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

Juha Honkaniemi, Werner Rammer, & Rupert Seidl

"Managing forests in the 21st century”
March 3-5 2020, Potsdam, Germany
Norway spruce – icon of Eurasian forests

©Juha Honkaniemi
Valuable timber and forest management has increased the Norway spruce share

Changing the disturbance regime – wind and bark beetle disturbance increased

von Teuffel et al. 2004

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

Study landscape
iLand – landscape simulation 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)

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

Bark beetle U. Schmidt, 2005 (https://creativecommons.org/licenses/by-sa/2.0/)
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

Resample the composition (no Norway spruce)

Stand spatial structure

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)

Landscape configuration

- Dispersed
- 10%

Norway spruce share:
Climate change scenarios

Mean annual temperature

- Transient
- Stable

Mean annual precipitation

- Historic
- Moderate (RCP4.5)
- Warm (RCP8.5)
- Warm and wet (RCP8.5)
- Hot and dry (RCP8.5)
Resilience
OF Norway spruce TO climate change

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

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

\[ t=\text{year}, \ i=\text{climate change scenario}, \ j=\text{spatial scenario} \]

\[ \text{Resilience}_{ij} = \text{Recovery}_{ij} - \text{Impact}_{ij} \]
Norway spruce resilience
Average annual timber volume affected by disturbances

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

*i=landscape structure scenario, j=climate scenario*
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

Composition = 30% Norway spruce share
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
Norway spruce at the trailing edge: the effect of landscape configuration and composition on climate resilience

Juha Honkaniemi · Werner Rammer · Rupert Seidl
Thank you!