Life Cycle Assessment of Agricultural Systems: Introduction

Thomas Nemecek

Agroscope Reckenholz-Tänikon Research Station ART
CH-8046 Zurich, Switzerland

http://www.agroscope.ch
thomas.nemecek@agroscope.admin.ch

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Overview

- Specific aspects of agriculture
- Consequences for agricultural LCA
- Defining system boundaries
- Defining the functional unit
- Impact assessment for biodiversity and soil quality
- Variability of agricultural production and use of multivariate statistics

Examples of application of LCA:
- Cropping system analysis
- Animal production, meat, milk and cheese
- Biofuels
- Environmental assessment of farms
Specific aspects of agricultural systems

- Strong reliance on natural resources: land, water, sunlight, nutrients, soil, biodiversity
- Dependence on living organisms
- Open systems
- Processes are difficult to control: e.g. nutrient leaching, erosion, N₂O emissions
- Emissions are difficult to measure, due to the open nature of the systems
- Small-scale structure: numerous farm businesses
- Complex systems, only partly understood
- Nonlinear nature of many environmental mechanisms
- High variability of processes and products, due to soil, climate, topography, agricultural management, traditions
Consequences of these specificities of agriculture (1)

- Environmental models and data need to be developed or adapted to agriculture
- Account for non-linear relationships of environmental processes
- Difficulty to clearly delimit the ecosphere (environmental system) and the technosphere (economic system): e.g. agricultural soil, biodiversity in the field
- Due to the variability a large number of observations is needed to get representative data (but often insufficient resources)
- Efficient LCA databases and calculation procedures are required to manage this large number of observations
Consequences of these specificities of agriculture (2)

- Since measurements at a large scale are not feasible, environmental models are needed, reflecting the main influencing factors.
- Need to include specific impact categories, related to the use of natural resources: land use, land use change, biodiversity, soil quality, water resources.
- Need to adapt some impact categories, e.g., impact of pesticides on ecotoxicity.
- Collaboration between agronomists, environmental scientists and local experts is required.
Fossil energy and carbon footprint are not enough for agricultural systems

Fossil energy use is identified by all methodologies as the most important driver of environmental burden of the majority of the commodities included, with the main exception of agricultural products (x).  

Huijbreghts et al. (2010)
20-60% of environmental impacts in Europe related to the food sector

- 20% of energy use for food sector
- Other impacts even higher share

Source: EIPRO study (Tukker et al. 2006)
Defining system boundaries: Temporal system boundaries

- **Annual crops:**
  - Starting after harvest of previous crop (including fallow period or catch crop, if no product)
  - Ending with harvest of the considered crop

- **Permanent crops:**
  - Annual basis (1\textsuperscript{st} January to 31\textsuperscript{st} December) or
  - Multiannual cropping cycle (distinguishing different phases: planting, young plantation, main yielding phase, eradication)
Single crop or cropping system?

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Grass-clover mixture</td>
<td>Potatoes</td>
<td>Green manure</td>
<td>Winter wheat</td>
</tr>
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<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>1</td>
<td>2</td>
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<td>Grass-clover mixture</td>
<td>Forage catch crop</td>
<td>Grain maize</td>
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<table>
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<tbody>
<tr>
<td>Month</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fallow</td>
<td>Spring barley</td>
<td>Grass-clover mixture...</td>
<td></td>
</tr>
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</table>
## Methodology: Crop combinations

### Crop Rotation

<table>
<thead>
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<th>Year</th>
<th>Month</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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<th>10</th>
<th>11</th>
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</tr>
<tr>
<td>Oil Seed Rape</td>
<td>Fallow ...</td>
<td>Winter Wheat</td>
<td>Fallow ...</td>
<td>Winter Barley</td>
<td>Fallow ...</td>
<td>Oil Seed Rape</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Crop Combination

1. Winter Barley | Fallow ... | Oil Seed Rape
2. Oil Seed Rape | Fallow ... | Winter Wheat
3. Winter Wheat | Fallow ... | Winter Barley
Comparison of different crop rotations with (P) and without (S) pea

Source: Hayer et al. (2011)
Relationship between N fertilisation and global warming potential

Source: Hayer et al. (2011)
Defining system boundaries: Example of crop production

