Mechanistic modelling of root rot, wind and bark beetle dynamics in Finland

EFSA/EPPO Joint Workshop – ”Modelling in Plant Health”

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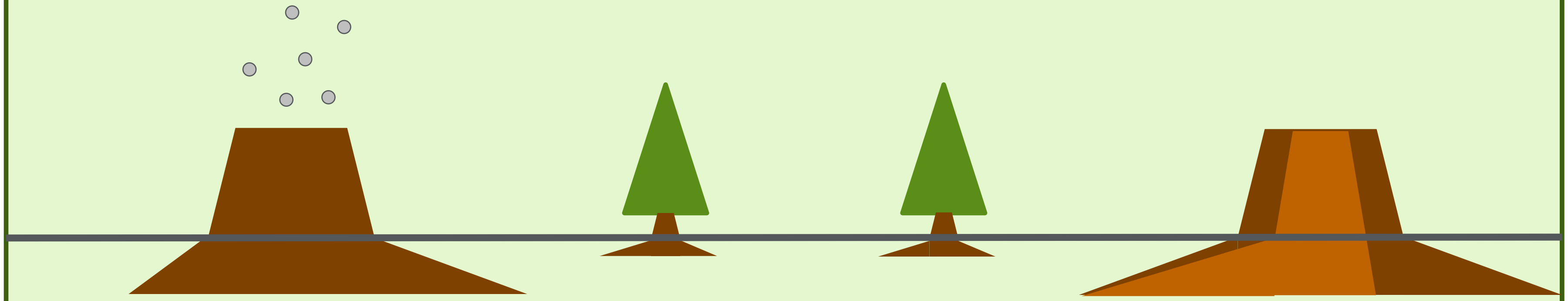
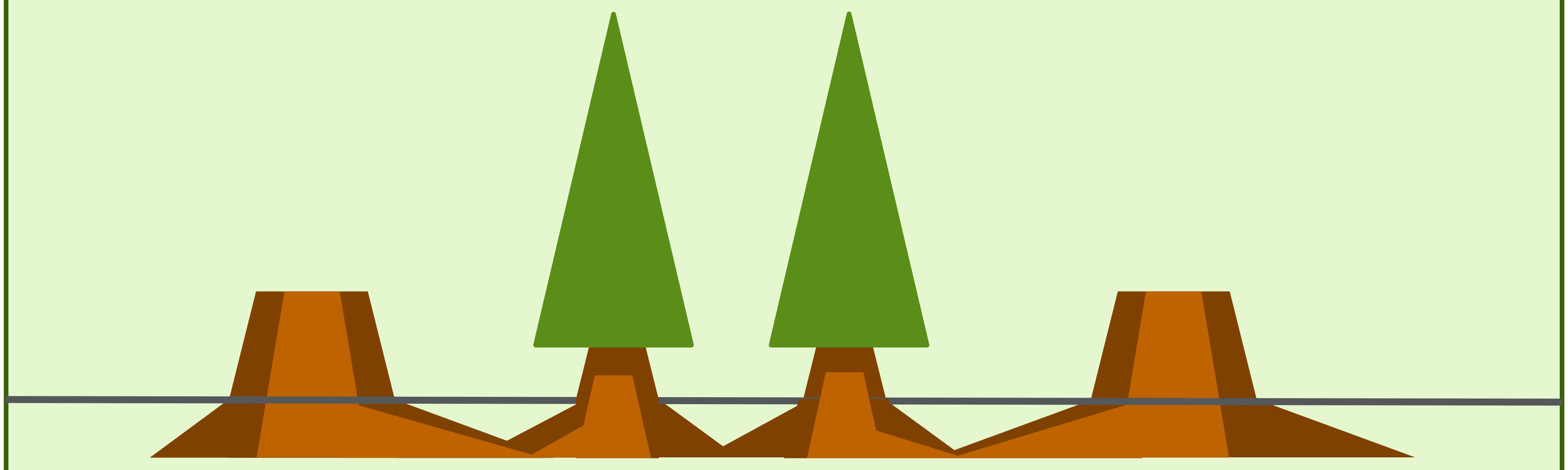
Norway spruce and damages

