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Sequester or Harvest – the Optimum Use of Managed Forests to Mitigate Climate Change

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  - Bioenergy Use Benefits and Discount Rate
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Introduction

Competing Uses of Forest Carbon

- Store carbon into the forest ecosystems
- Use forest carbon for energy
- Use forest carbon for materials

- What is the best balance: sequester or harvest?

Projection of Germany's Carbon Stocks (Karjalainen et al. 2002)

Table 3

Calculated carbon stocks in tree biomass, soil and products in 1990 and 2050 and stock change 1990–2050 for German forests and products under current and changing climates

Year	Tree biomass		Soil		Products	Sum	
	Current climate	Changing climate	Current climate	Changing climate	Both climates	Current climate	Changing climate
Average stock 1990 (Mg C/ha)	86.8	86.8	62.9	66.7	6.7	156.4	160.2
Total stock 1990 (Tg C)	860	860	623	660	66	1549	1586
Average stock 2050 (Mg C/ha)	161.4	174.5	72.2	73.6	9.6	243.2	257.7
Total stock 2050 (Tg C)	1599	1728	715	729	95	2409	2552
Stock change 1990–2050 (Mg C/ha per year)	1.2	1.5	0.2	0.1	0.05	1.5	1.6
Stock change 1990–2050 (Tg C per year)	12.3	14.5	1.5	1.2	0.5	14.3	16.2

Note that products stock and stock change are the same under both climates, since harvesting levels were kept constant. Total stocks have been calculated from the average estimates assuming the forest area was 9.9 million ha.

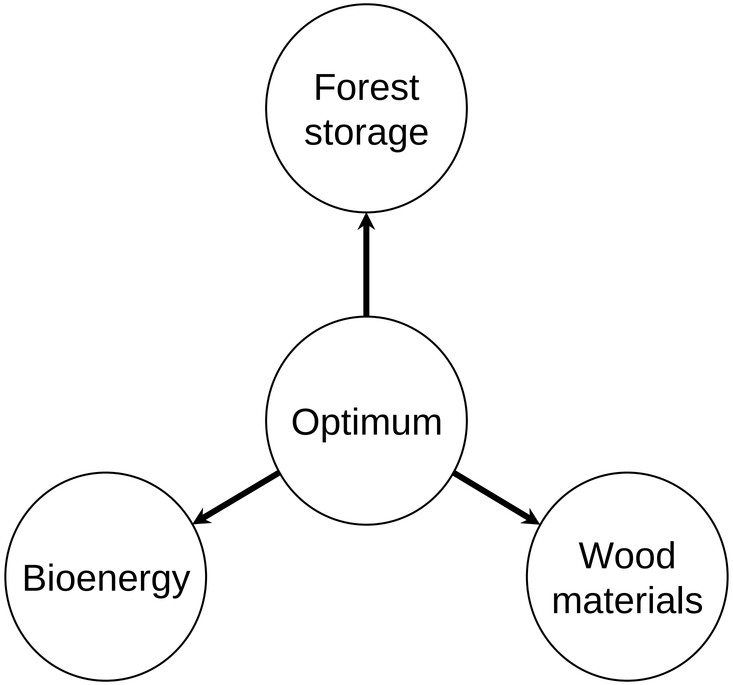
Optimum Use of Forests to Mitigate Climate Change

Ways to Define Optimality

- Traditional timber production: net present value of forest management returns
- Climatic benefits for mitigation: reductions in atmospheric CO_2 concentration
  - Carbon storage in forests and wood products
  - Displaced emissions in energy production
  - Displaced emissions in material production
- Other non-timber benefits

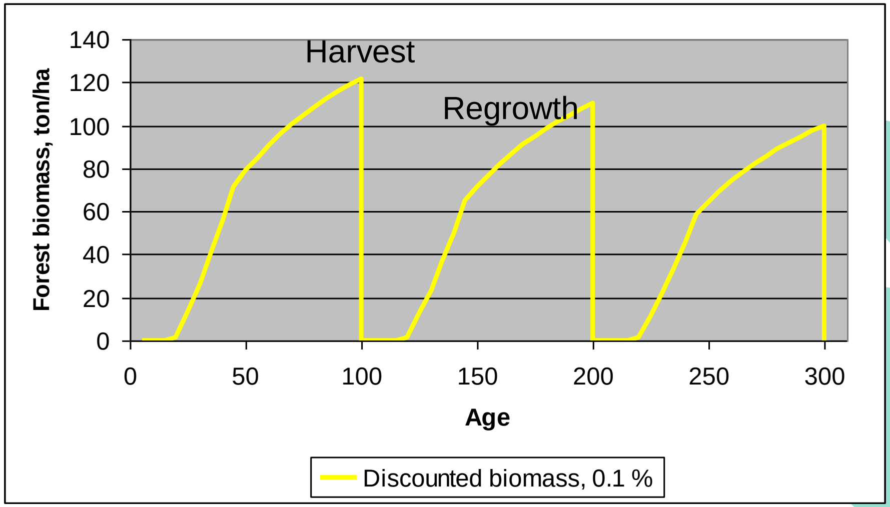
Competing Uses of Forest Carbon for Climatic Benefits

- Store carbon into the forest ecosystems
- Use forest carbon for energy
- Use forest carbon for materials

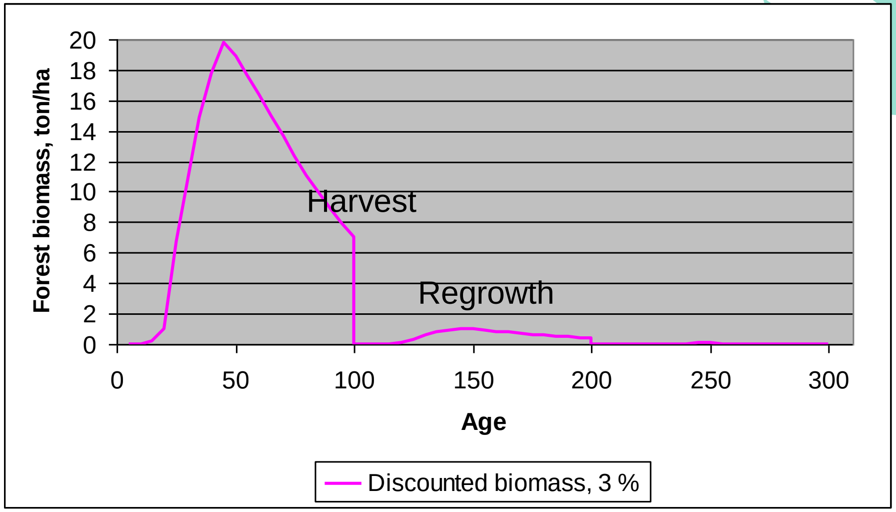


Societal Time Preference:
Interest rate affects the value of climatic benefits

- A low interest rate (societal time preference) makes the regrowth of forest highly valued (0.1 % case). Then, harvesting is beneficial as the loss of biomass (valued as 120 ton/ha) is largely compensated by the future growth (valued as 110 ton/ha).



- A normal interest rate (here, 3 % real) makes the regrowth less valued. Then harvesting is discouraged as the loss of biomass (valued as 7 ton/ha) is not compensated by the future growth (valued as 1 ton/ha).



Displaced Emissions

- The aim is to arrive at relative displacement factors

$$\frac{\Delta \text{Fossil carbon emissions}}{\Delta \text{Carbon in wood used}} = \frac{\Delta C_F}{\Delta C_W}$$

- Displacement factors show how efficient wood carbon is in reducing fossil emissions
- Bioenergy use
  - Include emissions from the bioenergy chain
- Material use
  - Include emissions from the life cycle of wood products
- A range of values is tested in the current study for energywood (small-sized wood) and sawlogs

Previous Case Studies from Sweden and Finland (Gustavson, Pingoud, Sathre)

Multi-storey buildings constructed of wood, compared to hypothetical equivalent buildings made of reinforced concrete

Wälludden building
Växjo, Sweden
16-flat building
1190 m^2 floor area

Viikki building
Helsinki, Finland
21-flat building
1175 m^2 floor area

Substitution Multipliers (Pingoud et al. 2009)

Fossil emission substitution multipliers when more wooden houses are built (avoided emissions are computed relative to increased carbon content):

Sawtimber (Swedish house)	-2.05
Sawtimber (Finnish house)	-1.31
Pulpwood (baseline for p&p, additional for energy)	-0.89
Pulpwood (spruce, only to p&p)	0.48
Pulpwood (pine, only to p&p)	0.13
Energywood (harvest residues)	-0.89

Analysis Tool

Model Characteristics

- Society/forest owner maximizes the discounted net benefits over an infinite time horizon
- Stand level analysis; SMA optimization software
  - Determines the optimal timing and intensity of thinnings and pre-commercial thinnings, rotation length
- MELA based growth models (individual-tree, distance-independent)
- The objective function can be
  - the present value of carbon sequestration
  - displaced emissions due to wood use
  - NPV of timber production

  or some combination of the three

Joint Production Model

Related to harvests | Related to growth

$$\pi = \left[\sum_{t=0}^{T} (h_t - l_t - ec_t)(1+r)^{-t} - w + \sum_{t=0}^{T} cr_t (1+r)^{-t} \right] \frac{1}{1-(1+r)^{-T}}$$

