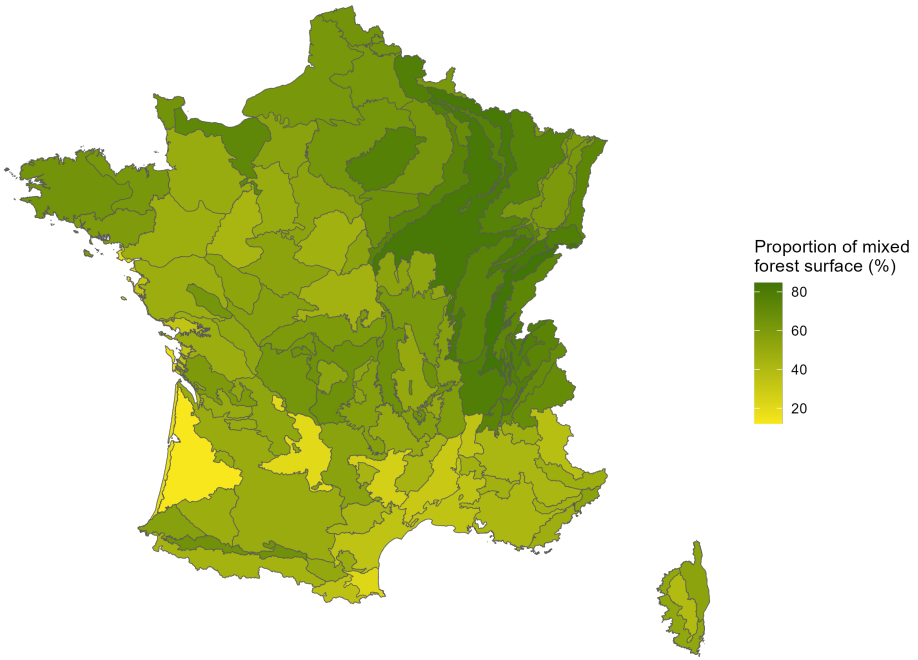
Monitoring de la résilience de croissance des mélanges d'espèces ligneuses sous changement climatique

Lionel Hertzog, Patrick Vallet & Jean-Daniel Bontemps

03/04/2024

Context

- Forest policy push towards diversification of forest stands
- Mixed stands currently represent around 50% of forests with regional disparity
- The widespread presence of mixed stands allow their monitoring using observatory data (i.e. only mixed stands that "works")



Why mixed stands?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For the sake of resilience and multifunctionality, let's diversify planted forests!

Christian Messier, Jürgen Bauhus, Rita Sousa-Silva, Harald Auge, Lander Baeten, Nadia Barsoum, Helge Bruelheide, Benjamin Caldwell, Jeannine Cavender-Bares, Els Dhiedt ... See all authors

First published: 16 July 2021 | https://doi.org/10.1111/conl.12829 | Citations: 65


ECOLOGY LETTERS

Letter | Full Access

Temporal stability in forest productivity increases with tree diversity due to asynchrony in species dynamics

Xavier Morin, Lorenz Fahse, Claire de Mazancourt, Michael Scherer-Lorenzen, Harald Bugmann

First published: 12 September 2014 | https://doi.org/10.1111/ele.12357 | Citations: 148

Extrait du cahier des charges du volet renouvellement forestier du plan de relance:

La diversification est un des leviers stratégiques pour l'adaptation à court et long termes des forêts et garantir la résilience des peuplements forestiers. La diversification en essences, en structures, en traitements, à différentes échelles, permet statistiquement de diminuer les risques dans l'espace et dans le temps. Des forêts biodiverses à l'échelle des parcelles, des peuplements, des massifs permettent ainsi de réduire leur sensibilité aux perturbations (exemples : attaques de pathogènes spécifiques à une essence, sensibilité différentes aux aléas climatiques selon les essences et les âges, hétérogénéité face à la prise au vent, etc) et, dans un contexte d'incertitudes, de ne pas concentrer l'investissement du propriétaire forestier sur une seule source de création de valeur. La diversification en essences – sur la base des seuils définis *infra* – est

Objectives

- Identify mixed stands with higher stability in forest growth than respective monospecific stands
- Explore multi-dimensionality of stability (trade-offs)
- Define a nationwide monitoring system of forest growth stability of mixed and pure stands

