# Supplementary Material for

## Modelling dynamic soil organic carbon flows of annual and perennial energy crops to inform energy-transport policy scenarios in France

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# 1 Pre-treatment of techno-economic data for the coupling

## 1.1 Details on the biomass commodities outputs from the techno-economic model

The following considered dedicated annual and perennial energy crops, including residues, associated with the techno-economic outputs of biomass commodity supply the transport sub-sector, are listed in Table 1.

Table 1. Specifications of analysed energy crops in TIMES-MIRET

| Country | Energy crop | Feature | Crop type | Biomass commodity | Commodity type | TIMES-MIRET Code |
|---|---|---|---|---|---|---|
| France | Wheat | Annual | Grain | Starch | D | BIOSTAWHE |
| | | | Grain | Straw | R | BIORESWHE |
| France | Rapeseed | Annual | Oil crops | Oil | D | BIOOILRAP |
| | | | | Straw | R | BIORESRAP |
| France | Maize | Annual | Grain | Starch | D | BIOSTACOR |
| | | | | Straw | R | BIORESCOR |
| France | Sunflower | Annual | Oil crops | Oil | D | BIOOILSUN |
| France | Triticale | Annual | Grain | Starch | D | BIOSTATRI |
| | | | | Straw | R | BIORESTRI |
| France | Sugar beet | Annual | Vegetable | Sugar | D | BIOSUGFS |
| France | Miscanthus | Perennial | LGC grass | LGC | D | BIOLGCMIS |
| France | Other LGC (Switch grass) | Perennial | LGC grass | LGG | D | BIOLGCOTH |
| Brazil | Soybean | Annual | Protein crops | Oil | D | BIOOILSOY |

D = Dedicated; R = Residue; LGC = Lignocellulose

## 1.2 Data on chemical composition of energy crops

Table 2. Nutritional values and equivalent residual fraction

| Energy crops | Fresh matter $t \cdot t^{-1}$ | Starch $t \cdot ha^{-1}$ | Sugar $t \cdot ha^{-1}$ | Oil $t \cdot ha^{-1}$ | |
|---|---|---|---|---|---|
| Maize | 0.8630 | 0.6380 | 0.0170 | 0.0360 | a |
| Rapeseed | 0.9240 | 0.0360 | 0.0550 | 0.4400 | a |
| Wheat | 0.8780 | 0.5630 | 0.0280 | 0.0180 | a |
| Triticale | 0.8680 | 0.5880 | 0.0300 | 0.0120 | a |
| Sunflower | 0.9280 | 0.0120 | 0.0250 | 0.4460 | a |
| Sugar beet | N/A | N/A | 0.1750 | N/A | b |
| Soybean | 0.8950 | 0.0520 | 0.0750 | 0.1840 | a |

Sources: a (INRA-CIRAD-AFZ, 2017), b (Zabed et al., 2017)

## 1.3 Computation of land occupation requirements

Calculation of land occupation of biomass commodities outputs from the techno-economic model supply associated with dedicated annual crops and perennial grasses as well as residual straw is carried out by means of Eq. 1 to Eq. 2. The computation is based on yield proportions (crop products or residual) as well as corresponding chemical contents (starch, sugar or oil), retained from Table 2.

Eq. 1

$$Annual\ crops\ [ha] = \frac{Biomass\ commodity\ [t]}{Commodity\ chemical\ content\ [\%] \times Crop\ yield\ [t \cdot ha^{-1}]}$$

Eq. 2

$$Perennial\ grasses\ [ha] = \frac{Biomass\ commodity\ [t]}{Crop\ yield\ [t \cdot ha^{-1}]}$$

Eq. 3

$$Residues\ [ha] = \frac{Biomass\ commodity\ [t]}{Removal\ yield\ [\%] x\ Residue\ yield\ [t \cdot ha^{-1}]}$$

## 1.4 Computation of final energy supply

### 1.1.1 Biofuel supply and greenhouse gas emissions

Conversion factors concerning low heating values (LHV) and biofuel yields per biomass commodity and biofuel pathways, as well as GHG emission factors are estimated from the Well-To-Wheel (WTW) method for transport fuels by the scientific reference of the European Commission Joint Research Centre (EC-JRC) (Edwards et al., 2014) and adjusted to wet matter. The latter provides a relevant widely used assessment, although it does not involve emission from building facilities, vehicle productions nor end-of-life paths (https://ec.europa.eu/jrc/en/jec/activities/wtw).

Finally, we re-expressed all CO2-equivalent values into CO2, CH4 and N2O elementary flows based on the proportional values provided in the EC-JRC report appendices (Edwards et al., 2014) and IPCC Global Warming Potentials (GWP) factors (Myhre et al., 2013). The fossil-sourced GHG inventories per biomass-to-biofuel pathway form part of the complete dynamic carbon balance (fossil + biogenic), were assessed with the dynamic LCA method by Levasseur et al. (2010).

Low heating value (LHV) estimates, in $MJ \cdot kg^{-1}$, for bioethanol is 27 and for biodiesel 37 (Edwards et al., 2014). Yield efficiencies vary for bioethanol between 0.31 and 0.62 $kg_{Ethanol} \cdot kg_{Grain}^{-1}$, and less for biodiesel between 0.99 and 1 $MJ_{Biodiesel} \cdot MJ_{Oil}^{-1}$, as shown in Table 3.

Table 3. Ethanol and Biodiesel yields

| | Ehtanol Yield [$kg_{EtOH}\cdot kg_{Grain}$ DM$^{-1}$] | | Biodiesel Yield [$MJ_{BioDSL}\cdot MJ_{Oil}^{-1}$] |
|---|---|---|---|
| Maize | 0.62 | Rapeseed | 1.019 |
| Wheat | 0.31 | Soybean | 0.999 |
| Sugar beet | 0.33 | Sunflower | 0.999 |
| Dedicated | 0.43 | HPOFS* | 1.006 |
| Straw | 0.43 | | |

*Hydro-treated pyrolysis oil from straw

### 1.5 Computation of greenhouse gas emissions

The following estimates are based on the carbon neutral approach. GHG emissions of bioethanol vary considerably among the different commodities, whereas the emission factor for dedicated (22.8 g $CO_2$-eq) and residual (9.2 g $CO_2$-eq) lignocellulose are lower than from sugar beet (40.3 g $CO_2$-eq), wheat (69.4 g $CO_2$-eq) or maize (80.3 g $CO_2$-eq). Biodiesel GHG emissions from oleaginous crops range between 46 to 55 g $CO_2$-eq. The emission factor 11.5 g $CO_2$-eq by (O'Connell et al., 2019) was considered for hydro treated pyrolysis of oil from residual straw given pathway in the LTECV scenario. IPCC GWP factors are used: 1 g of $CO_2$-eq per 1 g $CO_2$, 28 g of $CO_2$-eq per 1 g $CH_4$ and 265 g of $CO_2$-eq per 1 g $N_2O$ (Myhre et al., 2013).

Table 4. Well-to-wheels GHG emission factors in $gCO_2eq\cdot MJ^{-1}$, including carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxides ($N_2O$) proportions

| | Code | $gCO_2eq\cdot MJ^{-1}$ | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|
| EU sugar beet to ethanol | SBET1a | 40.3 | 83% | 5% | 12% |
| EU wheat to ethanol | WTET1a | 69.4 | 70% | 4% | 25% |
| Corn (maize) (average used in EU) to ethanol | CRET2a | 80.31 | 71% | 5% | 24% |
| EU farmed (WF) or waste (WW) wood to ethanol | WFET1 | 22.8 | 85% | 3% | 12% |
| EU wheat straw to ethanol | STET1 | 9.19 | 94% | 3% | 3% |
| Rapeseed to biodiesel (Rapeseed Methyl Ester) | ROFA1 | 53.88 | 50% | 3% | 47% |
| Sunflower to biodiesel (Sunflower seed Methyl Ester) | SOFA3 | 45.9 | 51% | 3% | 46% |
| Soybeans to biodiesel (Soy Methyl ester) | SYFA3a | 55.13 | 50% | 3% | 47% |

Source: (Edwards et al., 2014)

## 2 Soil organic carbon modelling

### 2.1 Structure of the model

The structure of the two-compartment model adopted from Hénin and Dupuis (1945) is illustrated in Fig. 1.

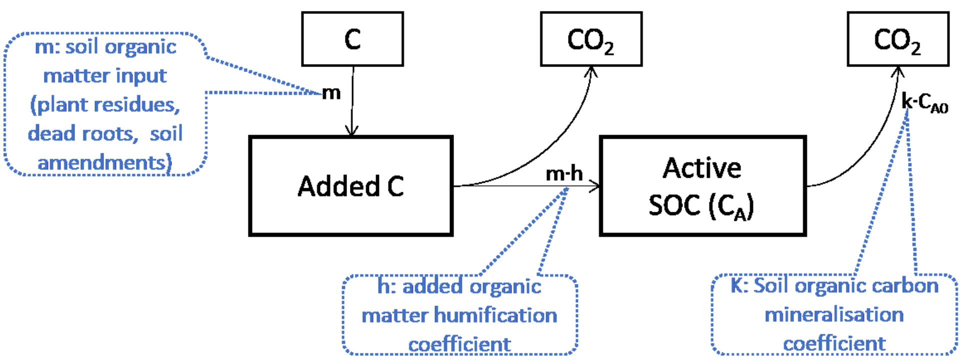



Fig. 1. Carbon pools and transfer equations for dynamic soil organic carbon modelling (adapted from Hénin and Dupuis (1945) and Saffih-Hdadi and Mary (2008))

## 2.2 Review mineralisation coefficient

The mineralisation coefficient *k* represents the annual decay of soil organic carbon, that is to say the rate of humus destroyed every year. In France the mean ratio is often estimated at 2% (Frisque, 2007; Le Villio et al., 2001; UNIFA, 1998). A review of several studies indicated a range for France between 0.7% and 9%, with mean values at 4% (Table 5).

Table 5. Reference values for mineralisation coefficient

| Country | Type of soil | Climate | Mineralisation *k* coefficient [$y^{-1}$] | |
|---|---|---|---|---|
| Sweden | Clay loam | Climate Ultuna | 0.019 | [a] |
| Denmark | Sandy loam | Climate Askov | 0.044 | [a] |
| France | Calcareous clay | Climate Issoudun | 0.033 | [a] |
| France | Sandy clay loam | Climate Grignon | 0.038 | [a] |
| France | Clay loam | Climate Boigneville | 0.050 | [a] |
| France | Sandy loam | Climate Serreslous | 0.094 | [a] |
| France | Sandy loam | Climate Doazit | 0.090 | [a] |
| Thailand | Sand | Climate Khon Kaend | 0.348 | [a] |
| Denmark | Sandy loam | Climate Askov | 0.043 | [a] |
| France | Neutral sandy | N/A | 0.020 | [b] |
| France | acidic sand | N/A | 0.010 | [b] |
| France | sandy limestone | N/A | 0.017 | [b] |
| France | N/A | Climate Picardie | 0.092 | [c] |
| France | medium silt | N/A | 0.016 | [b] |
| France | N/A | Climate Picardie | 0.074 | [c] |
| France | clay silt | N/A | 0.013 | [b] |
| France | limestone silt | N/A | 0.009 | [b] |
| France | N/A | Climate Picardie | 0.059 | [c] |
| France | clay | N/A | 0.010 | [b] |
| France | N/A | Climate Picardie | 0.041 | [c] |
| France | N/A | mean annual temperature | 0.070 | [d] |
| France | Clay-limestone | N/A | 0.007 | [b] |
| France | N/A | Climate Picardie | 0.048 | [c] |
| France | limestone | Climate Picardie | 0.037 | [c] |
| France | Pergamino soil series | N/A | 0.070 | [e] |
| France | | Temperate general | 0.020 | [bf] |
| France | | Mediterranean general | 0.030 | [bf] |
| Argentina | N/A | N/A | 0.060 | [g] |
| Brazil | N/A | N/A | 0.100 | [g] |

Sources : [a.] (Saffih-Hdadi and Mary, 2008), [b.] (Le Villio et al., 2001), [c.] (Duparque et al., 2007a) [d.] (Moreno et al., 2016), [e.] (Irizar et al., 2015), [f.] (Henin and Dupuis, 1945) [g.] (Piccolo et al., 2008).

