Forest ecology

Forest structure, Disturbances, Reproduction and seedling establishment

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Forest structure

= distribution of tree attributes (components) 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 measure in the forest – limited set of attributes
   - Estimate according to allometric equations
Forest inventories

- Standardized system measurement of data about forest structure
- Set of inventory plots with representative cover across study area
- Mapping (and marking) tree positions
- Measuring dendrometric parameters
Forest structure

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

- **Structure**

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

The diagram illustrates the interconnections between forest structure, function, and processes.
How does the structure influence forest functions?


- Attributes used in the analysis
  - Function: Plot productivity (Aboveground Wood Production)
  - Structure:
    - 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?

Forest productivity estimated on tree level by the intensity of shading by competitors — aggregated to stand level.
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) lost 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 m³ .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 disturbances
Climate and disturbances

- 3 pathways of climate 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(^{34}) Ignition (for example, lightning activity) Fire spread (for example, wind speed(^{63}))</td>
<td>Fuel availability (for example, vegetation productivity(^{67})) Flammability (for example, vegetation composition) Fuel continuity (for example, vegetation structure(^{68}))</td>
<td>Fuel availability (for example, via wind or insect disturbance) Fuel continuity (for example, avalanche paths as fuel breaks(^{69}))</td>
</tr>
<tr>
<td>Drought</td>
<td>Occurrence of water limitation Duration of water limitation(^{70}) Intensity of water deficit(^{70})</td>
<td>Water use and water-use efficiency (for example, tree density and competition) Susceptibility to water deficit (for example, tree species composition(^{71}))</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(^{72}))</td>
</tr>
</tbody>
</table>
• **Direct** effects especially important for **abiotic (climate driven)** disturbances

• **Indirect** effects important for **windstorms** = root vert. structure

• **Interacting** effect crucial for **biotic** disturbances
Disturbances under climate change

[Map showing disturbances under climate change for different continents (North America, Europe, Asia, South America, Africa, Oceania) with color coding for increasing and decreasing disturbance activity.]
Disturbance effects on ecosystem functions

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 biodiversity and ecosystem services

"Disturbance paradox"
- Positive effect on diversity (Why?)
- Negative effect on other services

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<tr>
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<th>Disturbance</th>
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<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Effect size</td>
<td></td>
</tr>
<tr>
<td>Climate change</td>
<td>No</td>
<td>22,295</td>
<td>21,975</td>
<td>-319.8</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>22,421</td>
<td>21,917</td>
<td>-503.4</td>
</tr>
</tbody>
</table>

Effect size: +126.3  -57.4  -183.6

Results are for the period 2021-2030, and effect sizes relate to a 20-year analysis period. Projections are for a continuation of reference management, and the median over an ensemble of climate scenarios is reported for assessments under climate change.
Post-fire recovery of NDVI in Canadian boreal forests – proxy for biodiversity
Disturbances in the Czech Republic

Armillaria ostoyae
Disturbances in the Czech Republic

Cienciala et al. (2017): European Journal of Forest Research
Disturbances in the Czech Republic
Disturbances in the Czech Republic

Bark beetle regions

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

https://www.kurovcovamapa.cz/
Disturbances in the Czech Republic

Species composition

Bark beetle infestation sensitivity

Species composition

Bark beetle infestation resistance

Forest health

Age

Rotation period (years)

Disturbance severity (%)

50%

30%

20%

10%

0%
Disturbances in the Czech Republic

- 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 normal 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
Seedling establishment
Seedling establishment

- Link to disturbances – gap opens the space for seedling establishment and survival
  – Applies to natural forests
Masting, Seed rain

- Synchronized production of large amount of fruits (*masting*) or seeds (*seed rain*)
- Important in harsh conditions
Masting, Seed rain

Increasing chance for seedling survival
Does seedling structure relate to forest expansion?

• Yes, but be aware of great seedling mortality
• Important for treeline research
Does sedling structure relate to forest expansion?

• Probability of mortality in the 1\textsuperscript{st} year after establishment
  – 75 % at forest margin
  – 90 % above the forest margin
Thank you for your attention!