Forest products in climate policy: carbon sequestration and substitution

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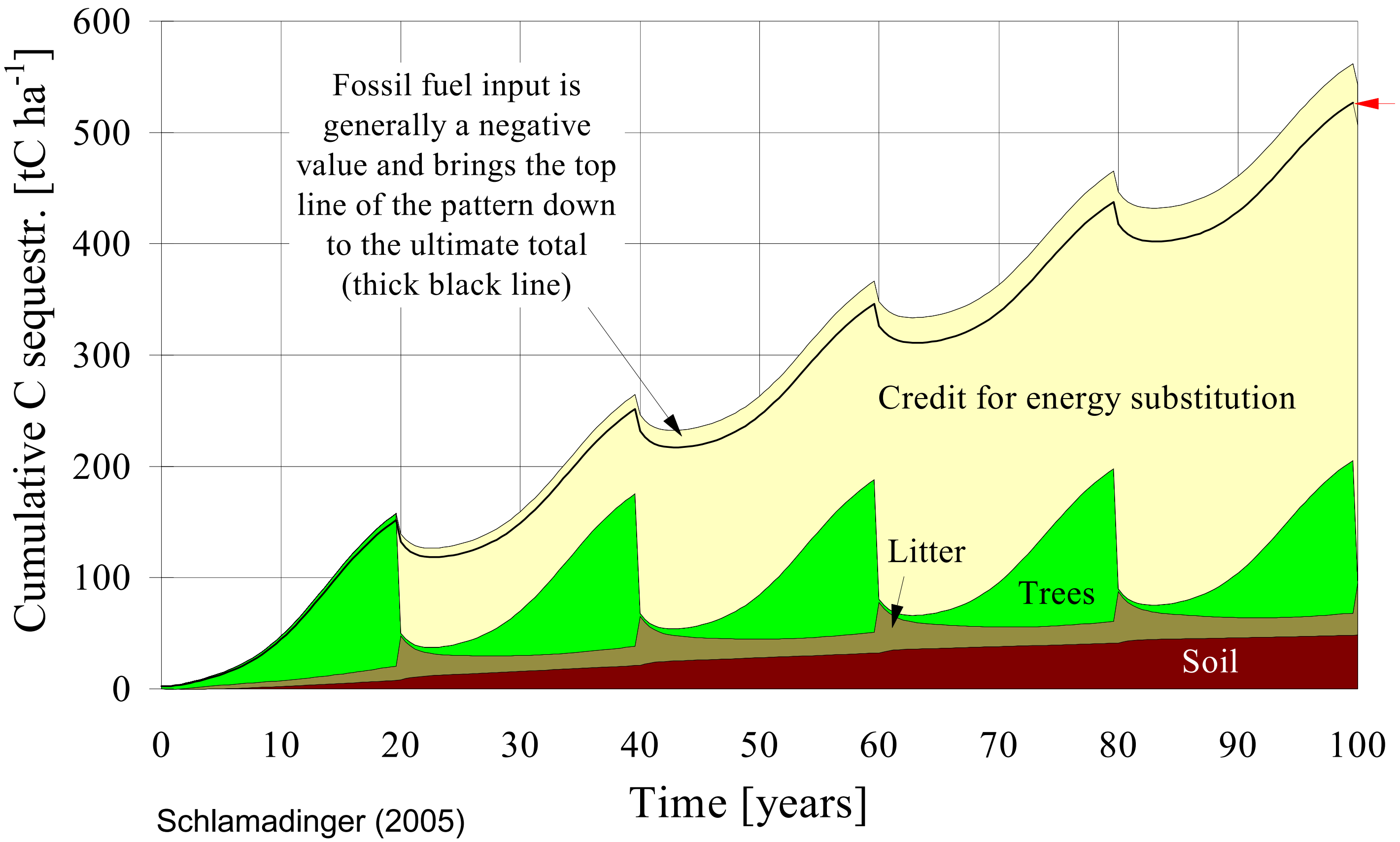
Options

Forests and forest products in climate change mitigation:

- carbon sequestration in forests
- carbon sequestration in forest products
- energy substitution by wood fuels
- material and energy substitution by wood products

C sequestration vs. energy substitution

Model results: fuelwood plantation on agricultural land



Fossil fuel input is generally a negative value and brings the top line of the pattern down to the ultimate total (thick black line)

Schlamadinger (2005)