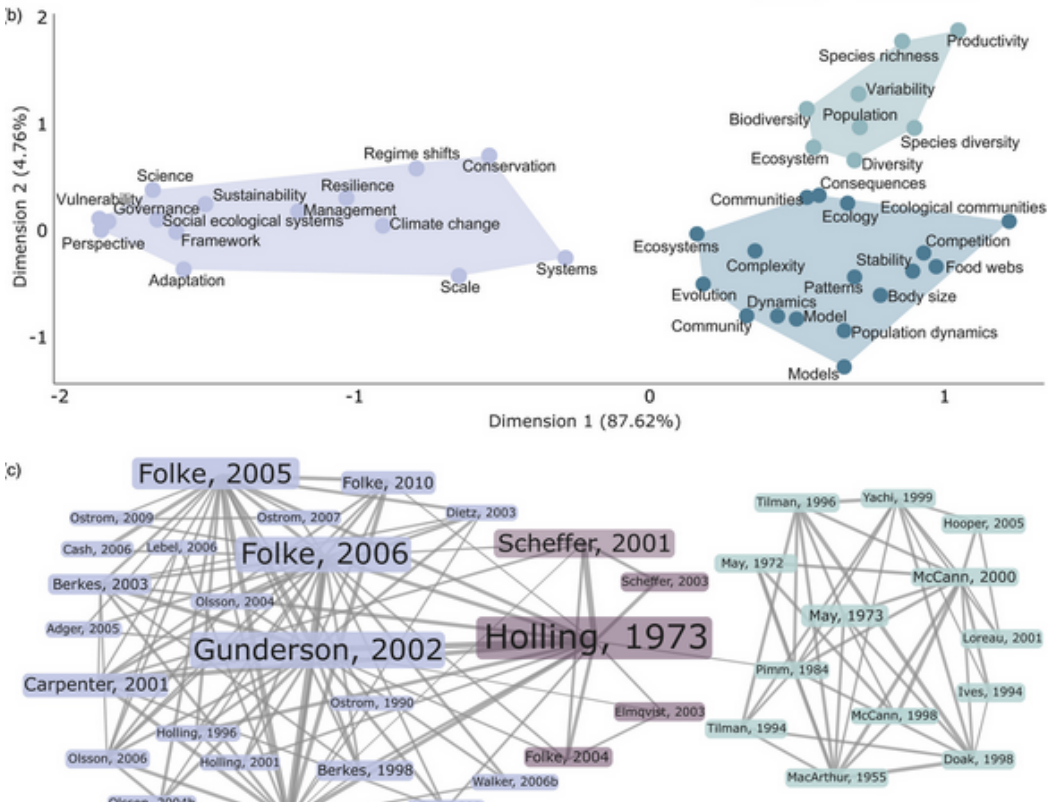
Questions

1. What indices of stability?
2. Which modelling approach?
3. How to define mixed stands and which mixtures to monitor?

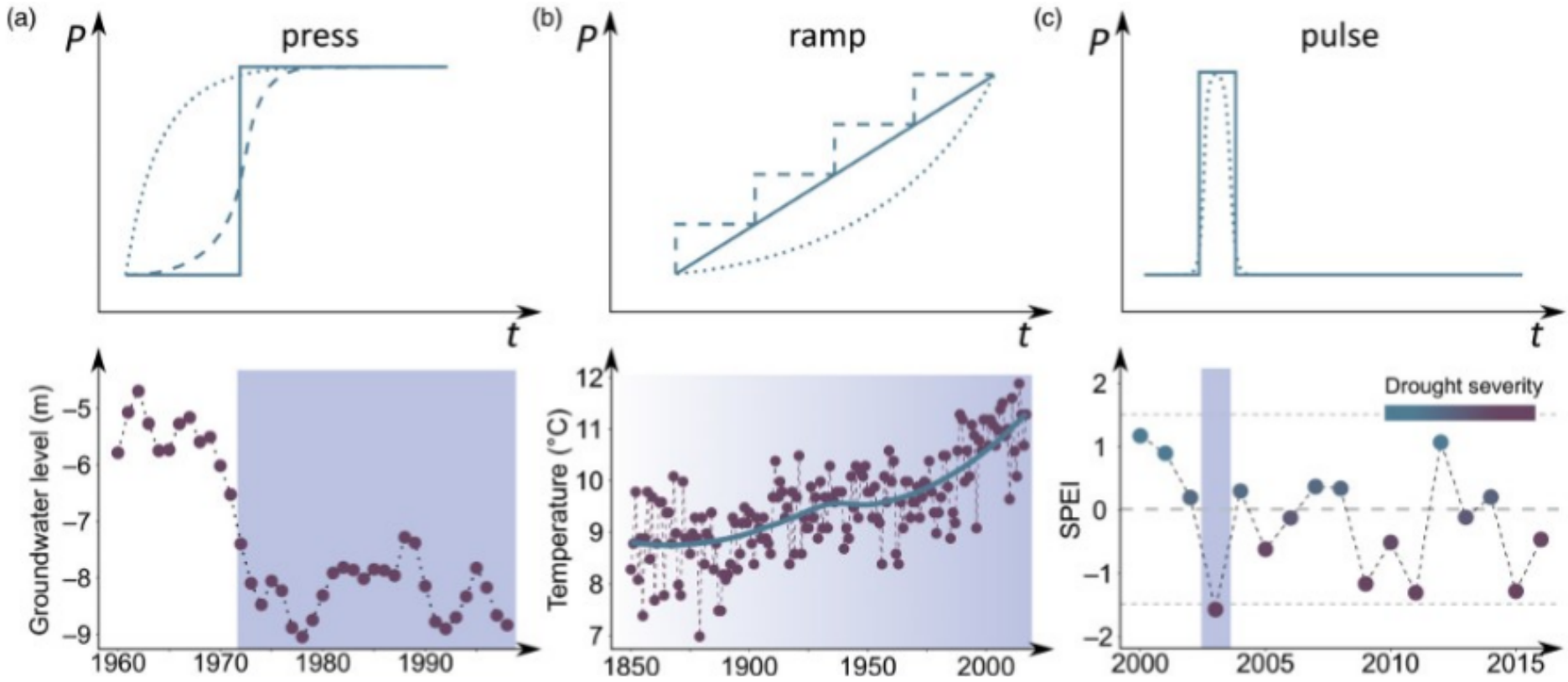
What is resilience/stability/resistance?

