Business from technology

Land use in life cycle assessment of greenhouse gas emissions

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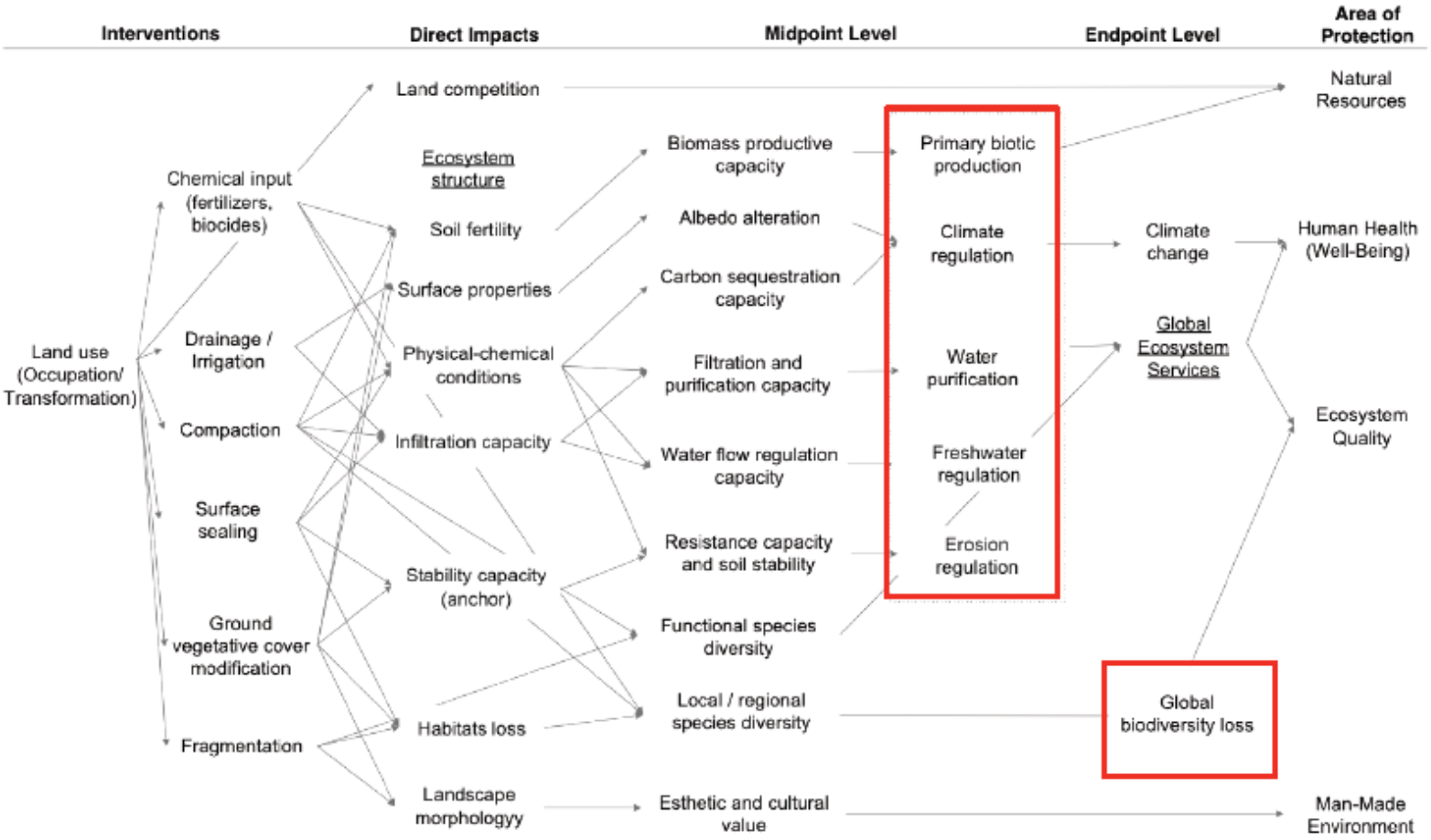
Background: What do we know about land use in LCA?

Impact assessment: Cause - effect chain



Saad & Margni 2012

Cause – effect chain adapted from Saad (2010) and Lindeijer et al. (2002)

Background

- Land use is typically the most dominant source of GHG emissions related to bioenergy production
- GHG balances related to land use are due to
  - Carbon sequestration into and emissions from terrestrial biomass and soil
  - Methane emissions due to anaerobic decay of biomass
  - Nitrous oxide emissions due to fertilization and decay of biomass
- Changes in surface albedo and other geophysical factors such as forest aerosols, evapotranspiration and cloud cover may also be significant as regards to climate impacts of land use
- Different methods have been applied based on various principles of determining the spatial and temporal system boundary for land use
- The results may heavily depend on the approach applied
- Some of the methods applied are conflicting with the fundamental principles of LCA

Main approaches in LCA

- *Attributional LCA* → *describes the environmentally relevant physical flows of a past, current or potential future product system at a given point of time*
  - some kind of average data applied
  - allocation, system boundary setting?
  - → Suitable for describing the system as it is
  - → Cannot describe the impacts of any change