To compute the *k* coefficient we used Eq. 4 of the AMGv2 model (Clivot et al., 2019), dependent on soil temperature (*T*), clay content (*A*) and calcium carbonate ($CaCO_3$):

$$K = K_0 f_1(T) f_2 (A) f_3 CaCO_3) \quad \text{Eq. 4}$$

with $K_0$ = 0.290 [$yr^{-1}$].

$K_0$ [$yr^{-1}$] is the potential mineralisation rate in the reference condition, ranging between 0.165 and 0.290 [$yr^{-1}$]. . The formulation for temperature in Eq. 5 allows accounting for a quasi-exponential effect of mean temperature in France (up to 25°C).

$$f_1(T) = \frac{a_T}{1+(a_T-1)\exp(c_T \times T_{Ref})\exp(C_T \times T))} \qquad if\ T \geq 0, \qquad \text{Eq. 5}$$

$$f_1(T) = 0 \qquad if\ T < 0.$$

with $a_T$ = 25, $c_T$ = 0.120$K^{-1}$ and $T_{Ref}$ = 15°C

The effect of clay (*A*) content [$g{\cdot}g^{-1}$ soil] on mineralisation is described by an exponential law, according to Eq. 6, with constant *a* [$g{\cdot}g^{-1}$ soil] assumed to be 2.519 (Clivot et al., 2019).

$$f_2(A) = \exp(-a_m A) \qquad \text{Eq. 6}$$

The effect of calcium carbonate [$CaCO_3$] is computed with Eq. 7.

$$f_3(CaCO_3) = \frac{1}{1 + c_m CaCO_3} \qquad \text{Eq. 7}$$

with $c_m$=1.67 and 1.50 [$g{\cdot}g^{-1}$ soil]

### 2.2.1 Soil texture, soil type and climate typology of France

Data for clay contents in France according to main soil texture and types are listed in Table 6.

Table 6. Clay content according to main soil texture and types in France

| Soil texture | Soil type | Clay (%) | | Sand (%) | | | Silt (%) |
|---|---|---|---|---|---|---|---|
| | | min | min | min | max | min | max |
| Clayey | Clay | 30 | 55 | 55 | 70 | 55 | 80 |
| | Silty clay | 30 | 55 | 55 | 70 | 80 | 100 |
| | Heavy clay | 45 | 0 | 0 | 55 | 0 | 100 |
| | Sandy clay | 25 | 55 | 55 | 75 | 0 | 55 |
| Silty | Clayey silt | 18 | 70 | 70 | 82 | 85 | 100 |
| | Medium silt | 8 | 82 | 82 | 92 | 85 | 100 |
| | Light silt | 0 | 92 | 92 | 100 | 85 | 100 |
| Balanced | Light sandy silt | 0 | 92 | 92 | 100 | 45 | 85 |
| | Clayey-sandy silt | 18 | 70 | 70 | 82 | 65 | 85 |
| | Medium sandy silt | 8 | 82 | 82 | 92 | 65 | 85 |
| | Sandy silt | 8 | 82 | 82 | 92 | 45 | 65 |
| | Sandy-clayey silt | 18 | 70 | 70 | 82 | 45 | 65 |
| Sandy | Sand | 0 | 90 | 90 | 100 | 0 | 20 |
| | Clayey sand | 10 | 75 | 75 | 90 | 0 | 45 |
| | Silty sand | 0 | 88 | 88 | 100 | 20 | 45 |

Source: (Gis Sol, 2011)

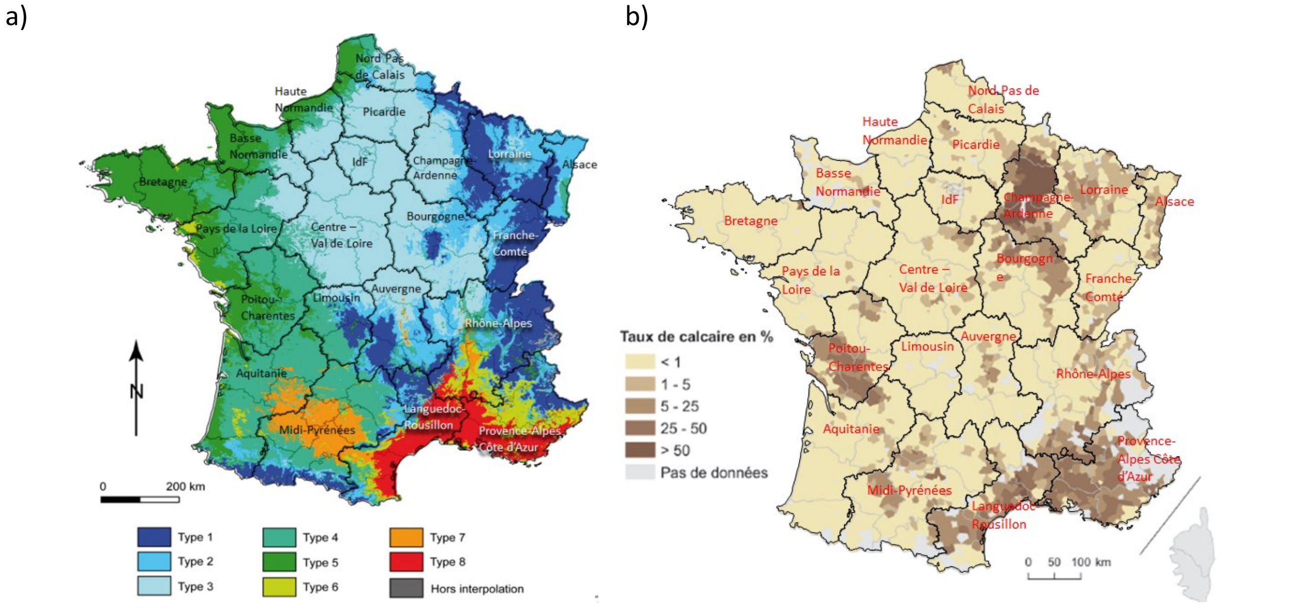



Fig. 2. a) Climate typology of the French territory in 8 classes (adapted from Joly et al. (2010)), and b) Calcium carbonate content [%] concerning calcium carbonate [$CaCO_3$] of agricultural soils in France, (adapted from Gis Sol (2011))

### 2.2.2 Calculated values for national crops

Mineralisation coefficient *k* is based on mean clay content and climatic typology computed with Eq. 4 to Eq. 6. Results from the computation are given in Table 7 for all climatic types of France. Assumption for the coupling: Consideration of the mineralisation constant for type 3 due to the largest area of cereals and oily seeds production in France.

Table 7. Climate typology in France with mean temperature, clay and calcium carbonate contents to calculate the soil mineralisation coefficient

| Type | Name | Temperature [°C] | Clay [%] | Calcium carbonate [%] | Mineralisation coefficient (*k*) [$y^{-1}$] |
|---|---|---|---|---|---|
| Type 1 | Mountain climate | 9 | 18.5 | 5 | 0.0841 |
| Type 2 | Semi-continental climate and mountain margin climate | 10 | 25.2 | 5 | 0.0799 |
| Type 3 | Degraded oceanic climate of the Central and Northern Plains | 11 | 16.8 | 1 | 0.1176 |
| Type 4 | Altered oceanic climate | 12.5 | 22.0 | 5 | 0.1160 |
| Type 5 | Oceanic climate | 12.5 | 14.9 | 1 | 0.1470 |
| Type 6 | Altered Mediterranean climate | 12.5 | 15.6 | 35 | 0.0961 |
| Type 7 | Climate of the South-western Basin | 13 | 42.6 | 5 | 0.0731 |
| Type 8 | Mediterranean climate | 13 | 15.6 | 35 | 0.1018 |

### 2.2.3 Calculated values for imported soybean

The *k* coefficient of imported soybean is also based Eq. 4 to Eq. 6, with reference soil temperature at 27°C, representing about 2°C higher temperature of surface soils in soybean cropland (Nagy et al., 2018).

Table 8. Mean temperature and clay content to calculate the mineralisation coefficient

| Country | Crop | Temperature [°C] | Clay [%] | Calcium carbonate [%] | Mineralisation coefficient (*k*) [$y^{-1}$] |
|---|---|---|---|---|---|
| Brazil | Soybean | 25 | 43 | 4 | 0.07332 |

Sources: (Ensinas et al., 2016; Nagy et al., 2018)

# 3 Calculation of plant carbon allocation and soil organic carbon inputs

### 3.1.1 Relative plant C allocation coefficients

$$R_P + R_S + R_R + R_E = 1$$ Eq. 8

Table 9. Relative plant carbon (C) allocation coefficients

| Crop | Yield [a] t ha$^{-1}$ | Relative plant C allocation coefficients [b] RP | RS | RR | RE |
|---|---|---|---|---|---|
| Wheat | 6.410 | 0.298 | 0.426 | 0.166 | 0.110 |
| Rapeseed | 11.980 | 0.107 | 0.576 | 0.191 | 0.126 |
| Maize | 22.788 | 0.325 | 0.352 | 0.194 | 0.129 |
| Sunflower | 3.655 | 0.360 | 0.540 | 0.100 | 0.000 |
| Triticale | 3.479 | 0.260 | 0.506 | 0.142 | 0.092 |
| Sugar beet | 95.240 | 0.872 | 0.048 | 0.048 | 0.032 |
| Soybean | 2.720 | 0.304 | 0.455 | 0.146 | 0.095 |
| Miscanthus | 15.714 | 0.268 | 0.303 | 0.322 | 0.107 |
| Switchgrass (proxy grass species) | 5.190 | 0.441 | 0.000 | 0.308 | 0.200 |

Sources: a (Besnard et al. 2014; Strullu et al. 2014; Cattelan and Dall'Agnol 2018; AGRESTE 2019), b (Bolinder et al. 2007b; Strullu 2011; Strullu et al. 2014; Wiesmeier et al. 2014 (from 1995 to 2010); Agostini et al. 2015; Carvalho et al. 2017), for miscanthus aboveground inputs between 40% and 67% (Carvalho et al., 2017; Strullu, 2011; Strullu et al., 2014) and perennial belowground proportions of rhizomes 75% and roots 25% (Agostini et al., 2015).
Descriptions of sub-indices: P - agricultural aboveground product, S - residual aboveground compartment, R - root/rhizome tissue, E - extra-root material

### 3.1.2 Net primary productivity

The C proportion in four plant fractions is defined by Eq. 9 (M. A. Bolinder et al., 2007):

$$NPP = C_P + C_S + C_R + C_E$$ Eq. 9

For this study, the carbon content of the product ($C_P$) was calculated from mean annual yield values of the product ($Y_p$) and the respective carbon content ($C_y$) given in Eq. 10. The proportions of the other crop plant fractions are estimated by means of the relative plant C allocation coefficients Table 9 respectively applying Eq. 11 to Eq. 13 (Wiesmeier et al., 2014).

$$C_P = Y_p \times C_y$$ Eq. 10

$$C_S = \left({}^{R_S}/_{R_P}\right) \times C_P$$ Eq. 11

$$C_R = \left({}^{R_R}/_{R_P}\right) \times C_P$$ Eq. 12

$$C_E = \left({}^{R_E}/_{R_P}\right) \times C_P$$ Eq. 13

### 3.1.3 Details on exogenous inputs

Organic soil amendment/fertiliser input is estimated based on the following data and assumptions.