Ecosystem stability is supposed to be one of the 'unifying concepts' in ecology. But this concept, and its relations with other attributes of the systems (e.g. diversity), have caused much controversy, mainly due to confusion as to what is meant by 'stability'. Noy-Meir (1974)

Bibliometric analysis, van Meerbeek 2021 JoE



Stability I: indices linked to perturbation

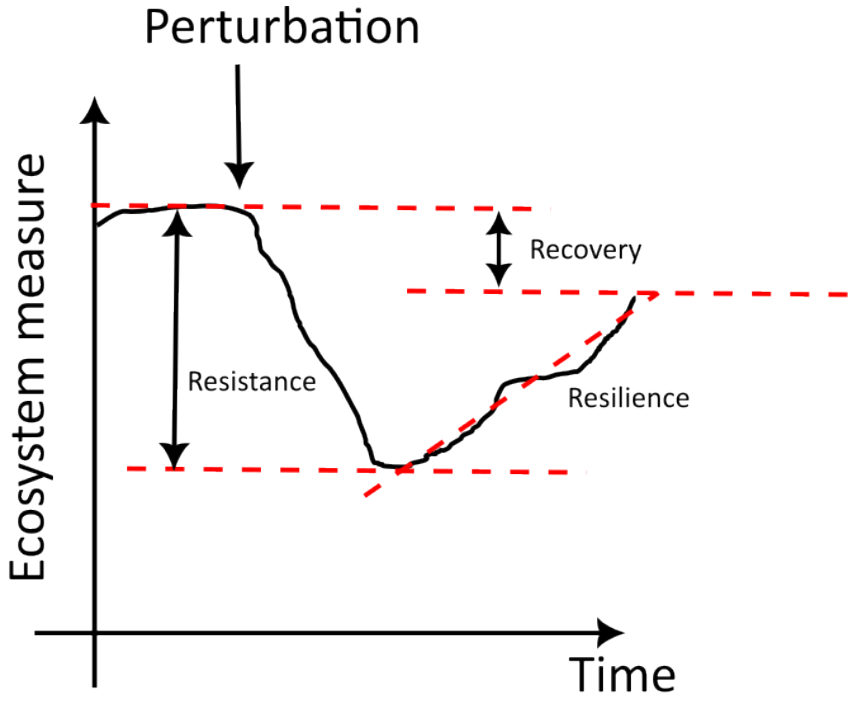


Van Meerbeek et al. 2021 JoE

Stability I: indices linked to perturbation

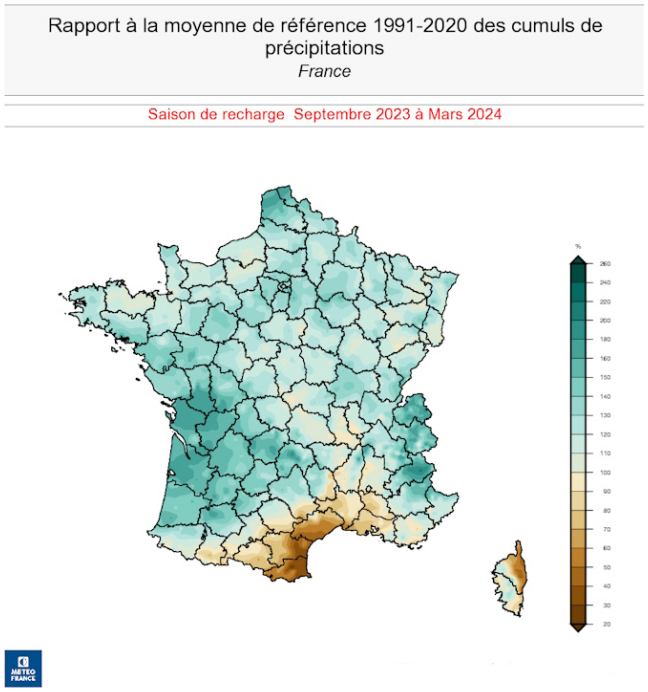
a: Resistance	Initial sampling after disturbance	Measured as initial log response ratio $a = \ln\left(\frac{F_{dist}}{F_{con}}\right)$
b: Resilience	Intermediate samplings	Measured as slope of regression of relative function over time: $\ln\left(\frac{F_{dist}}{F_{con}}\right) = i + b * t,$ where i = intercept, t = time
c: Recovery	Final sampling	Measured as final log response ratio $c = \ln\left(\frac{F_{dist}}{F_{con}}\right)$

Hillenbrand et al. 2017 Ecol. Lett.



Which perturbations?

- Pulse perturbations (drought, storm, fires ...) are usually spatially and temporally restricted
- This restricted coverage makes a monitoring of their effects at the national level not straightforward:
  - Detection and delimitation of the perturbation, use of remote sensing?
  - Issue of having enough data points from forest inventory, starting project PEPR forestt (M. Pulkkinen)



