



Trends in Adaptive Capacity of European Forests, and Related Futures of its Value Chain

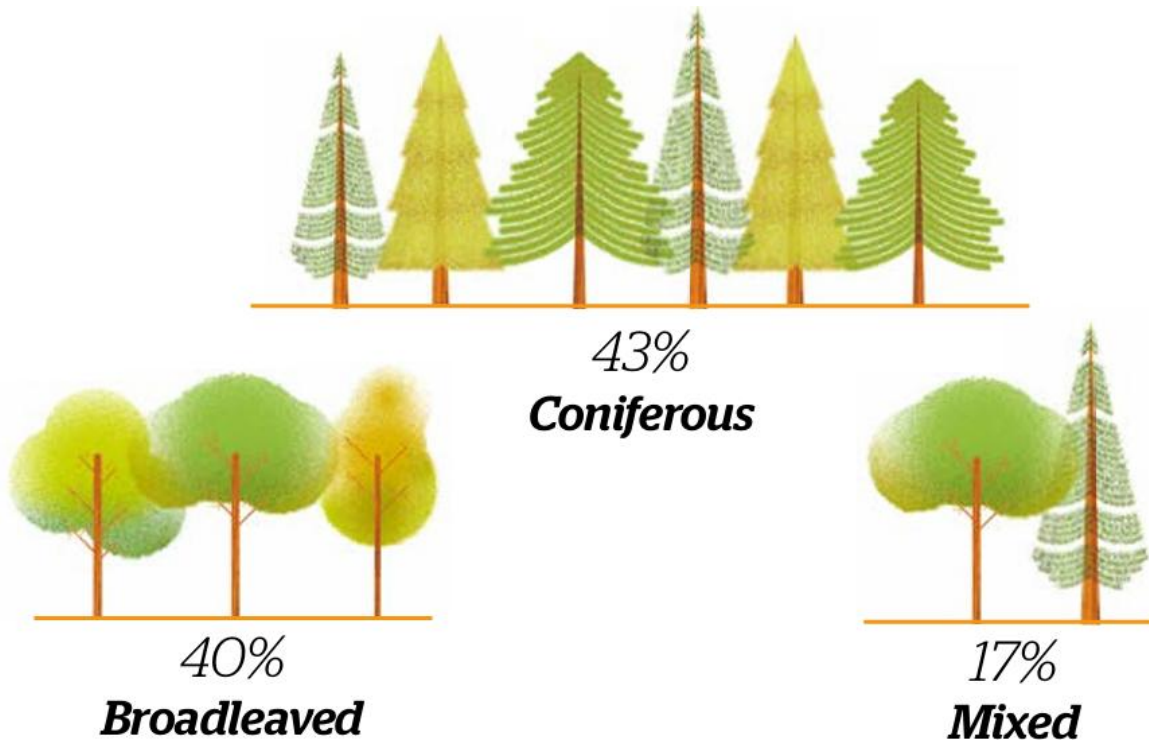
Prof. Bart MUYS

Roundtable on Resilient Forests and
Forest-Value Chain for Europe's Future, Brussels 25/06/2026

Forest Extent



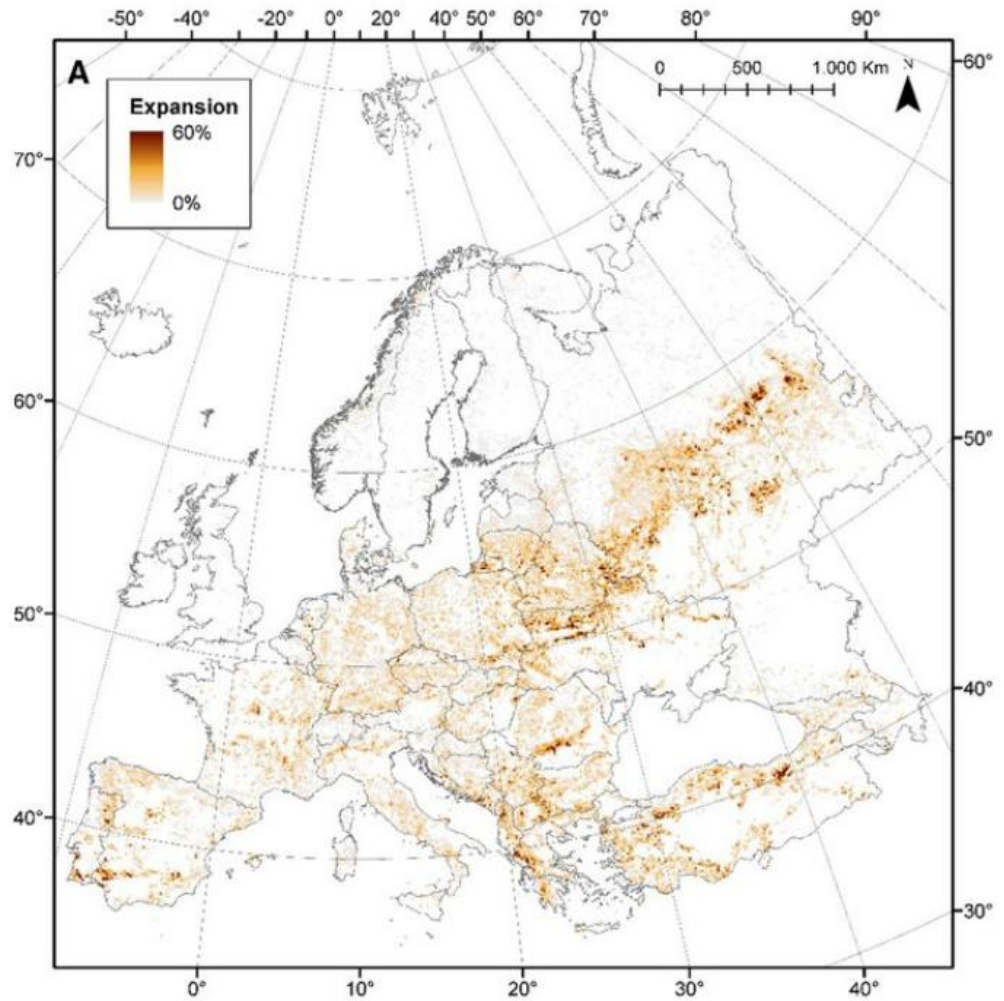
**Forest cover 35%
of Europe's total land area**



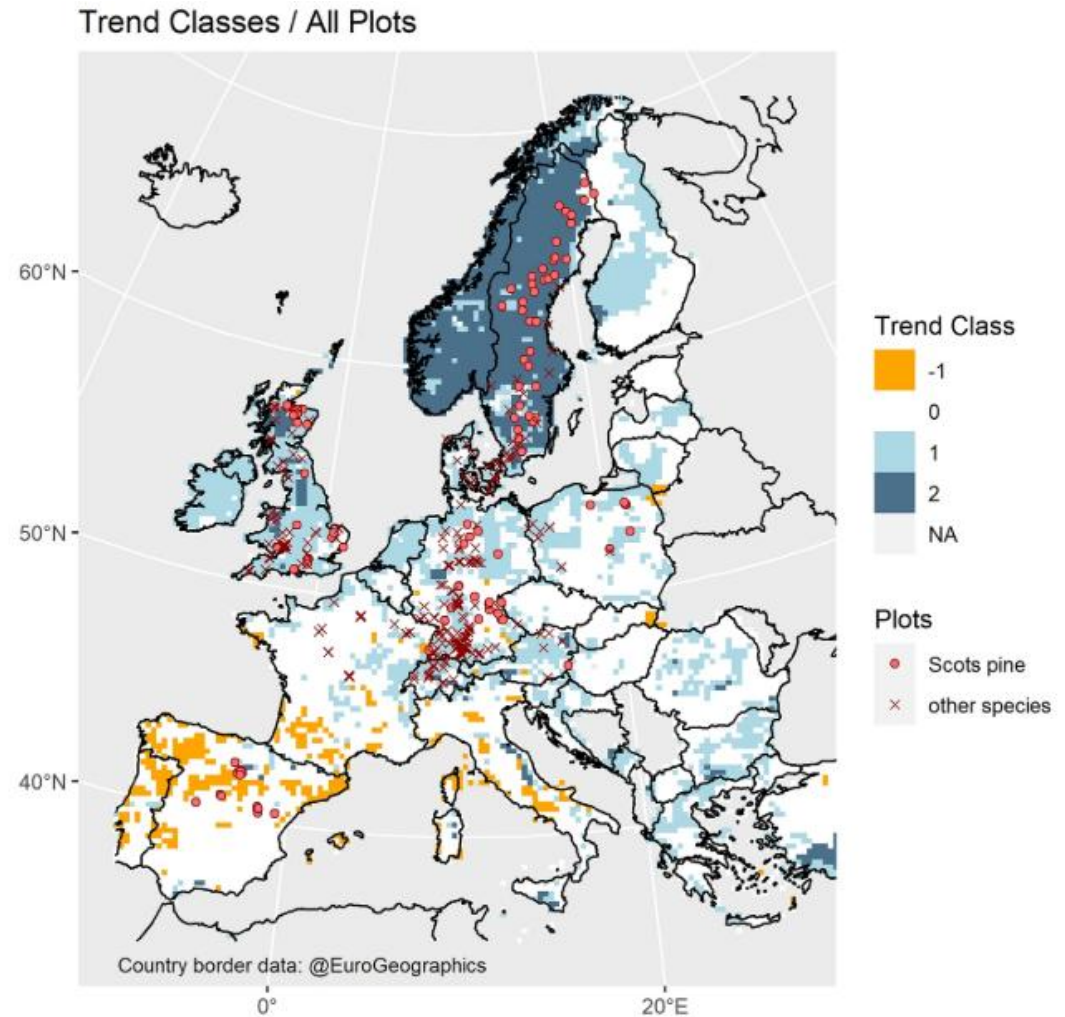
Total Forest Area: Over 227 million hectares in European continent, with a significant 9% increase over three decades.