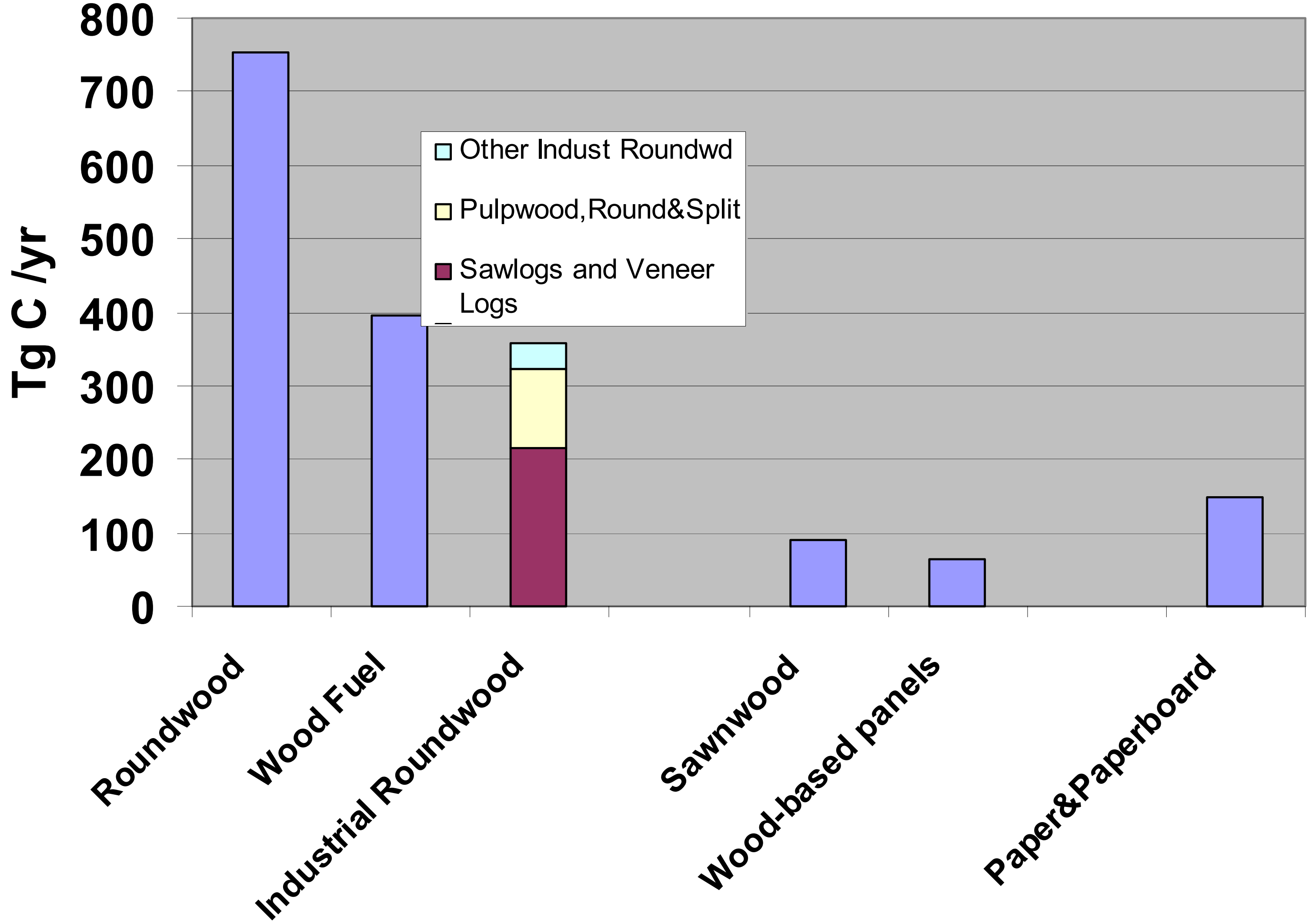
Carbon sequestration in forest products

- Global C sequestration in forest products
- Inventories of forest products in Finnish building stock

Global C sequestration in forest products:

Background data: global consumption of forest products in 2003

(based on FAOSTAT 2005)



Conversion factors: Wood 0.225 MgC/m3, WB Panels 0.294 MgC/m3, P&Pboard 0.45 MgC/ Mg(air dry)

Global C sequestration in forest products:

Estimation tool: the dynamic FODWOOD model

- Originally developed for **national GHG inventories** (IPCC Guidelines)
- Input data:FAO statistics on HWP production and trade rates since 1961 (available for most countries) + estimated rates before that.
- In addition: estimates on **HWP lifetimes** and **carbon conversion factors** required.
- **FODWOOD** model applied in this study to calculate global estimates.

Global C sequestration in forest products:

FODWOOD model: First order decay of forest products

- First order decay of forest product pools assumed; basic differential equation:

$$\frac{dS(t)}{dt} = I(t) - kS(t) \qquad S(t_0) = S_0$$

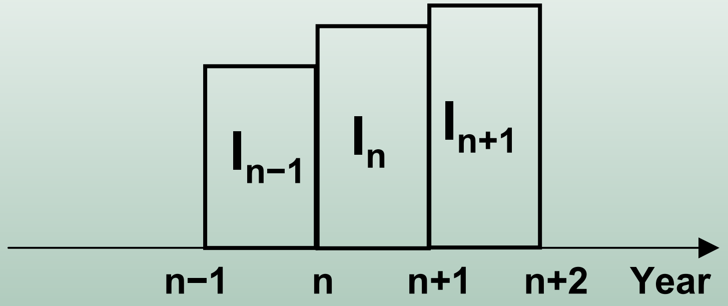
where **S(t)** is the carbon stock at time **t**, **I(t)** is the inflow rate to the pool, **kS(t)** is the outflow rate from the pool, where **k** is the decay coefficient, $\mathbf{S_0}$ is the initial stock of the pool in the past at time $\mathbf{t_0}$.

Global C sequestration in forest products:

FODWOOD model: First order decay algorithm

(Pingoud and Wagner 2006)

- Inflow rate to the C pool of HWP, $\mathbf{I_n}$, is assumed to be **constant within each year n**



- **Analytical solution**: C stock $\mathbf{S_{n+1}}$ in the beginning of year n+1 can be calculated from the recursive formula:

$$S_{n+1} = e^{-k} \cdot S_n + (1 - e^{-k})/k \cdot I_n$$

where k is the decay coefficient (1/yr) of the pool.

