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Development of a regionalized agricultural production inventory

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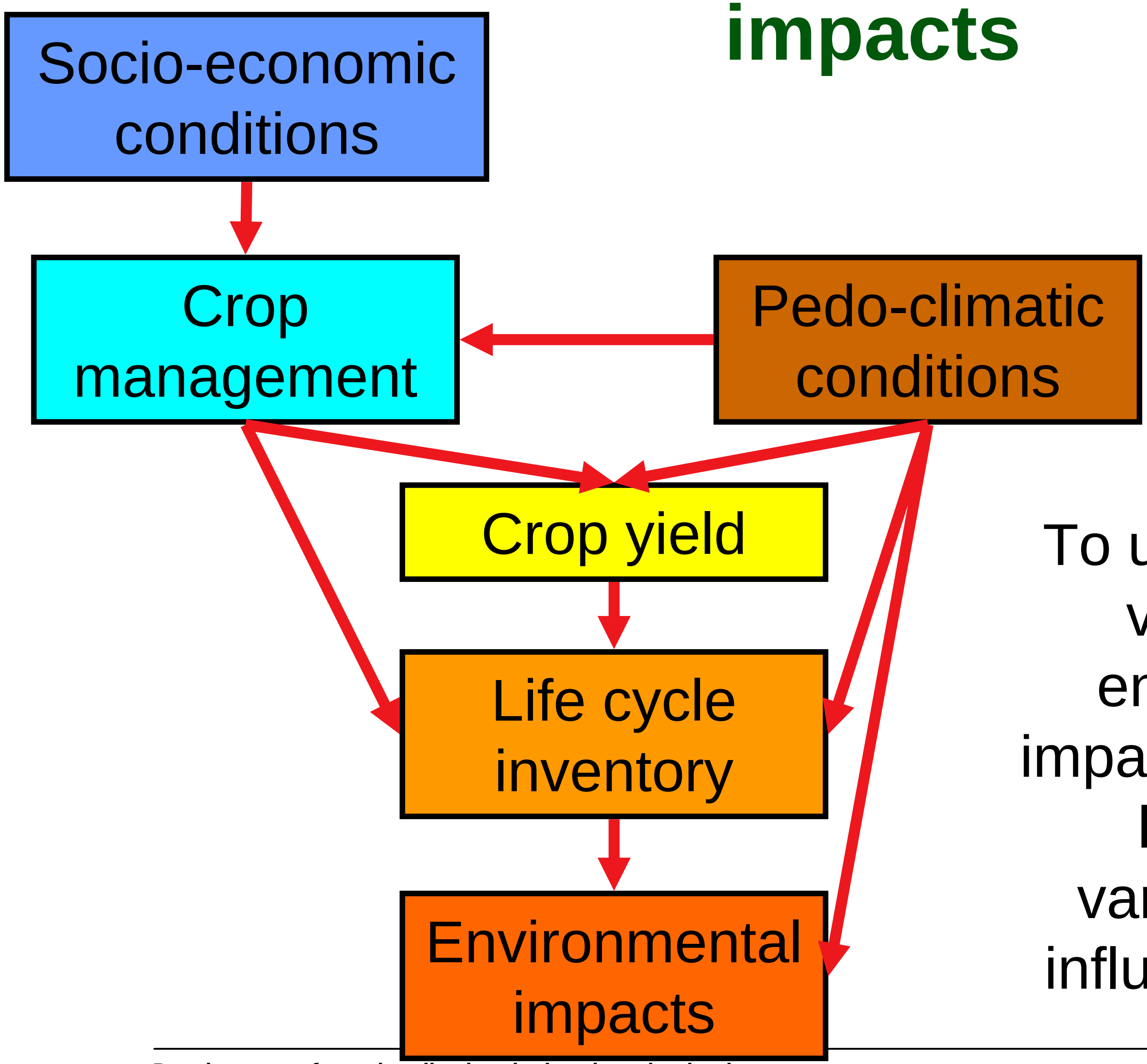
Outline