- *Consequential LCA* → *method aiming to describe how environmentally relevant flows would have been or would be changed in response to possible decisions that would have been or would be made*
  - marginal data applied when appropriate
  - extension of the system boundary necessary
  - perception, data availability?
  - → Suitable for describing the consequences of possible decisions
  - → Cannot be carried out in a comprehensive manner

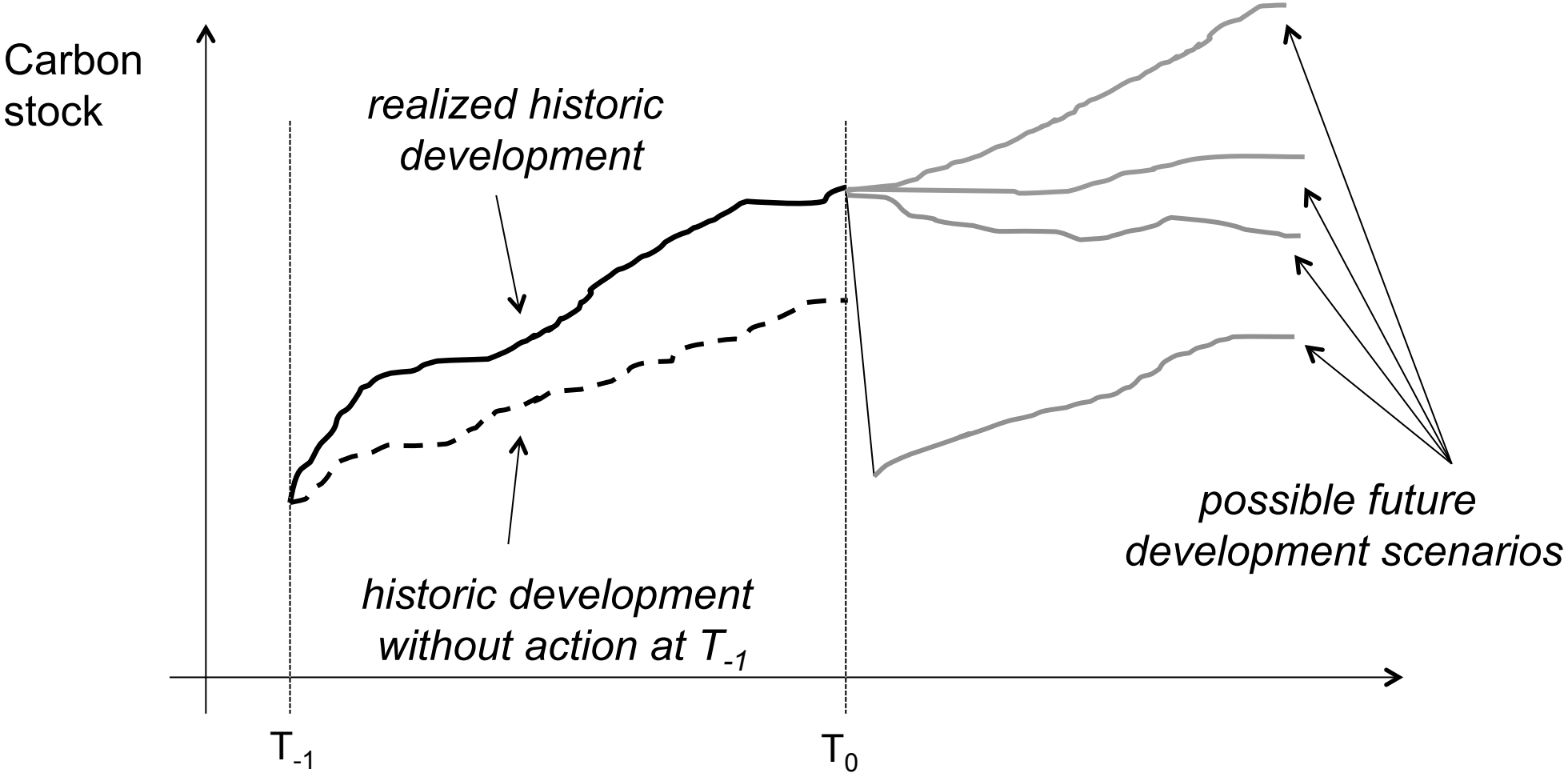
e.g. Finnveden et al. 2012

Perspectives and principles in emission determination in LCA

- Retrospective and prospective purposes to assess historic, current or possible future product systems
- Two principles in determining the GHG emissions within a product system
  - 1) As they occur
  - 2) Compared to some reference situation
- Determining GHG emissions from land use
  - As they occur: to monitor actual emissions, but does not (necessarily) reflect the emissions from the product system studied

  → **The appropriate reference situation is required**

Should we look back into the past or only into the future?



