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Geographical extrapolation of crop life cycle inventories and impacts

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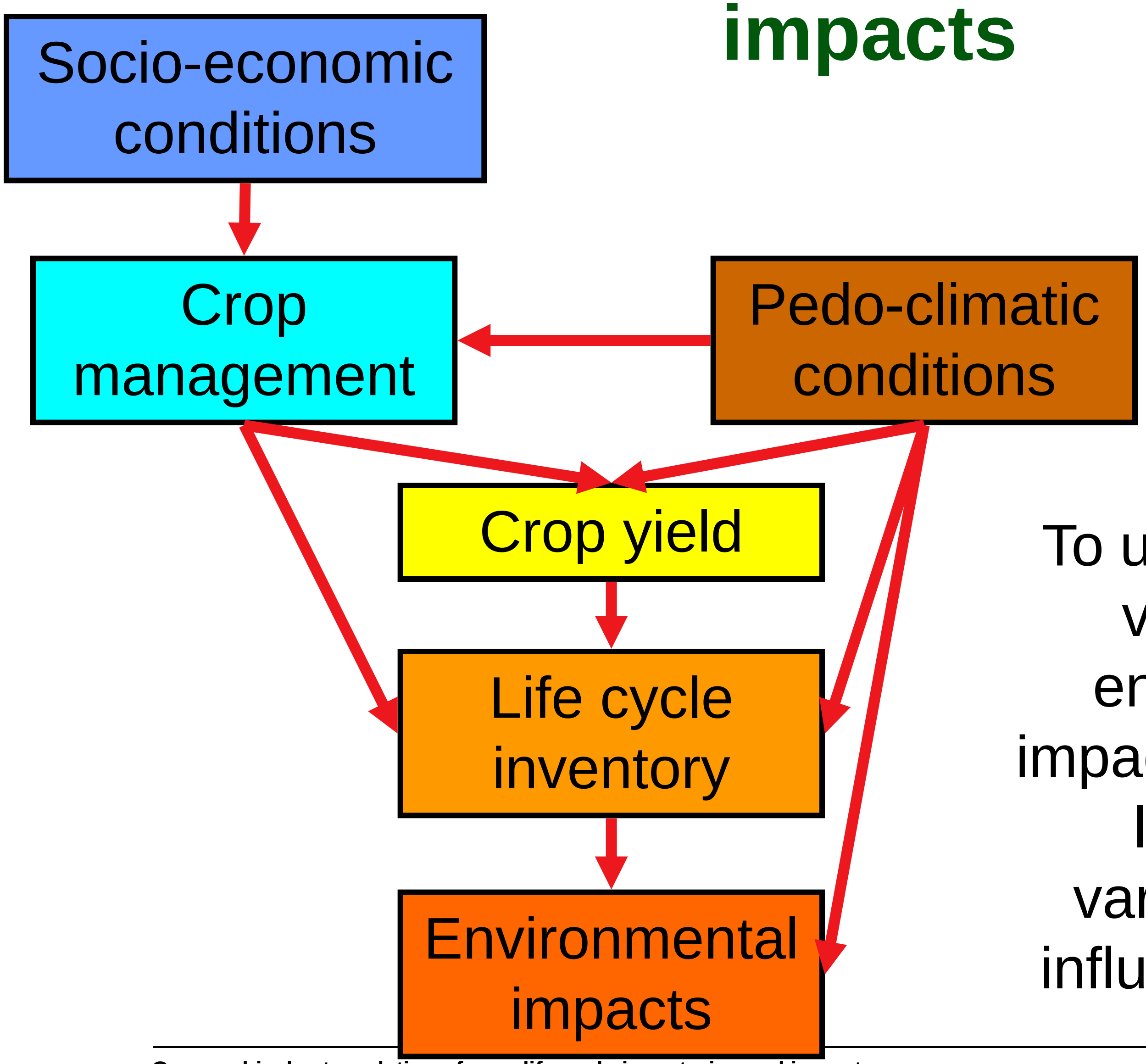
Outline

