Impact of crop rotation and crop residue management on soil organic matter content

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Introduction and objectives

In Flanders, as in many European countries, organic matter decline in agricultural soils is a major problem and farmers are encouraged to improve their soil organic matter management. In this context, the Soil Service of Belgium developed the "Cslim©" (Csmart) application, based on the RothC model. This application allows farmers to predict the organic carbon evolution in their fields, taking into account field history, soil type, initial C-content and future crop rotations. Literature data are used to estimate C inputs from crop residues as well as their decomposable/resistant plant material (DPM/RPM) ratios. However, several observations made in arable fields indicated that predictions made by the application didn't always correspond to reality.

In this research the organic matter input from 5 important arable crops in Flanders as well as their DPM/RPM ratios were investigated in 2 different soil textures in order to improve the predictive power of the Cslim© application.

Materials and methods

Crop residues from grain maize, sugar beets, winter wheat, potatoes and peas were harvested in arable fields in the Loamy Region of Flanders. They were weighed, dried, grinded and analysed.

Two soil types, a sandy and a loamy soil, were sampled from arable fields in resp. the Campine and the Loamy Region. The OC-content was analysed with the adapted Walkley&Black method.

The residues were mixed with the two soils in quantities corresponding to field conditions, and incubated in controlled laboratory conditions. During incubation, CO_2-production was measured weekly in order to determine organic matter decomposition. Humification coefficients (hc) and DPM/RPM ratios of the plant residues were derived from the mineralisation curves. Finally, Cslim© simulations using the newly derived C inputs and DPM/RPM ratios were compared to simulations with the originalvalues based on literature, for different crop combinations.

Results

Field measurements and analysis of used crop residues and comparison with literature data (blue columns).

		FM	DM	DM	DM lit.	OM	OC	OC	N	P	C:N	C:N lit.	C:P	N:P
		kg/ha	%	kg/ha		% of DM		kg/ha	% of DM					
wheat	straw	8613	81	6977	3320	91	53	3667	0.77	0.12	68	90	426	6
	stubble	2100	82	1722	1680	55	32	546	0.59	0.08	54		405	7
	roots	1450	82	1189	2500	55	32	377	0.59	0.08	54		405	7
maize	straw	32233	55	17728	10000	85	49	8749	0.77	0.10	65	65	486	8
	roots	12020	44	5229	3000	52	30	1578	0.50	0.10	62		307	5
potatoes	leaves	17523	14	2493	1100	73	42	1049	2.17	0.12	19	25	357	18
	roots	1513	20	299	600	90	52	155	1.48	0.08	36		624	18
sugar beets	leaves	32623	21	6916	5000	68	39	2709	2.05	0.14	19	18	290	15
	tops	6283	21	1294		89	51	665	1.22	0.16	43		330	8
	root rests	1380	27	368	550	86	50	184	0.65	0.12	78		446	6
peas	leaves	25317	18	4646	4500	86	50	2321	3.22	0.39	16	20	127	8
	pods	12000	18	2202		86	50	1100	3.22	0.39	16		127	8
	roots	8850	86	7611	360	77	45	3405	2.44	0.26	18		171	9

Incubation data and comparison with data used in Cslim© (blue columns).

	amounts added in incubation jars				incubation results (average loam& sand)					data Cslim©			
	above-ground	below-ground	above-ground	below-ground	total	C min.	C hum. (EOC)	hc	DPM/RPM	total C	EOC	hc	DPM/RPM
	kg DM/ha		kg C/ha		kg C/ha					kg C/ha			
wheat - straw incorp.	5000	2500	2278	793	3071	1874	1198	0.39	1.18	4380	1580	0.36	1.36
wheat - straw removed	1680	2500	533	793	1326	902	424	0.38	1.19	2530	1040	0.41	1.35
potatoes	1100	600	463	312	775	527	248	0.34	1.29	1560	470	0.30	1.52
maize	10000	3000	4935	905	5840	3679	2161	0.38	1.20	3890	1330	0.34	1.35
sugar beets	5000	550	2263	274	2538	1650	888	0.35	1.26	2780	810	0.29	1.54
peas	4500	360	2248	161	2409	1638	771	0.34	1.29	2530	770	0.30	1.50

