Forest ecology

Forest structure, Disturbances, Reproduction and seedling establishment
Lecturer

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Forest structure

= distribution of tree attributes (variables) within a forest ecosystems

1. Geographical attributes (coordinates)
   - spatial structure

2. Non-geographical attributes
   - stand structure
How to quantify forest structure?

1. Spatial structure
   - Measured using geodetic devices, GPS, tapes, ...

2. Non-spatial structure
   - Directly measured in the forest – limited set of attributes
   - Estimate according to allometric equations
Forest inventories

- Standardized methodology for monitoring forest structure and its changes over time
- Set of inventory plots with representative cover across study area
- Mapping (and tagging) tree positions
- Measuring dendrometric parameters
National forest inventories
Forest structure

Function → Structure → Processes

Structure Processes

Function e.g., Biodiversity, Productivity, Soil development ...

Processes e.g., Mortality, Seed dispersal, Climate change, Forest management, ...


...
How does the structure influence forest functions?


- Attributes used in the analysis
  - Function: Plot productivity (Aboveground Wood Production)
    - Response variable
  - Structure: (predictors)
    - Plot basal area \( BA = \sum_{i=1}^{n} \pi \cdot RBH_i^2 \) 
    - SD of tree heights 
    - Species diversity (number of species)
How does the structure influence forest functions?

(a) Productivity (t odm ha\(^{-1}\) yr\(^{-1}\)) vs. basal area (BA)

(b) Species number vs. productivity
Different species differ in their productivity for the same BA and variability in heights – large differences in productivity between monocultures compared to mixed forests.
Disturbances

= an event causing unforseen i) loss of living forest biomass or ii) decline in wood actual or potential value (Scheelhas et al. 2003: Glob. Chan. Biol.)

- Disturbance intensity in Europe between 1950-2000
  - 35 million m$^3$.yr$^{-1}$ (0.15 % of growing stock volume)
    ≈ 1.4 billion € .yr$^{-1}$
  - 53 % storms, 16 % fires, 16 % biotic pathogens, 3 % snow
Past and future of forest disturbances
Climate change and disturbances

- 3 pathways of climate change influence on disturbance severity
  1. Direct – increasing water potential, litter moisture, ...
  2. Indirect – fire fuel availability (through NPP), ...
  3. Interaction – amount of deadwood for insect development or fire incision (after windstorm, fire), ...

<table>
<thead>
<tr>
<th>Disturbance agent</th>
<th>Direct effects: climate impact through changes in...</th>
<th>Indirect effects: climate impact through changes in...</th>
<th>Interaction effects: climate impact through changes in...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>Fuel moisture\textsuperscript{a4} Ignition (for example, lightning activity) Fire spread (for example, wind speed\textsuperscript{a6})</td>
<td>Fuel availability (for example, vegetation productivity\textsuperscript{e7}) Flammability (for example, vegetation composition) Fuel continuity (for example, vegetation structure\textsuperscript{a8})</td>
<td>Fuel availability (for example, via wind or insect disturbance) Fuel continuity (for example, avalanche paths as fuel breaks\textsuperscript{a9})</td>
</tr>
<tr>
<td>Drought</td>
<td>Occurrence of water limitation Duration of water limitation\textsuperscript{a0} Intensity of water deficit\textsuperscript{a0}</td>
<td>Water use and water-use efficiency (for example, tree density and competition) Susceptibility to water deficit (for example, tree species composition\textsuperscript{e7})</td>
<td>Water use and water-use efficiency (for example, insect-related density changes) Susceptibility to water deficit (for example, fire-mediated changes in forest structure\textsuperscript{e7})</td>
</tr>
</tbody>
</table>
- Direct effects important mainly for **abiotic (climate driven)** disturbances
- Indirect effects important for **windstorms** = root vertical structure
- Interacting effects crucial for **biotic** disturbances
Climate change and disturbances
Disturbance effects on ecosystem functioning

Carbon sink projections (Tg C) of European forests reflecting future climate change and change in disturbance intensity

Proportion of observed positive/negative interactions between disturbances and ecosystem services

„Disturbance paradox“
- Positive effect on diversity (Why?)
- Negative effect on other services
Disturbances in the Czech Republic

Armillaria ostoyae
Biotic disturbances in the Czech Rep.

Cienciala et al. (2017): European Journal of Forest Research
Biotic disturbances in the Czech Rep.
Biotic disturbances in the Czech Rep.

Bark beetle expansion

- 117 tis. ha Catastrophic
- 317 tis. ha Critical
- 553 tis. ha Endangered

[Map showing distribution and risk levels for bark beetle expansion]
Biotic disturbances in the Czech Rep.
Mechanical disturbances in the Czech Rep.

- Low resistance of Czech forests to wind damage
  - Dominance of spruce with shallow rooting system
  - Prevalence of shallow rooting systems due to nutritinal degradation of soils
  - Low diversity of forests
  - Increasing wind speed due to climate change
Kyrill windstorm

- mid-January 2007
- The largest windstorm in Central Europe since 1870
- Windspeed up to 200 km.h\(^{-1}\)
- 47 fatalities across Europe (4 in Czech Republic)
- Huge damage to forests
  - Followed by smaller storms Emma and Ivan in 2008
Kyrill windstorm

- The largest effects on forests in Central Europe
- Czech Republic
  - $6.05 \times 10^6$ m$^3$ ($\approx 70\%$ of mean annual harvested volume)
  - 40 million EUR
How to deal with windstorm consequences?

**Czech Forests, s.e.**
- Quickly harvest all damaged wood
- Quickly plant new seedlings

Consequences:
- Preventing bark beetle expansion
- Low stability of artificially planted forests

**Šumava National park**
- Harvesting only about 60-70% of damaged wood, the rest kept in forest for decaying
- 50% of planting, 50% for natural seedling establishment

Consequences:
- Strong bark beetle outbreak
- Stable semi-natural forests
Fire disturbances in the Czech Rep.

- High susceptibility
  - Dry and warm regions
    - Lowlands
    - Sandstone rocky areas
  - Pine and birch forest stands
    - Resin, needles, bark
  - High population density/high density of touristic trails
    - Human induced fires

Drivers of forest fire occurrence in the cultural landscape of Central Europe

Martin Adámek, Zuzana Jankovská, Věroslava Hadincová, Emanuel Kula, Jan Wild

Landscape Ecol
https://doi.org/10.1007/s10980-018-0712-2
Fire disturbances in the Czech Rep.

- České Švýcarsko forest fire
  - Largest forest fire in the history of the Czech Republic
  - 23. 07. – 12. 08. 2022
  - 1600 ha (Czech Republic) + 250 ha (Germany)
  - Synergy of multiple drivers
    - Abnormally dry and hot climate
    - Low moisture content in the soil and biomass
    - Windy weather
    - Naturally prone region (pines, shallow rocky soils)
Seedling establishment
Seedling establishment

- Link to disturbances
  - gap opening of the forest floor
  - Space for seedling establishment and survival
- Applies to natural forests
Masting, Seed rain

- Synchronized production of large amounts of fruits (*masting*) or seeds (*seed rain*)

- Ecologically important in harsh conditions (strong growth limitation)
Masting, Seed rain

Increasing chance for seedling survival
Is seedling structure linked to forest range expansion?

- Yes, but be aware of significant seedling mortality
- Important for treeline research
Is seedling structure linked to forest range expansion?

- Probability of mortality in the 1st year after establishment
  - 75% at forest margin
  - 90% above the forest margin
Thank you for your attention