Life Cycle Assessment (LCA) of organic food and farming systems

Focusing on greenhouse gas emissions, carbon sequestration potential and methodological challenges and status

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RTOACC workshop at FAO, Rome, Italy, November 2010

Background

- Food production and consumption: approx. 25% of GHG (33% if deforestation for agriculture included)

- Organic agriculture:
  - Offers alternative food production systems (and food supply and consumption?)

- Does organic make a difference with regard to climate change?
  - Not specifically considered in regulation
  - Need to know to preserve credibility and comply with organic principles

- Life Cycle Assessment (LCA) – best tool for greenhouse gas emissions

- Challenges of LCA for organic products
  - Interactions in farming systems
  - Carbon sequestration

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Aim of the report

- Overview and contribution to Life Cycle Assessment (LCA) methods, models and databases to be used for greenhouse gas estimates of organic food and farming systems

Three main sections:

1. Overview of greenhouse gas emissions of organic vs. conventional products

2. Main methodological challenges within LCA of organic products
   a. How to allocate and account for interactions in farming systems?
   b. How to account for carbon sequestration?

3. Inventory and emissions for LCA of organic products
   a. Representativity and consistency of data
   b. Estimation of emissions

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Outline of the report

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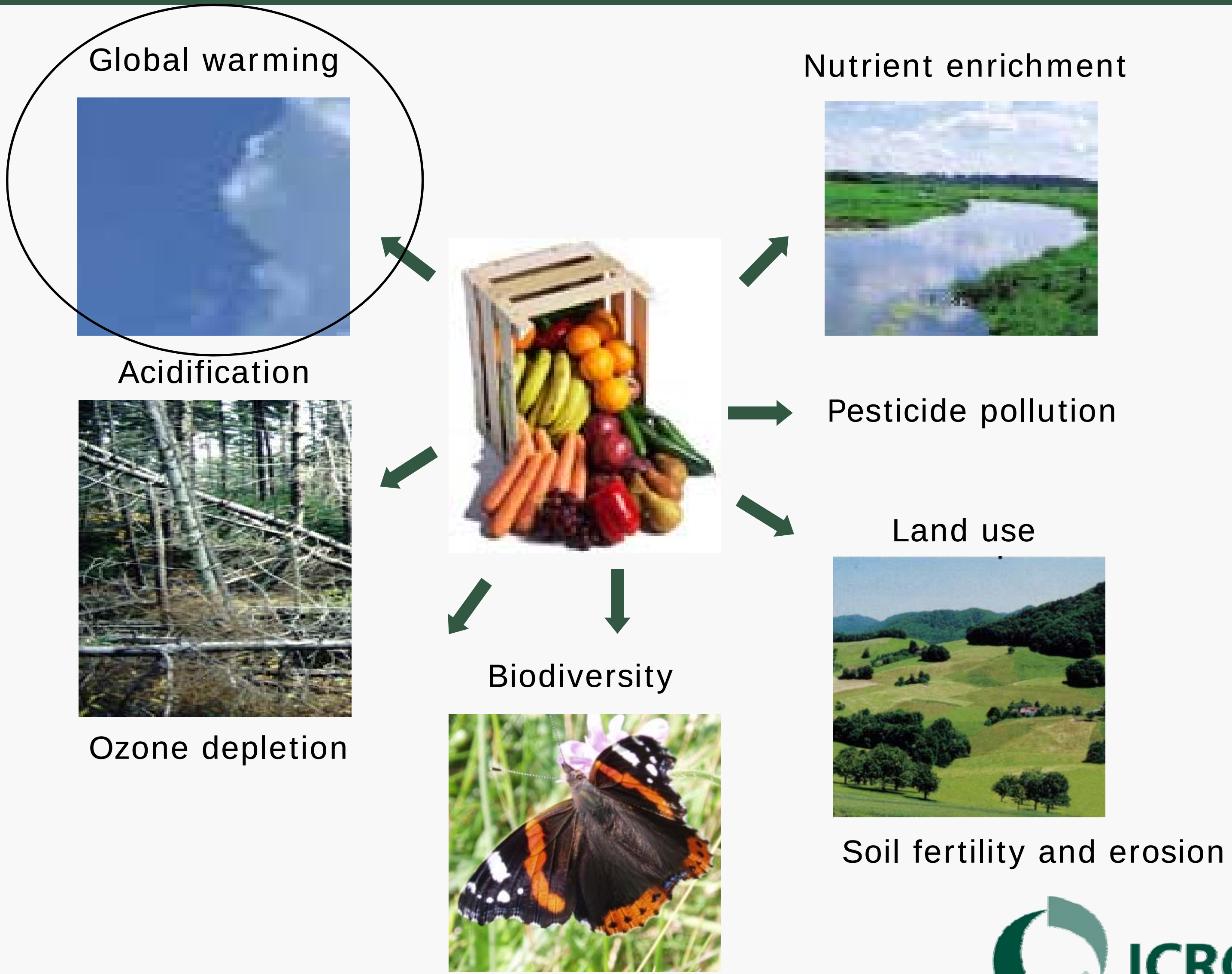
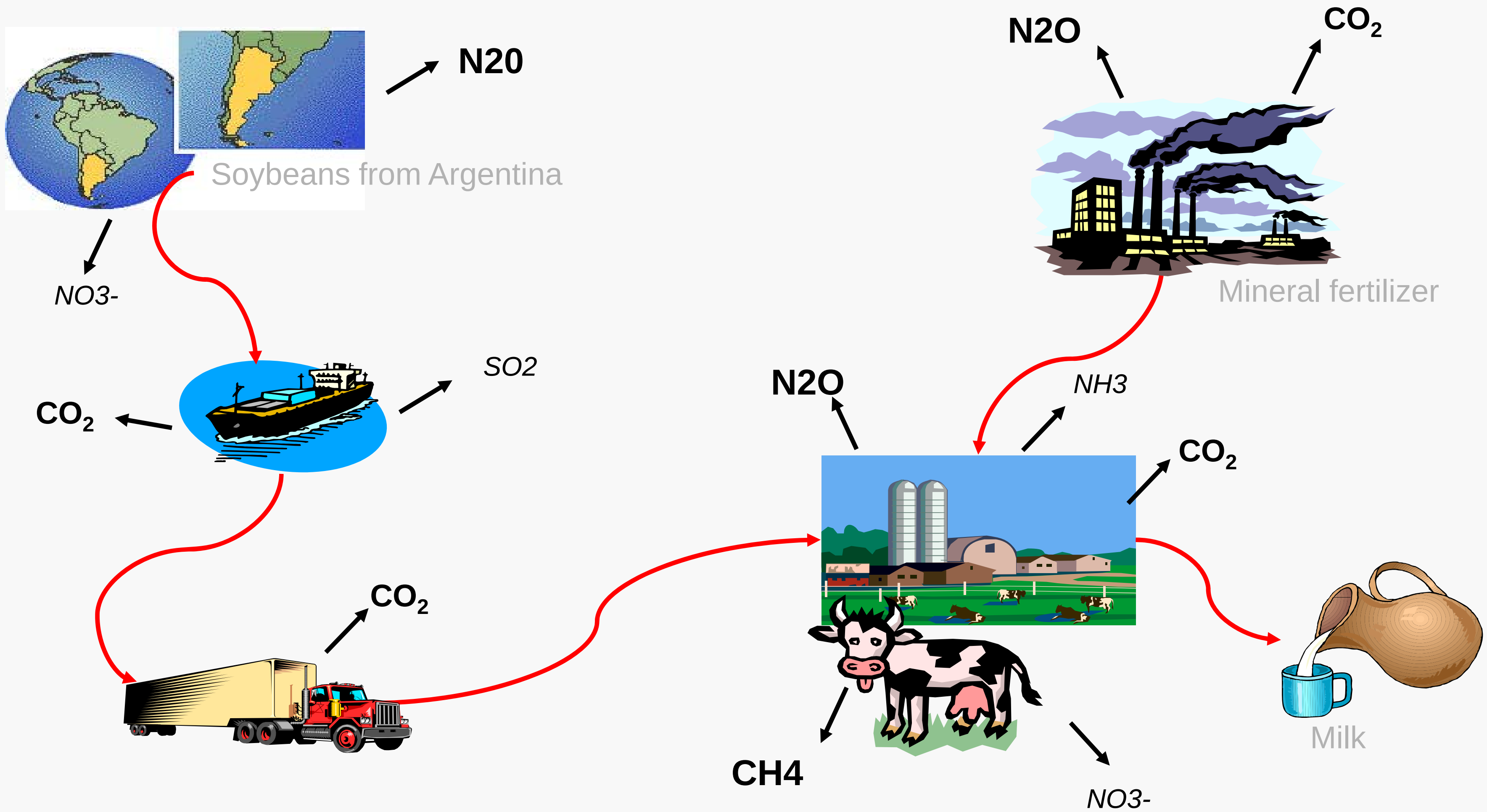
1.3 LCA methodology



1.3 LCA methodology: Example of LCA of conventional milk



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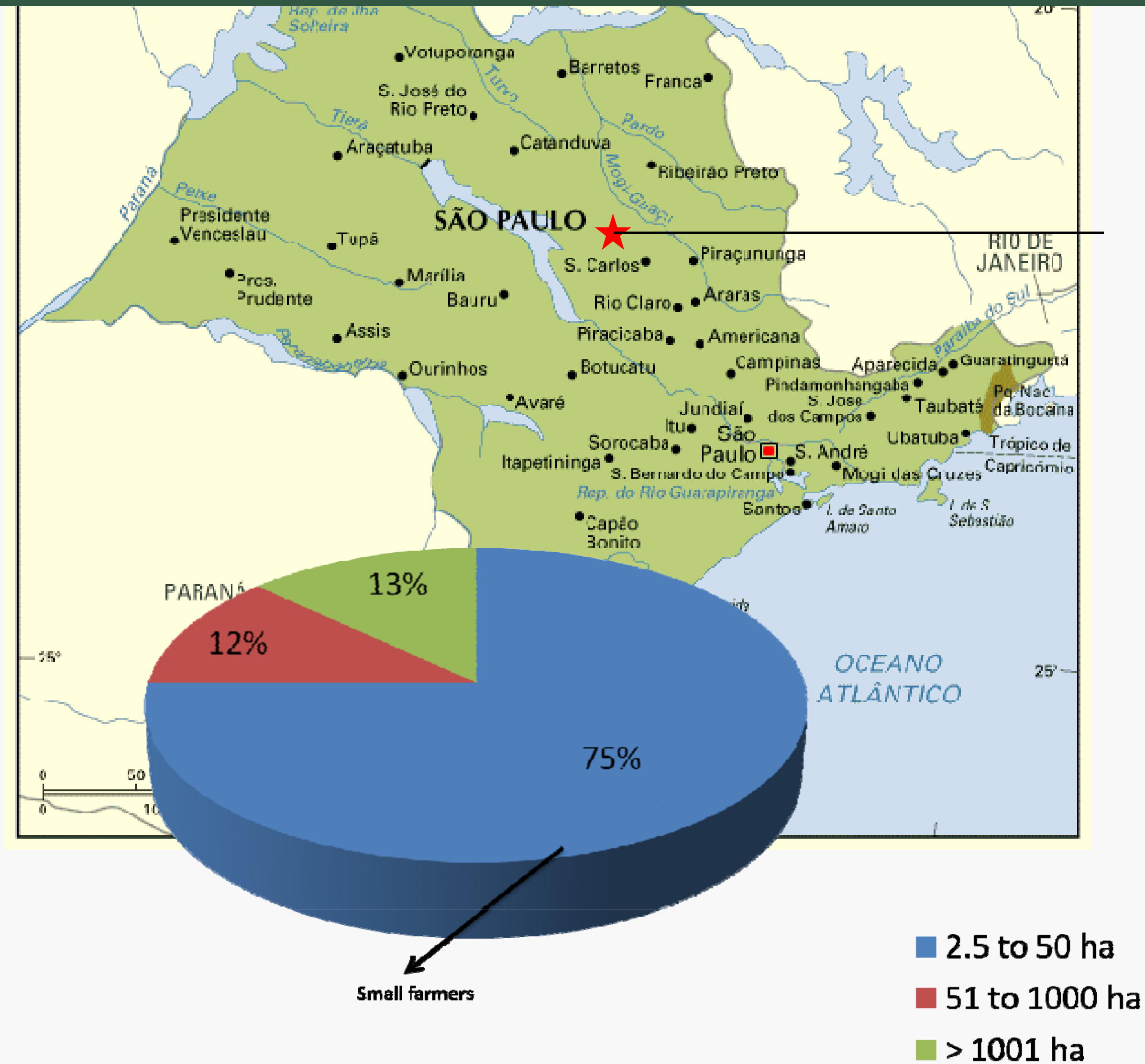
1.3 LCA methodology