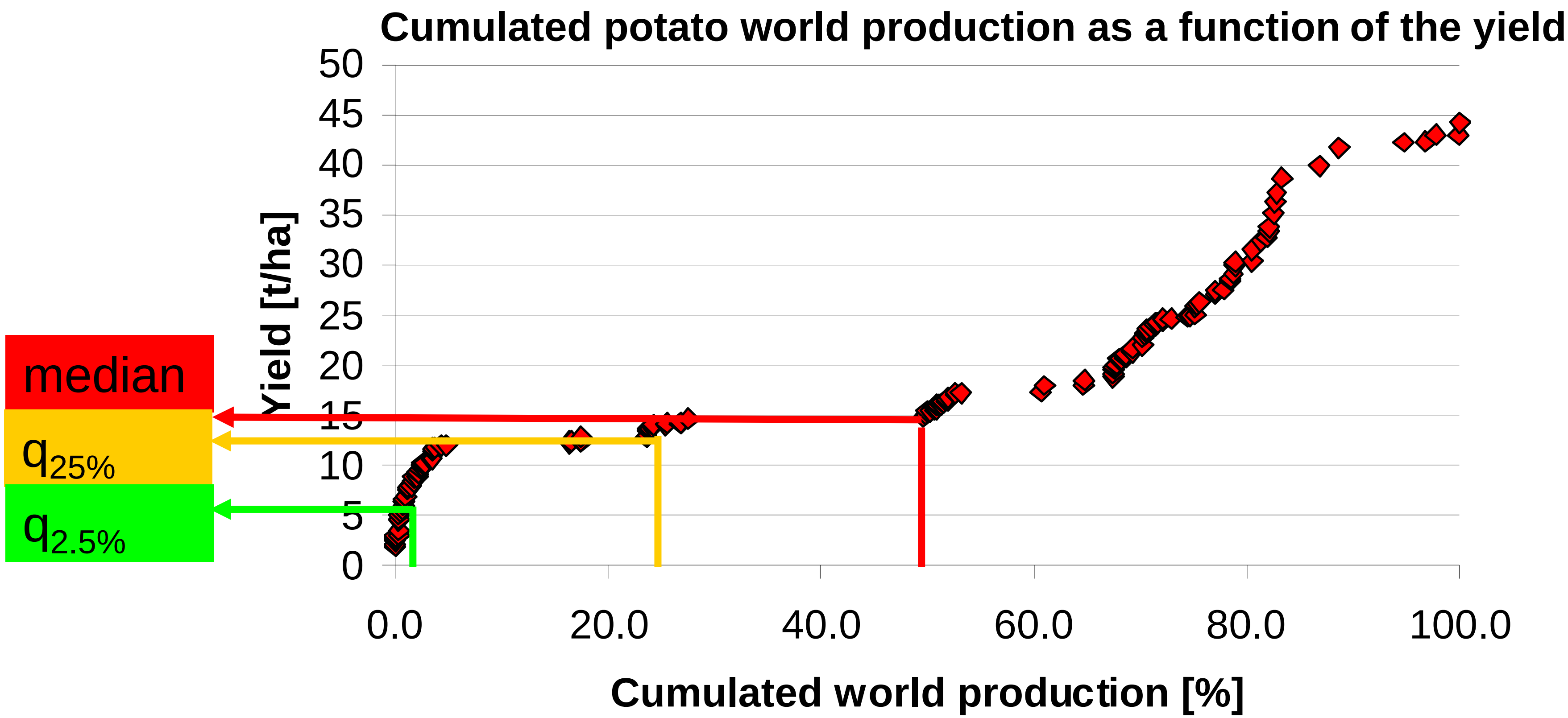
1. Agricultural data variability
2. Different approaches for LCI modelling in agriculture
3. Extrapolation by yield correction
4. Modular Extrapolation in Agricultural LCA (MEXALCA)
5. First results
6. First validation
7. Conclusions
8. Outlook

Factors influencing environmental impacts



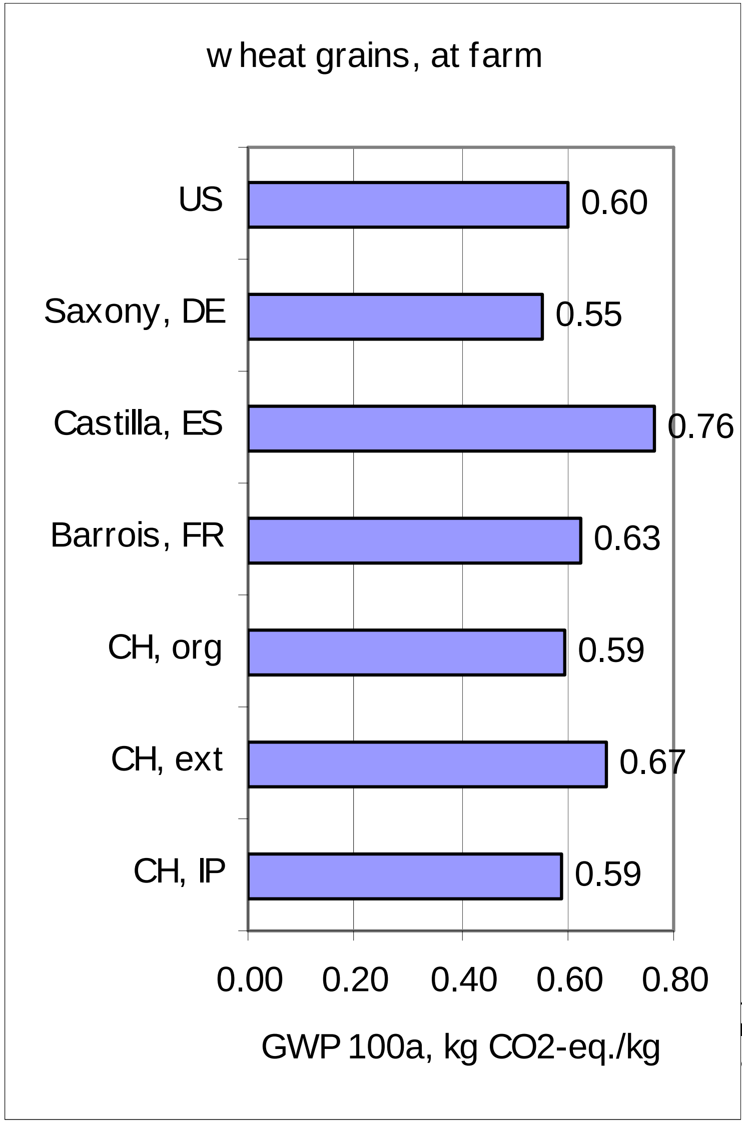
To understand the variability of environmental impacts, we need to look on the variability of the influencing factors