Forest Expansion

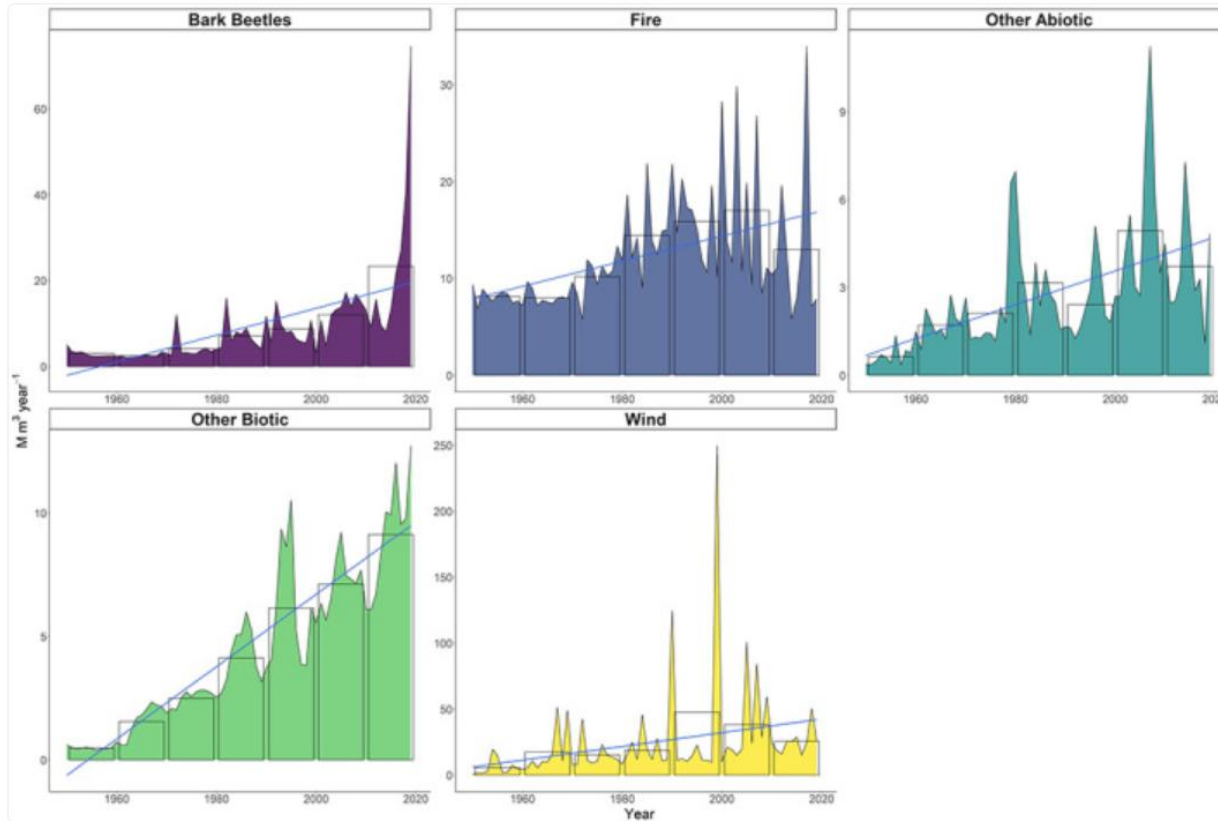
1992-2015



Forest Growth



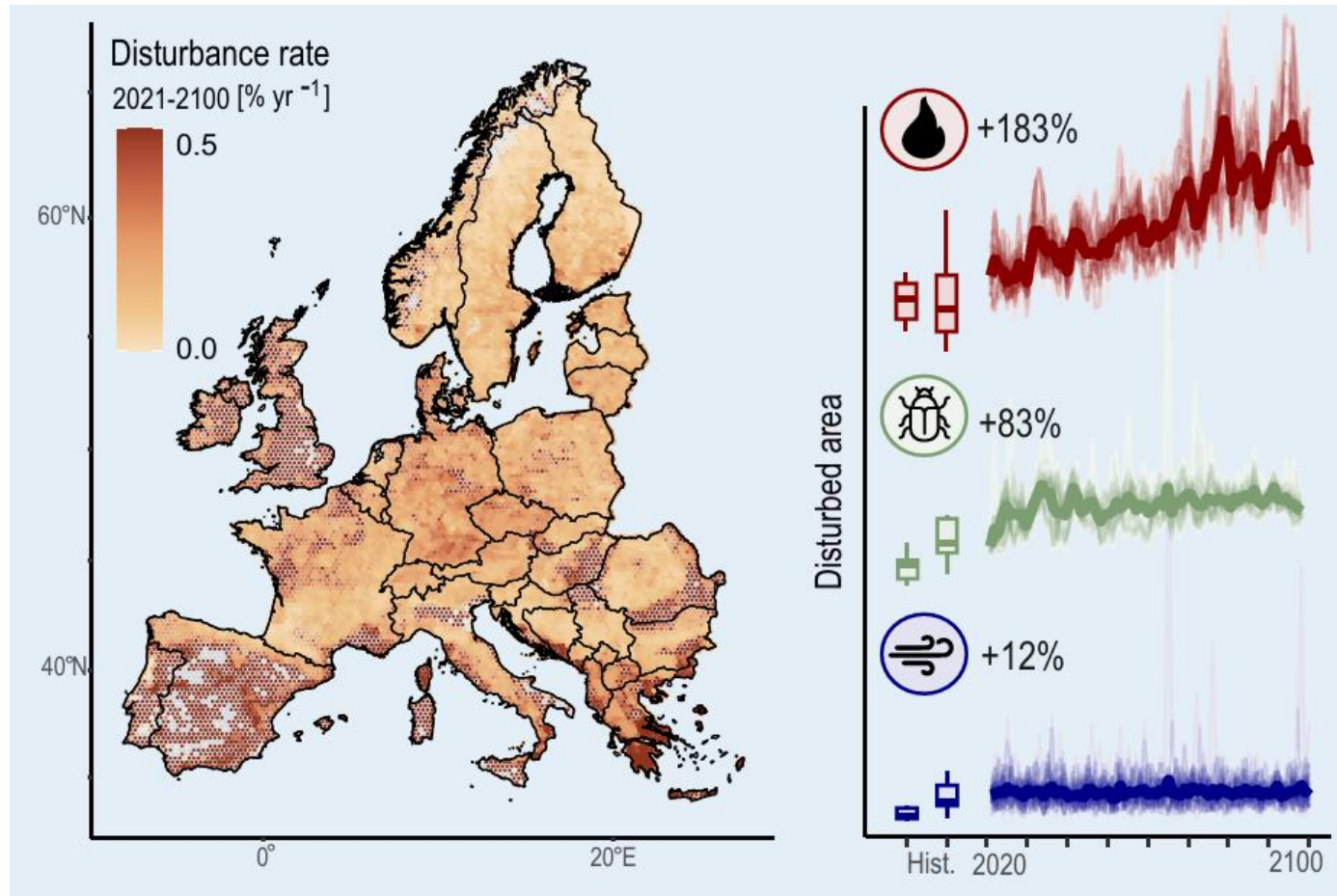
Current trends in forest disturbances



- Strong increase in tree mortality in a range of European forest types
- Often attributed to heat, drought and other climate change related disturbances
- A potential threat to productivity and climate mitigation potential

Patacca et al. 2023, *Global Change Biology* (open access)

