Appendix 9.4

Test of SOM parameterizations (SMB2 to SOM2 fractions and respiration from bio incorporation)

1. Background

In connection with writing the technical documentation (in 2024-2025), it was discovered that an error in the parameterization of the pathway from SMB2 (SMB-FAST) to SOM2 has been present in the model since the C++ version of Daisy was introduced.

The SMB-pools are described with a C/N-ratio, a turnover rate or a halftime, an efficiency, and a specification of fractions describing how the material is divided into pools once decayed (see Table 1 and Chapter 9, part 7).

Table 1: The parameterization of the SMB2 (SMB-FAST) and SMB1 (SMB-SLOW) pools in C++ before version 7

SMB-FAST (SMB2)	*SMB-SLOW* (SMB1)
(C per N 6.7) (turnover_rate 0.000416667 [h^{-1}]) (efficiency 0.6 0.6) (fractions 0 0.4 0 0.6 0) (maintenance 0.000416667 [h^{-1}])	(C per N 6.7) (turnover_rate 7.708e-06 [h^{-1}]) (efficiency 0.6 0.6) (fractions 0 0.6 0 0.4 0) (maintenance 7.5e-05 [h^{-1}])

Table 2: The parameterization of the SMB2 (SMB-FAST) and SMB1 (SMB-SLOW) pools in C++ Daisy version 7

SMB-FAST (SMB2)	*SMB-SLOW* (SMB1)
(C per N 6.7) (turnover_rate 0.000416667 [h^{-1}]) (efficiency 0.6 0.6) (fractions 0 0.6 0 0.4 0) (maintenance 0.000416667 [h^{-1}])	(C per N 6.7) (turnover_rate 7.708e-06 [h^{-1}]) (efficiency 0.6 0.6) (fractions 0 0.6 0 0.4 0) (maintenance 7.5e-05 [h^{-1}])

Before the C++ version of Daisy was introduced, that is, in the original Fortran version (Hansen et al. (1990); Hansen et al. (1991)), the fractions for decaying material from SMB1 and SMB2 were similar with 60 % going to the SMB2 pool and 40% going to the SOM2 pool. In the C++ implementation before version 7, 40 % of the material decayed by the SMB2 pool was returned to the SMB2 pool and 60 % was moved to the SOM2 pool (see Table 3). We consider this a serious issue, as the parameters used for the pools rely on a calibration done in the original Fortran version (Bruun et al. 2003).

Table 3: Fractions describing how the decomposed material from SMB2 is divided into pools before C++ Daisy version 7 (first row) and for C++ Daisy version 7 (second row).

Daisy version	SMB1 (*SLOW*)	SMB2 (*FAST*)	SOM1	SOM2	SOM3
SMB2 before version 7	0	40	0	60	0
SMB2 for version 7	0	60	0	40	0

In addition to the mistake in the parameterization of the pathway from SMB2 to SOM2, bio-incorporation has been implemented with a respiration loss of carbon on 50 % (See Chapter 9, part 3.2). The bio-incorporated material is allocated to a set of AOM-pools, which by default are *"AOM-SLOW-BIOINCORPORATION"* and *"AOM-FAST"* (see Chapter 9, part 6.4). The efficiency of the two pools is 0.5, so 50 % of the added material is lost by respiration. Thus, with the current parameterization the CO_2-production will be higher with earthworms present, as respiration will take place both by earthworms and by the SMB2-pool. Zhang et al. (2013) found that the presence of earthworms increased CO_2-formation over the first three weeks, while the net loss of soil organic carbon was similar with and without earthworms after 8 weeks (see more in Chapter 9, part 6,4). Thus, the parameterization and pathways for bio-incorporated material in Daisy may be debated and the carbon loss is probably overestimated by the default parameterizations.

In order to rectify the error in the parameterization of SMB2 to SOM2 pathway and evaluate the effect of the bio-incorporation respiration two SOM-parameterizations we tested termed SOM2000 and SOM2025. SOM2000 is identical to the default parameterizations in the C++ versions before version 7, with 40 % of the decomposed material from the SMB2 pool going back to the SMB2 pool and 60 % going to the SOM2 pool and a bio-incorporation loss of 50 % before allocation to the AOM pools. SOM2025 is identical to the default parameterizations in Daisy 7 with 60 % of the decomposed material from the SMB2 pool going back to the SMB2 pool and 40 % going to the SOM2 pool and the respiration loss for bio-incorporated material is 0 before allocation to the AOM pools. Thus, the SOM2025 resembles the SOM-parameterization before the C++ implementation of Daisy, that Bruun et al. (2003) used for calibration and validation of the soil organic matter dynamics in Daisy.

