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Production possibility frontiers for energy wood, timber production and biological diversity in North Karelia, Finland

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Contents

- Renewable energy from forests
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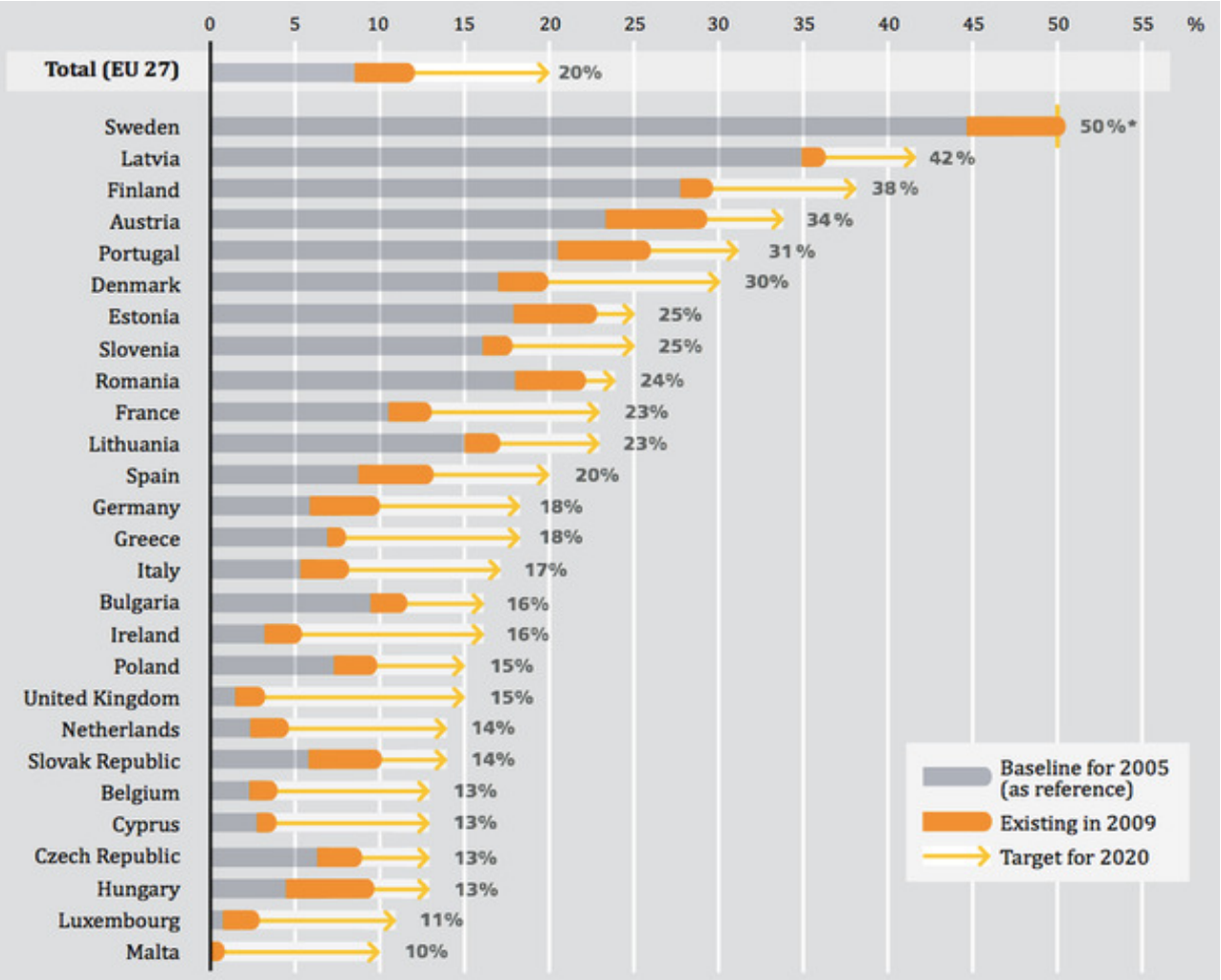
- The frontiers
- Conclusions

Based on: Kärkkäinen, L., Kurttila, M. Salminen, O. & Viiri, H. 2014. Effects of Energy Wood Harvesting on Timber Production Potential and Biological Diversity in North Karelia, Finland. Forest Science. In press.