Example: LCA of organic orange juice



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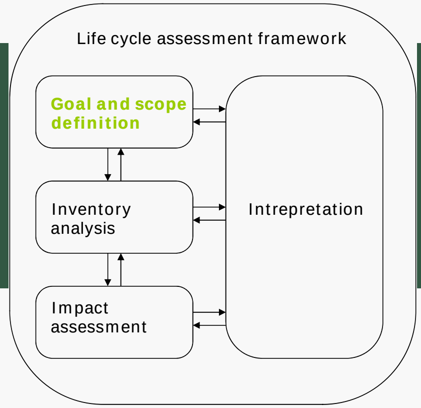
1.3 LCA methodology: Example of LCA of orange juice

Objective



- To compare the environment impacts in the production of organic oranges at small-scale farms with organic large-scale farms and or small-scale conventional farms in Brazil.

- To identify the environmental hotspots in the product chain of organic orange juice from small-scale Brazilian farms imported to Denmark.

Input production → transport → **Production of oranges** → transport → **Juice concentrate factory, Brazil** → transport → **Juice factory, Germany** → transport → **Import to Denmark**

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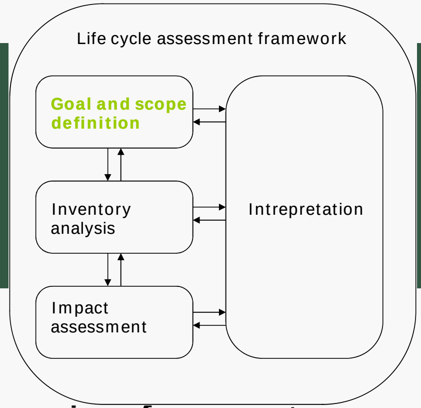
1.3 LCA methodology: Example of LCA of orange juice

Functional unit



- One tonne of oranges produced in the State of São Paulo, Brazil leaving farm gate

- One litre of organic orange juice grown and processed to concentrate in Brazil, reconstituted and imported to retail distribution centre in Denmark

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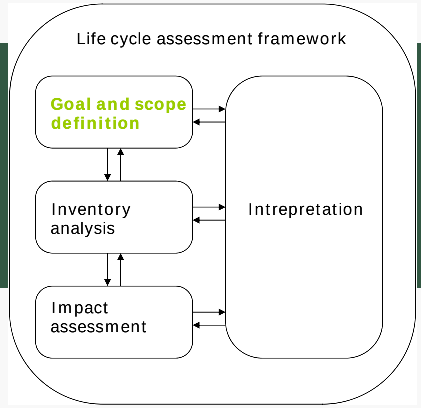
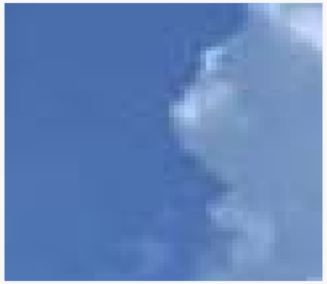
1.3 LCA methodology: Example of LCA of orange juice

Impact categories



Global warming



Eutrophication

Non-renewable energy use

Acidification

Biodiversity

Land use

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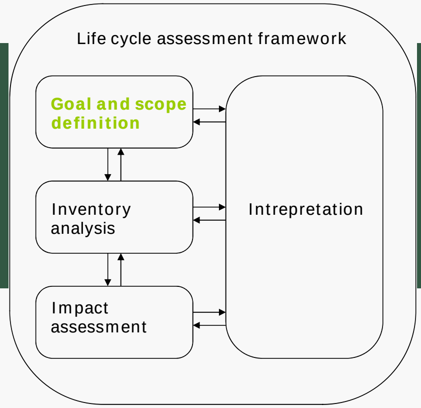
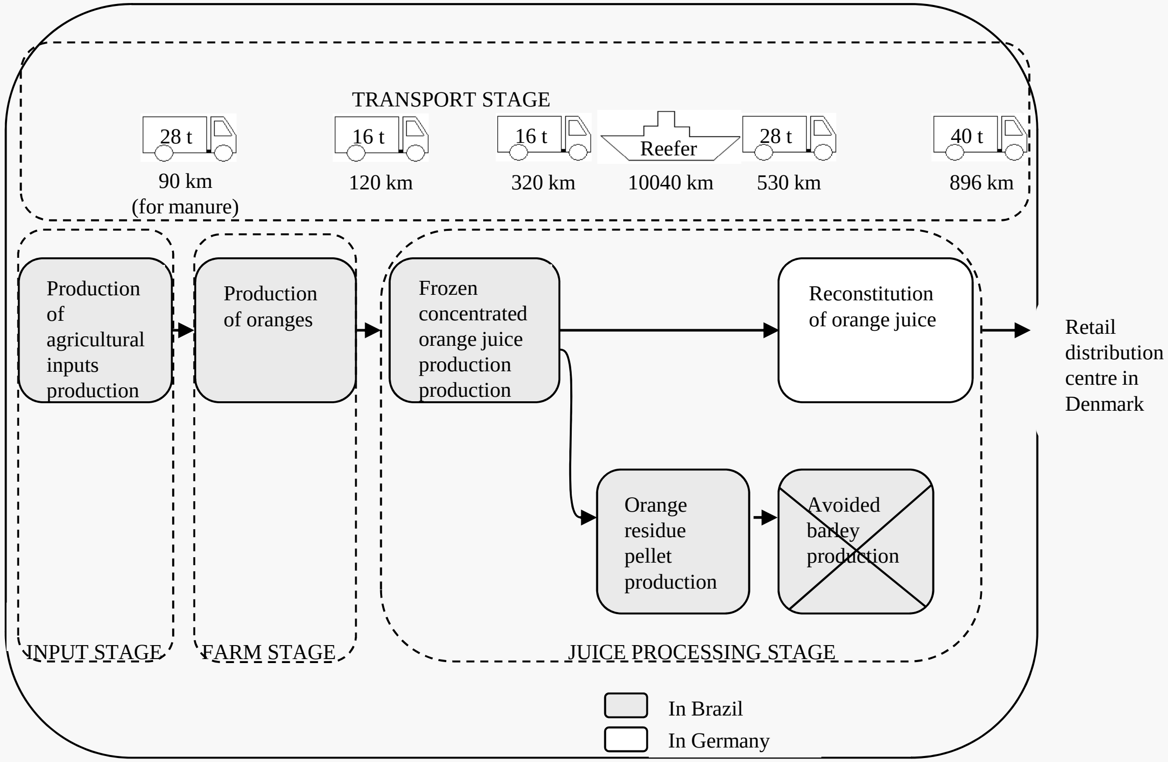
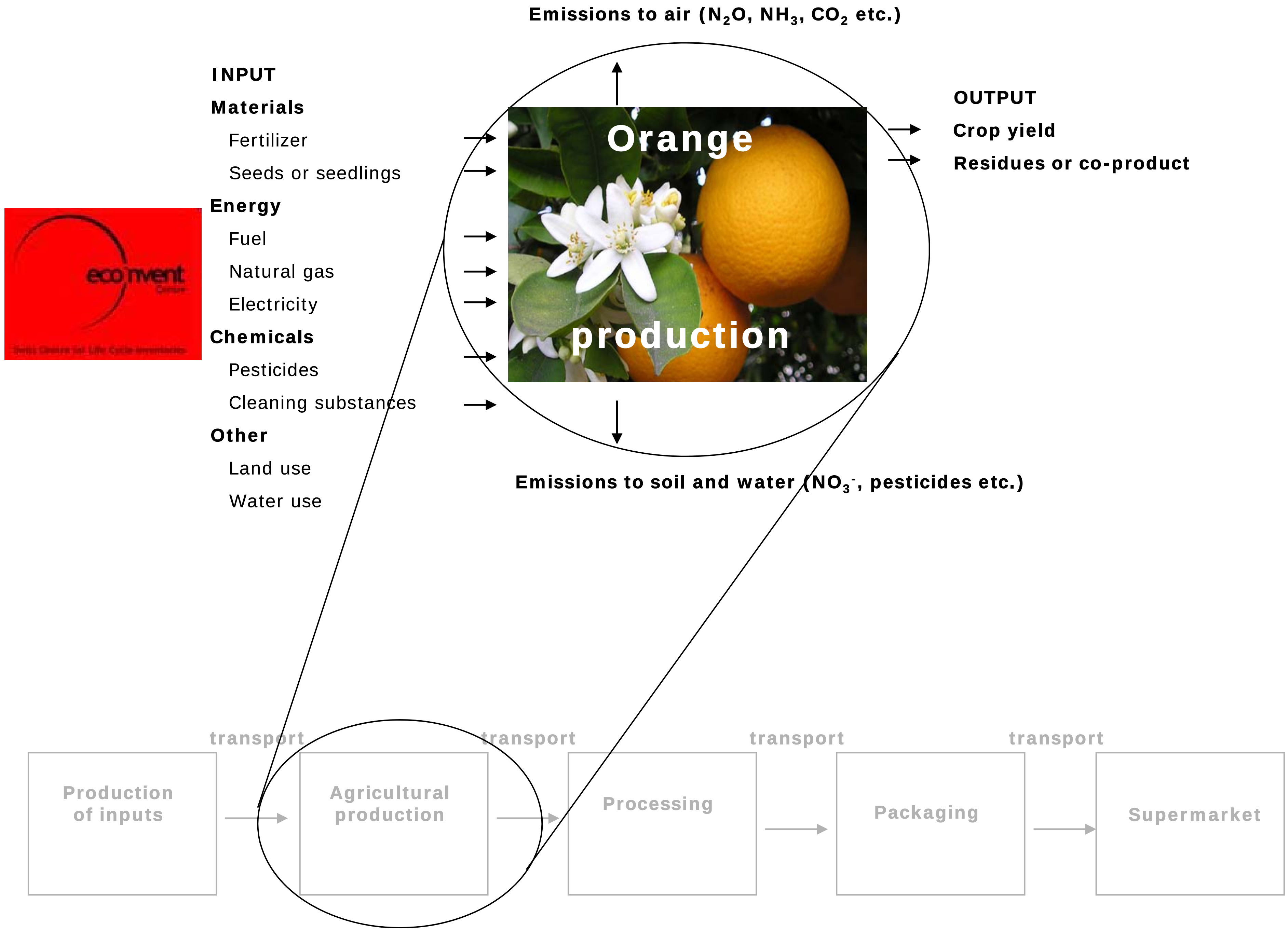
1.3 LCA methodology: Example of LCA of orange juice