Table 10. N content of main organic fertilisers used in France

| Organic amendments | use in France (contribution) % | | Average N content $kg \cdot t^{-1}$ | |
|---|---|---|---|---|
| Cattle manure and slurry | 59% | a | 4.40 | b |
| Poultry manure and droppings | 11% | a | 17.4 | b |
| Swine manure and slurry | 10% | a | 5.40 | b |
| Others (compost as proxy) | 20% | a | 11.6 | b |

Sources: a (AGRESTE, 2014), b (Avadí, 2019)

Table 11. National French averages of N inputs to crops (representing the organic fertiliser inputs to the average ha of crop)

| | N requirements of crops from exclusively mineral sources $kg \cdot ha^{-1}$ | N requirements of crops from mineral sources $kg \cdot ha^{-1}$ | N requirements of crops from organic sources $t \cdot ha^{-1}$ | Cattle manure and slurry delivered $t \cdot ha^{-1}$ | Poultry manure and droppings delivered $t \cdot ha^{-1}$ | Swine manure and slurry delivered $t \cdot ha^{-1}$ | Compost delivered $t \cdot ha^{-1}$ | Percentage of crops applying organic fertilisers % |
|---|---|---|---|---|---|---|---|---|
| Wheat | 169 | 140 | 81 | 0.82 | 0.04 | 0.11 | 0.10 | 8% |
| Triticale | 107 | 87 | 122 | 5.26 | 0.25 | 0.72 | 0.67 | 32% |
| Maize | 133 | 92.5 | 144 | 11.07 | 0.52 | 1.51 | 1.41 | 57% |
| Rapeseed | 169 | 153 | 87 | 3.99 | 0.19 | 0.55 | 0.51 | 34% |
| Sugar beet | 123 | 95 | 126 | 9.52 | 0.45 | 1.30 | 1.21 | 56% |
| Sunflower | 56 | 45 | 124 | 2.84 | 0.13 | 0.39 | 0.36 | 17% |
| Miscanthus | 52 | 21 | 31 | 1.51 | 0.07 | 0.21 | 0.19 | 36% |
| Switch grass | 65 | 38 | 27 | 0.98 | 0.05 | 0.13 | 0.13 | 27% |
| Sources | a | a | a | b | b | b | b | a |

Sources: a (AGRESTE, 2014), b Computed from average N contents, % of crops applying organic fertilisation, and contribution of organic fertilisers to national use Table 11

The input of organic fertiliser (*i*) per energy crop (*j*) is computed by means of Eq. 14:

$$Input\ Fertiliser_{organic_{ij}} = Fertiliser_{organic_{ij}} \times crop_i\ applying\ Fertiliser_{organic_j}(\%) \quad \text{Eq. 14}$$

$$Fertiliser_{organic_{ij}} = \frac{N_{organic_j} \times Fertiliser_{organic_j}\ use\ in\ the\ country\ of\ origin\ (\%)}{Mean\ N_i\ content}$$

### 3.1.4 Correction factor for carbon inputs to the soil

The carbon inputs ($C_i$) per plant fraction may be adjusted by means of correction factors (S), according to Eq. 15 (Wiesmeier et al., 2012) as not all the crop plant fractions return to the soil.

$$C_i = (C_P \times S_P) + (C_S \times S_S) + (C_R \times S_R) + (C_E \times S_E) \quad \text{Eq. 15}$$

# 4 Computed time-dynamic soil organic carbon flows per management scenario

## 4.1 Scenario 1: Aboveground, Belowground and Exogenous inputs

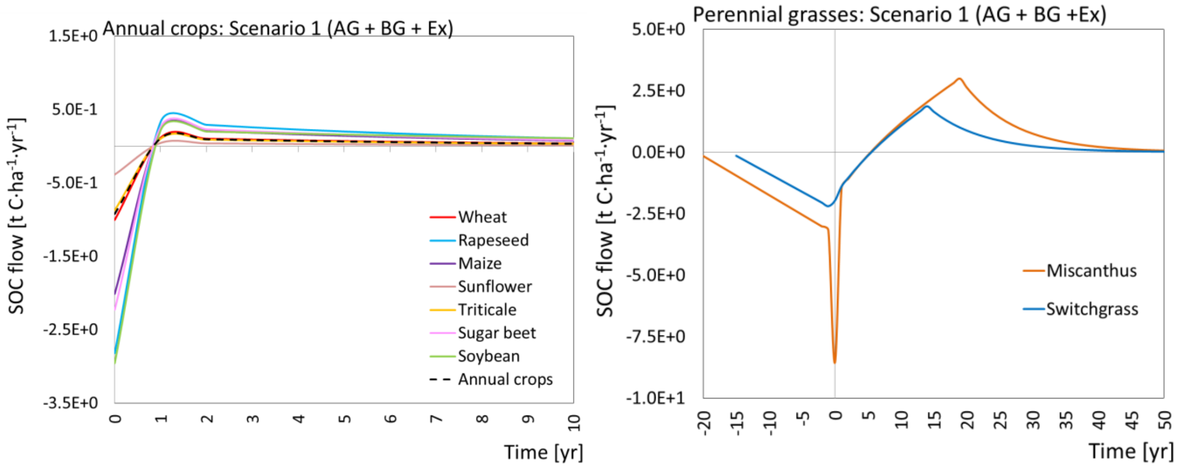



Fig. 3. Scenario 1 annual soil organic carbon elementary flows of annual crops and perennial grasses

Table 12. Scenario 1 SOC flows [t C·ha$^{-1}$ ·yr$^{-1}$]

| | Annual Crops | | | | | | | | Perennial grasses | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Annual | Wheat | Rapeseed | Maize | Sunflower | Triticale | Sugar beet | Soybean | Miscanthus | Switch grass |
| -20 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.588E-1 | 0.000E+0 |
| -19 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.177E-1 | 0.000E+0 |
| -18 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -4.765E-1 | 0.000E+0 |
| -17 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -6.353E-1 | 0.000E+0 |
| -16 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -7.942E-1 | 0.000E+0 |
| -15 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -9.530E-1 | -1.465E-1 |
| -14 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.112E+0 | -2.930E-1 |
| -13 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.271E+0 | -4.396E-1 |
| -12 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.429E+0 | -5.861E-1 |
| -11 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.588E+0 | -7.326E-1 |
| -10 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.747E+0 | -8.791E-1 |
| -9 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.906E+0 | -1.026E+0 |
| -8 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.065E+0 | -1.172E+0 |
| -7 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.224E+0 | -1.319E+0 |
| -6 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.382E+0 | -1.465E+0 |
| -5 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.541E+0 | -1.612E+0 |
| -4 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.700E+0 | -1.758E+0 |
| -3 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.859E+0 | -1.905E+0 |
| -2 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.018E+0 | -2.051E+0 |
| -1 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.177E+0 | -2.198E+0 |
| 0 | -9.214E-1 | -1.003E+0 | -2.819E+0 | -2.011E+0 | -3.856E-1 | -8.716E-1 | -2.227E+0 | -2.956E+0 | -8.561E+0 | -1.970E+0 |
| 1 | 1.084E-1 | 1.180E-1 | 3.315E-1 | 2.365E-1 | 4.535E-2 | 1.025E-1 | 2.619E-1 | 2.167E-1 | -1.460E+0 | -1.397E+0 |
| 2 | 9.562E-2 | 1.041E-1 | 2.925E-1 | 2.087E-1 | 4.002E-2 | 9.045E-2 | 2.311E-1 | 2.008E-1 | -1.092E+0 | -1.052E+0 |
| 3 | 8.437E-2 | 9.184E-2 | 2.581E-1 | 1.842E-1 | 3.531E-2 | 7.982E-2 | 2.039E-1 | 1.861E-1 | -7.487E-1 | -7.300E-1 |
| 4 | 7.445E-2 | 8.104E-2 | 2.278E-1 | 1.625E-1 | 3.116E-2 | 7.043E-2 | 1.800E-1 | 1.725E-1 | -4.271E-1 | -4.287E-1 |
| 5 | 6.569E-2 | 7.151E-2 | 2.010E-1 | 1.434E-1 | 2.749E-2 | 6.215E-2 | 1.588E-1 | 1.598E-1 | -1.246E-1 | -1.456E-1 |
| 6 | 5.797E-2 | 6.310E-2 | 1.773E-1 | 1.265E-1 | 2.426E-2 | 5.484E-2 | 1.401E-1 | 1.481E-1 | 1.610E-1 | 1.214E-1 |
| 7 | 5.115E-2 | 5.568E-2 | 1.565E-1 | 1.117E-1 | 2.141E-2 | 4.839E-2 | 1.236E-1 | 1.372E-1 | 4.316E-1 | 3.743E-1 |
| 8 | 4.513E-2 | 4.913E-2 | 1.381E-1 | 9.852E-2 | 1.889E-2 | 4.270E-2 | 1.091E-1 | 1.272E-1 | 6.891E-1 | 6.146E-1 |
| 9 | 3.983E-2 | 4.335E-2 | 1.218E-1 | 8.694E-2 | 1.667E-2 | 3.768E-2 | 9.626E-2 | 1.178E-1 | 9.350E-1 | 8.439E-1 |
| 10 | 3.514E-2 | 3.825E-2 | 1.075E-1 | 7.671E-2 | 1.471E-2 | 3.324E-2 | 8.494E-2 | 1.092E-1 | 1.171E+0 | 1.064E+0 |
| 11 | 3.101E-2 | 3.375E-2 | 9.486E-2 | 6.769E-2 | 1.298E-2 | 2.933E-2 | 7.495E-2 | 1.012E-1 | 1.397E+0 | 1.275E+0 |
| 12 | 2.736E-2 | 2.978E-2 | 8.371E-2 | 5.973E-2 | 1.145E-2 | 2.588E-2 | 6.614E-2 | 9.378E-2 | 1.616E+0 | 1.478E+0 |
| 13 | 2.414E-2 | 2.628E-2 | 7.386E-2 | 5.270E-2 | 1.010E-2 | 2.284E-2 | 5.836E-2 | 8.690E-2 | 1.828E+0 | 1.675E+0 |
| 14 | 2.130E-2 | 2.319E-2 | 6.518E-2 | 4.651E-2 | 8.916E-3 | 2.015E-2 | 5.149E-2 | 8.053E-2 | 2.033E+0 | 1.865E+0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 1.880E-2 | 2.046E-2 | 5.751E-2 | 4.104E-2 | 7.868E-3 | 1.778E-2 | 4.544E-2 | 7.462E-2 | 2.233E+0 | 1.646E+0 |
| 16 | 1.659E-2 | 1.806E-2 | 5.075E-2 | 3.621E-2 | 6.942E-3 | 1.569E-2 | 4.009E-2 | 6.915E-2 | 2.428E+0 | 1.452E+0 |
| 17 | 1.464E-2 | 1.593E-2 | 4.478E-2 | 3.195E-2 | 6.126E-3 | 1.385E-2 | 3.538E-2 | 6.408E-2 | 2.619E+0 | 1.282E+0 |
| 18 | 1.292E-2 | 1.406E-2 | 3.951E-2 | 2.819E-2 | 5.405E-3 | 1.222E-2 | 3.122E-2 | 5.938E-2 | 2.806E+0 | 1.131E+0 |
| 19 | 1.140E-2 | 1.241E-2 | 3.486E-2 | 2.488E-2 | 4.770E-3 | 1.078E-2 | 2.755E-2 | 5.503E-2 | 2.990E+0 | 9.979E-1 |
| 20 | 1.006E-2 | 1.095E-2 | 3.076E-2 | 2.195E-2 | 4.209E-3 | 9.513E-3 | 2.431E-2 | 5.099E-2 | 2.638E+0 | 8.805E-1 |
| 21 | 8.874E-3 | 9.659E-3 | 2.715E-2 | 1.937E-2 | 3.714E-3 | 8.394E-3 | 2.145E-2 | 4.725E-2 | 2.328E+0 | 7.770E-1 |
| 22 | 7.830E-3 | 8.523E-3 | 2.395E-2 | 1.709E-2 | 3.277E-3 | 7.407E-3 | 1.893E-2 | 4.379E-2 | 2.054E+0 | 6.856E-1 |
| 23 | 6.909E-3 | 7.521E-3 | 2.114E-2 | 1.508E-2 | 2.892E-3 | 6.536E-3 | 1.670E-2 | 4.058E-2 | 1.812E+0 | 6.050E-1 |
| 24 | 6.096E-3 | 6.636E-3 | 1.865E-2 | 1.331E-2 | 2.551E-3 | 5.767E-3 | 1.474E-2 | 3.760E-2 | 1.599E+0 | 5.338E-1 |
| 25 | 5.379E-3 | 5.856E-3 | 1.646E-2 | 1.174E-2 | 2.251E-3 | 5.089E-3 | 1.300E-2 | 3.485E-2 | 1.411E+0 | 4.710E-1 |
| 26 | 4.747E-3 | 5.167E-3 | 1.452E-2 | 1.036E-2 | 1.987E-3 | 4.490E-3 | 1.147E-2 | 3.229E-2 | 1.245E+0 | 4.156E-1 |
| 27 | 4.189E-3 | 4.559E-3 | 1.281E-2 | 9.143E-3 | 1.753E-3 | 3.962E-3 | 1.012E-2 | 2.992E-2 | 1.099E+0 | 3.667E-1 |
| 28 | 3.696E-3 | 4.023E-3 | 1.131E-2 | 8.068E-3 | 1.547E-3 | 3.496E-3 | 8.933E-3 | 2.773E-2 | 9.696E-1 | 3.236E-1 |
| 29 | 3.261E-3 | 3.550E-3 | 9.977E-3 | 7.119E-3 | 1.365E-3 | 3.085E-3 | 7.883E-3 | 2.570E-2 | 8.555E-1 | 2.856E-1 |
| 30 | 2.878E-3 | 3.132E-3 | 8.803E-3 | 6.282E-3 | 1.204E-3 | 2.722E-3 | 6.956E-3 | 2.381E-2 | 7.549E-1 | 2.520E-1 |
| 31 | 2.539E-3 | 2.764E-3 | 7.768E-3 | 5.543E-3 | 1.063E-3 | 2.402E-3 | 6.137E-3 | 2.207E-2 | 6.661E-1 | 2.223E-1 |
| 32 | 2.241E-3 | 2.439E-3 | 6.854E-3 | 4.891E-3 | 9.377E-4 | 2.120E-3 | 5.416E-3 | 2.045E-2 | 5.878E-1 | 1.962E-1 |
| 33 | 1.977E-3 | 2.152E-3 | 6.048E-3 | 4.316E-3 | 8.274E-4 | 1.870E-3 | 4.779E-3 | 1.895E-2 | 5.186E-1 | 1.731E-1 |
| 34 | 1.745E-3 | 1.899E-3 | 5.337E-3 | 3.808E-3 | 7.301E-4 | 1.650E-3 | 4.217E-3 | 1.756E-2 | 4.576E-1 | 1.528E-1 |
| 35 | 1.539E-3 | 1.676E-3 | 4.709E-3 | 3.360E-3 | 6.443E-4 | 1.456E-3 | 3.721E-3 | 1.627E-2 | 4.038E-1 | 1.348E-1 |
| 36 | 1.358E-3 | 1.479E-3 | 4.155E-3 | 2.965E-3 | 5.685E-4 | 1.285E-3 | 3.283E-3 | 1.508E-2 | 3.563E-1 | 1.189E-1 |
| 37 | 1.199E-3 | 1.305E-3 | 3.667E-3 | 2.616E-3 | 5.016E-4 | 1.134E-3 | 2.897E-3 | 1.397E-2 | 3.144E-1 | 1.049E-1 |
| 38 | 1.058E-3 | 1.151E-3 | 3.235E-3 | 2.309E-3 | 4.426E-4 | 1.000E-3 | 2.556E-3 | 1.295E-2 | 2.774E-1 | 9.260E-2 |
| 39 | 9.332E-4 | 1.016E-3 | 2.855E-3 | 2.037E-3 | 3.906E-4 | 8.828E-4 | 2.256E-3 | 1.200E-2 | 2.448E-1 | 8.171E-2 |
| 40 | 8.235E-4 | 8.963E-4 | 2.519E-3 | 1.798E-3 | 3.446E-4 | 7.790E-4 | 1.990E-3 | 1.112E-2 | 2.160E-1 | 7.210E-2 |
| 41 | 7.266E-4 | 7.909E-4 | 2.223E-3 | 1.586E-3 | 3.041E-4 | 6.874E-4 | 1.756E-3 | 1.030E-2 | 1.906E-1 | 6.362E-2 |
| 42 | 6.412E-4 | 6.979E-4 | 1.961E-3 | 1.400E-3 | 2.683E-4 | 6.065E-4 | 1.550E-3 | 9.548E-3 | 1.682E-1 | 5.614E-2 |
| 43 | 5.658E-4 | 6.158E-4 | 1.731E-3 | 1.235E-3 | 2.368E-4 | 5.352E-4 | 1.367E-3 | 8.848E-3 | 1.484E-1 | 4.954E-2 |
| 44 | 4.992E-4 | 5.434E-4 | 1.527E-3 | 1.090E-3 | 2.089E-4 | 4.722E-4 | 1.207E-3 | 8.199E-3 | 1.310E-1 | 4.371E-2 |
| 45 | 4.405E-4 | 4.795E-4 | 1.348E-3 | 9.616E-4 | 1.844E-4 | 4.167E-4 | 1.065E-3 | 7.598E-3 | 1.156E-1 | 3.857E-2 |
| 46 | 3.887E-4 | 4.231E-4 | 1.189E-3 | 8.485E-4 | 1.627E-4 | 3.677E-4 | 9.395E-4 | 7.041E-3 | 1.020E-1 | 3.403E-2 |
| 47 | 3.430E-4 | 3.733E-4 | 1.049E-3 | 7.487E-4 | 1.435E-4 | 3.245E-4 | 8.290E-4 | 6.525E-3 | 8.997E-2 | 3.003E-2 |
| 48 | 3.026E-4 | 3.294E-4 | 9.258E-4 | 6.606E-4 | 1.267E-4 | 2.863E-4 | 7.315E-4 | 6.046E-3 | 7.939E-2 | 2.650E-2 |
| 49 | 2.670E-4 | 2.907E-4 | 8.170E-4 | 5.829E-4 | 1.118E-4 | 2.526E-4 | 6.455E-4 | 5.603E-3 | 7.006E-2 | 2.338E-2 |
| 50 | 2.356E-4 | 2.565E-4 | 7.209E-4 | 5.144E-4 | 9.862E-5 | 2.229E-4 | 5.696E-4 | 5.192E-3 | 6.182E-2 | 2.063E-2 |