EU renewable energy shares for the years 2005 and 2009 and targets for 2020 (REN21 2014)



Finland has targets for forest chips

- Use in 2011 was 7.5 Mill. m^3
- Target for 2020 set to 13.5 Mill. m^3
  - Could be even larger if the use in biorefineries will increase
  - In North Karelia study area, the figures were 0.85 Mill m^3 and 1.4 Mill m^3, respectively (including firewood)

- Forest chips burned in heat and power plants year 2011 came from:
  - Small diameter trees 45 %
  - Cutting residues 33 %
  - Large low quality timber 8 %
  - Stumps and roots 14 %

→ Largely side product from traditional forestry

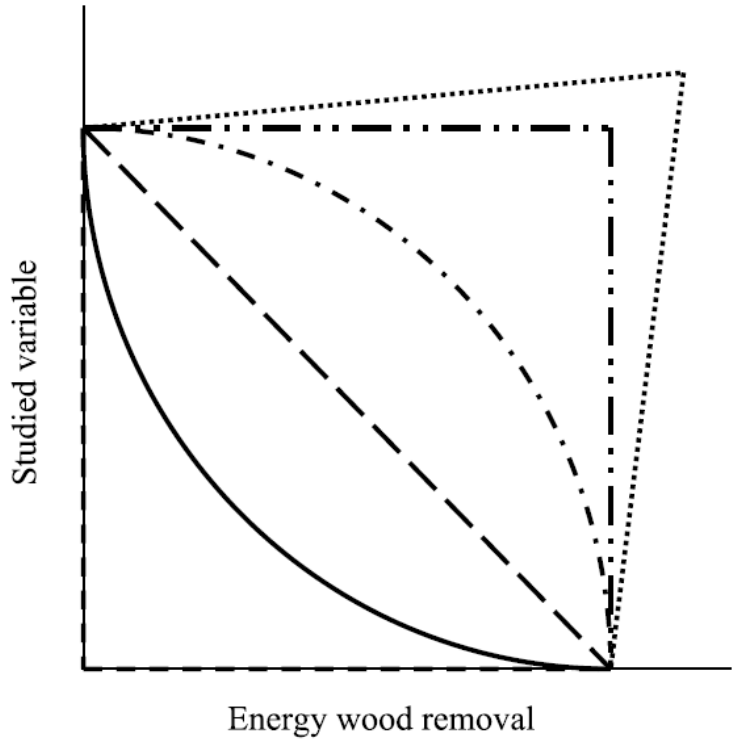
Our objective: to study the effects on other forest uses

- If forest resources are used efficiently, increased use of bioenergy will have effects on other forest uses

Research questions:

1. Is the current use efficient?
2. What kind of relationship energy wood production has with timber production and biodiversity?