Note relationship: Average lifetime = 1 / k   Half-life = ln 2 / k

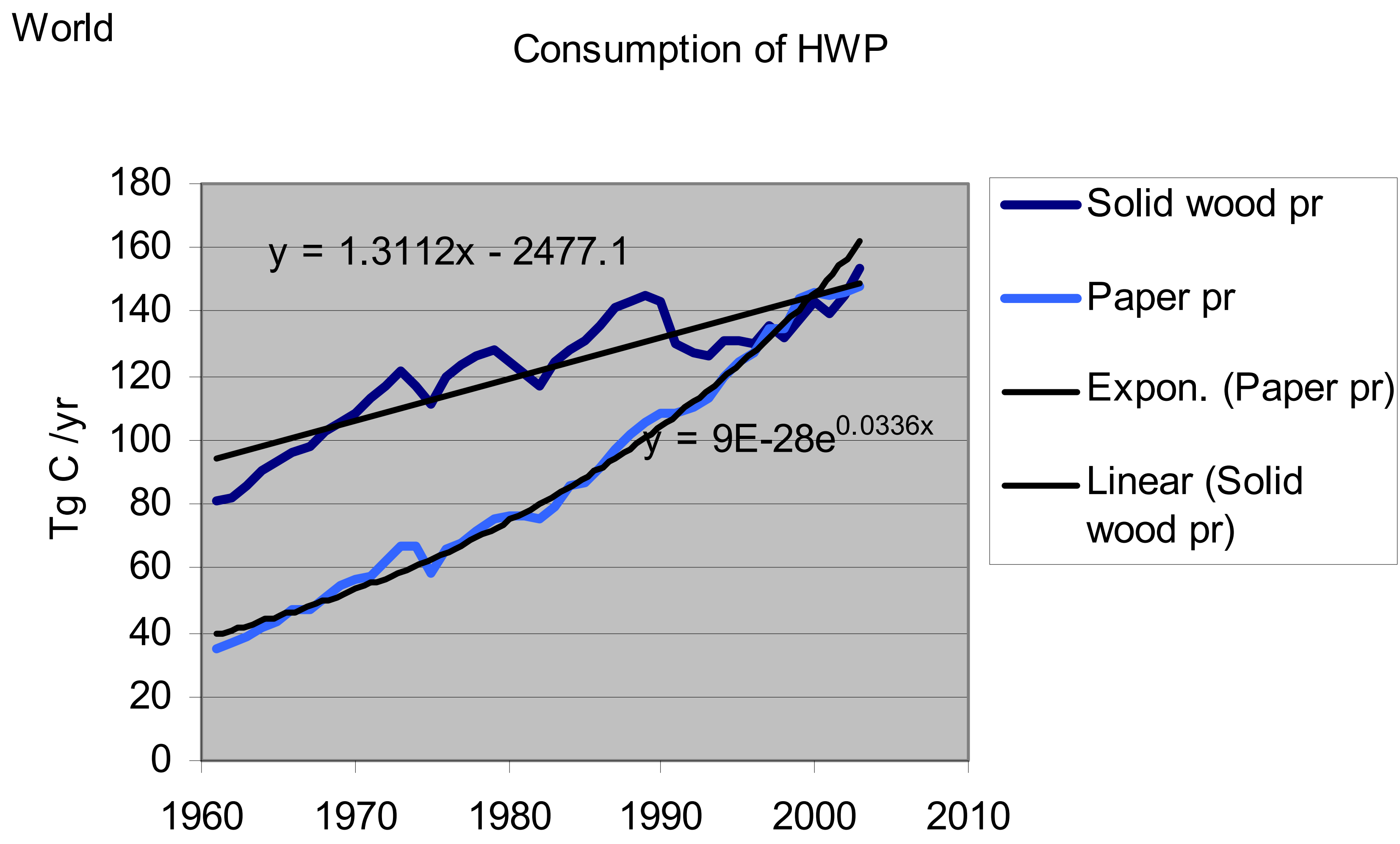
Global C sequestration in forest products:

FODWOOD model: what forest products pools are included

- **Two subpools of semifinished products**: **solid wood products** (Sawnwood, Wood-Based Panels) and **paper products** (Paper and Paperboard) with different k-values. Other Industrial Roundwood excluded.
- HWP in landfills not considered in this study.
- Inflow rates to these pools: apparent consumption rates of HWP = production + imports − exports
- Integration of the equations is started from year 1900 assuming a zero initial stock ($S_0=0$).
- More subpools could be used, if statistics of their inflows and estimates of their k-values were available.

Global C sequestration in forest products:

FODWOOD model input data: global consumption of semi-finished forest products (FAOSTAT) converted to C fluxes



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Global C sequestration in forest products:

FODWOOD model: additional assumptions

- Estimated annual rates of increase for industrial roundwood production globally **=1.28%** between 1900 and 1961 (K.Skog). Consumption of HWP is assumed to be proportional to rw prod rate.