System boundaries and allocation



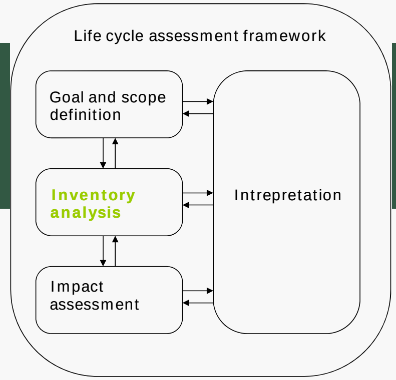


INVENTORY



Emissions to air (N_2O, NH_3, CO_2 etc.)
INPUT
Materials
Fertilizer
Seeds or seedlings
Energy
Fuel
Natural gas
Electricity
Chemicals
Pesticides
Cleaning substances
Other
Land use
Water use
Orange production
OUTPUT
Crop yield
Residues or co-product
Emissions to soil and water (NO_3^-, pesticides etc.)
transport
transport
transport
transport
Production of inputs
Agricultural production
Processing
Packaging
Supermarket

1.3 LCA methodology: INVENTORY - Estimate emissions



Emissions to air (N_2O, NH_3 etc.)

N INPUT

- Organic fertilizer →
- Mineral fertilizer →
- N_2 fixation →
- Precipitation, deposition →
- Seeds or seedlings →

N OUTPUT

- → Crop yield
- → Residues or co-product

Emissions to soil and water (NO_3^- etc.)

IPCC guidelines 2006

$$N_{input} - N_{output} = N_{surplus}$$

- Denitrification (incl. N_2O)
- Ammonia loss (NH_3)
- Nitrate loss (NO_3^-)
- Soil N pool

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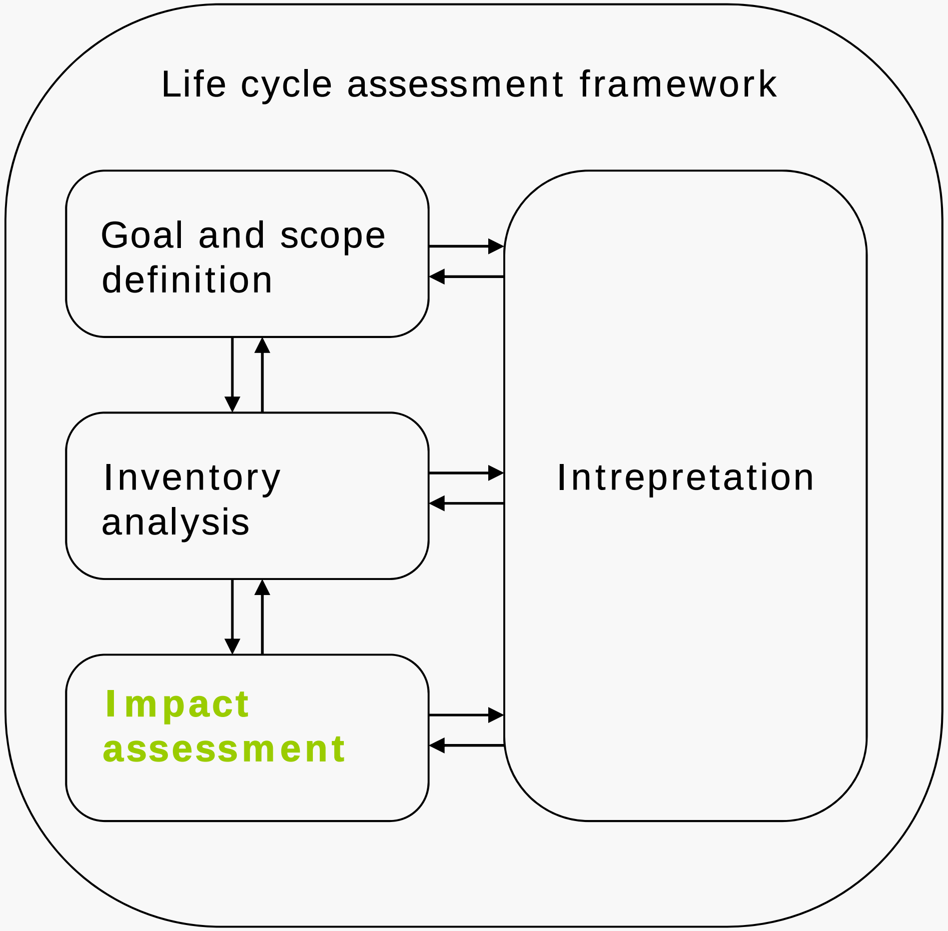
1.3 LCA methodology: Impact assessment



- **Emissions are converted and aggregated into the chosen impact categories**

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1.3 LCA methodology: IMPACT ASSESSMENT

From emissions to impact category…

Impact category	Unit	Contributing elements	Characterization factors
Land use	m^2	Land occupation	1 for all types of land use
Non-renewable energy	MJ	Non-renewable energy consumption	1
Global warming	CO_2 equivalents	CO_2	1
		CH_4	25
		N_2O	298
Acidification	SO_2 equivalents	SO_2	1
		NH_3	1.88
		NO_x	0.70
Eutrophication	NO_3^- equivalents	NO_3^-	1
		PO_4^{3-}	10.45
		NH_4^+	3.64
		NO_x	1.35

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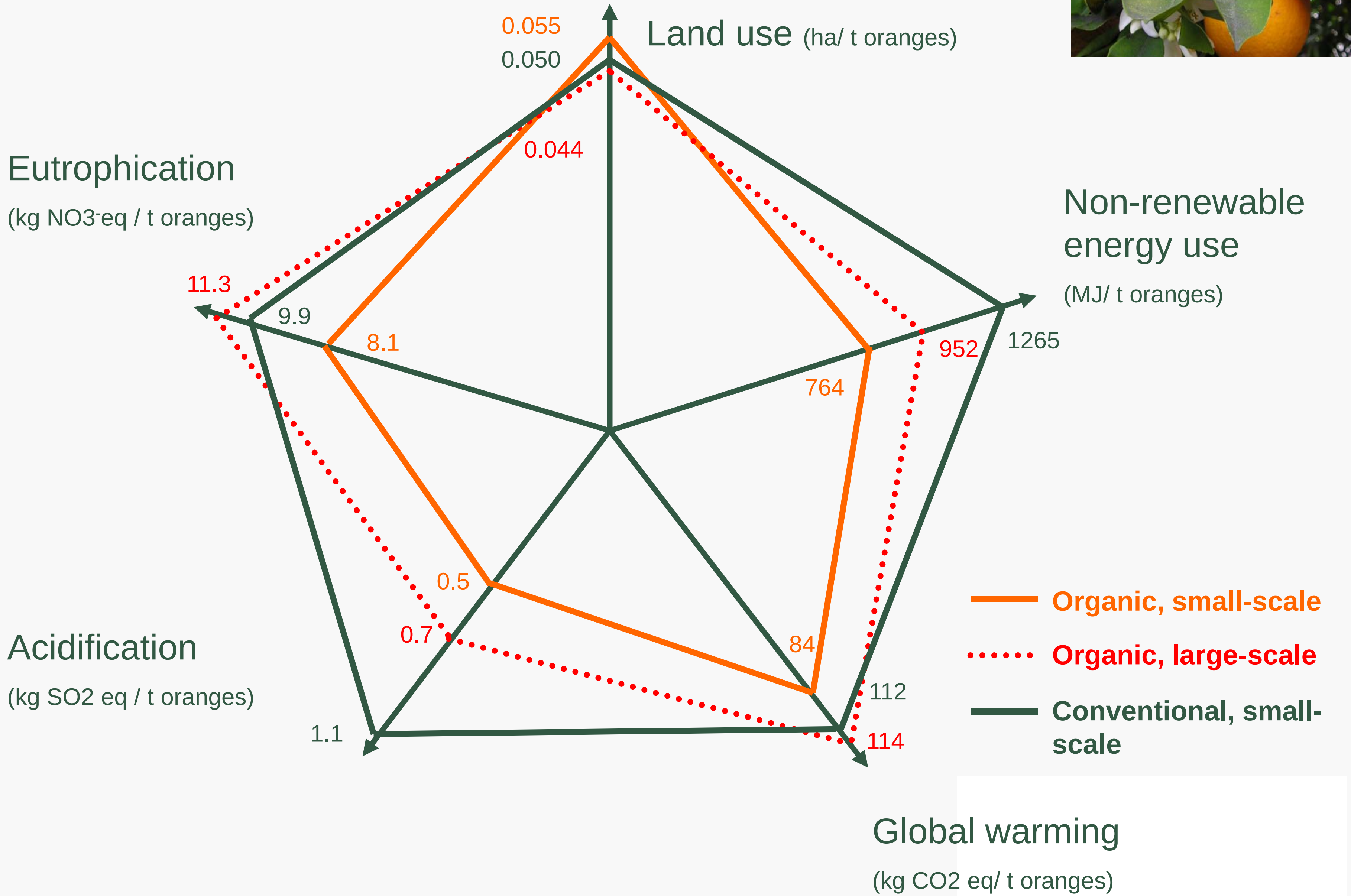
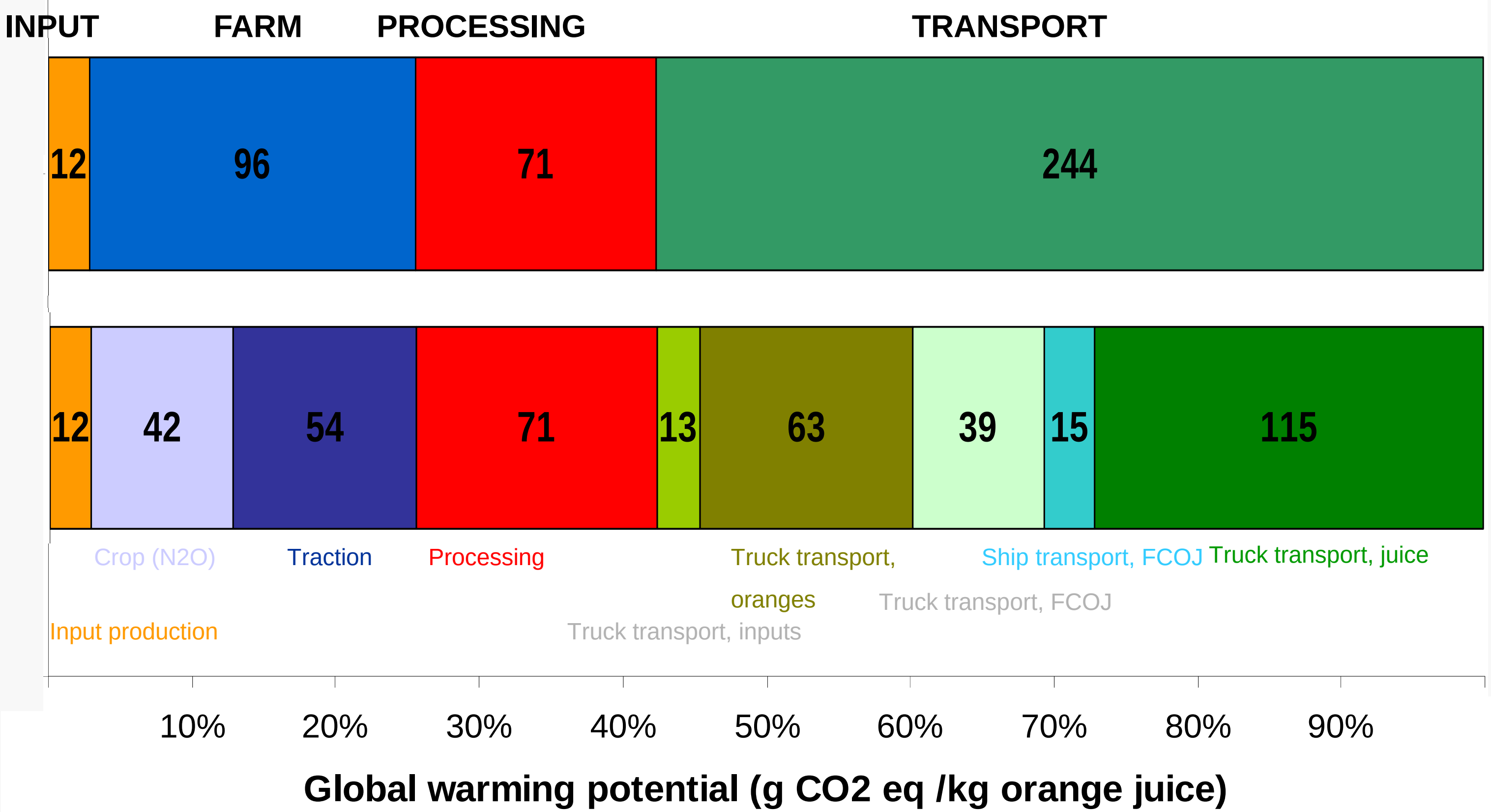
Environmental impacts at farm gate