- Norway spruce (*Picea abies*) is one of the most economically important tree species in the boreal forests of northern Europe
- Root rot (*Heterobasidion annosum*) and bark beetles (*Ips typographus*) are the most important biotic damage agents and wind the most important abiotic.
- Climate change benefits all of these agents:
  - Root rot: longer growth season, increased metabolic rate
  - Bark beetles: increased reproduction
  - Wind: decreasing anchorage (no frost and higher precipitation)

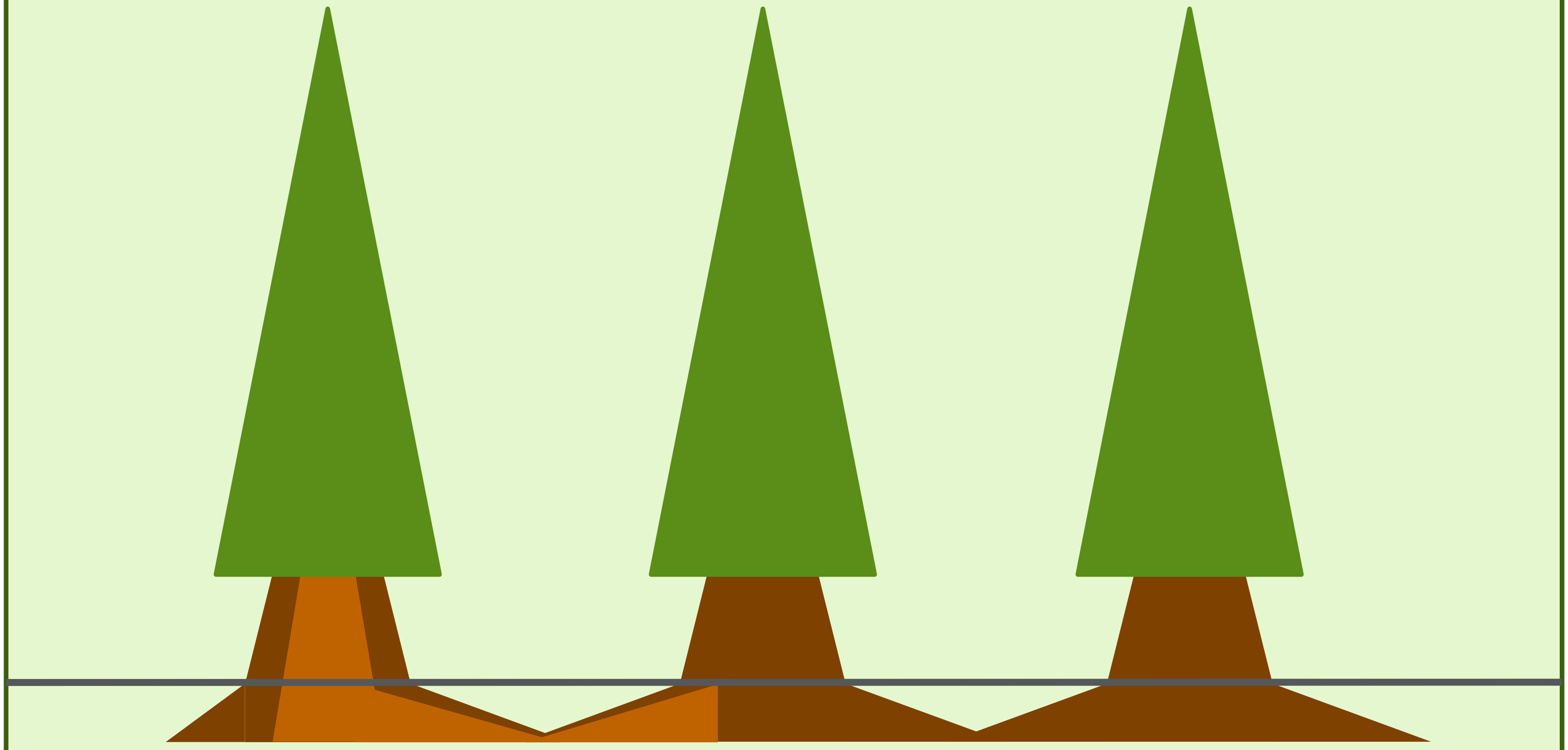
Heterobasidion annosum dispersal to the stand via spores



