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The effect of landscape structure on the climate resilience of lowland Norway spruce forests

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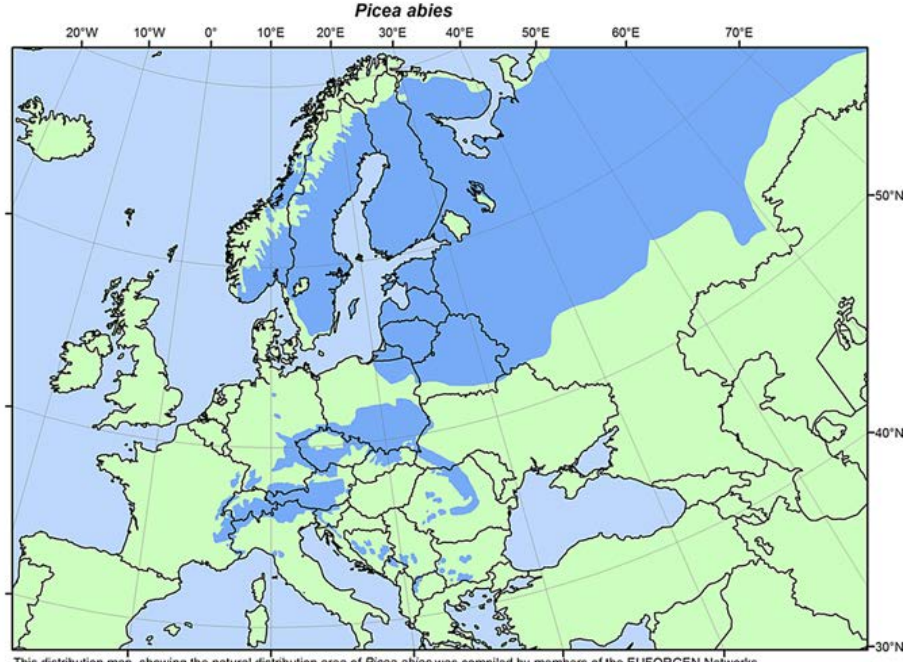
Norway spruce – icon of Eurasian forests

EUFORGEN



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This distribution map, showing the natural distribution area of *Picea abies* was compiled by members of the EUFORGEN Networks based on an earlier map published by H. Schmidt-Vogt in 1977 (Die Fichte, Verlag Paul Parey, Hamburg and Berlin, p.647).

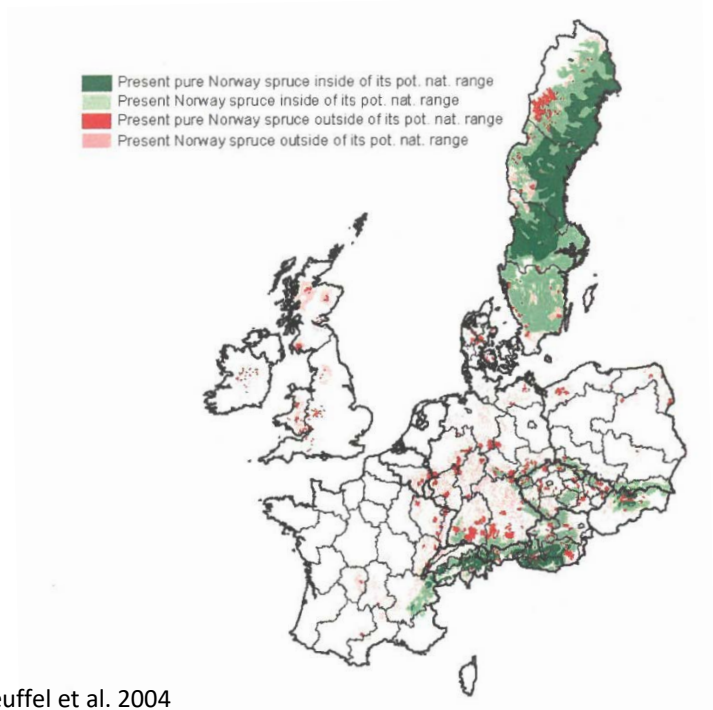
Citation: Distribution map of Norway spruce (*Picea abies*) EUFORGEN 2009, www.euforgen.org.

