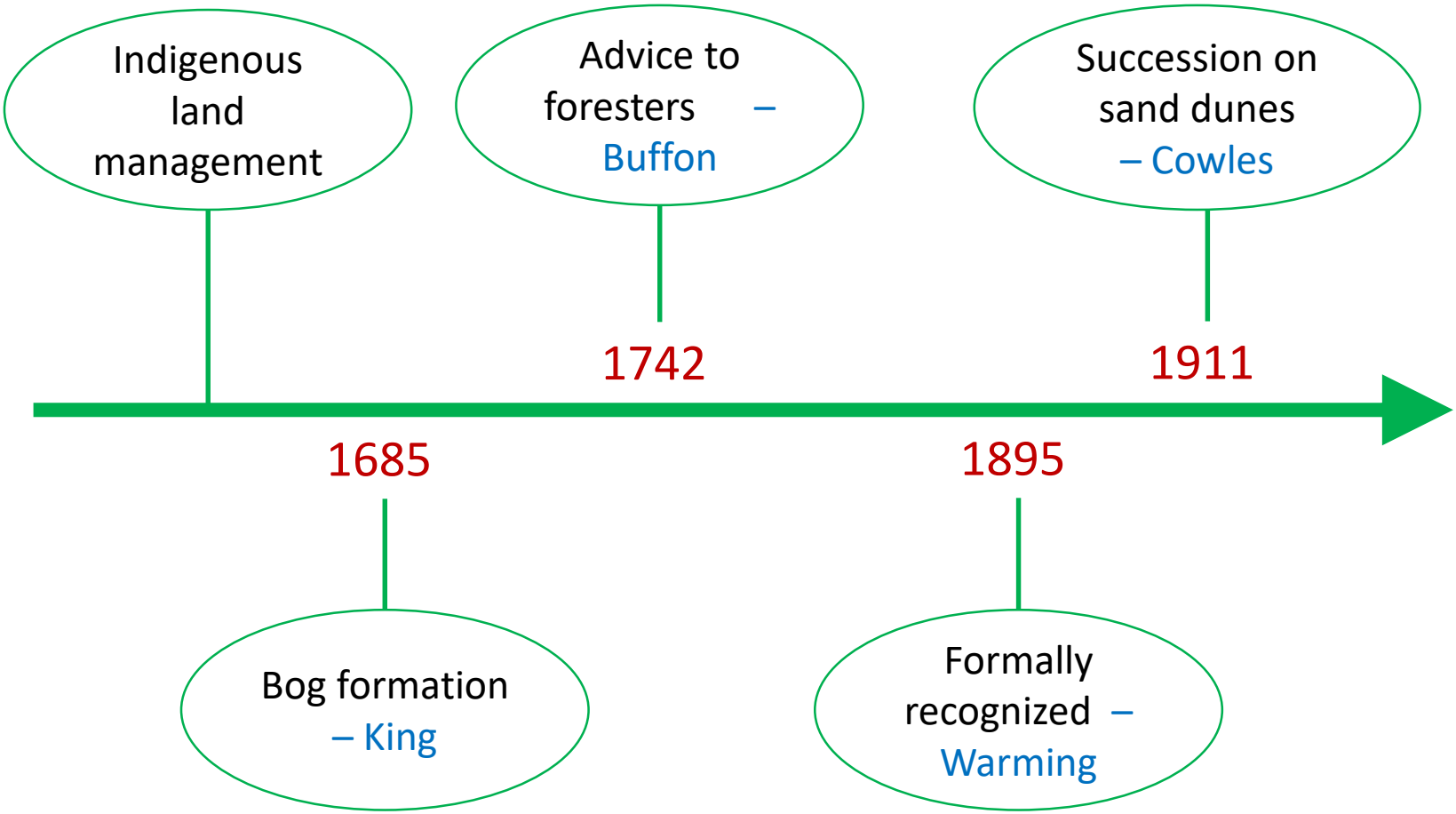
- **Literature review (150+/200+ papers) (keywords + search engines)**
  - Theory and model development
  - Ecological processes and influential factors
  - Network analysis: factors and conceptual models
  - Synthesized succession pathways