Spatial impacts of land occupation

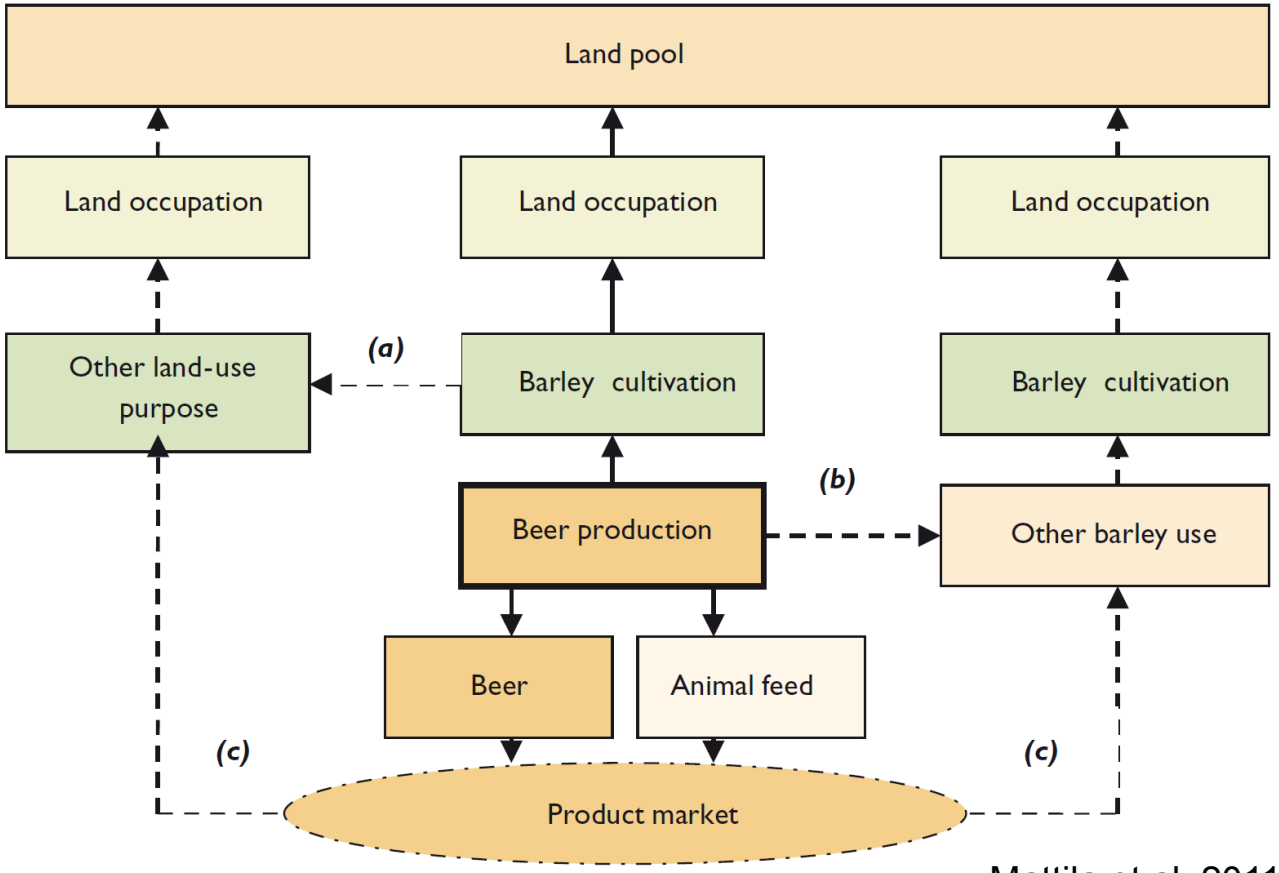
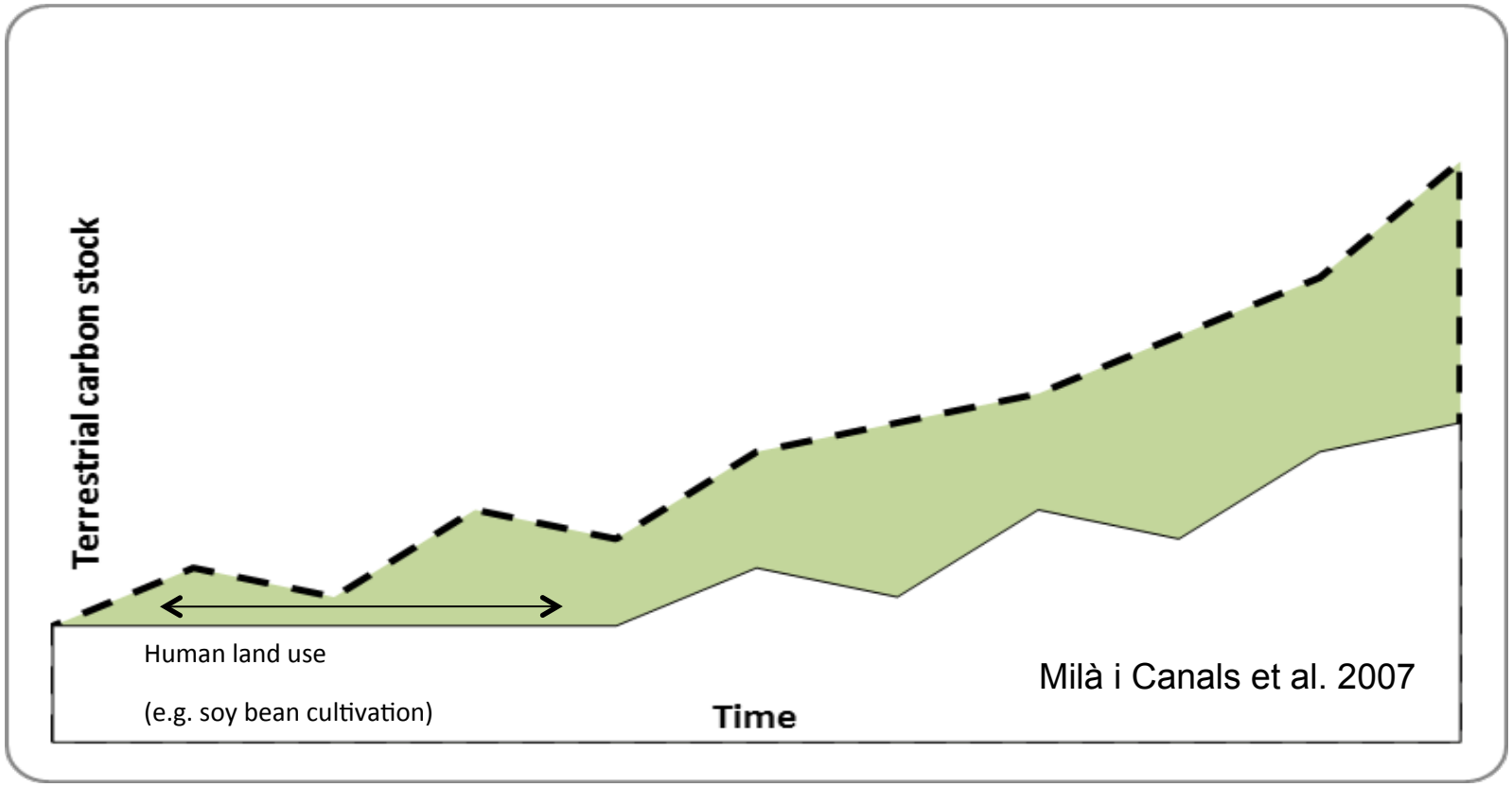