where

h_t = stumpage return from harvest,

l_t = logging cost,

ec_t = emission cost or displaced emission related to harvest,

w = regeneration costs,

cr_t = carbon sequestration payment

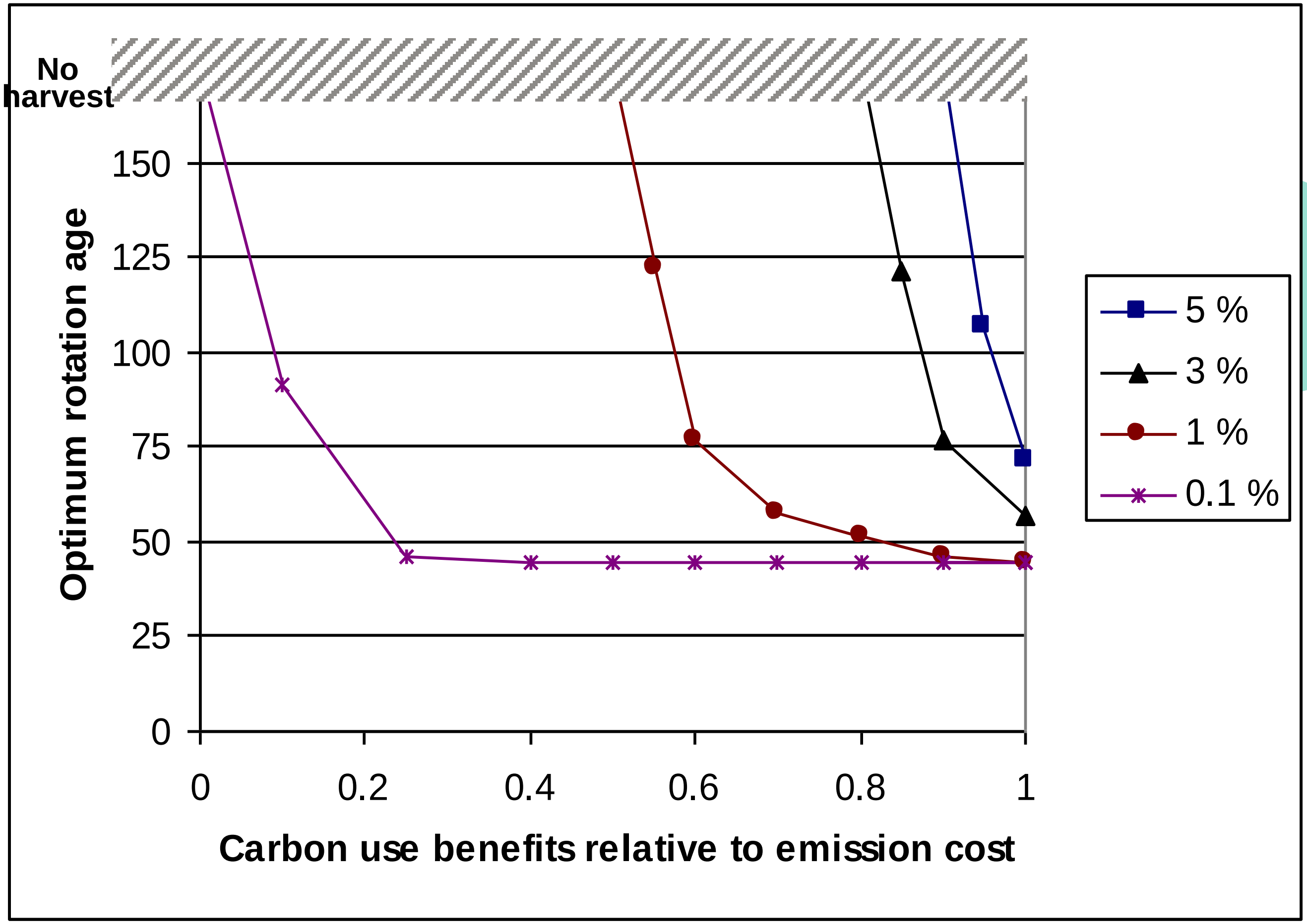
all discounted at rate *r* for a rotation of T

Results on Optimum Management for CC Mitigation

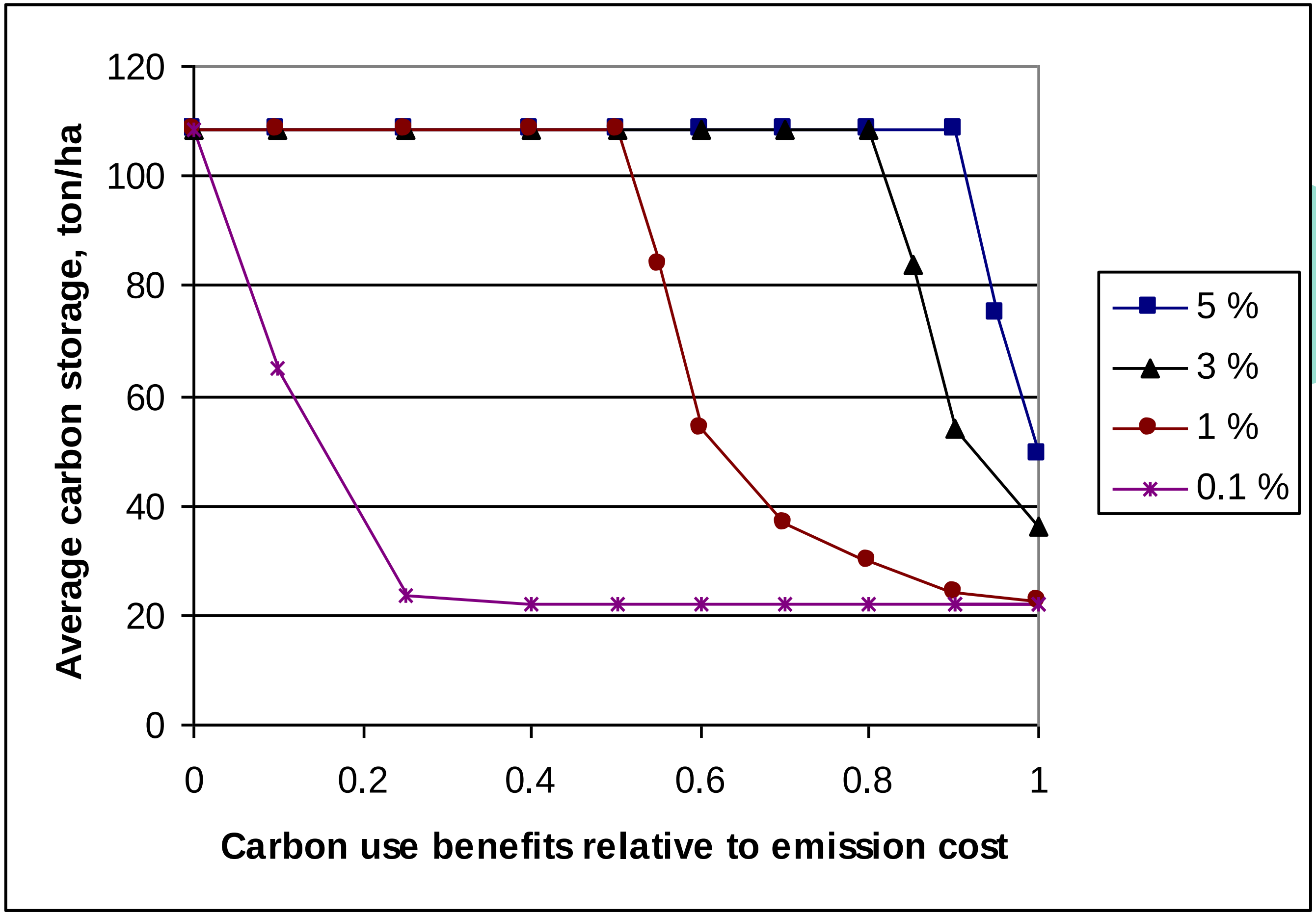
Optimum Management for Bioenergy

- Maximizes the present value of carbon storage (= keeping carbon out of the atmosphere) + using carbon for energy consumption avoiding emissions (call it ”use benefits”)
- No thinnings
- Vary 2 parameters:
  - Annual carbon storage values 0.1, ..., 5 % of emission cost (= infinite storage)
  - Use benefits of wood carbon is relative to the emission cost (0 ... 1)
- At what age is it optimal to harvest a stand?
- Maximum rotation of 175 years implies no harvest

Scots Pine: Optimum Bioenergy Rotation

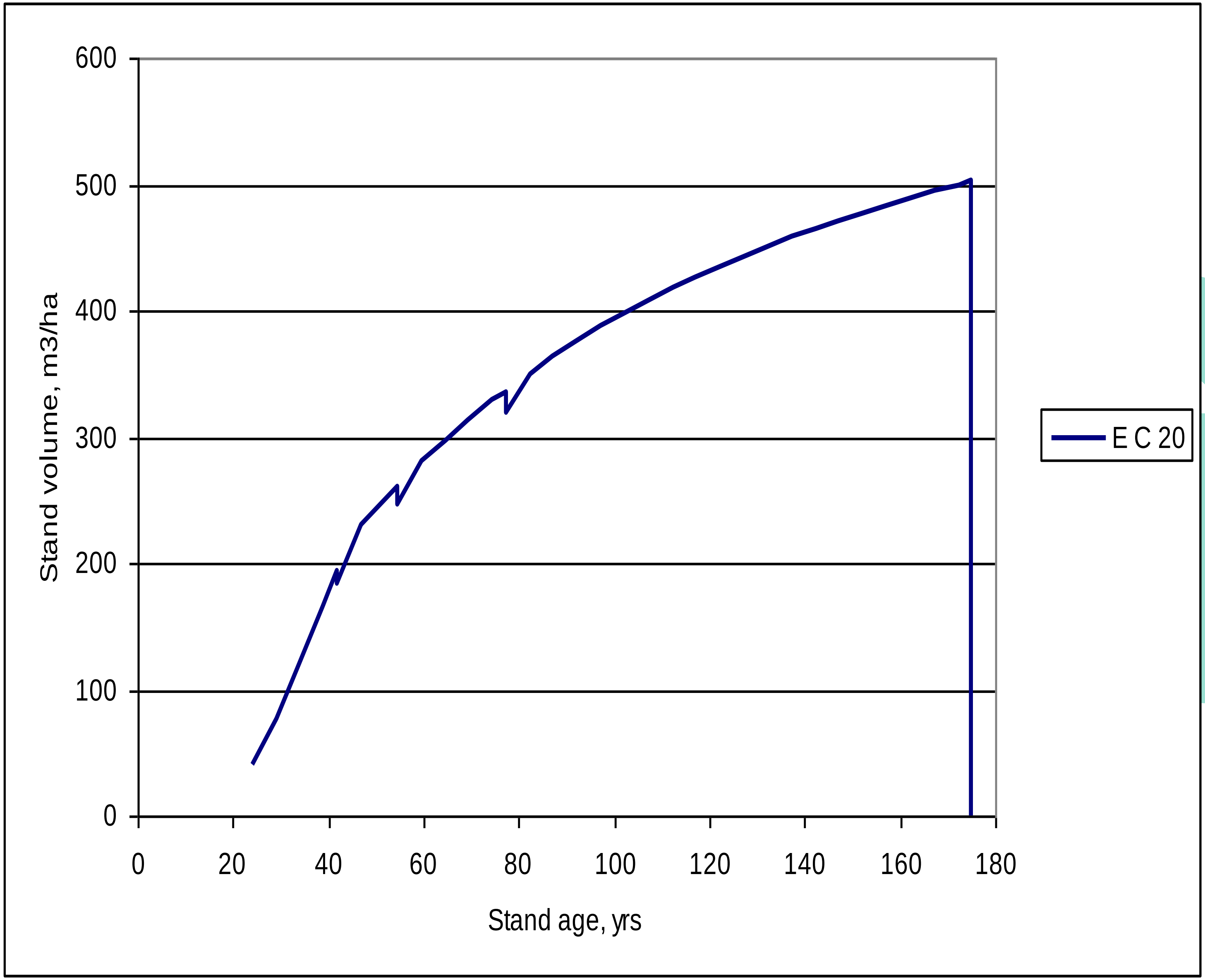


Scots Pine: Optimum Carbon Storage in the Bioenergy Case



Optimum Bioenergy Carbon Management with Thinnings

- Thinnings enabled, but without any costs (stumpage returns still excluded)
- Carbon use benefit is given as reduced emission cost (no use benefits → emission cost 20 €/ton CO_2)
- Otherwise the same as the above
- 3 % interest rate case