Resources:
- Infrastructure:
  - Buildings
  - Machinery
- Field production:
  - Catch crops
  - Field work processes:
    - Soil cultivation
    - Fertilisation
    - Sowing
    - Chemical plant protection
    - Mechanical treatment
    - Harvest
    - Transport

System boundary:
- Animal production system
  - Animal excrements
  - Manure storage

Inputs:
- Seed
- Fertilisers (min. & org.)
- Pesticides
- Energy carriers
- Irrigation water

Products:
- Silage maize
- Sugar beets
- Fodder beets
- Beetroot
- Carrots
- Cabbage
- Wheat
- Barley
- Rye
- Oats
- Grain maize
- CCM
- Faba beans
- Soya beans
- Protein peas
- Sunflowers
- Rape seed

Co-Product:
- Straw

Product treatment:
- Grain drying
- Potato grading

Direct and indirect emissions

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Defining system boundaries:
Farm/Animal products

System boundary = farm gate

**Resources**
- **Infrastructure**
  - Buildings
  - Equipment
  - Machines
- **Purchased inputs**
  - Energy carriers
  - Fertilisers
  - Seed
  - Pesticides
  - Feedstuffs, straw
  - Animal
  - Water

**Field operations**
- Tillage
- Sowing
- Fertilisation
- Maintenance
- Irrigation
- Harvest
- Transport to farm

**Purchased inputs**
- Energy carriers
- Fertilisers
- Seed
- Pesticides
- Feedstuffs, straw
- Animal
- Water

**Animal production**
- Feeding
- Milking
- Manure management
- Grazing

**Indirect emissions**

**Direct emissions**

**Vegetal products, e.g.**
- Wheat
- Maize
- Potatoes
- Vegetables

**Animal products**
- Milk
- Meat
- Eggs
- Wool

**Introduction to agricultural LCA**
Thomas Nemecek | © Agroscope Reckenholz-Tänikon Research Station ART
Defining system boundaries: Where to draw the line between animal and plant production?

- Animal production (incl. feedstuffs, buildings, emissions, etc.)
  - Manure storage and treatment
  - Manure application (incl. machinery use and emissions)
  - Nutrient use in plant production

Introduction to agricultural LCA
Thomas Nemecek | © Agroscope Reckenholz-Tänikon Research Station ART
Multifunctionality of agriculture: Functions and functional units

1. **Land management function**: ha*year  →  goal: minimize land use intensity

2. **Productive function**: physical unit (MJ gross calorific value)  →  goal: optimise eco-efficiency (minimal impact per produced energy unit)

3. **Financial function**: monetary unit  →  goal: optimise eco-efficiency (minimal impact per € gross margin 1)
SALCA methodology
Method for biodiversity - framework

- **11 Indicator species groups** were determined considering ecological and LCA criteria: flora, birds, mammals, amphibians, molluscs, spiders, carabids, butterflies, wild bees, and grasshoppers.
- Two characteristics: **overall species diversity** of the indicator species groups and **ecologically demanding species**
- Extensive **inventory data about agricultural practices**: occupation, emissions, farming intensity indicators (e.g. number of cuts) and process figures (e.g. herbicide type). Beside typical cultivated fields, semi-natural habitats were integrated.
- **Characterisation based on scoring system** was evolved to estimate every indicator species group’s reaction to agricultural activities followed by an aggregation step resulting in **scores**.
- **Aggregation** and **normalisation** of scores: biodiversity value and biodiversity potential
SALCA-Biodiversity

Estimation of impacts on biodiversity

Agricultural Activities (AA)

AA-1
AA-2
AA-3
AA-4
AA-5

Biodiversity = Indicator Species Groups (ISG)

ISG-1
ISG-2
ISG-3
ISG-4
ISG-5

Impact

Insecticide application
Mowing
Wild flower strips

Birds
Butterflies
Spiders

Bottom-up approach: Scores based on scientific and expert knowledge
## SALCA methodology
### Method for biodiversity – DOK trial

