SYDDANSK UNIVERSITET

Modeling environmental consequences of dLUC in a fully renewable energy system in Denmark:

Effect of crop types, soil, climate, residues management, initial carbon level and turnover time

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Quantifying and managing land use effects of bioenergy, Campinas, September 19th 2011

Outline

- Introduction
- Model overview
- Inventory results
- LCA results
- Conclusion

Introduction

- **Denmark: ambition to reach a 100% renewable energy system (RES) by 2050;**

- **A 100 % RES would require more biomass than what is immediately available as residues:**
  - Biomass potential needed ≈ 300 – 450 PJ y^{-1}
  - Available biomass residues ≈ 200 PJ y^{-1}

- **Conversion of agricultural land from food/feed crops to energy crops necessary (and/or imports)**

- **Goal: Addressing national dLUC consequences of such conversions through building a robust, transparent & disaggregated consequential life cycle inventory (LCI)**

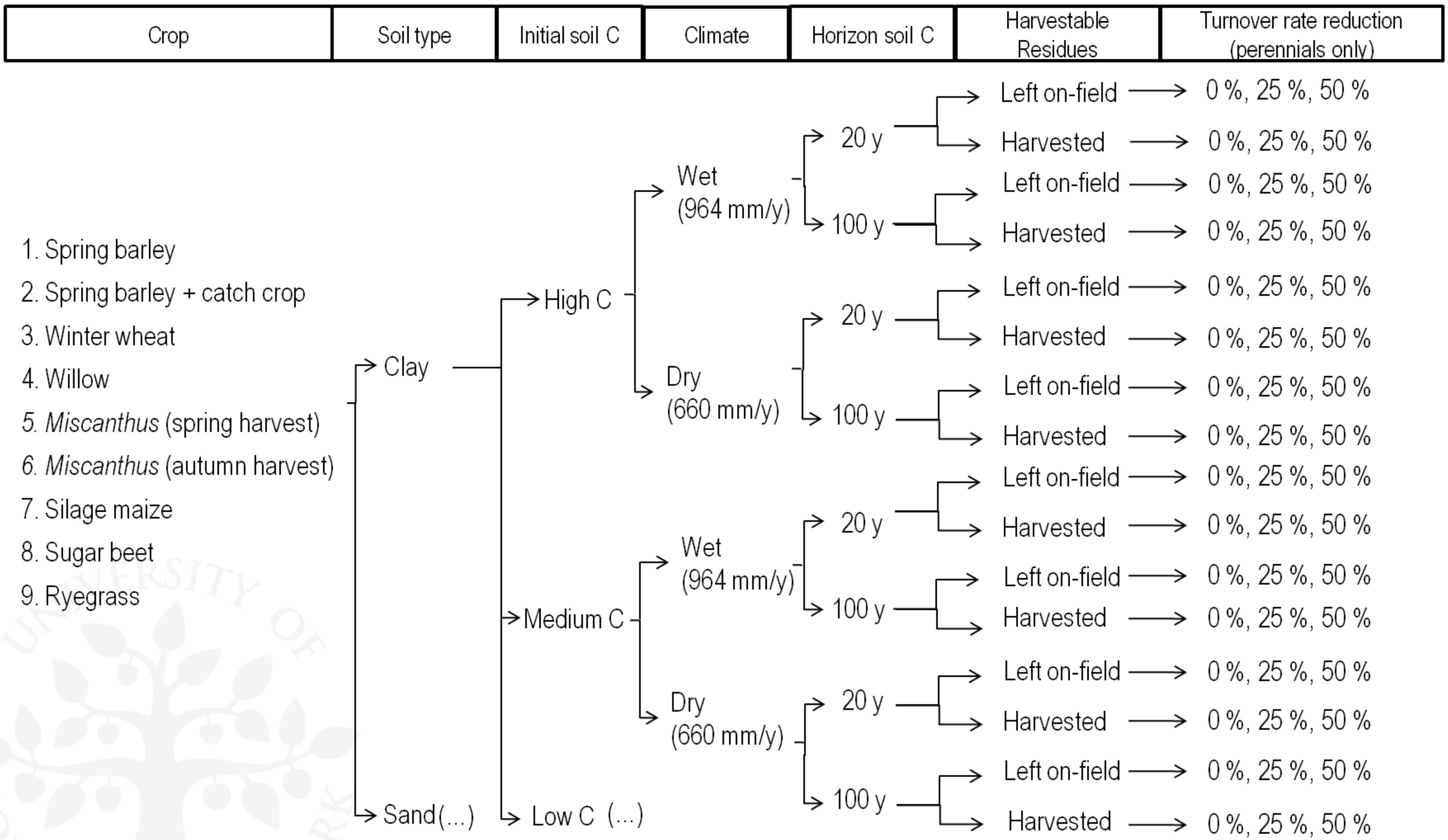
Introduction

- **Why building a specific database?**
  - Site-specific nature of emission processes;
  - Difference in inputs;
  - Need for transparent and disaggregated data;
  - Need to include perennial crops