First published online in 2003 - Updated on 13 September 2013

Km
0 375 750 1,500

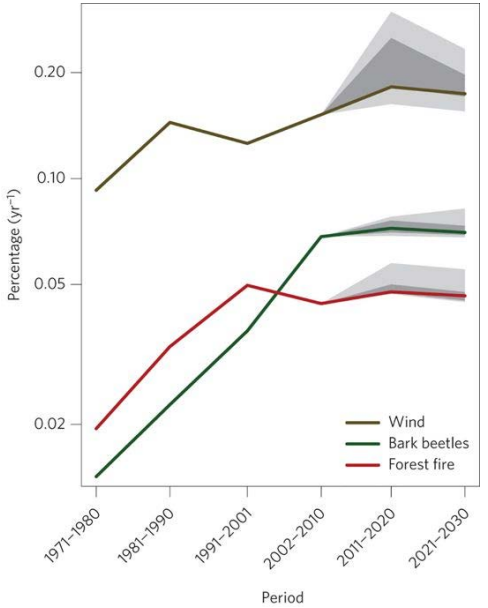
Norway spruce at the trailing edge

Valuable timber and forest management has increased the Norway spruce share



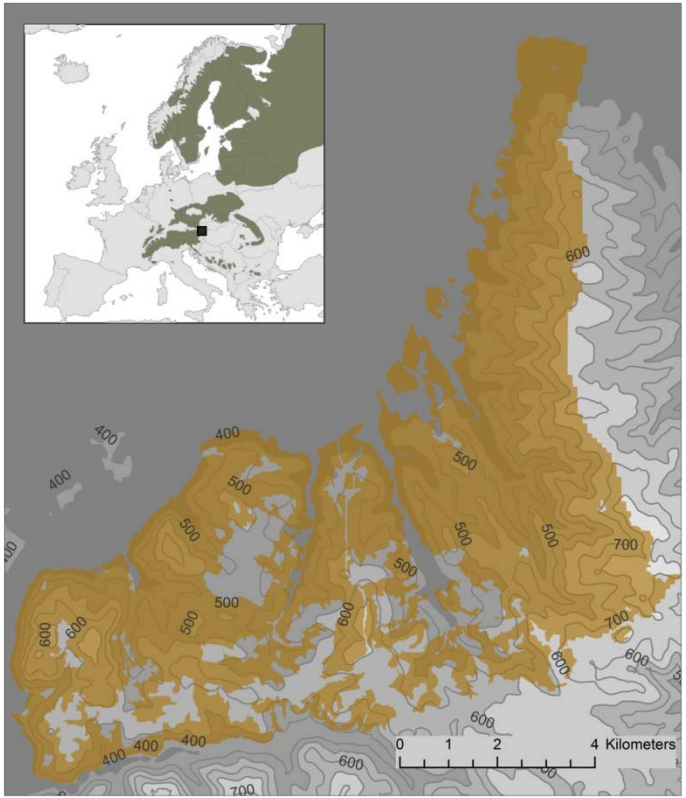
von Teuffel et al. 2004

Changing the disturbance regime – wind and bark beetle disturbance increased



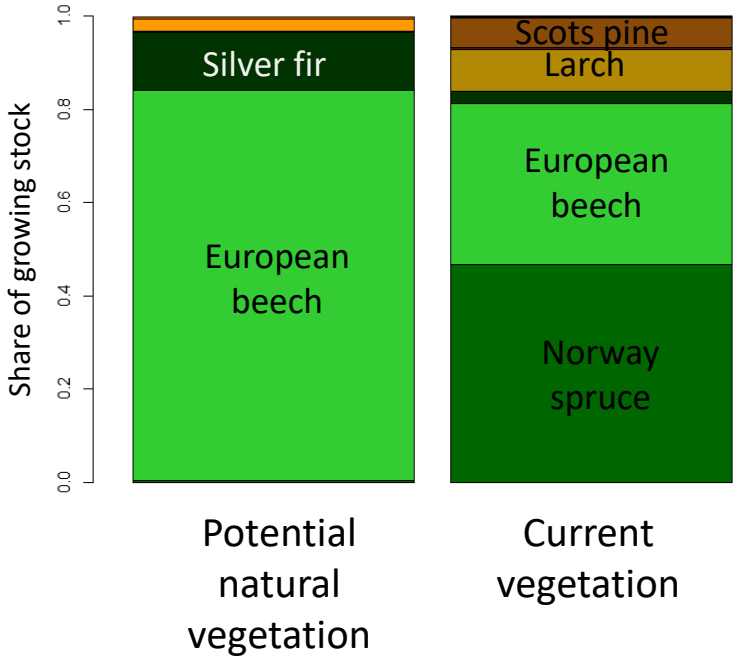
Seidl et al. 2014, Nat. Clim. Change

Study landscape

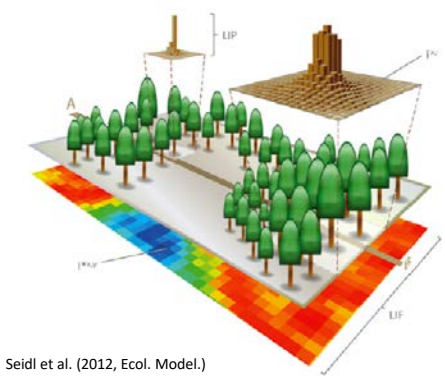


Bucklige Welt

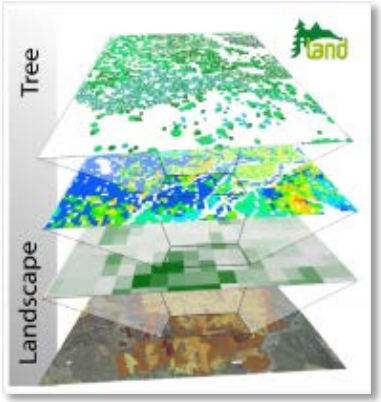
- **Lower Austria**
- **Low elevation** (230– 740m asl)
- **Pannonic** warm, subcontinental climate
- **Total area** 9,183 ha
- **Forest area** 6,700 ha



iLand – landscape simulation model



Seidl et al. (2012, Ecol. Model.)



- Spatially explicit , process-based simulation model for forested landscapes
- Simulating ecosystem processes from the level of single trees to the landscape scale