1.3 LCA methodology.
Example: LCA of organic orange juice



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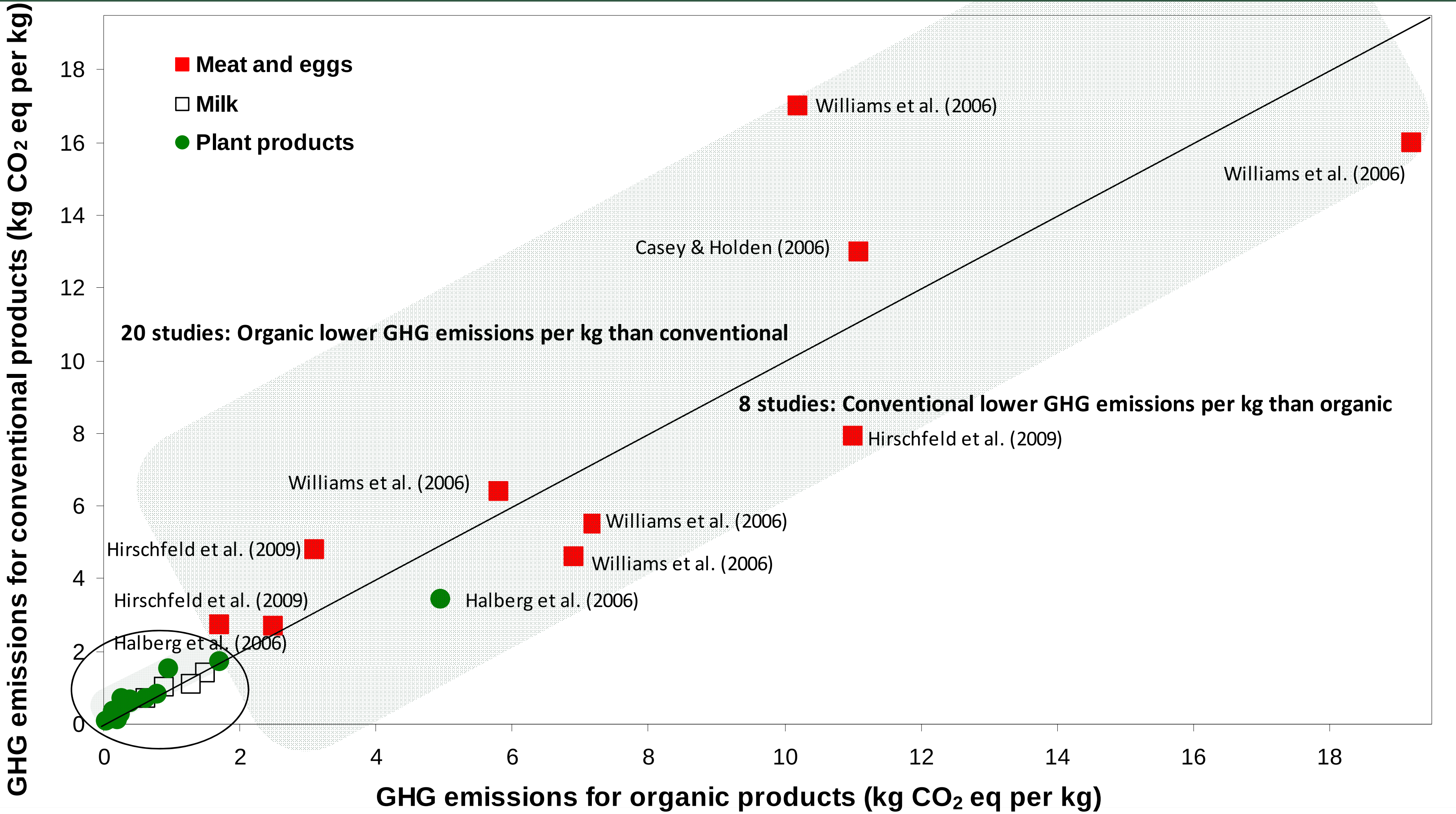
2 Greenhouse gas emissions: Organic vs. conventional



Idea after Niggli et al.(2008)

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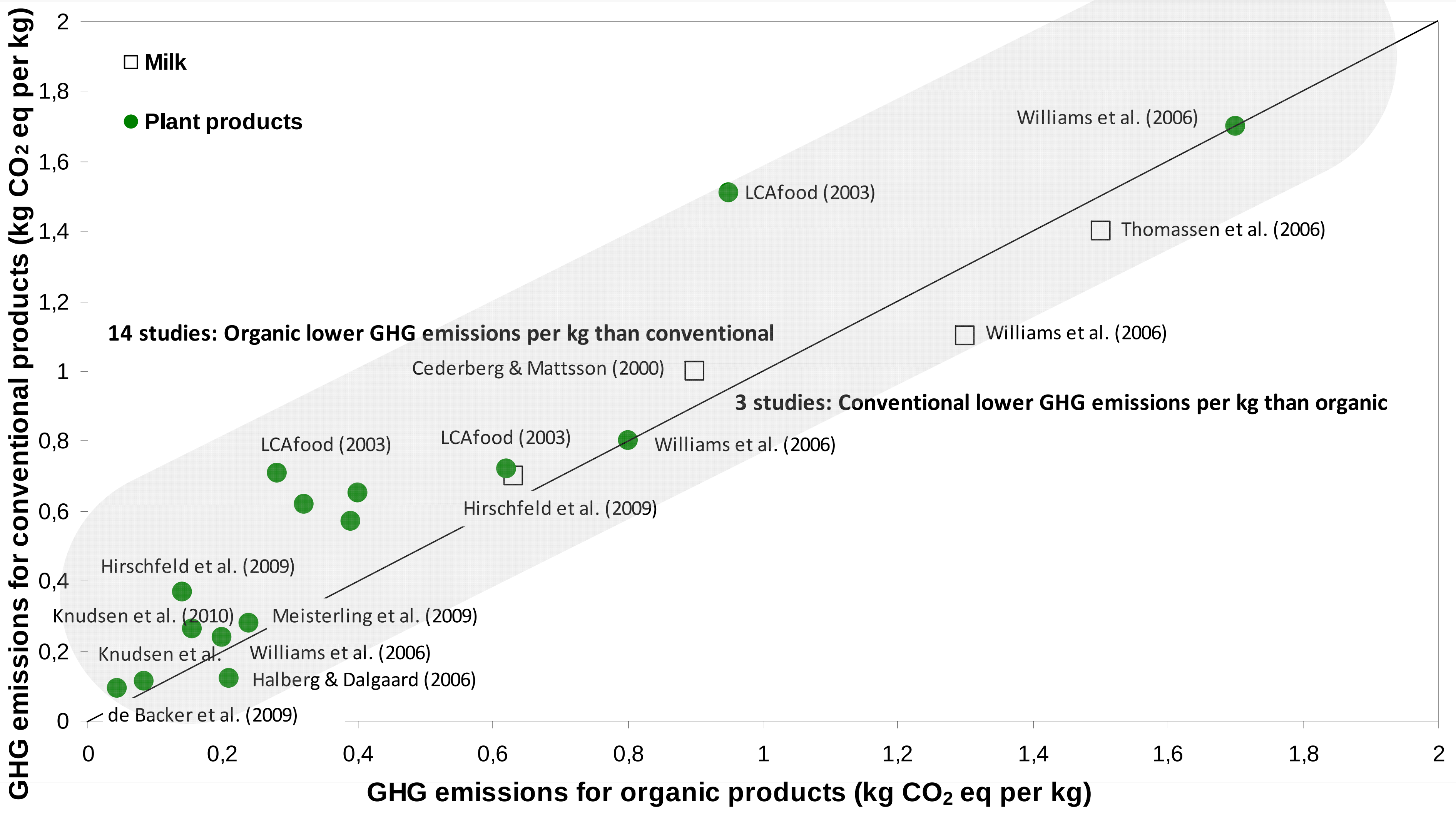
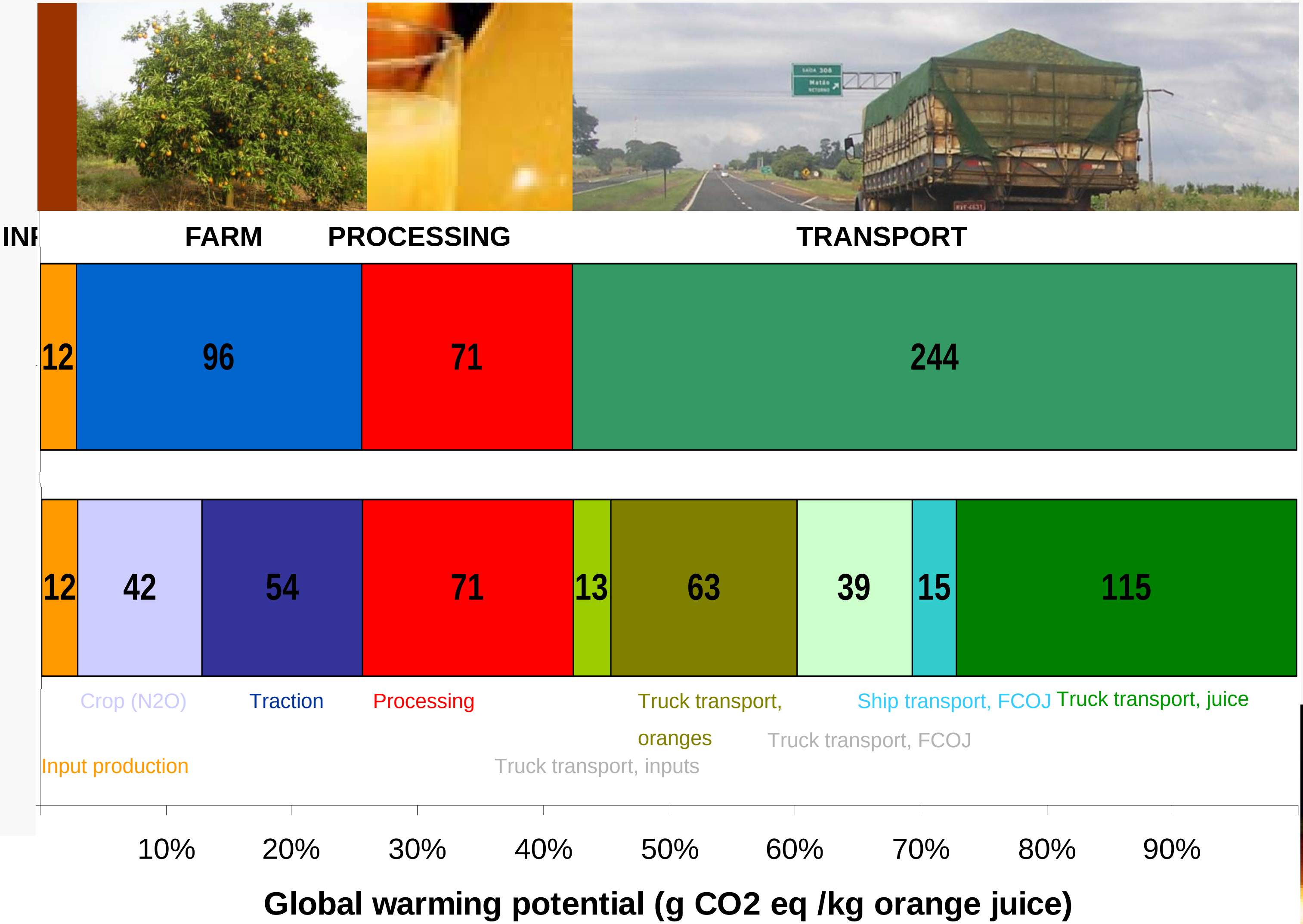
2 Greenhouse gas emissions: Organic vs. conventional



