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Balancing Ecology and Economy in Forestry: A simple model of uneven-aged management

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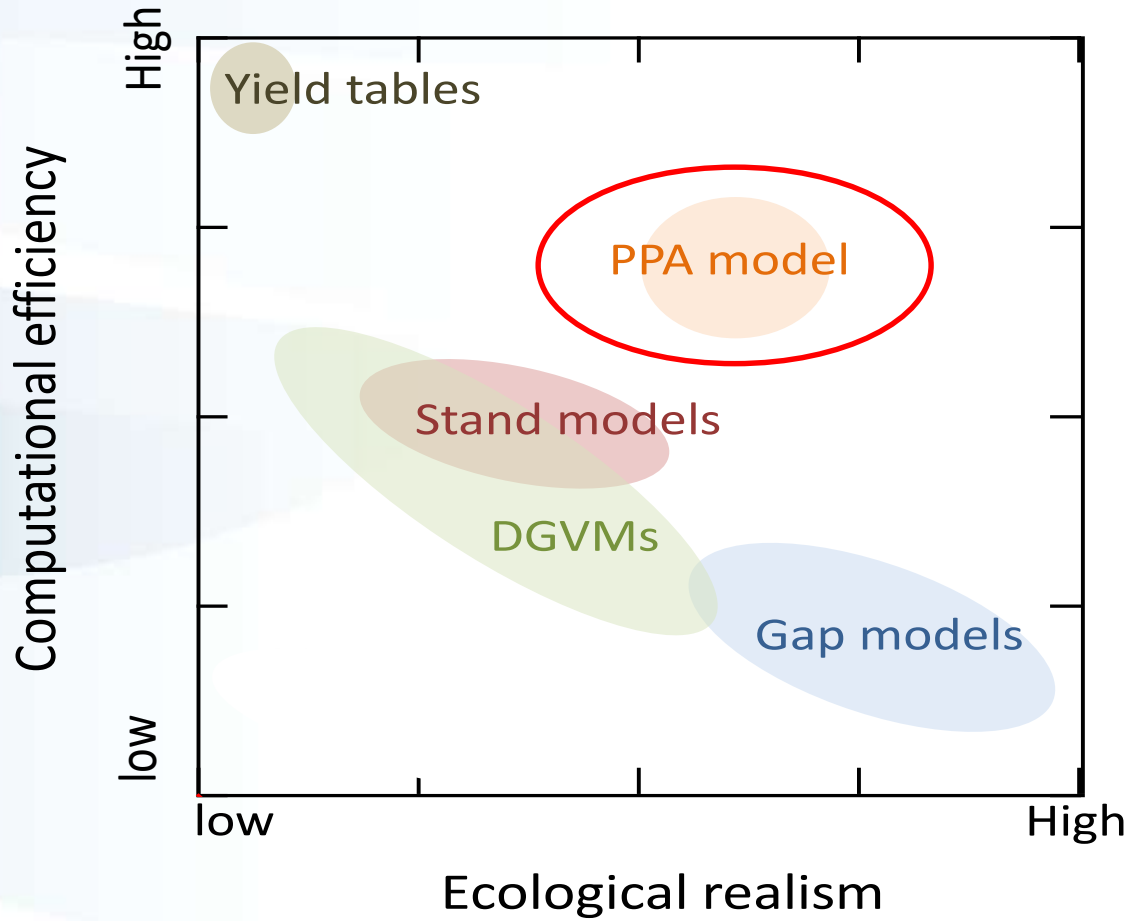
Background

- Uneven-aged forests management can be a good way to maintain ecological values in forests managed for profit
- Modeling of uneven-aged forests and selective cutting is difficult because of the competitive interactions among trees of different sizes
  - Competition for light is asymmetric: taller trees shade shorter trees, which is complicated to model
- But – a new approximation of the light environment makes it much easier This leads to simpler modeling of uneven-aged management
- We use this model to evaluate the trade-off between economic profit and ecological value of a forest.