  - Tree (e.g. competition, photosynthesis)
  - Stand (e.g. resource availability, management)
  - Landscape (e.g. seed dispersal, disturbances)

Disturbance modules

Wind disturbance

- Operates at the grain of **individual trees**
- Wind speed data as input
- Simulates storm events dynamically based on a dose-response approach, taking into account changes in stand structure during a wind event

Bark beetle

- Simulates:
  - spatially explicit dispersal of beetles
  - beetle phenology and development
- **Interaction** of wind and bark beetles is explicitly simulated by increased colonization and reproduction success in wind disturbed trees

Norway spruce at the trailing edge

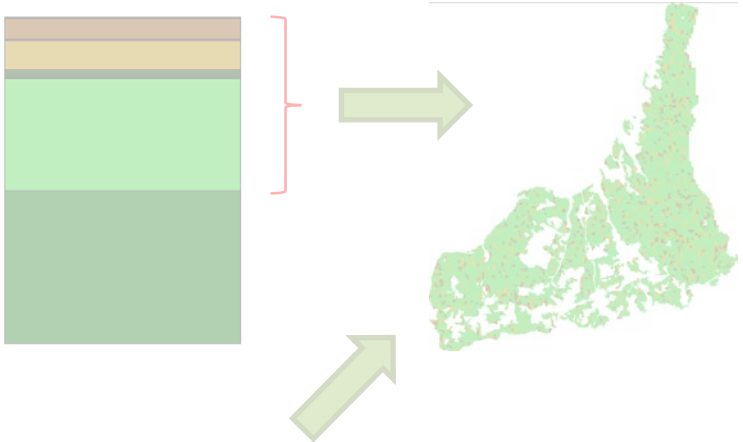
Research questions

- How does the landscape structure affect the resilience of Norway spruce to climate change?
- How landscape structure affects the natural disturbances of Norway spruce?