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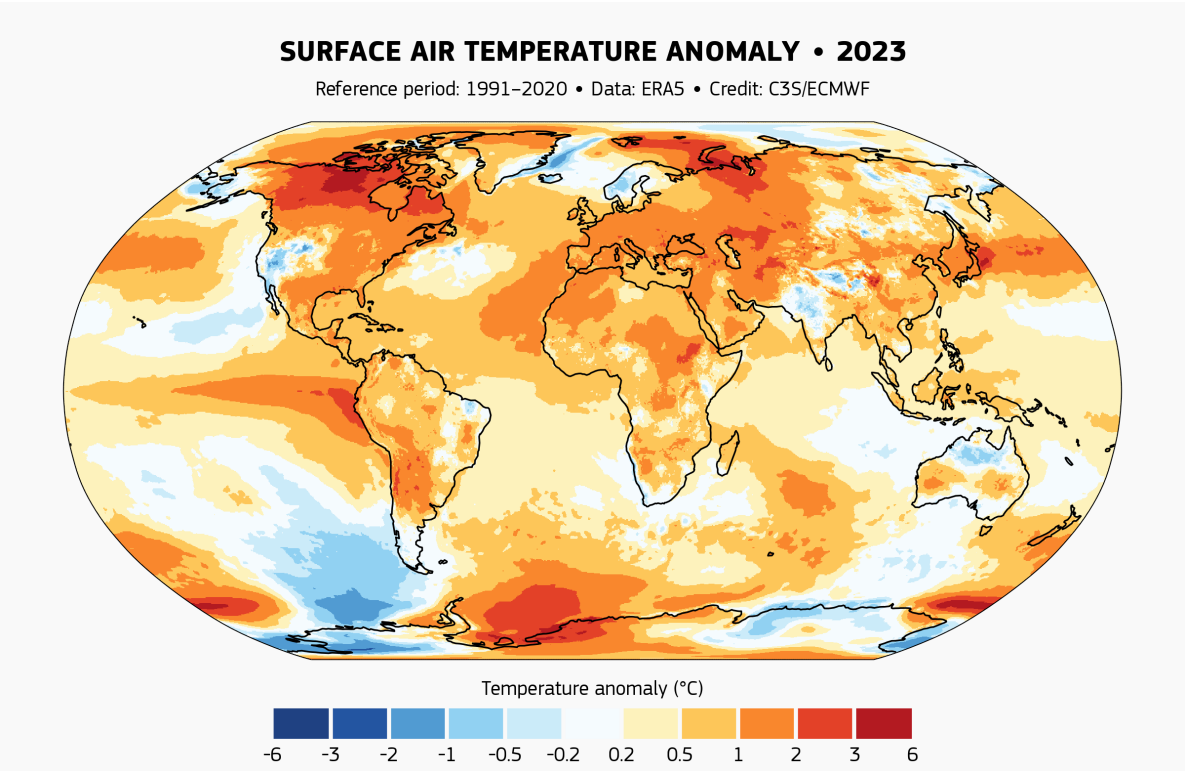
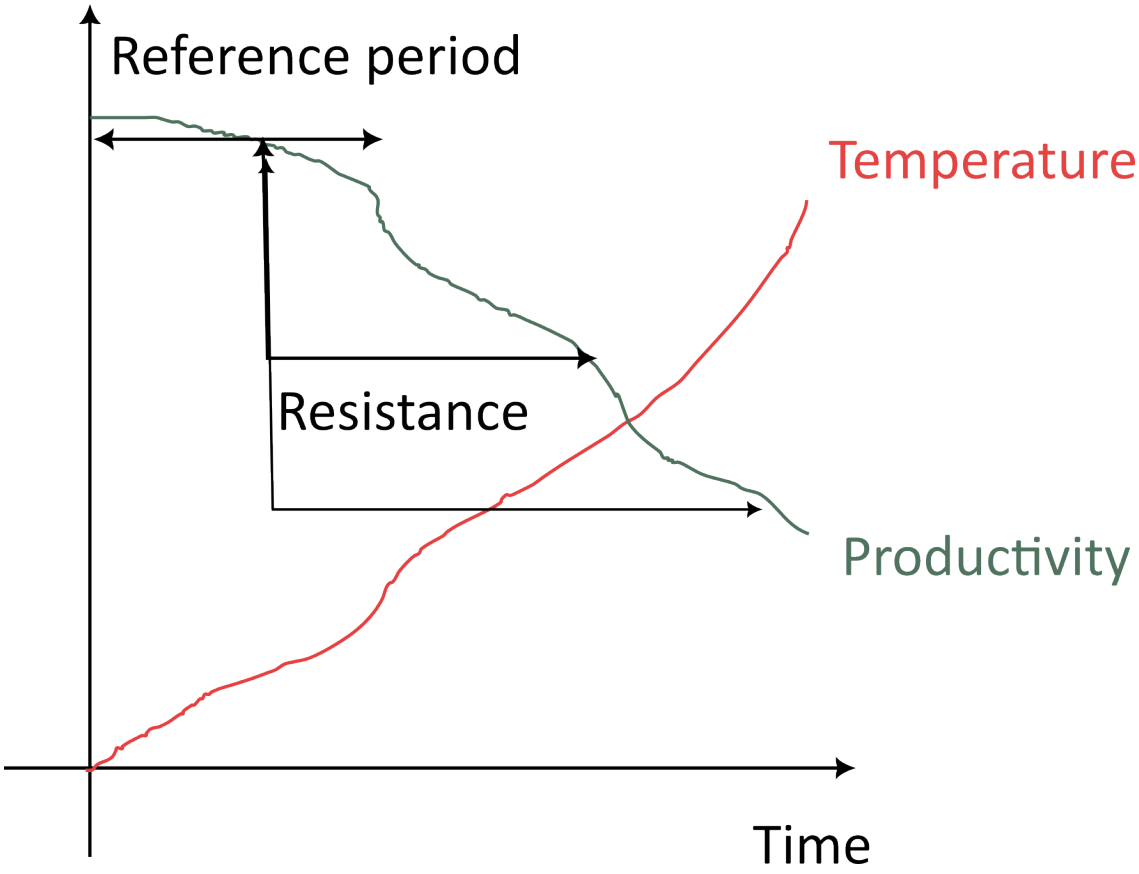
  - Issue of having enough data points from forest inventory, starting project PEPR forestt (M. Pulkkinen)
- Temperature warming is however ubiquitous (albeit at different pace)