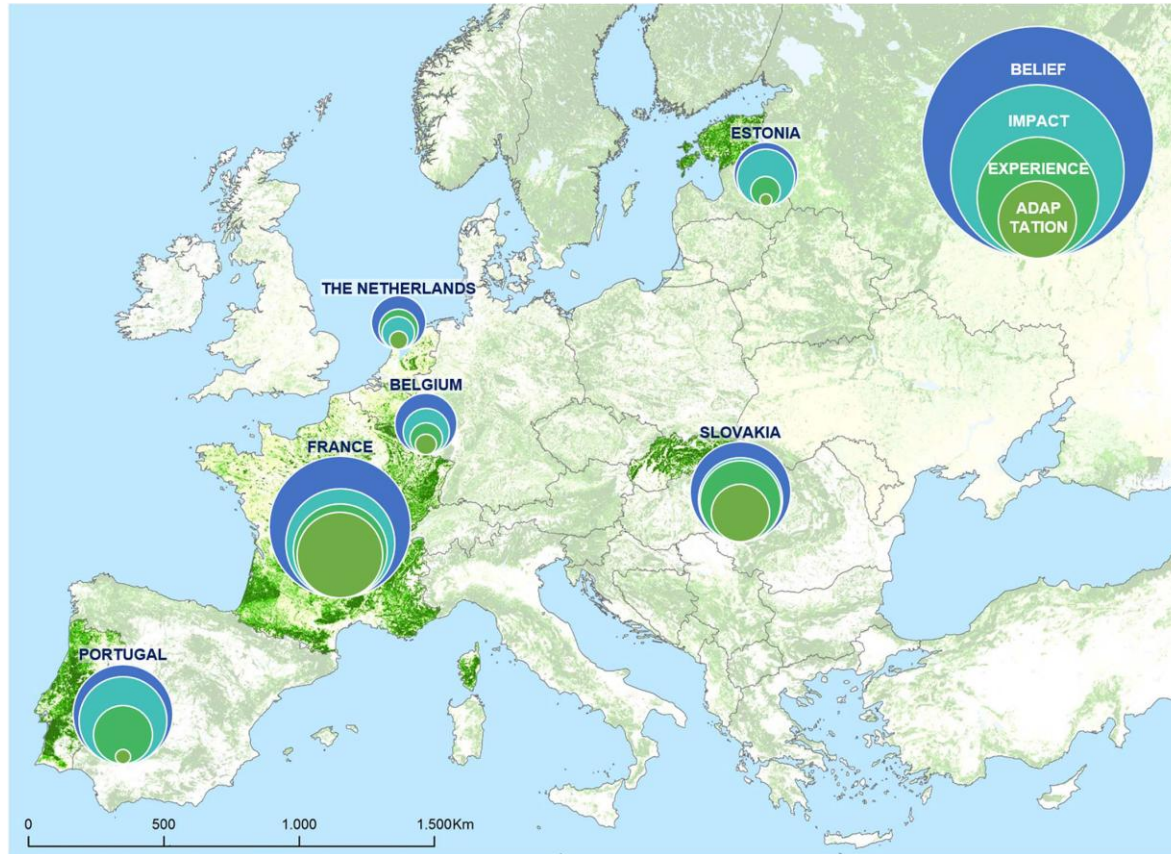
Future trends in forest disturbances



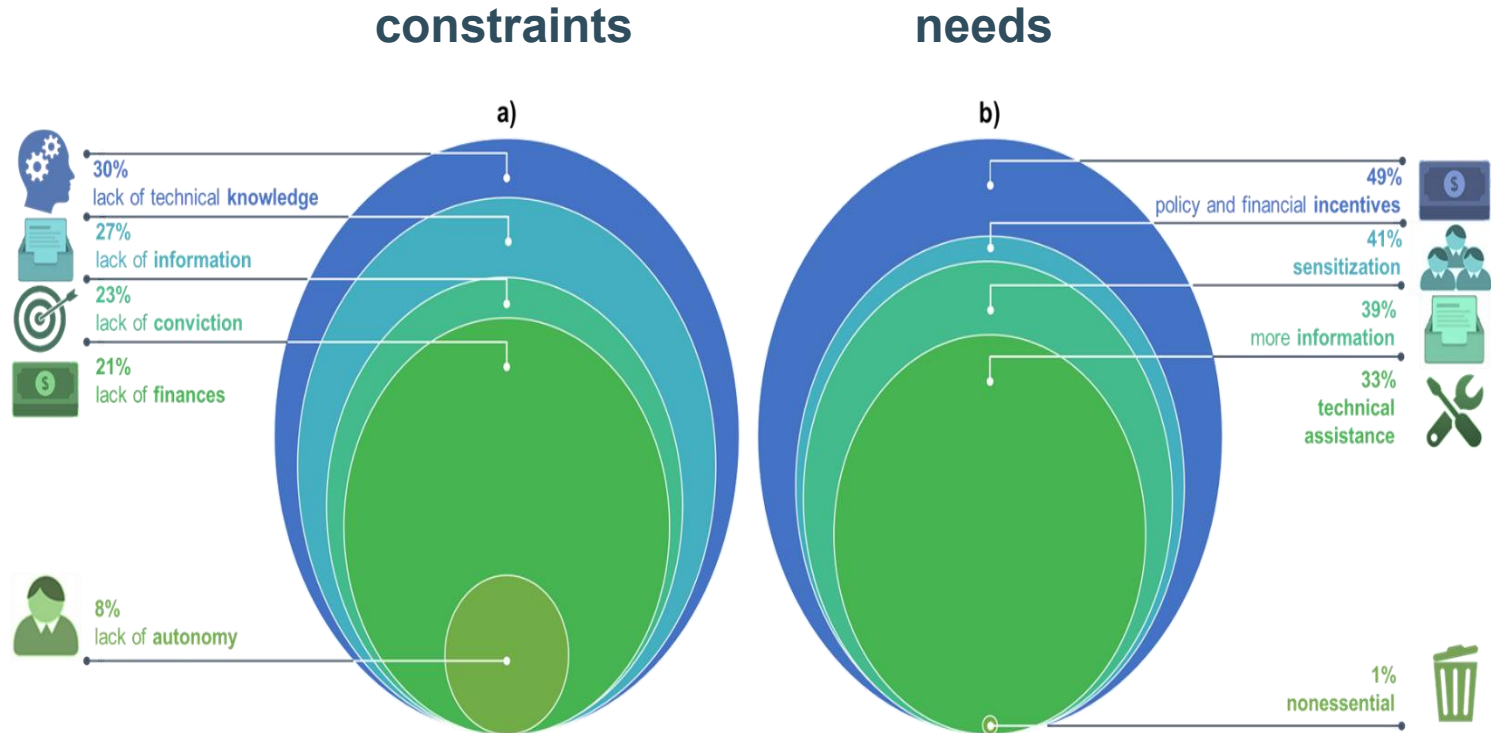
Grünig et al. 2026 *Science*

Climate change will increase forest disturbances in Europe throughout the 21st century

Climate change adaptation: gap between belief and action



Forest owners/managers constraints/needs to adapt



Adaptation continues to lag behind

Muys and Messier *Annals of Forest Science* (2023) 80:43
<https://doi.org/10.1186/s13595-023-01208-5>



Annals of
Forest Science

OPINION PAPER

Open Access

Climate-smart forest management caught between a rock and a hard place

Bart Muys^{1*} and Christian Messier²



Abstract

Key message The UNFCCC COP 27 in Sharm El-Sheikh confirmed that climate policies too heavily rely on climate mitigation by forests rather than on de-fossilizing the energy system, to keep global warming within the safe 1.5 °C. Reliable mitigation by forests would imply healthy productive forests well adapted to climate change, and this is no longer the case. The current trend in loss of forest vitality shows that the adaptation of forests is urgently needed, but measures are being insufficiently adopted by foresters on the ground. In this letter, we wonder about the reasons for this inaction paralyzing climate-smart forestry and propose a way forward using a diversity-based no-regret approach in line with available knowledge.

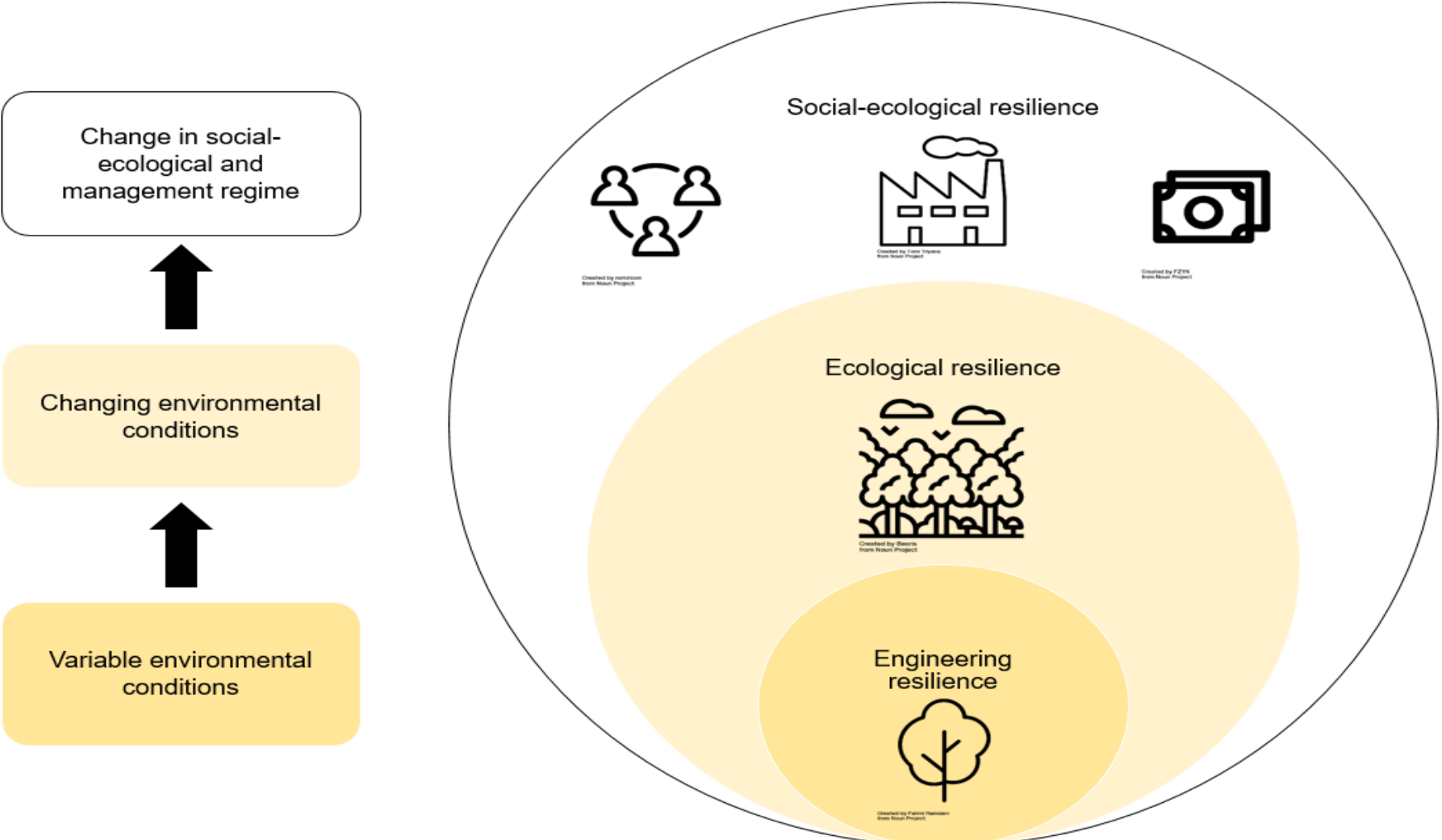
Keywords Climate change, Disturbance, Mitigation, Adaptation, Conservation, Assisted migration, Tree diversity, Invasiveness, Exotic