Figure 4. Illustration of impacts of beer production on land use through (a) land area competition, (b) feedstock competition, and(c) product substitution.

Temporal impacts of land occupation



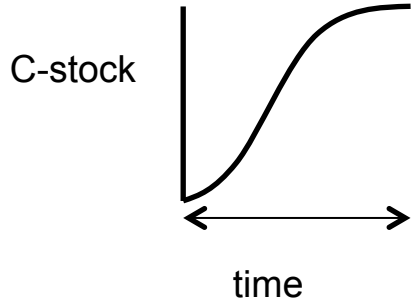
How to determine the reference land use?

- According to UNEP-SETAC and ILCD Handbook (based on Milà i Canals et al. 2007), the (dynamic) reference situation should be:
  - **"natural relaxation" in attributional LCA**
  - **alternative (most likely) land use in consequential LCA**.
- Should the reference land use reflect the land area which is actually used within the studied product system?
  - Plots - territorial land use - country-specific land use - regional land use - global land use
  - Attributional LCA relies on some kind of average data, but different types of system boundaries could be appropriate
  - Consequential LCA aims to capture the conseqeunces which do not necessarily take place within the product system

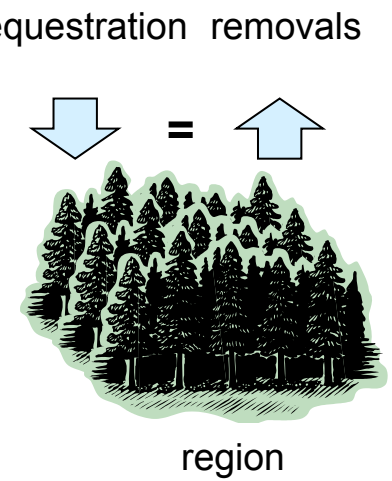
Land use in the case of forest biomass

About carbon neutrality of forest biomass

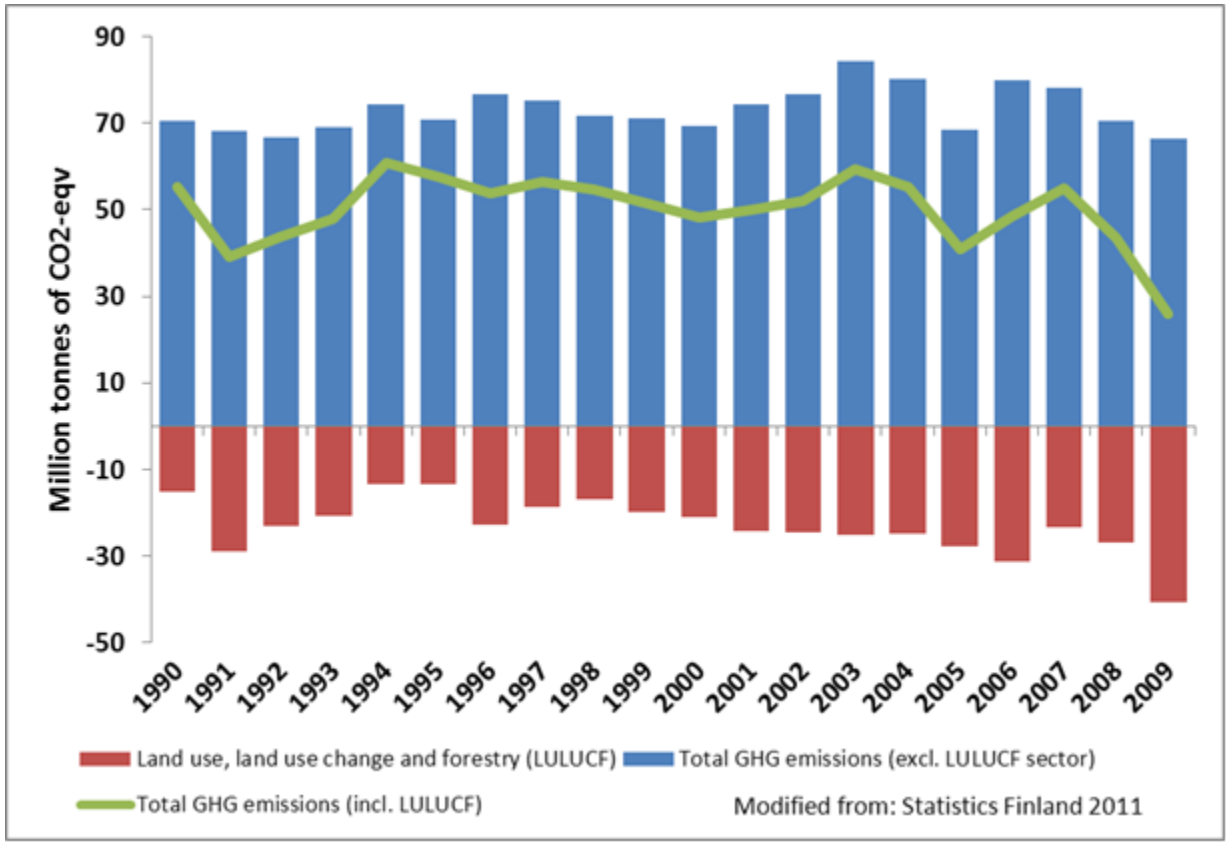
- Temporal carbon neutrality



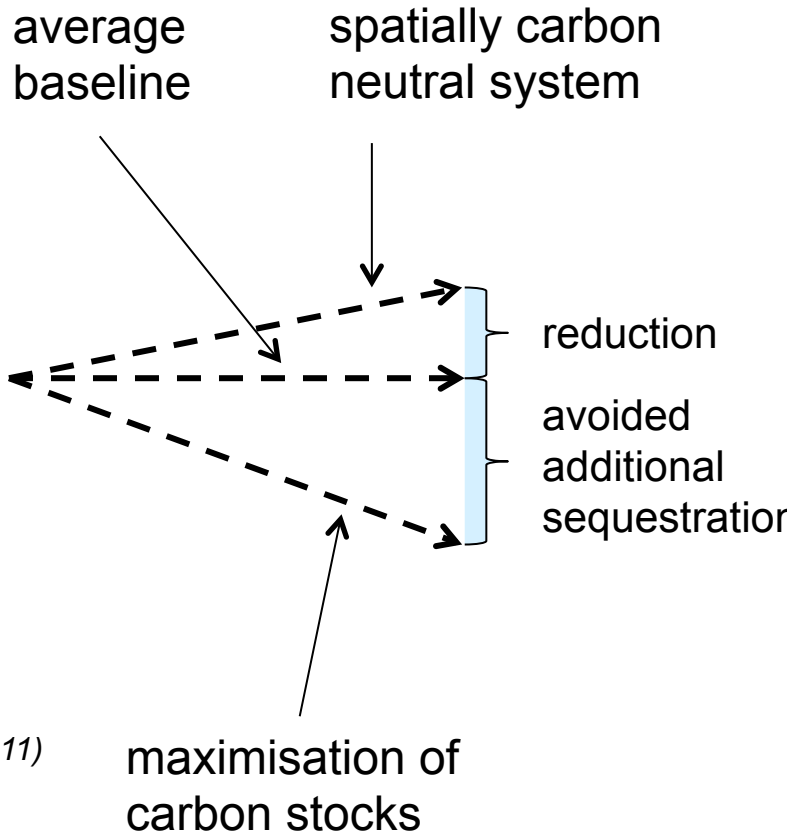
- Spatial carbon neutrality



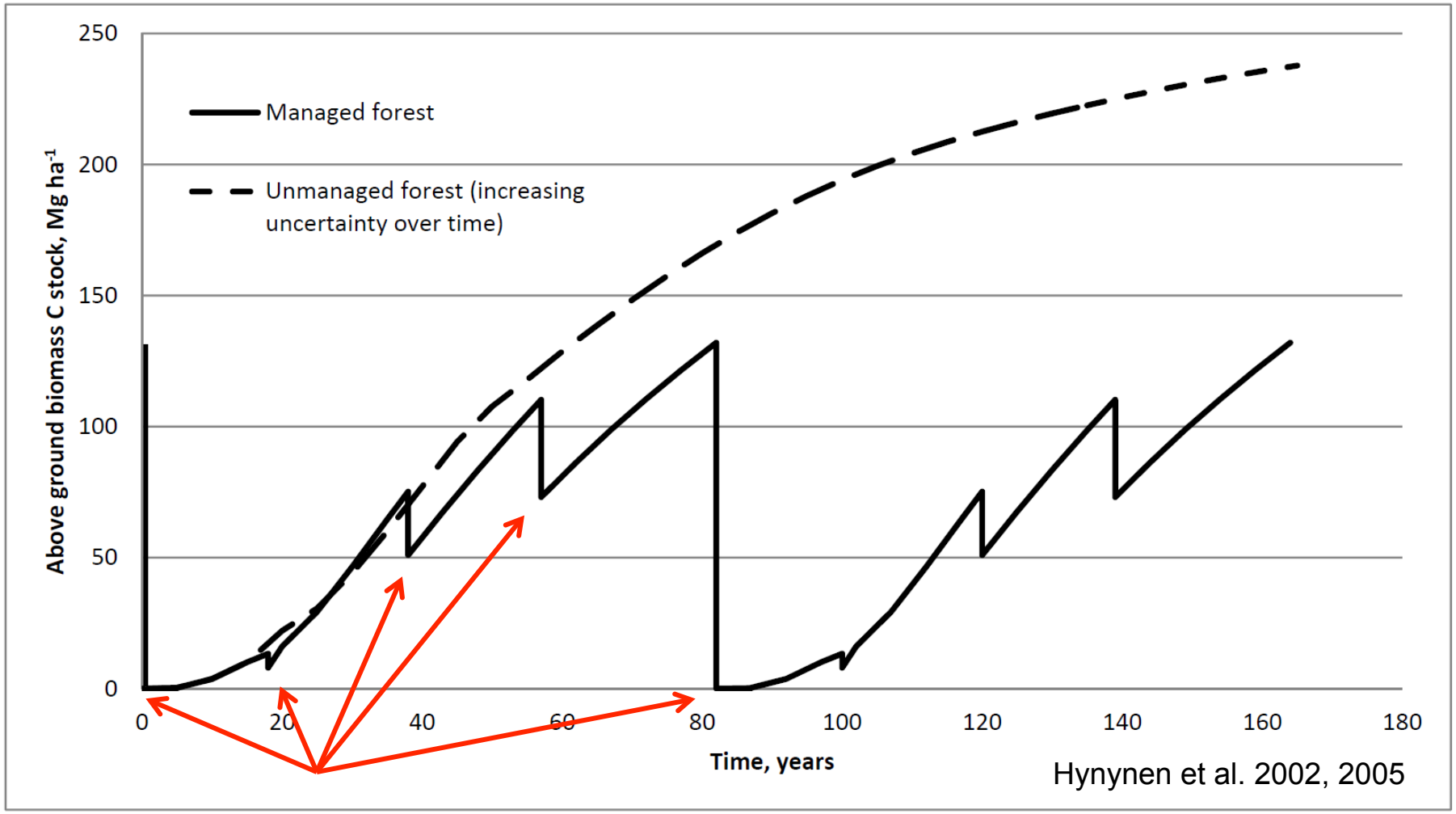
Carbon stock reduction or avoided additional sequestration?



Greenhouse gas emissions and removals in Finland in 1990-2009 (Statistics Finland 2011)