Idea after Niggli et al.(2008)

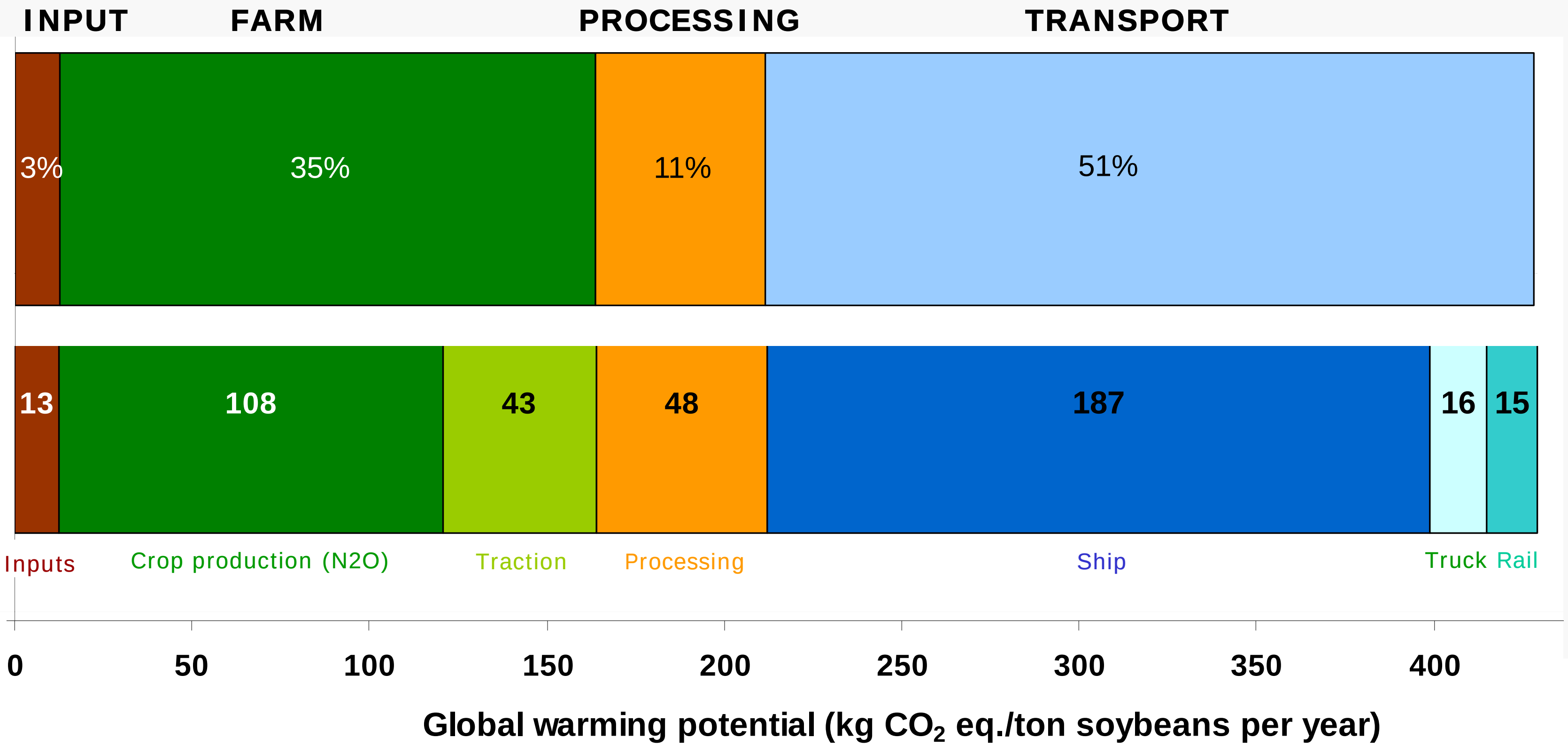
2.4 Important hotspots and mitigation options in organic food chains:

Organic orange juice imported from Brazil to Denmark



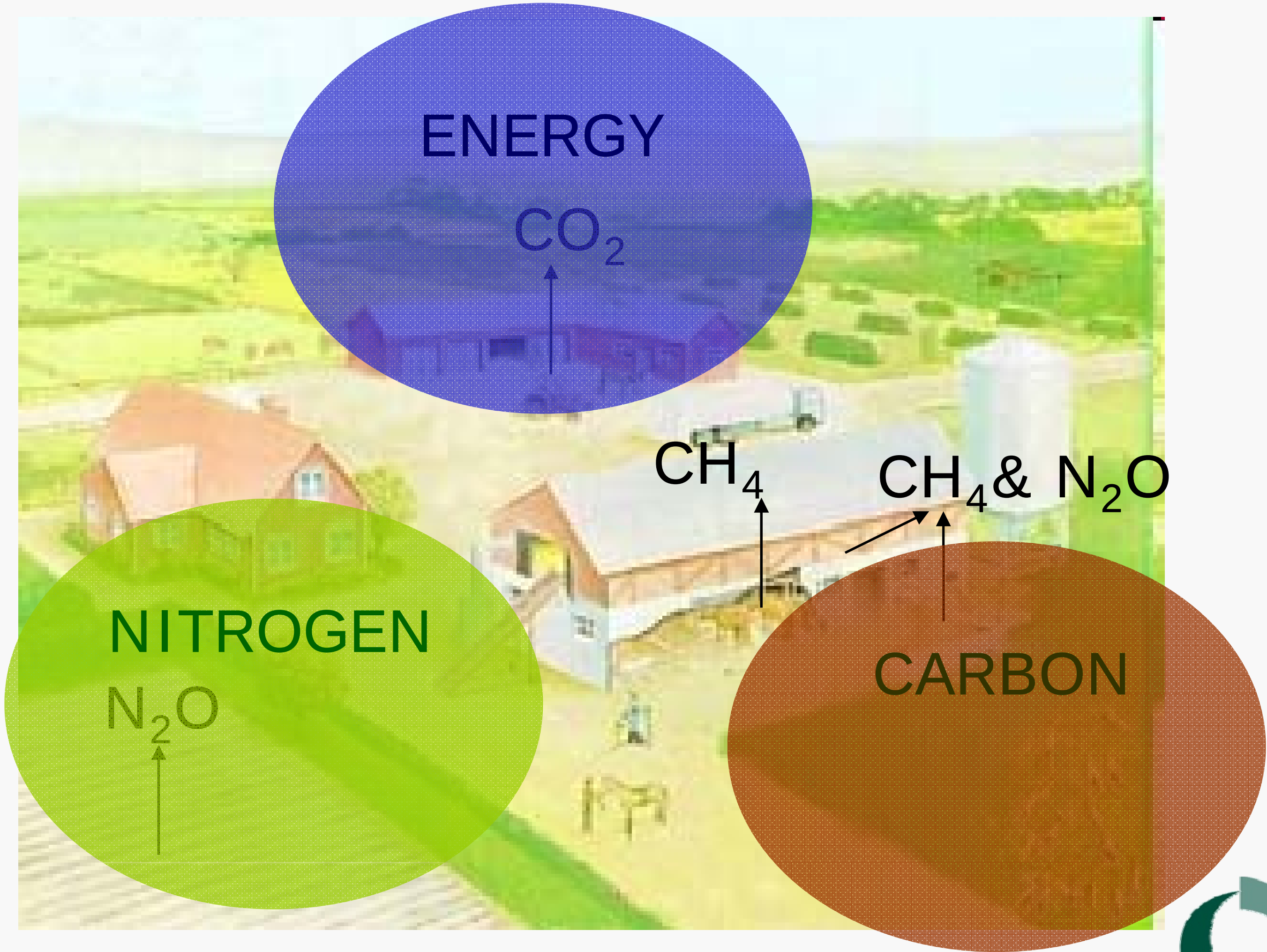
2.4 Important hotspots and mitigation options in organic food chains:

Organic soybeans imported from China to Denmark



2.4 Important hotspots and mitigation options in organic food chains:

Mitigation options: Farm level



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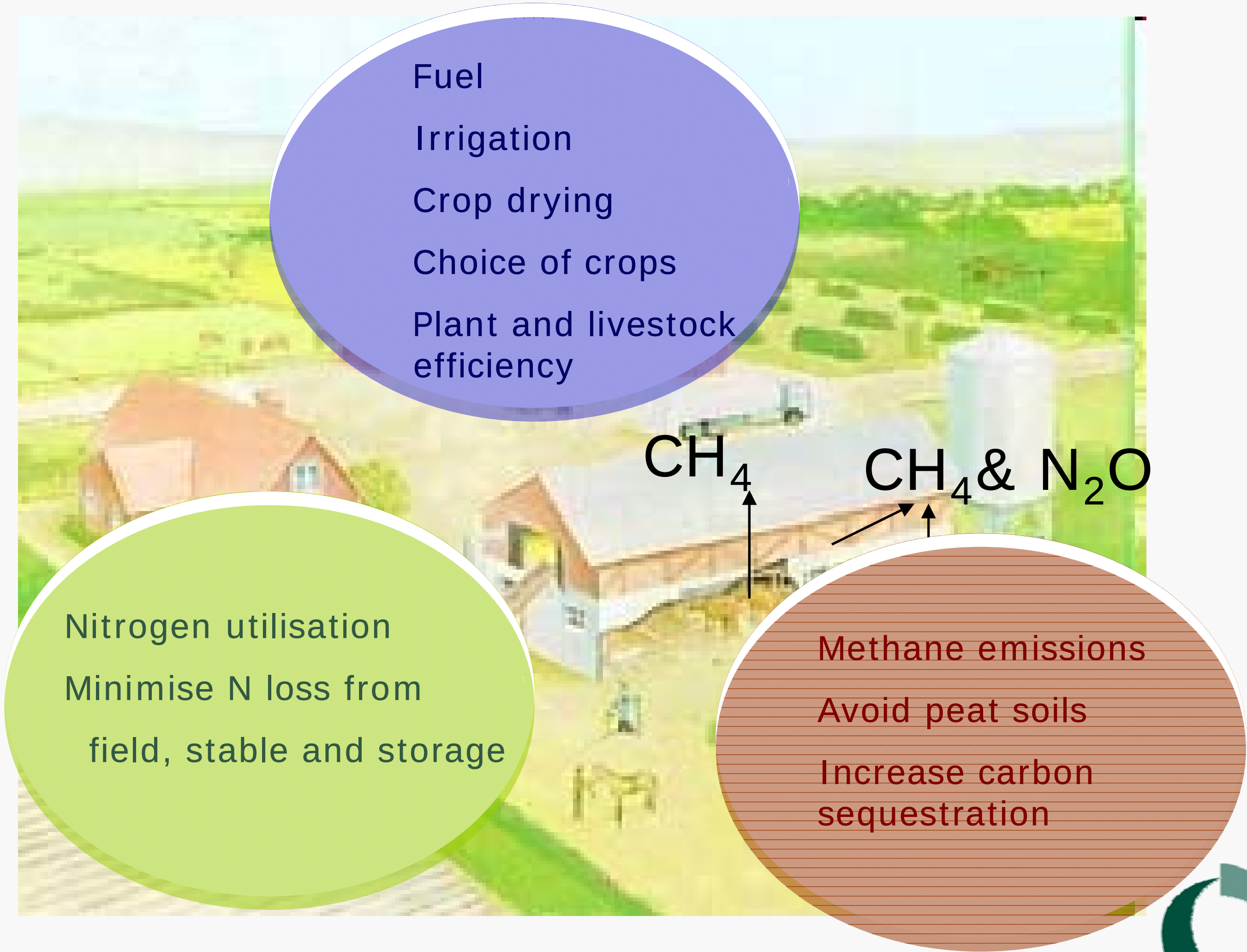
2.4 Important hotspots and mitigation options in organic food chains:

Mitigation options: Farm level



2.4 Important hotspots and mitigation options in organic food chains

Mitigation options: Food system issues

- Reduce meat consumption
- Minimise transport of inputs and products
- Minimise food waste
- Reduce packaging
- Reduce consumption of highly processed food

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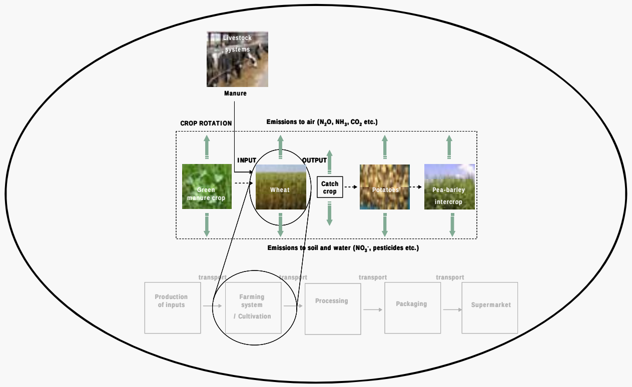
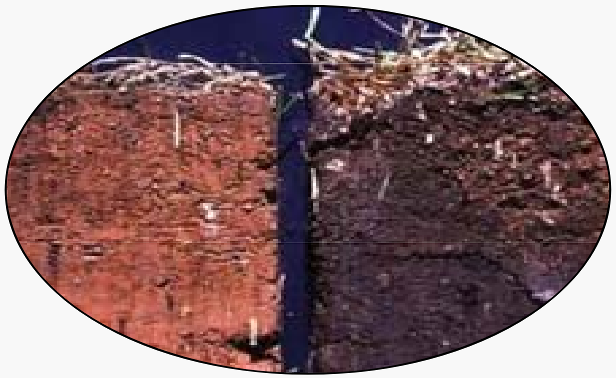
3 LCA of complex agricultural systems: methodological challenges

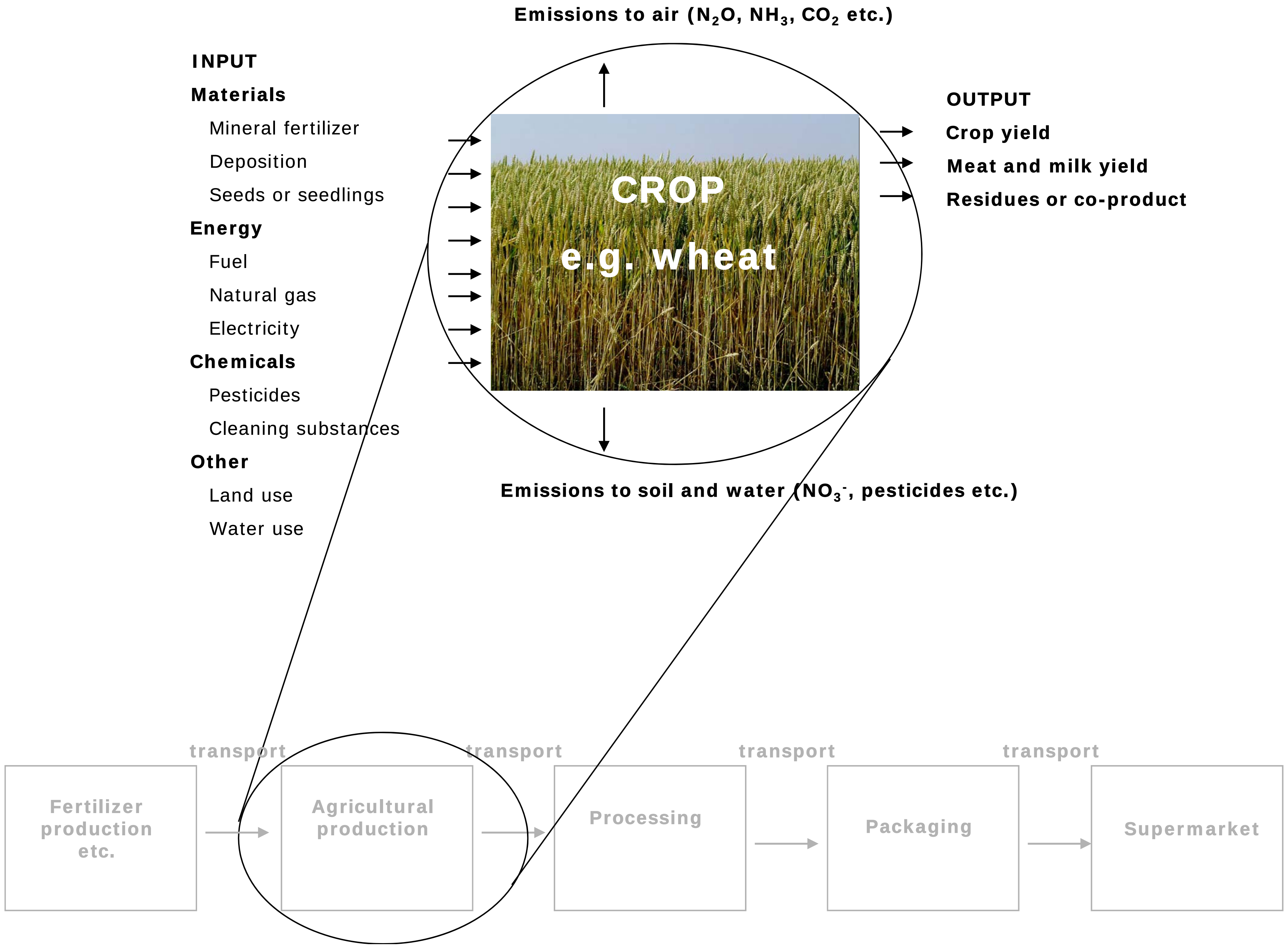
3.1 How to allocate and account for interactions in farming systems?



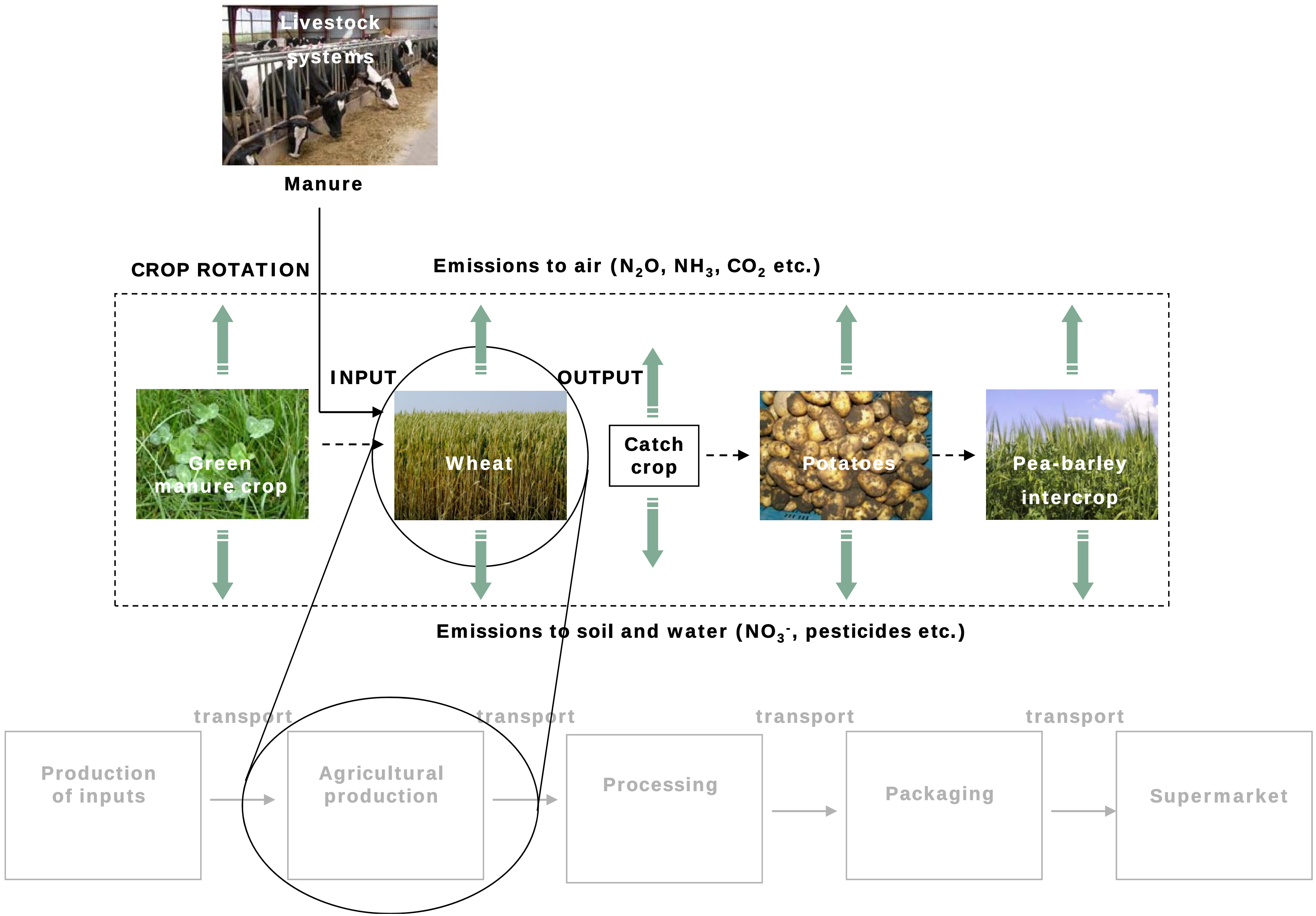
3.2 How to account for carbon sequestration in LCA?



