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LCA of sunflower oil addressing alternative land use change scenarios and practices

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Outline

- **Introduction**
  - Background and Motivation
  - Main goal
- **Life-Cycle Model and Inventory**
  - Life Cycle model
  - Land use change scenarios and carbon calculations
  - Inventory: Sunflower cultivation and oil extraction
- **Results**
  - GHG balance (LUC scenario analysis)
  - LCIA results (excluding LUC)
  - Normalised results
- **Conclusions**

Background and Motivation

- Sunflower is one of the leading oilseed crops used for the production of oil for human consumption. Sunflower oil is also an important crop for biodiesel production in southern European countries;

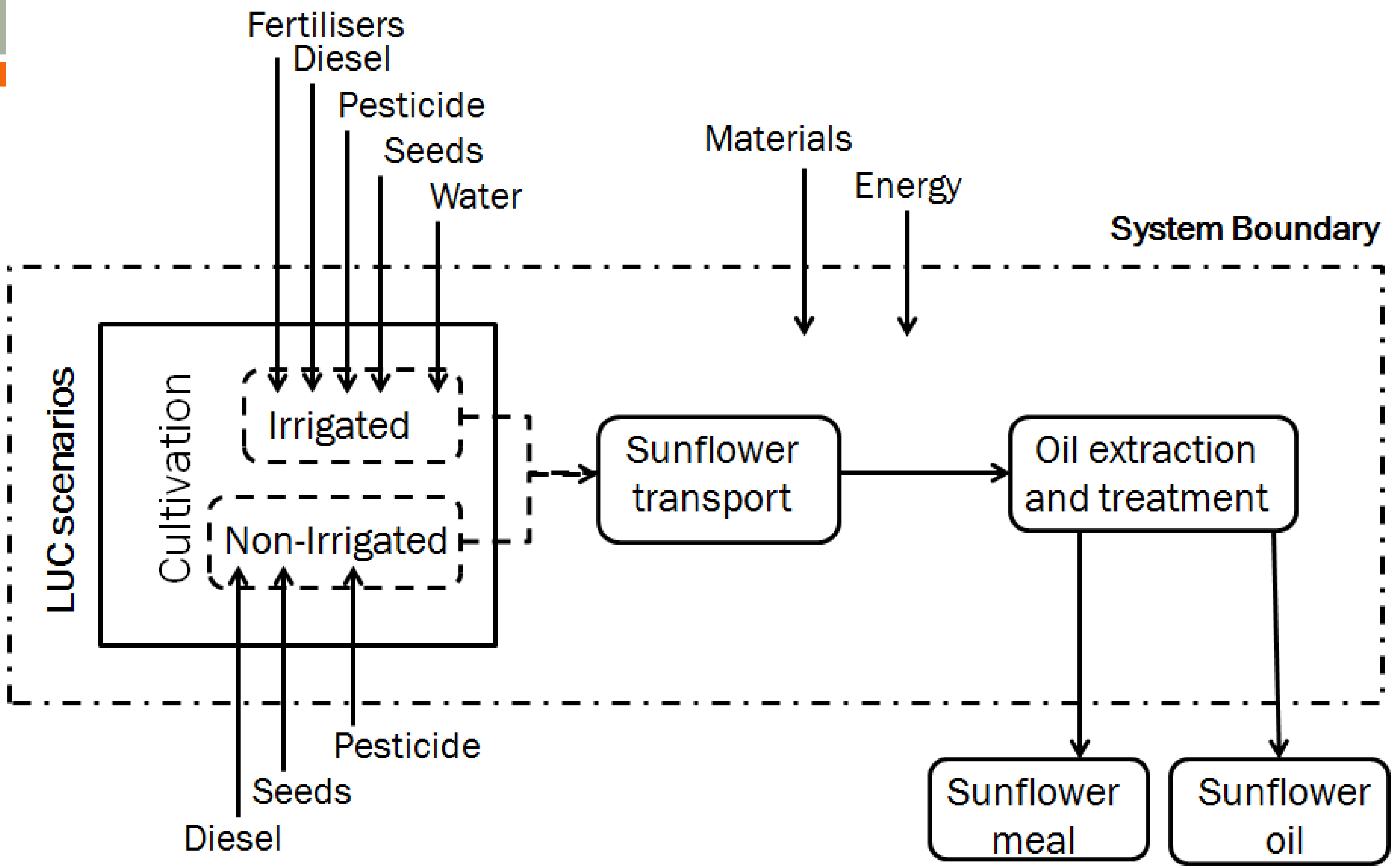
- Increasing prices of food products together with the expansion of biodiesel produced from vegetable oils in Europe may lead to an increase in the production of sunflower in Portugal, which can be achieved by the expansion of sunflower plantation area (extensification) or by an increase in the productivity (intensification);

