Business from technology

Land use in life cycle assessment and greenhouse gas emissions

IEA Bioenergy Task 38 Workshop 2012

Vienna, 16 November 2012

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Background: What questions are we trying to answer?

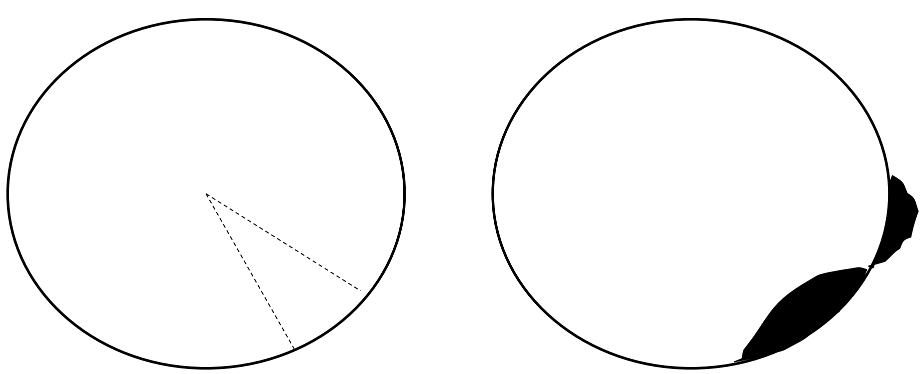
- Climate impacts of
  - Currently existing activities?
  - Changes induced by e.g. bioenergy policies?
- Should one describe an agrobiomass of forest biomass system in a uniform way, irrespective of the end-use application (4F: food, feed, fuel, fibre)?
- Is one interested of competing upgrading routes or improvements in bioenergy chains? Or only of the final result compared to competing systems with the same function?
- Can the potential answer be found with one uniform approach?

Background: 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

Attributional vs consequential



Attributional **Consequential**

Source: Dalgaard 2010

Background: UNEP-SETAC Life Cycle Initiative and land use

Land Use in LCA — Framework for LCIA of Land Use

Land Use in LCA (Subject Editor: Llorenç Milà i Canals)

Key Elements in a Framework for Land Use Impact Assessment Within LCA

Llorenç Milà i Canals[1*], Christian Bauer[2], Jochen Depestele[3], Alain Dubreuil[4], Ruth Freiermuth Knuchel[5], Gérard Gaillard[5], Ottar Michelsen[6], Ruedi Müller-Wenk[7] and Bernt Rydgren[8]

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Int J LCA **12** (1) 5 – 15 (2007)

Introduction

Land use by agriculture, forestry, mining, house-building or industry leads to substantial impacts, particularly on biodiversity and on soil quality as a supplier of life support functions. Unfortunately there is no widely accepted assessment method so far for land use impacts. Within the UNEP-SETAC Life Cycle Initiative[1], key elements in a Life Cycle Impact Assessment (LCIA) framework of land use have now been treated and are presented in this paper.

The goals of this paper are to start a dialogue with experts outside the Life Cycle Assessment (LCA) field and to provide guidelines to LCIA method developers on the key elements to be addressed when assessing impacts from land use. The discussion presented here is valid both for midpoint and damage approaches (Jolliet et al. 2004), and specific comments

[1] Taskforce on Resources and Land Use within the UNEP-SETAC Life Cycle Initiative Working Group on LCIA, hereafter called TF2. See <http://www.lci-network.de/lciacorner>

Background: UNEP-SETAC Life Cycle Initiative and land use

- UNEP-SETAC has developed land use impact assessment for LCA since 2002

  http://lcinitiative.unep.fr/

Two phases and some framework papers

- Milà i Canals et al. 2007
- Koellner et al. (2013?)