The spectrum of forest models



Size-structured forest model

Transport equation (Lotka-McKendrick-von Foerster equation)

$N = N(t, s)$

Number of trees of size s at time t

$N(t + \Delta t, s + \Delta s)$

Growth (g)

Mortality = natural mortality (μ) + harvesting (c)

$$\frac{N}{t} + \frac{(gN)}{s} = (\mu + c)N$$

Production of new baby trees

$$g(t, 0, E)N(t, 0) = \int_0^{\infty} F(t, s, E)N(t, s)\,ds$$

Fecundity

We assume steady state => equations can be solved analytically

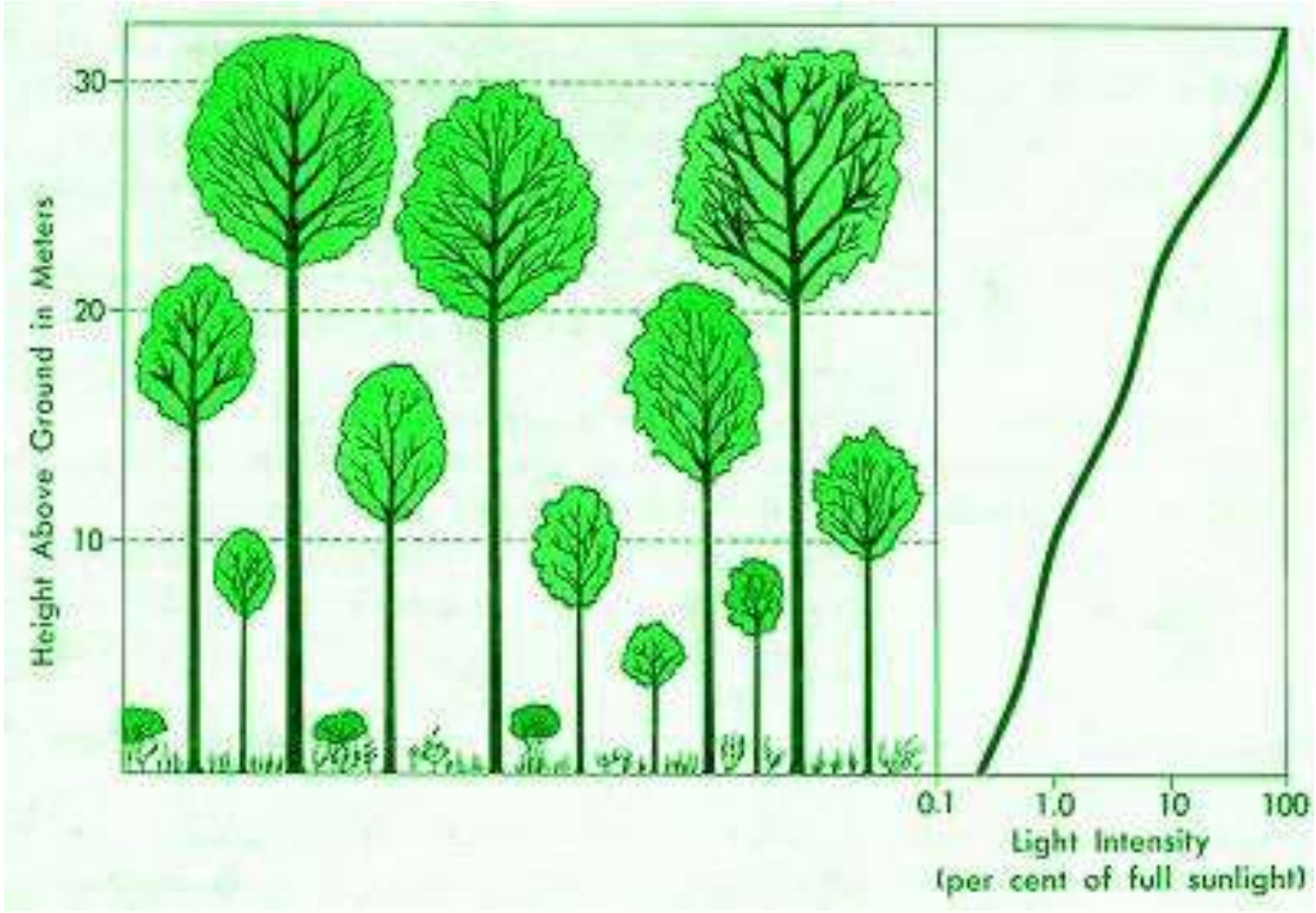
Competition for light

Competition happens via the light environment = E

$$E = E(t, N(t,x))$$

Growth $g = g(t, s, E)$

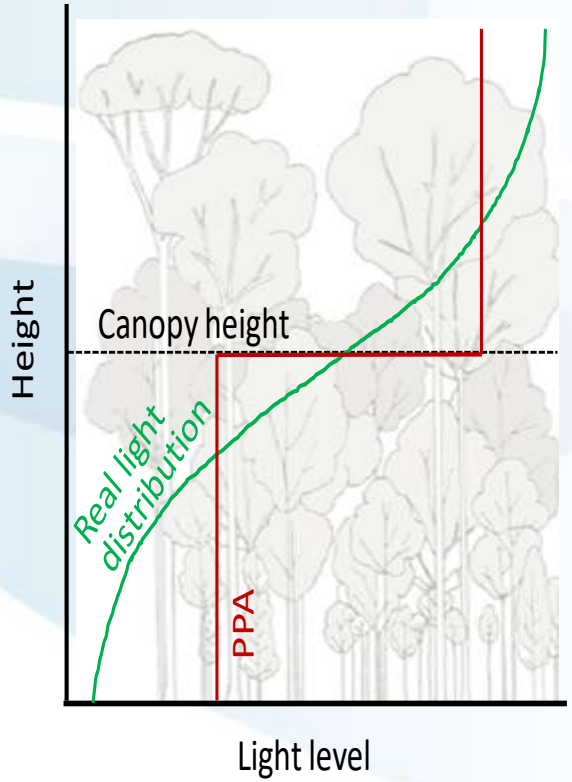
Mortality $= (t, s, E)$

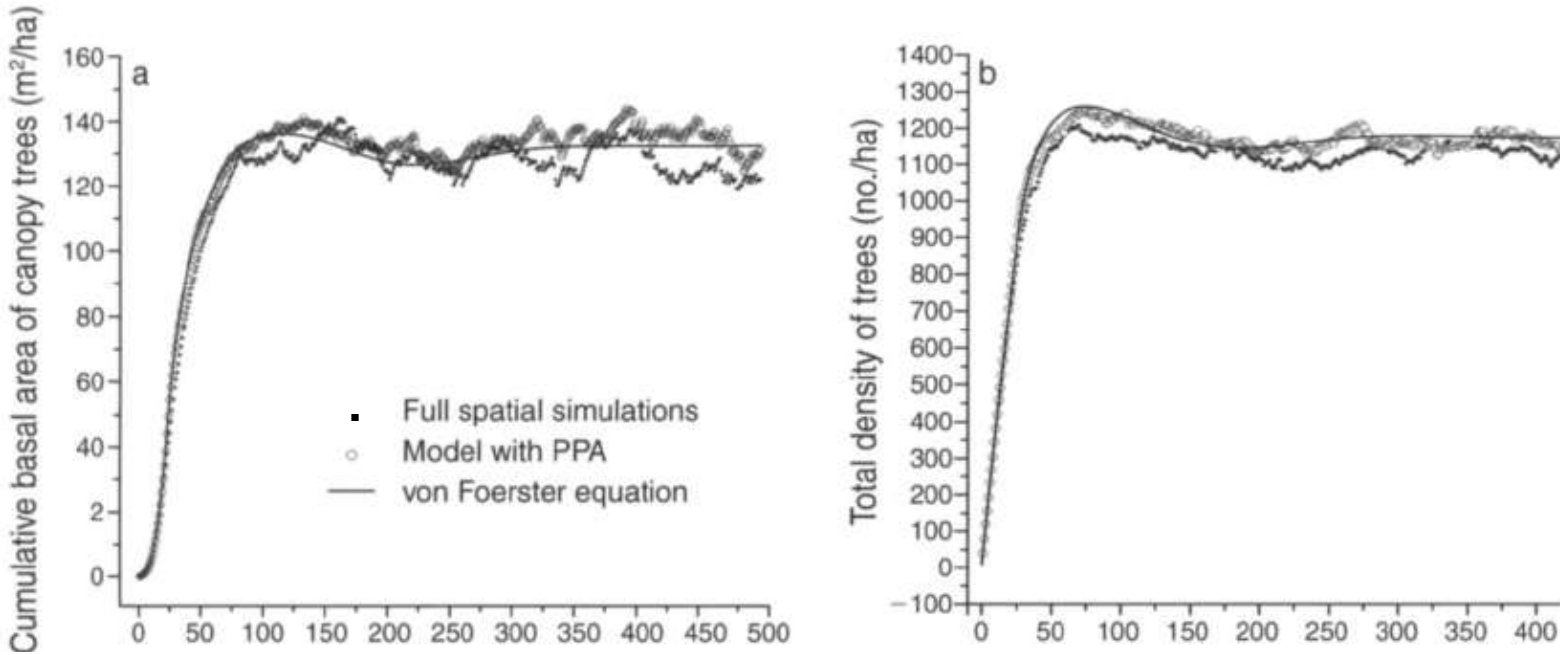


Perfect plasticity approximation (PPA)