## 4.2 Scenario 2: Aboveground carbon inputs only

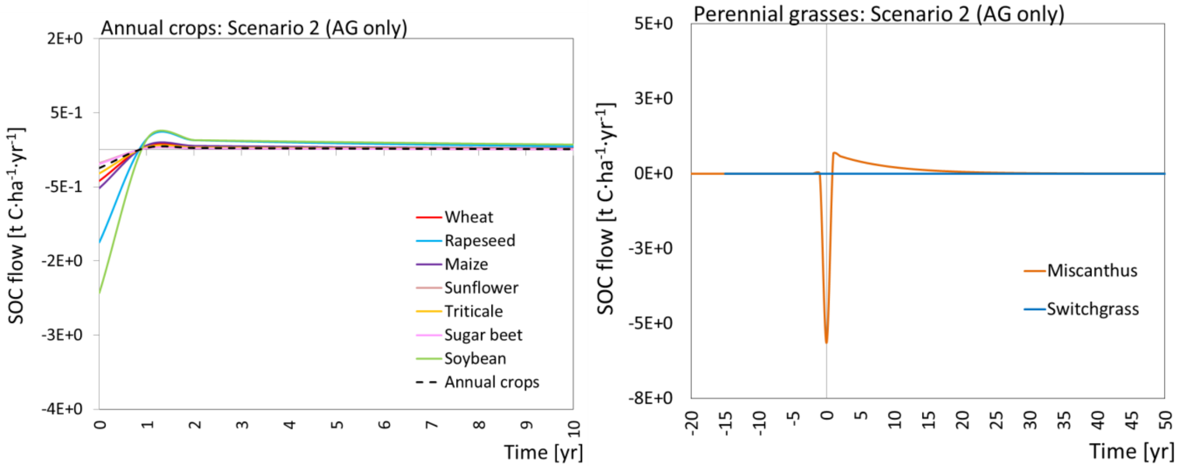



Fig. 4. Scenario 2 annual soil organic carbon elementary flows of annual crops and perennial grasses

Table 13. Scenario 2 SOC flows [t C·ha$^{-1}$·yr$^{-1}$]