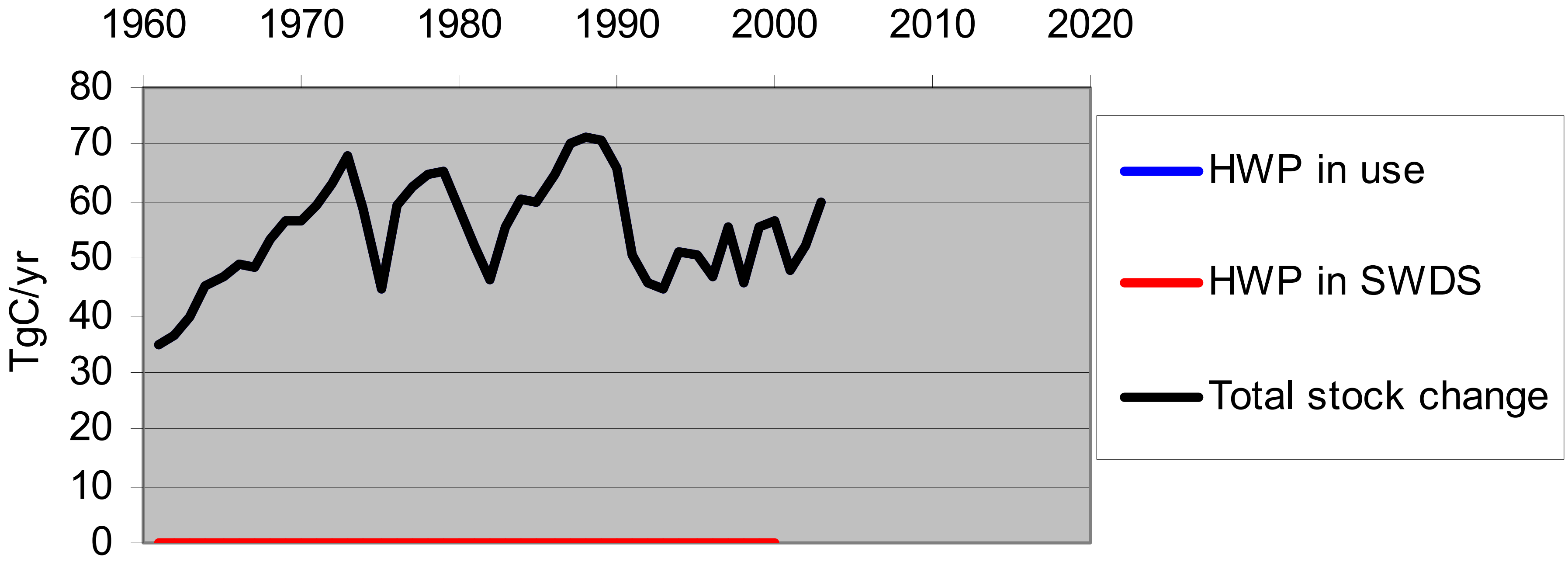
- Half-life of sawnwood and wb panels is **30 yrs** (or average lifetime = 43 yrs).

- Half-life of paper and paperboard is **1 yrs** (or average lifetime = 1.4 yrs).

Global C sequestration in forest products:
FODWOOD model: RESULTS, forest products (HWP) in use

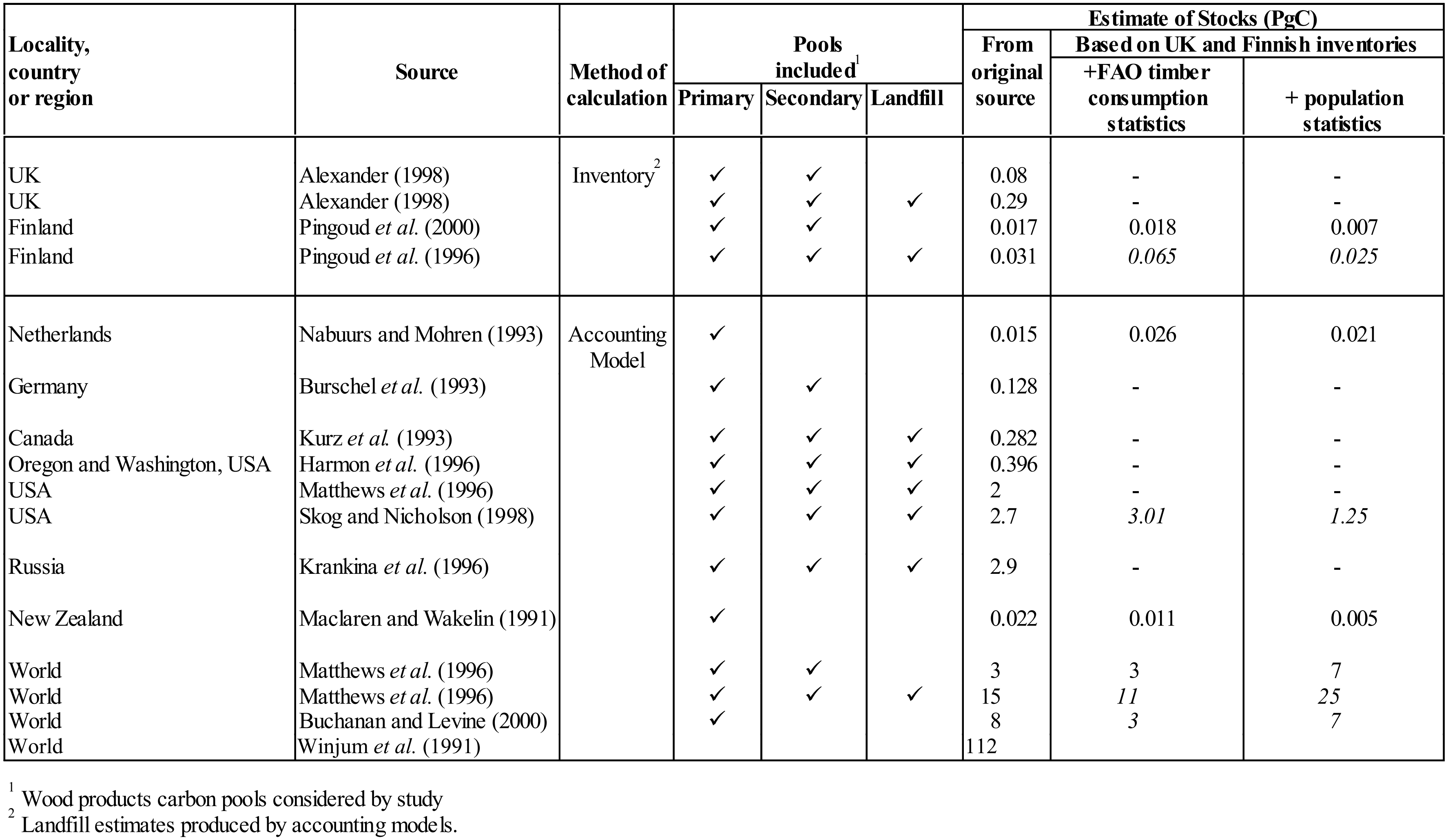
World

Stock change approach:
1) C stock changes



Global C sequestration in forest products:

Comparison to other studies



Locality, country or region	Source	Method of calculation	Pools included[1]			Estimate of Stocks (PgC)		
			Primary	Secondary	Landfill	From original source	Based on UK and Finnish inventories +FAO timber consumption statistics	+ population statistics
UK	Alexander (1998)	Inventory[2]	✓	✓		0.08	-	-
UK	Alexander (1998)		✓	✓	✓	0.29	-	-
Finland	Pingoud *et al.* (2000)		✓	✓		0.017	0.018	0.007
Finland	Pingoud *et al.* (1996)		✓	✓	✓	0.031	*0.065*	*0.025*
Netherlands	Nabuurs and Mohren (1993)	Accounting Model	✓			0.015	0.026	0.021
Germany	Burschel *et al.* (1993)		✓	✓		0.128	-	-
Canada	Kurz *et al.* (1993)		✓	✓	✓	0.282	-	-
Oregon and Washington, USA	Harmon *et al.* (1996)		✓	✓	✓	0.396	-	-
USA	Matthews *et al.* (1996)		✓	✓	✓	2	-	-
USA	Skog and Nicholson (1998)		✓	✓	✓	2.7	*3.01*	*1.25*
Russia	Krankina *et al.* (1996)		✓	✓	✓	2.9	-	-
New Zealand	Maclaren and Wakelin (1991)		✓			0.022	0.011	0.005
World	Matthews *et al.* (1996)		✓	✓		3	3	7
World	Matthews *et al.* (1996)		✓	✓	✓	15	*11*	*25*
World	Buchanan and Levine (2000)		✓			8	*3*	*7*
World	Winjum *et al.* (1991)					112		

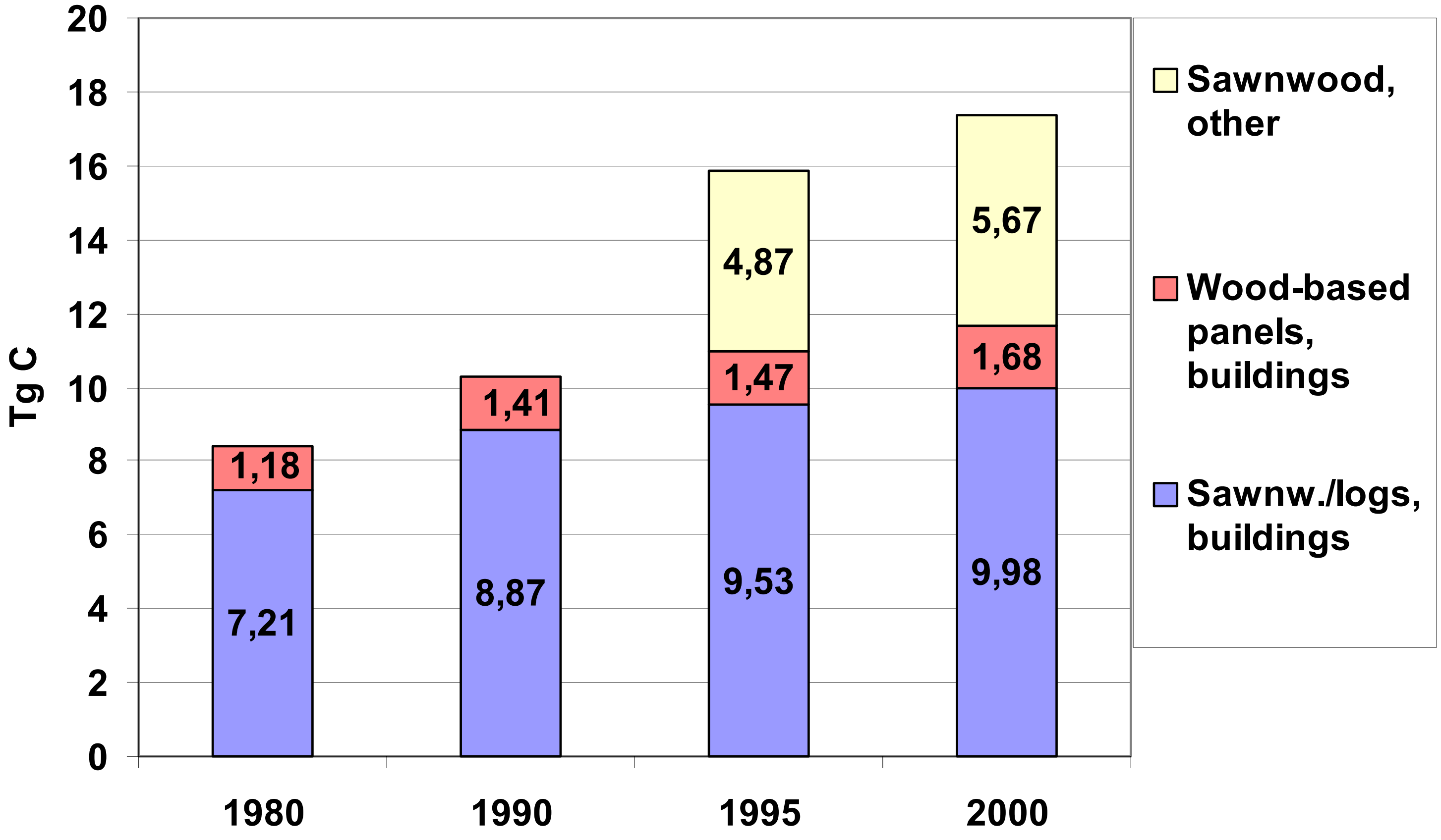
[1] Wood products carbon pools considered by study

[2] Landfill estimates produced by accounting models.