- **Findings**
  1) Theory and model development
  2) Influential factors vs existing models
  3) Disturbance interaction

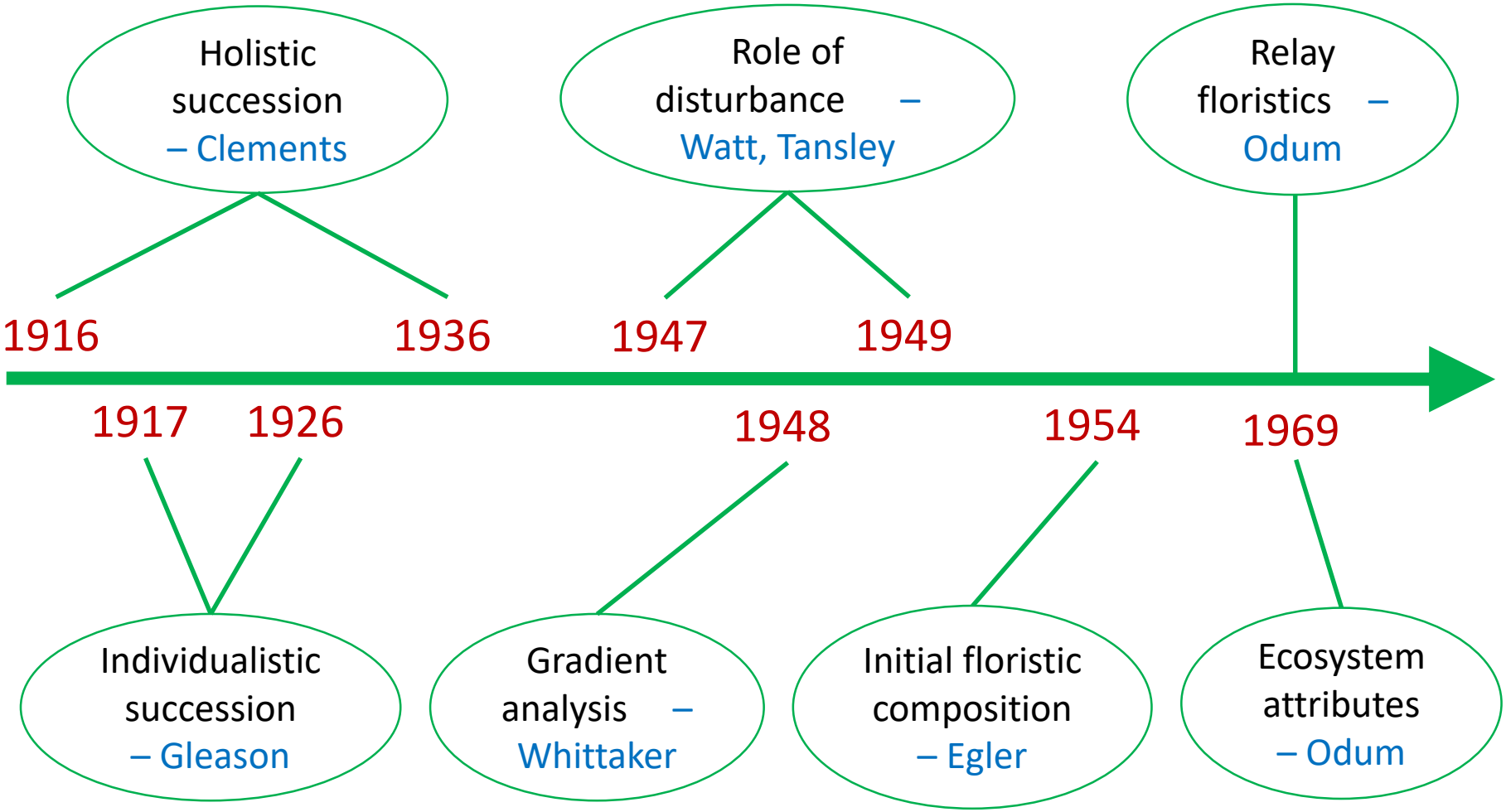
Findings: 1) Theory and model development