| yr | Annual Crops Total Annual | Wheat | Rapeseed | Maize | Sunflower | Triticale | Sugar beet | Soybean | Perennial grasses Miscanthus | Switch grass |
|---|---|---|---|---|---|---|---|---|---|---|
| -20 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -19 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -18 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -17 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -16 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -15 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -14 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -13 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -12 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -11 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -10 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -9 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -8 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -7 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -6 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -5 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -4 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -3 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -2 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -1 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| 0 | -2.457E-1 | -4.193E-1 | -1.248E+0 | -5.170E-1 | -1.795E-1 | -3.180E-1 | -1.903E-1 | -1.932E+0 | -5.645E+0 | 0.000E+0 |
| 1 | 2.889E-2 | 4.931E-2 | 1.468E-1 | 6.080E-2 | 2.111E-2 | 3.740E-2 | 2.239E-2 | 1.417E-1 | 6.639E-1 | 0.000E+0 |
| 2 | 2.549E-2 | 4.351E-2 | 1.295E-1 | 5.365E-2 | 1.863E-2 | 3.300E-2 | 1.975E-2 | 1.313E-1 | 5.858E-1 | 0.000E+0 |
| 3 | 2.250E-2 | 3.839E-2 | 1.143E-1 | 4.734E-2 | 1.644E-2 | 2.912E-2 | 1.743E-2 | 1.217E-1 | 5.169E-1 | 0.000E+0 |
| 4 | 1.985E-2 | 3.388E-2 | 1.009E-1 | 4.177E-2 | 1.451E-2 | 2.570E-2 | 1.538E-2 | 1.127E-1 | 4.561E-1 | 0.000E+0 |
| 5 | 1.752E-2 | 2.989E-2 | 8.900E-2 | 3.686E-2 | 1.280E-2 | 2.267E-2 | 1.357E-2 | 1.045E-1 | 4.025E-1 | 0.000E+0 |
| 6 | 1.546E-2 | 2.638E-2 | 7.853E-2 | 3.253E-2 | 1.129E-2 | 2.001E-2 | 1.198E-2 | 9.681E-2 | 3.551E-1 | 0.000E+0 |
| 7 | 1.364E-2 | 2.328E-2 | 6.929E-2 | 2.870E-2 | 9.966E-3 | 1.765E-2 | 1.057E-2 | 8.971E-2 | 3.134E-1 | 0.000E+0 |
| 8 | 1.203E-2 | 2.054E-2 | 6.114E-2 | 2.532E-2 | 8.794E-3 | 1.558E-2 | 9.324E-3 | 8.314E-2 | 2.765E-1 | 0.000E+0 |
| 9 | 1.062E-2 | 1.812E-2 | 5.395E-2 | 2.235E-2 | 7.760E-3 | 1.375E-2 | 8.228E-3 | 7.704E-2 | 2.440E-1 | 0.000E+0 |
| 10 | 9.370E-3 | 1.599E-2 | 4.761E-2 | 1.972E-2 | 6.847E-3 | 1.213E-2 | 7.260E-3 | 7.139E-2 | 2.153E-1 | 0.000E+0 |
| 11 | 8.268E-3 | 1.411E-2 | 4.201E-2 | 1.740E-2 | 6.042E-3 | 1.070E-2 | 6.406E-3 | 6.616E-2 | 1.900E-1 | 0.000E+0 |
| 12 | 7.295E-3 | 1.245E-2 | 3.707E-2 | 1.535E-2 | 5.331E-3 | 9.444E-3 | 5.653E-3 | 6.131E-2 | 1.676E-1 | 0.000E+0 |
| 13 | 6.437E-3 | 1.099E-2 | 3.271E-2 | 1.355E-2 | 4.704E-3 | 8.333E-3 | 4.988E-3 | 5.681E-2 | 1.479E-1 | 0.000E+0 |
| 14 | 5.680E-3 | 9.695E-3 | 2.886E-2 | 1.195E-2 | 4.151E-3 | 7.353E-3 | 4.401E-3 | 5.264E-2 | 1.305E-1 | 0.000E+0 |
| 15 | 5.012E-3 | 8.554E-3 | 2.547E-2 | 1.055E-2 | 3.663E-3 | 6.488E-3 | 3.884E-3 | 4.878E-2 | 1.152E-1 | 0.000E+0 |
| 16 | 4.423E-3 | 7.548E-3 | 2.247E-2 | 9.307E-3 | 3.232E-3 | 5.725E-3 | 3.427E-3 | 4.521E-2 | 1.016E-1 | 0.000E+0 |
| 17 | 3.903E-3 | 6.661E-3 | 1.983E-2 | 8.213E-3 | 2.852E-3 | 5.052E-3 | 3.024E-3 | 4.189E-2 | 8.967E-2 | 0.000E+0 |
| 18 | 3.444E-3 | 5.877E-3 | 1.750E-2 | 7.247E-3 | 2.516E-3 | 4.458E-3 | 2.668E-3 | 3.882E-2 | 7.912E-2 | 0.000E+0 |
| 19 | 3.039E-3 | 5.186E-3 | 1.544E-2 | 6.395E-3 | 2.220E-3 | 3.934E-3 | 2.354E-3 | 3.597E-2 | 6.982E-2 | 0.000E+0 |
| 20 | 2.681E-3 | 4.576E-3 | 1.362E-2 | 5.643E-3 | 1.959E-3 | 3.471E-3 | 2.077E-3 | 3.334E-2 | 6.161E-2 | 0.000E+0 |
| 21 | 2.366E-3 | 4.038E-3 | 1.202E-2 | 4.979E-3 | 1.729E-3 | 3.063E-3 | 1.833E-3 | 3.089E-2 | 5.436E-2 | 0.000E+0 |
| 22 | 2.088E-3 | 3.563E-3 | 1.061E-2 | 4.393E-3 | 1.526E-3 | 2.703E-3 | 1.618E-3 | 2.863E-2 | 4.797E-2 | 0.000E+0 |
| 23 | 1.842E-3 | 3.144E-3 | 9.360E-3 | 3.877E-3 | 1.346E-3 | 2.385E-3 | 1.427E-3 | 2.653E-2 | 4.233E-2 | 0.000E+0 |
| 24 | 1.625E-3 | 2.774E-3 | 8.259E-3 | 3.421E-3 | 1.188E-3 | 2.104E-3 | 1.259E-3 | 2.458E-2 | 3.735E-2 | 0.000E+0 |
| 25 | 1.434E-3 | 2.448E-3 | 7.288E-3 | 3.018E-3 | 1.048E-3 | 1.857E-3 | 1.111E-3 | 2.278E-2 | 3.296E-2 | 0.000E+0 |
| 26 | 1.266E-3 | 2.160E-3 | 6.431E-3 | 2.663E-3 | 9.248E-4 | 1.638E-3 | 9.806E-4 | 2.111E-2 | 2.908E-2 | 0.000E+0 |
| 27 | 1.117E-3 | 1.906E-3 | 5.674E-3 | 2.350E-3 | 8.161E-4 | 1.446E-3 | 8.653E-4 | 1.956E-2 | 2.566E-2 | 0.000E+0 |
| 28 | 9.854E-4 | 1.682E-3 | 5.007E-3 | 2.074E-3 | 7.201E-4 | 1.276E-3 | 7.635E-4 | 1.813E-2 | 2.264E-2 | 0.000E+0 |
| 29 | 8.695E-4 | 1.484E-3 | 4.418E-3 | 1.830E-3 | 6.354E-4 | 1.126E-3 | 6.737E-4 | 1.680E-2 | 1.998E-2 | 0.000E+0 |
| 30 | 7.672E-4 | 1.309E-3 | 3.898E-3 | 1.615E-3 | 5.607E-4 | 9.932E-4 | 5.945E-4 | 1.557E-2 | 1.763E-2 | 0.000E+0 |
| 31 | 6.770E-4 | 1.155E-3 | 3.440E-3 | 1.425E-3 | 4.947E-4 | 8.764E-4 | 5.246E-4 | 1.443E-2 | 1.556E-2 | 0.000E+0 |
| 32 | 5.974E-4 | 1.020E-3 | 3.035E-3 | 1.257E-3 | 4.365E-4 | 7.733E-4 | 4.629E-4 | 1.337E-2 | 1.373E-2 | 0.000E+0 |
| 33 | 5.271E-4 | 8.997E-4 | 2.678E-3 | 1.109E-3 | 3.852E-4 | 6.824E-4 | 4.084E-4 | 1.239E-2 | 1.211E-2 | 0.000E+0 |
| 34 | 4.651E-4 | 7.938E-4 | 2.363E-3 | 9.789E-4 | 3.399E-4 | 6.021E-4 | 3.604E-4 | 1.148E-2 | 1.069E-2 | 0.000E+0 |
| 35 | 4.104E-4 | 7.005E-4 | 2.085E-3 | 8.637E-4 | 2.999E-4 | 5.313E-4 | 3.180E-4 | 1.064E-2 | 9.430E-3 | 0.000E+0 |
| 36 | 3.622E-4 | 6.181E-4 | 1.840E-3 | 7.622E-4 | 2.647E-4 | 4.688E-4 | 2.806E-4 | 9.857E-3 | 8.321E-3 | 0.000E+0 |
| 37 | 3.196E-4 | 5.454E-4 | 1.624E-3 | 6.725E-4 | 2.335E-4 | 4.137E-4 | 2.476E-4 | 9.135E-3 | 7.343E-3 | 0.000E+0 |
| 38 | 2.820E-4 | 4.813E-4 | 1.433E-3 | 5.934E-4 | 2.061E-4 | 3.650E-4 | 2.185E-4 | 8.465E-3 | 6.479E-3 | 0.000E+0 |
| 39 | 2.488E-4 | 4.247E-4 | 1.264E-3 | 5.236E-4 | 1.818E-4 | 3.221E-4 | 1.928E-4 | 7.844E-3 | 5.717E-3 | 0.000E+0 |
| 40 | 2.196E-4 | 3.747E-4 | 1.116E-3 | 4.620E-4 | 1.604E-4 | 2.842E-4 | 1.701E-4 | 7.269E-3 | 5.045E-3 | 0.000E+0 |
| 41 | 1.937E-4 | 3.306E-4 | 9.844E-4 | 4.077E-4 | 1.416E-4 | 2.508E-4 | 1.501E-4 | 6.736E-3 | 4.451E-3 | 0.000E+0 |
| 42 | 1.709E-4 | 2.918E-4 | 8.686E-4 | 3.598E-4 | 1.249E-4 | 2.213E-4 | 1.325E-4 | 6.242E-3 | 3.928E-3 | 0.000E+0 |
| 43 | 1.508E-4 | 2.574E-4 | 7.664E-4 | 3.174E-4 | 1.102E-4 | 1.953E-4 | 1.169E-4 | 5.784E-3 | 3.466E-3 | 0.000E+0 |
| 44 | 1.331E-4 | 2.272E-4 | 6.763E-4 | 2.801E-4 | 9.727E-5 | 1.723E-4 | 1.031E-4 | 5.360E-3 | 3.058E-3 | 0.000E+0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 45 | 1.174E-4 | 2.004E-4 | 5.968E-4 | 2.472E-4 | 8.583E-5 | 1.520E-4 | 9.100E-5 | 4.967E-3 | 2.699E-3 | 0.000E+0 |
| 46 | 1.036E-4 | 1.769E-4 | 5.266E-4 | 2.181E-4 | 7.573E-5 | 1.342E-4 | 8.030E-5 | 4.603E-3 | 2.381E-3 | 0.000E+0 |
| 47 | 9.145E-5 | 1.561E-4 | 4.646E-4 | 1.924E-4 | 6.682E-5 | 1.184E-4 | 7.085E-5 | 4.265E-3 | 2.101E-3 | 0.000E+0 |
| 48 | 8.069E-5 | 1.377E-4 | 4.100E-4 | 1.698E-4 | 5.897E-5 | 1.045E-4 | 6.252E-5 | 3.953E-3 | 1.854E-3 | 0.000E+0 |
| 49 | 7.120E-5 | 1.215E-4 | 3.618E-4 | 1.498E-4 | 5.203E-5 | 9.217E-5 | 5.517E-5 | 3.663E-3 | 1.636E-3 | 0.000E+0 |
| 50 | 6.283E-5 | 1.072E-4 | 3.192E-4 | 1.322E-4 | 4.591E-5 | 8.133E-5 | 4.868E-5 | 3.394E-3 | 1.444E-3 | 0.000E+0 |

## 4.3 Scenario 3: Belowground carbon inputs only

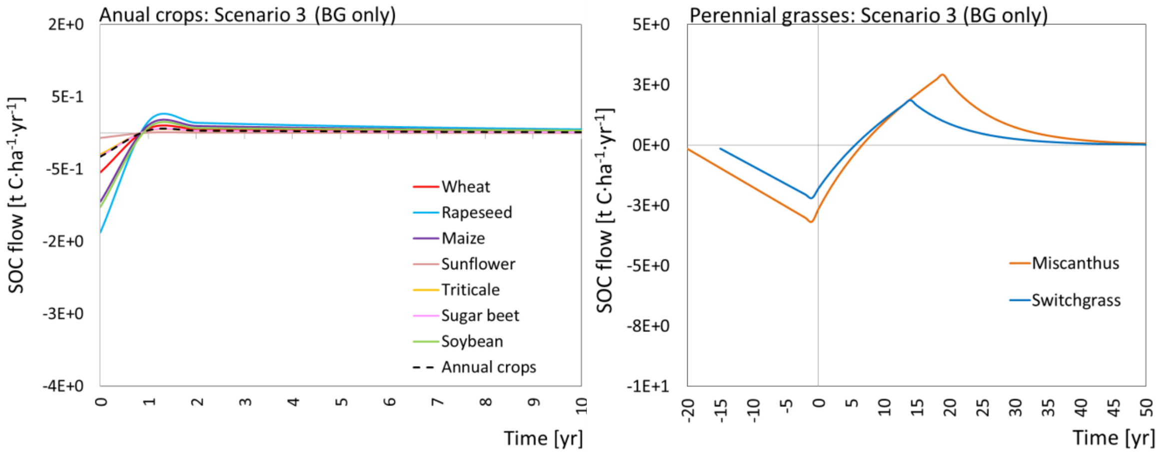


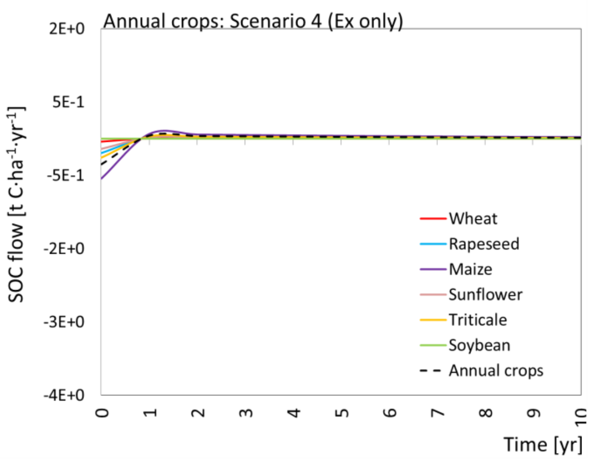

Fig. 5. Scenario 3 annual soil organic carbon elementary flows of annual crops and perennial grasses

Table 14. Scenario 3 SOC flows [$t\ C\cdot ha^{-1}\cdot yr^{-1}$]