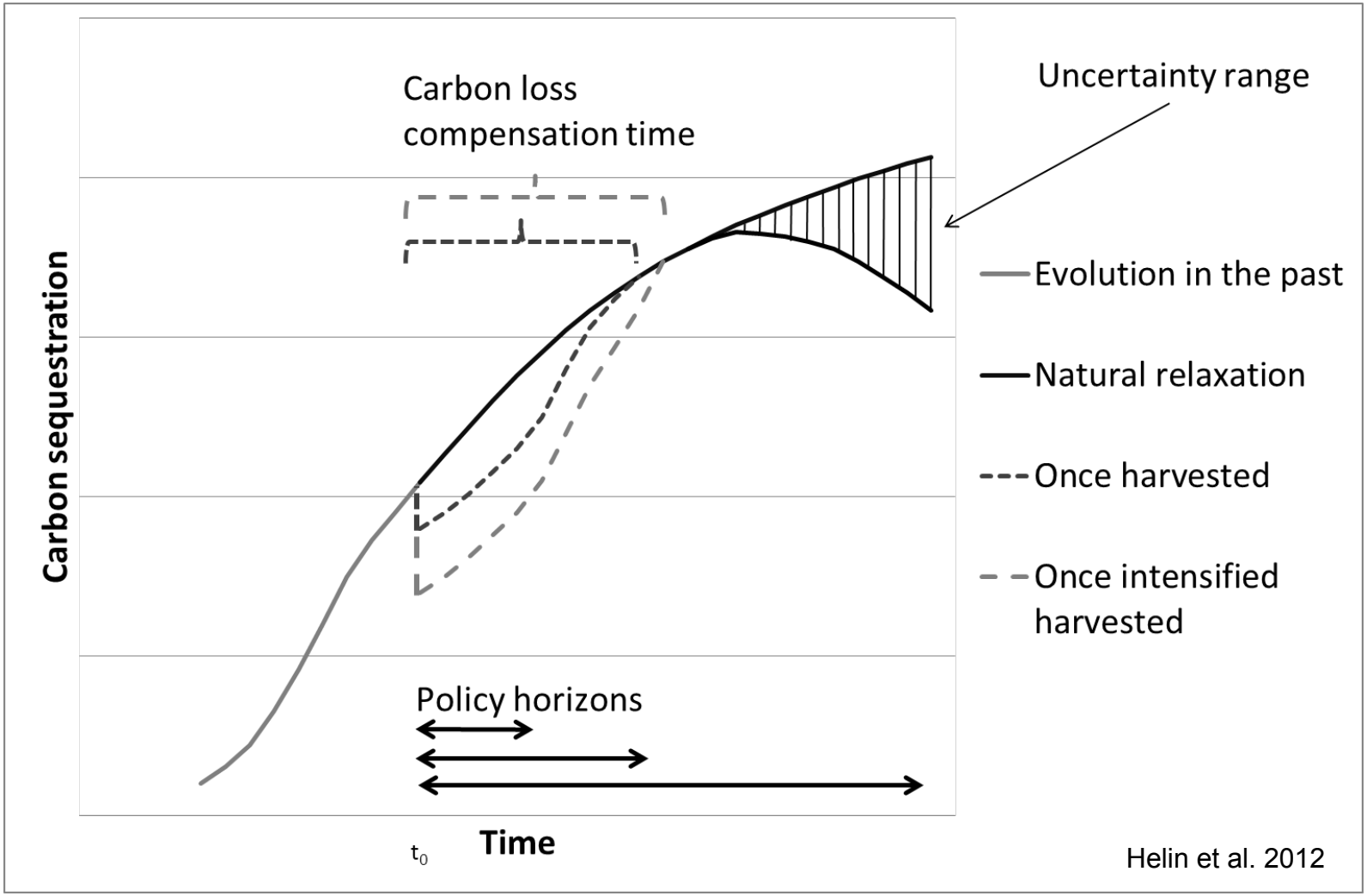


How to allocate stock changes between harvest operations taking place in different times?