LOCK-INS TO ADDRESS

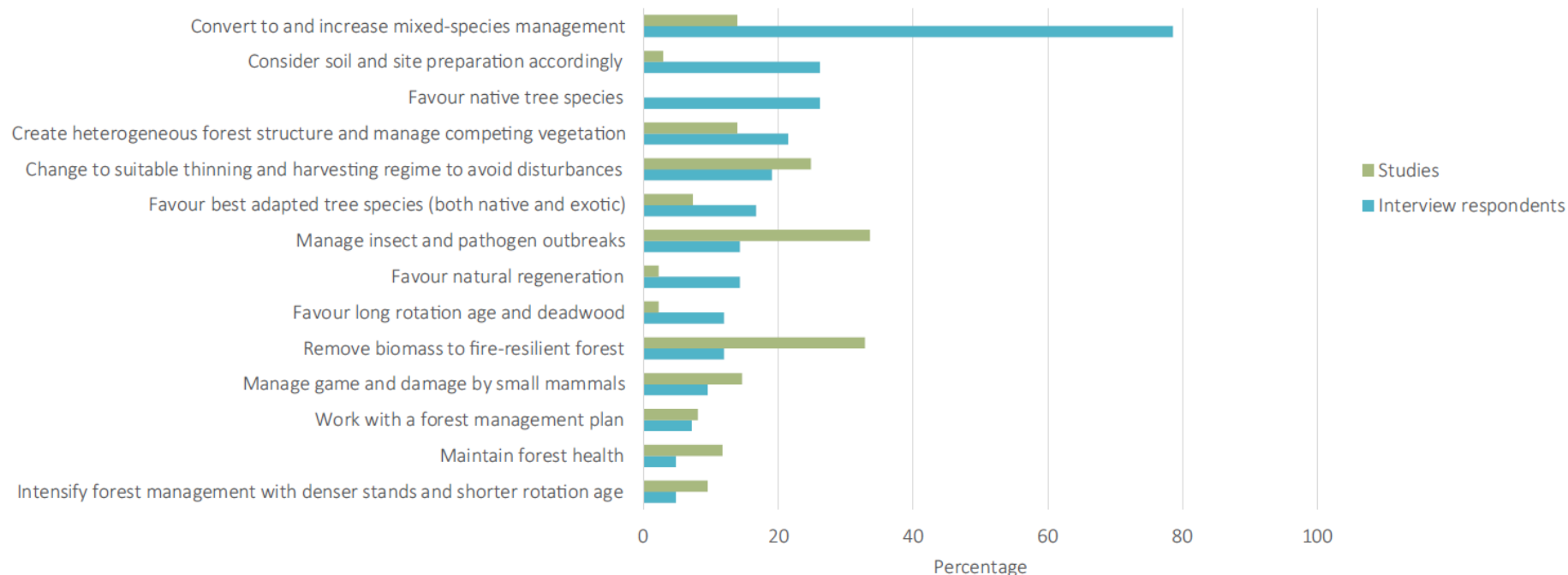
1. Forest owners & managers lack information (Sousa-Silva et al. 2018)
2. Forest industry dictates unadapted forest composition & structure
3. Nature Conservation implements EU Habitat Directive and Restoration law non-climate smart; nativeness at national scale is a threat for forest continuity

Resilience concepts

- Engineering resilience (Pimm, 1984)
 - *The time that it takes for variables to return towards their equilibrium following a disturbance.*
- Ecological resilience (Holling, 1973)
 - *The system's capacity to absorb external disturbance without changing as well as the ability to self-organize and build adaptive capacity.*
- Social-ecological resilience (Resilience Alliance)
 - *The capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organization, learning, and adaptation.*



Proposed adaptation options

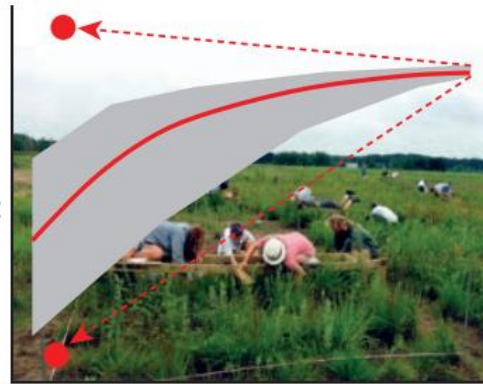


Major Options: Species choice AND Stand tending

No regret measure: tree diversity as an asset

Tree diversity – Productivity

Ecosystem function
(resource capture,
biomass production,
decomposition, nutrient
recycling)

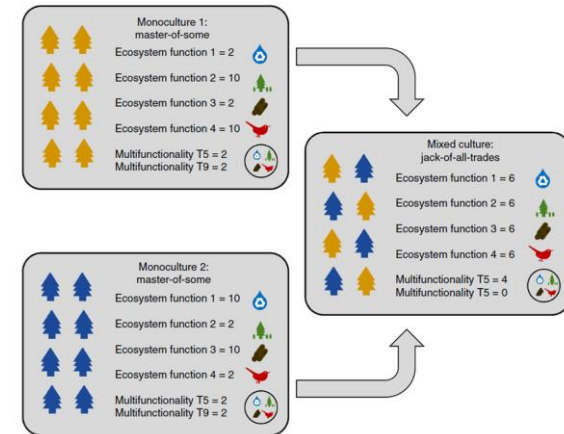


Biological diversity
(variation in genes, species,
functional traits)

Cardinale et al. 2012, *Nature*

Tree diversity – Insurance

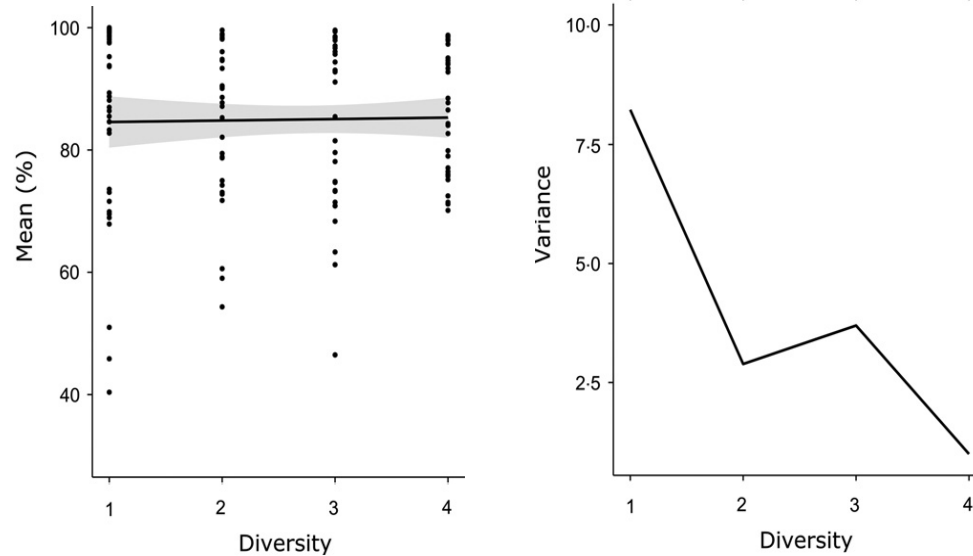
Tree diversity - multifunctionality



van der Plas et al. 2016,
Nature Communications

EFFECT on TREE VITALITY

Survival rates
from FORBIO
Tree Diversity
Experiment,
Belgium
(based on 89,000
young trees
scored)

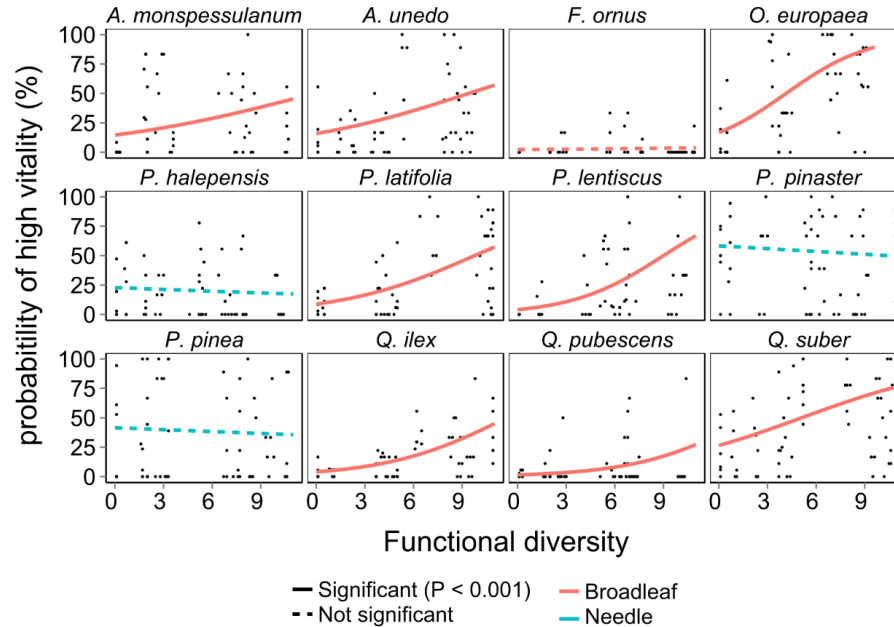


Mixture does not affect mean survival rate in an afforestation, but drastically reduces the uncertainty in the outcome