Early Work

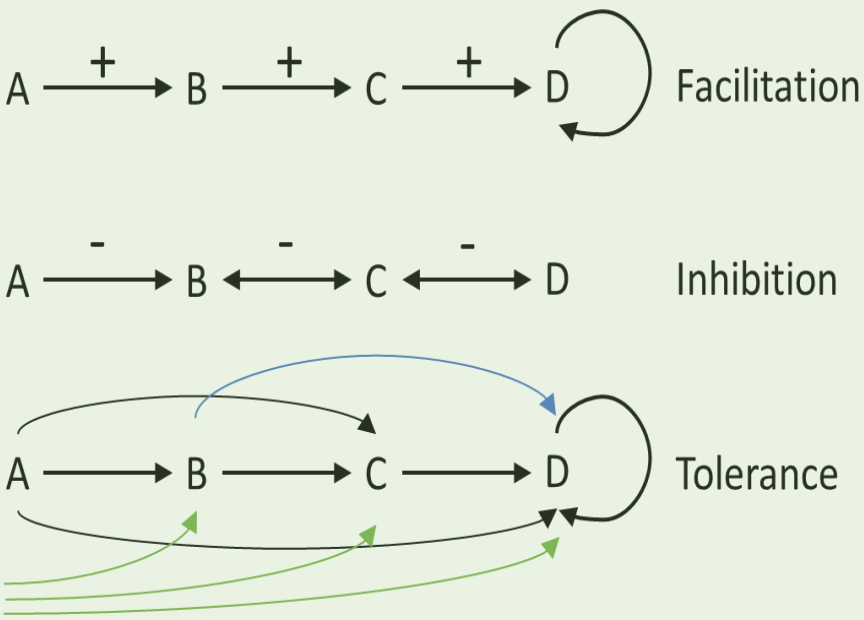

Indigenous land management
Advice to foresters – Buffon
Succession on sand dunes – Cowles
1742
1911
1685
1895
Bog formation – King
Formally recognized – Warming

Development of Theories



Modern Theories:

Mechanisms of succession



Connell and Slatyer 1977

Resources as driver of succession

Changing resource availability

Drury and Nisbet, 1973

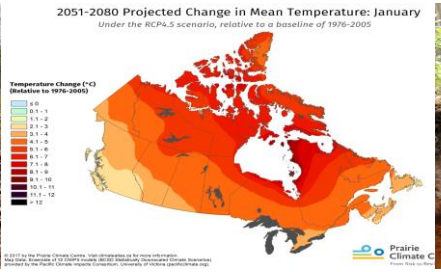
Disturbances as driver of succession

Species and resource availability altered by disturbance

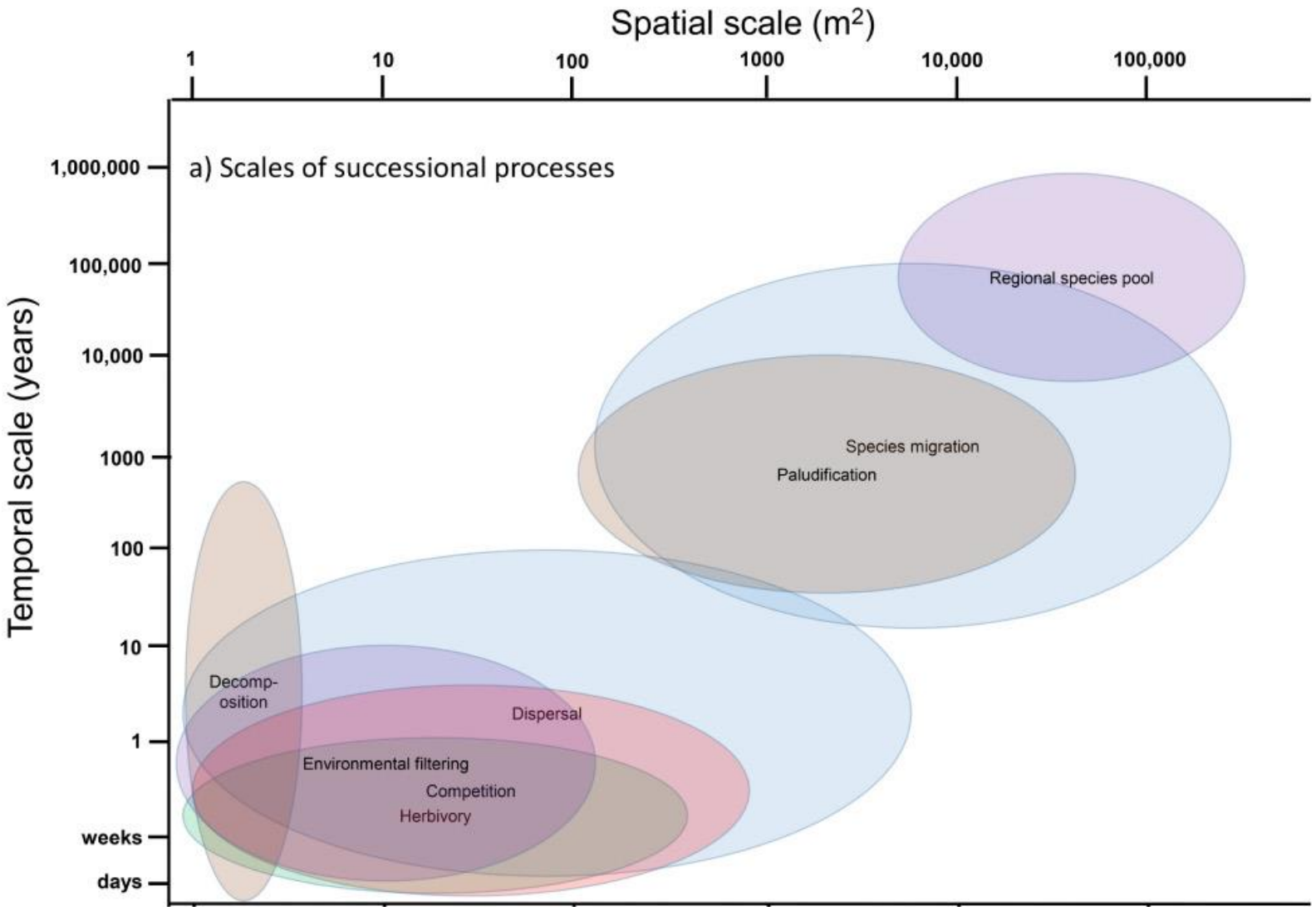
Complex nature of disturbances may cause varied succession