CONVENTIONAL



ORGANIC



Livestock systems
Manure
CROP ROTATION
Emissions to air (N_2O, NH_3, CO_2 etc.)
INPUT
OUTPUT
Green manure crop
Wheat
Catch crop
Potatoes
Pea-barley intercrop
Emissions to soil and water (NO_3^-, pesticides etc.)
transport
transport
transport
transport
Production of inputs
Agricultural production
Processing
Packaging
Supermarket

Problem: **How to find the environmental impact of the individual food crop when this is produced in a complex system and one cannot just grow more of that particular crop without impacting on/relying on the other parts of the system**

Options and our recommendation

In LCA this is translated to, how to allocate impacts (or benefits) of ressource flows within the system. **A simple example is how to allocate the environmental impact of meat and milk from a dairy production:**

The typical LCA reasoning

1. If the system can be considered as producing a main product and one or more by-products then allocate the entire impact to the main product and correct for any ressouce savings that the supply of by products results in. If this is not the case then:
2. If the individual product's drawing on ressources can be meaningsfull modelled by bio-physical relations then split the environmental impact according to this
3. Otherwise allocate according to mass or economic value

Can these principles be applied to integrated organic systems and how

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3.1 How allocate and account for interactions in farming systems?
Options and our recommendation

System delimitation at:

- **Crop** level:
  - Allocate environmental impacts (or benefits) from green manure, crop residues etc.) according to
    - Area (equally on the crops)
    - N residual/utilization effects of following crops
- **Crop rotation** level:
  - Use one functional unit (e.g. food basket in MJ)
  - Allocate environmental impacts according to
    - economic value of the crops, area (per ha) or mass (per kg DM)

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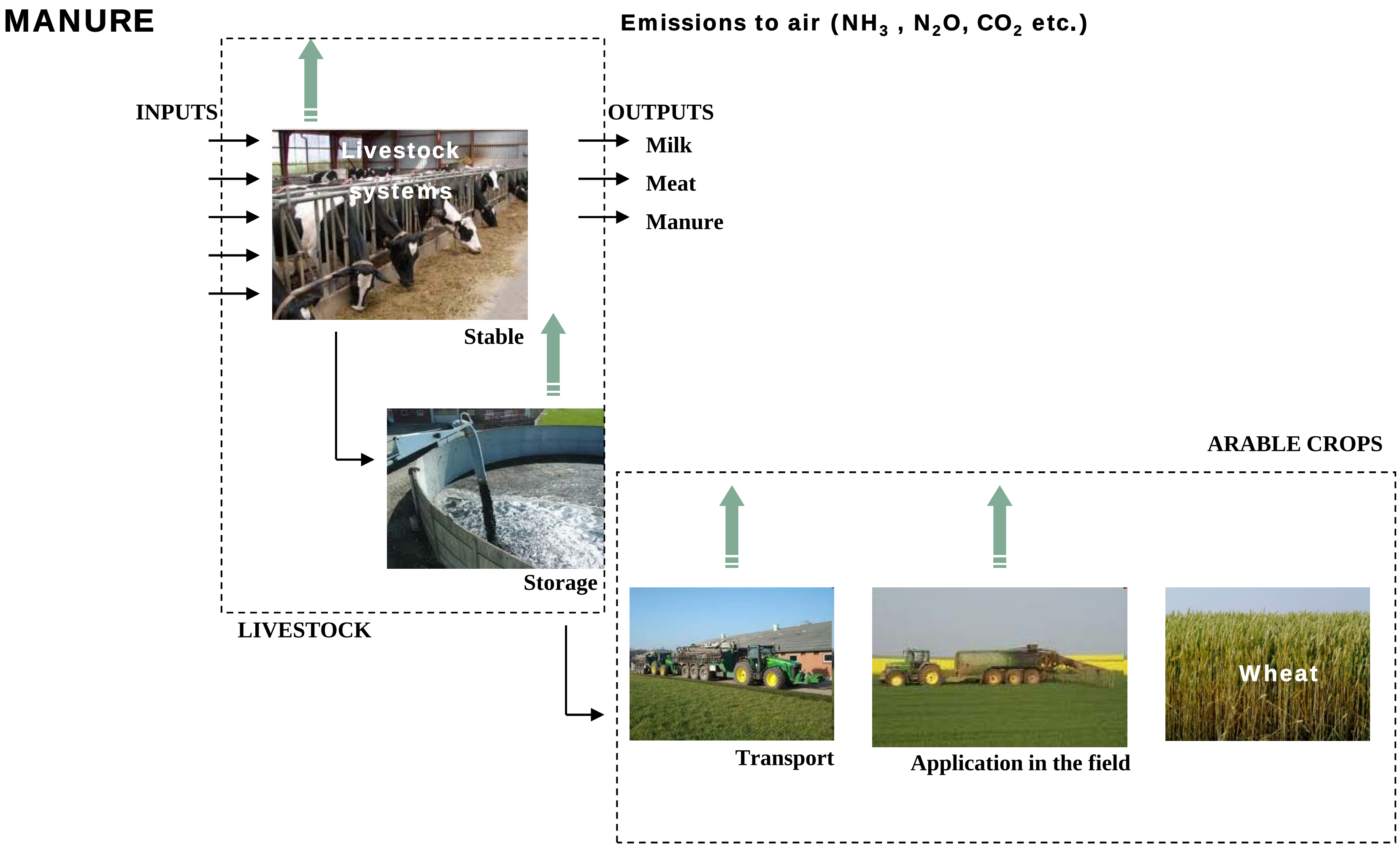
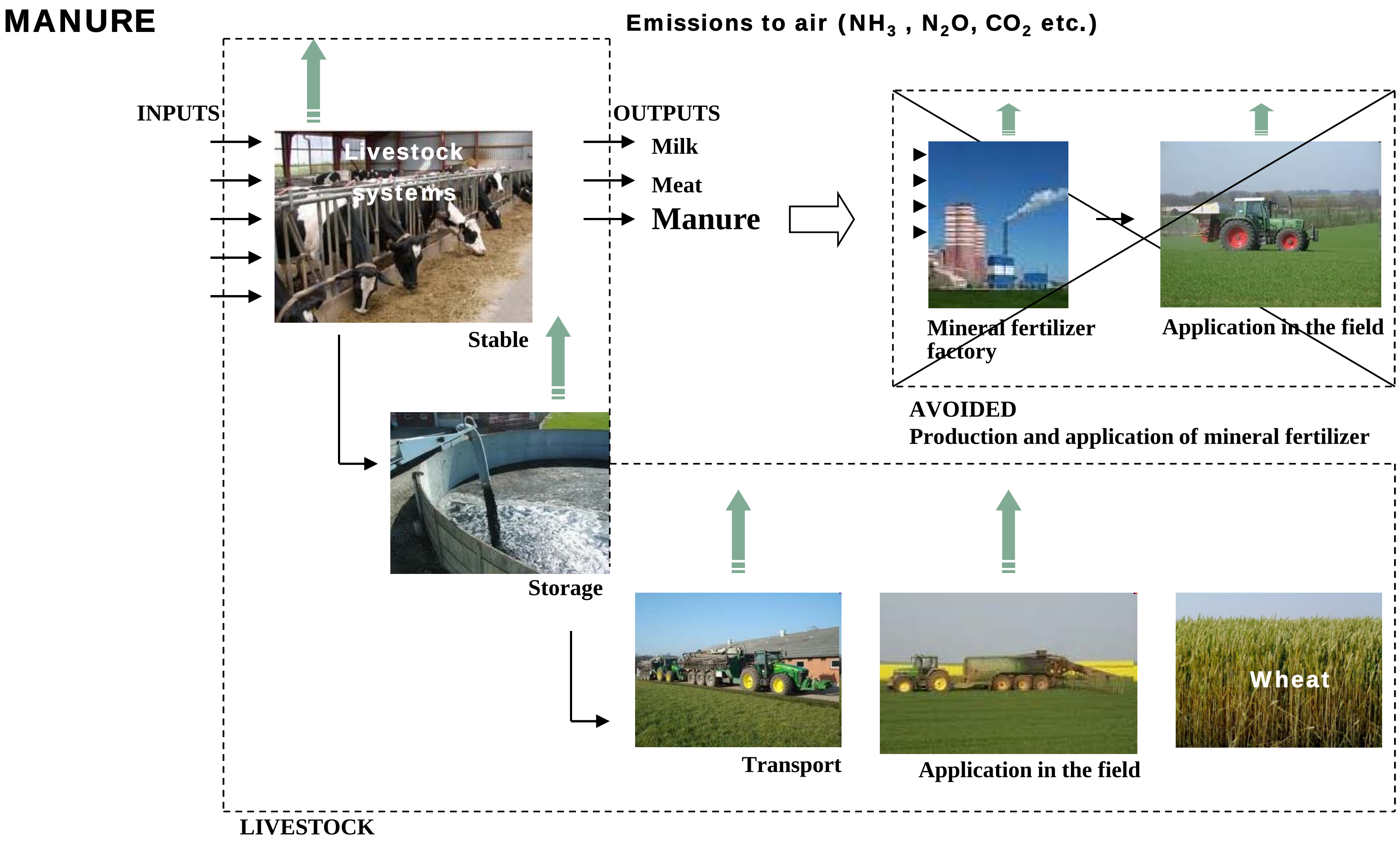