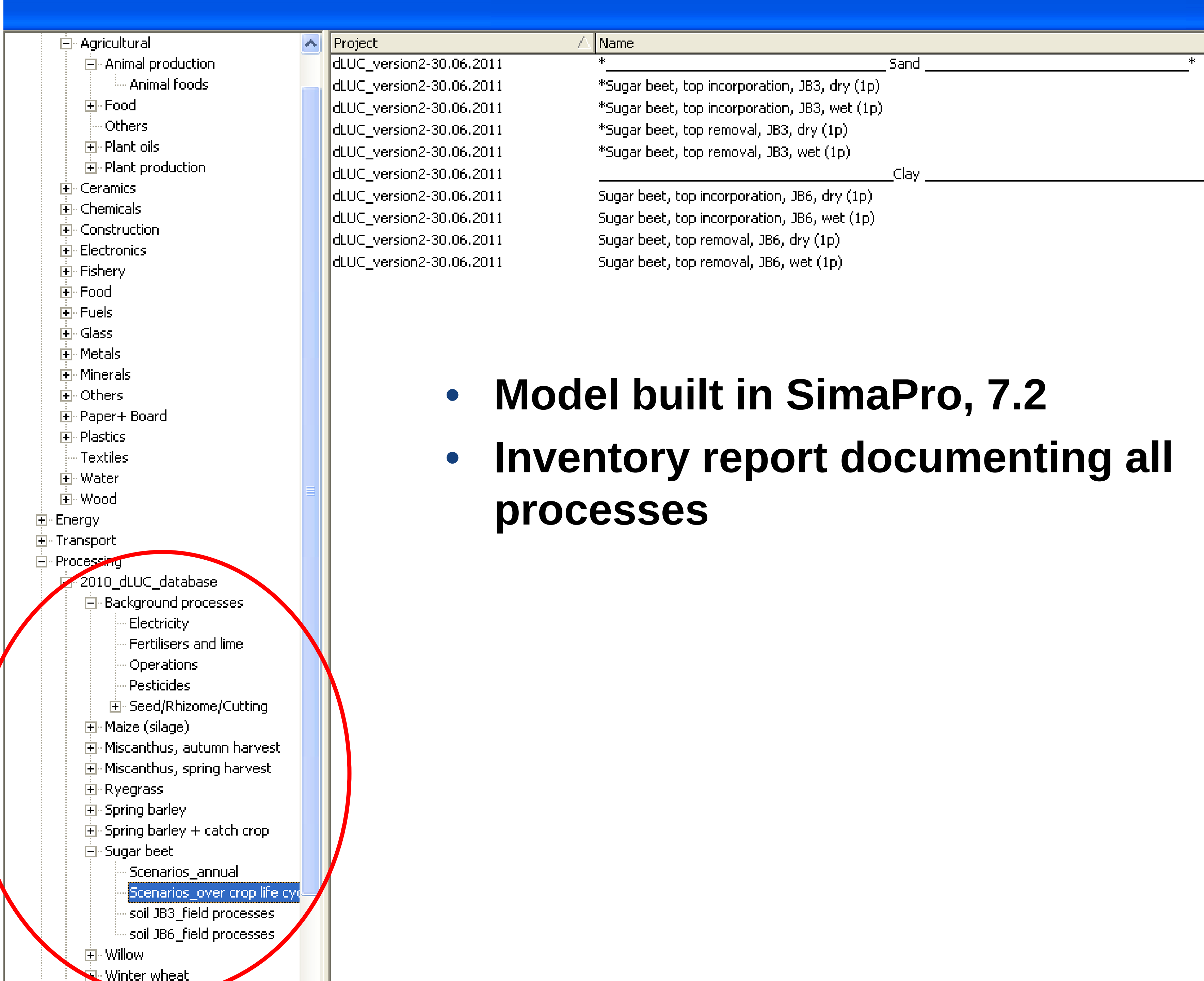
- **Conversion type: arable land to arable land**

- **Displaced crop: Spring barley**

Overview of the inventory structure



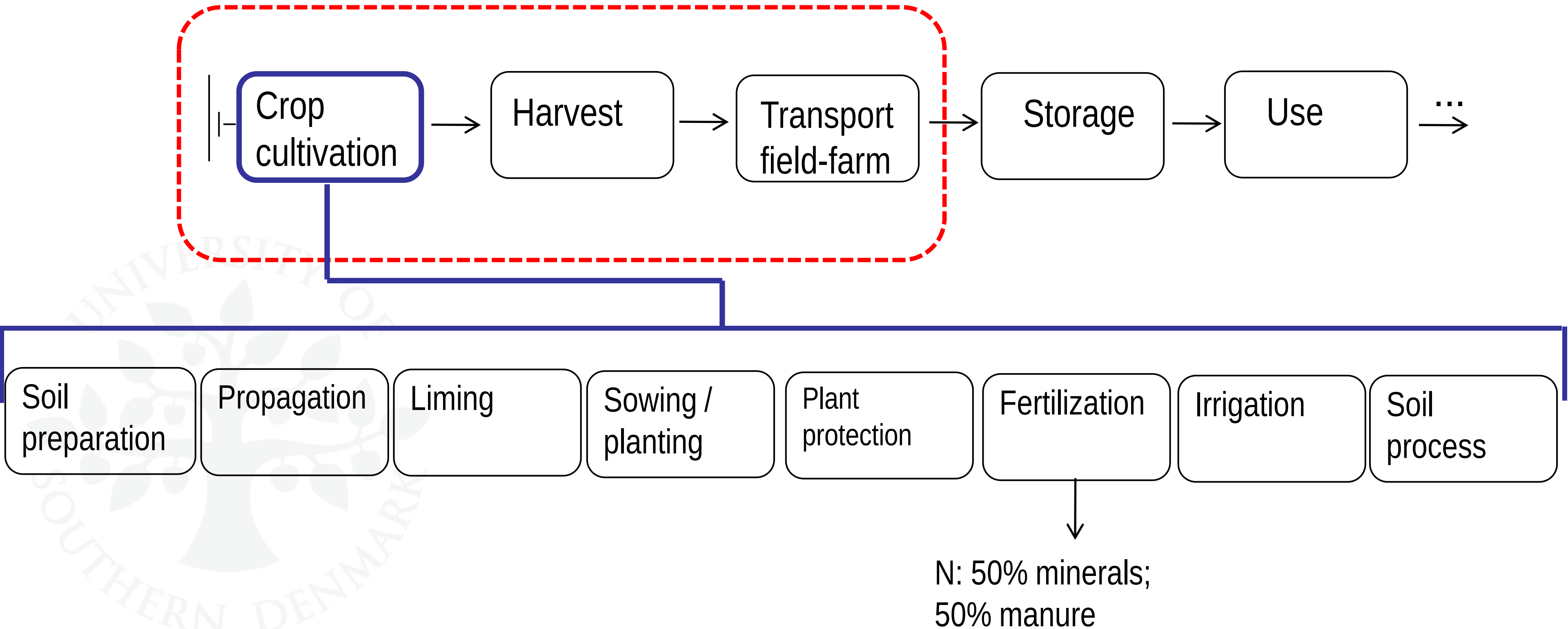
Combinations detail:	
Spring barley (1,2), winter wheat (3) & sugar beets (9): 4 crops x 2 soil x 3 initial soil C x 2 climate x 2 horizon time x 2 residues management	= 192 combinations
Miscanthus (6,7) & willow (4,5): 4 crops x 2 soil x 3 initial soil C x 2 climate x 2 horizon time x 1 residues management x 3 turnover rates	= 288 combinations
Rye grass (10) & silage maize: 2 crops x 2 soil x 3 initial soil C x 2 climate x 2 horizon time x 1 residues management	= 48 combinations
Total = 528 combinations	