Tilman

Findings: 2) Influential factors & synthesized pathways



Succession processes span multiple spatiotemporal scales

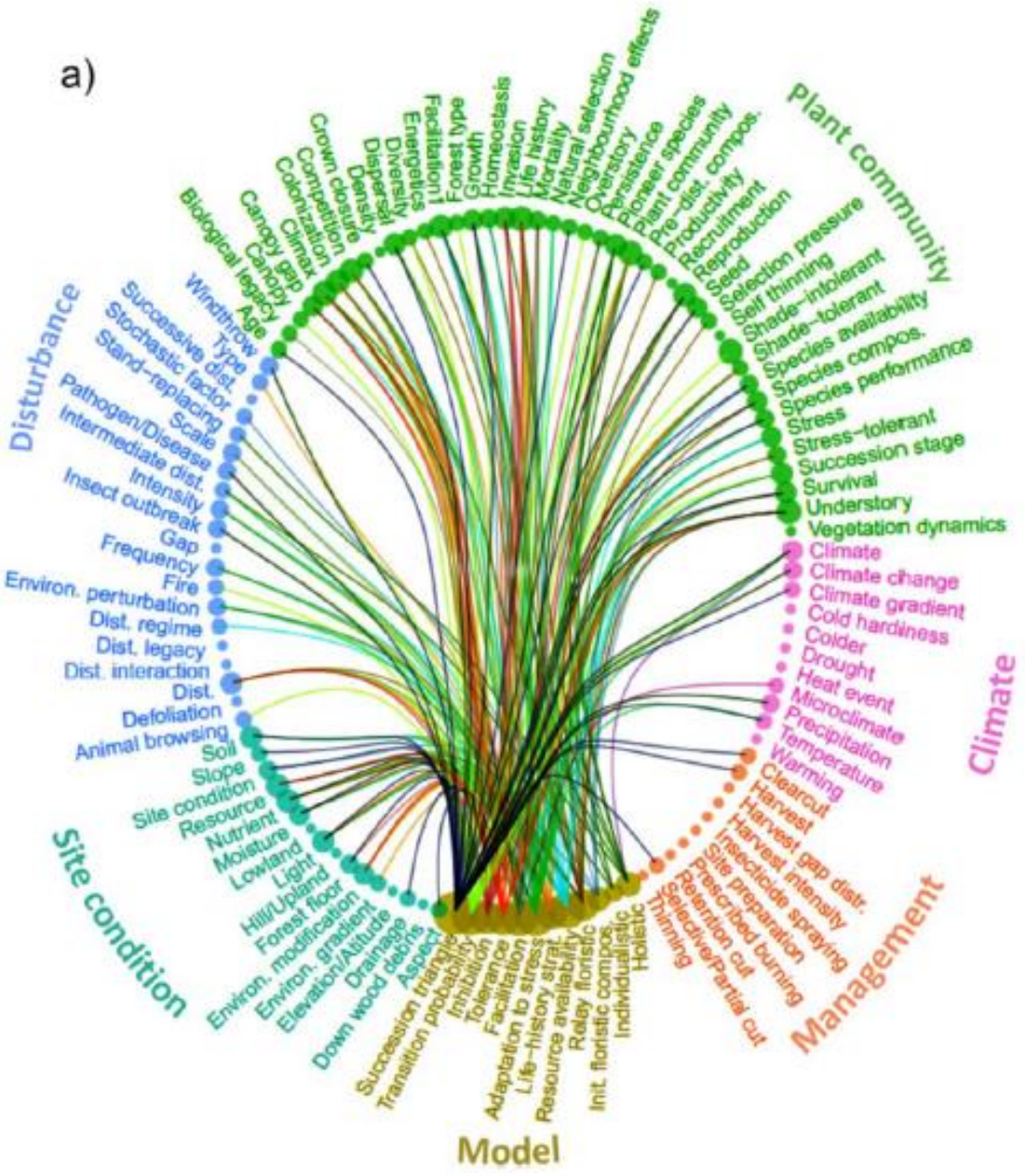


Succession theories and the factors they consider

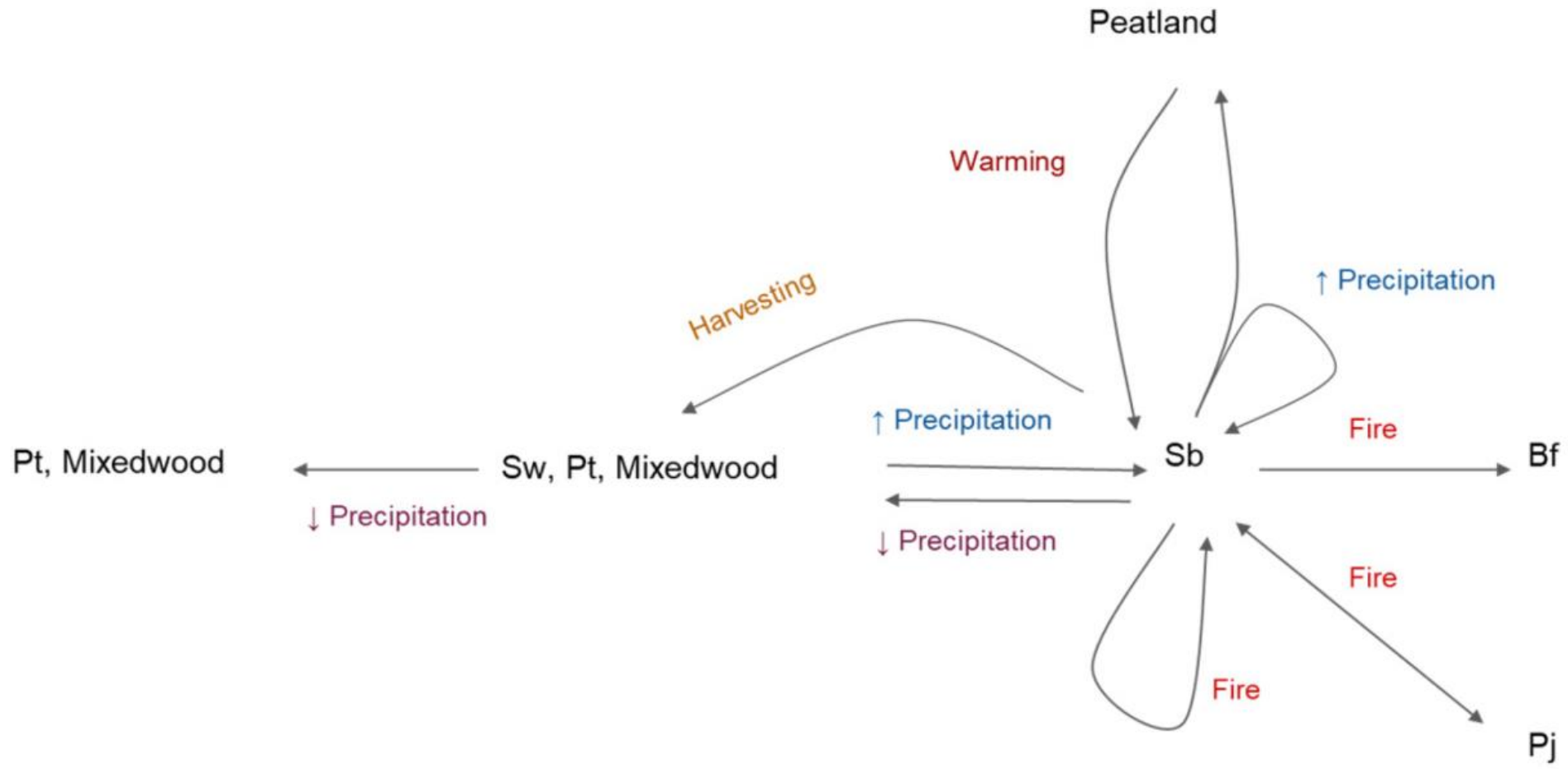
Many influential factors

Vs.