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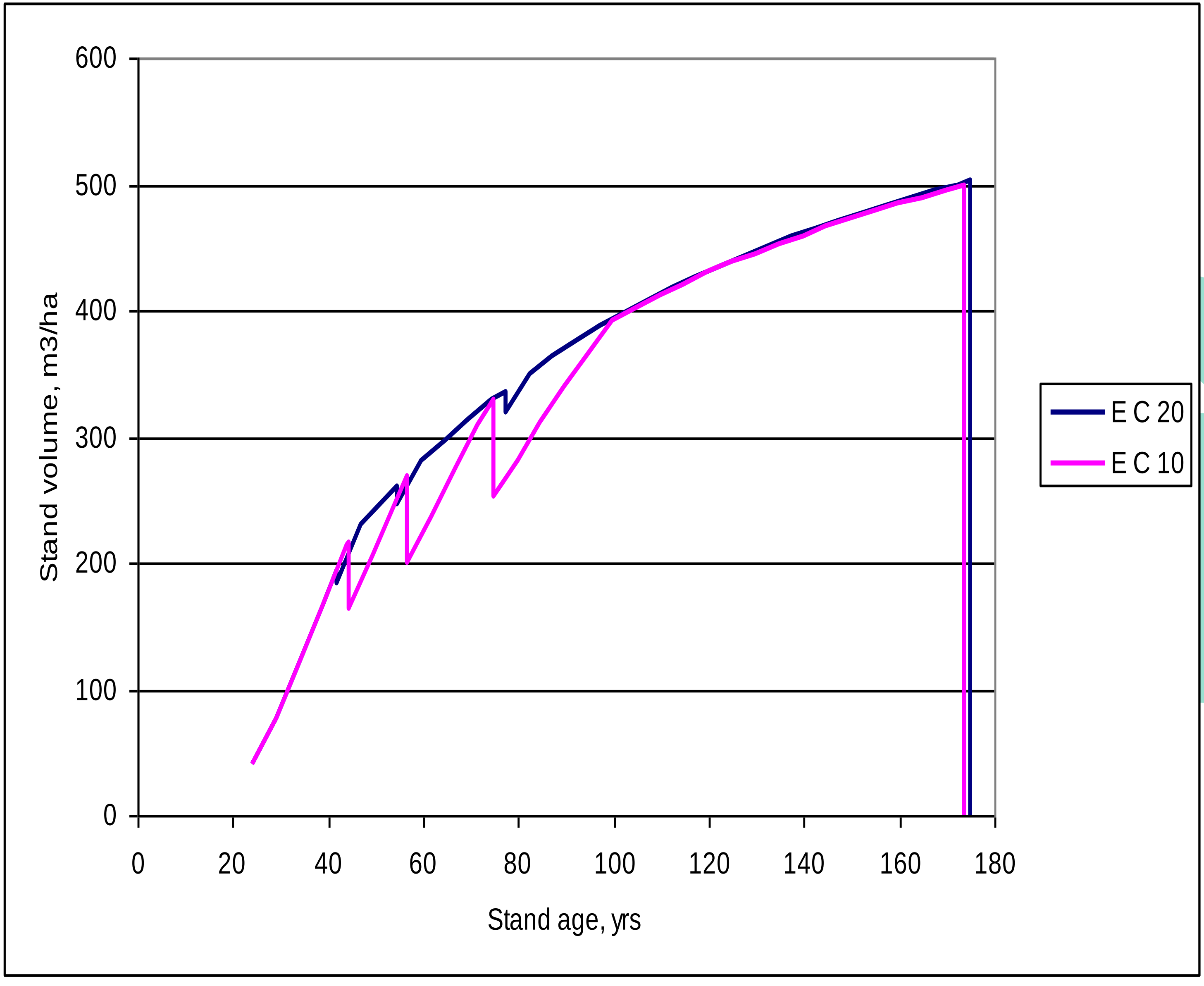

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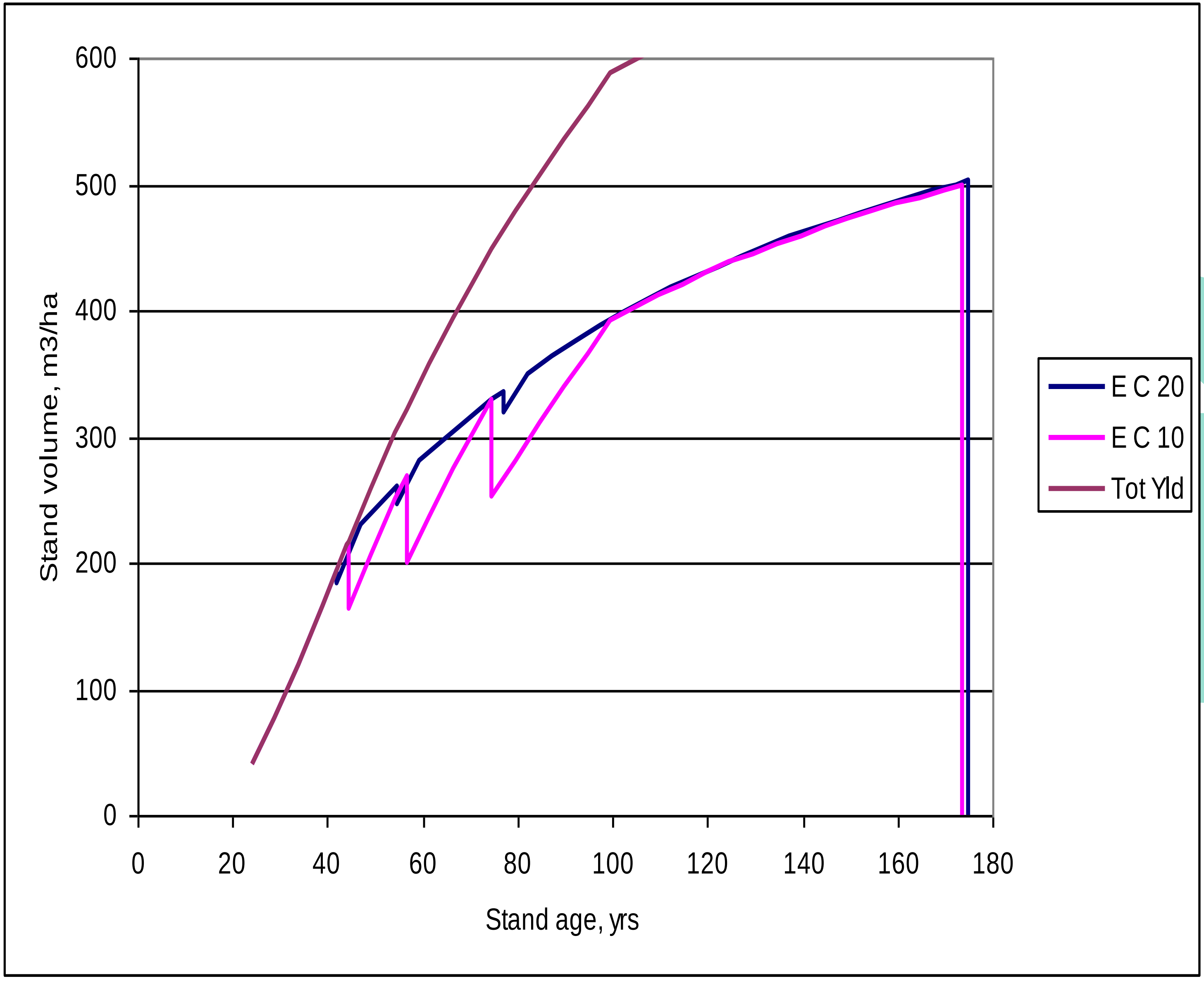
Why does thinning become optimal?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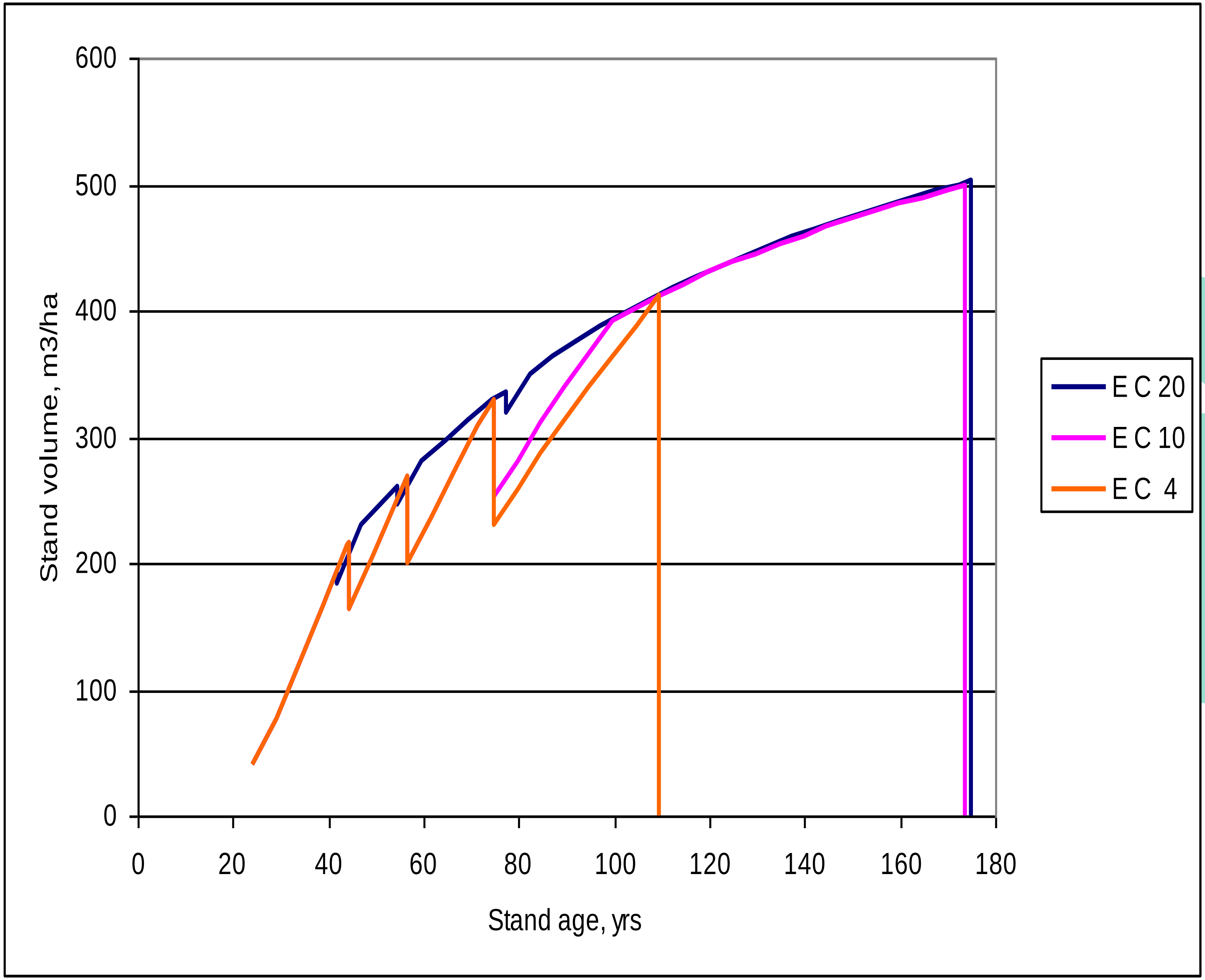
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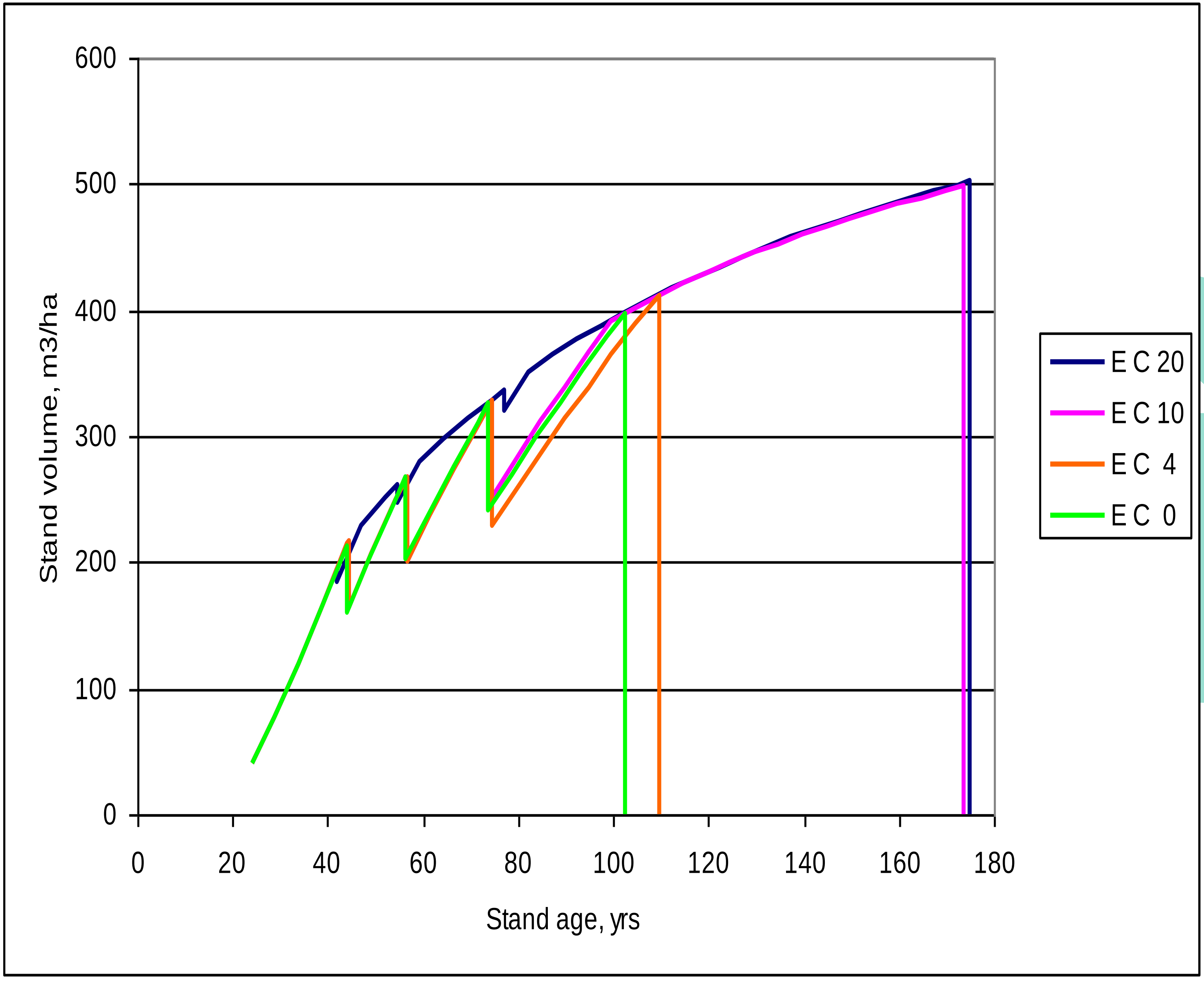