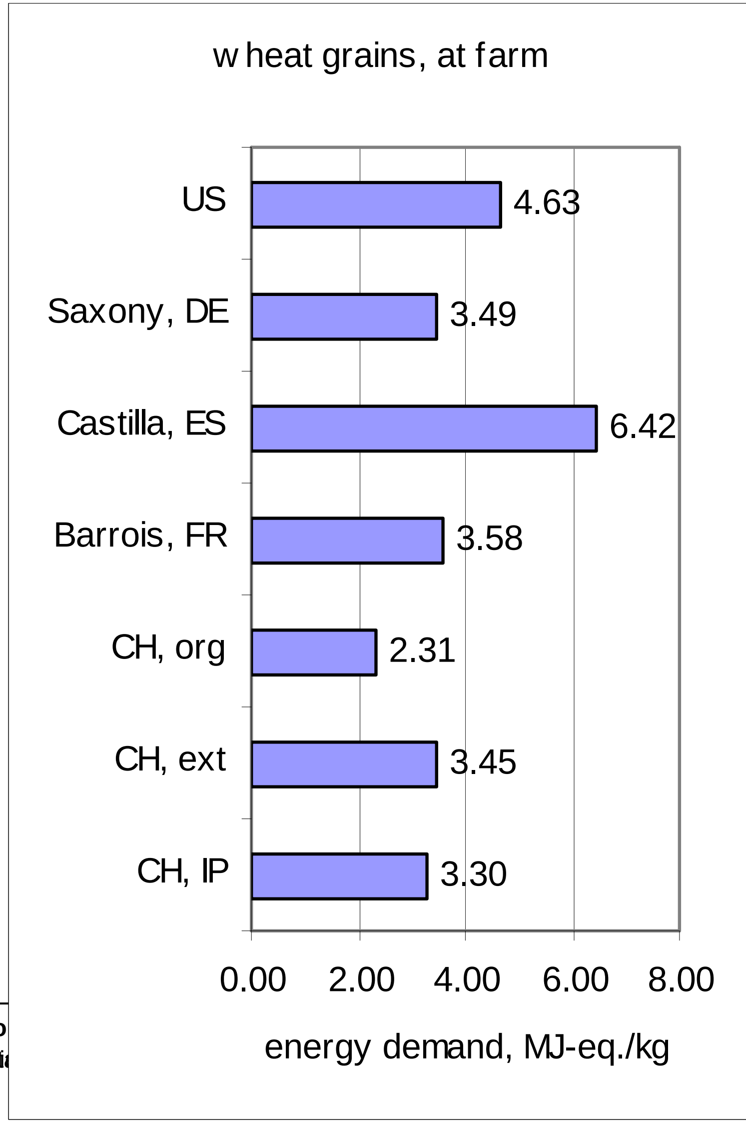
Variability of yields



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

Extrapolation by yield correction

- Product extrapolation: $E_p^c = e_p \times \frac{E_a^{c'}}{Y^{c'}} + (1 - e_p) \times \frac{E_a^{c'}}{Y^c}$
- Geographical extrapolation: $E_p^l = e_p \times \frac{E_a^{l'}}{Y^{l'}} + (1 - e_p) \times \frac{E_a^{l'}}{Y^l}$

Impacts related to the yield (constant per kg)

Impacts not related to the yield (constant per ha)

$e_p =$ Fraction of the impacts related to the yield

Estimation of this fraction:

- 0.7 for cereals from the ecoinvent datasets
- 0.5 as default value

Modular EXtrapolation for Agricultural LCA (MEXALCA)