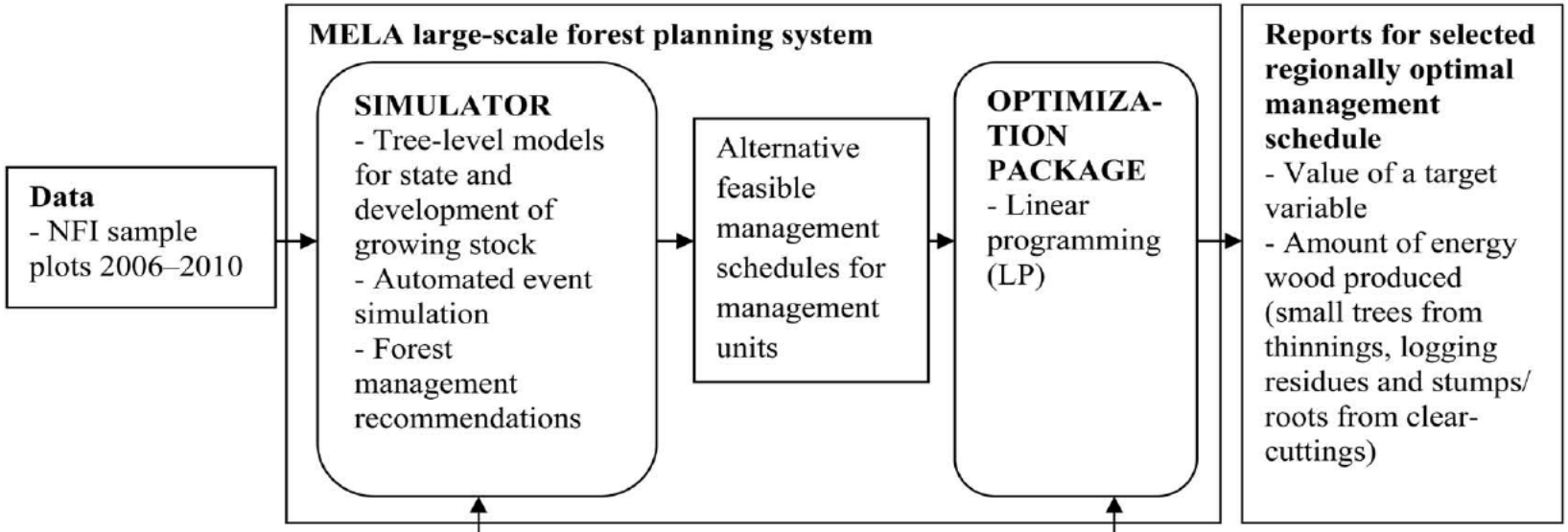
Approach: creation of two dimensional production possibility frontiers with large-scale forest planning system



Materials

- 1.4 million ha of forest and scrubland
  - Scots pine (*Pinus sylvestris*) 52%; Norway spruce (*Picea abies*), 28% birches and other deciduous trees 20%
  - Forests less than 40 years cover appr. 45%
- National forest inventory data 2006-2010 were used in calculations
  - 5061 management units (clusters of 3-6 sample plots)
  - Total of 1.065 mill. management schedules (on average 210 / unit)

Methods



Simulation instructions

- 40 years, divided into four 10-year periods
- A set of management activities with and without energy wood logging (for energy wood logging see Table 1)
- A set of unit prices, costs and subsidies for energy wood
  * Price (chipped energy wood at mill yard): 35 € m^{-3}
  * Costs: mechanized energy wood felling by harvester, mechanized energy wood harvesting by forwarder or bundler 85 € h^{-1}, manual energy wood felling 27.75 € h^{-1}, energy wood forest haulage with forwarder or stump lifting with excavators 65 € h^{-1}, terrain chipper 115 € h^{-1}, mobile chipper at road side 140 € h^{-1}, fixed stationary crusher 2.5 € m^{-3}, compensation of felling logging residues into piles 0.3 € m^{-3}, long-distance transport costs with trucks 75 € h^{-1}, costs of loading and unloading of trucks 53 € h^{-1}
  * State subsidies for energy wood harvesting from young thinning stands: removal and transportation 7 € m^{-3} (solid), chipping 1.7 € m^{-3} (loose)

LP formulation

- Other target variables but NPV
  * Maximization or minimization of a target variable (Eq.1)
  * Even-flow of a target variable as a constraint (Eq. 3)
  * Different levels of energy wood removals as a constraint (Eq. 4)

- NPV
  * Maximization of NPV (Eq. 2)
  * Different levels of energy wood removals as a constraint (Eq. 4)