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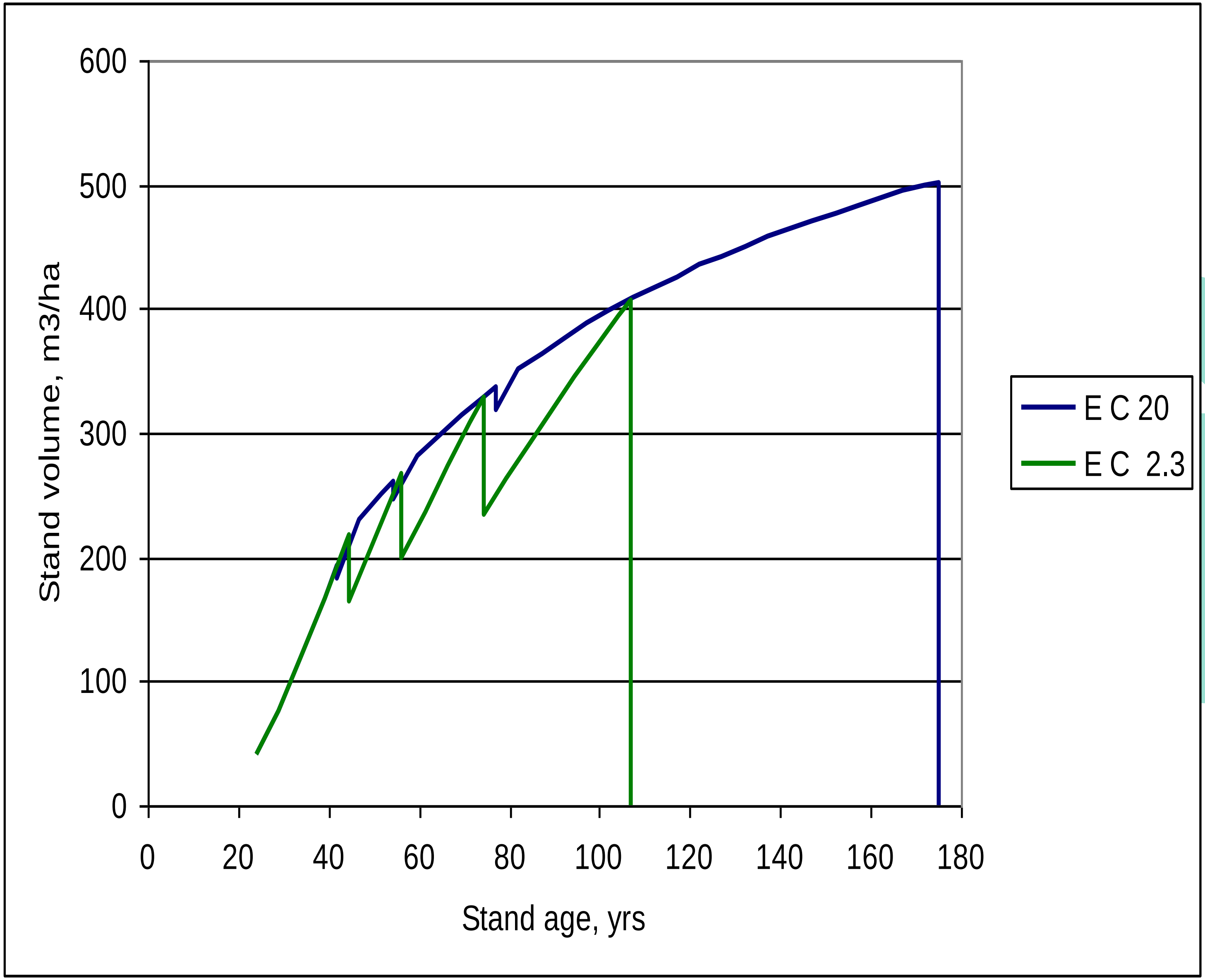
Carbon Benefits Only: Sawtimber for material substitution, pulpwood for energy substitution

- Base emission cost 20 €/ton CO_2
- Pulpwood emission cost is 2.3 €/ton CO_2 because of fossil energy usage and lower efficiency in energy generation (15 %) in bioenergy production
- Sawtimber is used for structural wood products that substitute concrete and steel in the same function
- That leads to avoided fossil emissions, computed per functional unit (not kg)
- Different assumptions of efficiencies in fossil emission reduction, given as emission costs:
  2.3, 0, -10, -20, -30 €/ton CO_2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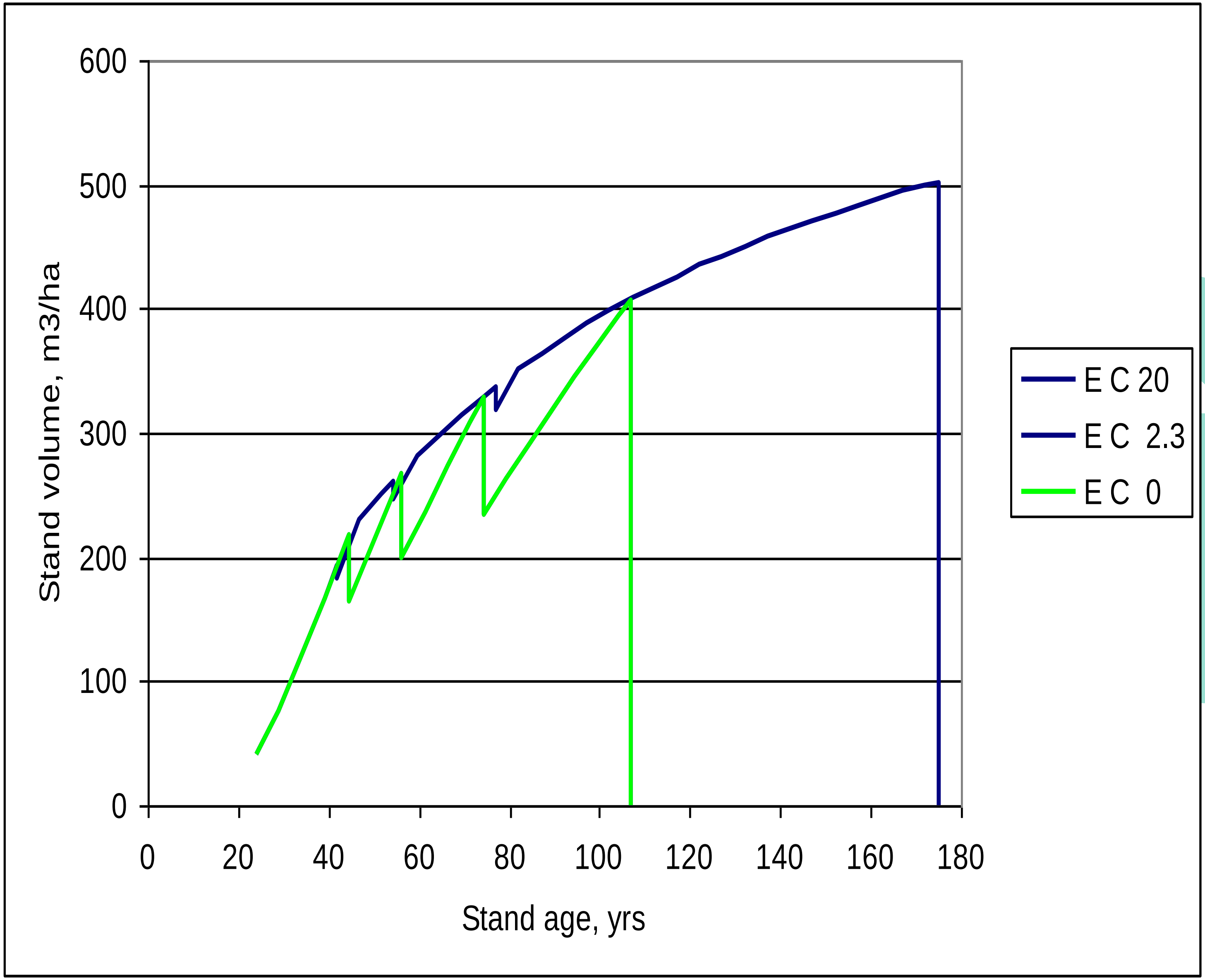