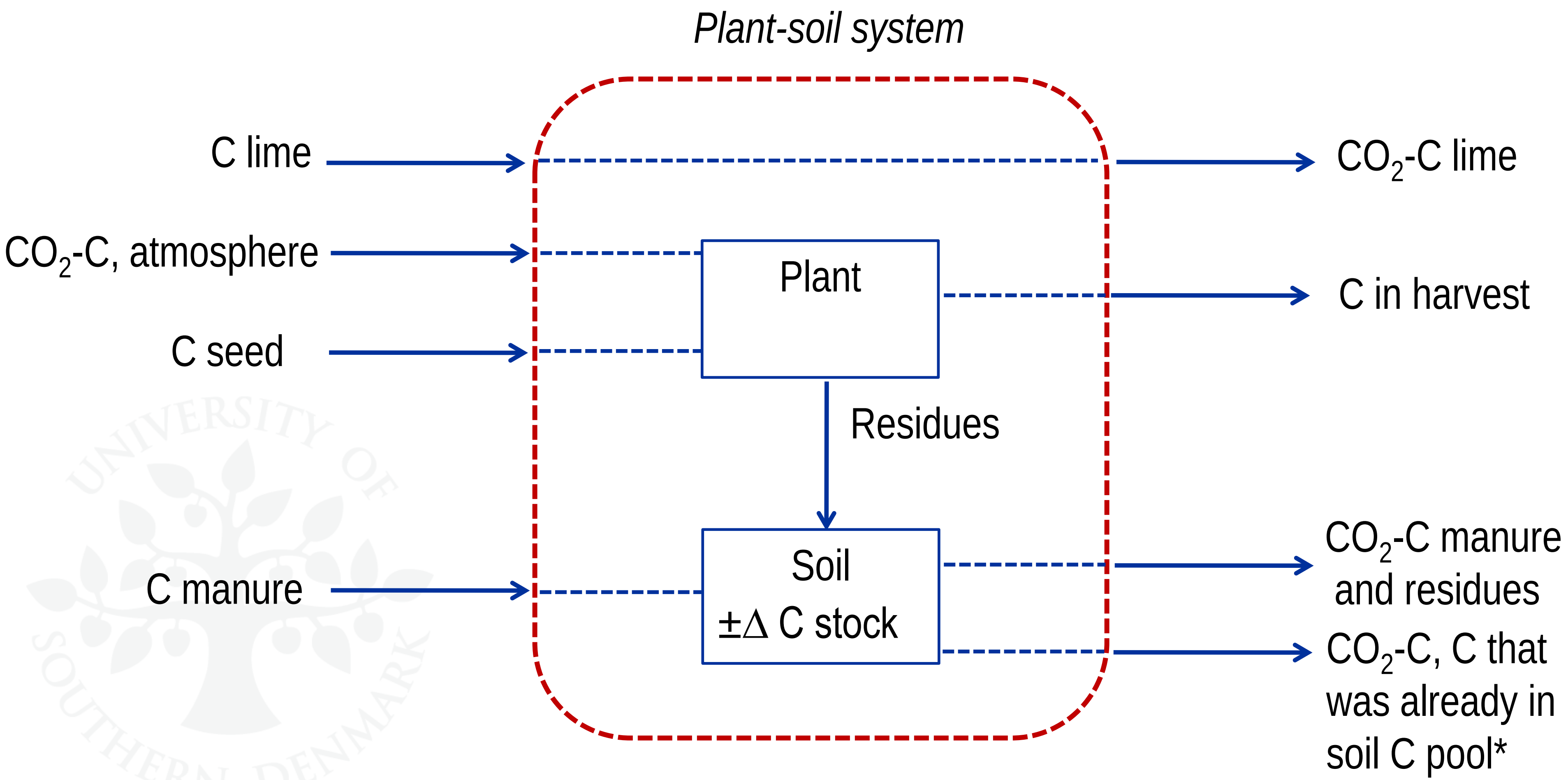
- **Model built in SimaPro, 7.2**
- **Inventory report documenting all processes**

