50 Years of contrasted residue management in an agricultural crop: impacts on the soil carbon budget and on heterotrophic respiration.

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1. Introduction.

- Agricultural soils are potentially large sources of CO_2, on which crop management has a considerable influence.
- Long-term carbon (C) budgets on croplands are scarce, but they are necessary to understand crop management influences on soil C dynamics.

OBJECTIVE:

➔ What is the impact of 50 years of differentiated residue management treatments on soil organic C (SOC) stocks and C outputs?

2. Material and Methods.

A. Experimental design:

- Longs Tours site, close to Gembloux.
- Soil = Luvisol with clay/silt/sand fractions of 12/85/3 %.
- 6 different crop residue management treatments (1 ➔ 6, Fig. 1),
- Since 1959.
- 6 plots (repetitions) in each treatment: 10 by 70 (or 60) m.
- All plots ploughed over 0-25 cm depth.

B. Studied treatments:

- T1: Exportation of crop Residues (RE).
- T4: Farm Yard Manure inputs every 3-4 years (FYM).
- T6: Restitution of the crop residues to the soil + green manure (RR).

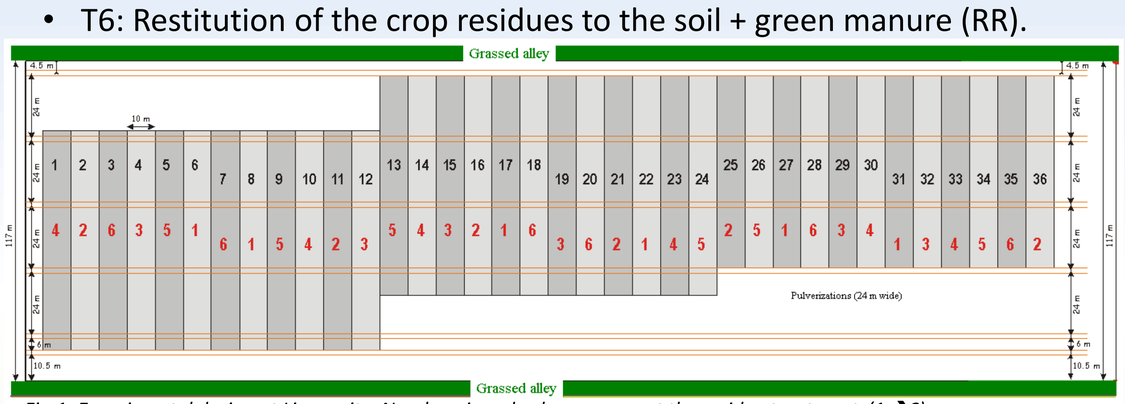


Fig.1: Experimental design at Liroux site. Numbers in red colour represent the residue treatments(1 ➔6).

C. Crop characteristics:

- From 1959 to 1974: 4-year rotation cycle: Sugar beet – Cereals – Legume – Cereals
- From 1975 onwards: 3-year rotation cycle: Sugar beet – Winter wheat – Winter barley

D. Soil carbon budget calculations in each treatment.

$$\Delta SOC_{mean} = \frac{\sum_{k=1959}^{2010} Input_k}{52} - Output_{mean}$$

where:

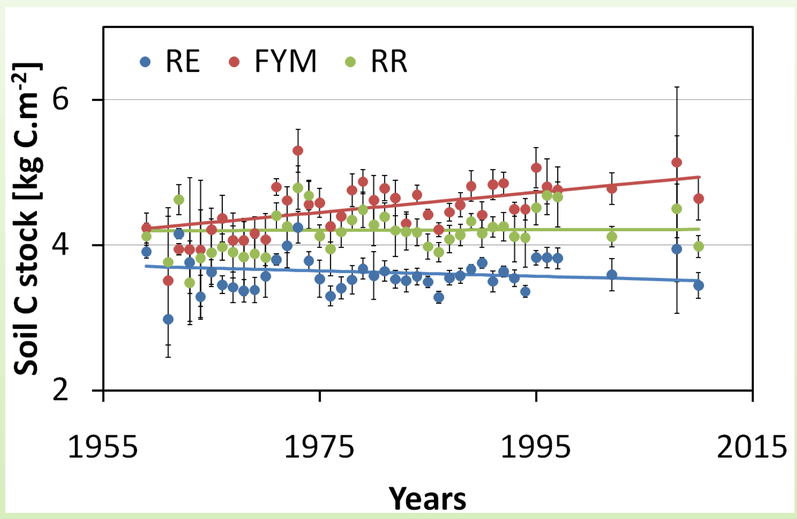
- ΔSOC_{mean} is the mean annual soil C sequestration rate over 1959-2010;
  ➔ **Estimated from yearly SOC data compiled since 1959.**
- $Input_k$ is the amount of C entering the soil on year *k*;
  ➔ **Estimated from:**
  1. Yearly crop residue input data (fresh biomass basis)
  2. Green manure input data (fresh biomass basis)
  3. Left-over residue amounts (roots, rhizodeposits, weeds, residues eventually not exported) (estimated from the literature)
- $Output_{mean}$ is the mean annual rate of C loss by heterotrophic respiration