Land use and climate regulation

- Müller-Wenk & Brandão 2010
- Brandão et al. 2010

VTT has not participated, only active implementation efforts in case studies

UNEP-SETAC Guideline on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA

UNEP SETAC Life Cycle Initiative

Special forum on Global Land use Impacts on Biodiversity and Ecosystem Services in LCA

February 17, 2012, ENEA Brussels

Thomas Koellner[1], Rosie Saad[2], Laura de Baan[3], Tabea Beck[4], Ulrike Bos[4], Miguel Brandão[5], Barbara Civit[6], Jan Paul Lindner[4], Manuele Margni[1], Llorenç Milà i Canals[7], Danielle Maia de Souza[2,5] and Ruedi Müller-Wenk[8]

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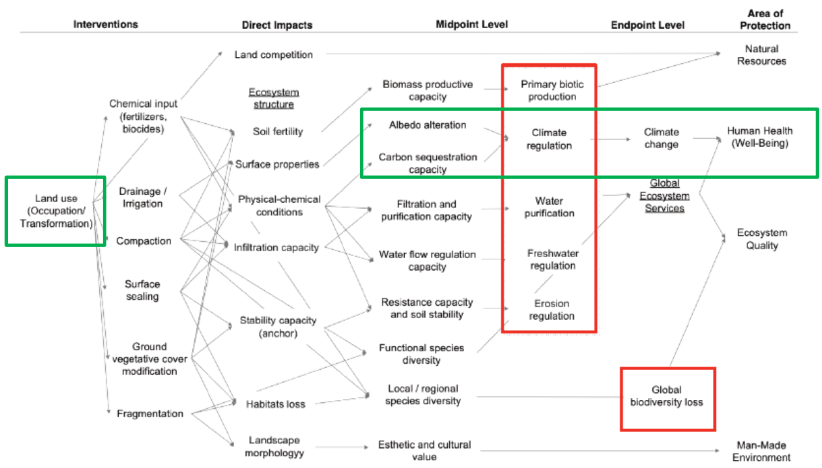
Source: Koellner et al. 2012
http://www.pes.uni-bayreuth.de/en/research/events/2012_UNEP_SETAC_Forum/index.html