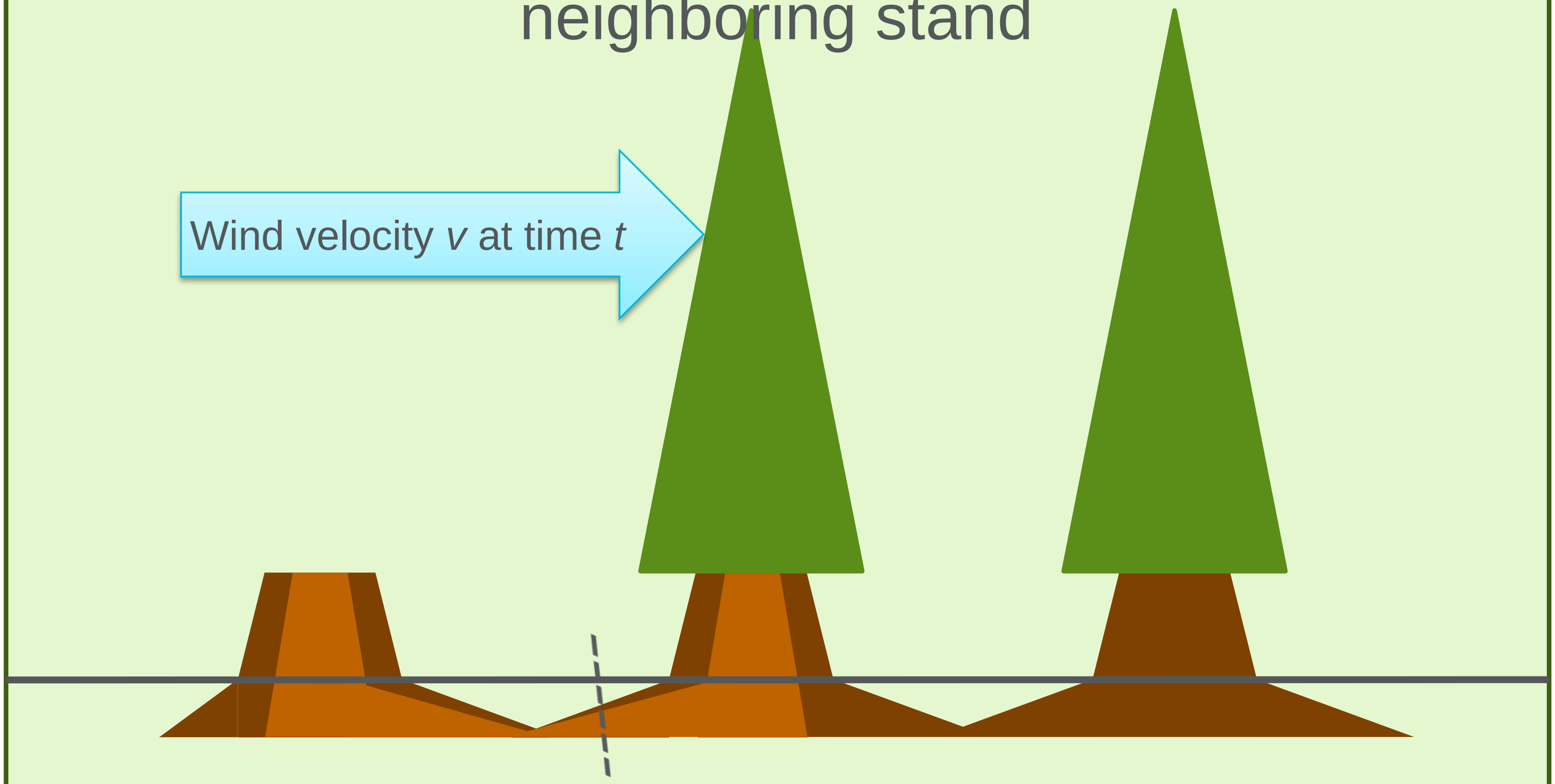
H. annosum vegetative spread to adjacent tree generation by mycelia via root systems