➔ Based on all this information, $Output_{mean}$ could be estimated for each treatment.

3. Results

A. Estimation of Δ SOC_{mean}

- Weighted least squares regressions applied to the yearly SOC data.
- Δ SOC_{mean} = slope of each regression, for each treatment.



Treatments	Slopes = Δ SOC_{mean} ($gC.m^{-2}.year^{-1}$)	p (slope = 0)
RE	- 4 (5)	0.15 (NS)
FYM	14 (6)	0.00 (***)
RR	0.3 (6)	0.91 (NS)

➔Significant C sequestration in the FYM treatment only.

B. Estimation of crop residue and green manure inputs.

Yearly crop residue (fresh biomass) estimates (field data: 1959-2010)

Crop residue % dry matter, % C (from literature)

	% dry matter	% C
Wheat	86.4 ± 6.7	44.7 ± 2.2
Sugar beet	15.2 ± 5.3	33.3 ± 1.8
Manure	32.0 ± 7.0	35.6 ± 10.0

Yearly crop residue carbon inputs

C. Left-over residue carbon inputs

- Same amounts in the three treatments
- Based on a literature survey

	Annual C amounts ($gC.m^{-2}.year^{-1}$)
Roots	126 ± 30
Rhizodeposits	71 ± 17
Weeds	72 ± 39
Residues not actually exported	75 ± 25
Total	**344 ± 58**

D. Soil carbon budgets

Mean annual C budget terms	Units	RE	FYM	RR
ΔSOC_{mean}	$gC.m^{-2}.year^{-1}$	- 4 ± 5	14 ± 6	0.3 ± 6
Crop residue C input	$gC.m^{-2}.year^{-1}$	0	154 ± 19	141 ± 5
Left-over C input	$gC.m^{-2}.year^{-1}$	344 ± 58	344 ± 58	344 ± 58
Green manure C input	$gC.m^{-2}.year^{-1}$	0	0	17 ± 0.3
C $output_{mean}$	$gC.m^{-2}.year^{-1}$	**348** ± 58	**484** ± 61	**502** ± 59
Daily mean C output	*$gC.m^{-2}.day^{-1}$*	*0.9 ± 0.2*	*1.3 ± 0.2*	*1.4 ± 0.2*

4. Discussion

- ❑ ΔSOCmean:
  - C sequestration only in FYM
  - Large uncertainties for RE and RR
- ❑ Carbon inputs:
  - More than 2/3 of the total inputs come from the left-over residues.
  - Same amounts of crop residues were brought to the soil in FYM and RR.
- ❑ C $Output_{mean}$:
  - In agreement with the literature.
  - In agreement with field measurements of soil respiration carried out at the seasonal scale (2010, 2011) and extrapolated at the annual scale.
  - Virtually no difference between FYM and RR.
- ❑ About 2.8 ± 1.5 % of the total C inputs are sequestered annually, on average, in the FYM treatment.
- ❑ What about the actual C dynamics over the 50 years? (here, mean values)

5. Conclusion and perspectives

- ❑ Importance of left-over residues
  - Both in terms of mean values and uncertainties
  - Literature-based ➔ more investigations needed
- ❑ SOC sequestration only in FYM
  - Even if FYM and RR received the same amounts of crop residues
- ➔ Importance of substrate quality, aggregate formation?
- ❑ Further investigations:
  - Microbial biomass, labile C
  - Aggregate formation and SOC protection against deciomposition
  - Field measurements (heterotrophic respiration)

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