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Changes in soil carbon stocks from 1960 to 2000 in the main Belgian cropland areas

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Inventories of soil organic carbon (SOC) stocks for 1960, 1990 and 2000 have recently become available for Belgium. From these inventories we selected three agricultural regions (Polders, Loam belt and Condroz) with 60 to 80 % of the agricultural area under cropland in order to analyse the driving forces of the changes in SOC stocks over time. The observed values of SOC stocks of typical soil associations for each agricultural region are compared to simulations with the RothC soil carbon model. After estimating the local parameters by fitting the model to SOC values from a long term experiment in central Belgium, the model was run from 1960 to 2000 for typical soil profiles of soil associations in the three agricultural regions. The main factors inducing changes in SOC stocks are the increase in plough depth as a result of continued mechanisation in the 1960's and the sustained input of organic amendments in the form of farm yard manure and slurry. In contrast to earlier publications on CO_2 emissions from agricultural soils, the model did not predict a decrease in SOC stocks for the period 1990–2000. The decrease in animal manure production observed during the 1990's for those regions with a concentration of intensive livestock breeding in Flanders suggests that SOC stocks in croplands will continue to decrease. This will lead to an emission of 0.41 Mt CO_2 per year for the three main cropland areas of Belgium in the near future and hence partly offset the carbon sequestration potential of improved cropland management (0.95 Mt CO_2 per year).
Keywords. Soil organic carbon, long term experiments, modelling, carbon sequestration, Belgium.

Variation des stocks de carbone entre 1960 et 2000 dans les principales zones agricoles de Belgique. Des inventaires nationaux en Belgique montrent une évolution des réserves de carbone organique du sol (COS) durant la période 1960 à 1990 et 2000. Dans le but d'analyser les principaux facteurs de ces changements, notre étude se concentre sur l'évolution des réserves de COS des associations de sols présentes dans les trois régions agricoles de Belgique dominées par les grandes cultures : les Polders, la région limoneuse et le Condroz. La comparaison des valeurs de COS observées dans l'inventaire avec les résultats d'un modèle de dynamique de carbone (RothC) permet de quantifier les facteurs les plus actifs dans l'évolution des réserves de COS. Après estimation des paramètres locaux par ajustement des paramètres du modèle à l'évolution des réserves de COS observées, nous avons simulé l'évolution des stocks de carbone pour les associations de sols typiques des trois régions agricoles sur la période allant de 1960 à 2000. Les principaux facteurs induisant des variations de COS sont l'augmentation de la profondeur de labour et l'accroissement des apports d'effluents d'élevage sous forme de fumier et de lisier. Contrairement aux résultats publiés précédemment dans la littérature, le modèle ne prédit pas de diminution du contenu en COS durant la période 1990–2000. La diminution de la production d'effluents d'élevage observée dans les années 1990 pour les régions avec un élevage intensif suggère que les stocks de COS continueront à baisser ce qui représente une émission de 0,41 Mt CO_2 par an pour les sols arables dans trois régions de grandes cultures en Belgique. Cette émission annule en partie le potentiel de séquestration d'une gestion améliorée des terres agricoles (0,95 Mt CO_2 par an).
Mots-clés. Carbone organique du sol, expérimentation à long terme, modélisation, puits de carbone, Belgique.

1. INTRODUCTION

Regional scale estimates of soil organic carbon stocks (SOC) are currently becoming available. Howard *et al.* (1995) demonstrated the large variation in SOC stocks for the United Kingdom with the bulk of the carbon stored in Scottish peat. Arrouays *et al.* (2001) reported spatial variation in SOC stocks induced by soil type, land use and climate in France. The influence of soil type, land use and climate on SOC stocks at the national scale implies that sequestration of carbon in the soil is limited to a local maximum, and that the carbon sequestration potential is spatially variable. The most appropriate way to study SOC content is on a unit area basis for a specified depth interval. In the literature two depth intervals are commonly used: 0–30 cm is considered to reflect the SOC stock which reacts quickly to changes in climate, land use and management, 0–100 cm represents the total carbon stocks and the depth to which soil data are available for most soils (e.g. Batjes, 1996).