Strigul N, Pristinski D, Purves D, Dushoff J, Pacala S (2008) Scaling from trees to forests: Tractable macroscopic equations for forest dynamics. Ecol Monogr. 78:523-545

Approximates the continuous light profile with only two levels: sun and shade





Harvesting strategies

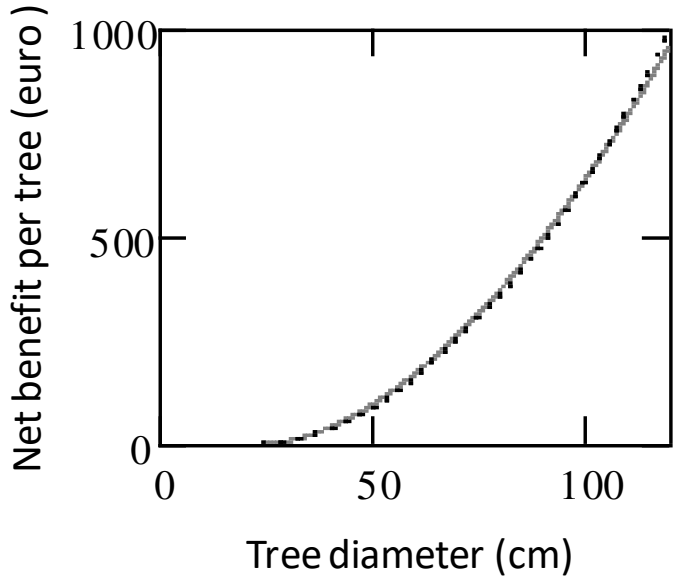
- Selective harvesting (Not clear-cutting)
- Harvesting defined by:
  - minimum diameter cut
  - % of trees cut per year