| | Annual Crops | | | | | | | | Perennial grasses | |
|---|---|---|---|---|---|---|---|---|---|---|
| yr | S1 Total Annual | S1 Wheat | S1 Rapeseed | S1 Maize | S1 Sunflower | S1 Triticale | S1 Sugar beet | S1 Soybean | S1 Miscanthus | S1 Switch grass |
| -20 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.588E-1 | 0.000E+0 |
| -19 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.177E-1 | 0.000E+0 |
| -18 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -4.765E-1 | 0.000E+0 |
| -17 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -6.353E-1 | 0.000E+0 |
| -16 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -7.942E-1 | 0.000E+0 |
| -15 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -9.530E-1 | -1.465E-1 |
| -14 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.112E+0 | -2.930E-1 |
| -13 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.271E+0 | -4.396E-1 |
| -12 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.429E+0 | -5.861E-1 |
| -11 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.588E+0 | -7.326E-1 |
| -10 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.747E+0 | -8.791E-1 |
| -9 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -1.906E+0 | -1.026E+0 |
| -8 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.065E+0 | -1.172E+0 |
| -7 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.224E+0 | -1.319E+0 |
| -6 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.382E+0 | -1.465E+0 |
| -5 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.541E+0 | -1.612E+0 |
| -4 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.700E+0 | -1.758E+0 |
| -3 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -2.859E+0 | -1.905E+0 |
| -2 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.018E+0 | -2.051E+0 |
| -1 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | 0.000E+0 | -3.177E+0 | -2.198E+0 |
| 0 | -3.255E-1 | -5.433E-1 | -1.374E+0 | -9.488E-1 | -6.600E-2 | -2.941E-1 | -3.172E-1 | -1.023E+0 | -2.644E+0 | -1.793E+0 |
| 1 | 3.828E-2 | 6.390E-2 | 1.616E-1 | 1.116E-1 | 7.762E-3 | 3.459E-2 | 3.731E-2 | 7.504E-2 | -2.156E+0 | -1.418E+0 |
| 2 | 3.378E-2 | 5.638E-2 | 1.426E-1 | 9.846E-2 | 6.849E-3 | 3.052E-2 | 3.292E-2 | 6.954E-2 | -1.706E+0 | -1.070E+0 |
| 3 | 2.980E-2 | 4.975E-2 | 1.258E-1 | 8.688E-2 | 6.044E-3 | 2.693E-2 | 2.905E-2 | 6.444E-2 | -1.290E+0 | -7.463E-1 |
| 4 | 2.630E-2 | 4.390E-2 | 1.110E-1 | 7.666E-2 | 5.333E-3 | 2.377E-2 | 2.563E-2 | 5.971E-2 | -9.051E-1 | -4.431E-1 |
| 5 | 2.320E-2 | 3.874E-2 | 9.796E-2 | 6.765E-2 | 4.706E-3 | 2.097E-2 | 2.262E-2 | 5.534E-2 | -5.465E-1 | -1.583E-1 |
| 6 | 2.048E-2 | 3.418E-2 | 8.644E-2 | 5.969E-2 | 4.152E-3 | 1.851E-2 | 1.996E-2 | 5.128E-2 | -2.113E-1 | 1.102E-1 |
| 7 | 1.807E-2 | 3.016E-2 | 7.627E-2 | 5.267E-2 | 3.664E-3 | 1.633E-2 | 1.761E-2 | 4.752E-2 | 1.032E-1 | 3.644E-1 |
| 8 | 1.594E-2 | 2.661E-2 | 6.730E-2 | 4.648E-2 | 3.233E-3 | 1.441E-2 | 1.554E-2 | 4.403E-2 | 3.993E-1 | 6.059E-1 |
| 9 | 1.407E-2 | 2.348E-2 | 5.939E-2 | 4.101E-2 | 2.853E-3 | 1.271E-2 | 1.371E-2 | 4.081E-2 | 6.793E-1 | 8.363E-1 |
| 10 | 1.241E-2 | 2.072E-2 | 5.240E-2 | 3.619E-2 | 2.517E-3 | 1.122E-2 | 1.210E-2 | 3.781E-2 | 9.450E-1 | 1.057E+0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 1.095E-2 | 1.828E-2 | 4.624E-2 | 3.193E-2 | 2.221E-3 | 9.899E-3 | 1.068E-2 | 3.504E-2 | 1.198E+0 | 1.269E+0 |
| 12 | 9.665E-3 | 1.613E-2 | 4.080E-2 | 2.818E-2 | 1.960E-3 | 8.735E-3 | 9.421E-3 | 3.247E-2 | 1.440E+0 | 1.473E+0 |
| 13 | 8.528E-3 | 1.424E-2 | 3.600E-2 | 2.486E-2 | 1.729E-3 | 7.708E-3 | 8.313E-3 | 3.009E-2 | 1.673E+0 | 1.670E+0 |
| 14 | 7.525E-3 | 1.256E-2 | 3.177E-2 | 2.194E-2 | 1.526E-3 | 6.801E-3 | 7.335E-3 | 2.788E-2 | 1.896E+0 | 1.861E+0 |
| 15 | 6.640E-3 | 1.108E-2 | 2.803E-2 | 1.936E-2 | 1.347E-3 | 6.001E-3 | 6.473E-3 | 2.584E-2 | 2.112E+0 | 1.642E+0 |
| 16 | 5.859E-3 | 9.781E-3 | 2.473E-2 | 1.708E-2 | 1.188E-3 | 5.295E-3 | 5.711E-3 | 2.394E-2 | 2.322E+0 | 1.449E+0 |
| 17 | 5.170E-3 | 8.631E-3 | 2.183E-2 | 1.507E-2 | 1.048E-3 | 4.673E-3 | 5.040E-3 | 2.219E-2 | 2.525E+0 | 1.279E+0 |
| 18 | 4.562E-3 | 7.616E-3 | 1.926E-2 | 1.330E-2 | 9.252E-4 | 4.123E-3 | 4.447E-3 | 2.056E-2 | 2.723E+0 | 1.128E+0 |
| 19 | 4.026E-3 | 6.720E-3 | 1.699E-2 | 1.174E-2 | 8.164E-4 | 3.638E-3 | 3.924E-3 | 1.905E-2 | 2.917E+0 | 9.957E-1 |
| 20 | 3.552E-3 | 5.930E-3 | 1.500E-2 | 1.036E-2 | 7.203E-4 | 3.210E-3 | 3.462E-3 | 1.766E-2 | 2.573E+0 | 8.786E-1 |
| 21 | 3.134E-3 | 5.232E-3 | 1.323E-2 | 9.137E-3 | 6.356E-4 | 2.833E-3 | 3.055E-3 | 1.636E-2 | 2.271E+0 | 7.753E-1 |
| 22 | 2.766E-3 | 4.617E-3 | 1.168E-2 | 8.063E-3 | 5.609E-4 | 2.500E-3 | 2.696E-3 | 1.516E-2 | 2.004E+0 | 6.841E-1 |
| 23 | 2.440E-3 | 4.074E-3 | 1.030E-2 | 7.115E-3 | 4.949E-4 | 2.206E-3 | 2.379E-3 | 1.405E-2 | 1.768E+0 | 6.036E-1 |
| 24 | 2.153E-3 | 3.595E-3 | 9.091E-3 | 6.278E-3 | 4.367E-4 | 1.946E-3 | 2.099E-3 | 1.302E-2 | 1.560E+0 | 5.326E-1 |
| 25 | 1.900E-3 | 3.172E-3 | 8.021E-3 | 5.539E-3 | 3.853E-4 | 1.717E-3 | 1.852E-3 | 1.207E-2 | 1.377E+0 | 4.700E-1 |
| 26 | 1.677E-3 | 2.799E-3 | 7.078E-3 | 4.888E-3 | 3.400E-4 | 1.515E-3 | 1.634E-3 | 1.118E-2 | 1.215E+0 | 4.147E-1 |
| 27 | 1.479E-3 | 2.470E-3 | 6.246E-3 | 4.313E-3 | 3.000E-4 | 1.337E-3 | 1.442E-3 | 1.036E-2 | 1.072E+0 | 3.659E-1 |
| 28 | 1.305E-3 | 2.179E-3 | 5.511E-3 | 3.806E-3 | 2.647E-4 | 1.180E-3 | 1.273E-3 | 9.602E-3 | 9.458E-1 | 3.229E-1 |
| 29 | 1.152E-3 | 1.923E-3 | 4.863E-3 | 3.358E-3 | 2.336E-4 | 1.041E-3 | 1.123E-3 | 8.898E-3 | 8.346E-1 | 2.849E-1 |
| 30 | 1.016E-3 | 1.697E-3 | 4.291E-3 | 2.963E-3 | 2.061E-4 | 9.186E-4 | 9.908E-4 | 8.245E-3 | 7.364E-1 | 2.514E-1 |
| 31 | 8.969E-4 | 1.497E-3 | 3.786E-3 | 2.615E-3 | 1.819E-4 | 8.106E-4 | 8.743E-4 | 7.641E-3 | 6.498E-1 | 2.218E-1 |
| 32 | 7.914E-4 | 1.321E-3 | 3.341E-3 | 2.307E-3 | 1.605E-4 | 7.153E-4 | 7.715E-4 | 7.080E-3 | 5.734E-1 | 1.958E-1 |
| 33 | 6.983E-4 | 1.166E-3 | 2.948E-3 | 2.036E-3 | 1.416E-4 | 6.311E-4 | 6.807E-4 | 6.561E-3 | 5.060E-1 | 1.727E-1 |
| 34 | 6.162E-4 | 1.029E-3 | 2.601E-3 | 1.796E-3 | 1.250E-4 | 5.569E-4 | 6.007E-4 | 6.080E-3 | 4.464E-1 | 1.524E-1 |
| 35 | 5.437E-4 | 9.077E-4 | 2.295E-3 | 1.585E-3 | 1.103E-4 | 4.914E-4 | 5.300E-4 | 5.634E-3 | 3.939E-1 | 1.345E-1 |
| 36 | 4.798E-4 | 8.009E-4 | 2.025E-3 | 1.399E-3 | 9.730E-5 | 4.336E-4 | 4.677E-4 | 5.221E-3 | 3.476E-1 | 1.187E-1 |
| 37 | 4.234E-4 | 7.067E-4 | 1.787E-3 | 1.234E-3 | 8.585E-5 | 3.826E-4 | 4.127E-4 | 4.838E-3 | 3.067E-1 | 1.047E-1 |
| 38 | 3.736E-4 | 6.236E-4 | 1.577E-3 | 1.089E-3 | 7.576E-5 | 3.376E-4 | 3.641E-4 | 4.484E-3 | 2.707E-1 | 9.240E-2 |
| 39 | 3.296E-4 | 5.503E-4 | 1.392E-3 | 9.610E-4 | 6.685E-5 | 2.979E-4 | 3.213E-4 | 4.155E-3 | 2.388E-1 | 8.153E-2 |
| 40 | 2.909E-4 | 4.855E-4 | 1.228E-3 | 8.480E-4 | 5.899E-5 | 2.629E-4 | 2.835E-4 | 3.850E-3 | 2.107E-1 | 7.194E-2 |
| 41 | 2.567E-4 | 4.284E-4 | 1.083E-3 | 7.482E-4 | 5.205E-5 | 2.320E-4 | 2.502E-4 | 3.568E-3 | 1.859E-1 | 6.348E-2 |
| 42 | 2.265E-4 | 3.781E-4 | 9.560E-4 | 6.602E-4 | 4.593E-5 | 2.047E-4 | 2.208E-4 | 3.306E-3 | 1.641E-1 | 5.602E-2 |
| 43 | 1.998E-4 | 3.336E-4 | 8.436E-4 | 5.826E-4 | 4.053E-5 | 1.806E-4 | 1.948E-4 | 3.064E-3 | 1.448E-1 | 4.943E-2 |
| 44 | 1.763E-4 | 2.944E-4 | 7.444E-4 | 5.141E-4 | 3.576E-5 | 1.594E-4 | 1.719E-4 | 2.839E-3 | 1.278E-1 | 4.362E-2 |
| 45 | 1.556E-4 | 2.597E-4 | 6.568E-4 | 4.536E-4 | 3.155E-5 | 1.406E-4 | 1.517E-4 | 2.631E-3 | 1.127E-1 | 3.849E-2 |
| 46 | 1.373E-4 | 2.292E-4 | 5.796E-4 | 4.003E-4 | 2.784E-5 | 1.241E-4 | 1.338E-4 | 2.438E-3 | 9.947E-2 | 3.396E-2 |
| 47 | 1.211E-4 | 2.022E-4 | 5.114E-4 | 3.532E-4 | 2.457E-5 | 1.095E-4 | 1.181E-4 | 2.259E-3 | 8.777E-2 | 2.997E-2 |
| 48 | 1.069E-4 | 1.784E-4 | 4.513E-4 | 3.116E-4 | 2.168E-5 | 9.661E-5 | 1.042E-4 | 2.094E-3 | 7.745E-2 | 2.644E-2 |
| 49 | 9.433E-5 | 1.575E-4 | 3.982E-4 | 2.750E-4 | 1.913E-5 | 8.525E-5 | 9.195E-5 | 1.940E-3 | 6.834E-2 | 2.333E-2 |
| 50 | 8.323E-5 | 1.389E-4 | 3.514E-4 | 2.426E-4 | 1.688E-5 | 7.522E-5 | 8.113E-5 | 1.798E-3 | 6.030E-2 | 2.059E-2 |

## 4.4 Scenario 4: Exogenous carbon inputs only



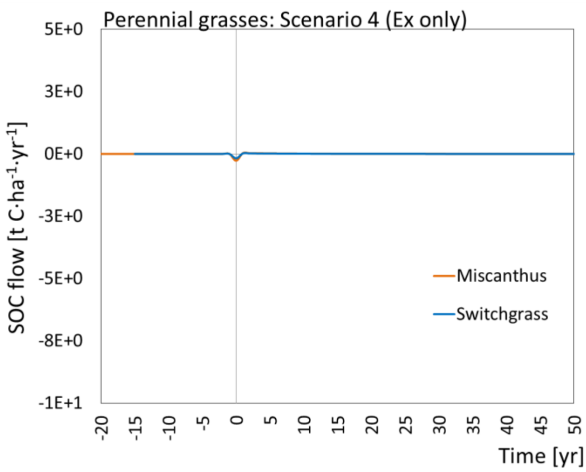



Fig. 6. Scenario 4 annual soil organic carbon elementary flows of annual crops and perennial grasses