Methods II: simulation rules for energy wood harvesting in MELA

	Thinning stands	Clear cutting areas
Site	Mineral soils: subdry and more fertile sites[1] Organic soils: subdry and more fertile sites [1]	Mineral soils: subdry and more fertile sites[1]
Components of a tree	Stems: Norway spruce-dominated stands[1] and stands of organic soils[2] Stems and branches (and foliage): mineral soils except spruce dominated stands[1]	Logging residues (branches, foliage, and stemwood waste) or logging residues and stumps and roots[1]
Method	Removal of all felled trees[1] Removal a portion of felled trees (integrated logging)[1]	
Size	Minimum dbh: 4 cm[3] Maximum dbh: 10 cm in integrated logging for Scots pine, Norway spruce, birch, and aspen[4] No maximum diameter in integrated logging for other tree species[4]	Minimum diameter of stumps lifted: 25 cm[2]
Minimum amount harvested	15 m^3 ha^{-1} [2]	15 m^3 ha^{-1} [2]
Amount left in the stand	Only stems harvested for energy wood: tops <3 cm, branches (and foliage)	Branches (and foliage): 30% Stumps: 10% of stumps, which diameter was ≥25 cm[2]

[1] Data from Äijälä et al. (2010).
[2] Juha Laitila, Finnish Forest Research Institute, pers. comm., May 2, 2012. According to Laitila, the minimum amount harvested could be 25 m^3 ha^{-1} in clearcutting areas, but in the MELA system, a minimum could not be set based on the cutting type.
[3] Data from Laitila et. al. (2004).
[4] Compare Hyvän metsänhoidon suositukset 2006.

LP problem formulations

$$\max \text{ (or min)} \sum_{i=1}^{m} \sum_{j=1}^{h} \sum_{t=1}^{T} w_{ijt}^{Q} x_{ij} \quad (1)$$

1: maximize (or minimize) the objective variable value

or

$$\max \text{NPV} = \sum_{i=1}^{m} \frac{\sum_{j=1}^{h} \sum_{i=1}^{T} \left(\sum_{q=1}^{k} (p_q - c_q) w_{ijt}^{q} x_{ij} \right) (1+r)^{T-t} + \text{SEV}_i}{(1+r)^{T}} \quad (2)$$

or

2: maximize soil expectation value (SEV,4%)

subject to

$$\sum_{i=1}^{m} \sum_{j=1}^{h} w_{ijt}^{Q} x_{ij} - \sum_{i=1}^{m} \sum_{j=1}^{h} w_{ijt-1}^{Q} x_{ij} = 0, \ \forall\, t = 1, \ldots, T \quad (3)$$

3: s.t. even flow constraints on target variables

$$\sum_{i=1}^{m} \sum_{j=1}^{h} w_{ijt}^{e} x_{ij} = E_t, \ \forall\, t = 1, \ldots, T, \ e \notin Q \quad (4)$$