- LUC and cultivation are emergent topics with important implications in terms of the greenhouse gas (GHG) balance of food and bioenergy crops

Goal

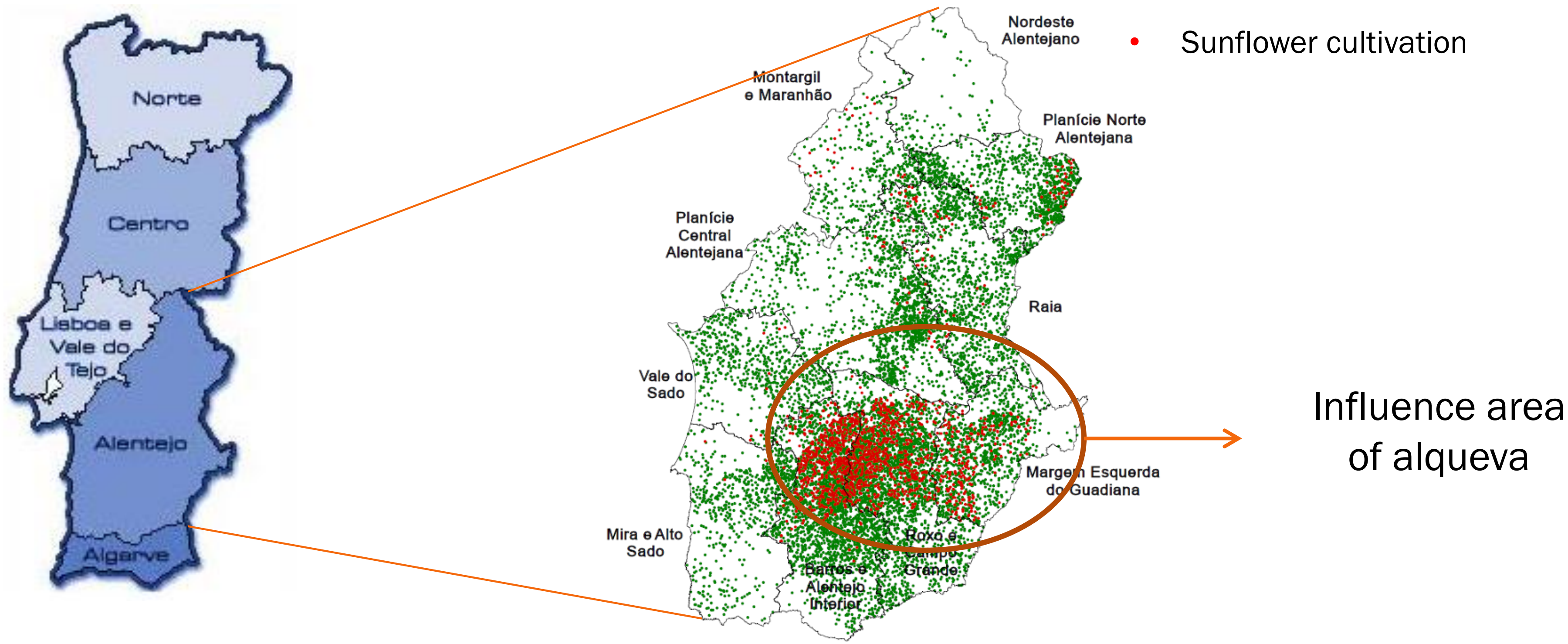
- To perform an LCA of sunflower oil produced in Portugal:
  - Comparative assessment of the environmental impacts of sunflower cultivated in irrigated and non irrigated land;
  - Assess 28 alternative Land Use Change (LUC) scenarios;
  - Identify the LC phase & processes with higher environmental impacts.