Table 15. Scenario 4 flows [t C·ha$^{-1}$ ·yr$^{-1}$]

| | Annual Crops | | | | | | | | Perennial grasses | |
|---|---|---|---|---|---|---|---|---|---|---|
| yr | Total Annual | Wheat | Rapeseed | Maize | Sunflower | Triticale | Sugar beet | Soybean | Miscanthus | Switch grass |
| -20 | -3.503E-1 | -4.037E-2 | -1.966E-1 | -5.455E-1 | -1.401E-1 | -2.595E-1 | -4.689E-1 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -19 | 1.399E-1 | 1.613E-2 | 7.854E-2 | 2.179E-1 | 5.597E-2 | 1.037E-1 | 1.874E-1 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -18 | 8.403E-2 | 9.686E-3 | 4.716E-2 | 1.309E-1 | 3.361E-2 | 6.225E-2 | 1.125E-1 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -17 | 5.046E-2 | 5.816E-3 | 2.832E-2 | 7.858E-2 | 2.018E-2 | 3.738E-2 | 6.756E-2 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -16 | 3.030E-2 | 3.493E-3 | 1.701E-2 | 4.719E-2 | 1.212E-2 | 2.244E-2 | 4.057E-2 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -15 | 1.819E-2 | 2.097E-3 | 1.021E-2 | 2.834E-2 | 7.277E-3 | 1.348E-2 | 2.436E-2 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -14 | 1.093E-2 | 1.259E-3 | 6.132E-3 | 1.701E-2 | 4.370E-3 | 8.093E-3 | 1.463E-2 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -13 | 6.561E-3 | 7.562E-4 | 3.682E-3 | 1.022E-2 | 2.624E-3 | 4.860E-3 | 8.783E-3 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -12 | 3.939E-3 | 4.541E-4 | 2.211E-3 | 6.135E-3 | 1.576E-3 | 2.918E-3 | 5.274E-3 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -11 | 2.366E-3 | 2.727E-4 | 1.328E-3 | 3.684E-3 | 9.461E-4 | 1.752E-3 | 3.167E-3 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -10 | 1.420E-3 | 1.637E-4 | 7.972E-4 | 2.212E-3 | 5.681E-4 | 1.052E-3 | 1.902E-3 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -9 | 8.530E-4 | 9.832E-5 | 4.787E-4 | 1.328E-3 | 3.412E-4 | 6.318E-4 | 1.142E-3 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -8 | 5.122E-4 | 5.904E-5 | 2.875E-4 | 7.977E-4 | 2.049E-4 | 3.794E-4 | 6.857E-4 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -7 | 3.076E-4 | 3.545E-5 | 1.726E-4 | 4.790E-4 | 1.230E-4 | 2.278E-4 | 4.118E-4 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -6 | 1.847E-4 | 2.129E-5 | 1.037E-4 | 2.876E-4 | 7.387E-5 | 1.368E-4 | 2.472E-4 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -5 | 1.109E-4 | 1.278E-5 | 6.224E-5 | 1.727E-4 | 4.436E-5 | 8.215E-5 | 1.485E-4 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -4 | 6.659E-5 | 7.676E-6 | 3.737E-5 | 1.037E-4 | 2.663E-5 | 4.933E-5 | 8.915E-5 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -3 | 3.999E-5 | 4.609E-6 | 2.244E-5 | 6.227E-5 | 1.599E-5 | 2.962E-5 | 5.353E-5 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -2 | 2.401E-5 | 2.768E-6 | 1.348E-5 | 3.739E-5 | 9.604E-6 | 1.779E-5 | 3.215E-5 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| -1 | 1.442E-5 | 1.662E-6 | 8.092E-6 | 2.245E-5 | 5.767E-6 | 1.068E-5 | 1.930E-5 | 0.000E+0 | 0.000E+0 | 0.000E+0 |
| 0 | -3.503E-1 | -4.037E-2 | -1.966E-1 | -5.455E-1 | -1.401E-1 | -2.595E-1 | -1.719E+0 | 0.000E+0 | -2.720E-1 | -1.776E-1 |
| 1 | 4.120E-2 | 4.748E-3 | 2.312E-2 | 6.416E-2 | 1.648E-2 | 3.052E-2 | 2.022E-1 | 0.000E+0 | 3.198E-2 | 2.089E-2 |
| 2 | 3.635E-2 | 4.190E-3 | 2.040E-2 | 5.661E-2 | 1.454E-2 | 2.693E-2 | 1.784E-1 | 0.000E+0 | 2.822E-2 | 1.844E-2 |
| 3 | 3.208E-2 | 3.697E-3 | 1.800E-2 | 4.995E-2 | 1.283E-2 | 2.376E-2 | 1.575E-1 | 0.000E+0 | 2.490E-2 | 1.627E-2 |
| 4 | 2.830E-2 | 3.262E-3 | 1.589E-2 | 4.408E-2 | 1.132E-2 | 2.097E-2 | 1.389E-1 | 0.000E+0 | 2.197E-2 | 1.435E-2 |
| 5 | 2.497E-2 | 2.879E-3 | 1.402E-2 | 3.889E-2 | 9.989E-3 | 1.850E-2 | 1.226E-1 | 0.000E+0 | 1.939E-2 | 1.267E-2 |
| 6 | 2.204E-2 | 2.540E-3 | 1.237E-2 | 3.432E-2 | 8.814E-3 | 1.632E-2 | 1.082E-1 | 0.000E+0 | 1.711E-2 | 1.118E-2 |
| 7 | 1.945E-2 | 2.241E-3 | 1.091E-2 | 3.028E-2 | 7.778E-3 | 1.440E-2 | 9.546E-2 | 0.000E+0 | 1.510E-2 | 9.862E-3 |
| 8 | 1.716E-2 | 1.978E-3 | 9.630E-3 | 2.672E-2 | 6.863E-3 | 1.271E-2 | 8.423E-2 | 0.000E+0 | 1.332E-2 | 8.702E-3 |
| 9 | 1.514E-2 | 1.745E-3 | 8.498E-3 | 2.358E-2 | 6.056E-3 | 1.122E-2 | 7.432E-2 | 0.000E+0 | 1.176E-2 | 7.679E-3 |
| 10 | 1.336E-2 | 1.540E-3 | 7.498E-3 | 2.081E-2 | 5.343E-3 | 9.896E-3 | 6.558E-2 | 0.000E+0 | 1.037E-2 | 6.776E-3 |
| 11 | 1.179E-2 | 1.359E-3 | 6.616E-3 | 1.836E-2 | 4.715E-3 | 8.732E-3 | 5.787E-2 | 0.000E+0 | 9.153E-3 | 5.979E-3 |
| 12 | 1.040E-2 | 1.199E-3 | 5.838E-3 | 1.620E-2 | 4.160E-3 | 7.705E-3 | 5.106E-2 | 0.000E+0 | 8.076E-3 | 5.276E-3 |
| 13 | 9.179E-3 | 1.058E-3 | 5.151E-3 | 1.429E-2 | 3.671E-3 | 6.799E-3 | 4.506E-2 | 0.000E+0 | 7.126E-3 | 4.655E-3 |
| 14 | 8.099E-3 | 9.336E-4 | 4.546E-3 | 1.261E-2 | 3.239E-3 | 5.999E-3 | 3.976E-2 | 0.000E+0 | 6.288E-3 | 4.108E-3 |
| 15 | 7.147E-3 | 8.238E-4 | 4.011E-3 | 1.113E-2 | 2.858E-3 | 5.294E-3 | 3.508E-2 | 0.000E+0 | 5.549E-3 | 3.625E-3 |
| 16 | 6.306E-3 | 7.269E-4 | 3.539E-3 | 9.821E-3 | 2.522E-3 | 4.671E-3 | 3.096E-2 | 0.000E+0 | 4.896E-3 | 3.198E-3 |
| 17 | 5.564E-3 | 6.414E-4 | 3.123E-3 | 8.666E-3 | 2.226E-3 | 4.122E-3 | 2.732E-2 | 0.000E+0 | 4.320E-3 | 2.822E-3 |
| 18 | 4.910E-3 | 5.660E-4 | 2.756E-3 | 7.647E-3 | 1.964E-3 | 3.637E-3 | 2.410E-2 | 0.000E+0 | 3.812E-3 | 2.490E-3 |
| 19 | 4.333E-3 | 4.994E-4 | 2.432E-3 | 6.747E-3 | 1.733E-3 | 3.209E-3 | 2.127E-2 | 0.000E+0 | 3.364E-3 | 2.197E-3 |
| 20 | 3.823E-3 | 4.407E-4 | 2.146E-3 | 5.954E-3 | 1.529E-3 | 2.832E-3 | 1.877E-2 | 0.000E+0 | 2.968E-3 | 1.939E-3 |
| 21 | 3.373E-3 | 3.888E-4 | 1.893E-3 | 5.254E-3 | 1.349E-3 | 2.499E-3 | 1.656E-2 | 0.000E+0 | 2.619E-3 | 1.711E-3 |
| 22 | 2.977E-3 | 3.431E-4 | 1.671E-3 | 4.636E-3 | 1.191E-3 | 2.205E-3 | 1.461E-2 | 0.000E+0 | 2.311E-3 | 1.510E-3 |
| 23 | 2.627E-3 | 3.028E-4 | 1.474E-3 | 4.091E-3 | 1.051E-3 | 1.946E-3 | 1.289E-2 | 0.000E+0 | 2.039E-3 | 1.332E-3 |
| 24 | 2.318E-3 | 2.671E-4 | 1.301E-3 | 3.609E-3 | 9.270E-4 | 1.717E-3 | 1.138E-2 | 0.000E+0 | 1.799E-3 | 1.175E-3 |
| 25 | 2.045E-3 | 2.357E-4 | 1.148E-3 | 3.185E-3 | 8.180E-4 | 1.515E-3 | 1.004E-2 | 0.000E+0 | 1.588E-3 | 1.037E-3 |
| 26 | 1.805E-3 | 2.080E-4 | 1.013E-3 | 2.810E-3 | 7.218E-4 | 1.337E-3 | 8.858E-3 | 0.000E+0 | 1.401E-3 | 9.152E-4 |
| 27 | 1.592E-3 | 1.835E-4 | 8.937E-4 | 2.480E-3 | 6.369E-4 | 1.179E-3 | 7.816E-3 | 0.000E+0 | 1.236E-3 | 8.076E-4 |
| 28 | 1.405E-3 | 1.620E-4 | 7.886E-4 | 2.188E-3 | 5.620E-4 | 1.041E-3 | 6.897E-3 | 0.000E+0 | 1.091E-3 | 7.126E-4 |
| 29 | 1.240E-3 | 1.429E-4 | 6.958E-4 | 1.931E-3 | 4.959E-4 | 9.184E-4 | 6.086E-3 | 0.000E+0 | 9.626E-4 | 6.288E-4 |
| 30 | 1.094E-3 | 1.261E-4 | 6.140E-4 | 1.704E-3 | 4.376E-4 | 8.103E-4 | 5.370E-3 | 0.000E+0 | 8.494E-4 | 5.548E-4 |
| 31 | 9.653E-4 | 1.113E-4 | 5.418E-4 | 1.503E-3 | 3.861E-4 | 7.150E-4 | 4.739E-3 | 0.000E+0 | 7.495E-4 | 4.896E-4 |
| 32 | 8.518E-4 | 9.818E-5 | 4.781E-4 | 1.327E-3 | 3.407E-4 | 6.309E-4 | 4.181E-3 | 0.000E+0 | 6.613E-4 | 4.320E-4 |
| 33 | 7.516E-4 | 8.663E-5 | 4.218E-4 | 1.171E-3 | 3.006E-4 | 5.567E-4 | 3.690E-3 | 0.000E+0 | 5.836E-4 | 3.812E-4 |
| 34 | 6.632E-4 | 7.645E-5 | 3.722E-4 | 1.033E-3 | 2.653E-4 | 4.913E-4 | 3.256E-3 | 0.000E+0 | 5.149E-4 | 3.364E-4 |
| 35 | 5.852E-4 | 6.745E-5 | 3.284E-4 | 9.114E-4 | 2.341E-4 | 4.335E-4 | 2.873E-3 | 0.000E+0 | 4.544E-4 | 2.968E-4 |
| 36 | 5.164E-4 | 5.952E-5 | 2.898E-4 | 8.042E-4 | 2.065E-4 | 3.825E-4 | 2.535E-3 | 0.000E+0 | 4.009E-4 | 2.619E-4 |
| 37 | 4.557E-4 | 5.252E-5 | 2.557E-4 | 7.096E-4 | 1.822E-4 | 3.375E-4 | 2.237E-3 | 0.000E+0 | 3.538E-4 | 2.311E-4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 4.021E-4 | 4.634E-5 | 2.257E-4 | 6.262E-4 | 1.608E-4 | 2.978E-4 | 1.974E-3 | 0.000E+0 | 3.122E-4 | 2.039E-4 |
| 39 | 3.548E-4 | 4.089E-5 | 1.991E-4 | 5.525E-4 | 1.419E-4 | 2.628E-4 | 1.742E-3 | 0.000E+0 | 2.754E-4 | 1.799E-4 |
| 40 | 3.131E-4 | 3.608E-5 | 1.757E-4 | 4.875E-4 | 1.252E-4 | 2.319E-4 | 1.537E-3 | 0.000E+0 | 2.431E-4 | 1.588E-4 |
| 41 | 2.762E-4 | 3.184E-5 | 1.550E-4 | 4.302E-4 | 1.105E-4 | 2.046E-4 | 1.356E-3 | 0.000E+0 | 2.145E-4 | 1.401E-4 |
| 42 | 2.437E-4 | 2.810E-5 | 1.368E-4 | 3.796E-4 | 9.749E-5 | 1.806E-4 | 1.197E-3 | 0.000E+0 | 1.892E-4 | 1.236E-4 |
| 43 | 2.151E-4 | 2.479E-5 | 1.207E-4 | 3.350E-4 | 8.602E-5 | 1.593E-4 | 1.056E-3 | 0.000E+0 | 1.670E-4 | 1.091E-4 |
| 44 | 1.898E-4 | 2.188E-5 | 1.065E-4 | 2.956E-4 | 7.591E-5 | 1.406E-4 | 9.316E-4 | 0.000E+0 | 1.473E-4 | 9.625E-5 |
| 45 | 1.675E-4 | 1.930E-5 | 9.399E-5 | 2.608E-4 | 6.698E-5 | 1.240E-4 | 8.221E-4 | 0.000E+0 | 1.300E-4 | 8.493E-5 |
| 46 | 1.478E-4 | 1.703E-5 | 8.293E-5 | 2.301E-4 | 5.910E-5 | 1.095E-4 | 7.254E-4 | 0.000E+0 | 1.147E-4 | 7.494E-5 |
| 47 | 1.304E-4 | 1.503E-5 | 7.318E-5 | 2.031E-4 | 5.215E-5 | 9.658E-5 | 6.401E-4 | 0.000E+0 | 1.012E-4 | 6.613E-5 |
| 48 | 1.151E-4 | 1.326E-5 | 6.457E-5 | 1.792E-4 | 4.602E-5 | 8.522E-5 | 5.648E-4 | 0.000E+0 | 8.933E-5 | 5.835E-5 |
| 49 | 1.015E-4 | 1.170E-5 | 5.698E-5 | 1.581E-4 | 4.061E-5 | 7.520E-5 | 4.984E-4 | 0.000E+0 | 7.882E-5 | 5.149E-5 |
| 50 | 8.958E-5 | 1.033E-5 | 5.028E-5 | 1.395E-4 | 3.583E-5 | 6.636E-5 | 4.397E-4 | 0.000E+0 | 6.955E-5 | 4.543E-5 |