#### Biodiversity points

<table>
<thead>
<tr>
<th>Species</th>
<th>D0</th>
<th>D1</th>
<th>D2</th>
<th>O1</th>
<th>O2</th>
<th>C1</th>
<th>C2</th>
<th>M2</th>
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<tbody>
<tr>
<td><strong>Total species richness</strong></td>
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<td></td>
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<tr>
<td><strong>Total aggregated</strong></td>
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<td>8.1</td>
<td>8.0</td>
<td>8.0</td>
<td>7.7</td>
<td>7.6</td>
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<td>Flora arable land</td>
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<td>4.1</td>
<td>4.2</td>
<td>4.1</td>
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<tr>
<td>Birds</td>
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<td>8.7</td>
<td>8.6</td>
<td>8.5</td>
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<td>Small mammals</td>
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<tr>
<td>Molluscs</td>
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<td>2.3</td>
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<td>Spiders</td>
<td>13.9</td>
<td>13.2</td>
<td>13.2</td>
<td>13.0</td>
<td>12.2</td>
<td>12.0</td>
<td>12.1</td>
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<tr>
<td>Carabids</td>
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<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
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<td>4.8</td>
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<tr>
<td>Grasshoppers</td>
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<td>9.8</td>
<td>9.5</td>
<td>9.9</td>
<td>9.6</td>
<td>9.4</td>
<td>9.3</td>
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<tr>
<td><strong>Species with high ecological requirements</strong></td>
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<tr>
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<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.2</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Spiders</td>
<td>13.4</td>
<td>12.7</td>
<td>12.6</td>
<td>12.5</td>
<td>11.6</td>
<td>11.5</td>
<td>11.6</td>
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<tr>
<td>Carabids</td>
<td>14.7</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
<td>13.7</td>
<td>13.6</td>
<td>13.7</td>
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<tr>
<td>Butterflies</td>
<td>9.8</td>
<td>8.8</td>
<td>8.5</td>
<td>8.8</td>
<td>8.4</td>
<td>8.4</td>
<td>8.5</td>
<td></td>
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<tr>
<td>Grasshoppers</td>
<td>10.9</td>
<td>9.6</td>
<td>9.3</td>
<td>9.6</td>
<td>9.4</td>
<td>9.2</td>
<td>9.1</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Higher values mean higher species richness

- **favourable**
- **very favourable**

D = Bio-dynamic
O = Organic
C = Conventional (mixed min./org. fertilisation)
M = Conventional (mineral fertilisation)
2 = normal fertilisation level
1 = 50% fertilisation level
0 = no fertilisation

Source: Nemecek et al. (2005)
SALCA methodology
Method for biodiversity – case study 1/2

Results of SALCA-Biodiversity. Biodiversity scores are given per ha cultivated crop. A, B, C, D are management systems with main characteristics:

**Grassland systems** (hay production):
- (A) 5 cuts/year, fertilised with slurry; 11t DM/ha
- (B) 4 cuts/year, fertilised with slurry; 9t DM/ha
- (C) 3 cuts/year, fertilised with solid manure; 5.6t DM/ha
- (D) 1 cut/year, no fertilisation; 2.7t DM/ha

**Winter wheat systems:**
- (A) Conventional production; 5.8t DM/ha
- (B) Integrated production – intensive; 5.5t DM/ha
- (C) Integrated production – extensive; 4.5t DM/ha
- (D) Organic production; 3.5t DM/ha

Scores of grassland (A) and winter wheat (B) systems are set as reference scores. Color codes are given for rough comparison:

- similar to the reference (95%<score<104%)
- better than the reference (105%<score<114%)
- much better than the reference (score >115%)
- no relevance for the considered system

Source: Jeanneret et al. 2006
SALCA methodology
Method for soil quality - framework

- Spatial system boundary = farm;
- Temporal system boundary = crop rotation period (6-8 years)
- Management data of all plots of a farm in a single year are considered as representative for a whole crop rotation
- Only influences of agricultural management practices are included, not immissions
- The development trend of soil properties is assessed, not absolute values

### Soil properties
- Physical
- Chemical
- Biological

### Criteria
According to ISO 14040 and ISO 14042
Depending on the needs of Life Cycle Assessment

### 9 Direct Indicators = measurable soil properties

<table>
<thead>
<tr>
<th>Physical</th>
<th>Rooting depth of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macropore volume</td>
<td></td>
</tr>
<tr>
<td>Aggregate stability</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>Soil organic matter</td>
</tr>
<tr>
<td>Inorganic pollutants</td>
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<tr>
<td>Organic pollutants</td>
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</tr>
<tr>
<td>Biological</td>
<td>Earthworm biomass</td>
</tr>
<tr>
<td>Microbial biomass</td>
<td></td>
</tr>
<tr>
<td>Microbial activity</td>
<td></td>
</tr>
</tbody>
</table>