Landscape setup

Stand spatial structure

Resample the composition
(no Norway spruce)



Normal forest for stand age

One management program:

- 100 year rotation
- thinnings and clearcut
- planting (+natural regeneration)
- salvage of wind disturbance
- trap trees to prevent bark beetle outbreaks

Landscape composition (Norway spruce share)

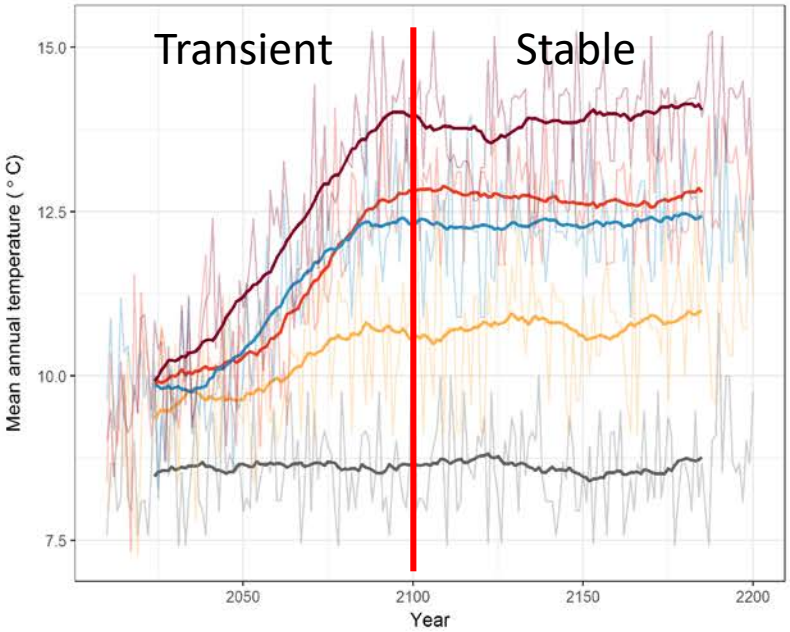
10%

Dispersed