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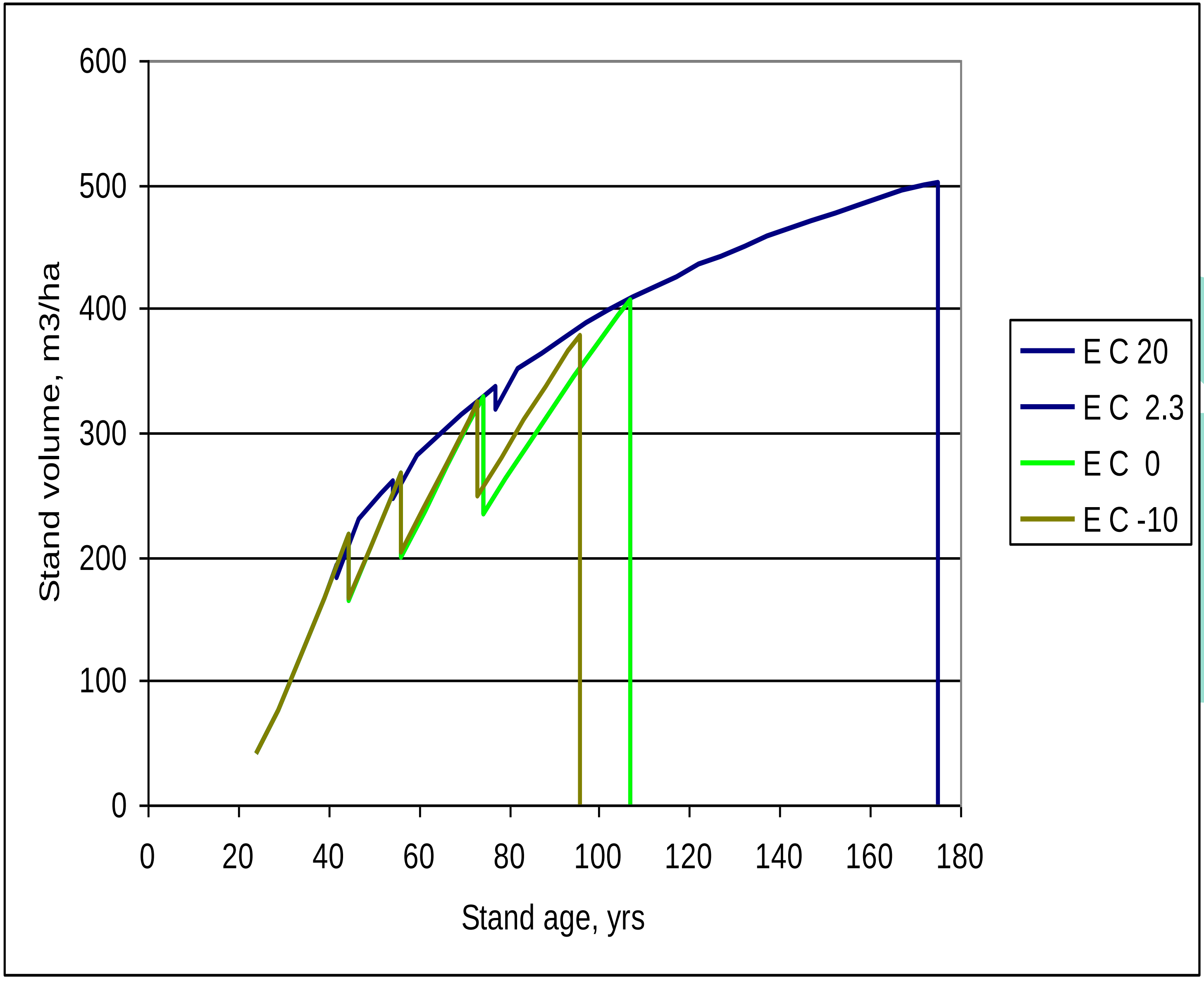

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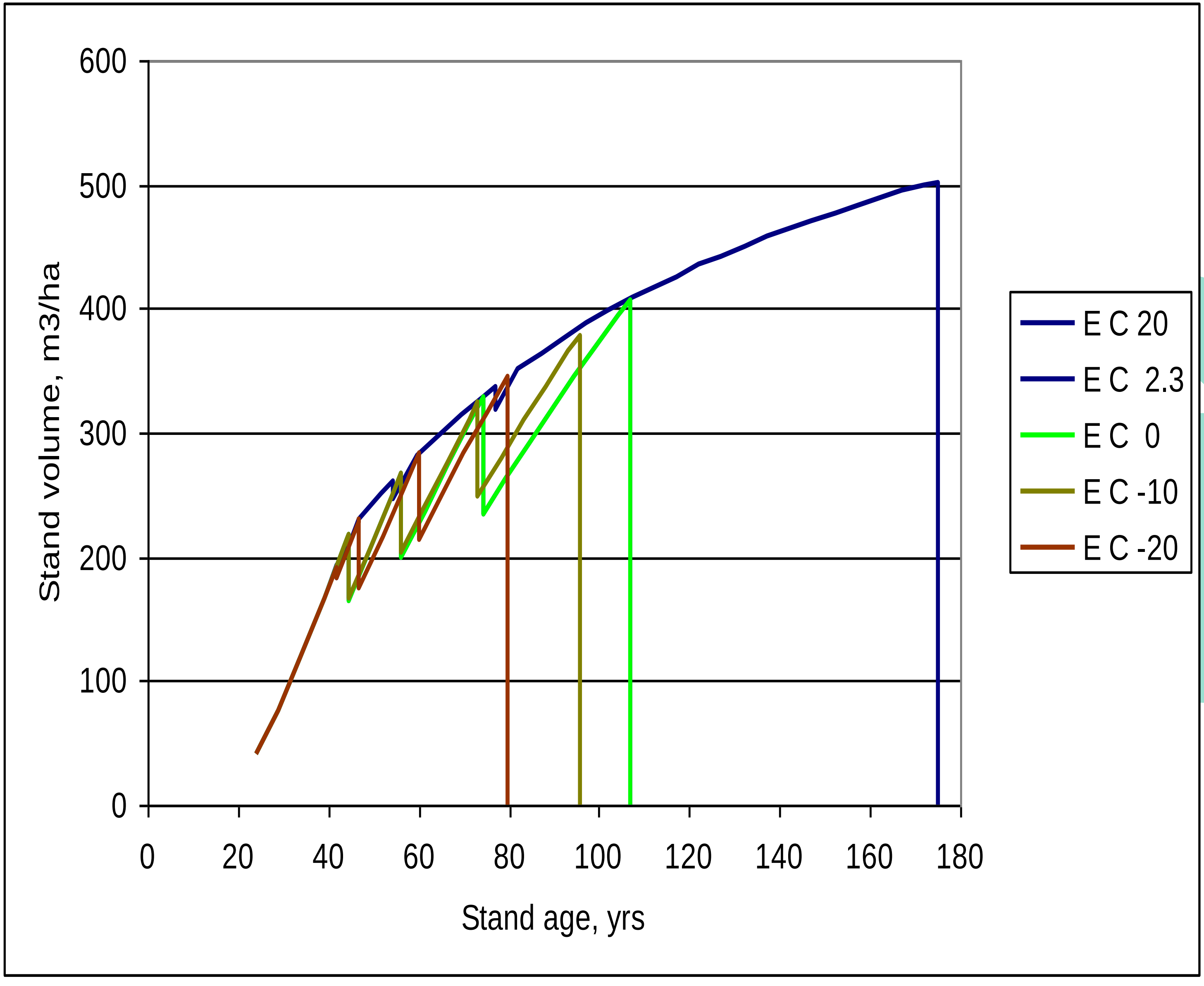
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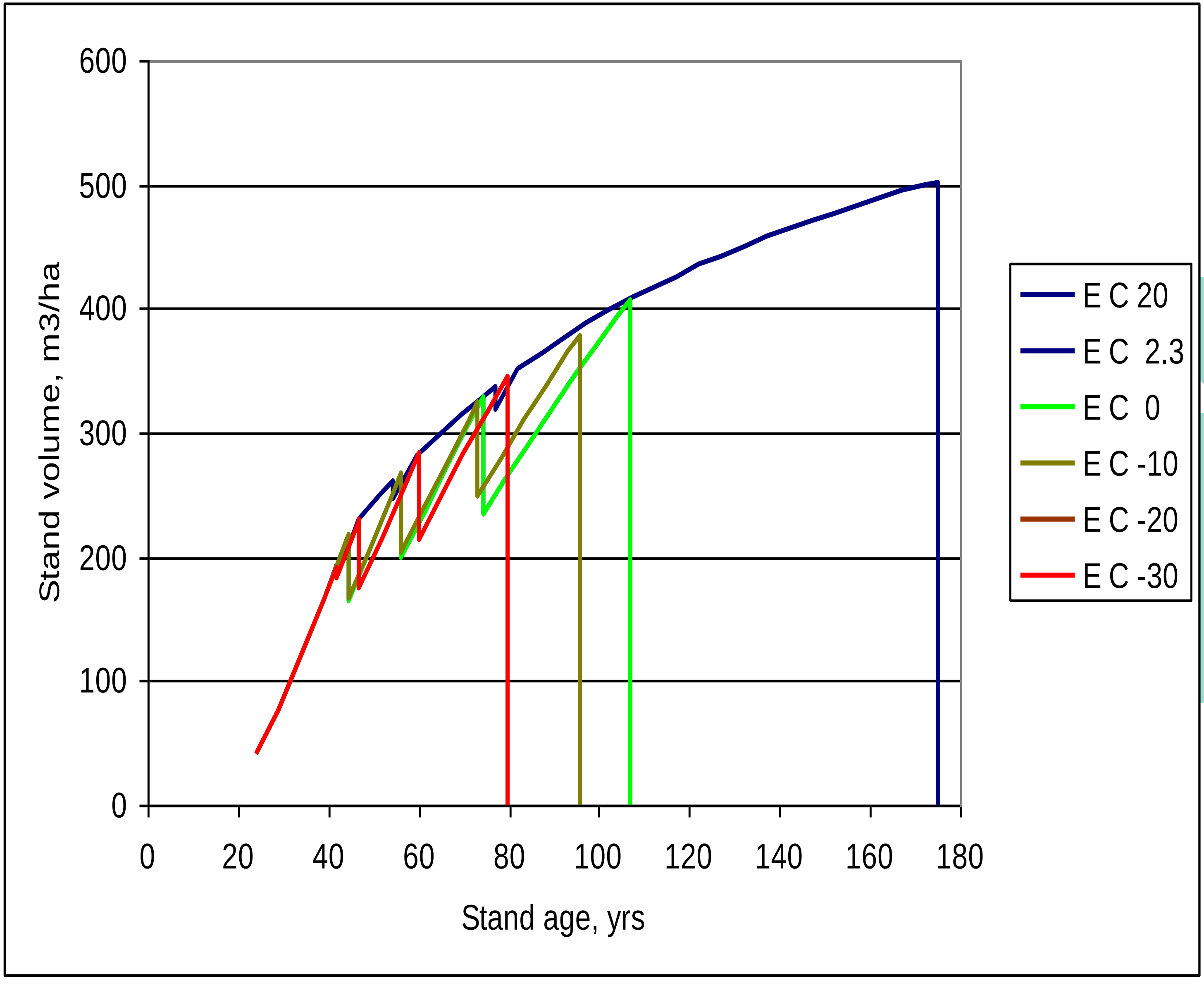