A GIS framework has been developed to estimate SOC stocks in Belgian terrestrial ecosystems (Lettens *et al.*, 2004). The basic units have uniform soil, climate and land use and are referred to as landscape units (LSU). The LSU are a topological intersection of the 1990 version of the CORINE Land Cover dataset (European Commission, 1993) and the digitised soil association map of Belgium (1/500,000; Tavernier, Maréchal, 1962). For 1960, the soil carbon density expressed in ton ha^{-1} can be computed directly from the profiles in the 'Aardewerk' database (Van Orshoven *et al.*, 1993; Lettens *et al.*, 2004). Carbon stocks are calculated for specified depth intervals using the carbon content, the horizon thickness, the bulk density and the stone content. For 1990 and 2000, the carbon content of arable soils is derived from several databases containing the results of routine fertility analyses. These inventories show that the SOC stock in the upper 30 cm of cropland soils increased from 1960 to 1990 and decreased again to 2000 (Lettens *et al.*, 2004). The decrease in SOC stock for Belgian croplands with 0.3 t C ha^{-1} yr^{-1} from 1990 to 2000 is slightly lower than the decrease of 0.90 t C ha^{-1} yr^{-1} in Flemish croplands reported by Sleutel *et al.* (2003) and the decrease under the business as usual scenario in European croplands of 0.84 t C ha^{-1} yr^{-1} reported by Vleeshouwers and Verhagen (2002). However, the drivers of these changes in SOC stocks are difficult to determine from either inventories aggregated at the regional scale or from modelling exercises at the European scale with gridcells of *ca.* 3,000 km^2. The spatially explicit inventories available for different time slices in Belgium consist of soil-land cover units of *ca.* 50 km^2 (LSU). These LSU provide an excellent starting point for research into the drivers of the SOC stock change in arable soils, and their observed SOC stocks can be used to evaluate the uncertainty of model predictions.

This paper combines regional scale SOC modelling with spatially explicit inventories of three different time slices i.e. 1960, 1990 and 2000 (Lettens *et al.*, 2004). The objective of this paper is to investigate the driving forces of the SOC dynamics from 1960 to 2000 at the regional scale by comparing the outcomes of a process based model to the SOC stocks of the landscape units distinguished by Lettens *et al.* (2004).

2. MATERIALS AND METHODS

2.1. Calibration of the RothC model

The RothC-26.3 model was developed to simulate the turnover of organic carbon in arable soils (Coleman, Jenkinson, 1996). The model has been tested against SOC stocks in long term experiments under a range of climate and soil conditions (Coleman *et al.*, 1997; Smith *et al.*, 1997). The internal structure and internal parameters were unaltered. The details of the RothC model and the model itself can be obtained from the GCTE SOMNET website (http://saffron.res.bbsrc.ac.uk/cgi-bin/somnet-models). In this paper the model was used to simulate the evolution of SOC stocks for the long term experiments in Gembloux (Frankinet *et al.*, 1993). These experiments are conducted by the Centre de Recherche Agronomique de Gembloux since 1959 and are one of the GCTE SOMNET sites. The silty soil with a clay percentage of 13.5% and an initial SOC stock of 38.28 t C ha^{-1} (0–22 cm) was ploughed to a depth of 22 cm and occasionally 35 cm. The rotation consists of sugar beet followed by 2 or 3 years of cereals, mainly winter wheat, winter barley, pigeon beans, oats and fallow. The mean monthly precipitation and potential evapotranspiration (Penman-Monteith) recorded at the meteorological station of Gembloux (at 3 km distance) were averaged for the 1959–1994 period. Amendments of farm yard manure (FYM) and slurry were converted to carbon input and averaged over the measurement period.