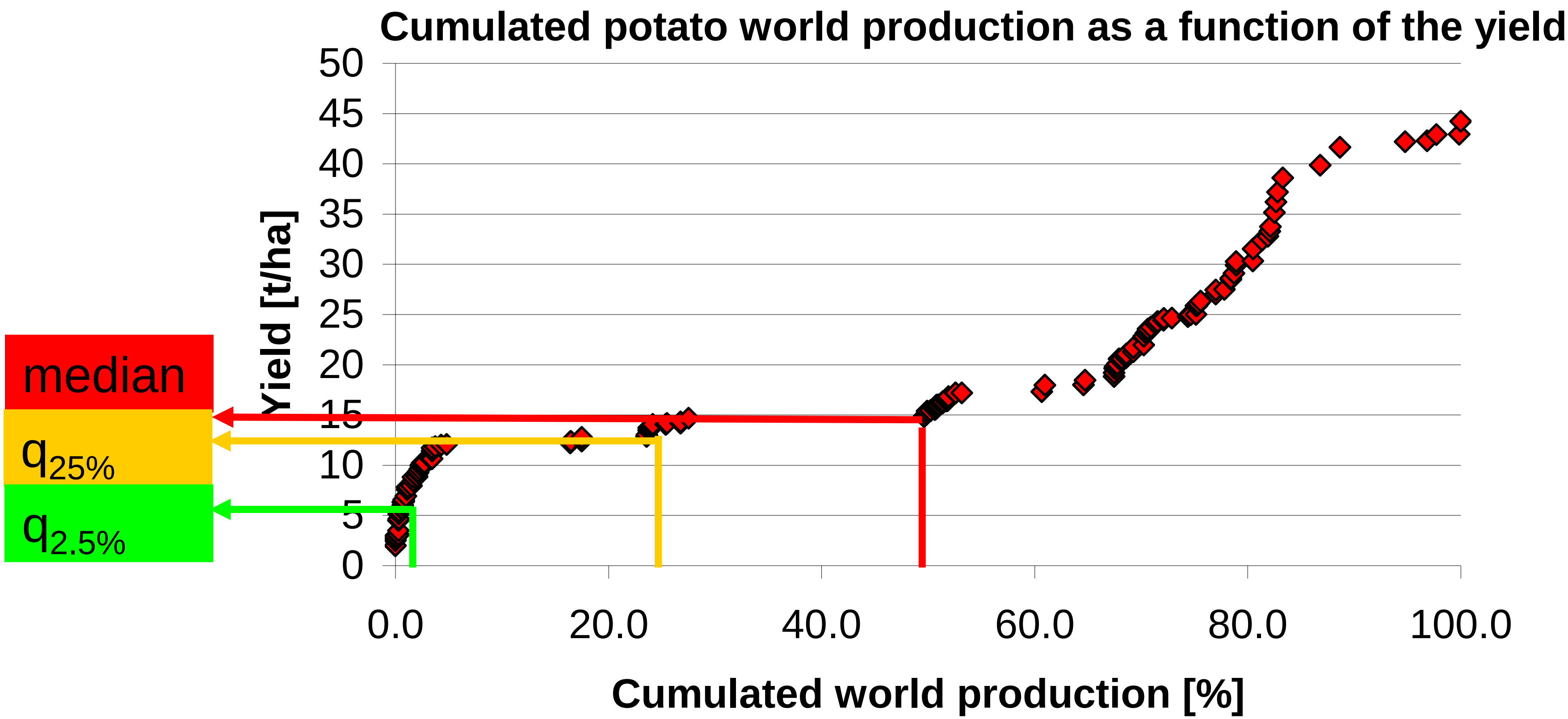
1. Agricultural data variability
2. Different approaches for LCI modelling in agriculture
3. Modular Extrapolation in Agricultural LCA (MEXALCA)
4. First results
5. First validation
6. Conclusions
7. Outlook