limited number of factors considered

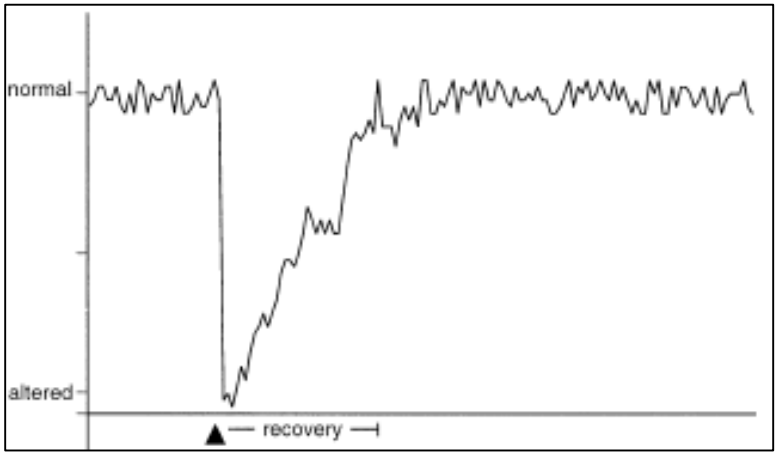


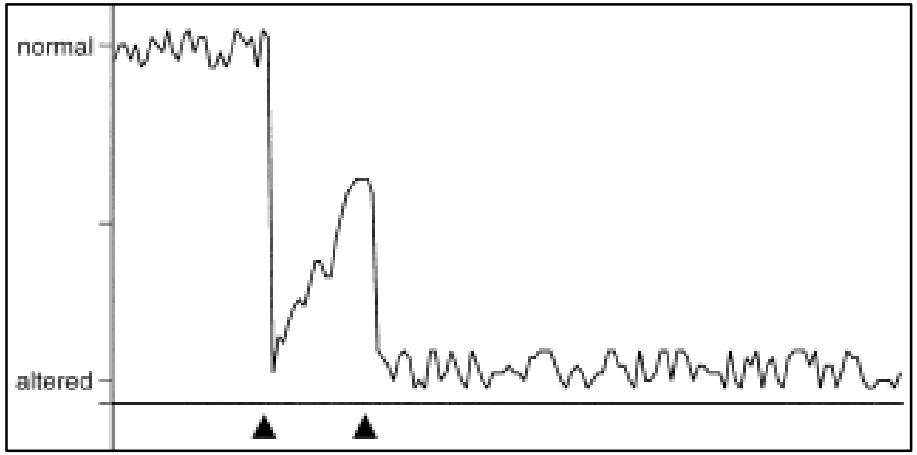
Synthesized hypothesized succession pathways: northern boreal



Bf = Balsam fir; Pj = Jack pine; Pt = Trembling aspen; Sb = Black spruce; Sw = White spruce

Findings: 3) Disturbance interactions





Paine et al. 2008. Compounded perturbations yield ecological surprises. Ecosystems 1:535–545

Limited number of papers studied disturbance interaction (< 10%)

Disturbance types	*Interaction*
Logging + defoliation	Synergistic or buffering
Logging + windthrow	Synergistic
Logging + fire	Synergistic
Windthrow + logging + fire	Buffering
Windthrow + logging	Synergistic
Windthrow + fire	Synergistic
Defoliation + fire	Synergistic or no effects
Defoliation + windthrow	Synergistic
Fire + logging	No effects

Interactions among disturbances were largely synergistic

Disturbance interaction effects

Logging

+

Fire

James et al 2011

Increased fire size converting landscape to early seral type

Boucher et al. 2017, Perrault-Herbet et al 2017

Failed regeneration + Expansion of unproductive land

Post-logging fire reversed succession, drove regeneration failure

Disturbance interaction effects

Fire + **Logging**

Brehaut and Brown 2020

Regeneration not influenced by harvesting

Post-fire harvesting had no detrimental effects on regeneration

Disturbance interactions

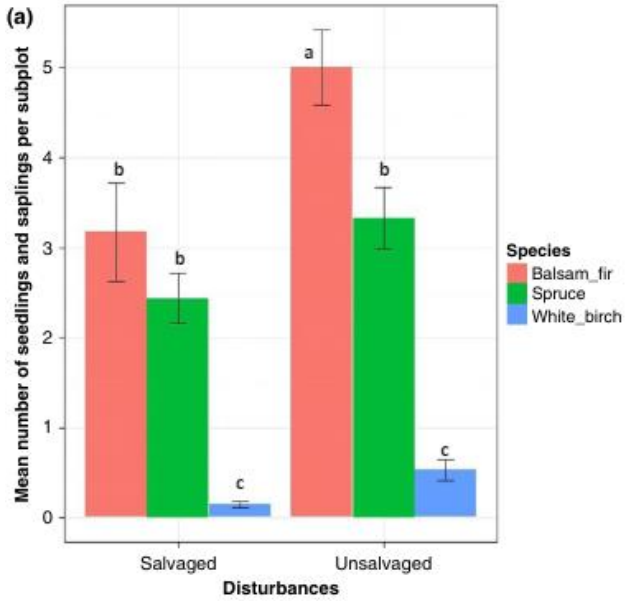
Windthrow

+

Salvage Logging

→

Reduced Balsam fir regeneration



Waldron et al 2014

Disturbance interactions

Windthrow + **Salvage Logging** + **Prescribed Burn**

Our results suggest that salvage logging impacts on woody plant communities are diminished when followed by a second high severity disturbance; (D'Amato et al 2011)