Source: Oberholzer et al. (2006)
SALCA methodology
Method for soil quality – impact assessment

Example: slurry application

Soil moisture
Soil structure
Soil texture

Risk of soil compaction by wheeling
Humus balance
Number of applications per year with possibly toxic effects
Amount of organic substances

Macropore volume
Aggregate stability
Soil organic matter
Microbial biomass
Earthworm biomass
Microbial activity

Management data
Impact classes
Processes
Direct indicators

Figure 1: Example of impact assessment of a slurry application
### Main characteristics of the analysed cultivation systems

<table>
<thead>
<tr>
<th></th>
<th>No fertiliser D0</th>
<th>Bio-dynamic D2</th>
<th>Bio-organic O2</th>
<th>Conventional K2</th>
<th>Mineral fertiliser M</th>
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</thead>
<tbody>
<tr>
<td>Soil tillage</td>
<td>ploughing</td>
<td>ploughing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertiliser type</td>
<td>no</td>
<td>Liquid manure, compost</td>
<td>Liquid manure, dung</td>
<td>Org. and mineral fertiliser</td>
<td>Mineral fertiliser</td>
</tr>
<tr>
<td>Fertiliser kg N/ha</td>
<td>0</td>
<td>93</td>
<td>86</td>
<td>165</td>
<td>125</td>
</tr>
<tr>
<td>Growth regulators and Fungicides</td>
<td>no</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Weed regulation type</td>
<td>mechanical</td>
<td></td>
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</tr>
<tr>
<td>Weed regulation, period and frequ.</td>
<td>Spring, 3 applications</td>
<td>Spring and autumn, 2 applications</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Seeding month</td>
<td>October</td>
<td>October</td>
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<tr>
<td>Harvest month</td>
<td>August</td>
<td>August</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Crop residues</td>
<td>removed</td>
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</tbody>
</table>
SALCA methodology
Method for soil quality – Results DOK

Results of SALCA-Soil Quality for the five treatments

<table>
<thead>
<tr>
<th>Direct Indicators for soil quality</th>
<th>D0</th>
<th>D2</th>
<th>O2</th>
<th>K2</th>
<th>M</th>
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</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Physical</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Macropore volume</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Aggregate stability</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Chemical</td>
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<td></td>
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</tr>
<tr>
<td>Corg content</td>
<td>--</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>Heavy metal content</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Biological</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Earthworm biomass</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Microbial biomass</td>
<td>-</td>
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<tr>
<td>Microbial activity</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

• **Minor differences between the three farming systems** because most management practices are similar or equal regarding soil quality. Some indicators do not show a positive effect in D2 because of slightly less organic input compared to O2 and K2.

• **D0 and M**: Impacts on soil quality because of insufficient organic carbon supply without organic fertilisers and removal of crop residues.

• **O2 and K2**: Positive effect of crop rotation on macropore volume is not negated by a high compaction risk.
Example of cropping systems research:
Organic and integrated farming / Energy demand in the DOC-trial

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Example of horticultural research (EU-project ENDURE): Global warming potential pome-fruit

GWP 100a

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Source: Frank Hayer (ART)

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Example of animal production research: EU-Project Grain Legumes (GLIP)
Effect of replacing soya beans in pig feed

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Source: Daniel Baumgartner (ART)
Evaluation of bioenergy production systems: Eutrophication potential

| Source: Thomas Kägi (ART) |

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Food LCA: Beef at point of sale

Source: Alig et al. (2012)
Food LCA: Chicken at point of sale

Source: Alig et al. (2012)
Variability and uncertainty: Factors influencing environmental impacts

To understand the variability of environmental impacts, we need to look on the variability of the influencing factors.
Variability of environmental impacts: GWP of wheat from literature
Potential use of multivariate statistics in LCA to explain variability