Factors influencing environmental impacts



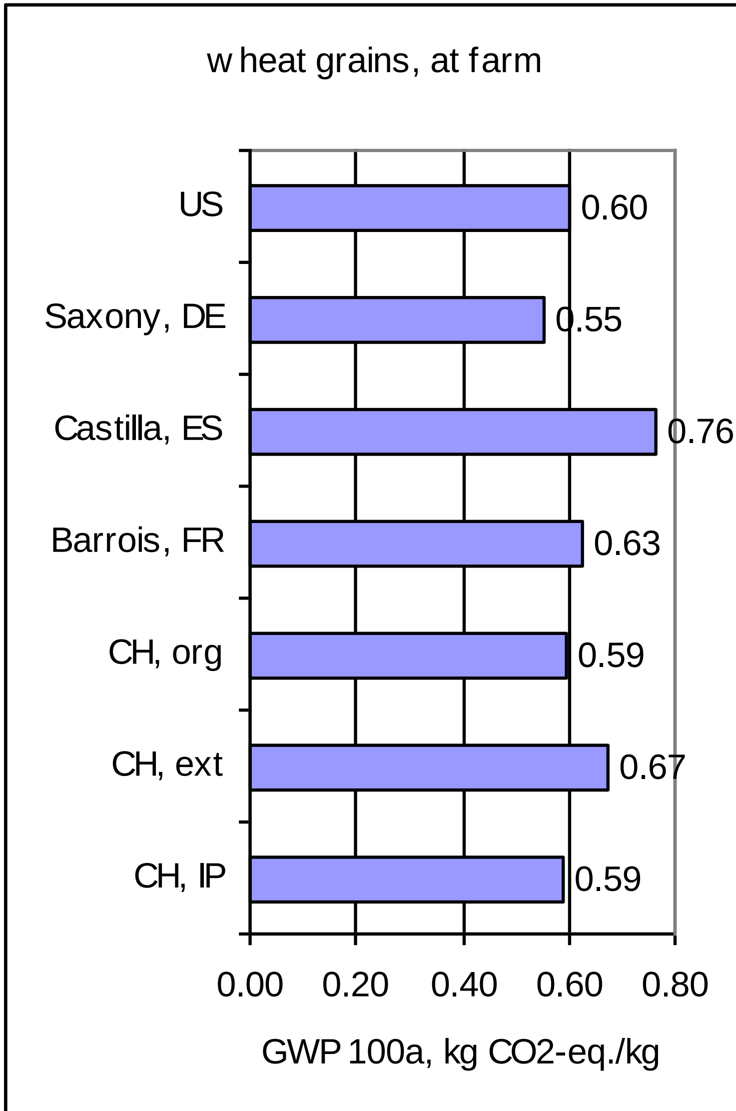
To understand the variability of environmental impacts, we need to look on the variability of the influencing factors