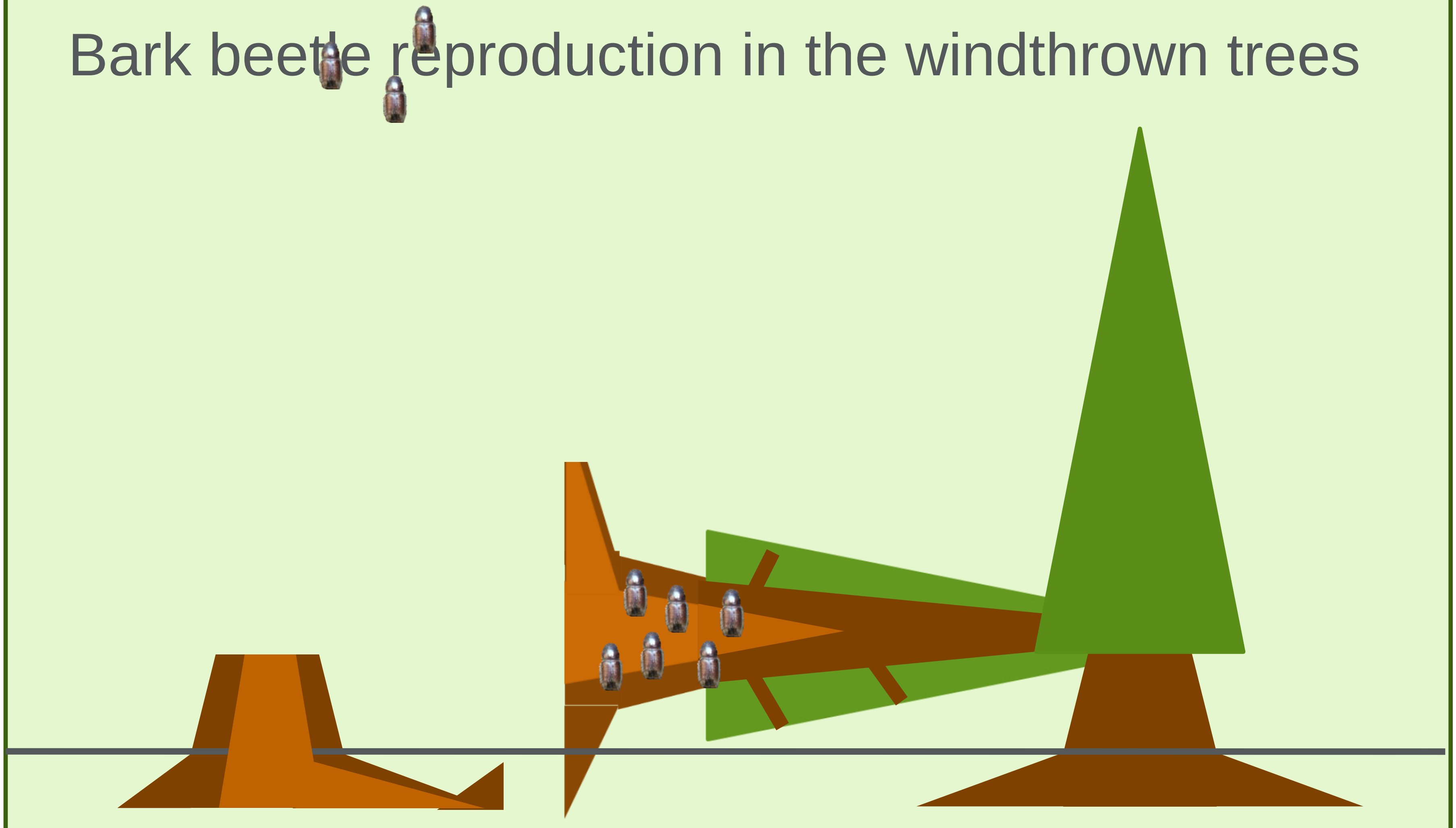
H. annosum spread and decay development



Increasing wind load after a clearcut of neighboring stand