Life-Cycle model



FU: 1 kg oil

Sunflower cultivation in Portugal



- ❖ **Climate region** – Warm temperate, dry
- ❖ **Soil type** - High Activity Clay Soils

Important aspects for the calculation of carbon stocks

Carbon calculations from LUC

Emissions from carbon-stock changes caused by LUC (kg CO_{2eq}/kg_{oil}) were calculated using this equation (Renewable Energy Directive, adapted from IPCC Tier 1)

$$e_l = (CS_R - CS_A) \times 44/12 \times 1/20 \times 1/P$$

CS_R - carbon stock associated with the each reference LU (grassland or perennial) (kg CO_{2eq}/ha)

CS_A - carbon stock associated with the actual LU (sunflower oil plantation) (kg CO_{2eq}/ha)

P - sunflower oil productivity (kg $_{oil}$/ha per year)

$$CS_i = SOC_i + C_{veg} = (SOC_{ST} \times F_{LU} \times F_{MG} \times F_I) + C_{veg}$$

SOC_{ST} - standard value of soil organic carbon

F_{LU}, F_{MG}, F_I - factors reflecting the difference in SOC associated with the **type of land use**, **management practice** and **different levels of carbon input to soil** compared to the SOC_{ST}

C_{veg} - above and below ground vegetation carbon stock in living biomass and in dead organic matter

Land Use Change Scenarios

28 LUC scenarios based on a combination of 4 actual & 7 previous Land Use

Actual Land Use			$SOC_i = (SOC_{ST} * F_{LU} * F_{MG} * F_I)$				SOC_i	C_{VEGi}	$CS_i = SOC_i + C_{VEGi}$
			SOC_{ST} (t C/ha)	F_{LU}	F_{MG}	F_I	(t C/ha)	(t C/ha)	(t C/ha)
Sunflower cultivation	Irrigated, RT, medium input	A1	38	0.8	1.02	1.00	31.0	**0**	31.0
	Irrigated, NT, medium input	A2	38	0.8	1.10	1.00	33.4	**0**	33.4
	Non-irrigated, RT, low input	A3	38	0.8	1.02	0.95	29.5	**0**	29.5
	Non-irrigated, NT, low input	A4	38	0.8	1.10	0.95	31.8	**0**	31.8
Reference Land Use									
Grassland (improved, medium input)		R1	38	1.0	1.14	1.00	43.3	**3.1**	46.4
Grassland (improved, high input)		R2	38	1.0	1.14	1.11	48.1	**3.1**	51.2
Grassland (severely degraded, medium input)		R3	38	1.0	0.70	1.00	26.6	**3.1**	29.7
Perennial crop (RT, high input, with manure)		R4	38	1.0	1.02	1.37	53.1	**43.2**	96.3
Perennial crop (RT, high input, without manure)		R5	38	1.0	1.02	1.04	40.3	**43.2**	83.5
Perennial crop (NT, high input, with manure)		R6	38	1.0	1.10	1.37	57.3	**43.2**	100.4
Perennial crop (NT, high input, without manure)		R7	38	1.0	1.10	1.04	43.5	**43.2**	86.7

4 actual land uses (A1-A4)