4: s.t. demanded even flow of energy wood from each period

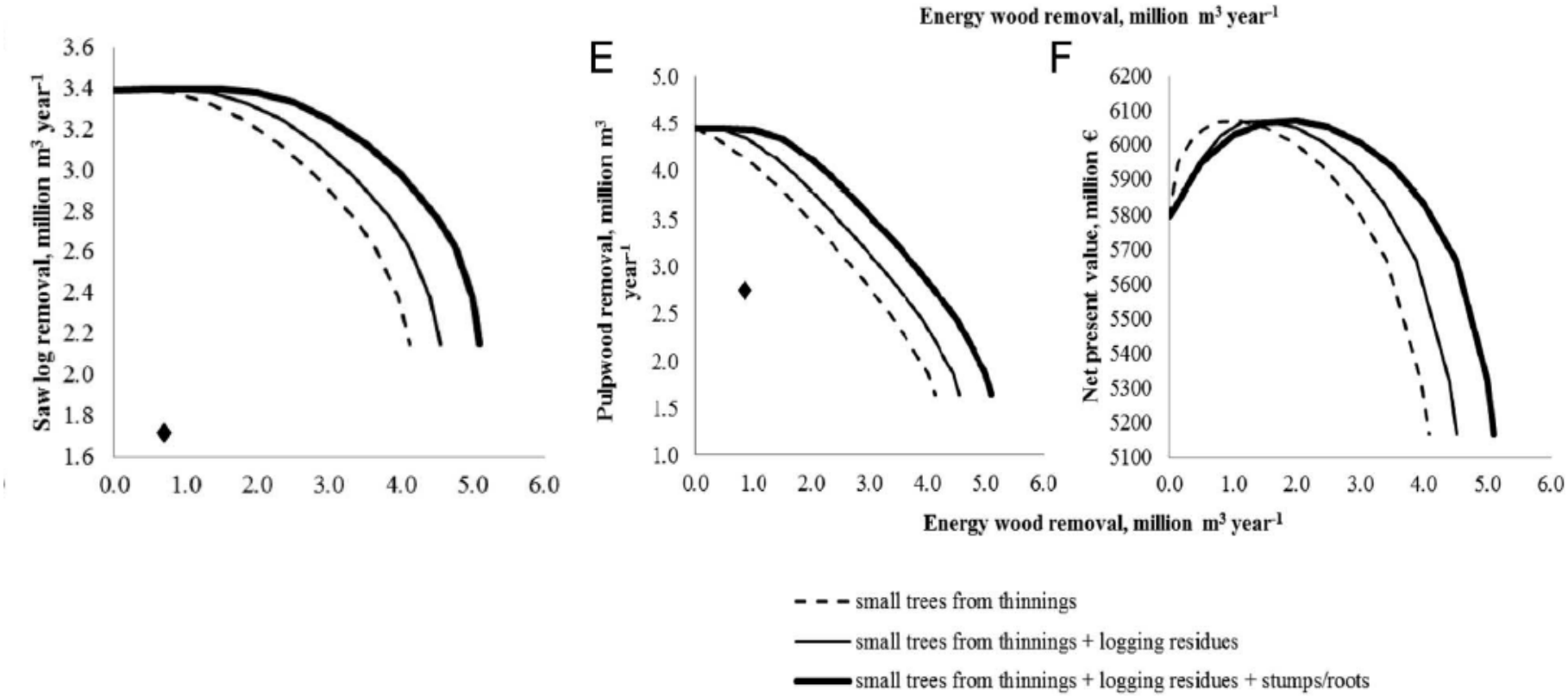
$$\sum_{j=1}^{h} x_{ij} = a_i, \ \varpi\, \forall\, i = 1, \ldots, m \quad (5)$$