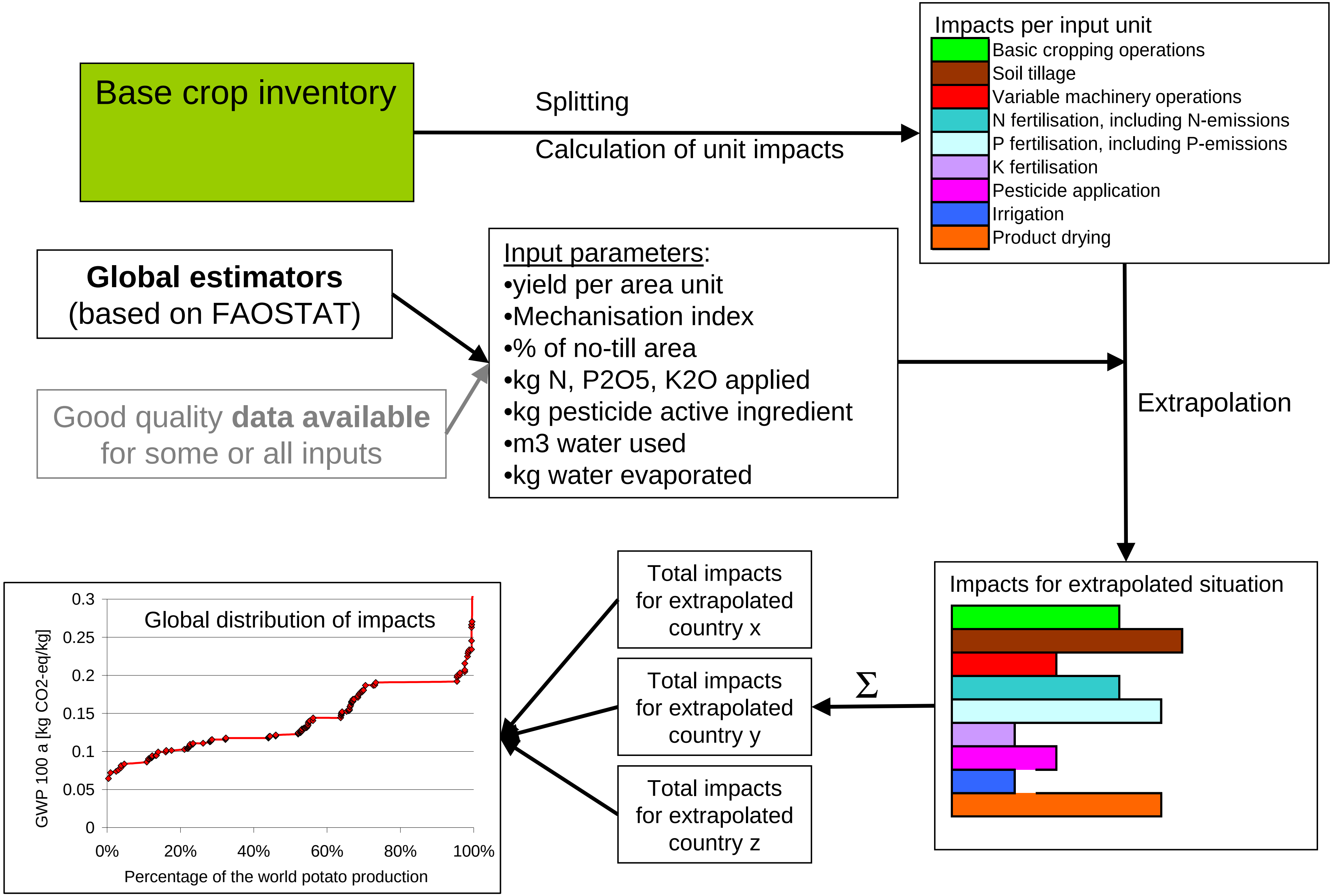
Basic idea:

- 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 and input unit
4. Determine amount of inputs 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