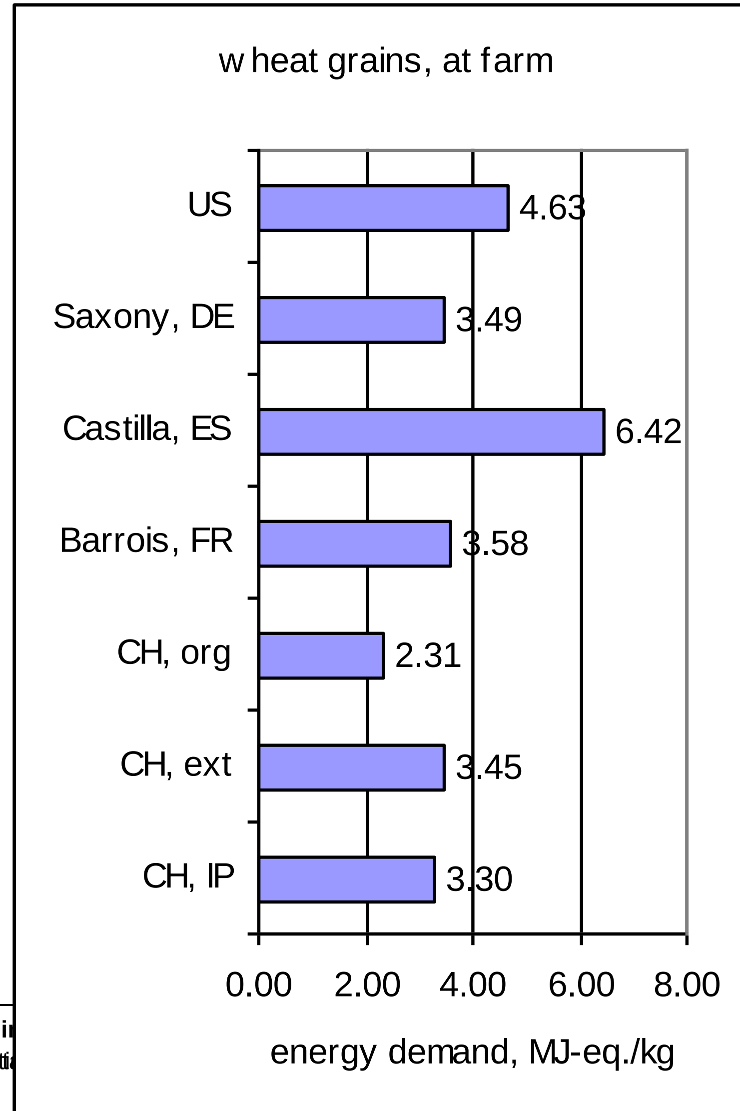
Variability of yields



Source: FAOSTAT

Wheat datasets in ecoinvent V2.01 (2007)





How to establish LCIs in agriculture?

The classical approach:

1. Establish detailed and specific inventories for each situation

Currently used alternatives:

2. Use proxies: what you think is the closest LCI
3. Streamlined LCA models

New approaches:

4. Extrapolation by yield correction
5. Modular extrapolation method

Modular EXtrapolation for Agricultural LCA (MEXALCA)

Basic idea:

- It is possible to split an inventory into different independent modules.
- This enables easier adaptation of an existing inventory to a new situation.

Working procedure:

1. Establish a base inventory for one or several typical situations
2. Split the inventory into independent modules
3. Calculate unit inventories/impacts per module
4. Determine amount of input used in each country (using global estimators derived from FAOSTAT)
5. Extrapolate inventory to any producing country
6. Estimate global/regional impacts (medians, means, distribution)

Extrapolation using MEXALCA

Base crop inventory

Splitting

Calculation of unit impacts

Impacts per input unit
- Basic cropping operations
- Soil tillage
- Variable machinery operations
- N fertilisation, including N-emissions
- P fertilisation, including P-emissions
- K fertilisation
- Pesticide application
- Irrigation
- Product drying

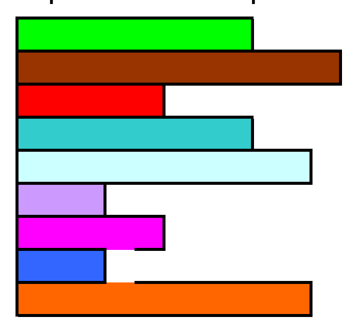
Global estimators
(based on FAOSTAT)

Good quality **data available** for some or all inputs

Input parameters:
- yield per area unit
- Mechanisation index
- % of no-till area
- kg N, P2O5, K2O applied
- kg pesticide active ingredient
- m3 water used
- kg water evaporated