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E C -10
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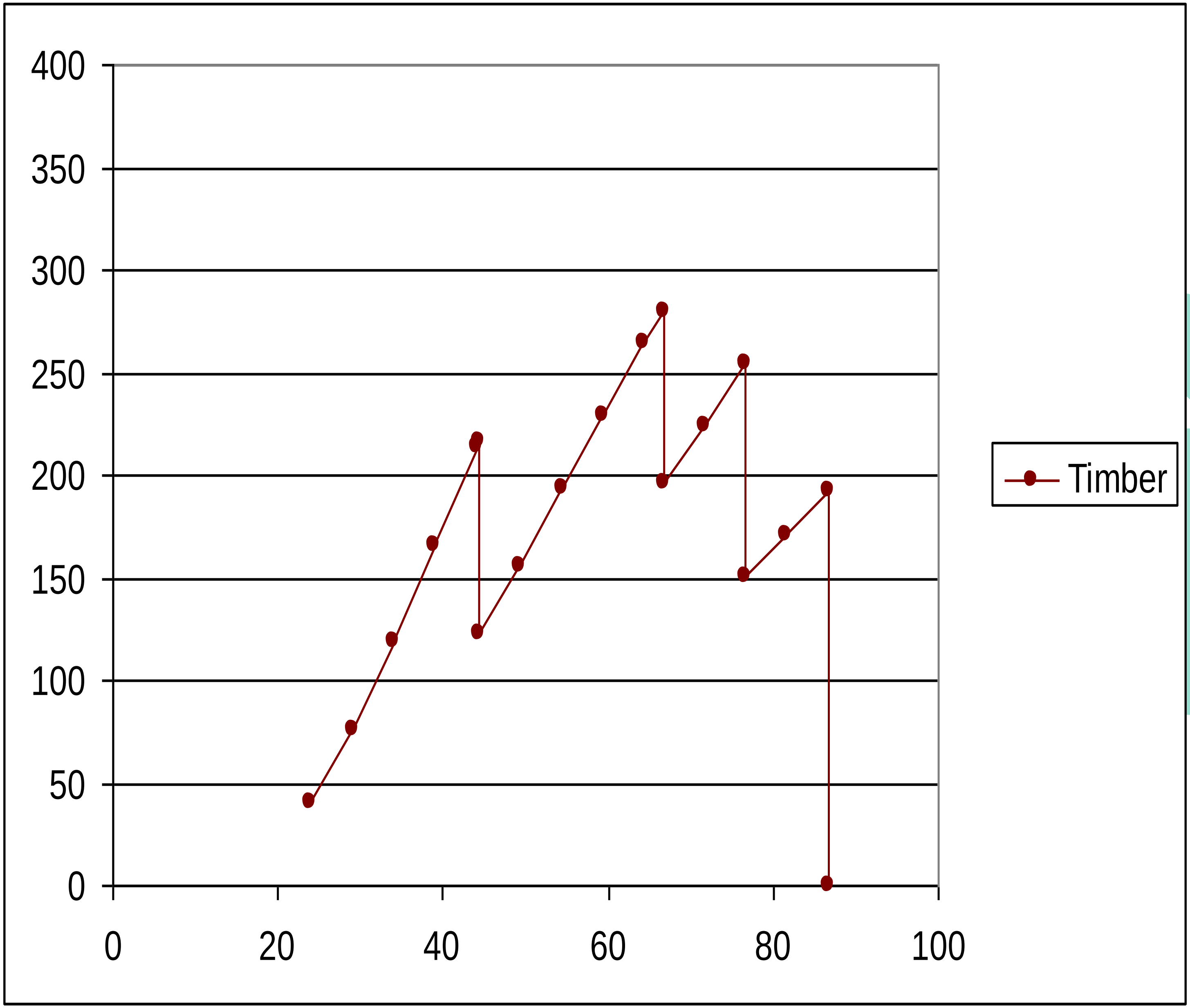
E C -30