The inert organic matter pool (IOM) was estimated from the initial SOC stock using the equation proposed by Falloon *et al.* (1998). RothC was then run to equilibrium, iteratively fitting carbon inputs to match the initial SOC stock and thus the distribution in compartments with different decomposition rates (Coleman, Jenkinson, 1996). The plant C input to the soil was estimated by optimising the total SOC stock predicted by the to the measured data of the control experiment. The same plant C input was then used adding FYM and/or crop residue as specified for the other experiments. The plant C input that fitted both the control experiment and those with amendments was retained. The performance of the model was evaluated on the root mean square error (RMSE) used by Smith *et al.* (1997):

$$RMSE = \frac{100}{\bar{O}} \sqrt{\sum_{i=1}^{n} \left(P_i - O_i\right)^2 / n} \qquad \textbf{Equation 1}$$

where O is observed, $\bar{O}$ is the mean of the observed values, P is predicted and n is the number of samples.

2.2. Regional application of the RothC model

The RothC model was run to equilibrium to reproduce the initial SOC stocks for these LSU given by Lettens *et al.* (2004) as a starting value. Once the plant input for Belgian croplands is determined (see above), the model was run for the LSU (i.e. soil associations under cropland). The predicted SOC stock for the upper 22 cm in 1990 and 2000 was then compared to the observed stocks in the LSU from the inventories by Lettens *et al.* (2004). Three agricultural regions with mainly arable agriculture on a climate gradient from clay to clay loam soils in the maritime plain (Polders), to silt to silt loam soils in middle Belgium (Loam belt) and stony loam soils on the transition to the semi-continental plateaus (Condroz) were selected (**Figure 1**). Time slices of approximately five years from 1958 onwards were selected from the agricultural statistics and the following variables were extracted: the total area in production (TAA) and the number of each type of livestock subdivided in age classes (INS, 1958–2002).

Farm yard manure and slurry production were calculated according to the methodology proposed by Dendoncker *et al.* (2004). These authors estimate the annual production of either FYM or slurry using the livestock in age classes, the type of housing, the time spent in the housing and excretion coefficients published by the Walloon Government (AGW, 2002). Farm yard manure and slurry inputs were then converted to carbon stocks using a dry matter content of 25% for FYM and 12% for slurry (Vlaamse Landmaatschappij, 2004) and a carbon content of 41% for both (Brady, Weil, 1996). We assume that FYM and slurry were spread from July to November on both arable and grassland soils within the agricultural region.

Figure 1. Location of the long term experiments (Gembloux) and the three agricultural regions — *Situation des essais permanents de Gembloux et des trois régions agricoles* : 1 = Dunes-Polders, 2 = Loam belt — *région limoneuse*, 3 = Condroz.

For all simulations, the tillage depth was considered to be 22 cm. This corresponds to the tillage depth of the long term experiments in Gembloux and to the sampling depth of the 1960, 1990 and 2000 SOC data. However, tillage depth has not remained constant over the 1960–2000 period. An increase in tillage depth results in a decrease of SOC concentrations in the topsoil, since a dilution over a larger volume of soil of the same plant input occurs (Van Meirvenne *et al.*, 1996). A tillage depth of 21 cm is reported in 1960 for the Loam belt (Van Oost *et al.*, 2000) and for western Flanders (Van Meirvenne *et al.*, 1996). As a result of mechanisation the tillage depth in the Loam belt increased to 25 cm in 1970 and remained constant thereafter (Van Oost *et al.*, 2000). This is confirmed by local farmers who state that the main constraint to deeper tillage is ploughing up the less fertile B horizon. We assume tillage depth to have increased from 21 cm in 1960 to 25 cm in 1970. Hence the modelled SOC stocks are multiplied by a factor decreasing from 1.0 in 1960 to 0.84 from 1970 to 2000.

The dominant, associated and included soil series for each soil association were chosen from paper maps (Lettens *et al.*, 2004). The clay content for the topsoil for each of these series was then extracted from the 'Aardewerk' database (Van Orshoven *et al.*, 1993). Weighing factors of 0.6, 0.35 and 0.05 for dominant, associated and included series were used to calculate the average clay content for the soil association.

Monthly precipitation and temperature for the centre of the three agricultural regions were extracted from a spatial climate database (ATEAM climatology) divided into 10' × 10' grid cells covering Europe (New *et al.*, 2002). These were aggregated to average monthly precipitation, temperature for the period 1960–2000. Monthly potential evapotranspiration was calculated from the temperature using the empirical formula of Thornthwaite (Shaw, 1994).