Van de Peer et al. 2017, *J. Appl. Ecol.*

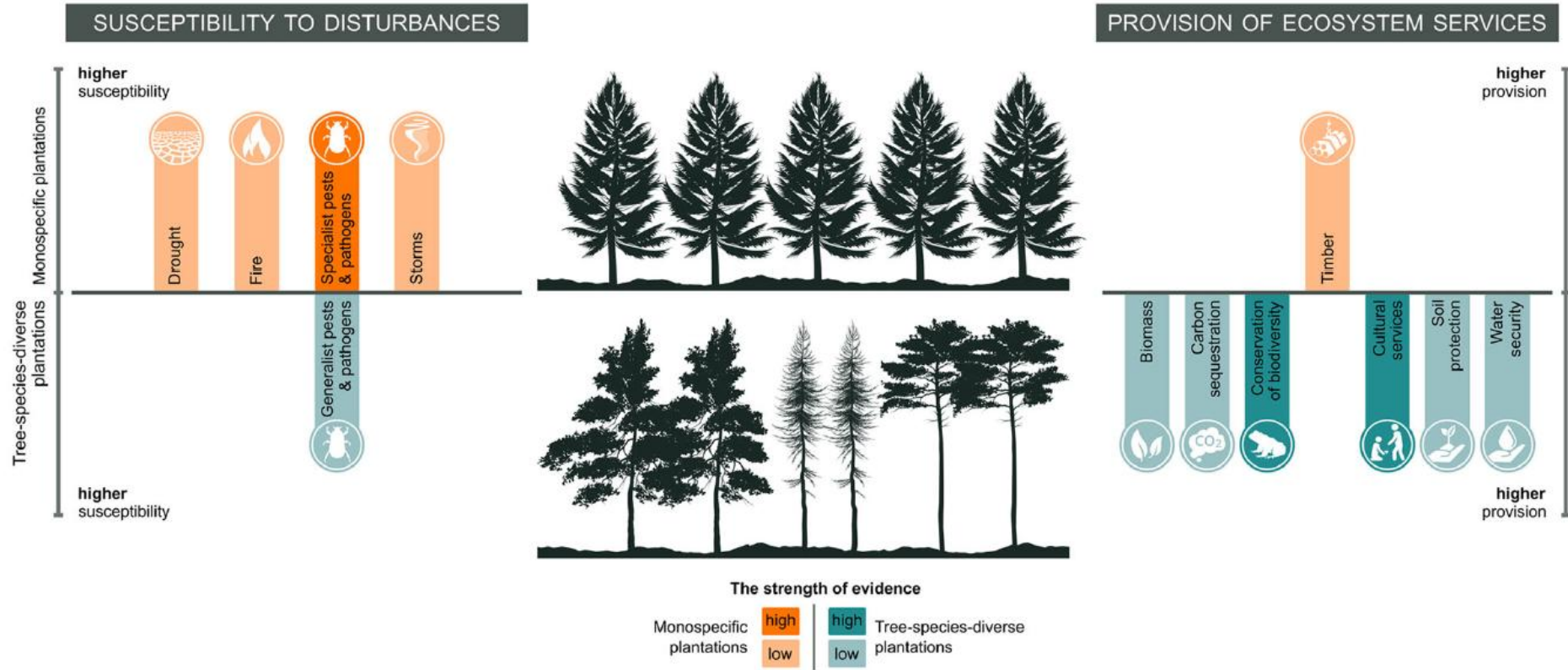
EFFECT on TREE VITALITY

Vitality scoring in
 IDENT Tree
 Diversity
 Experiment,
 Macomer,
 Sardinia,
 (19,700 young
 trees scored)



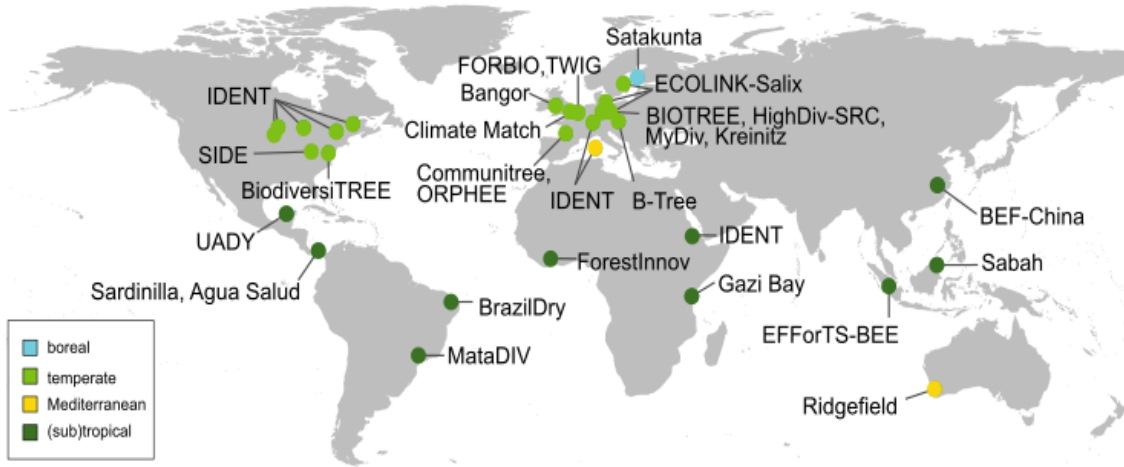
Restoration of Mediterranean forest is more successful when using mixtures

Monocultures vs. Mixtures in forestry



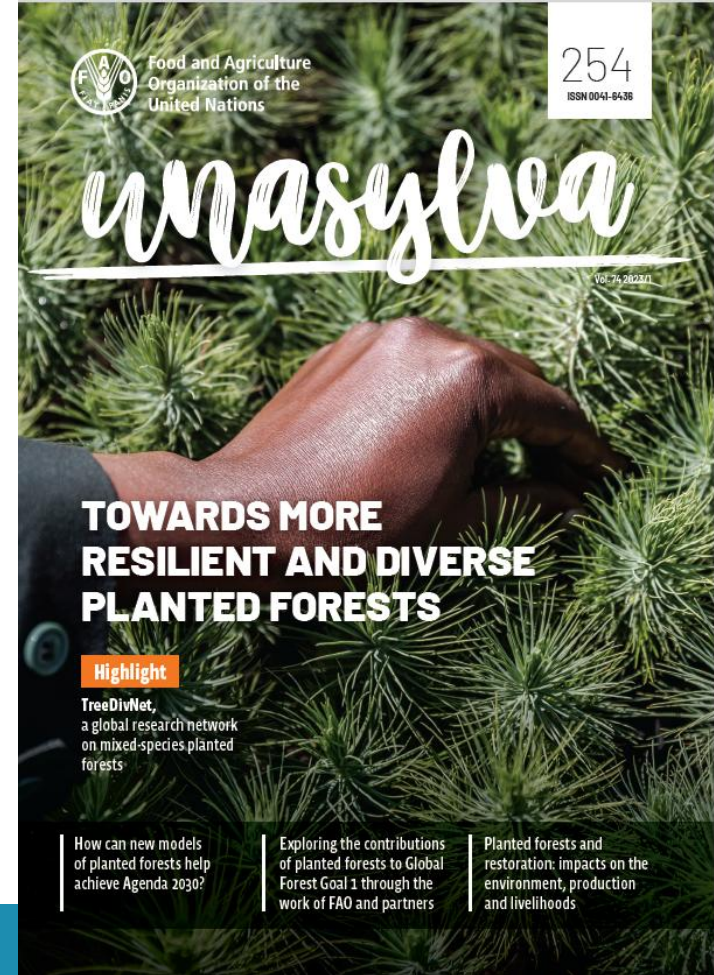
Messier et al. 2022. For the sake of resilience and multifunctionality, let's diversify planted forests *Conservation Letters*