Extrapolation

Impacts for extrapolated situation

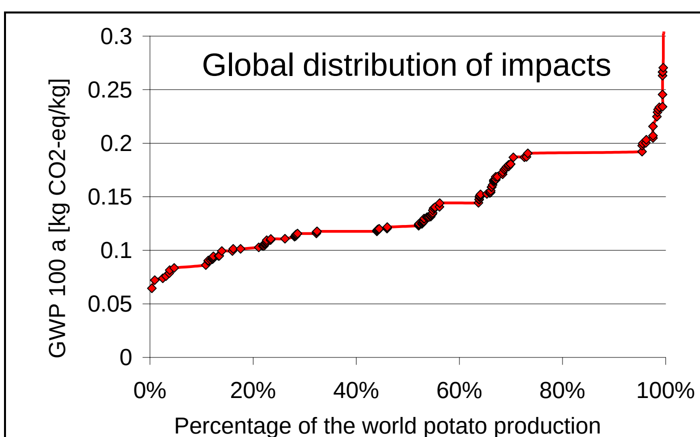


Σ

Total impacts for extrapolated country x

Total impacts for extrapolated country y

Total impacts for extrapolated country z

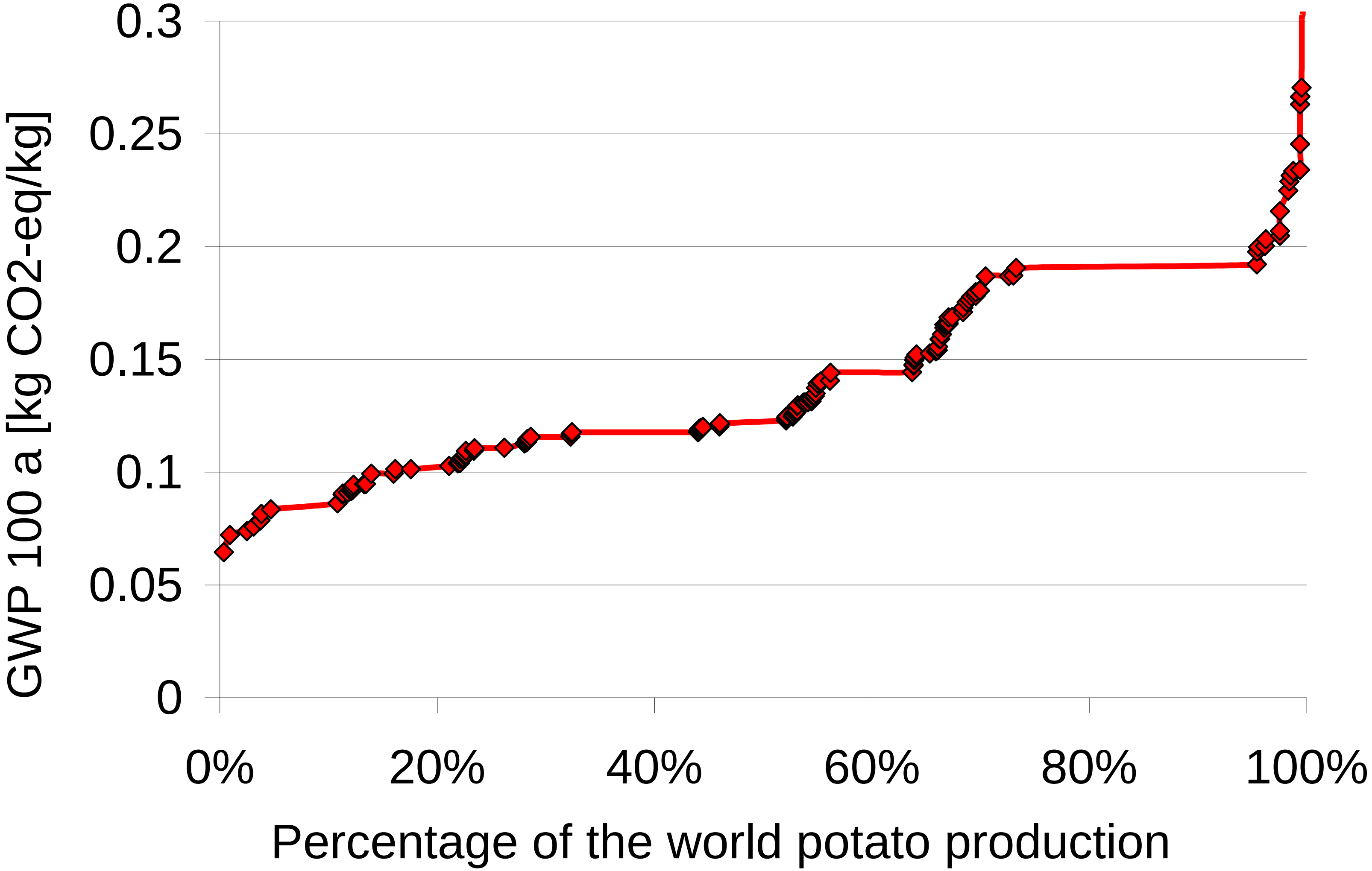


Results: impacts per kg of potato in the world

QUANTILES		2.5%	10.0%	25.0%	median	75.0%	90.0%	97.5%
IMPACTS	Energy [MJ-eq]	9.11E-01	9.77E-01	1.27E+00	1.72E+00	3.00E+00	3.05E+00	4.15E+00
	GWP [kg CO2-eq]	7.38E-02	8.58E-02	1.11E-01	1.23E-01	1.91E-01	1.92E-01	2.05E-01
	O3 form. [kg ethylene-eq]	2.84E-05	3.13E-05	4.75E-05	6.59E-05	8.50E-05	8.53E-05	1.07E-04
	Nutr. enrich. [kg N-eq]	1.85E-03	1.92E-03	2.41E-03	3.44E-03	5.54E-03	5.61E-03	7.52E-03
	Acidific. [kg SO2-eq]	9.44E-04	1.14E-03	1.23E-03	1.49E-03	2.27E-03	2.30E-03	2.82E-03