System boundary

All flows from and to the environment expressed for :
1 ha of land in a year

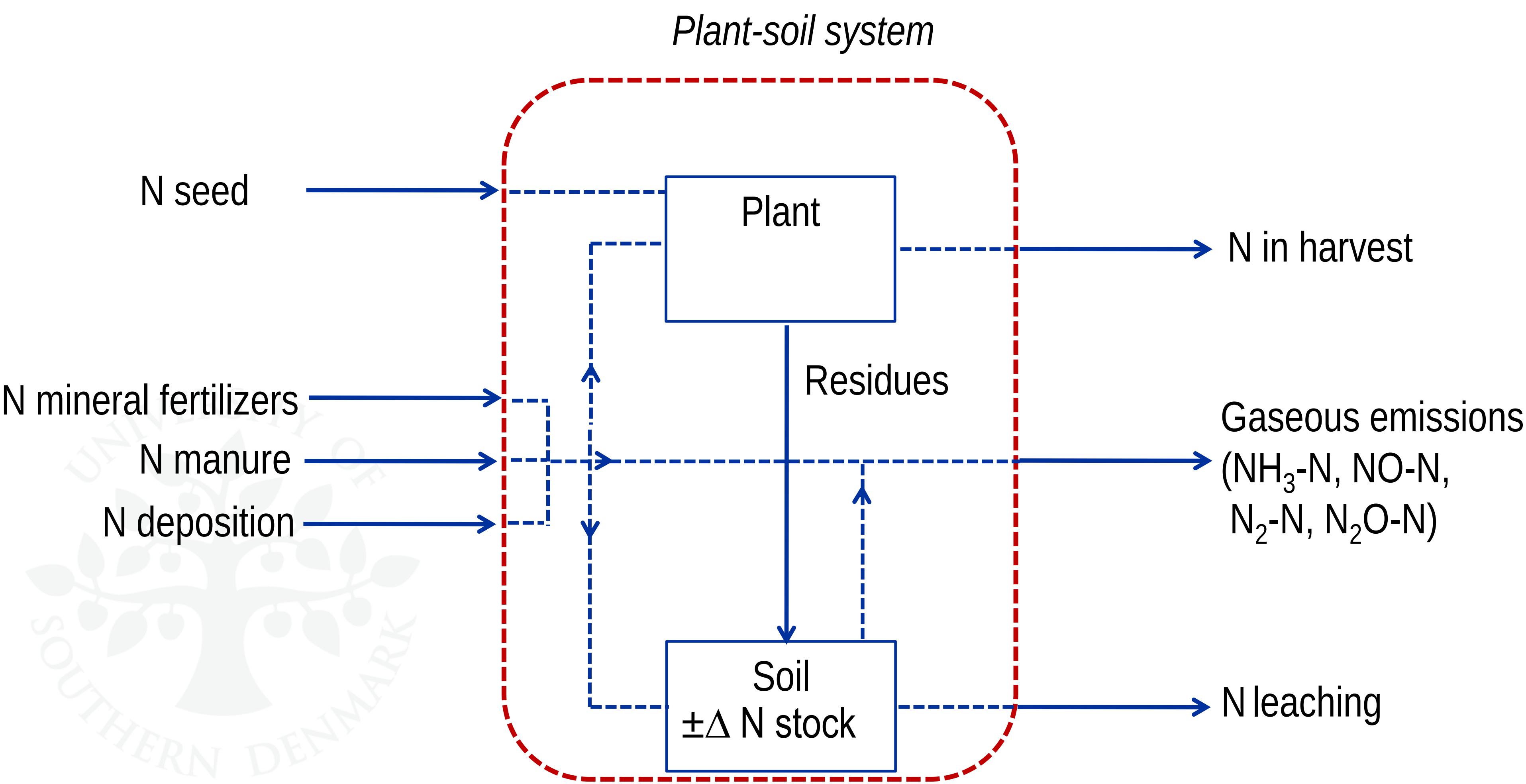


Soil processes – overview for C



* Facultative flow

Soil processes – overview for N

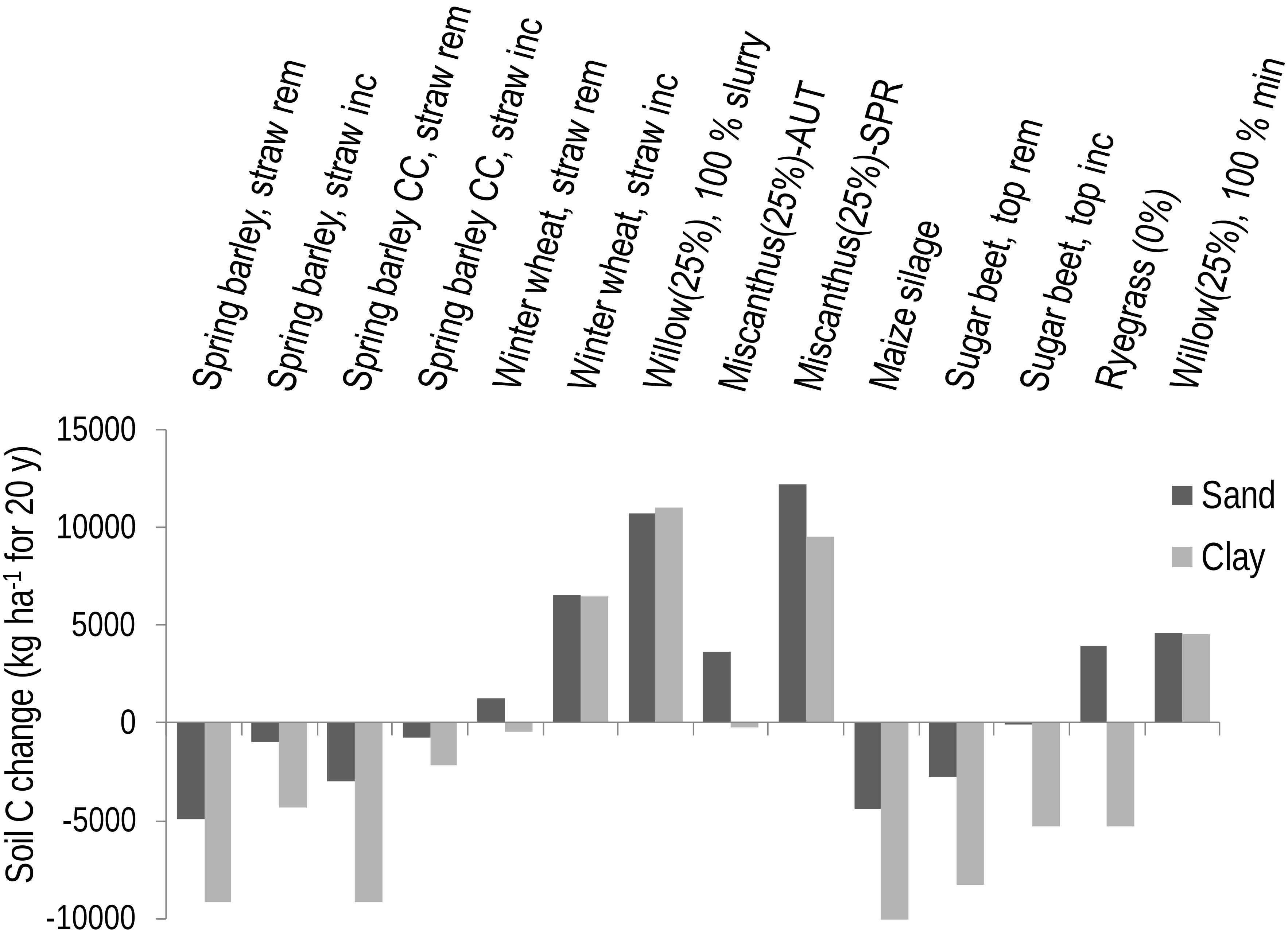


Overview of inventory results

1. **Balance of applied nutrients, per crops *x* soil type *x* climate**
2. **Partition of dry matter (DM) per crops *x* soil type *x* climate:**
   i. Primary yield
   ii. Secondary yield
   iii. Above-ground residues
   iv. Below-ground residues
3. **Disaggregated inputs of C and N per crops *x* soil type *x* climate**
4. **Output flows of C**
5. **Output flows of N**
6. **Others: Output flows of P, NMVOC, Cu, Zn & Sensitivity analysis**