7 reference land use (R1-R7)

NT– no tillage; RT– reduced tillage

L-C Inventory (Portuguese data) : cultivation and oil extraction

Main Inputs	Irrigated	Non-Irrigated	
N	0.007	-	kg
K_2O	0.021	-	kg
P_2O_5	0.021	-	kg
Pesticide (atrazine)	0.001	0.0023	kg
Seeds (cultiv.)	0.0023	0.0046	kg
Diesel	0.0523	0.1539	L
Water	1.5	-	m^3

Product	Irrigated	Non-Irrigate	
Sunflower seeds	1	1	kg
Productivity	3000 ↑	650 ↓	kg/ha

Main Inputs		
Sunflower seeds	2.29	kg
Natural Gas	1.63	MJ
Bentonite	5.38×10^{-3}	kg
Hexane	2.53×10^{-3}	kg
Phosphoric acid	8.16×10^{-4}	kg
Electricity	9.66×10^{-2}	kWh
Co-products		
Sunflower oil	1	kg
Sunflower meal	1.29	kg

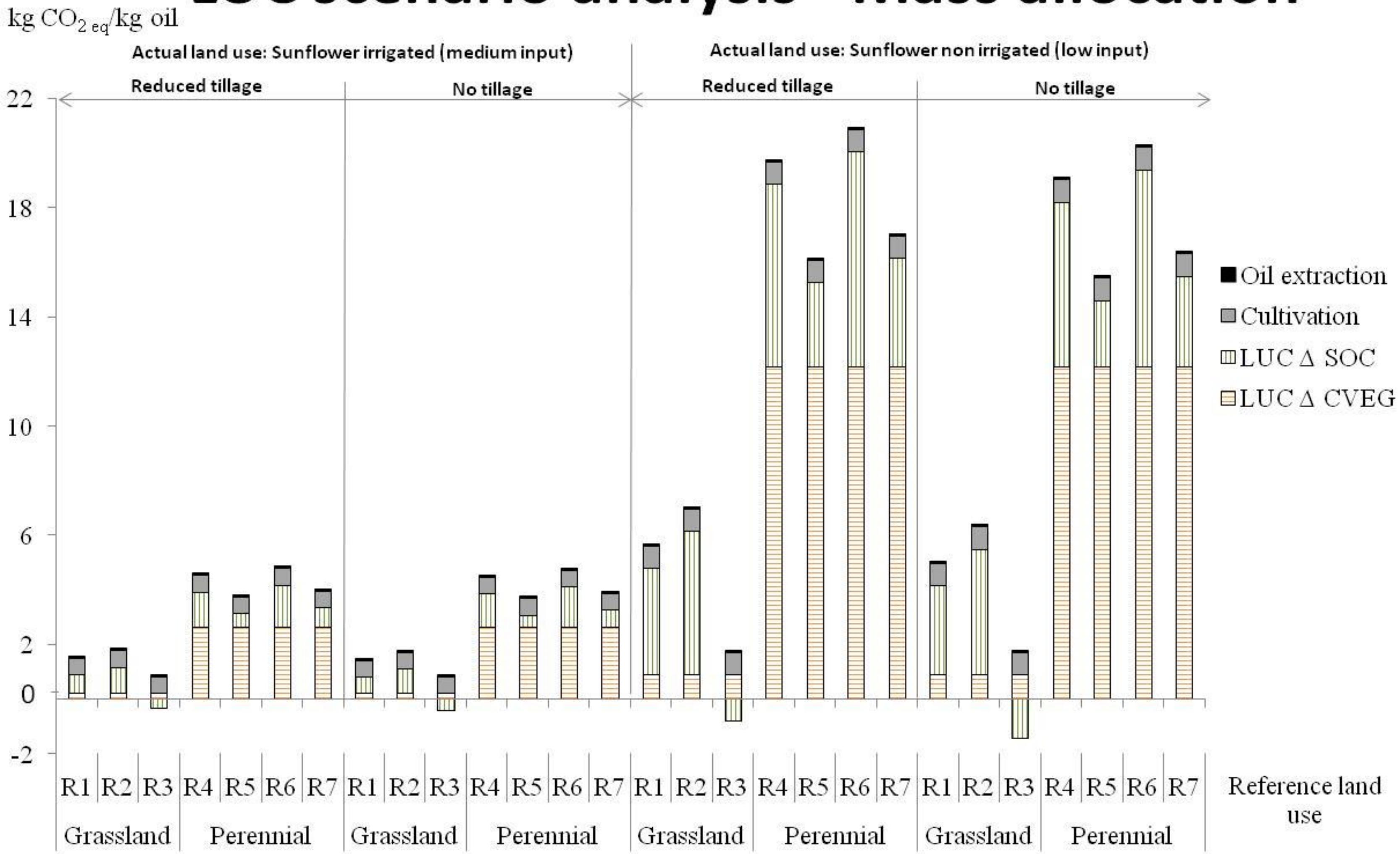
Multifunctionality