3. RESULTS AND DISCUSSION

3.1. Calibration of the RothC model on the Belgian long term experiments

The RothC-26.3 model was run to represent two of the treatments of the long term experiments in Gembloux. Crop residues were exported from the control plot which did not receive any organic amendments. This treatment was selected to iteratively adjust the plant input parameter to 2.5 t C ha^{-1} yr^{-1} (**Figure 2**). The FYM treatment was simulated using the same plant input. However, slurry and FYM were applied as specified in the experimental protocol (**Figure 2**).

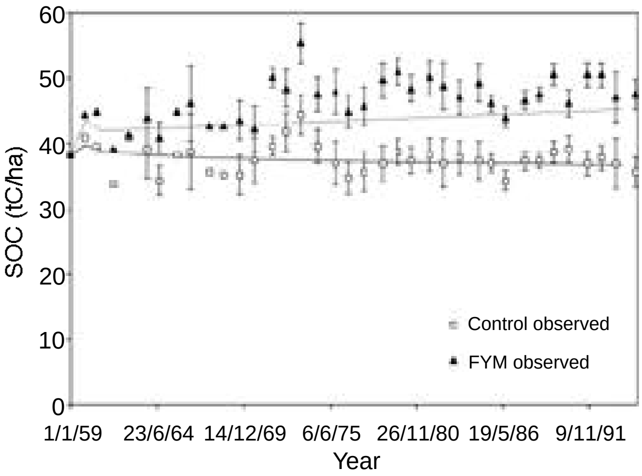

Figure 2. SOC dynamics in the 0–22 cm topsoil of the long term experiments of an arable rotation in Gembloux. A control is compared to a treatment receiving farm yard manure (FYM). Error bars indicate the 95% confidence limits around the mean — *Dynamique du carbone organique du sol (SOC) dans les essais permanents de Gembloux. Le traitement témoin (carrés blancs) est comparé au traitement qui reçoit du fumier (triangles noirs). Les barres d'erreur indiquent les limites de confiance à 95 %*.

Organic amendments were expressed in carbon input and were averaged over the duration of the experiment (in t C ha^{-1} yr^{-1}). The amendments were applied from July to November weighted according to the frequency of application in each month. After calibrating the plant input, the model reasonably represents the observed SOC stocks with uncertainties ranging from 5.8% RMSE (**Equation 1**) for the control to 9.5% for the FYM treatment. The RMSE's are in the same order of magnitude as the ones reported by Falloon and Smith (2003) for long term experiments in the UK, Hungary and Sweden.

3.2. Modelling SOC stocks for landscape units in three agricultural regions

We will now evaluate the performance of the RothC model when applied to the LSU of the spatially explicit inventories. Landscape units under cropland in three agricultural regions will be considered: Polders, Loam belt and Condroz (**Figure 1**). The total agricultural area (TAA) has decreased by 10–15% and within the agricultural area a gradual conversion from grassland to arable land has occurred from at least 1958 to 1990 (results not shown). Given the dominance of arable land in the agricultural regions and the low annual conversion rates, the possible impact of land conversions on the SOC stocks will not be considered.

The SOC stocks in the upper 22 cm for the arable LSU in each agricultural region are given in **table 1**. In the Polders, SOC stock increases with 0.5 t C ha^{-1} yr^{-1} between 1960 and 1990 and this increase is significant for 8 out of 10 LSU. This increase is comparable to the increase of 0.31 t C ha^{-1} yr^{-1} reported for a larger region including the Dunes-Polders which was reported by Van Meirvenne *et al.* (1996) based on a re-sampling in 1990 of 939 arable soils first analysed in the 1960's. However, these authors calculated their 1990 carbon stock to a depth of 36 cm taking into account the increase in tillage depth. The carbon stocks discussed in this paper refer to the upper 22 cm which have been diluted as a result of the increase in tillage depth from 21 to 25 cm (Van Oost *et al.*, 2000). From 1990 to 2000, the SOC stock decreased in the Polders by 0.3 t C ha^{-1} yr^{-1}. However, this decrease is significant for only 3 out of 10 LSU. This is in agreement with Sleutel *et al.* (2003) who could not find any significant trends either between 1990 and 2000 for the Polders region. SOC stocks in the Loam belt are generally low and only decrease very slightly (0.03 t C ha^{-1} yr^{-1}) between 1960 and 1990. The decrease is significant for 4 out of 6 of the soil associations, when association 36 is disregarded because of the small number of samples. The decrease from 1990 to 2000 is in the same order of magnitude as in the Polders region and is significant for 4 out of 6 of the soil associations. In the Condroz, the SOC stock decreases from 1960 to 1990 at a rate of 0.19 t C ha^{-1} yr^{-1}, whereby only 1 out of 7 soil associations shows a significant decrease. The increase from 1990 to 2000 is very slight and only significant for one soil association.