Results: impacts per input unit

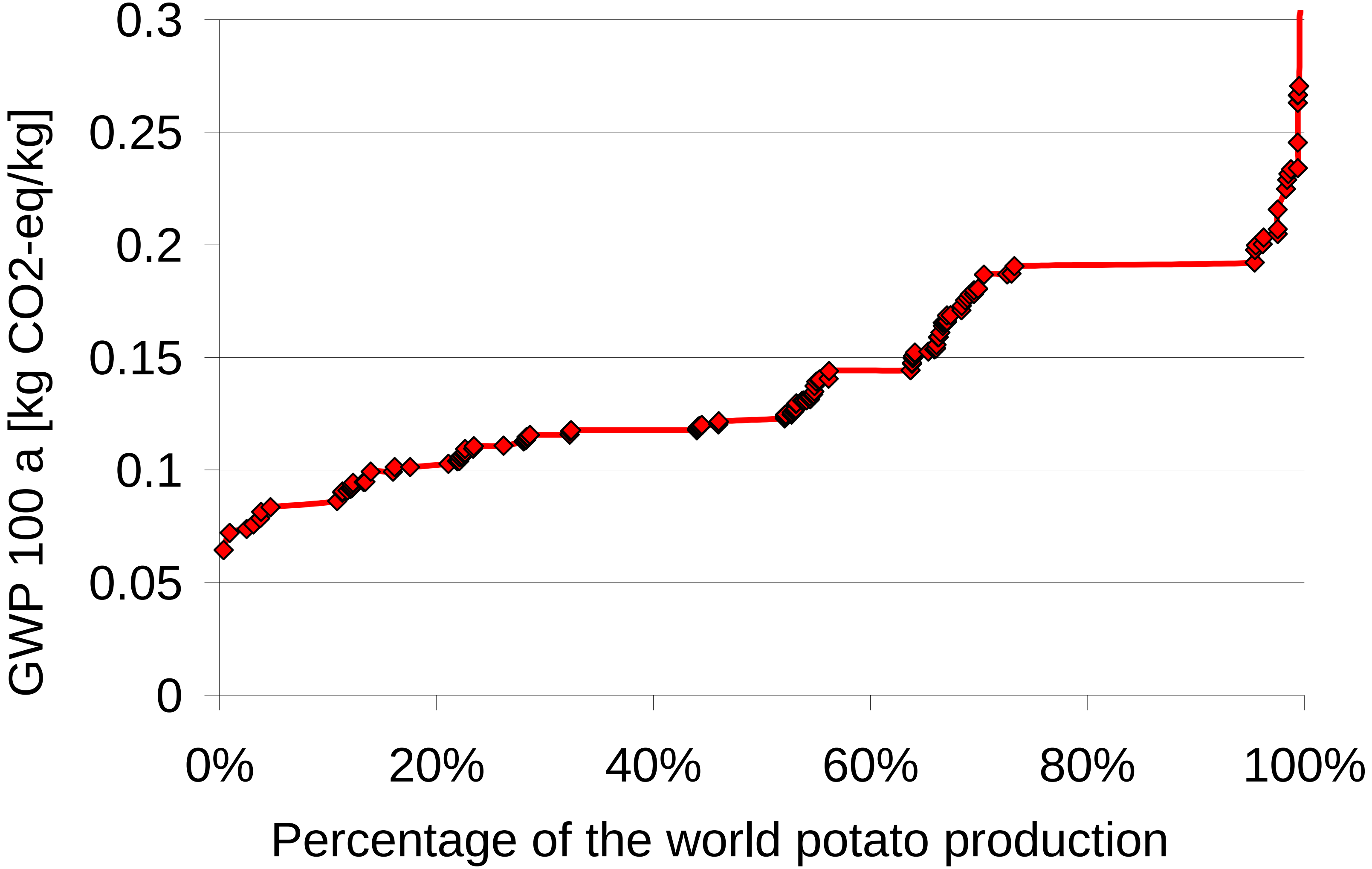
Potatoes *Impacts*	*Modules*								
	MachFix	MachTill	MachVar	Nfert	Pfert	Kfert	Pestic	Irrigat	Drying
non-renewable Energy [MJ-eq]	13604.50	1818.25	4621.45	70.91	31.26	10.69	341.5	9.988	0
GWP 100a [kg CO2-eq]	1074.68	118.49	272.66	13.45	2	0.614	15.127	0.247	0
photochemic O3 formation [kg ethylene-eq]	0.65	0.08	0.23	0.001	6E-04	2E-04	0.0092	2E-04	0
Nutrient enrichment [kg N-eq]	12.65	0.34	0.60	0.917	0.126	7E-04	0.023	2E-04	0
Acidification [kg SO2-eq]	9.38	0.95	1.80	0.282	0.039	0.003	0.099	9E-04	0
Aquatic ecotoxicity 100a [kg 1,4-DCB-eq]	56.92	0.13	0.45	0.015	0.404	0.007	114.99	4E-04	0
Terrestrial ecotoxicity 100a [kg 1,4-DCB-eq]	0.99	0.01	0.05	7E-04	0.009	3E-04	80.696	1E-04	0
Human toxicity 100a [kg 1,4-DCB-eq]	460.52	38.32	209.11	1.216	0.97	0.337	337.68	0.181	0