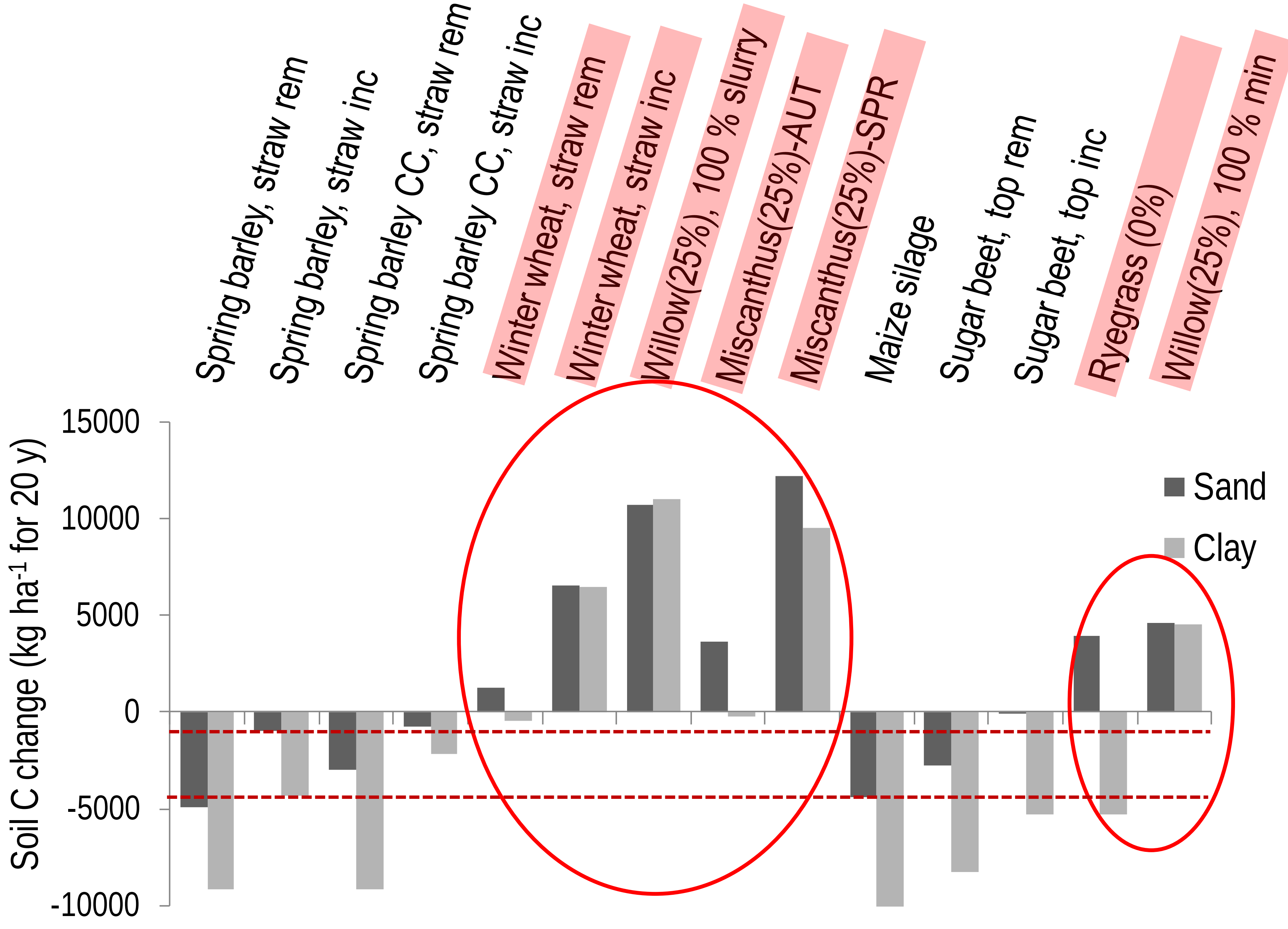
4. Output flows of C

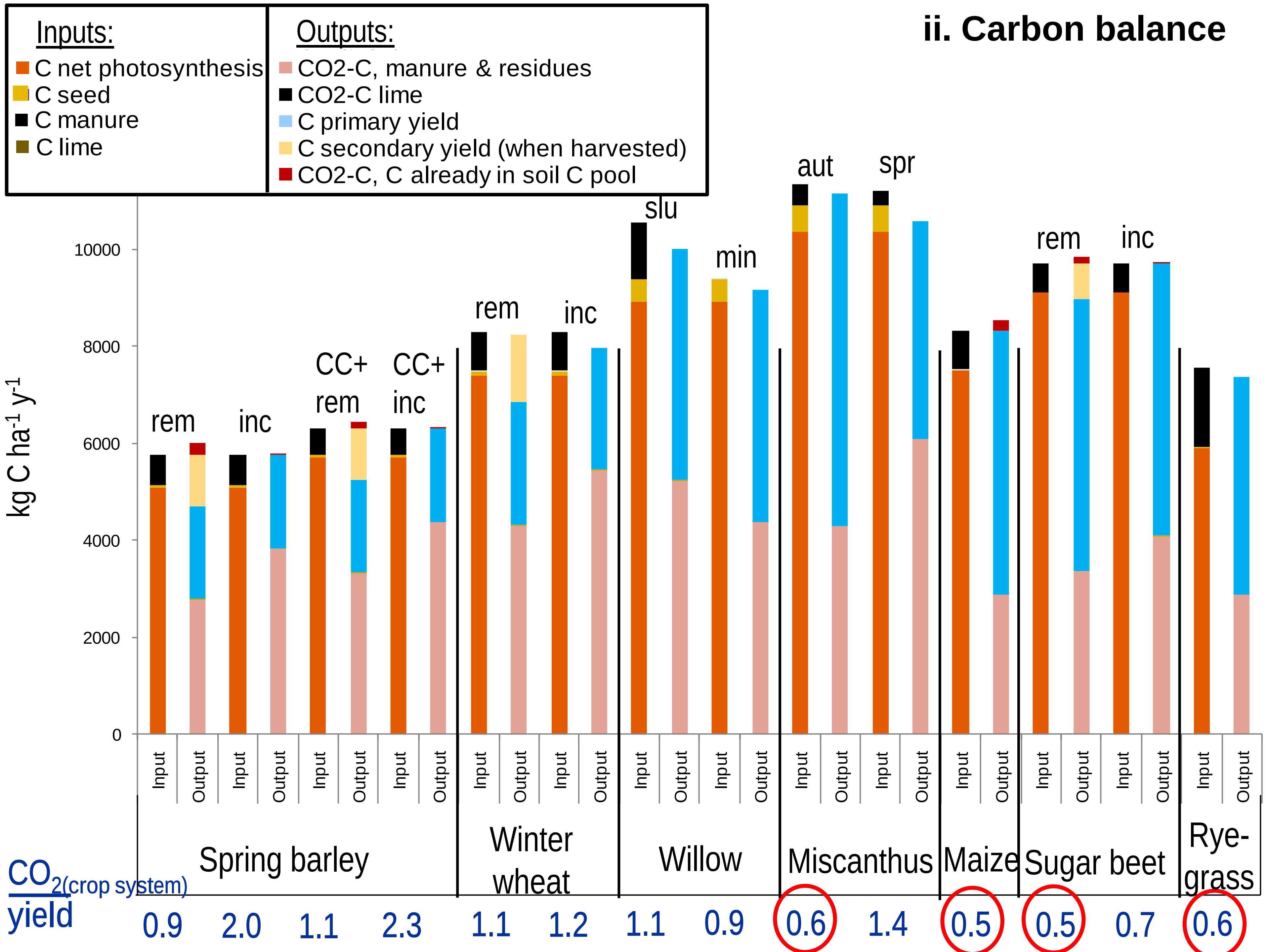
i. Effect of soil type (clay versus sand) on soil C accumulation