The dynamics of the SOC in the upper 22 cm of arable land was modelled for a soil association with low and high initial carbon stock in each agricultural region (**Figure 1**). The plant input of 2.5 t C ha^{-1} yr^{-1} calibrated for the long term in Gembloux was used. An export of crop residues was assumed. The production of FYM and slurry for each agricultural region is given in **table 2**. The results of a typical soil association in the Polders region and in the Loam belt are shown in **figure 3**. Starting from the 1960 SOC values, the RothC model generally predicts the observed values in 1990 reasonably well, since the model prediction passes nearly through the confidence limits of the observations. The decrease in SOC from 1960 to 1970 is a result of the dilution of organic inputs as a result of an increase in tillage depth. The mechanisation of agriculture was introduced after the second world war and completed in the 1960's. According to a survey among farmers in the Loam belt this led to an increase of tillage depth from *ca.* 18 cm for animal drought tillage to 25 cm in mechanised systems (Van Oost *et al.*, 2000). This trend is also reflected in the decrease of the number of horses declared by farmers which decreases rapidly until 1970 to reach a more or less stable value from 1975

Table 1. SOC stocks for the arable LSU in three agricultural regions. The number of samples and the 95% confidence limits are given — *Stocks de carbone organique du sol dans les unités paysagères arables de trois régions agricoles. Le nombre d'échantillons ainsi que les limites de confiance sont indiqués.*

Agricultural region Association	**1960**		**1990**		**2000**		**Δ 1960–1990**	**Δ 1990–2000**
	t C ha^{-1}	n	t C ha^{-1}	n	t C ha^{-1}	n	t C $ha^{-1}y^{-1}$	t C $ha^{-1}y^{-1}$
Dunes-Polders								
3	47.2 ± 6.9	18	50.8 ± 1	216	48.1 ± 1.7	135	0.1	-0.3
4	45.5 ± 4.3	33	56.5 ± 1.4	142	54.7 ± 3.6	40	0.4	-0.2
5	36.5 ± 6.6	27	63 ± 3	344	60.6 ± 3	332	0.9	-0.2
6	47.2 ± 9.5	15	61.3 ± 2.6	141	61.5 ± 3.1	130	0.5	0
7	26.7 ± 3.9	18	55.8 ± 2.6	34	54.4 ± 2.8	46	1	-0.1
8	34.8 ± 2.3	56	60.3 ± 1.8	346	57.3 ± 1.9	342	0.9	-0.3
9	60.7 ± 12.7	22	55.3 ± 1.6	316	50.8 ± 1.4	370	-0.2	-0.5
10	41.2 ± 4.8	26	61.6 ± 3	94	57.6 ± 3.1	87	0.7	-0.4
11	39.1 ± 6.2	30	67.5 ± 3.9	61	60.6 ± 2.8	67	0.9	-0.7
12	42.5 ± 4.1	30	53.5 ± 0.8	481	49.2 ± 1.1	344	0.4	-0.4
Loam belt								
30	43.3 ± 2.1	195	37.9 ± 0.8	1582	36.2 ± 0.5	1091	-0.2	-0.2
31	42.8 ± 1.3	524	40.9 ± 0.4	2358	32.8 ± 0.4	1407	-0.1	-0.8
32	35.4 ± 1.2	440	40.7 ± 0.6	1306	37 ± 0.5	1495	0.2	-0.4
33	38.6 ± 1.4	450	35.3 ± 1.1	605	35.4 ± 0.7	980	-0.1	0
34	47.2 ± 9.1	31	46.9 ± 5.1	39	44 ± 4.6	69	0	-0.3
35	35.7 ± 1.3	398	35.7 ± 1	85	32.9 ± 0.5	1077	0	-0.3
36	29.8 ± 2.8	4	36.2 ± 2.2	2	28.2 ± 1.1	3	0.2	-0.8
Condroz								
41	50.6 ± 5.6	55	42.5 ± 3.6	128	40.4 ± 1.6	133	-0.3	-0.2
42	40.2 ± 4.8	32	32.9 ± 2.5	56	35.8 ± 2.4	77	-0.2	0.3
43	37.9 ± 3.2	106	32.8 ± 2	76	35.1 ± 1.8	140	-0.2	0.2
44	39.1 ± 1.7	247	36.8 ± 1.4	208	37.7 ± 1.1	255	-0.1	0.1
46	54.0 ± 4	126	40.6 ± 1.8	186	45.3 ± 2.3	328	-0.4	0.5
47	43.5 ± 3.8	78	41.1 ± 5.7	62	39.7 ± 2.3	103	-0.1	-0.1
48	41.8 ± 3.3	64	40.4 ± 2.9	20	37.4 ± 2.7	75	0	-0.3