Cutting rate $c = c(t, s)$

$$\frac{N}{t} + \frac{(gN)}{s} = \quad (\quad + c)N$$

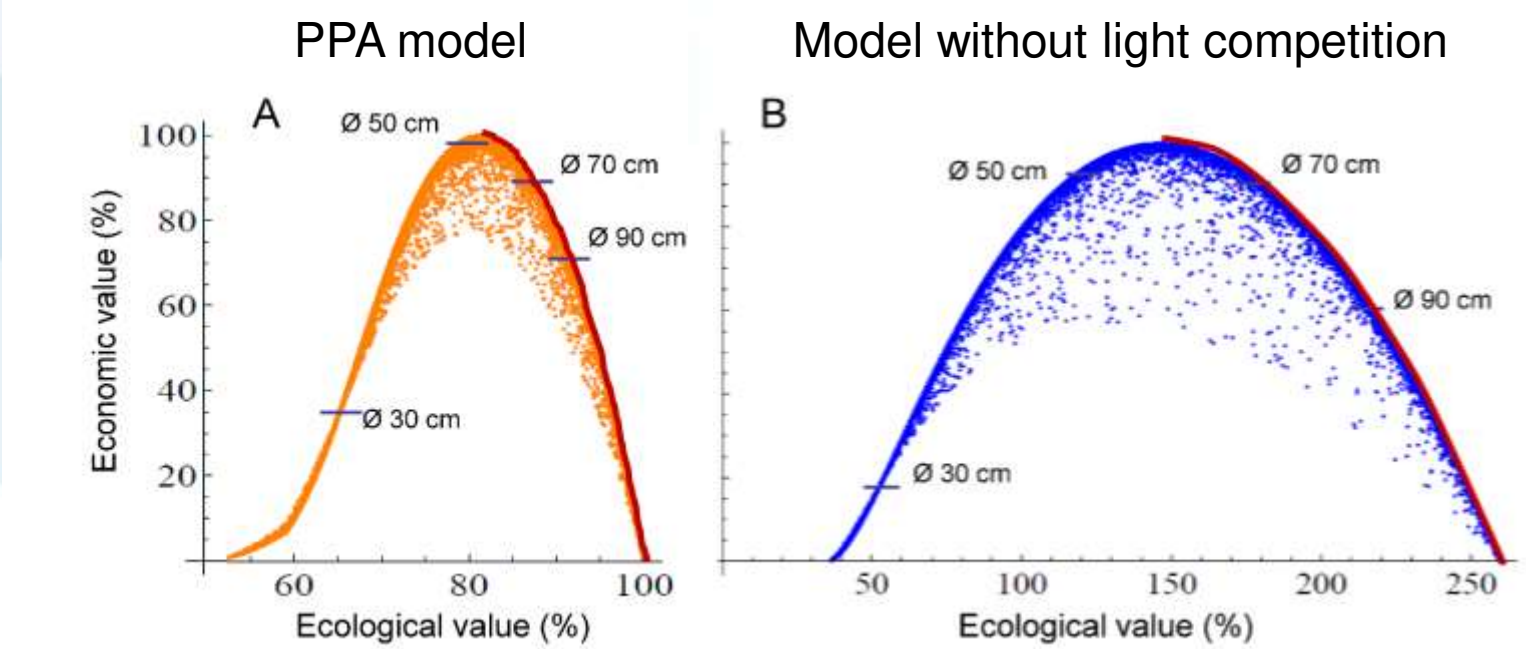
Economic and ecological values of the forest

- Net economic value increases with number of trees harvested and diameter of logs
  - harvesting costs are deducted
- Ecological value approximated by tree size variance in the forest compared to an undisturbed forest
  => Increases with maximum diameter
- Multiple harvesting scenarios with different minimum diameter and cutting rate were evaluated for red maple
- We also tested the importance of accounting for the asymmetric competition for light



Results

- Economic value is maximized if all trees are cut at 50cm diameter
- A higher minimum cutting diameter increases ecological value at the expense of economic benefit = a trade-off along a pareto front.
- A high ecological value = 80% can be achieved at maximum economic value
- Asymmetric competition for light matters: if it is ignored, the optimal cutting threshold and the feasible ecological values are overestimated



Conclusions

- The PPA approximation of light competition makes it possible to model uneven-aged forests with a simple and computationally fast model
- The model is useful for theoretical studies and for applied modeling where fast computation is required – e.g. for management optimization at high spatial resolution
- Uneven-aged management is good option for combining high ecological values with profitable forest production

Questions?

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Paper to come:
E Rovenskaya, Å Brännström, U Dieckmann, O Franklin (in prep.) Balancing ecological and economic objectives in forestry: A tractable model of uneven-aged management