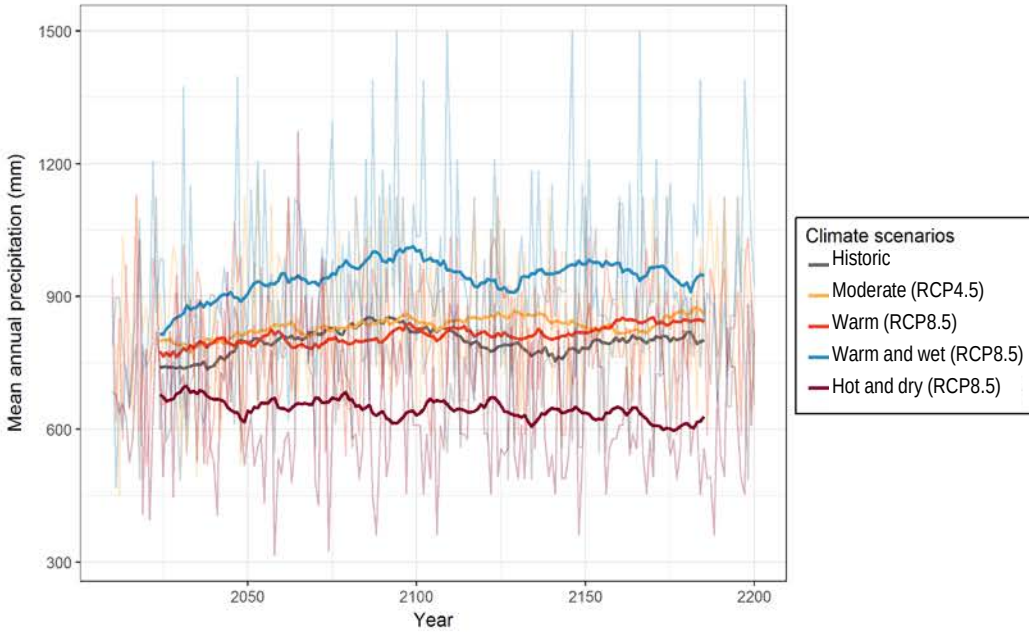
Landscape configuration

Climate change scenarios

Mean annual temperature



Mean annual precipitation



Resilience
OF Norway spruce TO climate change

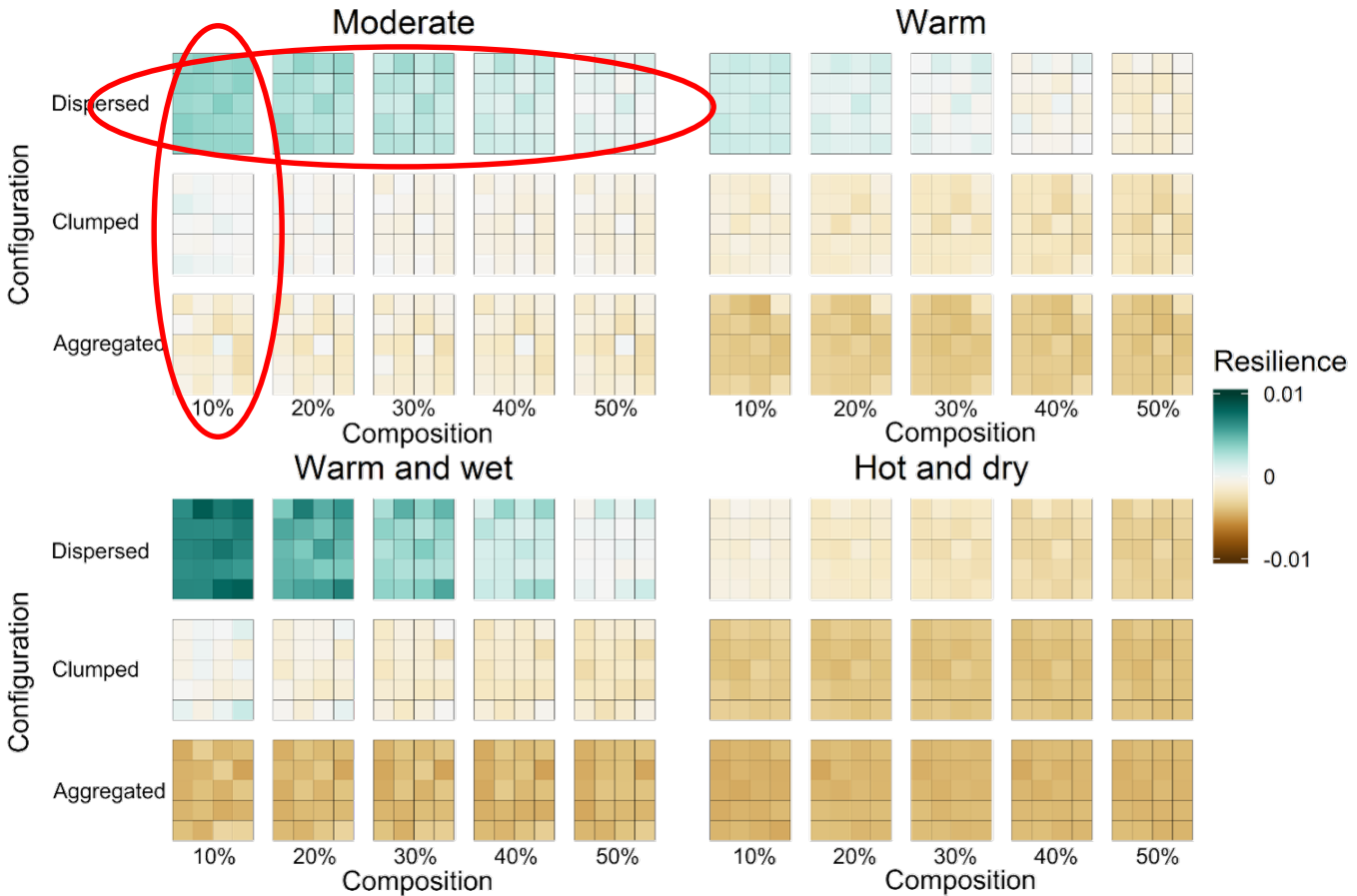
$$Recovery_{ij} = \frac{\frac{1}{n}\sum_{t=1}^{n}(annual\ growth\ m^3 yr^{-1})_{tij}}{\frac{1}{n}\sum_{t=1}^{n}(growing\ stock\ in\ historic\ climate\ m^3)_{tj}}$$