Add timber economics

- Road side sales returns (sawlogs 53 €/m^3, pulpwood 25 €/m^3)
- Logging costs
- Regeneration costs
- Pulpwood emission costs as bioenergy (2.3 €/ton CO_2)
- Sawtimber emission costs variable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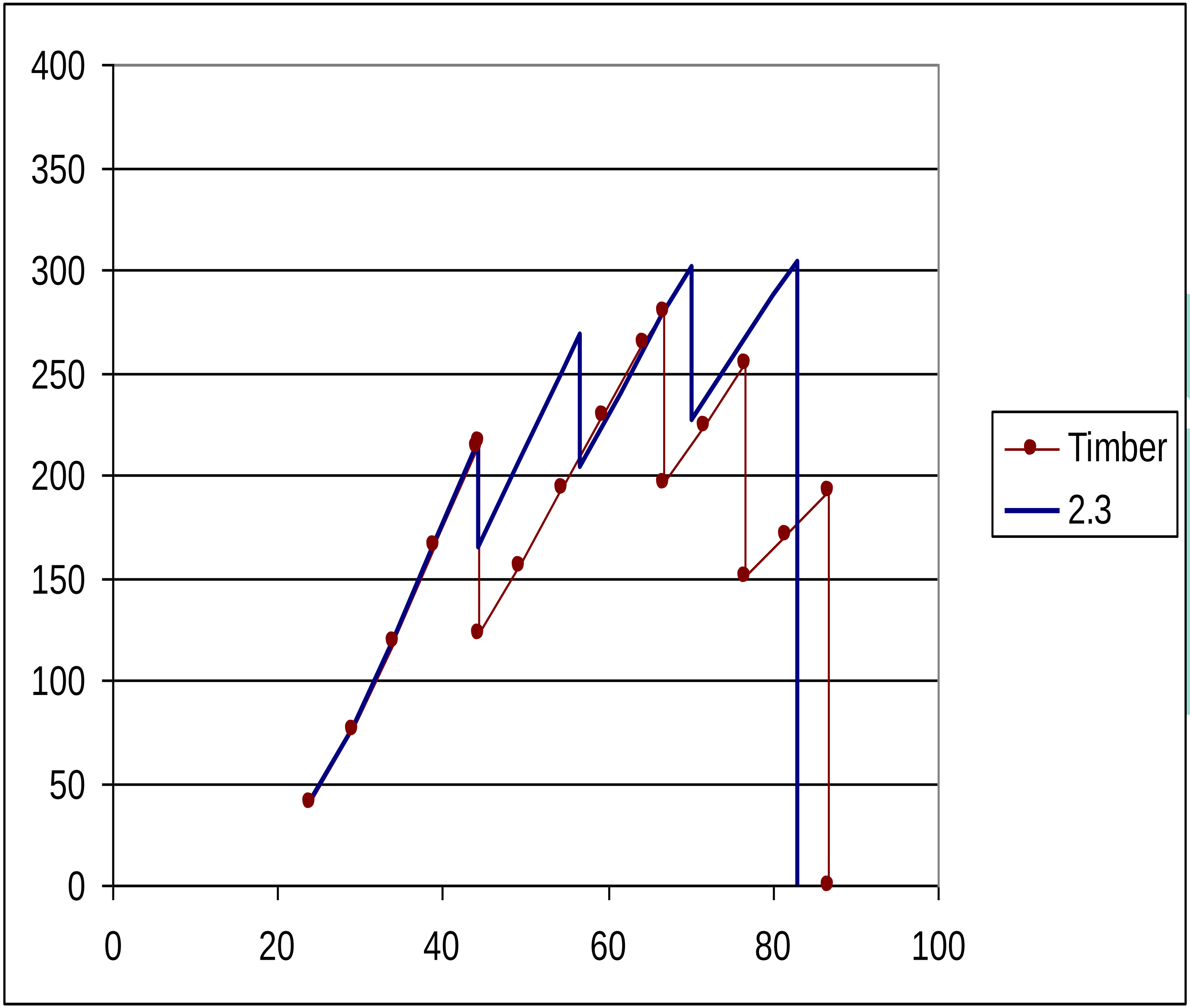
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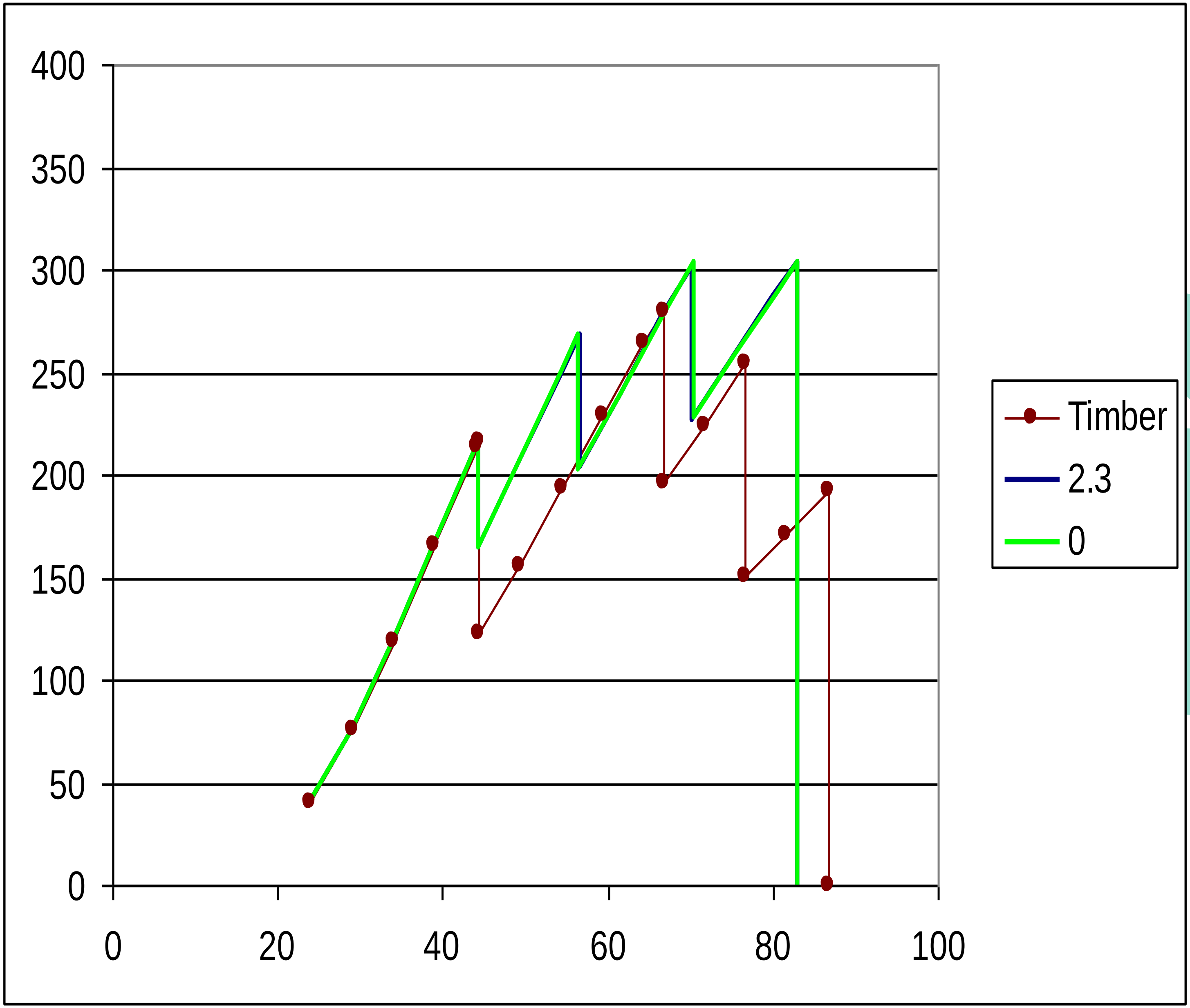
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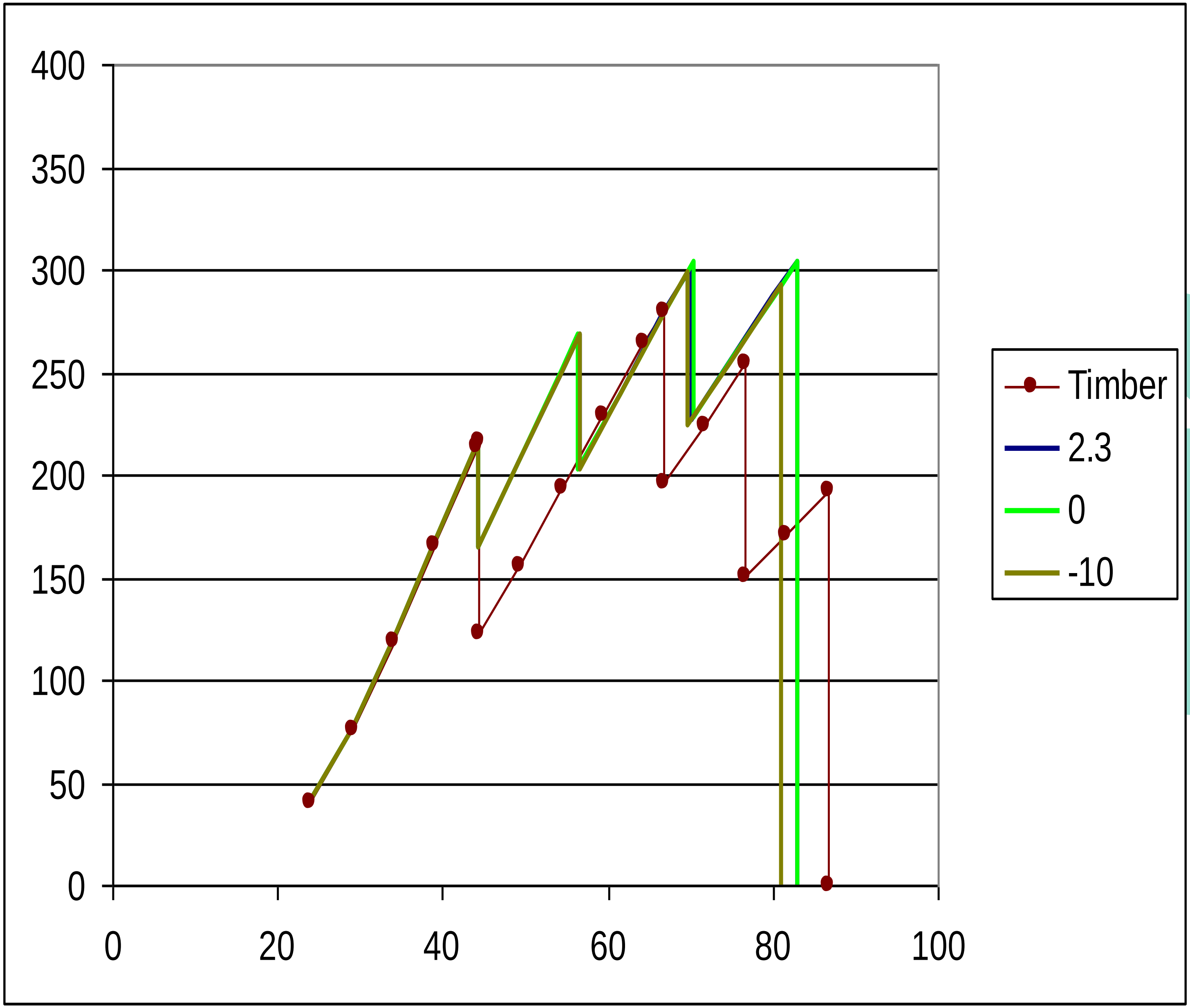
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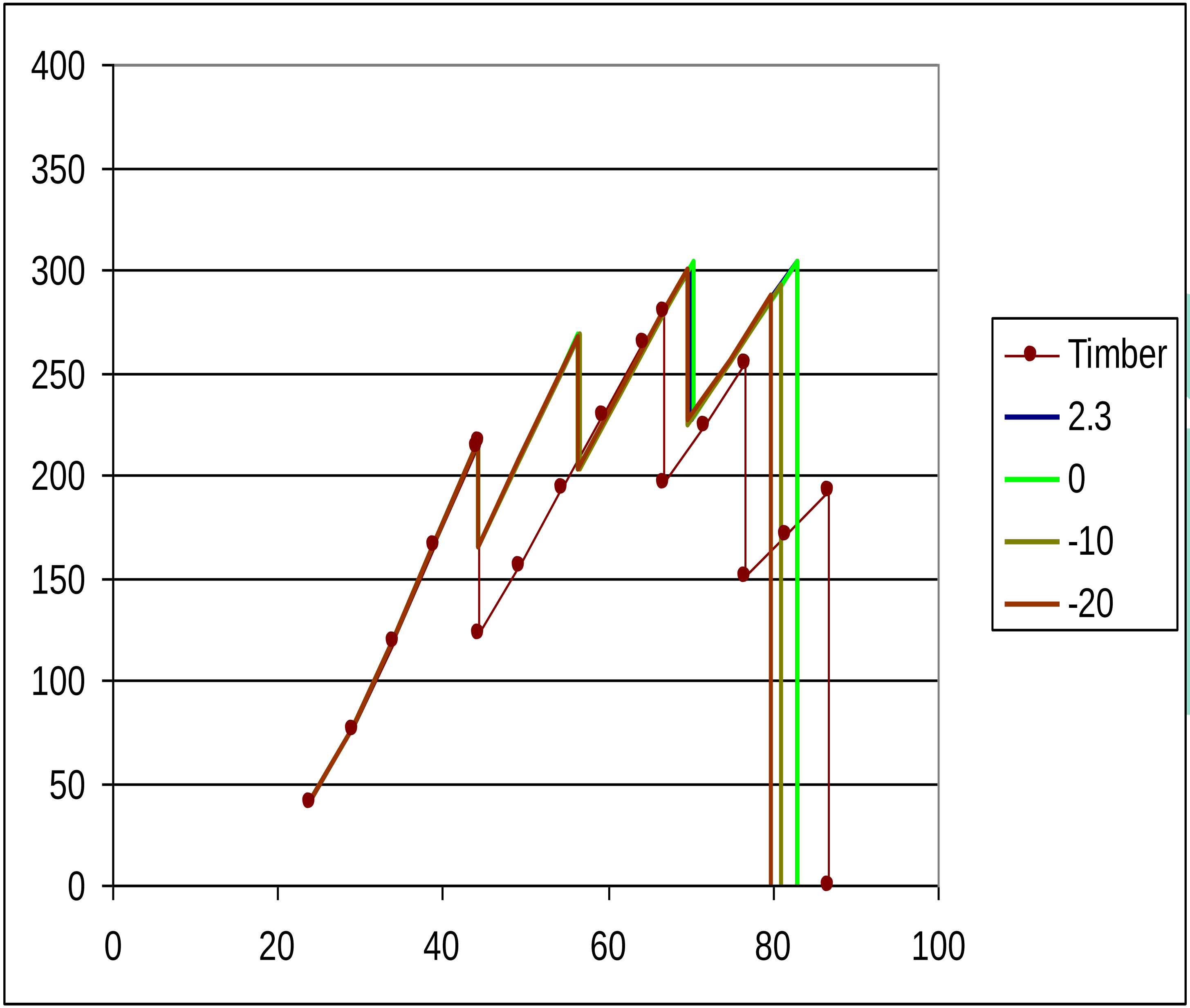