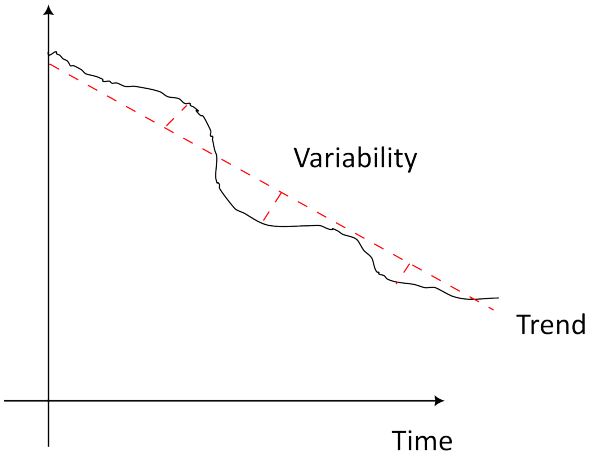


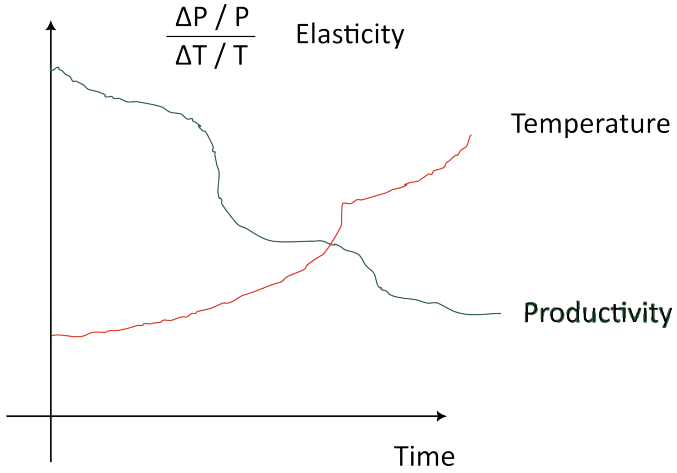
Resistance to climate warming



- Resistance as an indicator of stability adapted to nationwide monitoring of climate warming impact
- Resilience and recovery not applicable as climate warming is a press perturbation

Stability II: indices not linked to perturbation





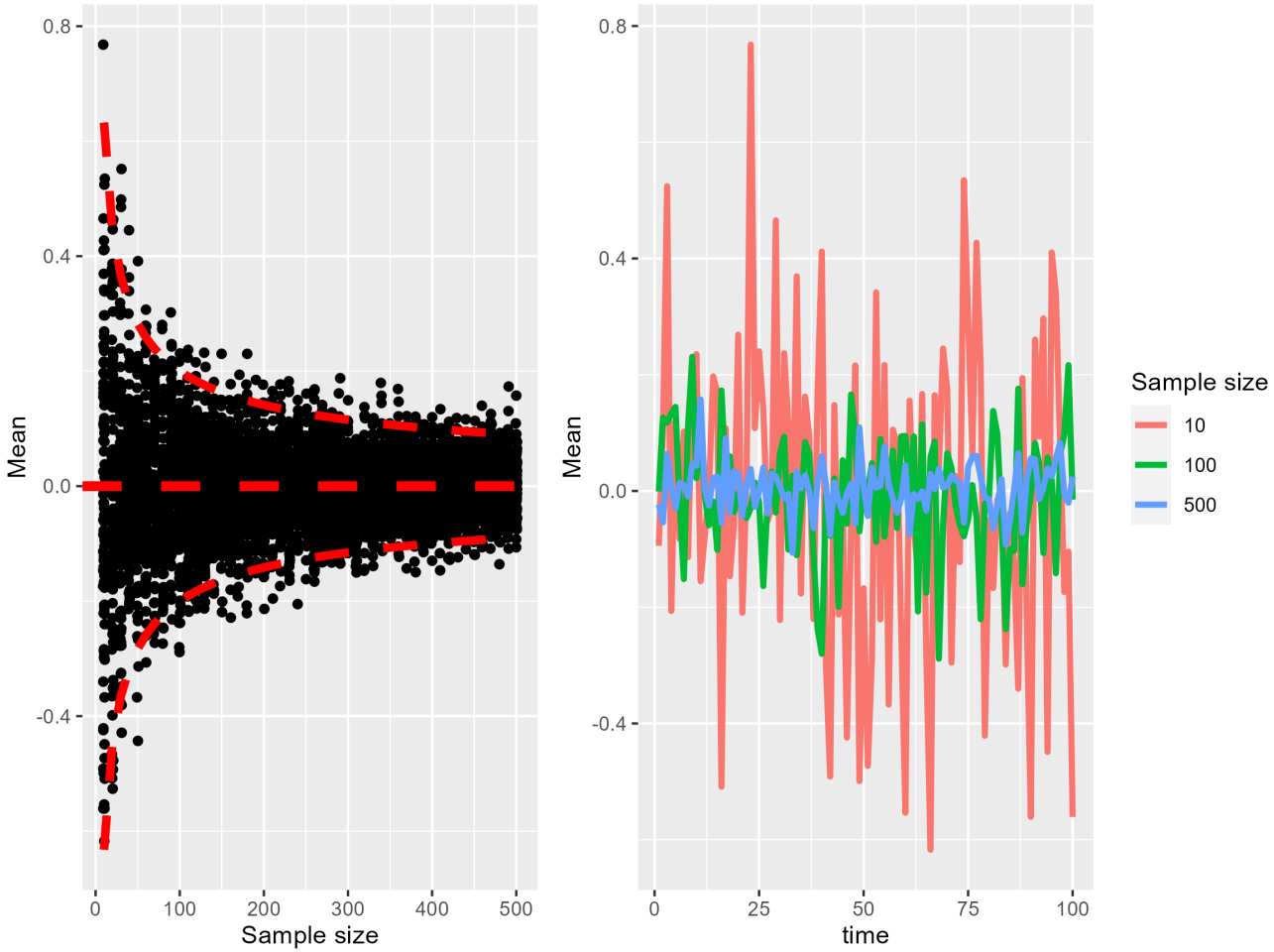
- Other indicators not related to a specific perturbation are possible
- Temporal trend coefficient can be interpreted as stability indicators
- Variability of the data (coefficient of variation) can also be an indicator of stability
- Elasticity of the variation in productivity to temperature variations