Results: impacts per kg of potato in the world

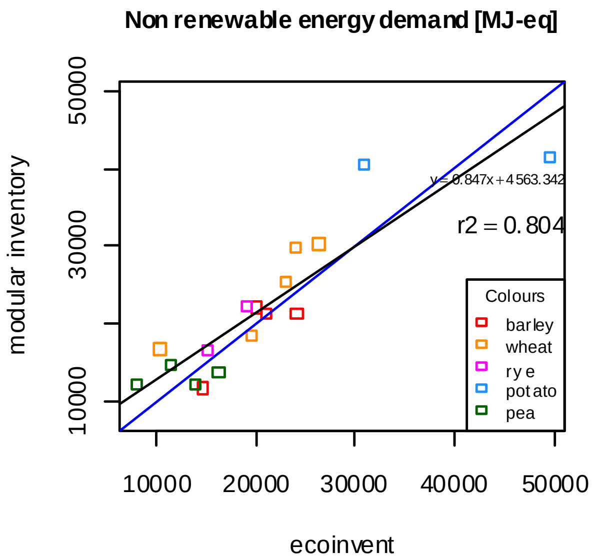
QUANTILES		2.5%	10.0%	25.0%	median	75.0%	90.0%	97.5%
	Energy [MJ-eq]	9.11E-01	9.77E-01	1.27E+00	1.72E+00	3.00E+00	3.05E+00	4.15E+00
	GWP [kg CO2-eq]	7.38E-02	8.58E-02	1.11E-01	1.23E-01	1.91E-01	1.92E-01	2.05E-01
	O3 form. [kg ethylene-eq]	2.84E-05	3.13E-05	4.75E-05	6.59E-05	8.50E-05	8.53E-05	1.07E-04
IMPACTS	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

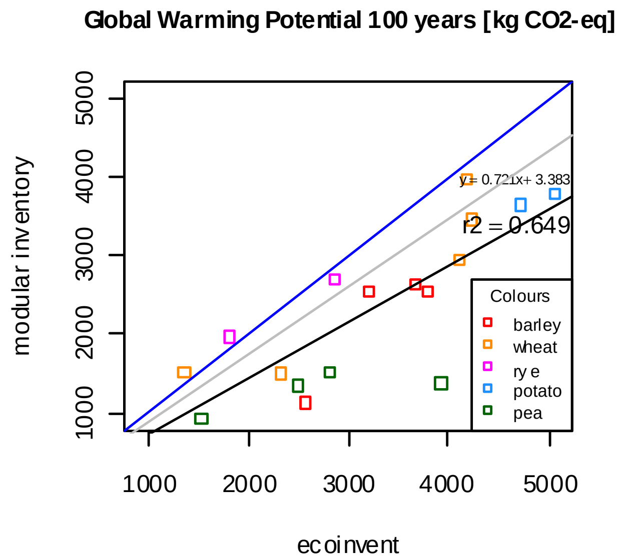
The modular inventory system enables us to calculate the inputs and impacts in any producing country and to calculate median and quantiles for the inputs and for the impacts for the global production (per kg of product or per cultivated ha).

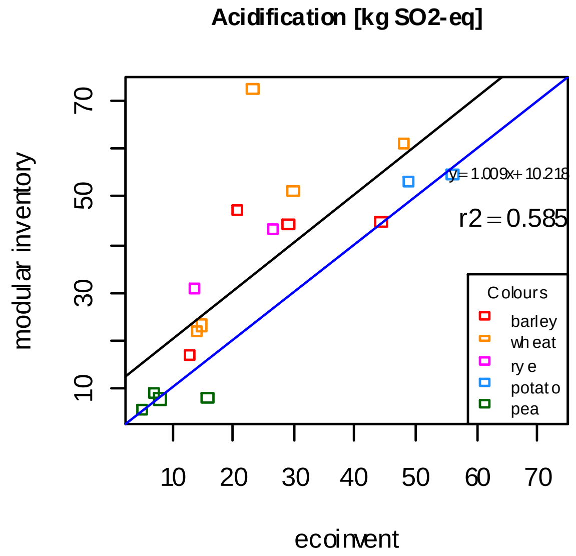
Results: estimated distribution of GWP of the potato production