A sensitivity analysis was performed for 3 allocation approaches:

- Mass (43% oil, 57% meal),
- Energy (65% oil, 35% meal),
- Economic (77% oil, 23% meal)

but results presented here are for mass-based allocation.

LUC scenario analysis - Mass allocation



- GHG intensity greatly depends on the LUC scenario (0.3-20.9 kg CO_{2eq}/kg_{oil}).
- Lowest values: conversion of grassland (R1, R2 & R3). For severally degraded grassland, Δ SOC is positive (negative contribution to emissions).
- Highest values: due to a high loss of C_{VEG} in the conversion of perennial crops (R4 to R7)
- No tillage has slightly lower emissions than reduced tillage.

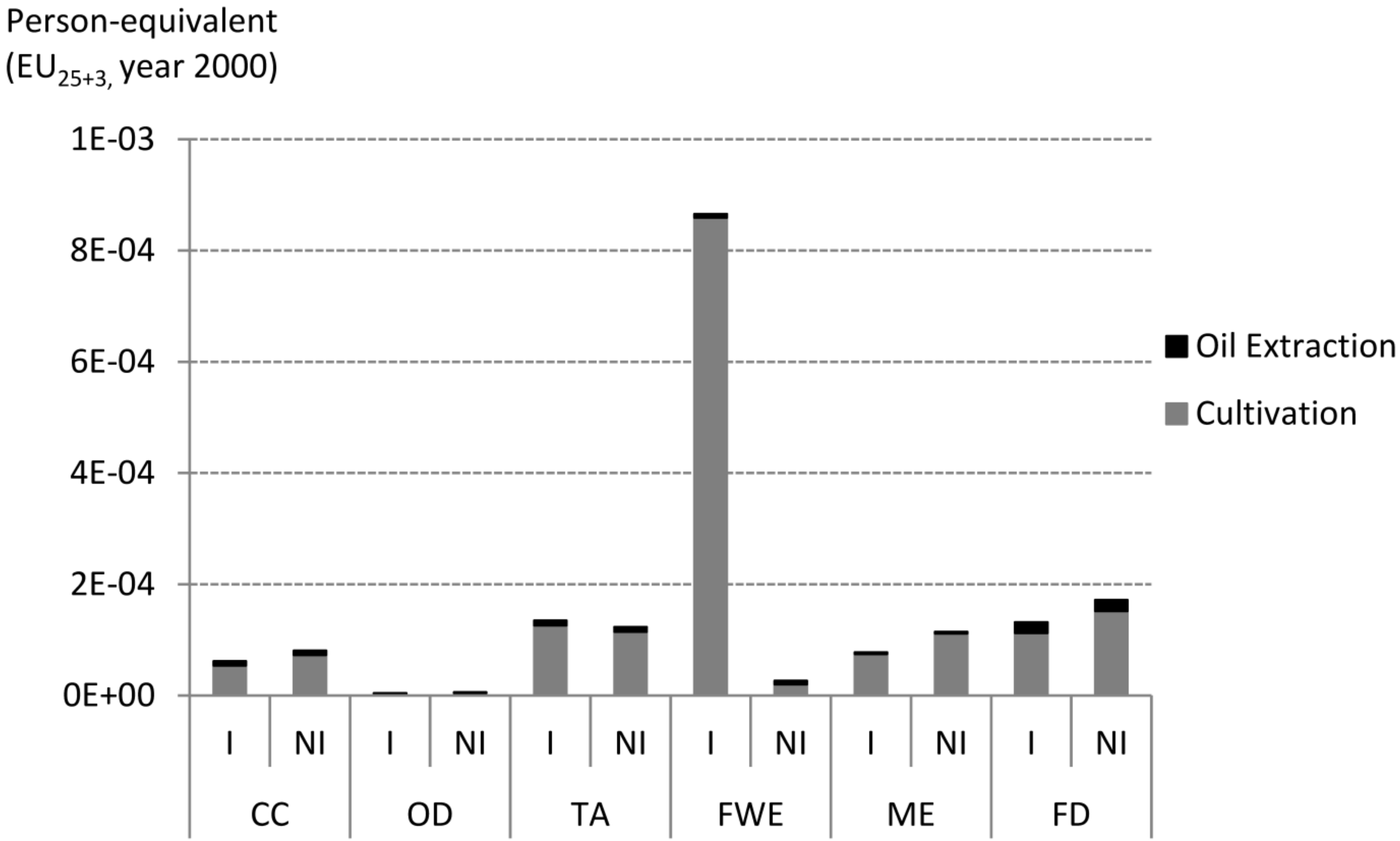
LCIA results (excluding LUC)

