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Modelling the occurrence of tree-related microhabitats in managed uneven-aged forest stands over time

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Miroslav Svoboda
Tree-related Microhabitats (TreMs) are morphological singularities on trees that constitute a substrate or life sites supporting forest biodiversity (cavities, bark losses, cracks, fungi ...)

Previous works show that (Lindenmayer 1993, Vuidot 2011, Larrieu 2012, 2014)
- TreMs are more frequent on large trees
- TreMs are more frequent on broadleaves than conifers
- TreM density is influenced by forest management

We know little about the dynamic process of TreM formation

Modelling TreM formation would make possible to include TreMs in forest dynamics and management simulators
Hypotheses:

- The rate of TreM formation
  (i) increases during tree growth?
  (ii) is higher for broadleaved species than conifers?

- TreM density can be increased in uneven-aged stands
  (i) by habitat-tree retention?
  (ii) by higher harvesting DBH?

Approach:
- Model TreM formation rates from observations of TreM presence on trees
- Make simulation experiments
Step 1: Collecting and harmonising TreM observations at an international scale

- Observations of TreM presence on trees
- A network of 8 research groups / 70,000 living trees
- 11 simplified TreM groups
- Harmonizing observations made with different field protocols (TreM definitions, size thresholds)
Step 2: Estimating TreM formation rates (Courbaud et al., 2017)

\[ X = \text{DBH at which a tree forms its first TreM} \]

\[ F_X(D) : \text{Proba of forming the first TreM before having a DBH of D} \]

Proportions of trees bearing at least 1 TreM at D
Calibrated on observations

\[ h(D) : \text{Hazard Rate Function} \]

Proba for a tree without TreM at D to have one at D + dD

\[ P(t) : \text{Annual Rate of TreM formation} \]

Proba of forming a new TreM between t and t+1

\[ P(t) = f(D, \Delta D) \]
Step 3: Simulating TreM formation in a forest stand

Model Samsara
Development platform CAPSIS

Individual-based
Spatially explicit
Mixed, uneven-aged stands

Recruitment

Light interception

Growth

TreM formation

Reproduction

Mortality

wood decomposition

Courbaud et al., 2015
Dufour-Kolawski et al., 2012
Results

The annual rate of TreM formation increases with DBH and with DBH increment.

Breeding woodpecker holes on *Fagus sylvatica*
Results

The effect of DBH on TreM formation rate varies among tree species

Ex: Rot holes

<table>
<thead>
<tr>
<th>DBH class (cm)</th>
<th>Hazard rate (probability/cm of increment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies</td>
<td>0.002, 0.004, 0.006</td>
</tr>
<tr>
<td>Acer</td>
<td>0.003, 0.004, 0.005</td>
</tr>
<tr>
<td>Betula</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Carpinus</td>
<td>0.003, 0.004, 0.005</td>
</tr>
<tr>
<td>Castanea</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Fagus_o</td>
<td>0.003, 0.004, 0.005</td>
</tr>
<tr>
<td>Fagus_s</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Fraxinus</td>
<td>0.003, 0.004, 0.005</td>
</tr>
<tr>
<td>Picea</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Prunus</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Quercus</td>
<td>0.002, 0.003, 0.004</td>
</tr>
<tr>
<td>Tilia</td>
<td>0.002, 0.003, 0.004</td>
</tr>
</tbody>
</table>