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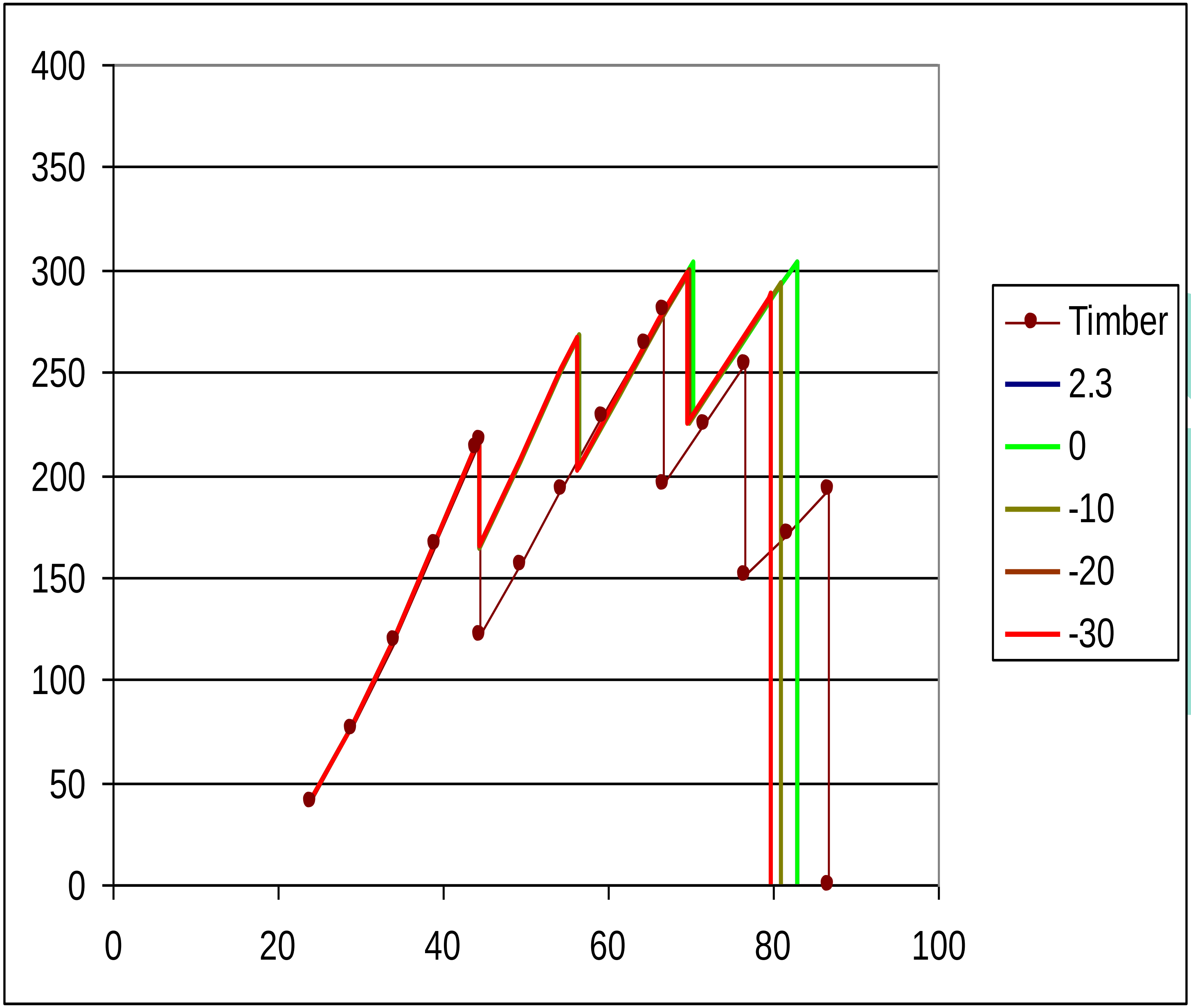
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Timber and carbon net present values (carbon subsidy 20 €/ton CO_2)

Sawtimber emission cost, €/ton CO2	Timber present value, €/ha	Carbon present value, €/ha	Total present value, €/ha
--	1018	0	1018
20	849	2075	2924
2.3	983	3399	4382
0	982	3472	4454
-10	990	3706	4696
-20	991	3950	4941
-30	992	4195	5187

Possible Release of Soil Carbon

Effect of loss of soil carbon at time of final harvest on the optimum management for climatic benefits, interest rate 3 %

Soil carbon loss, ton C ha^{-1}	Carbon utilization benefits 1.0		0.85		0.5	
	Rotation	Average volume, m^3 ha^{-1}	Rotation	Average volume, $m^3 ha^{-1}$	Rotation	Average volume, m^3 ha^{-1}
0	56.9	102.05	121.1	237.41	no harvest	-
1	61.2	114.16	141.2	266.51	no harvest	-
2	62.1	116.76	171.7	303.65	no harvest	-
5	71.2	140.17	no harvest	-	no harvest	-
10	91.2	184.55	no harvest	-	no harvest	-
20	161.7	292.33	no harvest	-	no harvest	-
40	no harvest	-	no harvest	-	no harvest	-
80	no harvest	-	no harvest	-	no harvest	-

Conclusions

- Carbon dynamics in forests are special because forests also act as carbon storages
- A comprehensive analysis must include forest growth, carbon storage and wood use benefits
- Including the value of storage increases the requirements for a climate-beneficial bioenergy system: a typical emissions reduction rate of 80% is required to merit harvest
- Low levels of emissions reductions due to wood use make storage more favorable from climatic point of view
- Efficient material substitution leads to silviculture that is close to timber-economic silviculture

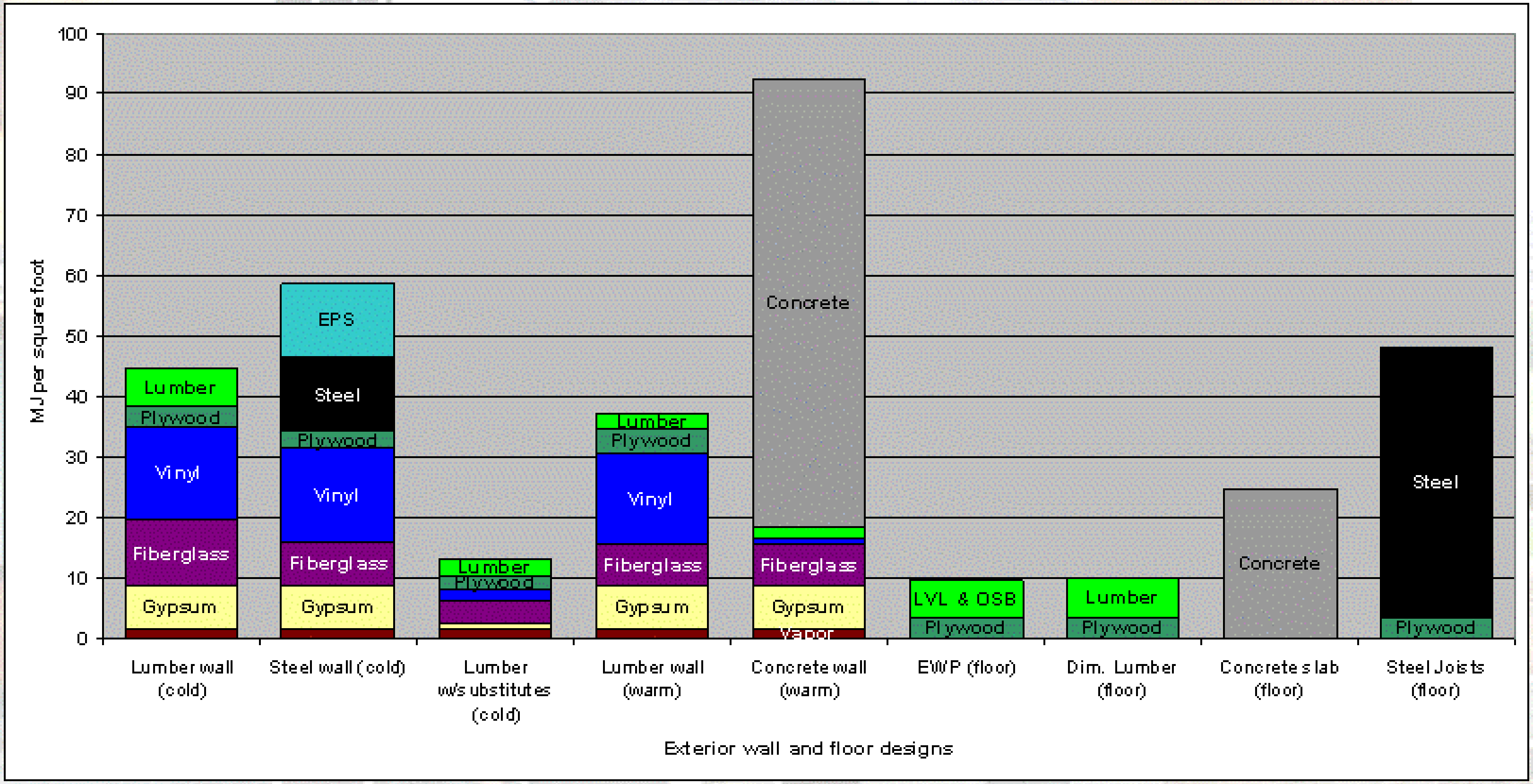
Conclusions (2)

- Soil carbon losses may be important and emphasize a high efficiency of the bioenergy chain
- Bioenergy from waste wood is somewhat different case
- Managed boreal Scots pine and Norway spruce rather similar
- How about other environments/species?
- Climate friendly products from a renewable material – a great potential
- Other environmental impacts must be controlled, as well
- We should ask: What wood carbon can do for the climate


Thank you!

Example from a CORRIM study: Lippke 2007

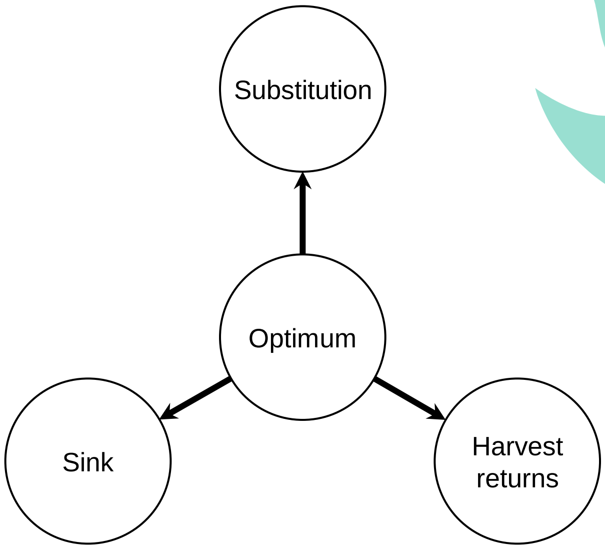
Detailed fossil fuel consumption across all designs



Integrating Sinks and Substitution

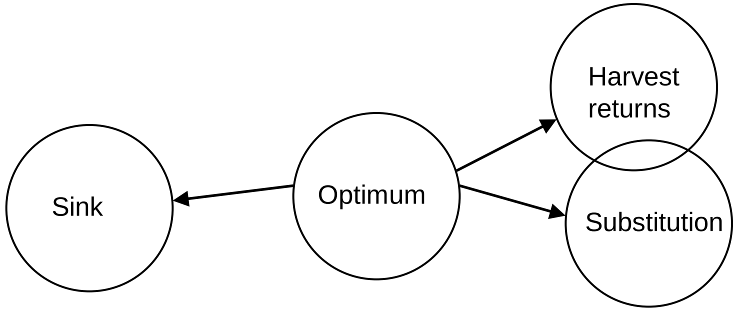
- Increasing sinks usually means reducing harvests
- Increasing harvests usually means reducing sinks

- To study them together, one needs to integrate 3 factors



Integrating Sinks and Substitution (2)

- Harvest returns and substitution are strongly parallel because
  - The more you use harvested wood, the higher the harvest returns
  - Sawtimber has high substitution effects and harvest value



Time Dimension

- Temporary carbon storage has value

  - a benefit from storing carbon for, e.g., 100 years

The above connects with the interest rate:

- Emission cost corresponds to value of permanent storage (carbon credit)
- The value of one year's carbon storage

  = interest rate * emission cost

  Interest rate can be seen as the societal time preference
- Why a positive interest rate/time preference?