2. Test setup

Two tests were established to compare C and N dynamics with the two SOM parameterizations (SOM2000 and SOM2025):

- Test 1: A sandy loam (sandy clay loam below 50 cm) and a coarse sandy soil with conventional tillage and continuous spring barley.
- Test 2: A sandy loam (sandy clay loam below 50 cm) with crop rotation and conventional tillage or with no tillage and mulching.

The sandy loam was described with the *Askov* soil column from the *"dk-soil.dai"* file distributed with Daisy. In the Danish classification, it is a "fine sandy clay"-soil (JB6) with free drainage. The sandy soil was described with the *Jyndevad* soil column from the *"dk-soil.dai"* file distributed with Daisy. In the Danish classification, it is a coarse sandy soil (JB1) with free drainage. For Test 2 a litter layer described by the *exp_mulch* model (see Appendix 3.1 on the advanced mulch model) and dissolved organic matter (DOM) (See Chapter 9, section 10) was added to the description of the soil column.

The continuous spring barley management was parameterized by repeating the *"SBarley w. MF"* activity from the *"dk-management.dai"* file distributed with Daisy. The soil was fertilized with 115 kg N ha^{-1} and ploughed on March 3rd. After seed bed preparation on April 4th the crop was sowed, and it was harvested either at maturity or latest on August 20th. 8 cm stub and 30 % of the stem above the stub was left in the field.

The crop rotations were 5-year rotations with winter wheat, spring barley, winter wheat, spring barley and winter rape. 8 cm stub and all stem and leaf material were left in the field at harvest. For the conservation agriculture rotation, a cover crop was sown after the first spring barley and no soil cultivation actions (e.g. tillage and seed bed preparation) were carried out. The winter wheat was defined by the *"Winter Wheat JG" parameterization* from the *wheat.dai* file, the spring barley was defined by the "*Spring Barley*" parameterization from the *sbarley.dai* file, and both the winter rape and the cover crop were defined by the "*Winter Rape"* parameterization from *the wrape.dai* file. All crop files are distributed with Daisy. The crops were fertilized with split applications as shown in Table 4. The fertilization was carried out in the date interval depending on the trafficable conditions or on the last day if no trafficable days were available before (defined by a soil water pressure at 10 cm depth below – 50 cm and a soil temperature at – 10 cm above 0 °C) (Table 4).

Table 4: Simulated fertilization of crops in crop rotations for Test 2

Crop	1st application	2nd application
Winter Wheat	March 30th - April 4th : 59.8 kg N ha^{-1}	April 18th - 23rd : 119.7 kg N ha^{-1}
Spring Barley	April 8th - 13th : 26 kg N ha^{-1}	April 23rd - 28th : 94.5 kg N ha^{-1}
Winter rape	August 16th : 65 kg N ha^{-1}	March 13th – 18th : 115.5 kg N ha^{-1}

Ammonium sorption was simulated with the new linear sorption model with K_{clay} = 213 [cm^3 g^{-1}] and K_{OC} = 23 [cm^3 g^{-1}] (See appendix 7.1).

The test was run for 30 years (1970-2000), with the first 5 years as warm up and the period 1975-2000 as results, using weather data from Taastrup, Denmark (*"dk-taastrup.dwf"* file distributed with Daisy).

The default options for initialization of the organic matter pools in the topsoil and subsoils have been used (see Chapter 9, section 9). For the subsoil we assume that the active pools are in equilibrium with the input and that the change in the inert pool is zero (ΔSOM3 = 0). Then, the equation system finds the size of the inert pool (The equilibrium assumption method 3: size of inert pool). The topsoil is initialized with the assumption that the fast pools (SMB2 and SOM2) quickly adapt to the input and size of the slow pool (SOM1). The input rate for carbon is estimated from the initial AOM-pool (The equilibrium assumption method 6: Quasi equilibrium).

3. Results

The results in terms of C and N dynamics in the system over the 25 years period (1975-2000) are shown below, first for Test 1 and then for Test 2.