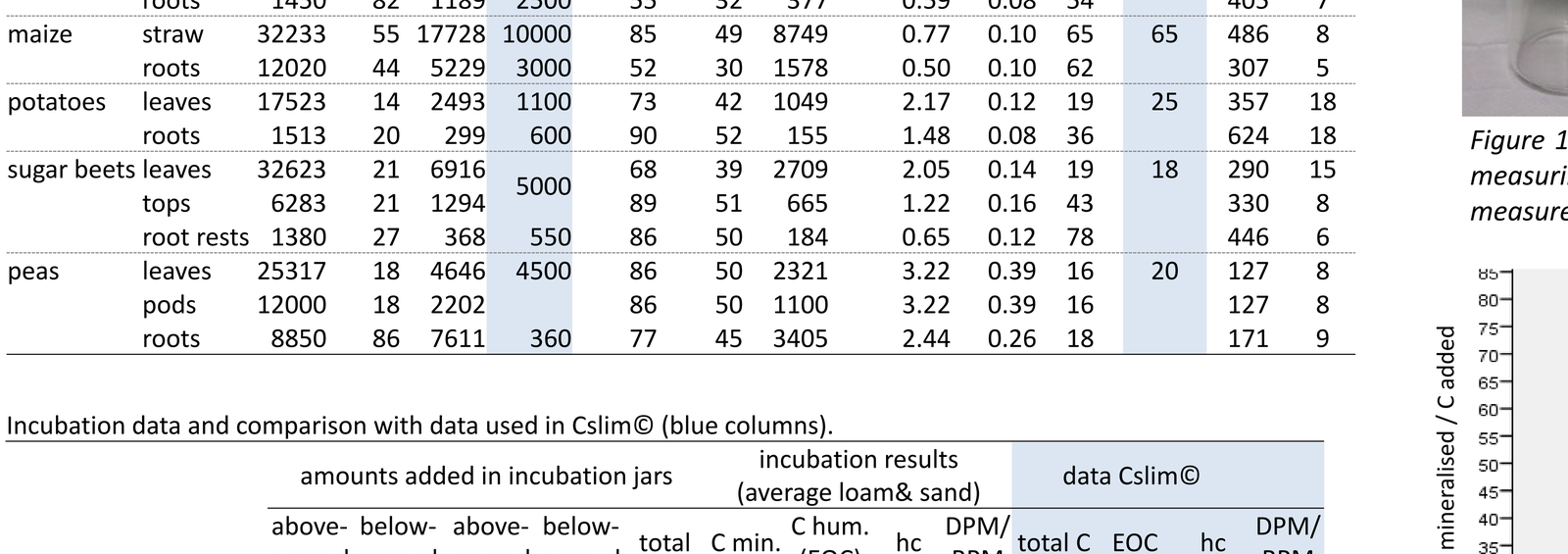

Figure 3: SOC-evolutions for monoculture grain maize (left) and an alternative crop rotation (right) simulated with RothC based on crop coëfficiënts from Cslim©, literature , field measurements and incubation results.