4. Output flows of C

i. Effect of soil type (clay versus sand) on soil C accumulation



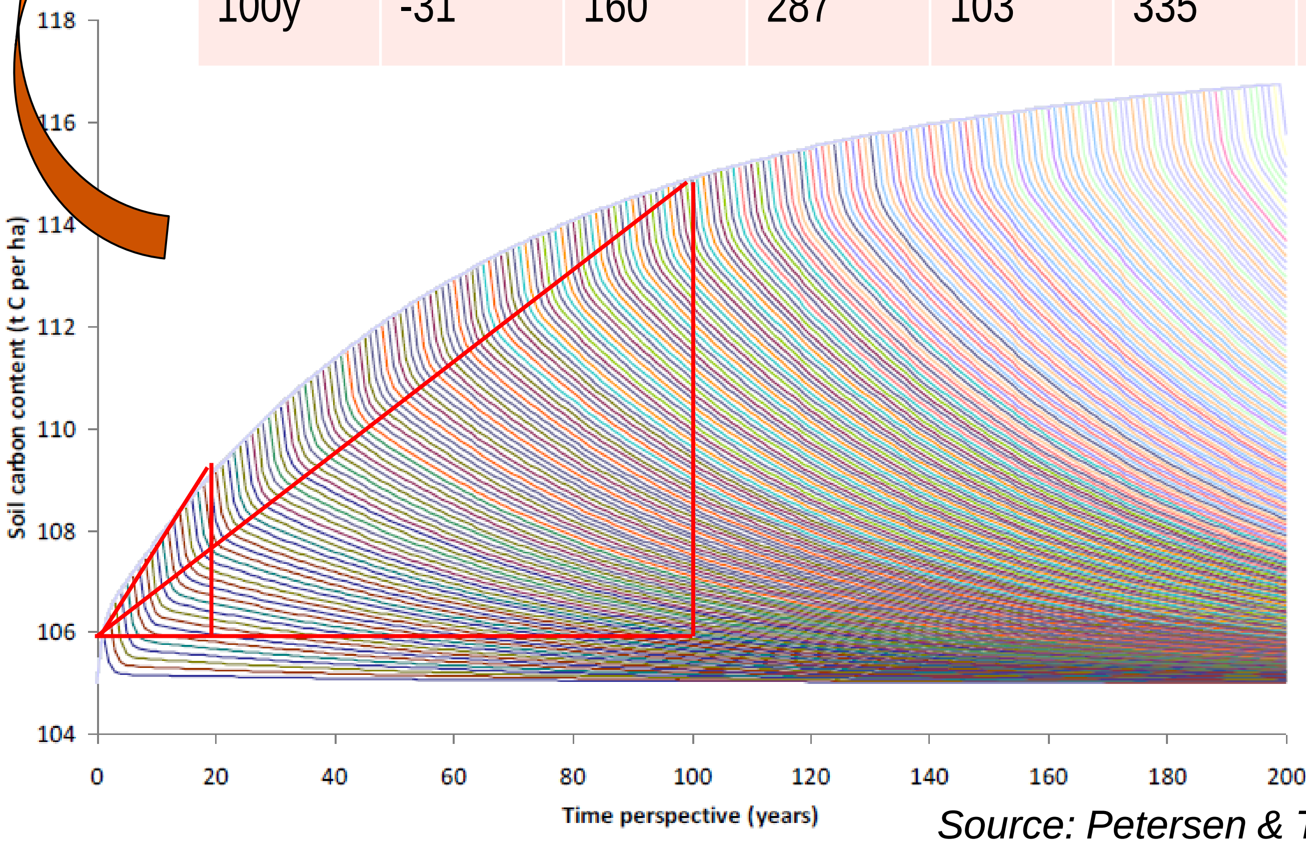


ii. Carbon balance
Inputs:
C net photosynthesis
C seed
C manure
C lime
Outputs:
CO2-C, manure & residues
CO2-C lime
C primary yield
C secondary yield (when harvested)
CO2-C, C already in soil C pool
kg C ha-1 y-1
0
2000
4000
6000
8000
10000
rem
inc
CC+ rem
CC+ inc
rem
inc
slu
min
aut
spr
rem
inc
Input
Output
Spring barley
Winter wheat
Willow
Miscanthus
Maize
Sugar beet
Rye-grass
CO2(crop system) / yield
0.9
2.0
1.1
2.3
1.1
1.2
1.1
0.9
0.6
1.4
0.5
0.5
0.7
0.6