Tree diversity as an asset



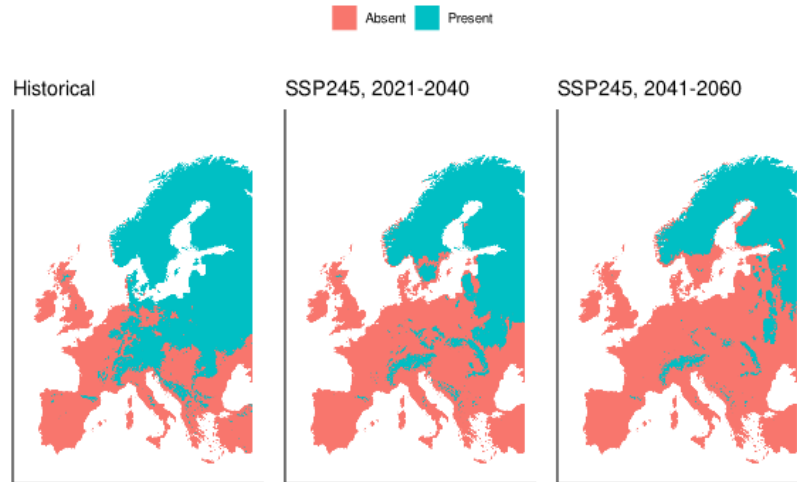
TreeDivNet

36 experiments, 900 ha of experimental area,
1,200,000 planted trees



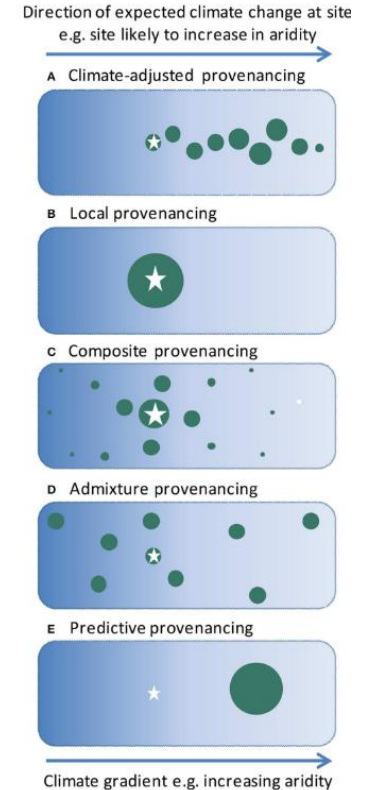
Forest Composition: Assisted migration

Climate change: threat to key tree species
Example: Norway spruce

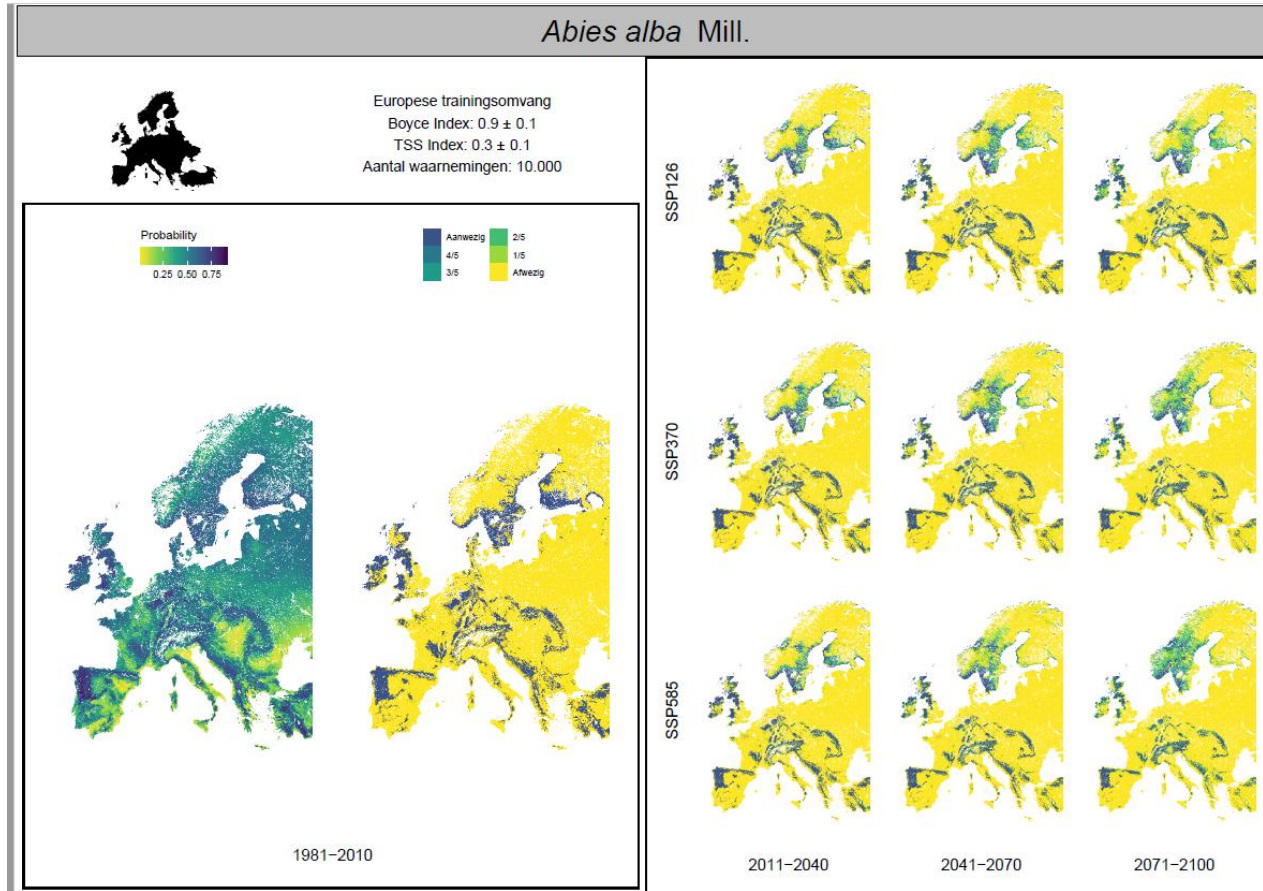


Rigid Natura2000 habitat types and nativism at national scale may threaten forest continuity.

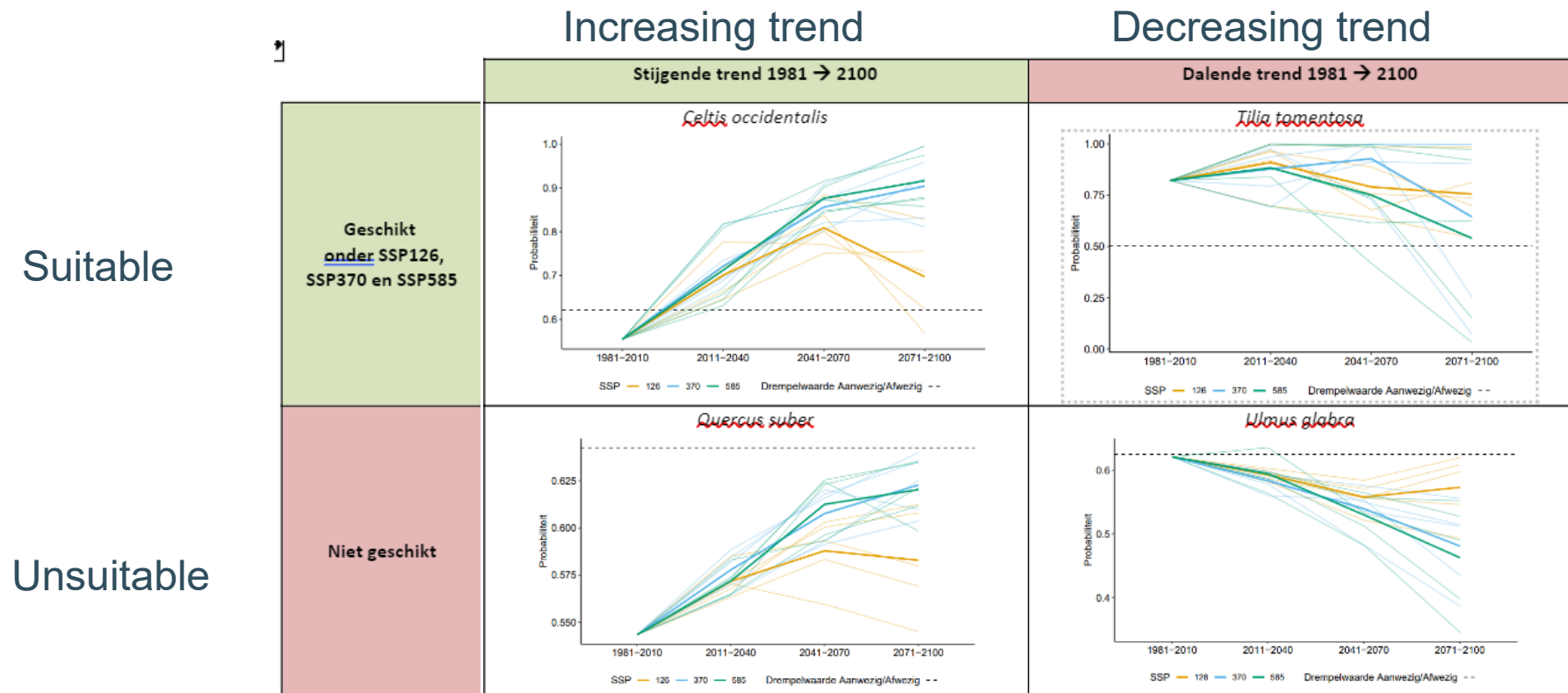
Widen nativeness definition to Native European and explore assisted migration of species and provenances (Prober et al. 2015)