Huge difference between small and large trees

Small difference between small and large trees
## Results

### Annual TreM production for DBH = 50 cm and ΔDBH= 1 cm/yr

<table>
<thead>
<tr>
<th>SpGroup/TreM</th>
<th>Rot Hole</th>
<th>Breed Wpeck</th>
<th>Bark Loss</th>
<th>Exposed HeartW</th>
<th>Crack</th>
<th>Crown DeadW</th>
<th>Polypore</th>
<th>Root Concav</th>
<th>Burr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies</td>
<td>0.0007</td>
<td>0.0009</td>
<td>0.0031</td>
<td>0.0005</td>
<td>0.0009</td>
<td>0.0016</td>
<td>0.0028</td>
<td>0.0020</td>
<td>0.0014</td>
</tr>
<tr>
<td>Picea</td>
<td>0.0006</td>
<td>0.0006</td>
<td>0.0028</td>
<td>0.0006</td>
<td>0.0009</td>
<td>0.0026</td>
<td>0.0003</td>
<td>0.0057</td>
<td>0.0013</td>
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<tr>
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<td>0.0008</td>
<td>0.0057</td>
<td>0.0012</td>
<td>0.0029</td>
<td>0.0029</td>
<td>0.0007</td>
<td>0.0033</td>
<td>0.0007</td>
</tr>
<tr>
<td>Betula</td>
<td>0.0026 NA</td>
<td>0.0053 NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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</tr>
<tr>
<td>Carpinus</td>
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<td>0.0013</td>
<td>0.0081</td>
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<td>0.0027</td>
<td>0.0020</td>
<td>0.0018</td>
<td>0.0026</td>
<td>0.0009</td>
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<tr>
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<td>0.0060 NA</td>
<td>NA</td>
<td>NA</td>
<td>0.0012</td>
<td>0.0034 NA</td>
<td>NA</td>
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<td>NA</td>
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<tr>
<td>Fagus_s</td>
<td>0.0021</td>
<td>0.0010</td>
<td>0.0028</td>
<td>0.0013</td>
<td>0.0010</td>
<td>0.0026</td>
<td>0.0009</td>
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<td>0.0016</td>
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<tr>
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<td>0.0009</td>
<td>0.0032</td>
<td>0.0013</td>
<td>0.0022</td>
<td>0.0033 NA</td>
<td>0.0025</td>
<td>0.0003</td>
<td>0.0020</td>
</tr>
<tr>
<td>Prunus</td>
<td>0.0027</td>
<td>0.0015</td>
<td>0.0036 NA</td>
<td>0.0016</td>
<td>0.0019</td>
<td>0.0028</td>
<td>0.0028</td>
<td>0.0020</td>
<td>0.0020</td>
</tr>
<tr>
<td>Quercus</td>
<td>0.0020</td>
<td>0.0007</td>
<td>0.0105</td>
<td>0.0007</td>
<td>0.0052</td>
<td>0.0032</td>
<td>0.0011</td>
<td>0.0024</td>
<td>0.0008</td>
</tr>
<tr>
<td>Tilia</td>
<td>0.0027 NA</td>
<td>0.0042 NA</td>
<td>0.0022</td>
<td>0.0036 NA</td>
<td>0.0043</td>
<td>NA</td>
<td>NA</td>
<td>0.0043 NA</td>
<td>NA</td>
</tr>
<tr>
<td>Ulmus</td>
<td>0.0022 NA</td>
<td>0.0047 NA</td>
<td>0.0021</td>
<td>0.0033 NA</td>
<td>0.0034</td>
<td>NA</td>
<td>NA</td>
<td>0.0034 NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

- **Higher than 1.25*mean**
- **Lower than 0.75*mean**

*Abies and Picea* have low production rates for most TreMs

Huge heterogeneity among broadleaved species

**High production rates of different TreMs are found on different tree species**
Model validation at the stand level

Predicted vs observed TreM occurrence
Large variations among TreMs and among stands

Ex: forest stand « Betchat »

Results
Results

Preliminary simulation result: Rot hole density after 50 years uneven-aged selection system
2 levels of D_Harvest x 2 levels of Retention

ANOVA 2 factors
D_harvest: **
Retention: NS

Consistent effect of Harvest limit diameter
TreM formation rates increase with DBH and DBH increment are usually higher for Broadleaves

High formation rates of different TreMs are found on different tree species

Habitat-tree retention is not the only way to promote TreMs Harvest limit diameter or species composition are important

In forest dynamics simulations, TreMs can be used as indicators of management effect on habitat quality for biodiversity

Field observations should be made using a standard TreM typology In order to build data sets large enough to estimate the formation rate of rare TreMs ex: Standardized hierarchical typology (Larrieu & al., 2018)
Thank you for your attention

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