Evaluating and planning for economic, ecological and social benefits from forests

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Functions of forests

• Ecological
• Cultural
• Social
• Economic
• Environmental
Forest management objectives

• Ecological
  – Populations of all species remain viable
• Social - cultural
  – Customary uses respected / improved
• Environmental
  – Carbon sequestration, water, protection against erosion
• Risk management
  – Minimize the risk of
    • Fires
    • Wind hazards
    • Outbreaks of pests and diseases
• Economic
Need to be measured and predicted

Two approaches

• **Economic**: all converted to money

• **MAUT**: any numerical measure will do

• All can be expressed in monetary units
  – Selling price, carbon credit, WTP ...
  – Sometimes unreliable, not worthwhile
Planning example from each management objective category

1. Social: Timber and berry
2. Environmental: Timber and carbon
3. Ecological: Timber and Siberian jay
4. Risk: Timber and wind risk
Social functions: bilberry and lingonberry

Collecting berries is a customary right
Measurement

• Empirical yield model
• Economic benefit: \( \text{Yield} \times (\text{Price} - \text{Cost}) \)
• Is berry harvesting a cost (or mushroom picking)?
  – \textbf{Benefit}: something positive
  – \textbf{Cost}: something negative (berry picking is fun, not negative!)
  – Depends on context (commercial vs. household)
• Great annual variation
  – The used model includes random year factor
  – 100 random yields calculated for every stand
  – \textbf{Cost} < \textbf{Price} only when yield is not very low
  – Collected only when \textbf{Cost} < \textbf{Price}
  – 75% of yield harvested in these years and stands
Results for 150 ha forest

- Max Ending volume
- Max NPV 4%
- Max Harvested volume
- Max Bilberry
- Max Lingonberry

![Graph showing results for 150 ha forest with metrics such as Volume, NPV, Harvest, Bilberry, and Lingonberry. The graph includes lines indicating the maximum values for each metric.]
Trade-off curves

- Mean annual berry harvest (kg/ha)
- Harvested volume (m³/30 years)

Lingonberry
Bilberry

Mean annual berry harvest, kg/ha

Lingonberry harvest, kg/ha
Bilberry harvest, kg/ha
Even-flow max npv

Total value 100 € per ha & year

Mean annual net income of timber production is 150 €/ha
Environmental functions: carbon sequestration

Carbon sequestration mitigates climate change
How calculated

What should be added to a traditional forest simulator
• Biomass models: 50% of dry mass is carbon
• Decomposition model (soil carbon)
• Product life cycle model (product carbon)

Carbon balance: Captured C – Released C during a time period

How calculated:
- Changes of carbon content in the three (biomass, soil, products) pools
- Harvesting, manufacturing and transporting releases
+ Substitution effects (reduced emissions from fossil fuels)

Pools need to be initialized!
• Otherwise only differences between policies can be analysed
• In the example: Soil and product C pools initialized with models
Living biomass C pool

- Growth
- Mortality
- Regeneration
- Harvests
- Litter
Dead organic matter
(soil organic matter)

- Mortality
- Litter
- Harvest residues

Decomposition

Yasso07 model
Wood-based products

Harvesting, transporting and manufacturing releases (negative)

Substitution effects, mainly sawn wood and biofuel (positive)
Results for 150 forest (30 years)

- Less pulpwood harvested
  - Smaller manufacturing releases
  - Greater substitution effects

- Harvesting branches and stumps
  - Increases product C balance
  - Decreases soil C balance
  - Net effect nil at first
  - Increases with time
Max C balance with NPV = 1 mill €

NPV maximized (more cuttings)
Ecological function: Siberian jay

Maintain habitat for Siberian jay – an umbrella species
How to measure ecological quality

Ecosystem approach
• Degree of similarity with natural landscape
• Area of old forest, deadwood volume, diversity indices, burned wood ...

Species approach
• A few keynote species selected
• Habitat suitability index (HSI) developed for each
• Sufficiency of habitat:
  
  Area where HSI > Threshold ≥ X ha

• If patch size, core area, connectivity etc. matter, landscape metrics can be used to influence landscape structure
Siberian jay

Habitat requirements known (bilberry, lichen, density)
There are models for bilberry and lichen!
Max 15 % of territory can be open area (like clear felling, young plantations)
CCF can be used to maintain population viability
Feeding habitat, expert model

\[ HSI_{Feeding} = \left( I_G I_{SD} I_{Bilberry} I_{Lichen} \right)^{\frac{1}{4}} \]
Nesting habit, expert model

\[ HSI_{\text{Nesting}} = (I_G I_{\text{SD}} I_{\text{Lichen}})^{1/3} \]
Feeding habitat
Nesting habitat
Results for 360 ha forest

- Must thin to have bilberries
- May cut areas which cannot become habitats (dry pine sites)

- Spruce-dominated forest
- RF and CCF schedules simulated for the stands

Graph showing
- Habitat area after 10 years, ha
- Harvested volume, m³/10 years
- Feeding
- Nesting
- CoreNesting

Legend:
- Orange line: Feeding
- Green line: Nesting
- Green line: CoreNesting
Initial nesting (left) & feeding (right) (green good, red bad)
Nesting after 30 years of heavy forestry

Cut 20000 m³/10 years
Maximize NPV

Cut 20000 m³/10 years
Max habitat 2045
Jay needs large continuous areas

- Maximize habitat – habitat boundary
- Boundary between adjacent stands which are both habitat
- Increases habitat area
- Aggregates habitats

Cut 20000 m³/10 years Max H–H boundary
Jay does not move easily

Proximity to observed Jay locations

Location weights for stands
Nesting habitats must be maintained in certain places

- Max location-weighted mean HSI

\[
\overline{HSI_w} = \frac{\sum A_i w_i HSI_i}{\sum A_i w_i}
\]

Fantastic!

Cut 20000 m³/10 years
Max loc-weighted HSI
Risk management: wind damages

Wind damages are the biggest abiotic risk in Finland
How to assess

- Probability $\times$ Expected damage minimized
- Often there are empirical data for both
- Complication: hazards are spatial phenomena

A possible solution
1. Develop a “good” plan (landscape structure)
   - Use indices, landscape metrics, etc.
2. Evaluate afterwards by using spread models
Wind damages

Prevailing wind direction

This edge is not risky

This is risky -> Low Critical Wind Speed
Results for 360 ha forest

- Even-aged management
- Cut 15,000 m³/10 years
- Max NPV 5%
- Clear-fellings result in risky edges
- Easy solution: minimize height differences of adjacent stands

Tree height in 2025 (dark = tall)
Situation after 10 years when height differences are minimized

Cut 15000 m$^3$/10 years Min Height differences
Thin more, clearcut less
Was it worthwhile?

Yes!

Volume loss in 30 years

NPV when damages simulated

Max NPV
Min height difference

Volume, m$^3$

0
500
1000
1500
2000
2500
3000
3500
4000

Max NPV
Min height difference

NPV, €

0
500000
1000000
1500000
2000000

Damages not simulated
Damages simulated
Thanks