C sequestration into forest products in Finland

Inventories of C stock of construction materials in Finland

(Pingoud et al. 2003)



Average annual C sequestration in forest products **1995-2000**:

- Sawnwood and wood-based panels in buildings: 0,13 Tg C /yr ≈ **0,5 Tg CO_2/yr**
- All forest products incl. civil engineering (=sawnwood other) 0,29 Tg C /yr ≈ **1 Tg CO_2/yr**

C sequestration in forest products: CONCLUSIONS

- Uncertainties of the global model-based study:
  - Only production of semi-finished products assumed to contribute forest product stocks
  - Lack of empirical data on average lifitimes of forest products (probably over-estimated)
  - Aggregated C conversion factors
  - Solid waste disposal sites excluded
- The C sequestration into forest products in use of the order of 1 % of global C emissions or less; in Finland the proportion of the same magnitude
- Small compared e.g. with the global terrestrial C sink, which is of the order of 2300 Tg C/yr (?)

Material and energy substitution by forest products + case studies

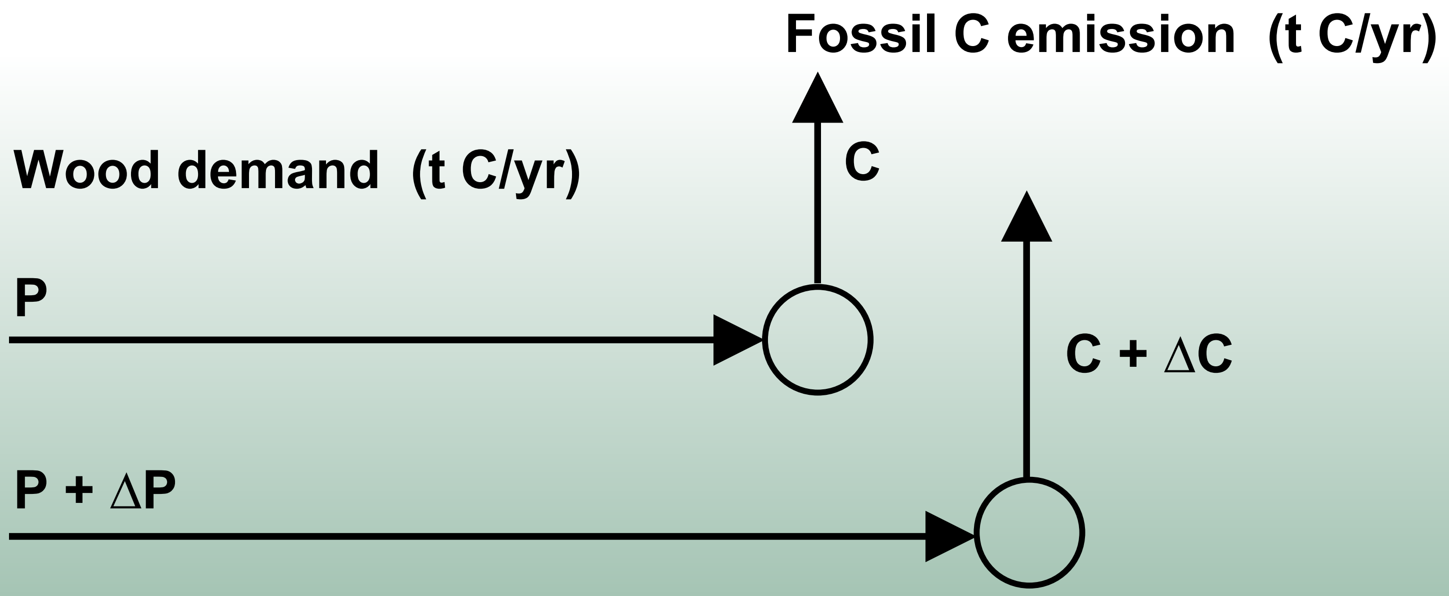
Material and energy substitution by forest products

Basics

- Indirect reductions in fossil-fuel emissions
- Reductions obtained compared to a base line / reference system (e.g. business as usual)
- The reference system fulfils the same function as the substitute (same energy service or material function)
- The emissions of the reference system must also be estimated to calculate the emission reductions due to substitution
- Substitution benefits can be utilised continuously, also when the C sink (sequestration) is saturated

Material and energy substitution by forest products: substitution factor

The substitution factor S can be defined e.g. as follows:



Fossil C emission (t C/yr)

Wood demand (t C/yr)

P

C

$P + \Delta P$

$C + \Delta C$

Substitution factor $S = \Delta C/\Delta P$

S < 0 means that the emissions are reduced when increasing wood demand in some function .

Note: S defined as above describes <u>marginal</u> emission reductions, i.e. reductions compared to <u>additional</u> wood use ΔP.

Material and energy substitution by forest products: some numerical estimates of substitution factors S

Sawlogs processed to construction materials (Swedish multi-storey house)	-2.05
Sawlogs processed to construction materials (Finnish multi-storey house)	-1.31
Wood for bionergy	-0.89
Pulpwood (spruce) to mechanical pulp and paper*	0.48*
Pulpwood (pine) to chemical pulp and paper*	0.13*
*Rough assumption that there would exist emission free substitutes for paper products	

Estimates based on the following papers and reports (note that wood construction materials are assumed to replace materials in a concrete house): Gustavsson-Pingoud-Sathre(2005), Pingoud-Lehtilä(2002) and Pingoud et al.(2006)

Material and energy substitution by forest products: trade-offs

Remarks:

- The substitution factors vary dependent on the end use of wood
- Some substitution factors are <u>less than -1</u>: the relative emission reduction can be greater than the carbon content of the raw material (stemwood) itself
- The quality of the wood produced (sawlogs, pulpwood, wood residues for bionenergy) has substantial impact on the substitution potentials
- Consequently, maximisation of biomass production would not necessarily lead to maximal substitution benefits

Material and energy substitution by forest products: trade-offs

Remarks (cont.):

- In GHG mitigation the use wood for both material and energy substitution is in all likelihood more beneficial than the use for energy substitution only
- Results of the case study Gustavsson et al. (2005): During the lifecycle of a wood house the substitution impact on fossil C emission-reductions could be multifold compared to the C sequestration into wood materials
- Numbers based on an individual case study: more studies required

Material and energy substitution by forest products: trade-offs

Questions:

- How to maximise the substitution benefits?
- What would be the best forest management strategies to maximise the benefits, including C sequestration into forests and forest products and the substitution impacts?
- Economic factors; market mechanisms in maximising the GHG benefits?