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

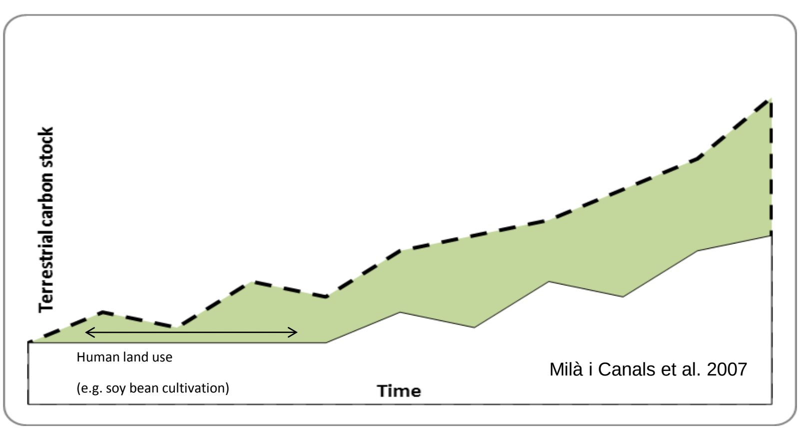
Impact assessment: Cause - effect chain



Saad & Margni 2012

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

Temporal impacts of land occupation

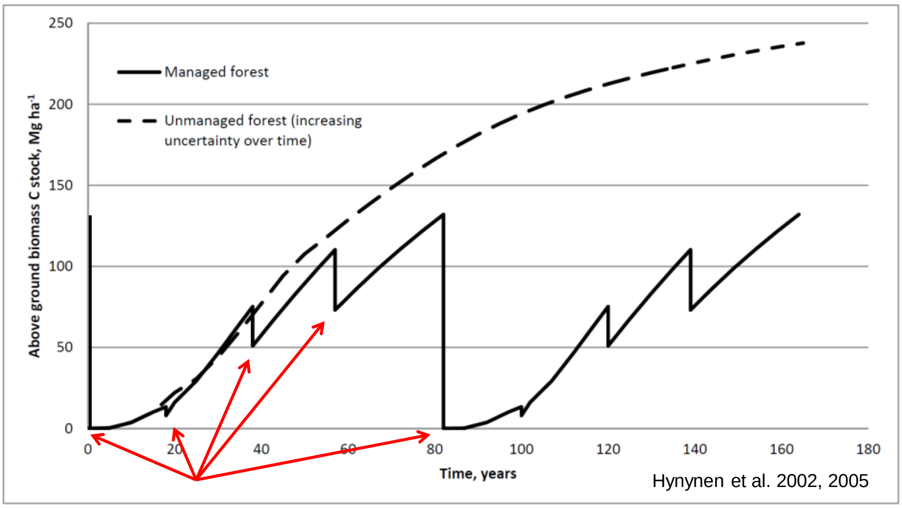


How to determine the reference land use?

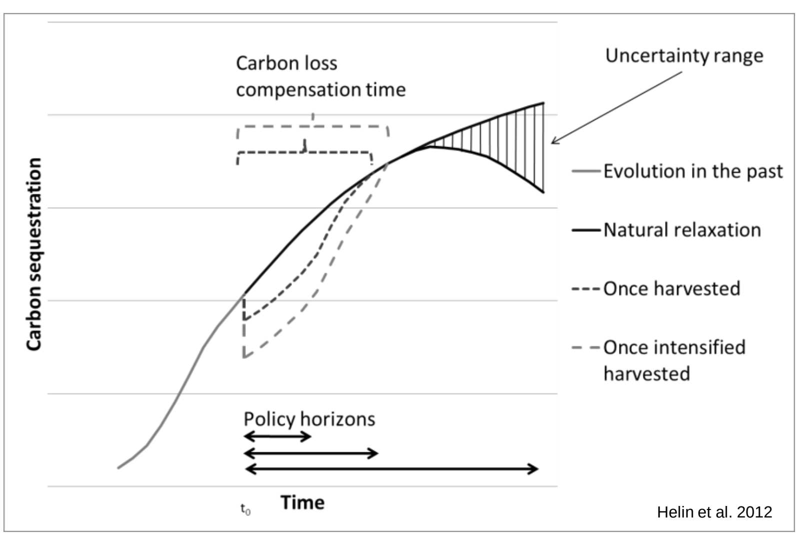
- According to UNEP-SETAC and ILCD Handbook (based on Milà i Canals et al. 2007), the (dynamic) reference situation should be:
  - **"natural relaxation" in attributional LCA**
  - **alternative (most likely) land use in consequential LCA**.
- A product system studied with LCA can be anything from 1 kg of biomass to e.g. whole biomass sector of a nation / continent etc

Land use in the case of forest biomass

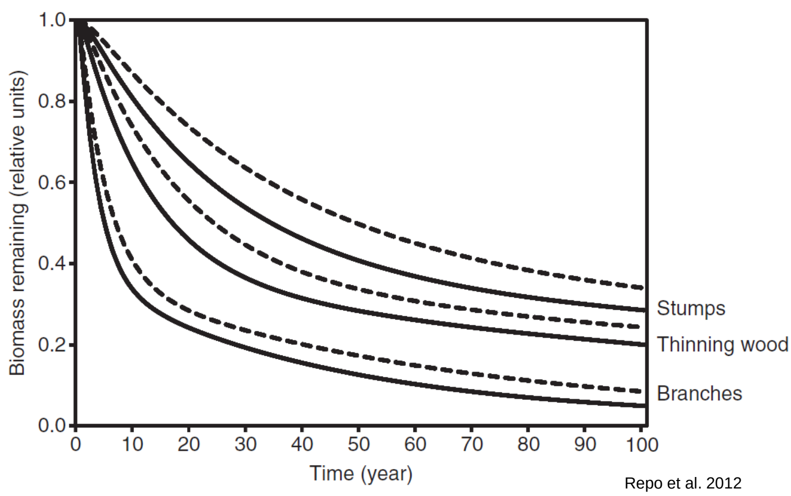
How to allocate stock changes between harvest operations taking place in different times?