Bark beetle reproduction in the windthrown trees



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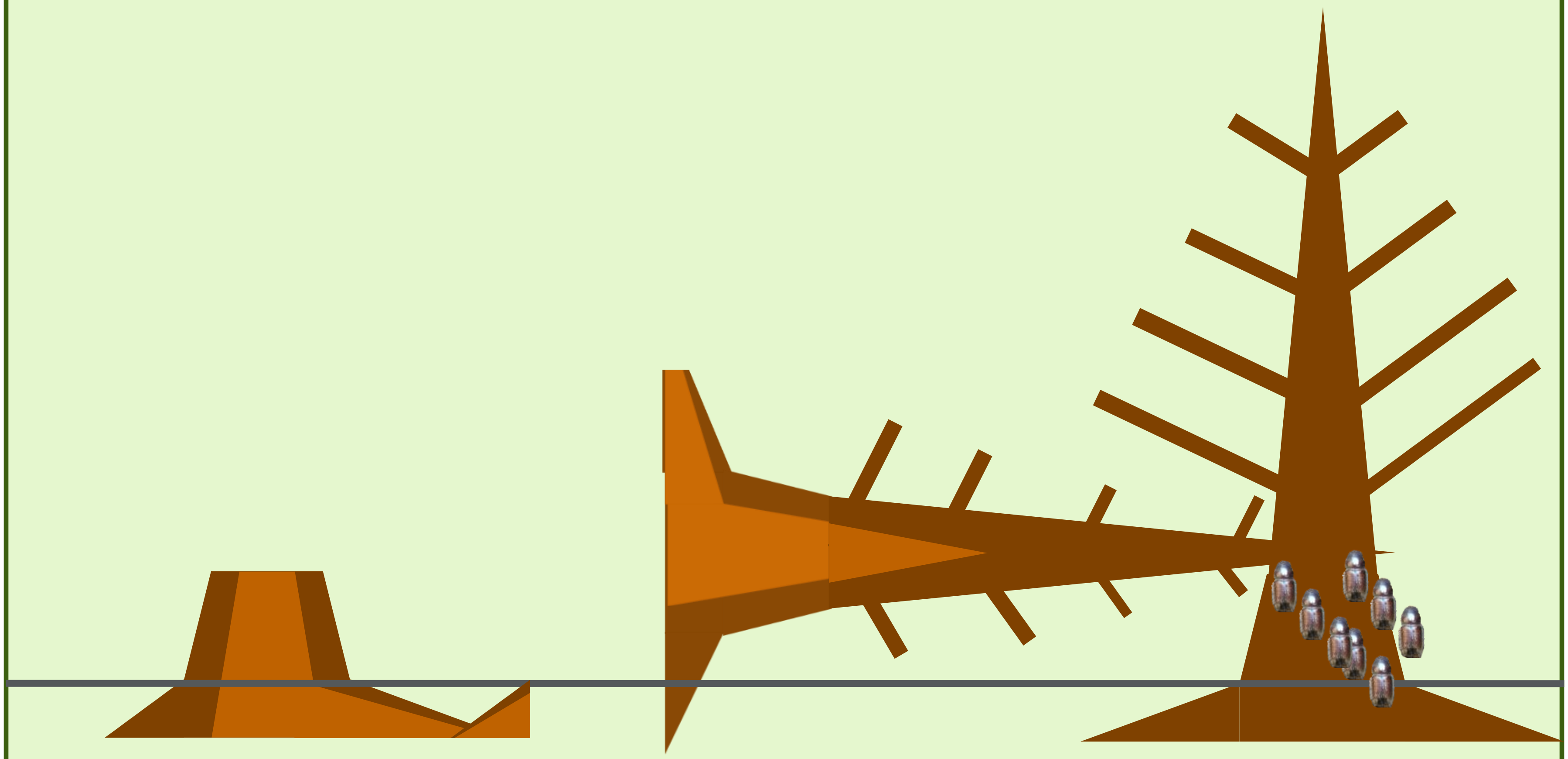
Bark beetle outbreak under favorable conditions