onwards (INS, 1958–2002). Overall, the changes in SOC stocks from 1990 to 2000 are consistent with the evolution of the manure production in the three agricultural regions: a decrease in both SOC stock and manure production in the Condroz, no obvious trends in the Loam belt and a clear increase in both manure and SOC in the Dunes-Polders region (**Tables 1** and **2**).

Overall the model fails to predict the decrease in SOC from 1990 to 2000. Sleutel *et al.* (2003) suggest that this decrease is due to stricter environmental regulations aimed to prevent nitrate pollution of surface and groundwater. In our calculations we assumed that all FYM and slurry produced in an agricultural region is spread on the agricultural area and the quantity of FYM and slurry produced was estimated from livestock numbers, type of housing and time spent in housing using the method proposed by Dendoncker *et al.* (2004). Since the bulk of FYM and slurry is produced by cattle and pigs, a mean nitrogen concentration of 4–6 kg per ton FYM or slurry can be assumed (Vlaamse Landmaatschappij, 2004; AGW, 2002). The manure production in **table 2** was converted to nitrogen production and then compared to the values published by the Flemish manure bookkeeping (Vlaamse Landmaatschappij, 2004). For Flanders we estimated a production of 197 kt N in 2000, which agrees well with the value of 191 kt N reported by the Flemish government (Vlaamse Landmaatschappij, 2004). In 2002, the total nitrogen load in FYM and slurry amounts to 59 kg N ha^{-1} in the Condroz to 70 kg N ha^{-1} in the Loam belt and 180 kg N ha^{-1} in the Dunes-Polders. These values are close to the maximum quantities which can be spread on arable land: 80 to 130 kg N ha^{-1} according to Walloon legislation (AGW, 2002) and 140 to 170 kg N ha^{-1} in nitrate vulnerable zones of Flanders (Vlaamse Landmaatschappij, 2004). The limits for grassland are higher at 210 to 230 kg N ha^{-1} in the Walloon region and from 250 to 310 kg N ha^{-1} outside nitrate vulnerable zones in Flanders. In particular for the

Table 2. Annual manure and slurry production, converted to carbon content, in each Belgian agricultural region — *Production annuelle de fumier et de lisier, exprimée en carbone, pour chaque région agricole belge.*

	t C ha^{-1} y^{-1}				
	1958	**1970**	**1980**	**1990**	**2002**
Polders	1.38	1.82	1.77	2.29	2.38
Sand	1.78	2.80	3.48	4.37	3.85
Campine	1.51	2.78	3.41	4.62	4.07
Sand-loam	1.33	1.96	2.26	2.77	2.53
Loam	1.05	1.19	0.99	1.05	1.07
Condroz	1.07	1.15	0.92	0.96	0.99
Herbagère Liègoise	2.44	2.39	1.99	1.80	1.67
Campine Hennuyère	1.25	1.48	1.15	1.13	1.06
High Ardenne	1.52	1.81	1.71	1.63	1.48
Herbagère Famenne	1.62	1.67	1.37	1.37	1.40
Famenne	1.15	1.29	1.14	1.28	1.39
Ardenne	1.25	1.47	1.36	1.72	1.79
Jura	0.99	1.15	1.36	1.28	1.31