	Aquat. Ecotox.[kg 1,4-DCB-eq]			1.18E-02	1.65E-02	2.30E-02	3.06E-02	5.24E-02
	Terr. Ecotox. [kg 1,4-DCB-eq]			5.41E-03	9.15E-03	1.26E-02	1.89E-02	3.50E-02
	Human tox.[kg 1,4-DCB-eq]	6.91E-02	6.96E-02	7.26E-02	8.34E-02	1.01E-01	1.40E-01	2.00E-01

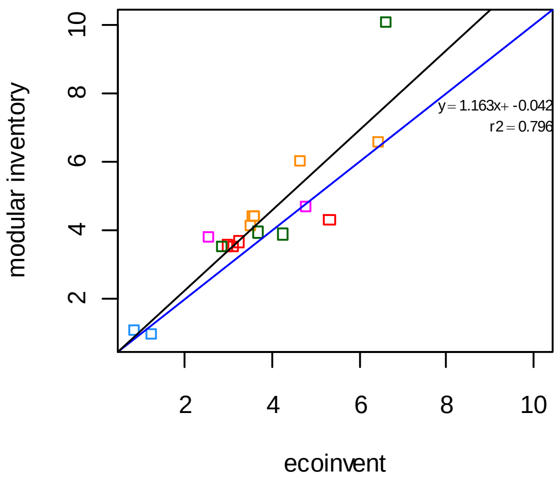
The modular inventory system enables us to calculate the inputs and impacts in any producing country and to calculate median and quantiles for the inputs and for the impacts for the global production (per kg of product or per cultivated ha).

Results: estimated distribution of GWP of potato

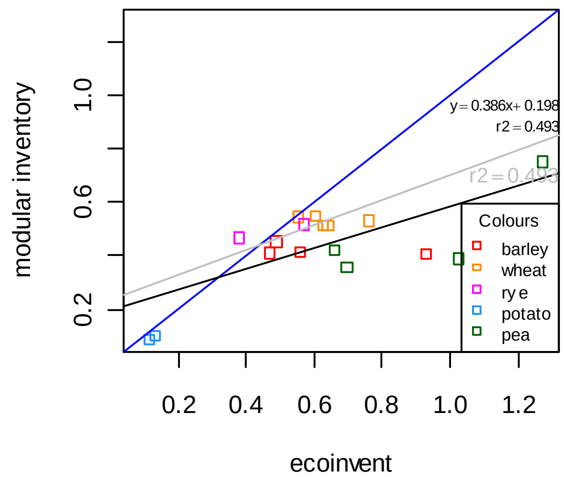


First validation: impacts per kg

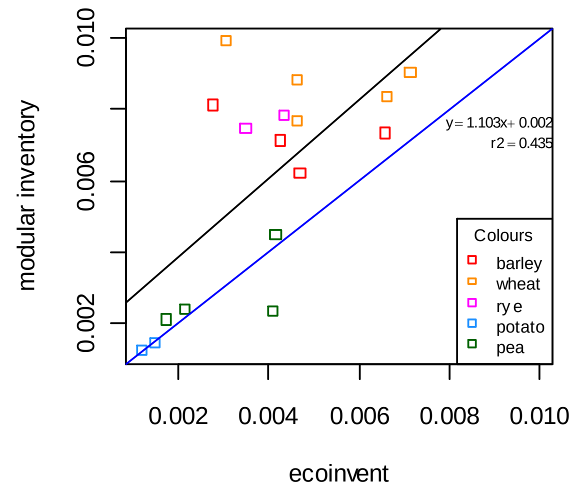
Non renewable energy demand [MJ-eq]