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



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:

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

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:

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

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):

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

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**

Open questions for discussion

- Can this division to attributional and consequential LCA be accepted?
- Should the framework for land use in LCA be considered in bioenergy context?
- Is there some potential disparities with the IEA standard methodology for bioenergy systems?

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Background

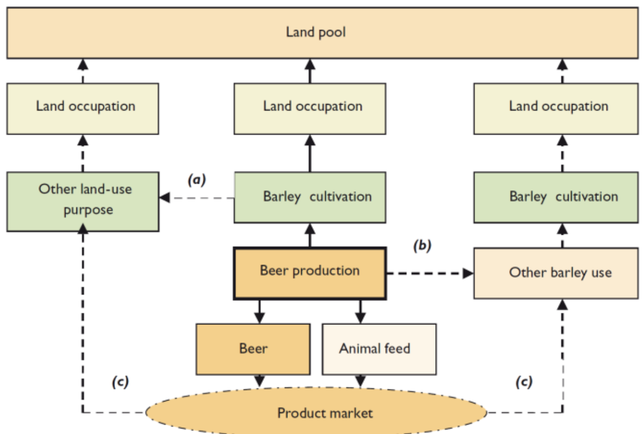
- Land use is typically the most dominant source of GHG emissions related to bioenergy production
- GHG balances related to land use are due to
  - Carbon sequestration into and emissions from terrestrial biomass and soil
  - Methane emissions due to anaerobic decay of biomass
  - Nitrous oxide emissions 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

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**

Spatial impacts of land occupation

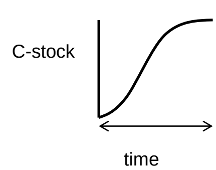


Mattila et al. 2011

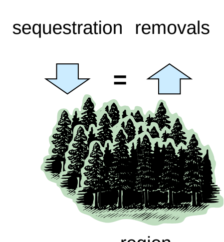
Figure 4. Illustration of impacts of beer production on land use through (a) land area competition, (b) feedstock competition, and(c) product substitution.

About carbon neutrality of forest biomass

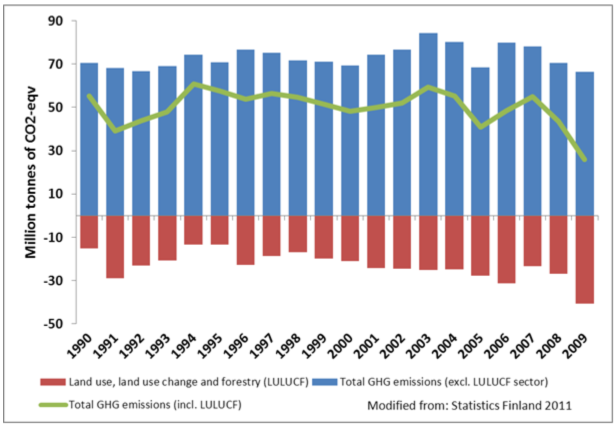
- Temporal carbon neutrality



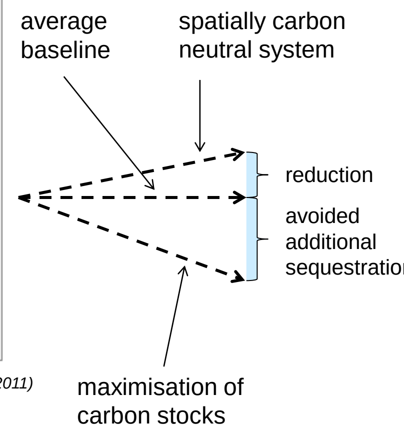
- Spatial carbon neutrality



Carbon stock reduction or avoided additional sequestration?



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



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