$$Impact_{ij} = \frac{\frac{1}{n}\sum_{t=1}^{n}(annual\ mortality\ m^3 yr^{-1})_{tij}}{\frac{1}{n}\sum_{t=1}^{n}(growing\ stock\ in\ historic\ climate\ m^3)_{tj}}$$

t=year, i=climate change scenario, j=spatial scenario

$$\boldsymbol{Resilience_{ij} = Recovery_{ij} - Impact_{ij}}$$

Norway spruce resilience



Natural disturbances

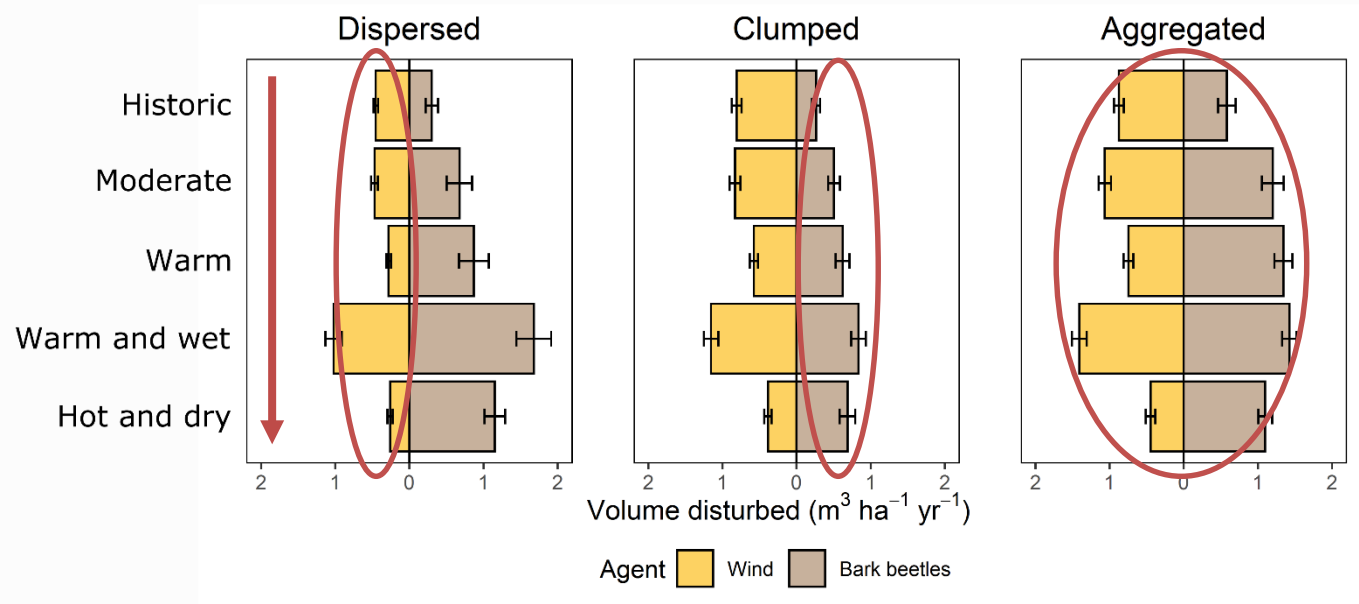
Average annual timber volume affected by disturbances

$$DisturbanceVolume_{ij} = \frac{1}{n}\sum_{t=1}^{n}(mortality\ by\ agent\ X, m^3)_{tij}$$

i=landscape structure scenario, j=climate scenario

Configuration

Composition = 30% Norway spruce share



1. Disturbances increase with climate change

2. Configuration matters:
   - Dispersed most resistant to wind
   - Clumped able to dilute the bark beetle outbreaks
   - Aggregated the most vulnerable to both wind and bark beetles

Conclusions

- Current forest compositions will be difficult to maintain in the future at the warm end of Norway spruce range
- Landscape structure has a significant effect on the climate resilience of Norway spruce
- Natural disturbances increase with climate change and are affected by the landscape structure
  - Configuration with less connectivity diluted the bark beetle outbreaks
  - Mixed species stands were the most resistant to wind disturbance

Focusing on landscape structure is a promising approach to reduce the natural disturbances and foster resilience

Landscape Ecol
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RESEARCH ARTICLE

Norway spruce at the trailing edge: the effect of landscape configuration and composition on climate resilience

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Thank you!