- To select proxies, we have to identify similar datasets
- Multivariate statistics (like principal component analysis, PCA) can be used to show similarities between environmental impacts
- It can be also used to group environmental profiles, e.g. of crops
- Analysis based on a set of midpoint LCIA indicators
- In the study applied to crop inventories from SALCA (Switzerland) and ecoinvent (global)
Principal component analysis of SALCA inventories

80% of variance explained by first two principal components
Principal component analysis of SALCA inventories

Relationship between impact indicators and factors 1 and 2
Factor 1:
- can group crops
- related to the yield

Data for Swiss crops from SALCA database: grouping by crop group (CER = cereals, LEG = legumes, MAI = maize, OIL = oil crops, ROOT = root crops, VEG = vegetables).
Factor 2: 
- related to the farming system and the intensity

Data for Swiss crops from SALCA database: grouping by farming system (Conv=conventional, IPint = integrated intensive, IPext = integrated extensive, Org = organic).
Principal component analysis of SALCA inventories

Yield is a key factor
Principal component analysis of ecoinvent inventories

Cereals in different countries
Potential use of multivariate statistics in LCA to explain variability

- Between 76 and 80% of the variability could be explained by the first two principal components.
- Factor 1 → crop (group) and yield
- Factor 2 → farming system (conventional, integrated, extensive, organic)
- More data are needed for more systematic analyses

The analysis helps to
- show similarities and differences between environmental profiles
- to find suitable proxies
- to derive simplified methods for extrapolations and approximations
Methodology example 1: Factor analysis
Milk production in 35 farms

Source: Rossier & Gaillard (2001)
## Methodology example 2: Principal component analysis (PCA)

445 apple orchards, Switzerland, 1997-2000

<table>
<thead>
<tr>
<th>No.</th>
<th>Impact categories</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Energy use (GJ eq. ha(^{-1}))</td>
<td>0.95</td>
<td>-0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>2</td>
<td>Global warming potential for 100 years (t CO(_2) eq. ha(^{-1}))</td>
<td>0.95</td>
<td>-0.01</td>
<td>0.20</td>
</tr>
<tr>
<td>3</td>
<td>Ozone formation (kg C(_2)H(_4) eq. ha(^{-1}))</td>
<td>0.94</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>4</td>
<td>Aquatic ecotoxicity (kg Zn eq. ha(^{-1}))</td>
<td>0.00</td>
<td>0.93</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>Terrestrial ecotoxicity (kg Zn eq. ha(^{-1}))</td>
<td>0.07</td>
<td>0.93</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>Aquatic eutrophication (kg PO(_4) eq. ha(^{-1}))</td>
<td>0.19</td>
<td>0.05</td>
<td>0.98</td>
</tr>
<tr>
<td>7</td>
<td>Terrestrial eutrophication (kg PO(_4) eq. ha(^{-1}))</td>
<td>0.90</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>8</td>
<td>Acidification (kg SO(_2) eq. ha(^{-1}))</td>
<td>0.94</td>
<td>0.13</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**Total variance explained**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial eigenvalues</td>
<td>4.58</td>
<td>1.76</td>
<td>0.89</td>
</tr>
<tr>
<td>Variance explained (% of variance)</td>
<td>57.19</td>
<td>22.00</td>
<td>11.17</td>
</tr>
</tbody>
</table>

N = 445; loadings exceeding 0.8 are in bold print.

Source: Mouron *et al.* (2006)
Result: The Management triangle

Context:
Site, farm structure, ...

- Energy demand, global warming potential, ozone formation
- Resource management: Mechanisation, buildings
- Pollutant management: Plant protection
- Nutrient management: Fertilisation
- Eutrophication, acidification
- Soil quality
- Biodiversity
- Ecotoxicity, human toxicity
Application of the management triangle to the environmental management of farms

Example for 35 milk producers, impacts per kg milk

Small area = favourable for the environment

Environmental management of apple orchards

Input-impact-map: correlations between selected impacts and input groups

445 apple orchards, Switzerland, 1997-2000; Pearson correlation (r)

Energy demand correlated to 8 of 13 inputs.

Aquatic ecotox. determined by insecticides (0.7) and fungicides (0.5).

Aquatic eutrophication depends on P-fertiliser (0.8) and N-fertiliser (0.4).