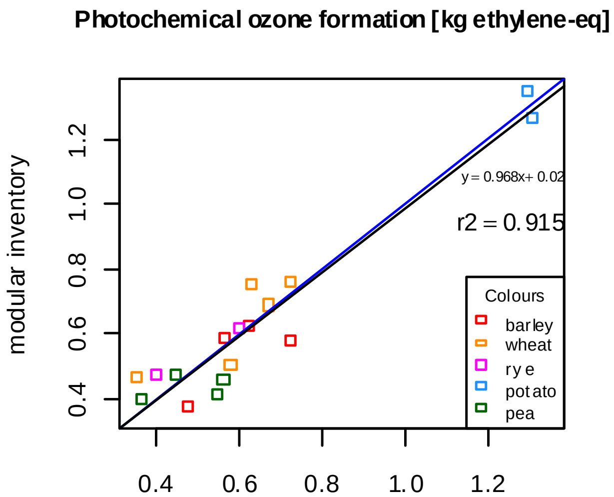


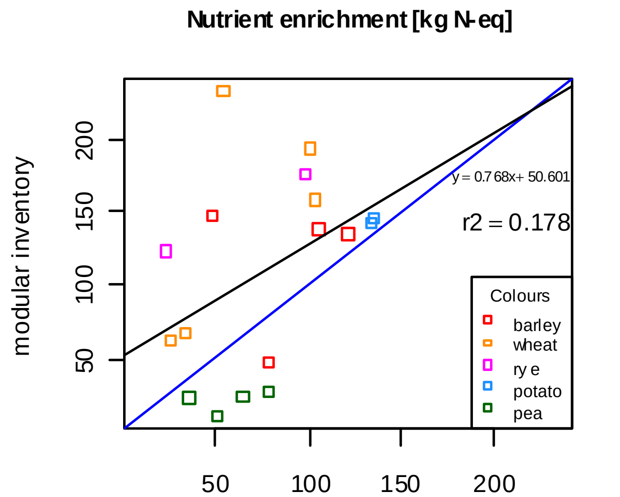
First validation: impacts per ha





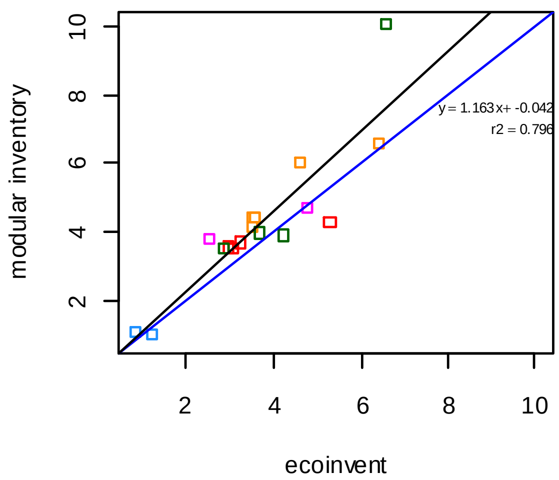




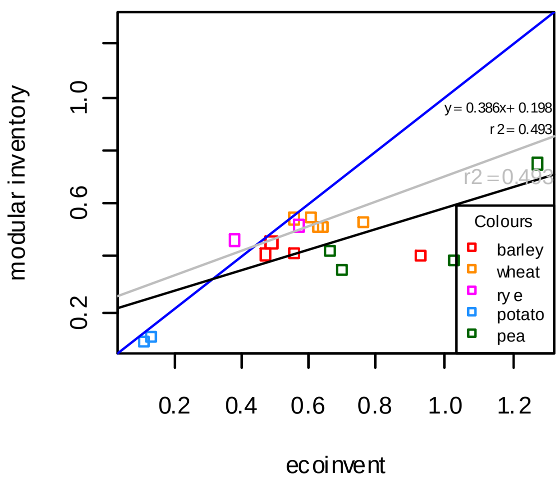


First validation: impacts per kg

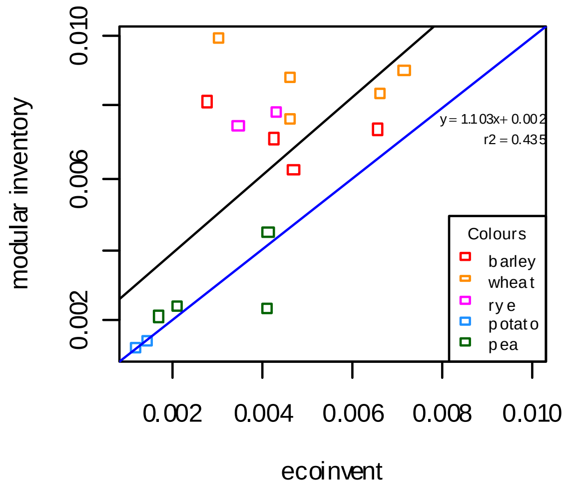
Non renewable energy demand [MJ-eq]



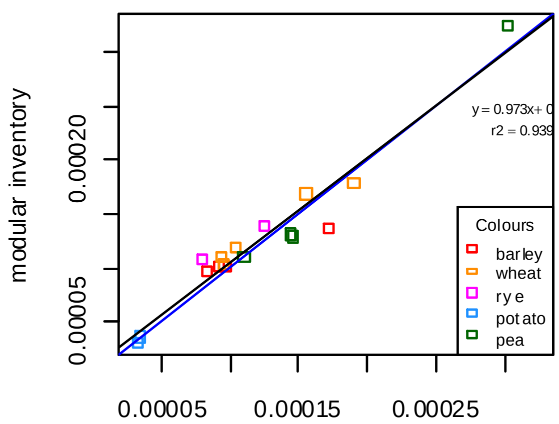
Global Warming Potential 100 years [kg CO2-eq]