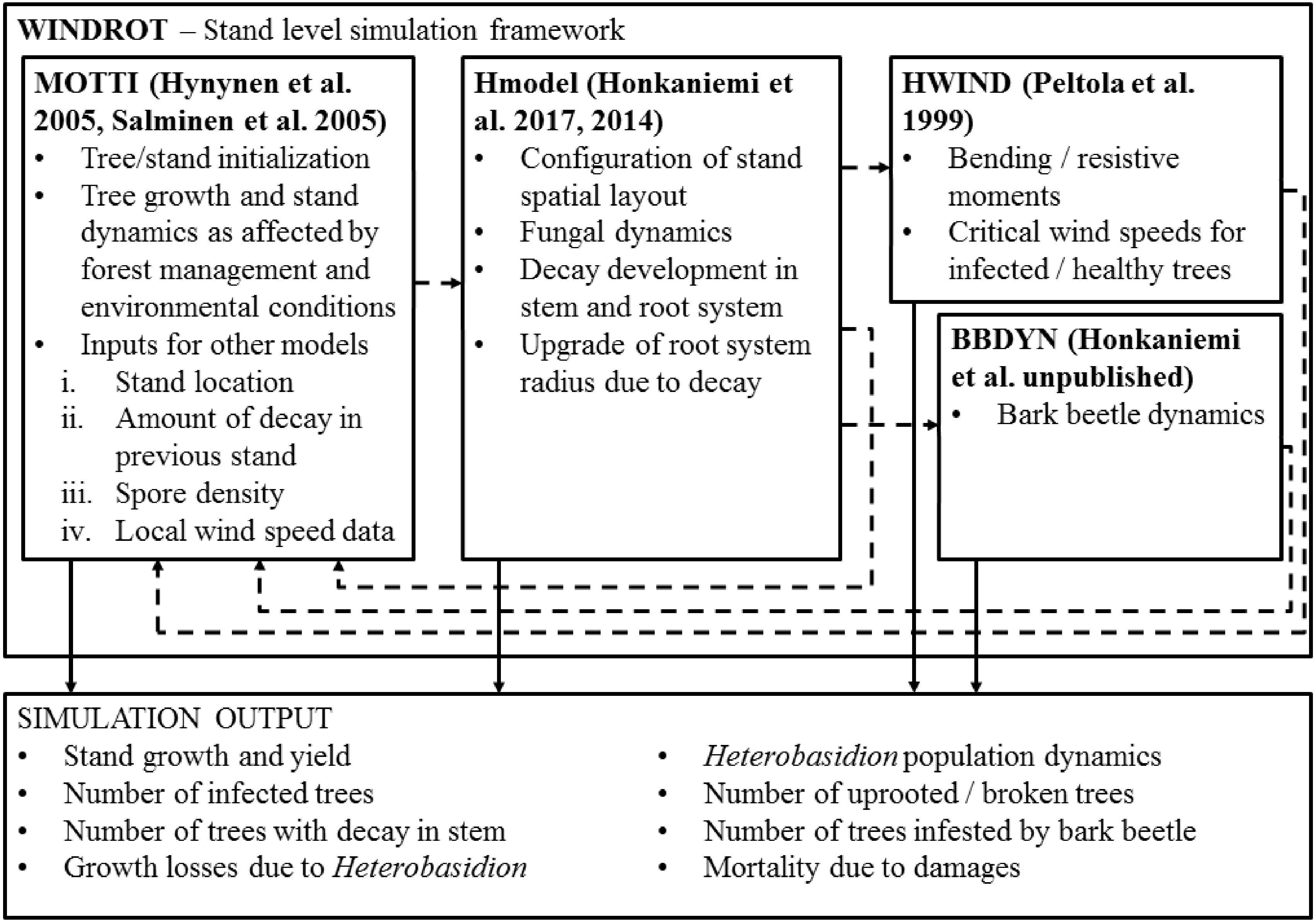
Research objectives

To develop a flexible platform for simulating multiple risks in Norway spruce dominated forests. This platform allows us to:

- Estimate economic losses in stand and landscape level
- Compare different forest management regimes and their effects on damage risks
- Compare different damage agent control methods and their effect on economic outcome

Mechanistic approach

- Aims at modeling the disturbance agent dynamics by defining the key processes
- Enables flexible simulation of different scenarios and the interaction of agents
- Evaluation of the mechanistic models
  - Whole model evaluation would require massive field data over at least one rotation length (especially for root rot); variation in the forest management, and disturbance agent inputs
  - Solution is partial evaluation of submodels or parts of the model