## 4.1 Comparison of all scenarios

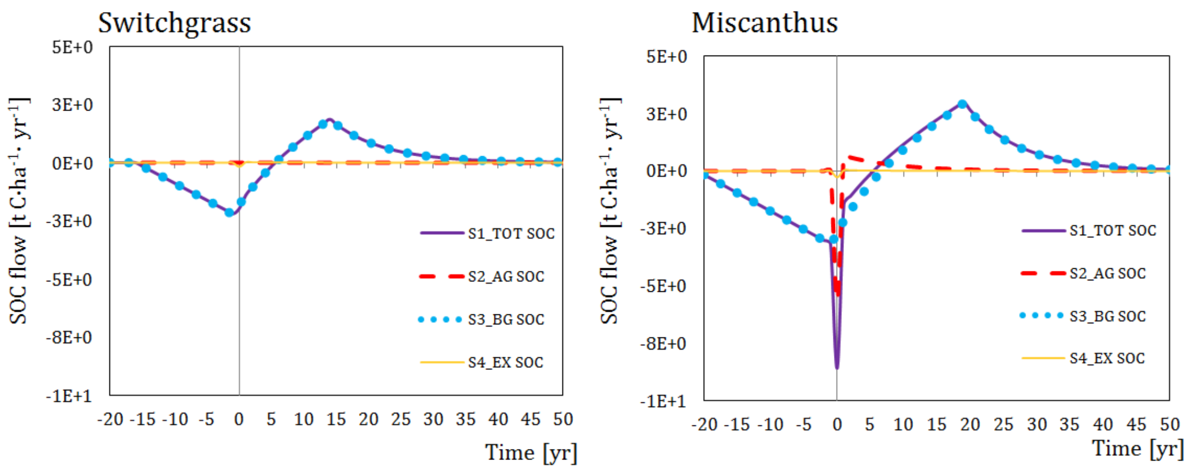



Fig. 7. SOC flows [t·C·ha$^{-1}$·yr$^{-1}$] per perennial energy crops and per management-driven variations

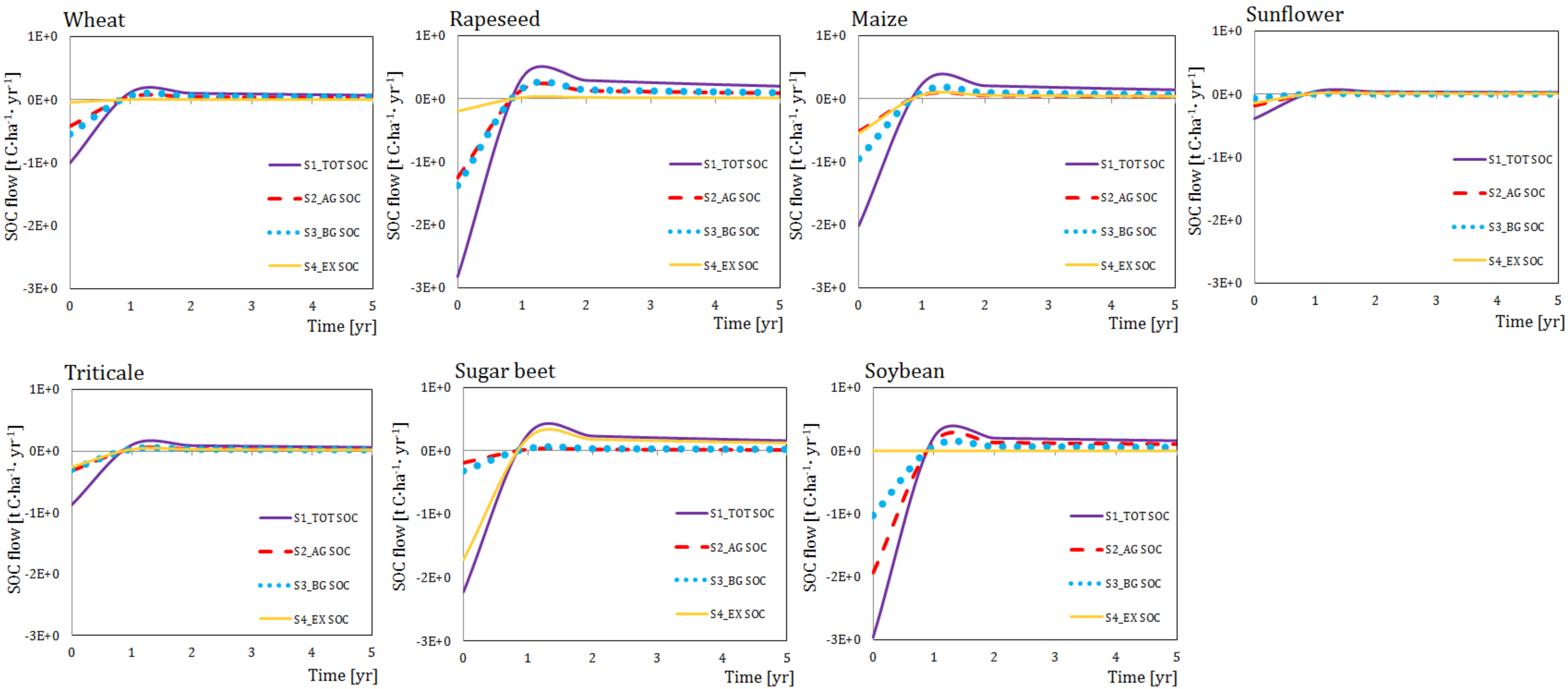



Fig. 8. SOC flows [t·C·ha$^{-1}$·yr$^{-1}$] per annual energy crops and per management-driven variations

# 5 Coupling results and sensitivity analysis

## 5.1 Cumulative radiative forcing results at year 2119

Fig. 9 shows the cumulative radiative forcing results at year 2119 for C-neutral and C-complete per SOC management-driven scenarios.

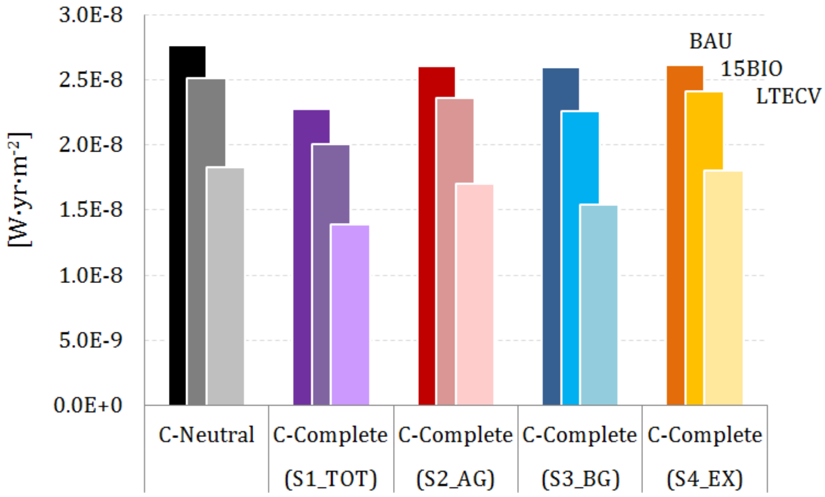



Fig. 9. Cumulative radiative forcing [W·yr·m$^{-2}$] over 100 years (2019-2119) per TIMES-MIRET scenario (BAU, 15BIO and LTECV) and management practices associated with soil organic carbon inputs

## 5.2 Sensitivity analysis on land occupation

The SOC_AG variations have significant consequences on the land occupation requirements, as plotted in Fig. 10. **Erreur ! Source du renvoi introuvable.**

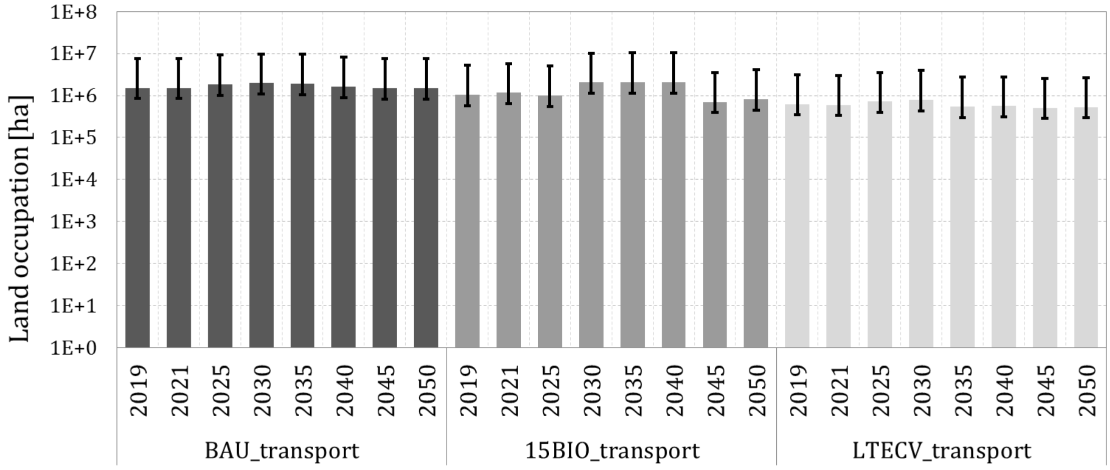



Fig. 10. Consequential variations of land occupation requirements [ha] linked with residue removal rates from the field for biofuel production, denoting increases by a factor of 5 with 90% removal and reductions by a factor of 0.56 with 10% removal rates as compared to original values

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