	CC (kg $CO_{2\ eq}$) x10^{-1}		OD (kg CFC^{-11}) x10^{-7}		TA (kg $SO_{2\ eq}$) x10^{-3}		FWE (kgP $_{eq}$) x10^{-4}		ME (kg N $_{eq}$) x10^{-3}		FD (kg oil $_{eq}$) x10^{-1}	
	I	NI	I	NI	I	NI	I	NI	I	NI	I	NI
Cultivation	6.08	8.22	0.72	1.05	4.34	3.94	3.56	0.085	1.42	2.12	1.87	2.53
Oil Extraction	0.81		0.10		0.28		0.025		0.047		0.32	
Total	6.89	9.03	0.82	1.15	4.62	4.22	3.59	0.11	1.47	2.17	2.19	2.85

* I - Irrigated; NI – Non irrigated; CC - climate change; OD – Ozone depletion; TA – Terre. Acidification; FWE – freshwater eutro.; ME – Marine eutro. FD – Fossil depletion

- Non-irrigated: higher environmental impacts for CC, ME, FD and OD mainly because of the low productivity per ha (650 kg/ha/year).
- Irrigated cultivation (3000 kg/ha/year): higher impacts for TA and FWE, due to the use of fertilisers.
- Cultivation is the phase with the highest environmental impacts (70-99%) for all categories.

Normalised results (excluding LUC)



Similar magnitude for all categories (0.6×10^{-4} - 1.7×10^{-4}), except for FWE and OD

Conclusions

- Huge variation in GHG intensity for sunflower oil for the various LUC scenarios: 0.3-20.9 kg CO_{2eq}/kg_{oil}
- Sunflower cultivated in non-irrigated land had higher environmental impacts in 4 categories (CC, ME, FD and OD) because of the low productivity per ha (650 kg/ha/year)
- Sunflower cultivated in irrigated land (3000 kg/ha/year)) had higher impacts in 2 categories (TA and FWE) due to the use of fertilisers
- Cultivation contributed 70%-99% to the life-cycle impacts in all categories, mainly due to fertilisers and diesel
- Agricultural practices and LUC scenarios have an important influence on GHG intensity. **To assure low GHG intensity, sunflower should preferably be cultivated in severely degraded grassland.**