Conclusion:

- The whole wood lifecycle from forest to end-use must be considered

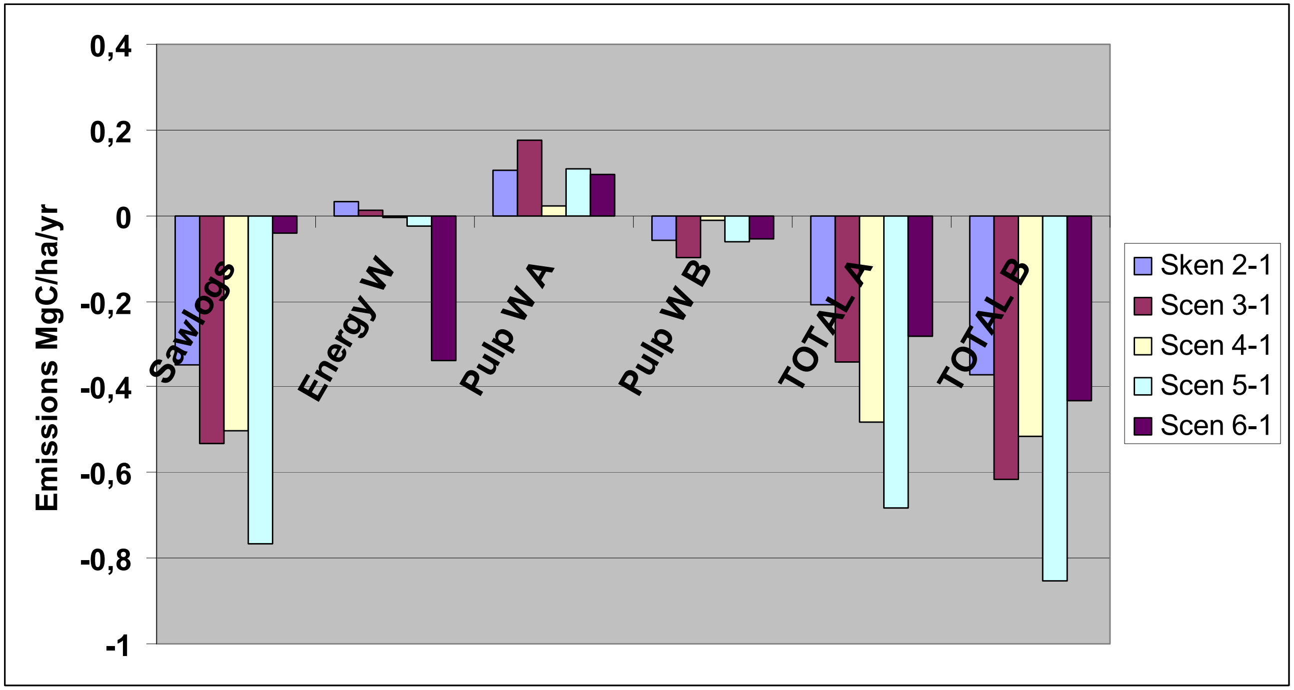
Material and energy substitution: simple integrated case study

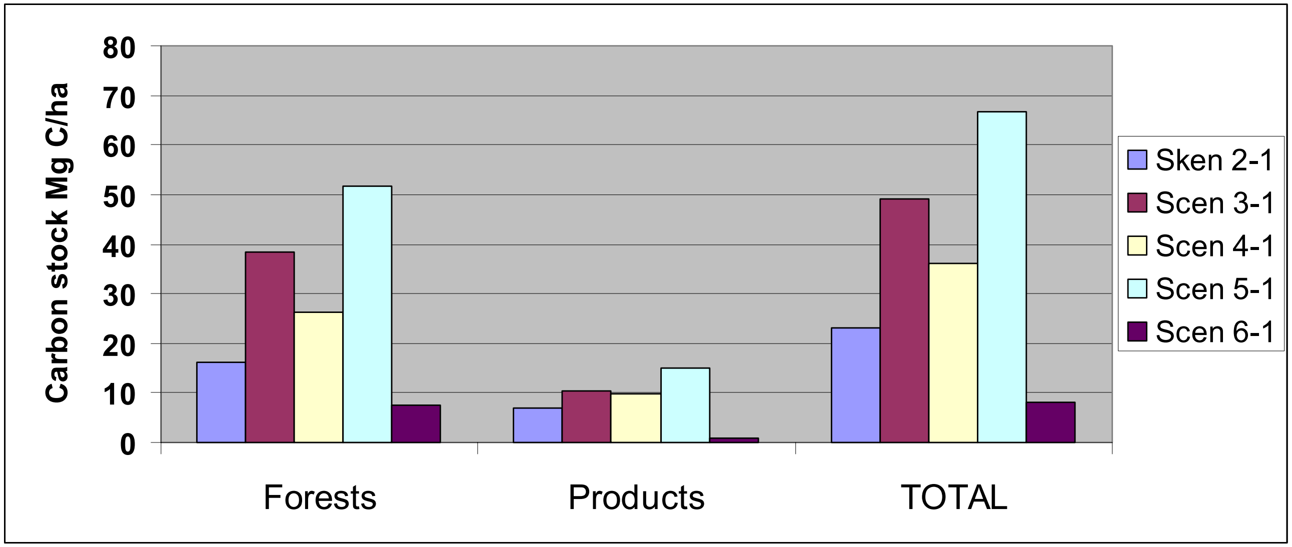
(Pingoud, Pohjola, Valsta and Karttunen 2006)