iii. Effect of horizon time

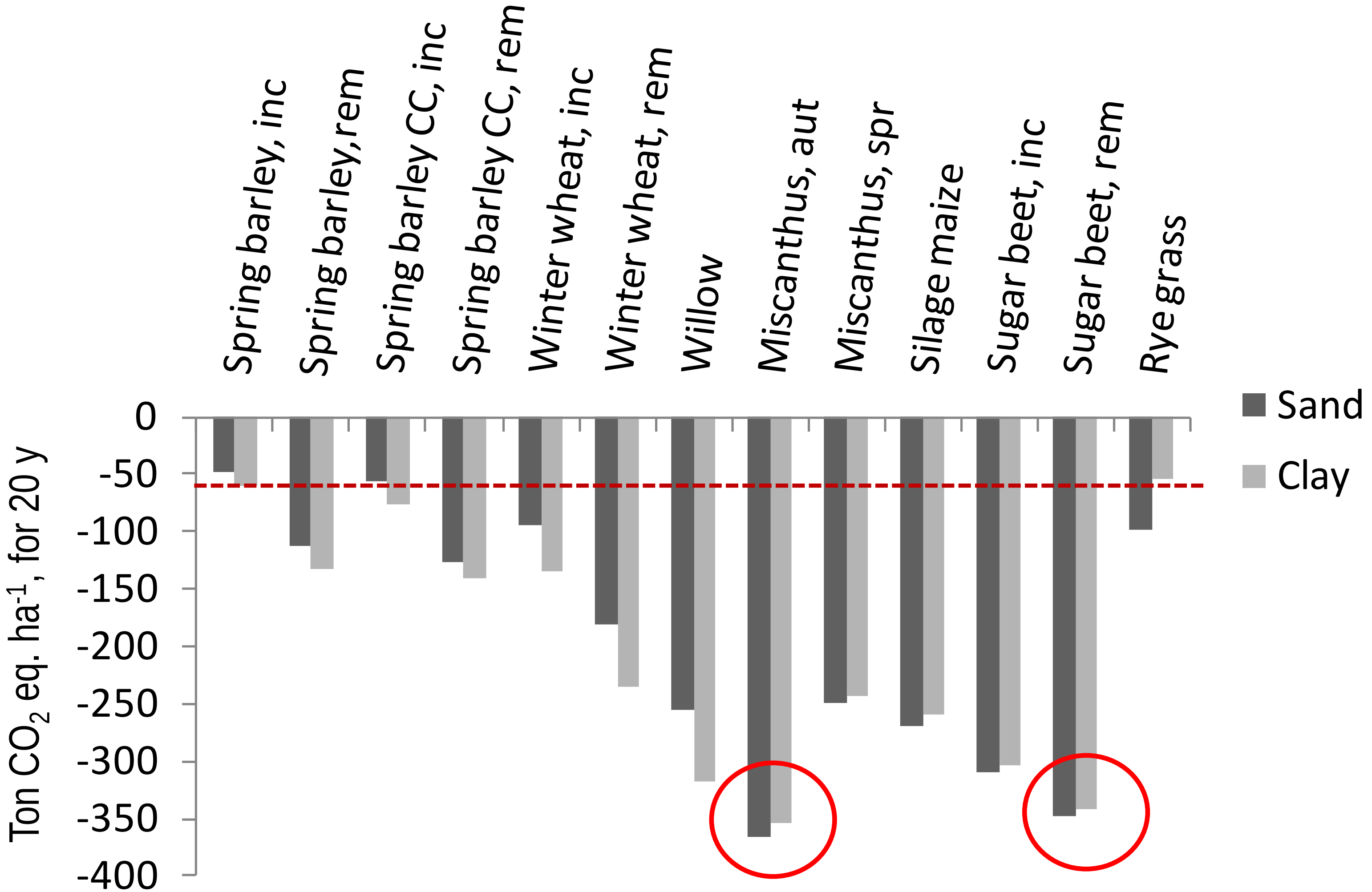
Annualized soil C changes in the various crop systems, for 20 and 100 y (kg C ha^{-1} y^{-1})

	Spring barley (inc.)	Winter wheat (inc.)	Willow (100% slurry)	Misc. (AUT)	Misc. (SPR)	Maize silage	Sugar beet (inc.)	Rye-grass
20y	-51	326	537	183	609	-218	-0.5	198
100y	-31	160	287	103	335	-114	-6.5	106



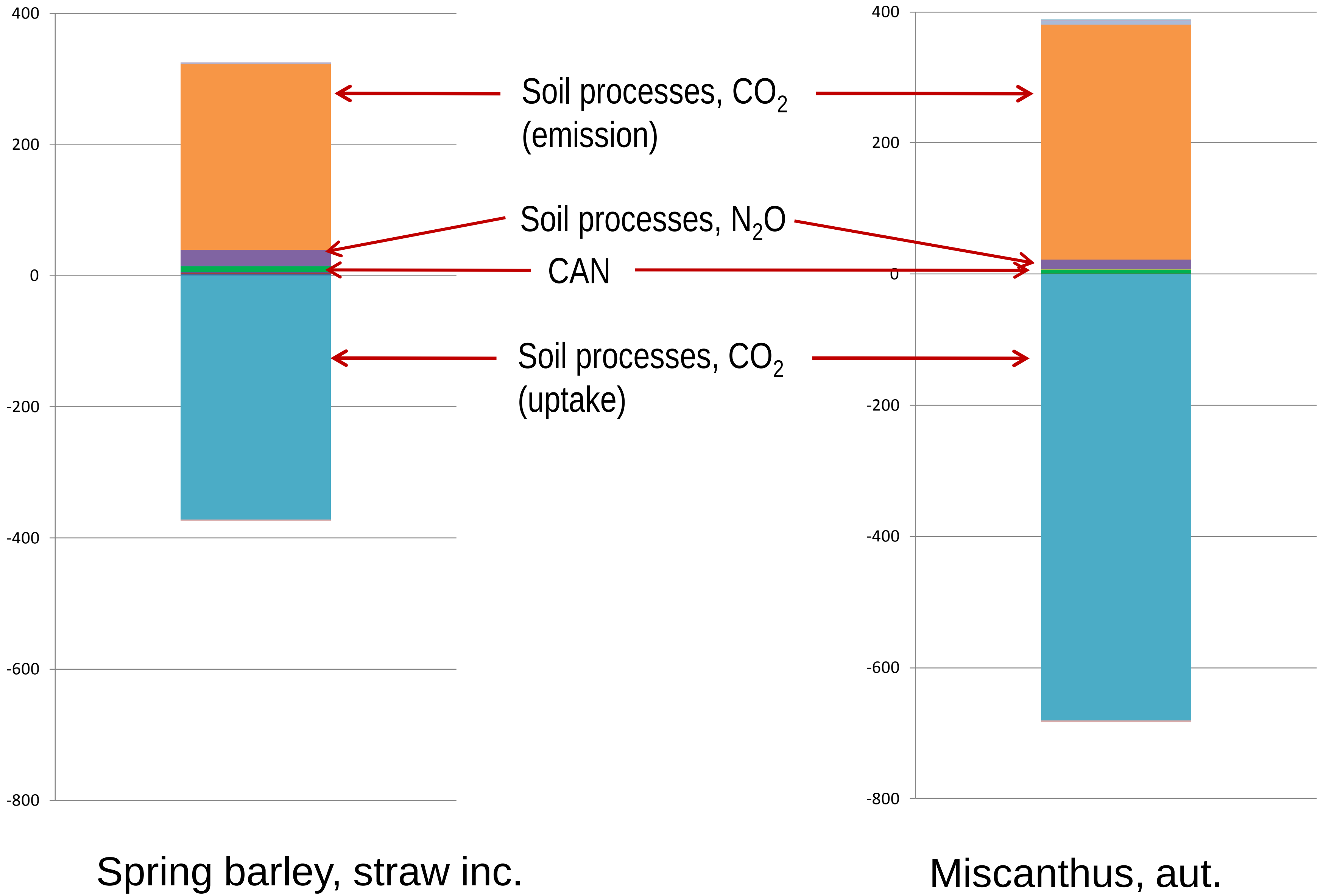
Source: Petersen & Trydeman Knudsen, 2010