5: s.t. management unit area constraints

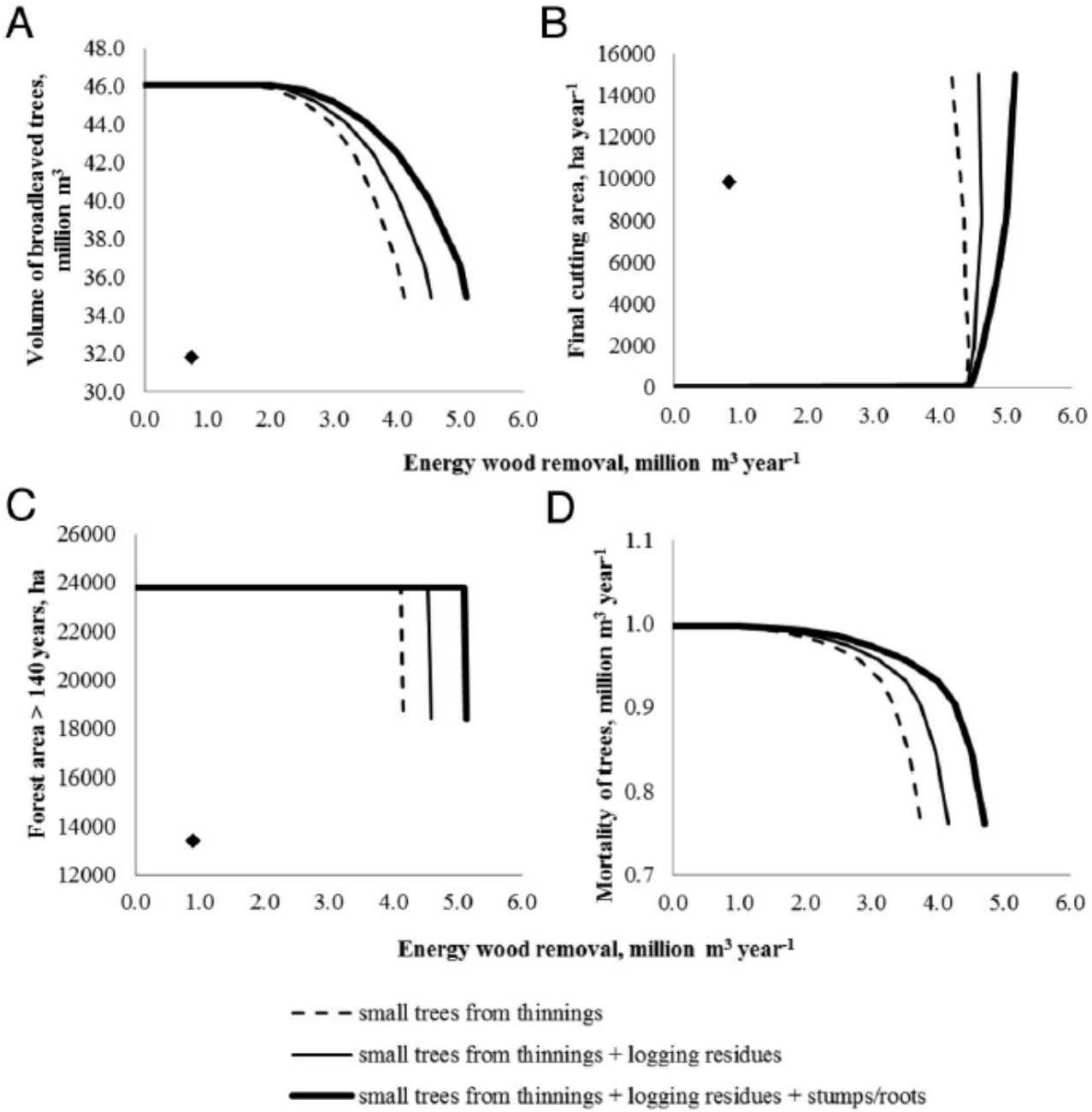
$$x_{ij} \geq 0, \ \varpi\, \forall\, i = 1 \ldots, m, \ \forall\, j = 1, \ldots, h \quad (6)$$