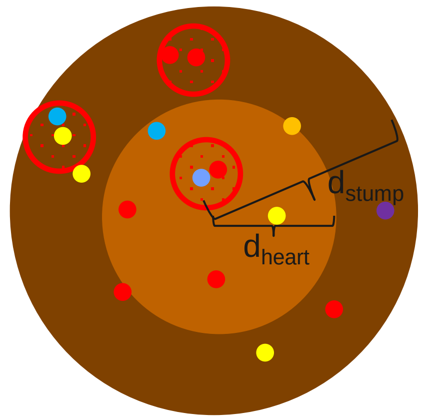


Honkaniemi et al., unpublished

Selected key features of the models

Heterobasidion primary infection

- Number of homokaryotic colonies ie. germinated spores (m^{-2} $24hr^{-1}$)
- Spores originate from different basidiocarps
- Maximum pairing distance (red dotted circle). Sensitivity simulated and evaluated against Möykkynen & Kontiokari (2001)
- Each basidiocarp has two different mating alleles (e.g. A_1A_2). Each basidiocarp has another one of those. Basidiocarps produce spores 50:50 between mating alleles

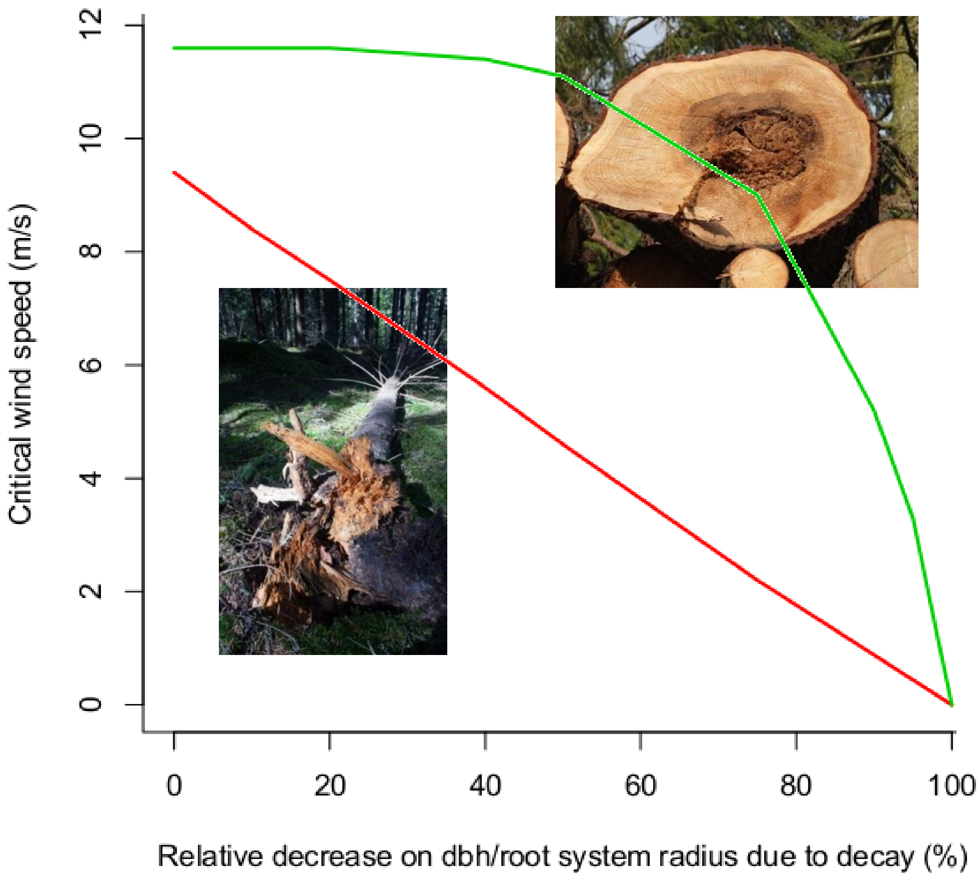


- The location of the heterokaryotic mycelia affects for its survival and colonization ability. In sapwood the colonization probability is 1/6 of the heartwood probability (Oliva et al. 2013).
- The infection probability is then calculated as follows:

$$P_{disease} = 1 - \left(1 - P_{survsap}\right)^{N_{pairsap}} \cdot \left(1 - P_{survhea}\right)^{N_{pairhea}}$$