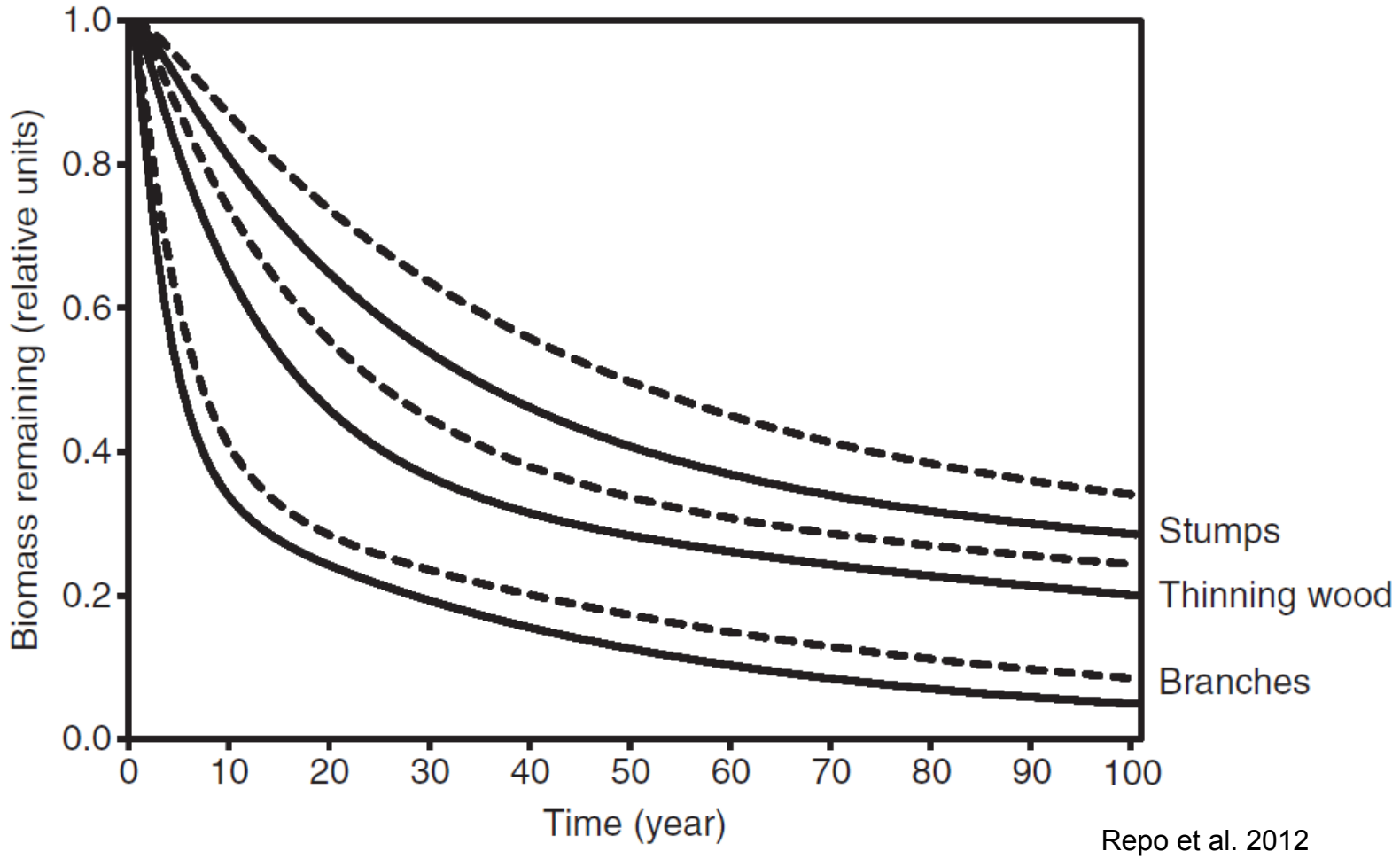
Hynynen et al. 2002, 2005

Determination of the reference situation in the case of forest biomass for product system