Confounding factors and modelling

- Forest growth is depending on numerous factors
- Some factors are constant over time and can be ignored for our purpose
- Other factors show temporal dynamics and need to be accounted for

$$growth \sim f(site, density, age, ...) \quad (1)$$

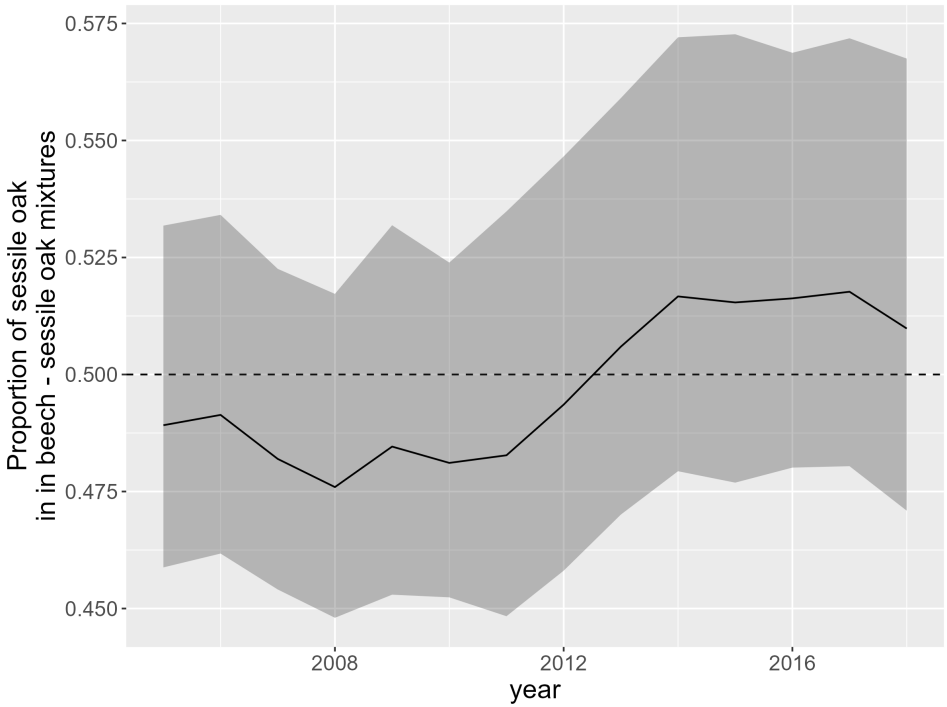
Confounding factors and sample size



With sufficient sample size, mean conditions are estimated with precision, which highlight the advantage of forest inventory data

Confounding factors

- Site conditions (soil, nutrient and water availability ...): assumed constant or temporal changes (i.e. water availability) associated to climate change
- Density: strong variation in stocks in forest (+60% in 40 years), confounder to consider
- Age: quadratic mean diameter, a proxy for stand development stage, increased in recent decades, confounder to consider
- In mixed stands: change in species dominance