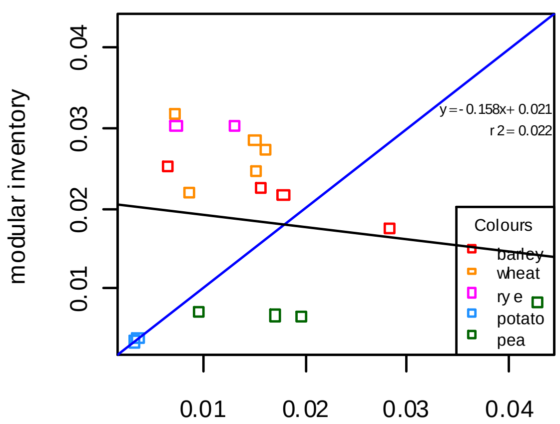
Acidification [kg SO2-eq]



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%

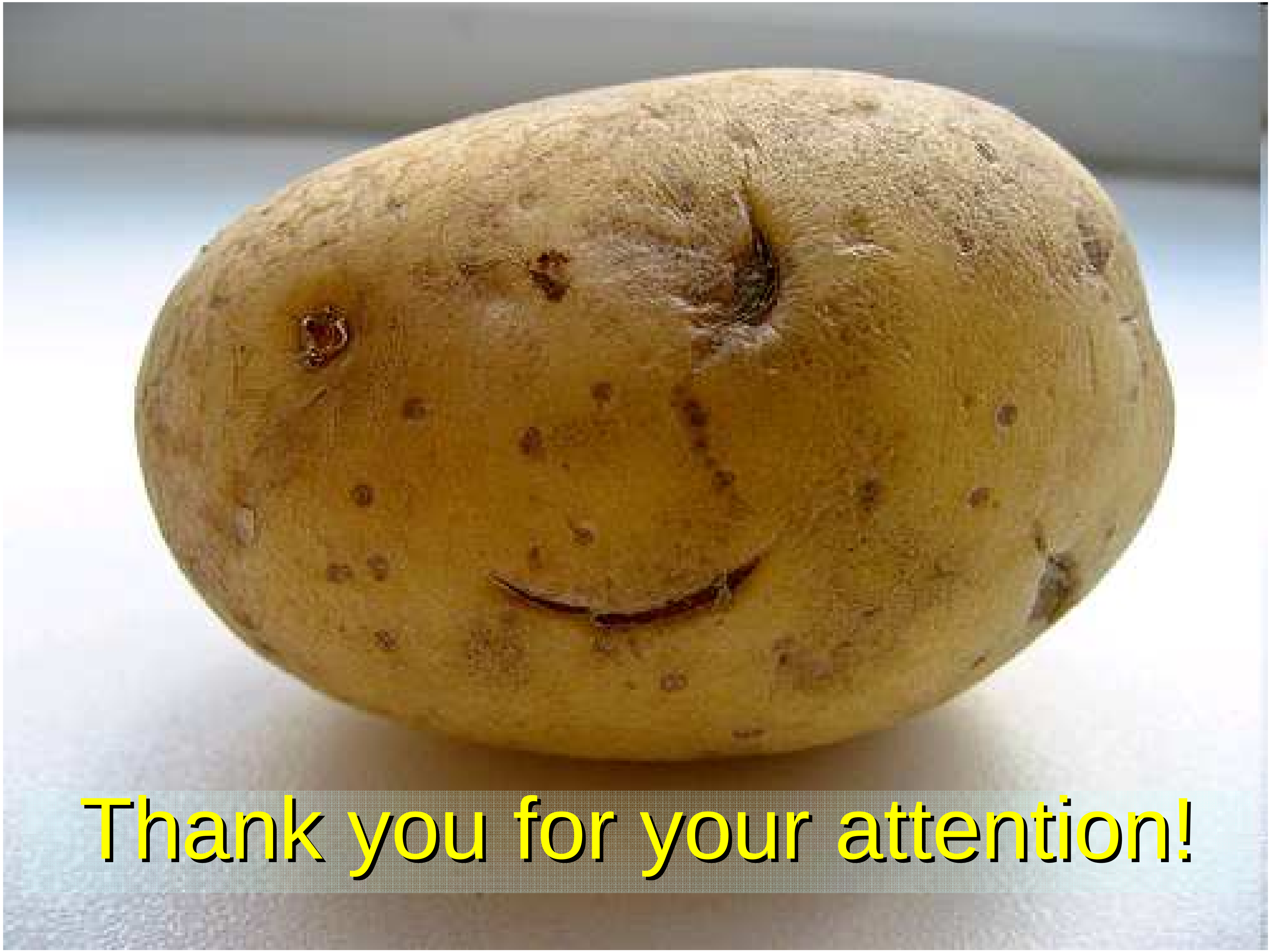
Variation: 5 to 10% | Variation: 10 to 50% | Variation: 50 to 100% | Variation: > 100%

Conclusions

- 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

Outlook

- Currently the method is being improved …
  - Estimation of area under tillage
  - Irrigation
  - Product drying
  - Improvement of the agricultural intensity indices
- … extended to further crops …
- … and validated by using further data.
- This is a promising way towards generic inventories, the method will be further developed


Thank you for your attention!