3.1 Test 1: Sand and sandy loam, conventional tillage and spring barley

The total C content (Kg C ha^{-1}) in the soil (0-200 cm) decreases over the 25 years for all setups. For both the sandy loam and the sandy soil the decrease and year to year dynamic is similar for the SOM2000 and SOM2025 parameterizations, but the SOM2025 parameterization in general simulates a slightly higher C content (Figure 1). However, when evaluating the C content in the SMB2 pool we see clear differences in the C content, but the year-to-year dynamics are similar (Figure 2). The higher content of C in the SMB2 pool with the SOM2025 parameterization, due to a higher return (60% of decade material from the SMB2 pool, leads to a higher CO_2 production from the SMB pools (Figure 3) and a slower decrease in the C content of the SOM2 pool (Figure 4). The C content in the SOM1 and SMB1 pools for the two parameterizations are almost similar (Figure 5 and Figure 6). Likewise, the amount of harvested C is similar for the two parameterizations (Table 5).

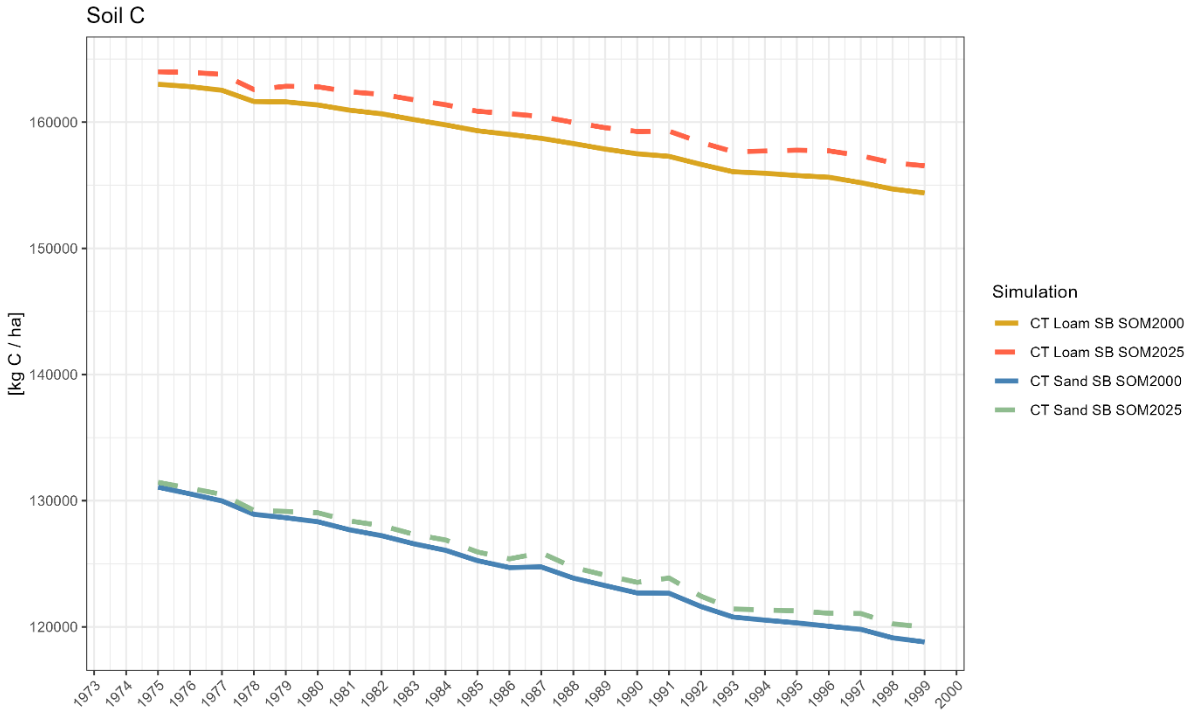

Figure 1: Total C content in the soil for Test1.