Polders area with an average manure production close to the nitrogen limits for arable land, significant quantities could be concentrated on grassland or exported to other regions with lower manure production (**Table 2**). Furthermore, the import of manure in the Loam belt from Flemish regions with a high production, such as the Campine and the Sandy region have been forbidden during the 1990's. Hence carbon inputs from organic amendments are probably overestimated for the 1990–2000 period (**Figure 3**). The importance of animal manure for the evolution of SOC stocks highlights the need to simultaneously consider emissions of non-CO_2 greenhouse gases such as CH_4 and N_2O emitted either directly by livestock or once spread on agricultural soils.

There is an urgent need to quantify the impact of the decrease in animal excrements on the recent decrease in SOC stocks in the major cropland areas of Belgium. Extrapolating the decrease in SOC stocks in the three agricultural regions, one can roughly estimate these croplands to release 0.41 Mt CO_2 per year from 1990 until 2002 (**Table 1**). This release partly offsets the C sequestration potential of management of agricultural land. Dendoncker *et al.* (2004) estimated the Belgian potential for options such as bio-energy crops, spreading animal manure only on arable land, no till farming and the use of cover crops at 0.95 Mt CO_2 yr^{-1}. These are realistic scenarios taking into account environmental legislation and adoption rates of new techniques.

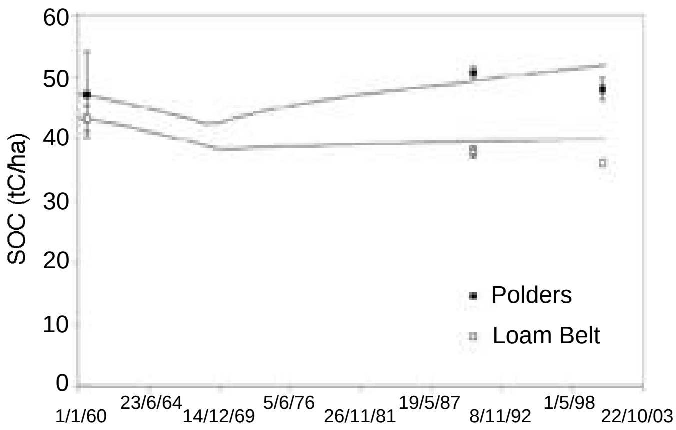

Figure 3. Examples of the evolution of SOC stocks in the upper 22 cm of soil associations under arable land in the Polders and Loam belt — *Exemples de l'évolution des stocks de carbone organique dans le sol (SOC) dans les associations de sol arable dans les Polders (carrés noirs) et la région limoneuse (carrés blancs)*.

4. CONCLUSIONS

After calibration of the RothC–26.3 model on long term experiments representing a typical arable rotation, the evolution in SOC stocks from 1960 to 2000 for the soil associations under cropland of three agricultural regions was simulated. For these regions on a climatic gradient across Belgium, statistical data on land use and livestock numbers are available from the 1950's onwards. In general RothC predicts a slight decrease for arable soils in the Loam belt and the Condroz and an increase in the Polders. The main drivers of the changes in SOC are an increase in tillage depth as a result of mechanisation in the 1960's and an increase in the livestock numbers in particular in the Polders and adjacent regions in Flanders. The model fails to predict the decrease in SOC from 1990 to 2000 for the soil associations in the Loam belt and the Polders. This is probably due to the fact that the input of manure is based on livestock numbers and excretion coefficients. In the 1990's limits for spreading of manure were introduced based on nitrogen loadings. In particular in the Polders regions these limits are exceeded for arable land and hence import of manure from neighbouring regions has probably diminished. This decrease in SOC will partly offset the potential for carbon sequestration through improved management of agricultural soils.

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