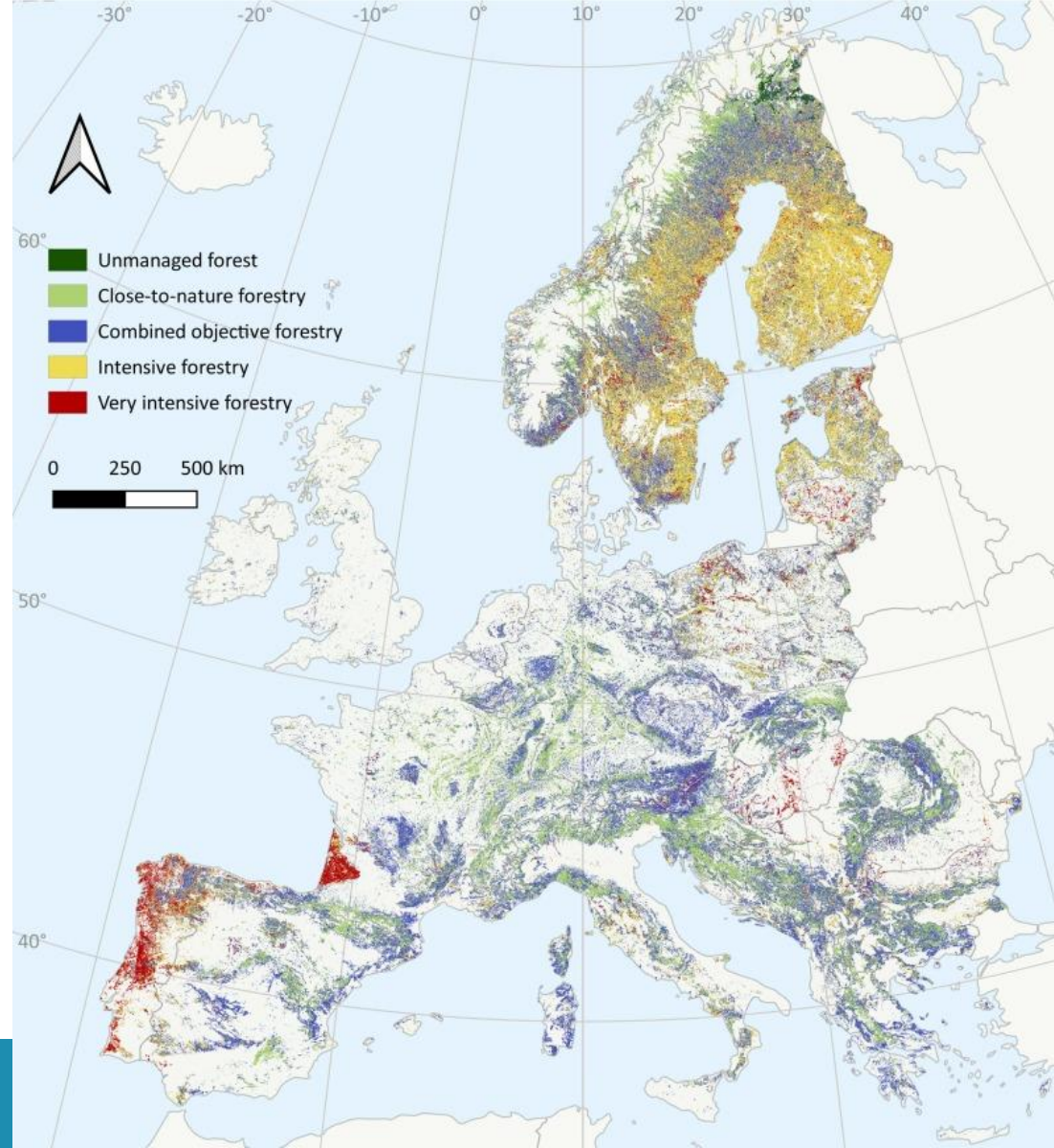
Tree Species Distribution Modeling



Tree Species suitability trends

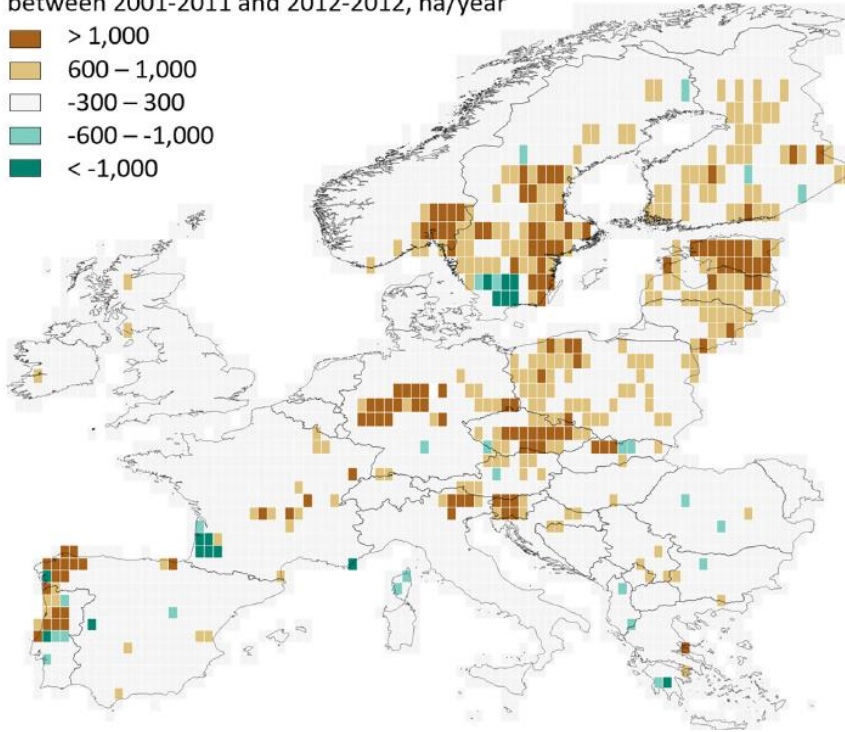
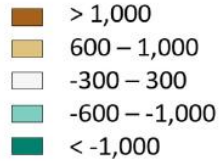


Management Regimes



Harvesting trends in Europe

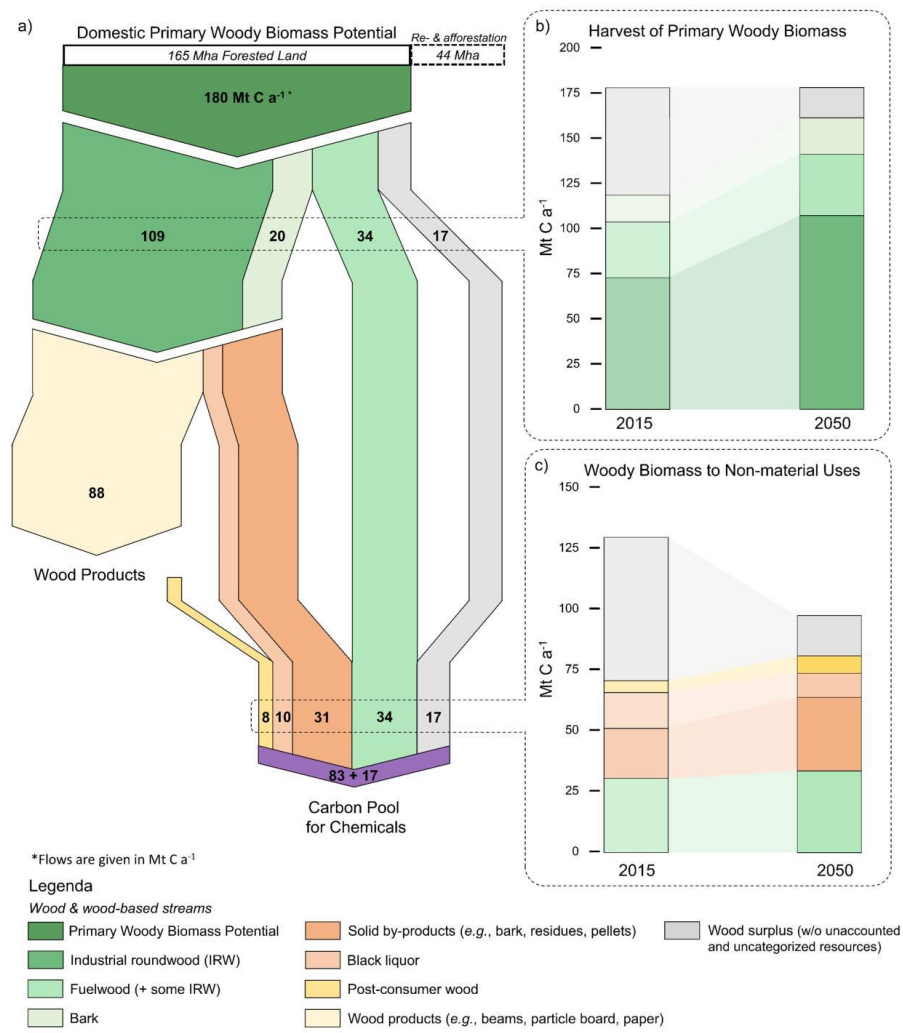
Change in annual tree canopy removal
between 2001-2011 and 2012-2012, ha/year



- Expressed per 50 x 50 km grid
- A considerable part is salvage logging
- RS monitoring as an early warning signal
- Needs further follow-up
- Points to the need of management plans and local monitoring

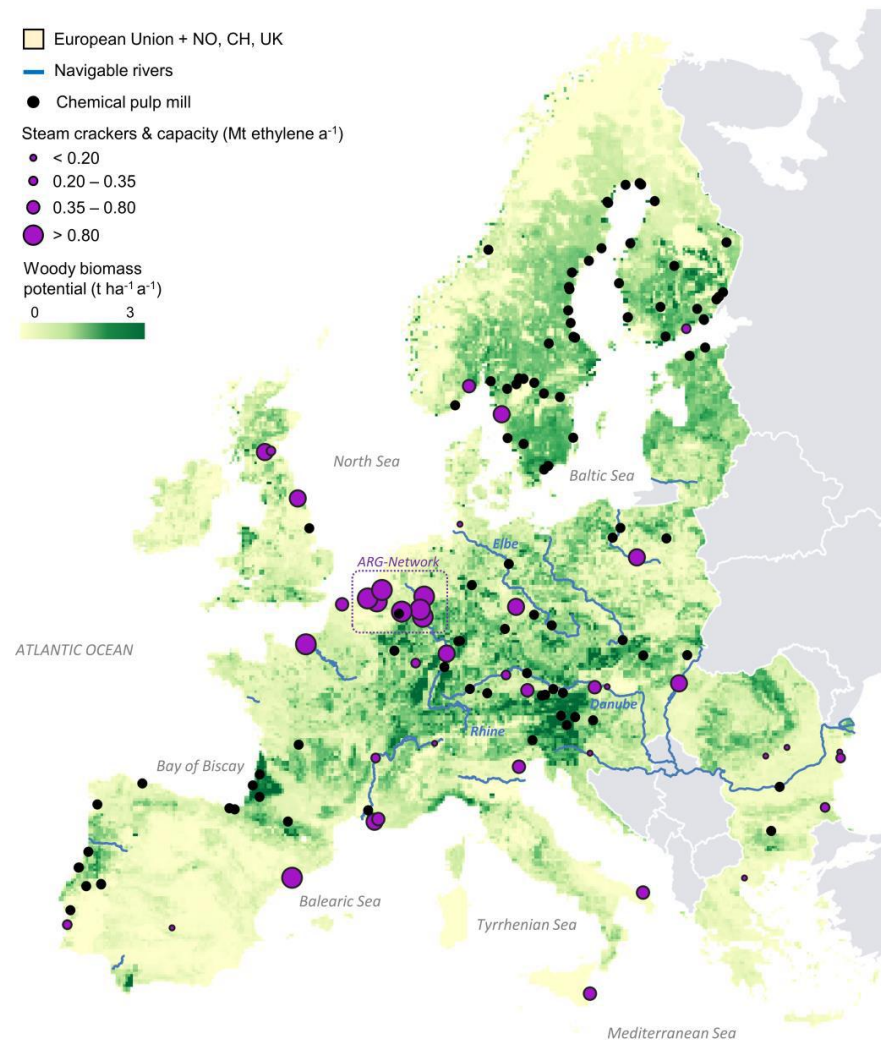
Feasibility of wood as a sustainable feedstock for chemicals production in Europe