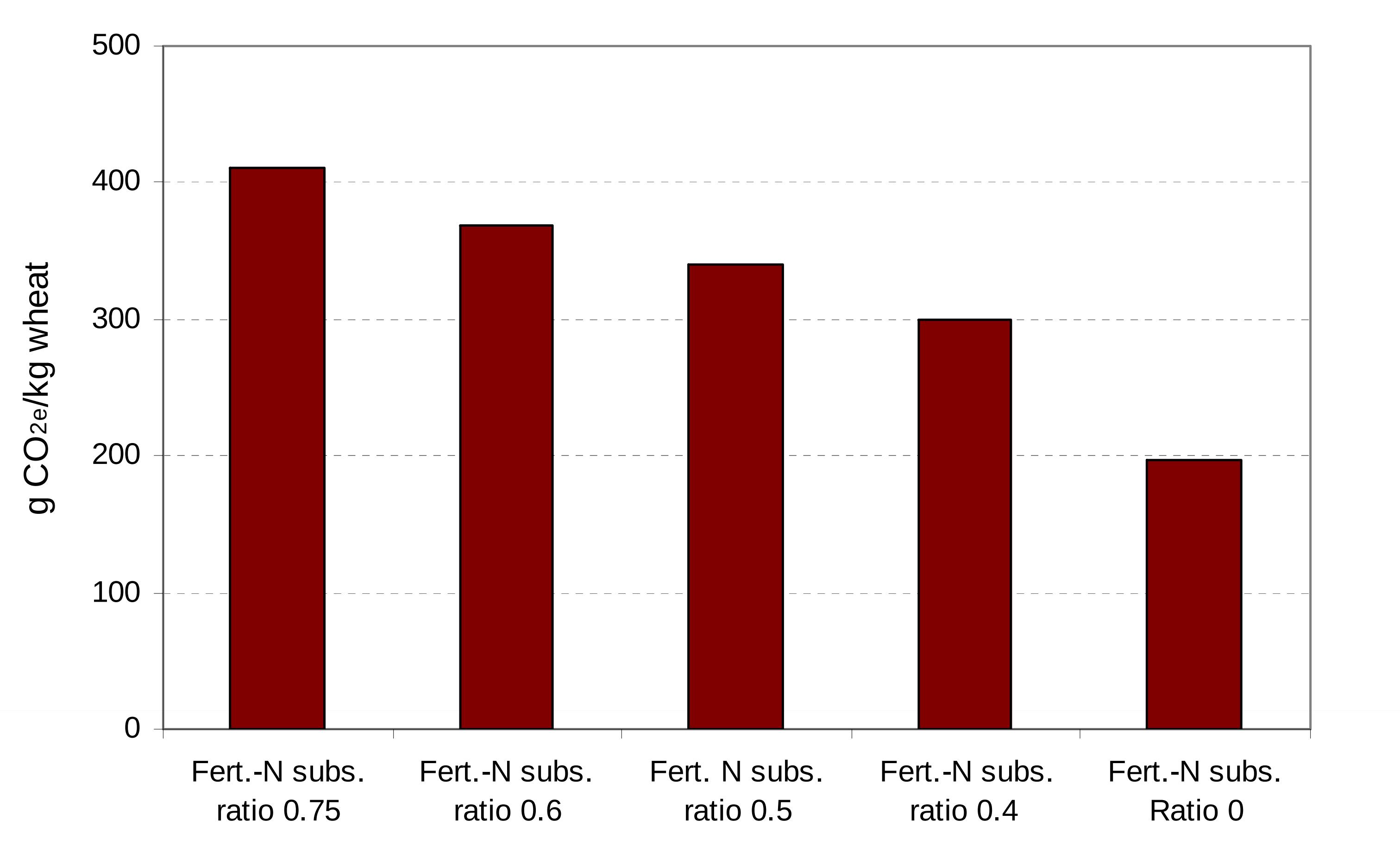
3.1 How to allocate environmental impacts from imported manure?



3.1 How to allocate environmental impacts from imported manure?

3.1 How to allocate and account for manure?

GWP of organic wheat as dependent on how the importeret ressource 'manure' has been accounted for, g CO2e / kg



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3.1 How allocate environmental impacts from imported manure?

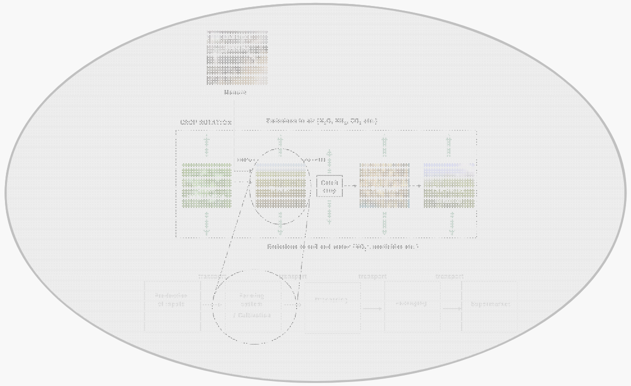
Options and our recommendation

- Regard manure as waste from livestock system
  - Plant production will pay for environmental emissions related to transport and application in the field

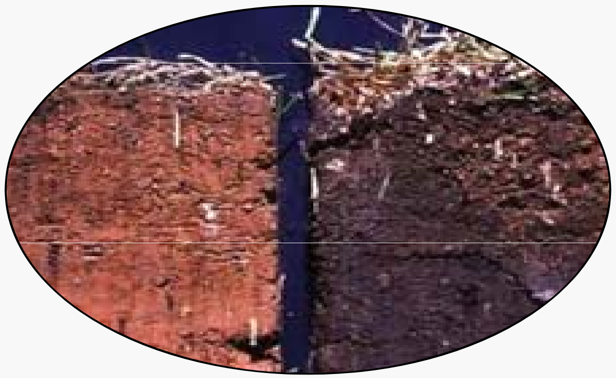
- Regard manure as a valuable source of N, that otherwise needs to be produced (what is the consequence of using it?) => thus find shadow price of alternative source
  - As mineral fertilizer => environmental costs of production and use of mineral fertilizer = shadow price
  - As green manure => environmental costs of production of green manure = shadow price
  - Other? (recycled waste)

3 LCA of complex agricultural systems: methodological challenges

3.1 How to allocate and account for interactions in farming systems?



3.2 How to account for carbon sequestration in LCA?



3.2 How to account for carbon sequestration in LCA?

- Changes in organic C stocks — Vegetation / Litter / Soil


  - Soil carbon change


  - Land use change (LUC)
    - Direct (new agricultural land for crop production)
    - Indirect (demand for previous land use move to other places)

3.2.1 Soil carbon sequestration

LCA of pig production in Denmark

	Organic pig production		Conventional pig production
	Free range sows	All pigs free range	
Global warming potential$_{100}$ (g CO_2 eq/ kg product)	2920	3320	2700
Effect of soil C change$_{20}$ (g CO2 eq/ kg product)	-300	-400	0
GWP, corrected	2620	2920	2700

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3.2 Soil carbon sequestration

LCA of orange production in Brazil

	Organic	Conventional
Global warming potential$_{100\ years}$ (g CO_2 eq/ kg product)	84	112
Effect of soil C change$_{IPCC\ 20\ years}$ (g CO_2 eq/ kg product)	-33	0
GWP, corrected (g CO_2 eq/ kg product)	51	112

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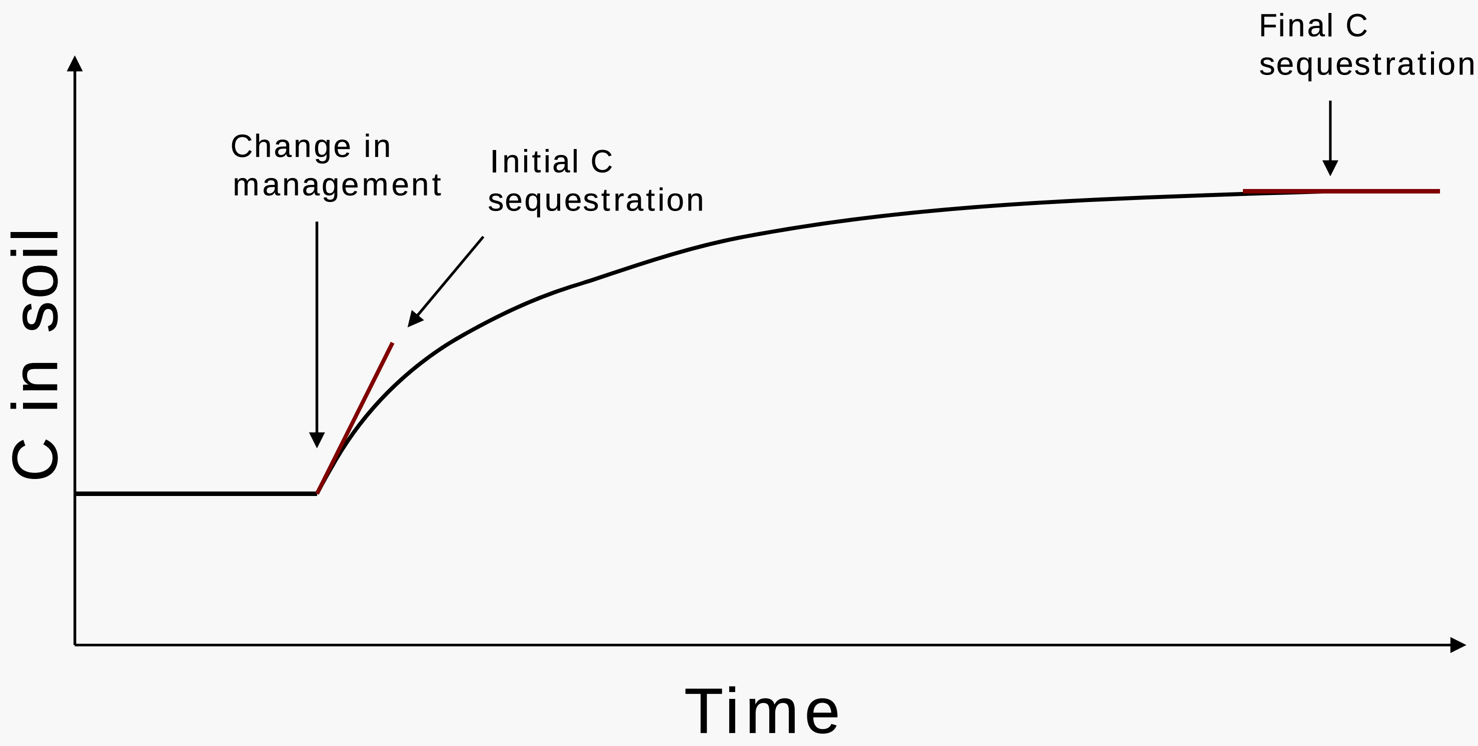
3.2.1 Soil carbon sequestration



3.2 Soil carbon sequestration

Consequential LCA of soybean production methods in China

	Organic	Conventional
Global warming potential$_{100}$ (g CO_2 eq/ kg product)	156	263
Effect of soil C change$_{\text{IPCC 20 years}}$ (g CO_2 eq/ kg product)	0	+188
Effect of soil C change$_{\text{New method 20 years}}$ (g CO_2 eq/ kg product)	0	+132
Effect of soil C change$_{\text{New method 100 year}}$ (g CO_2 eq/ kg product)	0	+79

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5 Conclusions and outlook

- LCA best tool for greenhouse gas emissions related to agricultural products
- Suboptimisation when fousing on climate change as single environmental impact category
- Farm production and transport are important hotspots
- Earlier studies: no remarkable difference in GHG emissions between organic and conventional products
  - However: soil carbon changes have traditionally not been included!
- Challenges of LCA for organic products
  - Interactions incl. manure should be adressed
  - Carbon sequestration should be included
- Quality data and emission estimates for inventory

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