6: s.t. positivity constraints

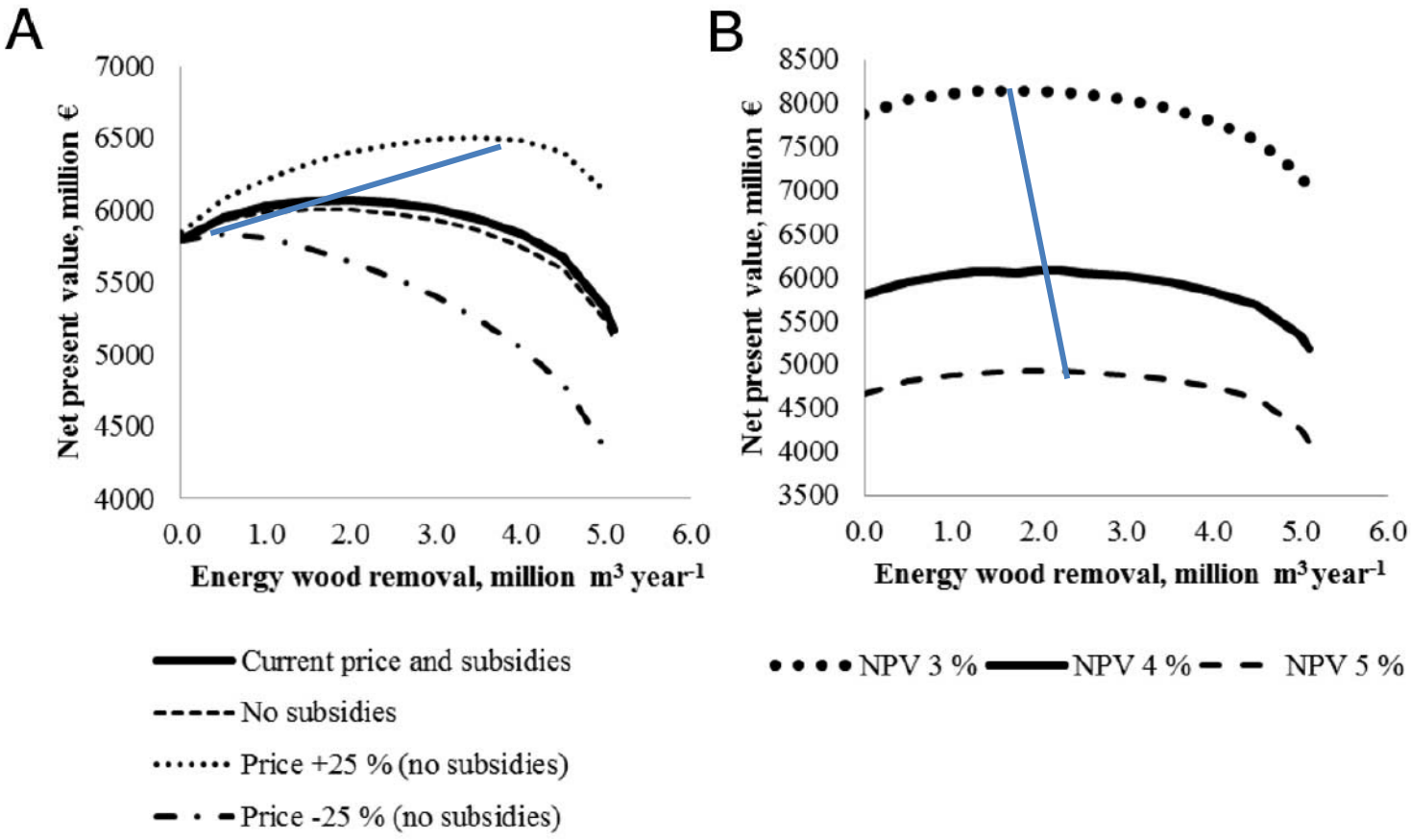
Results – timber production



Results – biodiversity



Sensitivity analysis – energy wood prices and interest rate



Analysis and discussion

- With given prices and interest rate, optimal production exceeds the set target level
  - At low levels no effects on saw log production
  - Rather linear marginal substitution rate with pulpwood
- Variables that were used to describe effects on biodiversity were affected heavily but only at high levels of energy wood harvesting
  - Logical explanations
  - The best indicators for biodiversity were missing,e.g. existence of large diameter deadwood in fertile forests

Answers to research questions

1. Technically - the current forest use is not at the efficient frontier
   - Simplified problem formulations that addressed only two variables at a time
   - Individual forest owners make their own decisions
     - In our calculations forest ownership structure was not considered
2. Energy wood production has **mainly competitive** relationship with timber production and biodiversity
   - However, without timber production it is impossible to reach the set targets of energy wood

Acknowledgements

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Juha Laitila and Jouni Hyvärinen (photos)


Forest
METLA
KNOWLEDGE
Know-how
Well-being
Thank you

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