The long-term trends in soil carbon stock and crop productivity depending on management in Estonia

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The dynamics of soil organic carbon (SOC) content and crop productivity were studied on three still continuing field experiments situated at the experimental station of the Estonian University of Life Sciences in Tartu, Estonia. Also the SOC model ICBM applied under Nordic conditions was tested for C stock calculations.

Experiment 1 established in 1964 on till material excavated to a depth of 1.5-3 m. The material was almost free from SOC (0.6 g kg^{-1}). 19 treatments.

Experiment 2 with 3-crop rotation (potato - spring wheat - spring barley) was established in 1989. Experimental factors were organic (without amendment, solid cattle manure and alternative organic fertilisers) and mineral fertilisers (0, 40, 80, 120 and 160 kg N ha^{-1}).

Experiment 3 with 5-crop rotation (barley undersown with red clover - red clover - winter wheat - pea - potato) was established in 2008. Experimental factors were organic (catch crops as green manures, catch crops as green manures combined with composted cattle manure) and conventional farming systems. The conventional farming systems differed in the amounts of mineral fertilizers used.

ICBM Model

ICMB is a five-parameter model (depending on how the model is used) that has two state variables, young and old soil organic carbon (Figure 1).

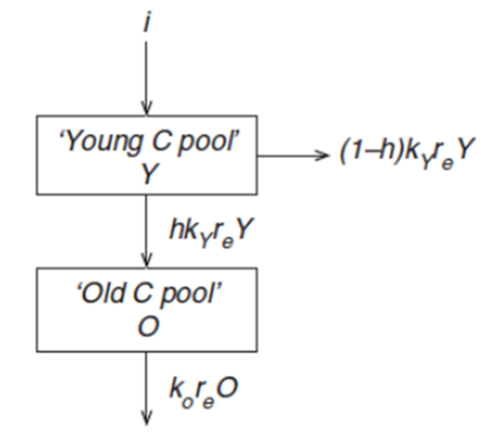

Figure 1. Structure of the ICBM: i=annual C inputs to soil, k_Y and k_O= first order decomposition rate constants for the young (Y) and old (O) soil organic carbon pools, h=humification coefficient, r_e=soil climate-management parameter.

Table 1. The crops DM yields of experiments

Experiment	Crop	DM yield of main product, t ha^{-1}
Experiment 1	Barley	1.2[1]
	Grasses	1.6[2]
	Grasses-clover	2.7[2]
Experiment 2	Potato	5.1
	Spring wheat	2.9
	Barley	3.0
Experiment 3	barley	2.9
	Clover	8.4
	Pea	2.3
	Potato	7.6
	Winter wheat	3.8

[1] Aboveground biomass measured at the of grain formation stage;
[2] Aboveground biomass

Table 2. The relative plant C allocation coefficients for calculations of annual NPP and C inputs

Crop	Relative plant C allocation coefficients			
	$R_{Product}$	R_{Shoot}	R_{Root}	$R_{Extra\text{-}root\ material}$
Barley[1]	0.451	0.400	0.090	0.059
Wheat[1]	0.322	0.482	0.118	0.078
Clover[1]	0.571	0.000	0.260	0.169
Pea[2]	0.233	0.577	0.115	0.075

[1] Based on Bolinder et al., 2007;
[2] Based on calculation of equations in Bolinder et al., 2007 (harvest index of pea 0.36 (Nisar et al., 2011) and shoot/root ratio 3.24 (Kumar and Goh, 2000)).


Experiment 1


Experiment 2


Experiment 3

Table 2. NPP, C inputs and C stock change, measured and simulated C stock of different experiments in Estonia

Experiment	Crop/crop rotation	Mineral N rate, kg N ha^{-1}	Organic fertilizer	NPP, kg C ha^{-1} y^{-1}	C input, kg C ha^{-1} y^{-1}	C stock, t ha^{-1}	C stock, t ha^{-1}	C stock change, kg ha^{-1} y^{-1}	ICMB
Experiment 1 (reddish-brown calcareous till)				Average of 1980-2012		Year 1964	Year 2012		Year 2012
	Barley	0	Without	1442	215	4.3	17.8	282	6.2
	Grasses	0		3338	2096	4.3	20.7	342	20.4
	Grasses-clover	0		4490	2108	4.3	29.0	515	21.4
Experiment 2 (*Fragi-Stagnic Albeluvisol* accord. WRB)				Average of 1990-2013		Year 1990	Year 2013		Year 2013
	Potato-Wheat-Barley	0	Without	2032	1027	31.0	29.9	-51	31.6
		40		2800	1327	30.5	30.4	-2	32.6
		80		3316	1513	29.6	30.5	40	34.1
		120		3549	1581	31.6	32.2	29	35.0
		160		3364	1496	30.7	32.4	81	33.9
		0	60 t manure ha^{-1} in rotation	2520	1152	30.0	34.5	216	40.6
		40		3275	1438	30.4	38.3	376	42.5
		80		3716	1583	29.9	37.4	359	42.8
		120		3856	1613	30.6	37.8	341	43.5
		160		3700	1552	30.5	39.9	448	43.2
Experiment 3 (*Stagnic Luvisol* accord. WRB)				Average of 2008-2013		Year 2008	Year 2013		Year 2013
	Barley undersown with red clover - Red clover - Winter wheat - Pea – Potato	0	Without	4467	3226	46.7	48.4	340	50.7
		(20) 40-50[1]		5415	3697	51.1	50.5	-120	55.8
		(20) 80-100		5198	3350	51.6	49.6	-400	55.7
		(20) 120-150		5179	3302	51.5	52.2	140	56.2
		0	CC[2]	4235	4415	52.7	56.5	760	57.2
		0	CC+40 t manure ha^{-1} in rotation	4130	4762	45.3	58.2	2580	50.9

[1] N rate depended on the specific crop;
[2] Catch crop (winter rape after pea; rye after potato; ryegrass after winter wheat