Helin et al. 2012

Decay of forest residues in the reference land use (no harvesting)



Repo et al. 2012

Handling the dynamics of carbon emissions and sequestration between the land use and the reference land use

The time integral of radiative forcing (RF) is a measure of the global warming energy absorbed due to the additional GHG emission, also called cumulative radiative forcing (CRF) or Absolute Global Warming Potential (AGWP). This cumulative warming impact, within the time frame (0,T), can be assessed for the C emissions due to a unit fossil C emission pulse released at time zero:

$$AGWP_{fos}(T) = \int_0^T RF\left(S_{fos}(t)\right)dt \quad (1)$$

For a unit C pulse from biomass harvest at time zero (causing a temporary C debt of the biomass stock), a similar equation can be presented:

$$AGWP_{bio}(T) = \int_0^T RF(S_{bio}(t))dt \quad (2)$$

where $S_{bio}(t)$ is the atmospheric CO_2 concentration due to the biomass unit C pulse so that in addition to the normal atmospheric decay of the fossil C pulse as above, biomass re-growth (e.g. growth of a new forest stand after the regeneration cut) also affects the concentration.

The so-called GWP_{bio} factor is defined (Cherubini et al. 2011) as the quotient of AGWPs in Eqs. (2) and (1):

$$GWP_{bio}(T) = \frac{AGWP_{bio}(T)}{AGWP_{fos}(T)} \quad (4)$$

GWP_{bio} is dimensionless and a function of the mitigation time frame (0,T) under consideration. It is analogous to the GWP factors describing the relative warming impact of non-CO_2 gases to that of CO_2. Another GWP factor can be defined by considering, in

Pingoud et al. 2012

Calculated GWP_{bio} factors for harvesting of forest residues compared to the reference land use (no harvesting)

	GWP_{bio}-20		GWP_{bio}-100	
	Southern Finland	Northern Finland	Southern Finland	Northern Finland
logging residues (branches)	0.413	0.475	0.164	0.210
stumps	0.809	0.865	0.459	0.532
thinnings	0.668	0.745	0.341	0.397

REFUGE-3 model, manuscript to be submitted

CO_2 emissions from wood combustion ~110 gCO_2/MJ
→ CO_2 emissions from logging residue combustion over 100 years = e.g. 0.164 * 110 g CO_2/MJ = **18 g CO_2/MJ**

Conclusions

Conclusions (1/2)

- Determining GHG emisisons from land use as they occur does not tell us if we are using the land effectively or ineffectively in reducing GHG emissions → reference land use is required
- It is only the future that matters as we cannot change the past
- Reference land use may be considered as hypothetical/unrealistic…
  - …but it should be analogically determined for each of the product systems under consideration
- 'Natural relaxation' is the most appropriate reference land use in attributional LCA → Only a few studies have applied it

Conclusions (2/2)

- In consequential LCA the reference land use should be the alternative option
  - land use should reflect the land that is influenced by the product system studied
- Reference land use should not necessarily be directly included in the product system studied
- Emissions compared to reference land use cannot be observed → they should be modelled
- Uncertainties are likely significant, especially those related to future development

References

- Finnveden, G., Hauschild, M.Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., Suh, S. 2009. Recent developments in life cycle assessment. Journal of Environmental Management 91, 1–21.
- Helin, T., Sokka, L., Soimakallio, S., Pingoud, K., Pajula, T. 2012. Approaches for inclusion of forest carbon cycle in life cycle assessment – A review. GCB Bioenergy (in press).
- Hynynen J, Ojansuu R, Hökkä H, et al. (2002) Models for predicting stand development in MELA system. The Finnish Forest Research Institute. Research Papers 835.
- Hynynen J, Ahtikoski A, Siitonen J et al (2005) Applying the MOTTI simulator to analyse the effects of alternative management schedules on timber and non-timber production. Forest Ecol Manag 207, 5–18.
- Mattila, T., Helin, T., Antikainen, R., Soimakallio, S., Pingoud, K., Wessman, H. 2012. Land use in life cycle assessment. The Finnish Environment 24/2011. Finnish Environmental Institute (SYKE), Helsinki, 2011. 86 p.
- Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Freiermuth Knuchel, R., Gaillard, G., Michelsen, O., Müller-Wenk, R., Rydgren, B. 2007. Key elements in framework for land use impact assessment within LCA. The International Journal of Life Cycle Assessment 12(1), 5–15.
- Pingoud, K., Ekholm, T., Savolainen, I. 2012. Global warming potential factors and warming payback time as climate indicators of forest biomass use. Mitigation and Adaptation Strategies for Global Change 17(4), 369–386.
- Saad, M, Margni, M. 2012. Land use impacts on freshwater regulation, erosion regulation and water purification: a spatial approach for a global scale level. Special forum on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA - February, 17th 2012.
- Statistics Finland 2011. Official Statistics of Finland (OSF): Greenhouse gases. http://www.stat.fi/til/khki/2009/khki_2009_2011-04-28_tie_001_en.html

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