Wood decay by *Heterobasidion* and tree stability

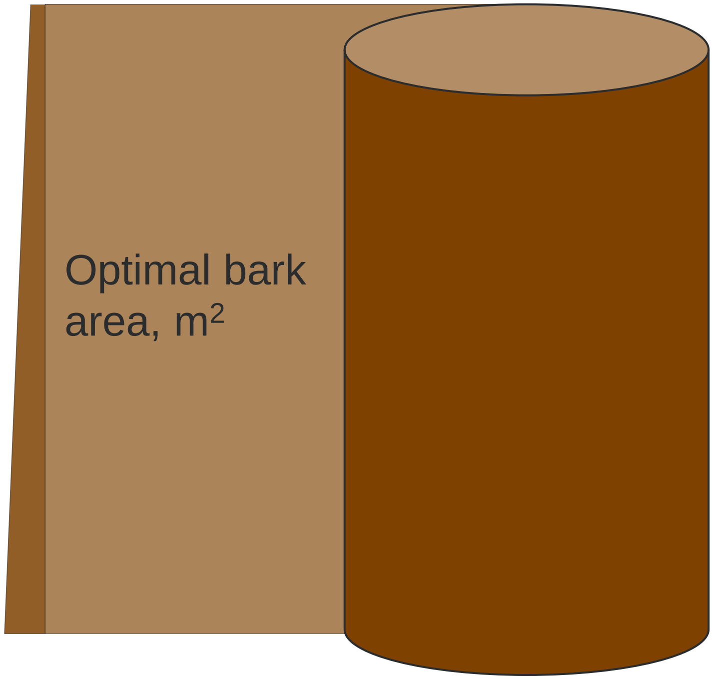
- Wood decay caused by *Heterobasidion annosum* decreases the tree stability
- Wood decay in the root system decreases the tree anchorage against uprooting
- Wood decay in the stem decreases the tree modulus of rupture for stem breakage
- Critical wind speeds needed to uproot or break a tree can be compared to local wind data

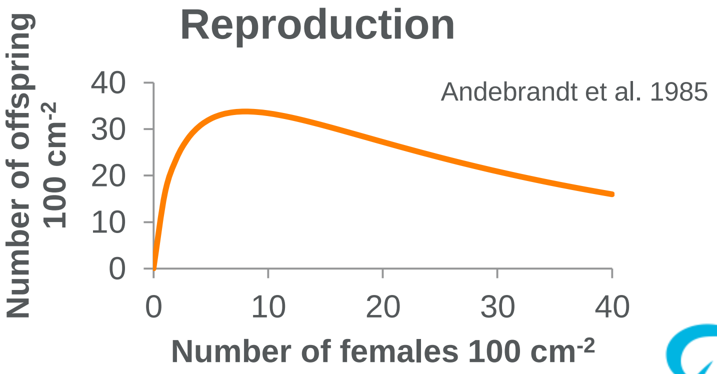


Bark area dependent dynamics for bark beetles

- Each tree has an bark area suitable for bark beetles (~2.5 – 5 mm bark thickness)

- The optimal bark area can be used to calculate tree specific limit values for the number of bark beetles (BB) for:
  - Reproduction rate
  - BB to start producing aggregating pheromones
  - BB to start producing anti-aggregating pheromones
  - Limit for tree resistance ie. BB to overcome the defence mechanisms and tree to die





Results from model performance analyses

- The model performance was tested under three different *Heterobasidion* risk scenarios, which vary in spore density and the amount of infections in the previous tree generation: low, medium, and high risk scenarios
- Simulations were carried out for typical Norway spruce stand in Southern Finland

- Key findings were:
  - *Heterobasidion* dynamics are driven by large stumps and the infections from previous stand
  - Wind damages are more sensitive to wood decay in the root system than wood decay in the stem
  - Increasing root rot risk increases the risk for wind damages
  - Risk for bark beetle outbreak increased with increasing wind damages and hence with increasing *Heterobasidion* risk

Conclusions

- ✓ The effects of biotic and abiotic damages increase with the changing climate in the coniferous forests of Nordic countries
- ✓ Assessment of these risks to forests would be crucial for forest management under the warming climate
- ✓ Due to agent interaction, different disturbance agent dynamics are not isolated and in reality affect each other
- ✓ Flexible platform enables the models to be used also for other similar organisms

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SUOMEN LUONNONVARAIN TUTKIMUSSÄÄTIÖ

METSÄMIESTEN SÄÄTIÖ
Ihminen ja metsä

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