LCA results: Global warming (for 20 y cultivation)

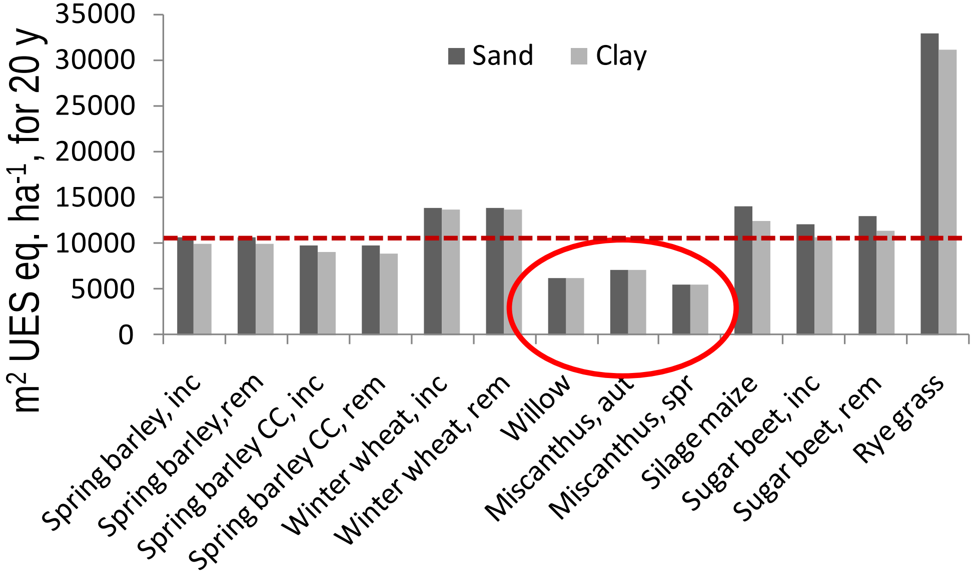


LCA results: Global warming breakdown

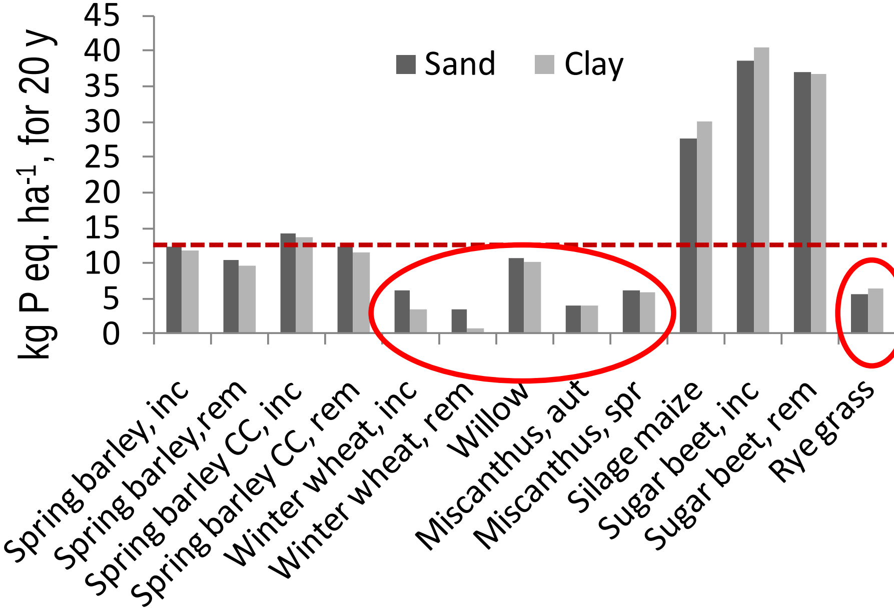
Ton CO_2 eq. ha^{-1}, for 20 y cultivation



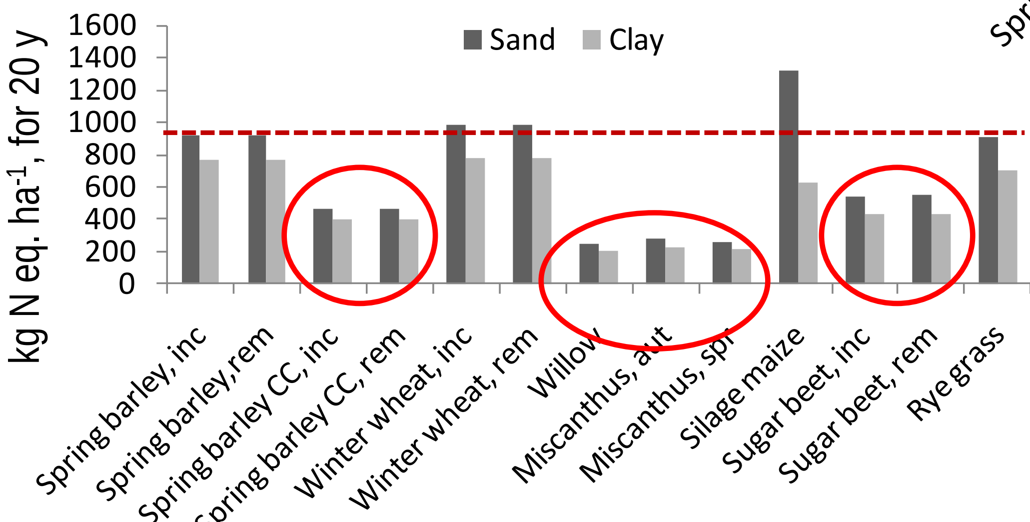
LCA results: Acidification and eutrophication



a. Acidification



c. Eutrophication - P



b. Eutrophication - N

Conclusion

- **LCI of high value: disaggregated, highly detailed, inclusion of perennial crops & soil C changes**

- **Effect of:**
  - Crop type: Perennials, but also silage maize and sugar beet.
  - Soil type: opposite effect C and N.
  - Residues management: Harvesting useful yield better than incorporation on a GW point of view but not for SOC. Favouring wheat straw.

- ***Miscanthus* may be highlighted as a promising energy crop**

Questions & Discussions

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More details in our coming paper:

Modelling the Environmental Consequences of Direct Land Use Changes from Energy crops in Denmark: a Consequential Life Cycle Inventory

To be soon submitted to GCB Bioenergy