Comparison of steady states of forest and forest product pools:

- Scenarios: normal forests with varying forest management strategies; constant yearly production rates of sawlogs, pulpwood and energy wood in each scenario; scenarios differ from each other in production rates (MOTTI model)
- Basic scenario 1 (Tapio silvicultural recommendations)
- Wood supply determines wood use: the higher the yearly sawlog production, the higher the share of wood frame houses; energy wood, residues used for bioenergy
- The difference between each scenario and scenario 1 was calculated (C stocks, yearly material and energy substitution)

Simple integrated case study, some results (spruce):

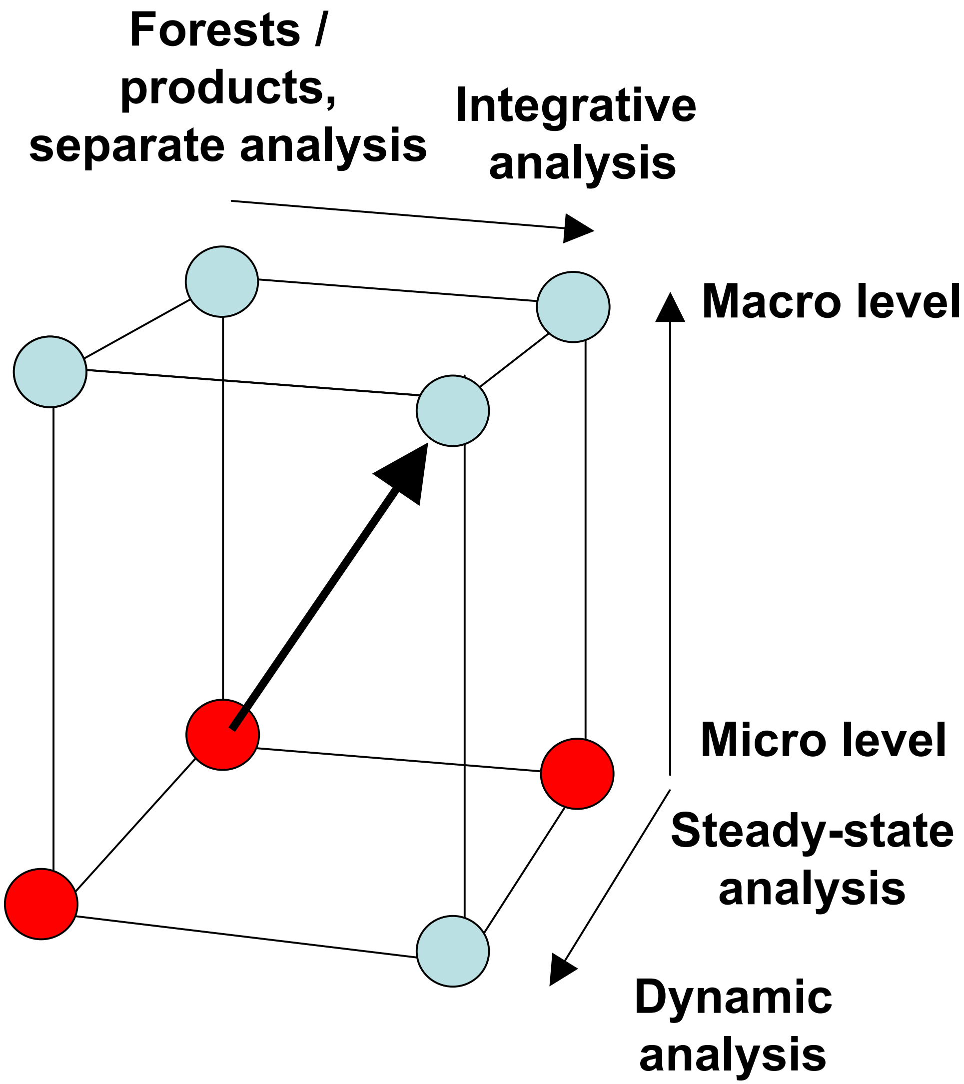




Simple integrated case study: conclusions

- There could be *win-win* solutions: higher substitution benefits and higher C stocks could be obtained by the same forest management strategy
- Case study extremely simplified, considering only steady states; transients from one state to another not considered
- Data on material substitution based on a single case study
- The integrative methodology should be developed further
- From steady-state micro-level analysis to dynamic macro-level analysis; inclusion of market impacts etc.

Development of the analytical framework



Forests / products, separate analysis

Integrative analysis

Macro level

Micro level

Steady-state analysis

Dynamic analysis

Simple integrated case study: Puuntarjontaskenaariot

Skenaario	Metsänhoitotoimet
1	Tapion suositusten mukainen metsänhoito, keskiläpimittakriteeri päätehakkuussa
2	Kuten 1, mutta kiertoaikaa lisätään 20 vuotta
3	Kuten 1, mutta kiertoaikaa lisätään 40 vuotta
4	Kuten 1, mutta kiertoaikaa lisätään 20 vuotta; puuston pohjapinta-alan korotus 4 m^2/ha
5	Kuten 1, mutta kiertoaikaa lisätään 40 vuotta; puuston pohjapinta-alan korotus 4 m^2/ha
6	Energiapuuharvennys 12 m valtapituusvaiheessa osana metsänkasvatusketjua