Predicted woody biomass flows for Europe in 2050 in a renewable biorefinery scenario



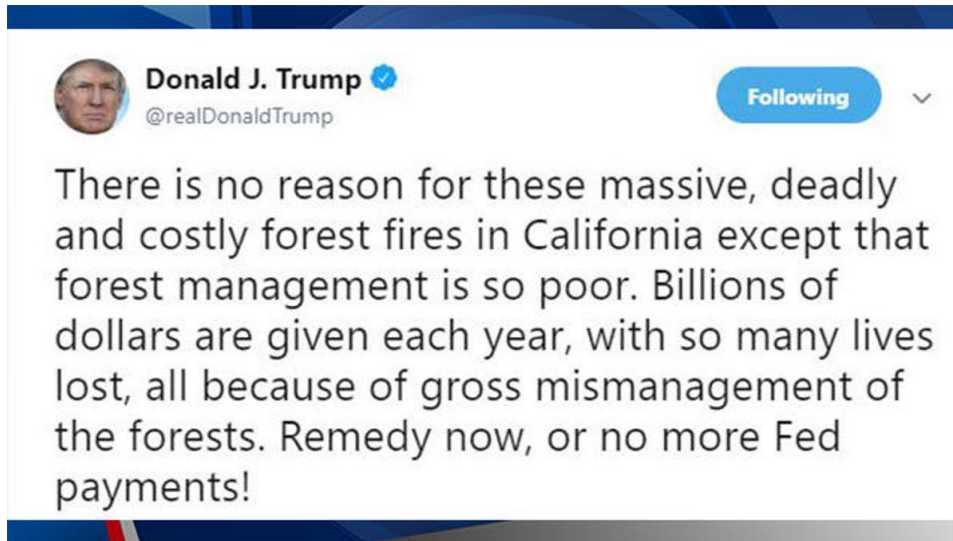
Compatibility between wood resources and chemical industry hubs

Spatial Distribution of the Woody Biomass Potential, the Wood based Industry, and the Chemical Industry in Europe



The case of fire resilience

Are megafires the consequence of Climate change?
Or land management?





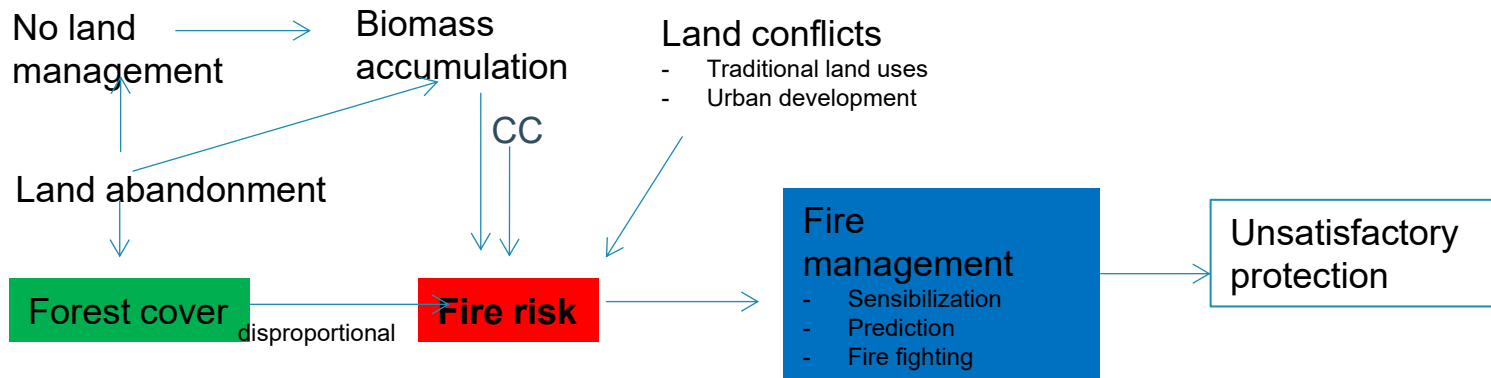
Davis et al. 2024. *Foreco*. Meta-analysis of thinning, prescribed fire on wildfire severity

Fire in the nexus

- Linear thinking



- Complex non-linear reality

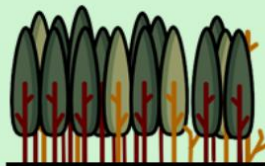


Challenge 5: fire in the nexus

How to manage for different ecosystem services under climate change, while reducing the megafire risk?

Business as usual: current management

Aim: continue current policies and management practices
How: selective cuttings (grading) every 15 -20 years
Result: high density, low diameters, many small-size deadwood



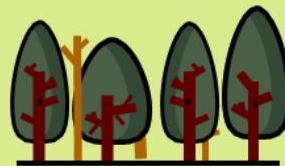
Promotion of wood energy

Aim: promote fuel biomass production (subsidies)
How: short rotations (<80 yrs), more intensive silviculture
Result: trees with medium diameter, almost no deadwood



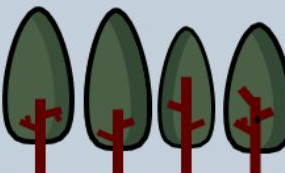
Promotion of carbon storage

Aim: adapt management for climate change mitigation
How: long rotations (~200 yrs)
Result: fewer larger trees, large snags and coarse woody debris



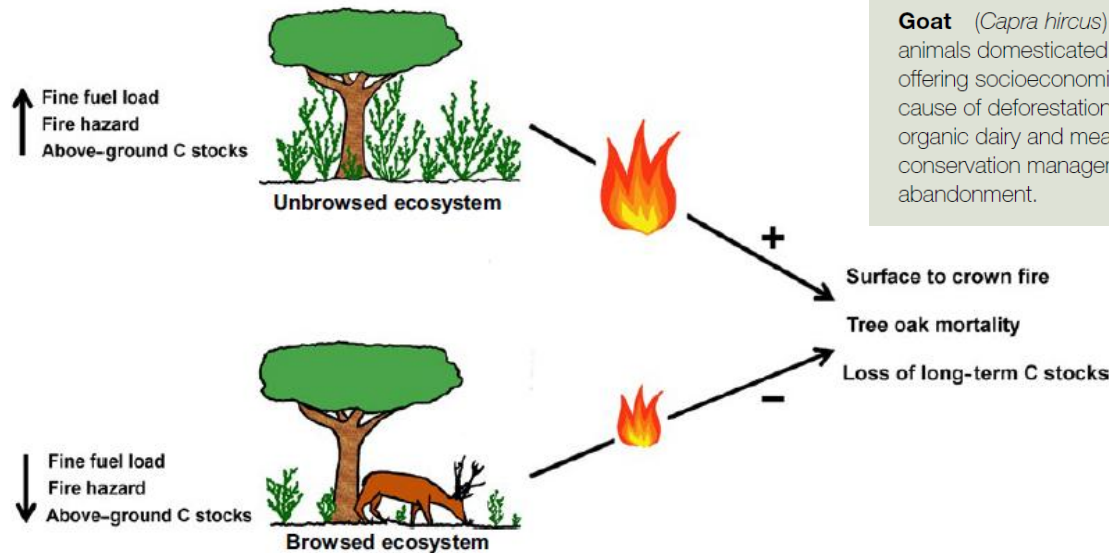
Reducing forest vulnerability to climate change

Aim: manage forest stands to cope with climate change
How: early and intense thinning
Result: few and large trees, little deadwood



Fire in the nexus

Rehabilitation of ungulates (rewilding or livestock)



Goat (*Capra hircus*). This roaming animal native to the Middle East was one of the earliest animals domesticated in the region. Since that time, goats have become a key household asset, offering socioeconomic protection and insurance to subsistence farmers. Often considered a cause of deforestation and land degradation, the species is undergoing a revival as a source of organic dairy and meat, an agent in fire prevention and, together with other herbivores, a key conservation management tool to save many endemic plants from extinction due to land abandonment.

Tardieu et al. 2018; in FAO SoMF

Fire in the nexus

Circular bioeconomy opens opportunities for win-wins in a fire resilient landscape:

DRIVERS:

- Increased demand for bioenergy (larger cleaner installations)
- Investment in local cross-laminated timber mills
- New small-sized biorefinery investments to replace petrochemical industry
- Subsidies for biodiversity management

EFFECTS:

- will reduce standing biomass stock in forests but increase forest vitality and increment
- will increase water infiltration and blue water harvesting
- will optimize climate mitigation between carbon sequestration, albedo effect and local cooling
- will increase biodiversity conservation in biodiversity hotspots/protected areas
- will offer a powerful fire prevention tool

Final Considerations

- European forest area is expected to expand further
- Climate change related disturbances become a major source of vitality loss
- European forests are a weakening carbon sink possibly evolving in a carbon source
- Mixture is an economic asset
- Major shifts in tree species composition need to be anticipated
- Depending on the Region, non-timber ecosystem services become more prominent, and may shift forest to zero or less intensive management
- Forest products will remain valuable resources; price levels will determine levels of mobilization
- Fire resilience is an interesting case for win-win management



Thank you for
your attention

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