Source: Mouron et al. (2006)
Conclusions multivariate analysis

- Midpoint impact indicators can be grouped by multivariate statistical methods
- Three dimensions were derived for farming systems:
  - Resource management
  - Nutrient management
  - Pollutant management
- Related to
  - Different environmental impacts
  - Different management options
  - Different time scales
- Enables improved management and communication
Global warming potential of dairy farms and amount of milk produced

![Graph showing the relationship between amount of milk produced and CO2-Eq./kg milk](image)

**Introduction to agricultural LCA**

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GWP of milk processed in dairies

![Graph showing CO2-eq/kg milk processed vs milk processed (kg)]
GWP and dairy size

<table>
<thead>
<tr>
<th>kg milk processed</th>
<th>CO2eq/kg milk processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-1.0 Mio. kg</td>
<td>0.00</td>
</tr>
<tr>
<td>1.0-1.5 Mio. kg</td>
<td>0.02</td>
</tr>
<tr>
<td>1.5-2.0 Mio. kg</td>
<td>0.04</td>
</tr>
<tr>
<td>2.0-3.0 Mio. kg</td>
<td>0.06</td>
</tr>
<tr>
<td>3.0-5.0 Mio. kg</td>
<td>0.08</td>
</tr>
<tr>
<td>5.0-10.0 Mio. kg</td>
<td>0.10</td>
</tr>
<tr>
<td>&gt;10.0 Mio. kg</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Communication of results to farmers
Overview of environmental impacts

Environmental impacts per ha UAA

Environmental impacts per Swiss-Fr. return

Environmental impact per MJ digestible energy

- energy demand (MJ-eq./MJ DE)
- terrestrial ecotoxicity (Toxp./ha)
- aquatic ecotoxicity (Toxp./ha)
- terrestrial ecotoxicity (Toxp./Fr.)
- aquatic ecotoxicity (Toxp./Fr.)
- global warming potential (CO2-eq./ha)
- eutrophication (N-eq./ha)

- energy demand (MJ-eq./Fr.)
- terrestrial ecotoxicity (Toxp./Fr.)
- aquatic ecotoxicity (Toxp./Fr.)
- global warming potential (CO2-eq./Fr.)
- eutrophication (N-eq./Fr.)

- energy demand (MJ-eq./MJ DE)
- terrestrial ecotoxicity (Toxp./MJ DE)
- aquatic ecotoxicity (Toxp./MJ DE)
- global warming potential (CO2-eq./MJ DE)
- eutrophication (N-eq./MJ DE)
Communication of results to farmers
Detailed environmental impacts

Share of the different means of production in the total energy demand

- Other inputs
- Animal husbandry
- Animals (purchase)
- Pesticides
- Machines
- Buildings/facilities
- Feedstuff (purchase)
- Energy carriers
- Fertilisation/Nutrients

 own farm

 model farm
Communication of results to farmers

Environmental impacts by product group

Environmental impact cow milk

- Energy demand MJ-eq/ha
- Own farm
- Model farm

Environmental impacts cattle breeding

- Energy demand MJ-eq./ha
- Own farm
- Model farm
- Global warming potential CO₂-eq./ha
- Eutrophication N-eq./ha
- Aquatic ecotoxicity Toxp./ha
- Terrestrial ecotoxicity Toxp./ha

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Communication of results to farmers
Comparison to similar farms

Energy demand: comparison of dairy farms

Eutrophication: comparison of dairy farms

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Milk production
Energy demand of specialised milk production farms
Milk production
Energy demand of specialised milk production farms

- Infrastructure & intrants industriels: 33%
- Intrants agricoles: 23%
- Consommation directe: 44%
- Agents énergétiques: 11%
- Semences (achats): 17%
- Fourrages (achats): 6%
- Animaux (achats): 19%
- Bâtiments/ équipements: 0%
- Machines: 0%
- Engrais: 3%
- Produits phytosanitaires: 0%
- Autres intrants: 0%
Conclusions

- The environmental impacts of agriculture and the food sector are considerable
- Agriculture has a number of specific aspects that need to be considered
- LCA provides good insights into the behaviour of the systems
- For this a close collaboration between agronomists, environmental scientists and local experts is required