Uncertainty of Carbon Economy Using the Faustmann Model

Rasoul Yousefpour and Andrey L. D. Augustynczik*

Chair of Forestry Economics and Forest Planning, University of Freiburg, Tennenbacherstr. 4, 79106 Freiburg, Germany; rasoul.yousefpour@ife.uni-freiburg.de


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Fate of anthropogenic CO2 emissions
Realizing Mitigation Efficiency of European Commercial Forests by Climate Smart Forestry

Rasoul Yousefpour, Andrey Lessa Derci Augustyniczik, Christopher P. O. Reyer, Petra Lasch-Born, Felicitas Suckow & Marc Hanewinkel
Immediacy of mitigation

IPCC Chart shows observed monthly temperatures (black line), estimated human-caused warming (red), and idealized potential pathways to meeting 1.5C limit in 2100 (grey, blue and purple). All relative to 1850-1900.
Discounting

The tradeoff between now and later is called time discounting.
We trade money/sensation/experience today for money/sensation/experience later.

Question: Which is worth more? $10,000 to be received with certainty one year from today, or: $10,000 received right now?

$9,500 received now?,

$8,000 received now?

$8,000 = 10,000 / (1+0,25)^1
or
10,000 = 8,000 * (1,25^1)
NPV, LEV

\[ NPV = Fh_t + \sum_{a=1}^{t} Th_a (1 + i)^{t-a} - c(1 + i)^t \]

\[ LEV = \frac{NPV (1+i)^r}{(1+i)^r - 1} \]

Th1-Th3 = Thinning
FH = Final harvest
t = Rotation period

Infinite series of Identical Even-aged Rotations

Discount Carbon → PTE (Present Tonne Equivalent)
Forest Carbon Cycle Uncertainty
Forest Carbon Uncertainty & Decisions

Model uncertainty

- Process-based models
- Higher parameter uncertainty
- Propagates to predictions

Climate uncertainty

- Temperature
- Precipitation
- CO2 concentration
**Protocol**

**Climate Scenarios:**
Realisation of no, low, and extreme scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5 by global climate models HadGEM2-ES, IPSL-CM5A-LR and NorESM1-M, downscaled by the regional climate model ISIMIP.

**Deterministic versus Stochastic Modelling:**
Model run with(out)uncertainty propagation.

**Weighting Carbon versus LEV:**
Equal, Favoring, Discouraging.

**Management Options:**
Increase/Decrease BAU Harvest Rate for *Fagus Sylvatica*.

**Discount LEV (Land Expectation Value):**
Fixed 2%.

**Discount Carbon (Present Tonne Equivalent carbon):**
Fixed 2%, No time preference.
Minimum Input

- **Climate data:** Temperature, solar radiation, VPD, precipitation
- **Site properties:** Fertility (0 – 1), soil texture
- **Management:** Initial tree biomass & stocking, thinning (time, intensity, type) and if applied: fertilization & irrigation

Figure 1: Components of 3-PG (Physiological Principles Predicting Growth).
Modelling and Optimization Approach

Management Options:

1- Forest Conservation (No management)
2- Business as usual (BAU)
3- **Intensified** forest wood utilization
4- **Reduced** forest wood utilization

5 options of N/ha x 5 options of % of biomass removal => 25 regimes

Weighing scheme for LEV and Carbon:

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Carbon weight</th>
<th>LEV weight</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<td>0.9</td>
</tr>
<tr>
<td>10</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>
Compromise Programming

1) **Deterministic** Optimum Case Euclidean norm

\[
\text{Min } Z = \sum_{j \in CC} \sqrt{w_1 \text{LEV}_{j-}^2 + w_2 \text{CAR}_{j-}^2}
\]

2) **Deterministic Robust** Case (L1 norm)

\[
\text{Min } Z = \sqrt{w_1 \text{VaR}_{\text{lev}}^2 + w_2 \text{VaR}_{\text{car}}^2}
\]

3) **Uncertain Robust** Case Euclidean norm

\[
\text{Min } Z = \sqrt{w_1 0.5(\text{LEV}_{\min} + \text{LEV}_{\max})^2 + w_2 0.5(\text{CAR}_{\min} + \text{CAR}_{\max})^2}
\]

- \( w_1 \): normalized weight for LEV
- \( w_2 \): normalized weight for Carbon
- CC: set of climate change scenarios
- \( i \): management regime
Sources of Model Uncertainty (random forest technique)

- Parameters related to CO2 fertilization
- Parameters related to absorbed PAR
- Direct impact on growth rates and wood production
- Focus for future data collection in order to produce narrower ranges
- a)-c): Thinning alternatives and d) no thinning (just mortality)

IncNodePurity (Incident Node Purity): A Gini index for showing parameter importance in random forest analysis

Higher IncNodePurity = Impacts on LEV

pRn = max. carbon allocation to roots
fCalpha700 = CO2 fertilization effect
Topt = optimal growth temperature
Alpha = canopy conductance
mS = stem mortality rate
wS1000 = stem mass of mean tree
Productivity of *Fagus sylvatica* under climate change – A Bayesian analysis of risk and uncertainty using the model 3-PG

Andrey L.D. Augustynczik a,b, Florian Hartig b,c, Francesco Minunno d, Hans-Peter Kahle e, Daniela Diaconu e, Marc Hanewinkel a, Rasoul Yousefpour a
Deterministic (robust) case

Figure 6: Carbon sequestration for the deterministic and robust towards climate optimal solutions. The solid lines represent the deterministic solution and the dashed lines show the robust solution. The dotted horizontal line shows the result for the BAU management and current climate.
Carbon Cost (EUR/PTE)
Concluding Lessons

- **Process-based models** are favored to integrate carbon cycle analysis and economy but s. t. uncertainty

- (No)Discounting (0 vs. 2%) has been found to be decisive regarding **carbon sequestration level and cost**

- Current **carbon trade price** is NOT sufficient to encourage commercial mitigation in forestry

- Quantification of **forest carbon budget** is uncertain and needs transparent guidelines to realize an effective carbon policy.
Thank you for attention!

Rasoul Yousefpour & Andrey L. D. Augustynczik
@ Chair of Forestry Economics and Forest Planning
Tennenbacher Straße 4, D-79106 Freiburg, Germany

Phone: +49-(0)761-203-3688
E-Mail: rasoul.yousefpour@ife.uni-freiburg.de
1- Risk premium for natural insurance is LOWER than risk premium for financial insurance?
2- Find the best combination of natural and financial insurance to deal with risks
Socio-Ecological Conflicts in Forest Management:
Risk of (Not) Adapting?

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https://workshop.inrae.fr/iufro-risk-analysis-nancy/