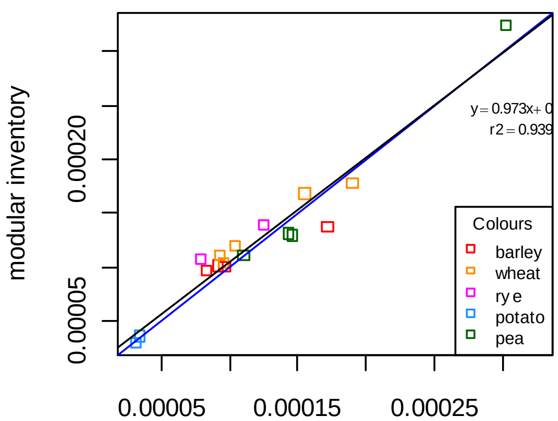
Global Warming Potential 100 years [kg CO2-eq]



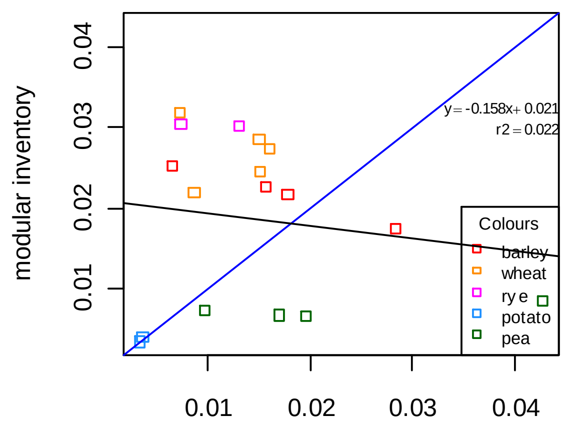
Acidification [kg SO2-eq]



Photochemical ozone formation [kg ethylene-eq]



Nutrient enrichment [kg N-eq]



Sensitivity analysis

- Performed considering the median (=$q_{50\%}$), $q_{10\%}$ and $q_{90\%}$ of each input (estimated variability of the inputs)

POTATO	INPUTS													
	MachVar		***Nfert***		***Pfert***		***Kfert***		***Pestic***		***Irrigat***		***Drying***	
Quantiles	q10%	q90%	q10%	q90%	q10%	q90%	q10%	q90%	q10%	q90%	q10%	q90%	q10%	q90%
IMPACTS														
non-renewable energy [MJ-eq]	-1%	7%	-11%	22%	-2%	3%	-1%	4%	-2%	7%	-27%	62%	0%	0%
GWP 100a [kg CO2-eq]	-1%	5%	-28%	55%	-2%	2%	-1%	3%	-1%	4%	-9%	21%	0%	0%
photo. ozone formation [kg ethylene-Eq]	-1%	11%	-5%	11%	-1%	1%	-1%	3%	-2%	6%	-15%	34%	0%	0%
nutrient enrichment [kg N-eq]	0%	0%	-64%	125%	-4%	5%	0%	0%	0%	0%	0%	1%	0%	0%
Acidification [kg SO2-Eq]	0%	3%	-47%	93%	-3%	3%	0%	1%	-1%	2%	-3%	6%	0%	0%
Aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	0%	0%	0%	1%	-3%	4%	0%	0%	-76%	288%	0%	0%	0%	0%
Terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]	0%	0%	0%	0%	0%	0%	0%	0%	-99%	377%	0%	0%	0%	0%
Human toxicity, 100a [kg 1,4-DCB-Eq]	-1%	7%	-4%	8%	-1%	2%	-1%	3%	-43%	165%	-11%	25%	0%	0%