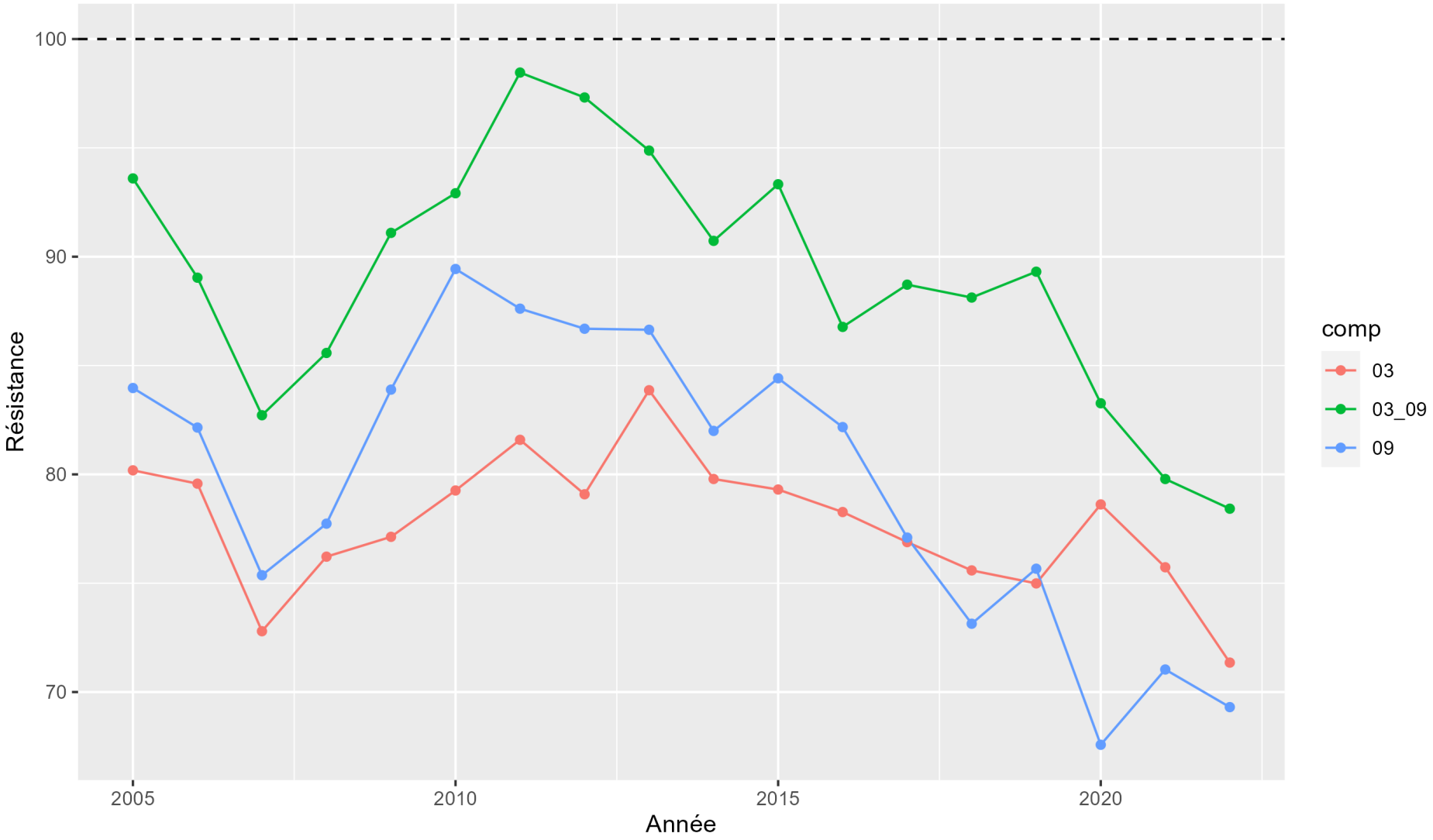


Modelling framework

1. Define a reference period and derive confounder values
2. Fit a model for every temporal window (i.e. year) with the confounders
3. Derive model predictions for the confounder values over the reference period
4. Derive indicators from the predictions (resistance ...)

$$\begin{aligned} P_y &\sim D(\mu, \sigma) \\ \mu &= f(V_y, M_y) \\ \tilde{P} &= f(V_{ref}, M_ref) \end{aligned} \tag{2}$$

Example Beech - sessile oak



Mixed stands definition

Two main options to define a mixed stands:

- Canopy cover (absolute or free-standing)
- Basal area

We use basal area in this project since canopy cover is only measured at species level since 2005 in the french forest inventory.

Mixed stands selection

Selected stands should be sampled we sufficient inventory points every year to provide reliable estimates.

At the most defined level mixed stands are defined at the species level.

$>= 100$	$>= 50$	$>= 30$
Oak (sessile and ped.) and Hornbeam	Silver fir and beech and spruce	Beech and hornbeam and sessile oak
Beech and sessile oak	Chestnut and ped. oak	Chestnut and sessile oak
		beech and ped. oak
		sessile and ped. oak
		scots pine and pubescent oak

Mixed stands selection

Groupings can be specified at different level of resolution:

- Definition at genus level: pine mixtures, oak mixtures ...
- Definition at functional level: deciduous and coniferous mixtures ...
- Other classification (phylogeny ...)?

Groupings can also be done between year (compromise temporal and species resolution)

Thank you for your attention
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