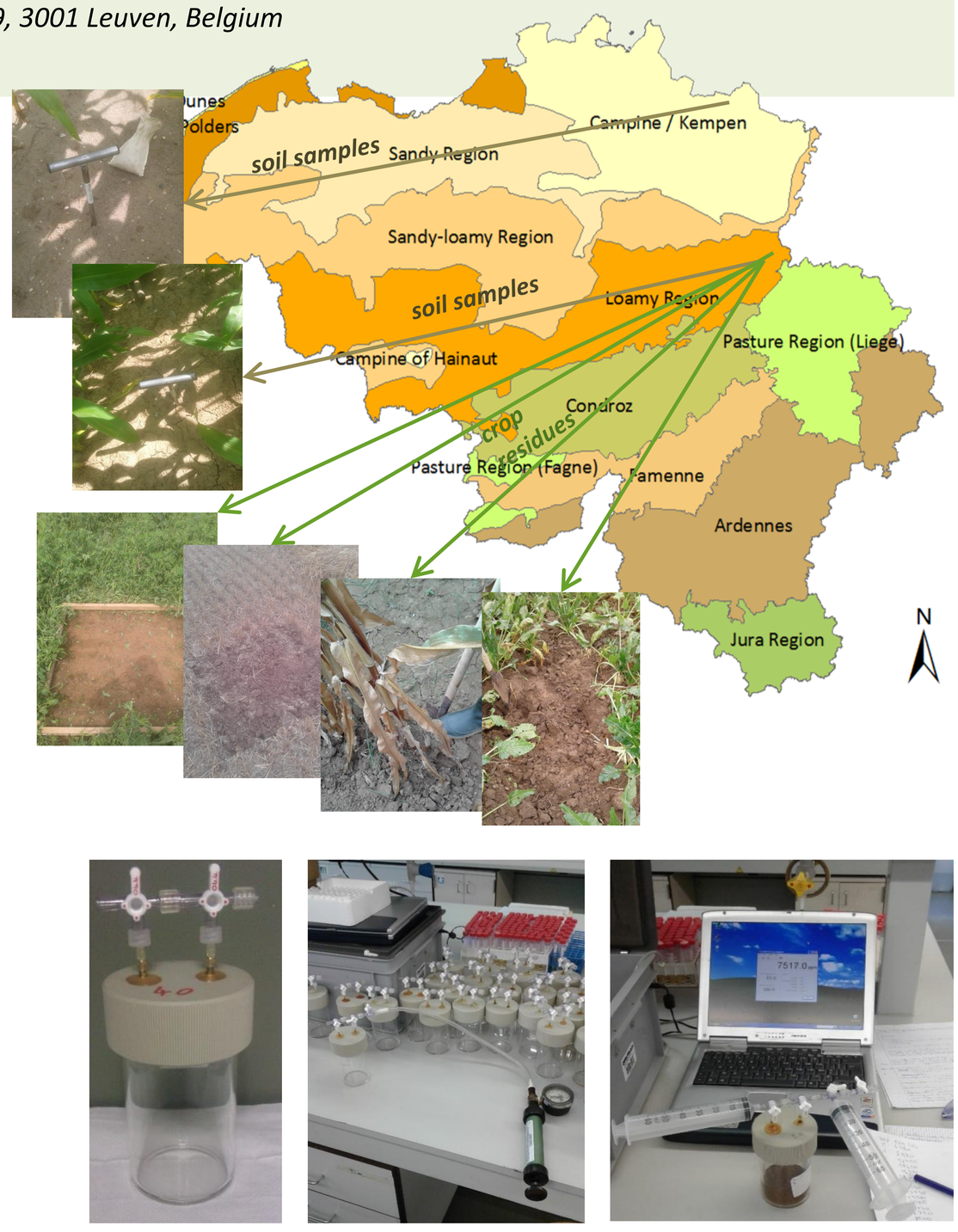

Figure 1: Incubation of soil - crop residue mixtures: sealable incubation jar with measuring taps (left); control of the airtightness of the jars (middle); measurement of the CO_2-concentration in a jar during incubation (right).

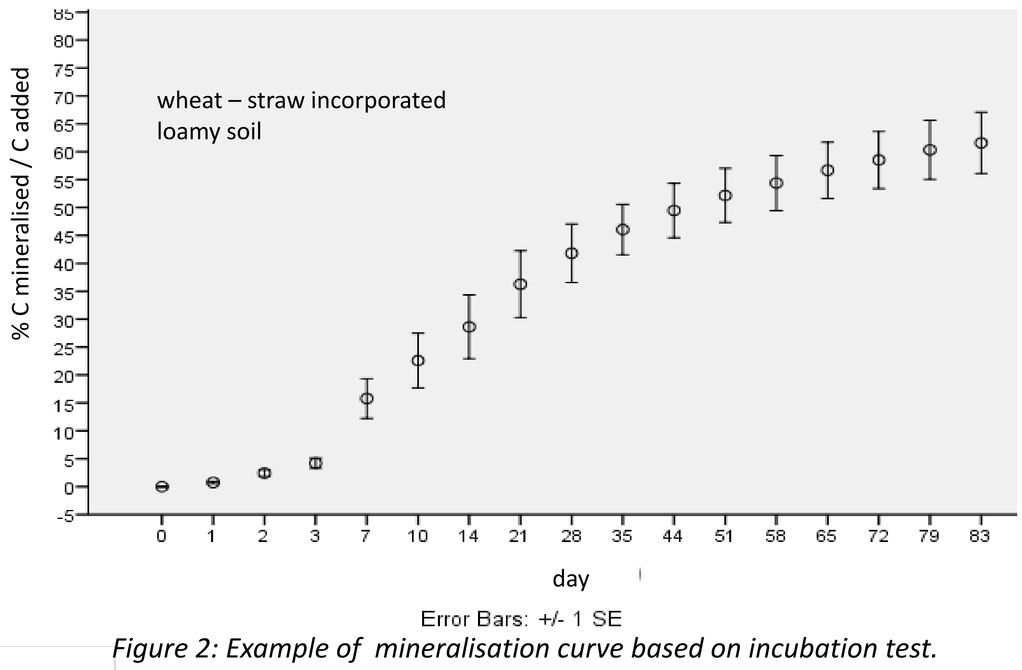

Figure 2: Example of mineralisation curve based on incubation test.

Conclusions

The crop residue biomasses measured in the fields were significantly higher than the figures given in literature and used in the Cslim© application. The decomposition rates measured in the incubation tests and the derived DPM/RPM ratios of the plant residues were slightly lower than those used in Cslim©, indicating higher humification rates. However, the effects of these differences on predicted C-evolution by the RothC model were negligible compared to the effects of crop residue biomass. Therefore it was concluded that the Cslim© application could be significantly improved using more realistic figures for crop residue biomass. Assuming that crop residues are strongly related to yields for most crops, the expected average yields of the crops could be used in each simulation to correct C input through crop residues.

References used:

- RothC – A model for the turnover of carbon in soil. Model description and users guide (updated June 2014). Coleman K.; Jenkinson D.S. Rothamsted Research, Harpenden, UK.
- Development of an expert system for advising C management in arable soils (Ontwikkelen van een expertsysteem voor het adviseren van het koolstofbeheer in de landbouwbodems). Soil Service of Belgium and Ghent University. 2009. Study commissioned by ALBON (Flemish Government). 146 pp.