Thank you!
Questions and Comments

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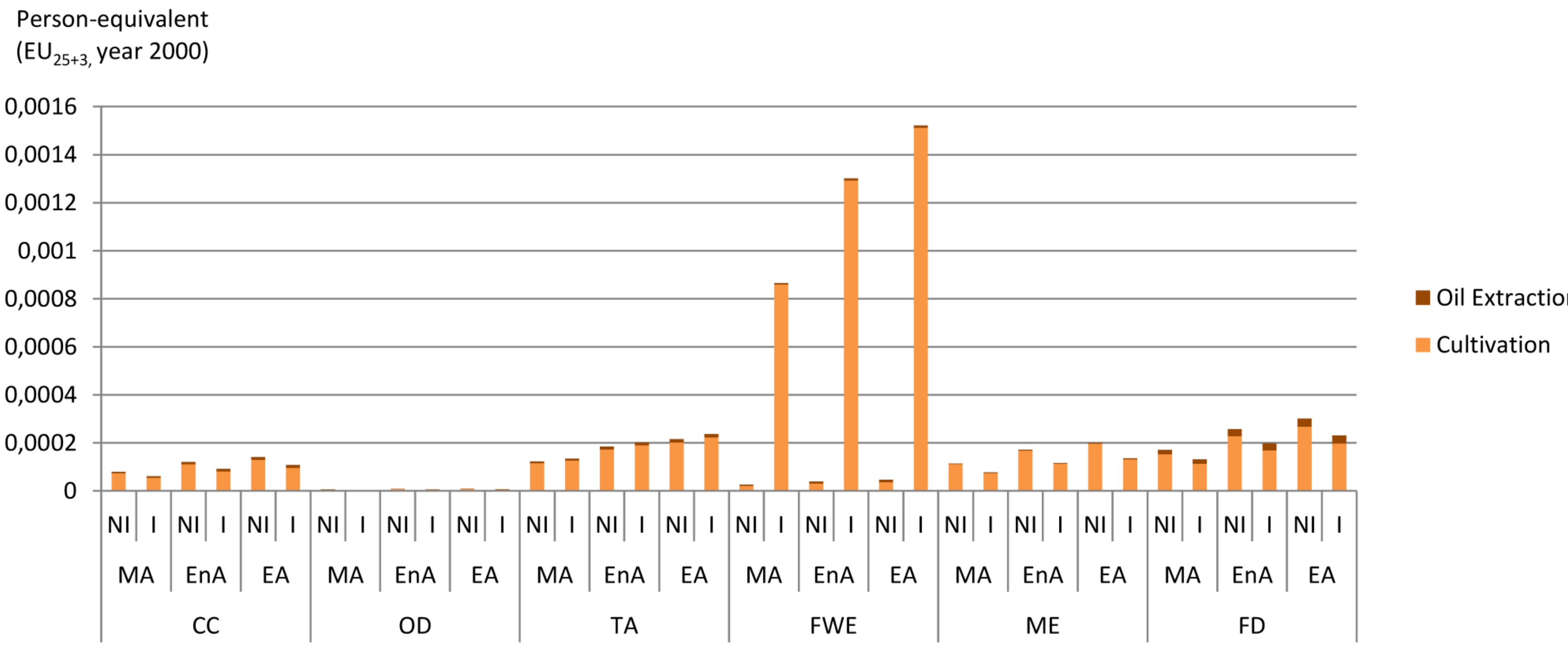
extra

Allocation method



- The allocation method had an important influence in the results
- The relationship between the three methods of allocation is always the same:
  - The highest impacts: economic allocation
  - The lowest impacts: economic allocation