Variation: 5 to 10%

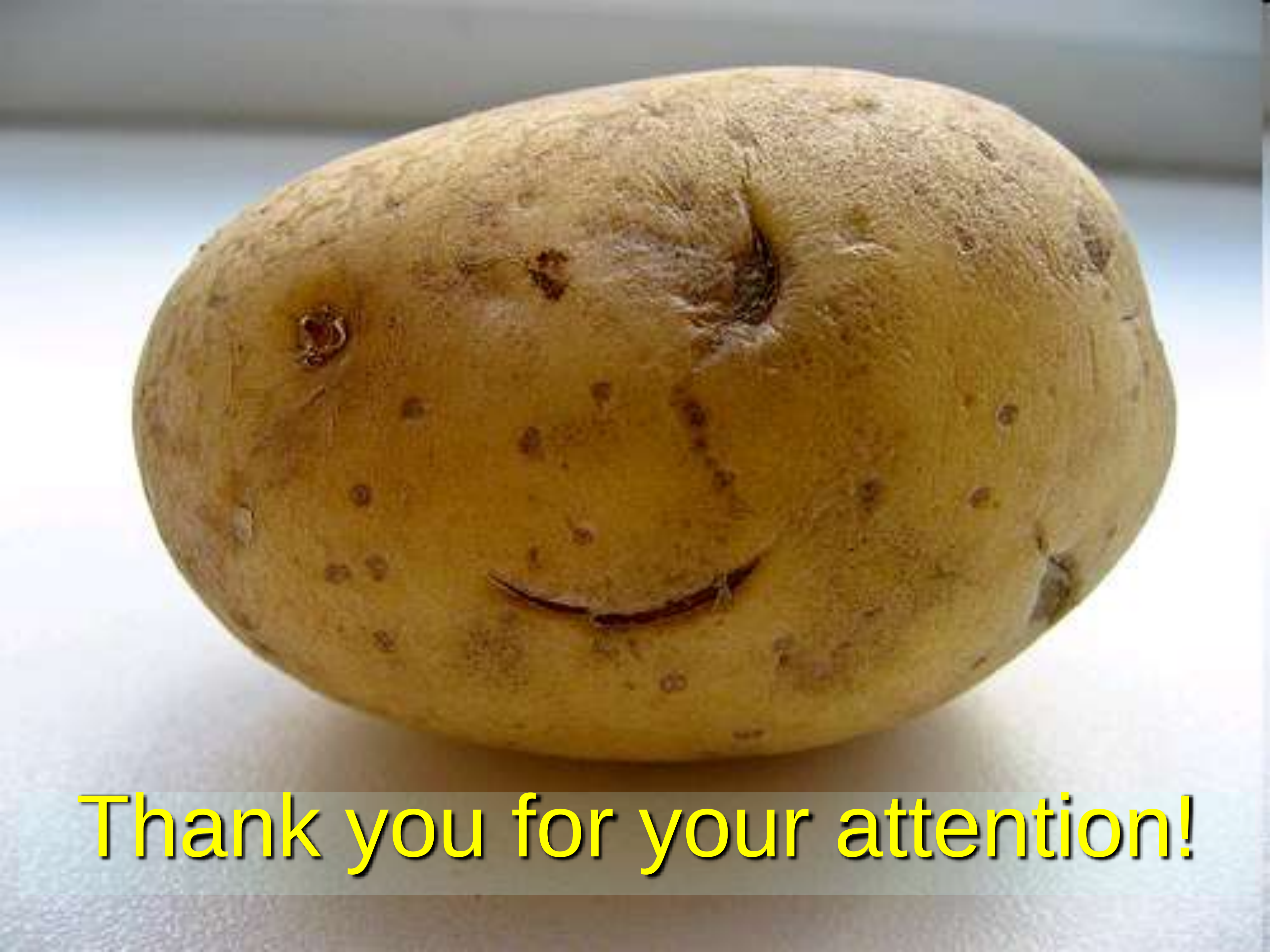
Variation: 10 to 50%

Variation: 50 to 100%

Variation: > 100%

Conclusions and outlook

- Agricultural management, pedo-climatic conditions and impacts are highly variable
- MEXALCA allows to create generic data sets on global and multinational level
- Good estimates possible for energy demand, global warming and ozone formation
- Difficult for eutrophication and acidification (no site-specific parameters considered) and toxicity (no detailed information on pesticide active ingredients)
- Does not replace specific LCIs, but provides reasonable estimates for many situations
- Nitrogen fertilisation and irrigation are key parameters for many impacts in most crops, pesticides determine the toxicity
- This is a promising way towards generic inventories, the method will be further developed


Thank you for your attention!