Improved forest management with better understanding of disturbance interaction

Key takeaways

1) Successional dynamics

- An old concept, understanding has been progressively better, complex interactions
- A continuous dynamic process, i.e., no stable climax community
- Fire is influential but understanding its interaction with other disturbances is critical

2) Implications for future study

- Need to clarify disturbance interactions, threshold beyond which buffering interactions tip to become synergistic interactions

Environmental Reviews

OPEN ACCESS | Review

A critical review of successional dynamics in boreal forests of North America

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Abstract

Forest succession is a dynamic process of progressive compositional development of ecological communities of species following natural or anthropogenic disturbance. Despite a rich history of conceptual frameworks, models, and empirical advances, the complex interactions among climatic conditions, disturbances, edaphic factors, and silvicultural treatments still challenge our ability to accurately predict forest succession, hindering application to forest management. Our goal was to improve understanding of forest succession in the managed boreal forests of North America by clarifying advances in knowledge and limitations in our understanding. We reviewed 152 peer-reviewed papers to: (*i*) document conceptual developments in forest succession; (*ii*) summarize drivers of North American boreal forest succession, including changes to forest composition and successional trajectories given climate change; and (*iii*) discuss the implications of the synthesized information for boreal forest management. While the element of stochasticity is expected to increase under climate change, successional dynamics are anticipated to remain predominantly deterministic. Southern boreal forests are at increased risk of mortality due to warming-driven drought and increased fires. Following disturbance, regeneration is likely to favor deciduous hardwoods. In boreal mixedwoods, increased fires would promote jack pine, and also black spruce on hydric and xeric sites. Dynamics of the northern boreal will depend on the balance between precipitation and evapotranspiration. Forest management must carefully select prescriptions to promote forest regeneration and composition that consider the long-term effects of changing climate and disturbance regimes. For instance, combining retention cut with mechanical site preparation would maintain site productivity and reverse open black spruce stand development in northern boreal stands. Our work shows that multiple disturbances have compounding effects on forest development, but further work is needed to better define thresholds for synergistic and buffering interactions. Modeling of boreal forest succession can be improved by incorporating more of the influential factors, but this is often limited by the lack of data. This information will guide the development of forest management strategies by exploring combinations of prescribed fire and variable intensity selection cutting systems to reproduce the effects of multiple interacting natural disturbances under climate change on successional dynamics.

Key words: history of ecology, site condition, plant traits, disturbance, climate, forest management, succession, forest dynamics

Résumé

La succession forestière est un processus dynamique de développement progressif de la composition des communautés écologiques d'espèces à la suite d'une perturbation naturelle ou anthropique. Malgré un riche historique de cadres conceptuels, de modèles et de progrès empiriques, les interactions complexes entre les conditions climatiques, les perturbations, les facteurs édaphiques et les traitements sylvicoles remettent toujours en question notre capacité à prédire avec précision la succession forestière, ce qui entrave son application à la gestion des forêts. L'objectif des auteurs consistaient à améliorer la compréhension de la succession forestière dans les forêts boréales aménagées d'Amérique du Nord en clarifiant les progrès dans les connaissances et les limites de notre compréhension. Ils ont examiné 152 articles évalués par des pairs pour (*i*) documenter les développements conceptuels de la succession forestière ; (*ii*) résumer les éléments moteurs de la succession des forêts boréales nord-américaines, y compris les changements dans la composition des forêts et les trajectoires de succession en fonction des changements climatiques ; et (*iii*) discuter des implications des informations synthétisées pour la gestion des forêts boréales. Bien que l'on s'attende à ce que l'élément de stochasticité augmente sous l'effet des changements climatiques, la dynamique


Thank you!
And
Questions?