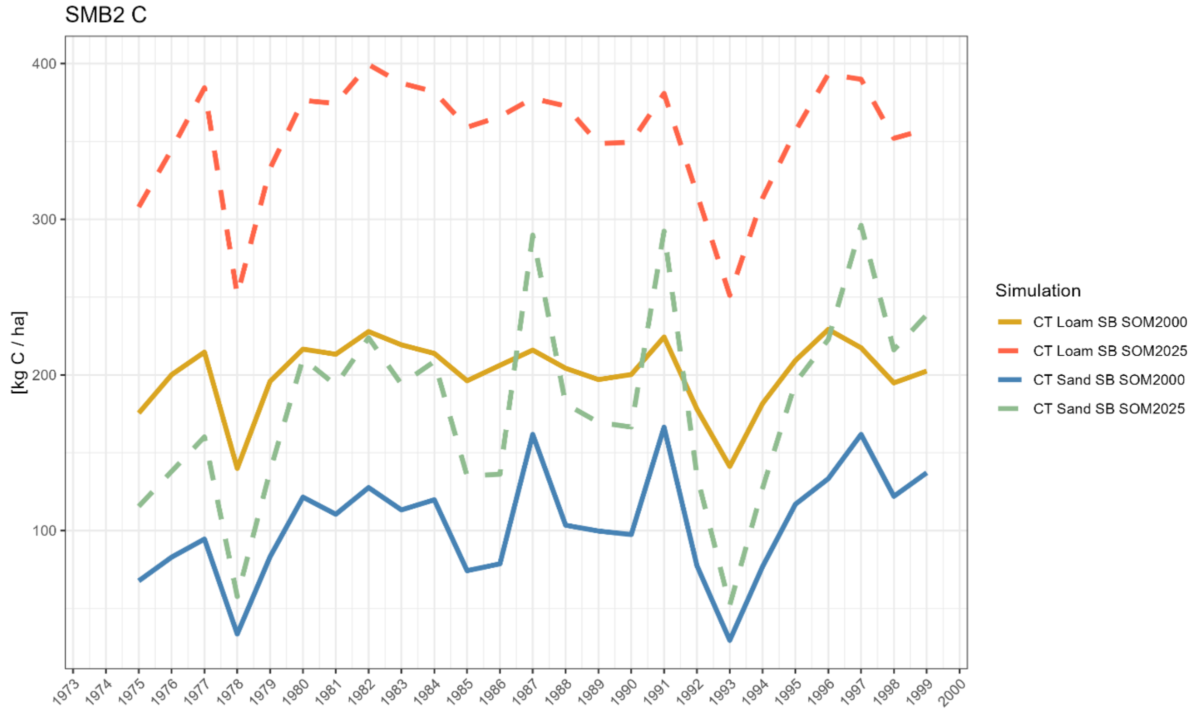

Figure 2: C content in the SMB2 pool for Test1.

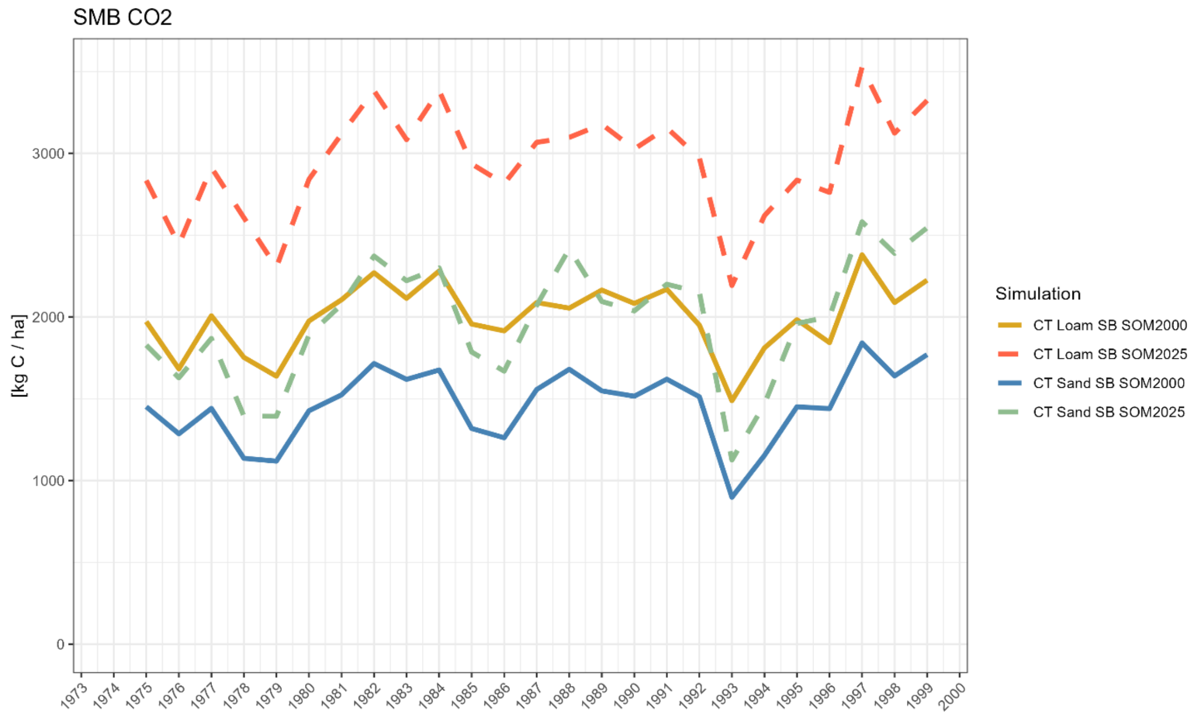

Figure 3: CO2 production from the SMB pools in Test1.

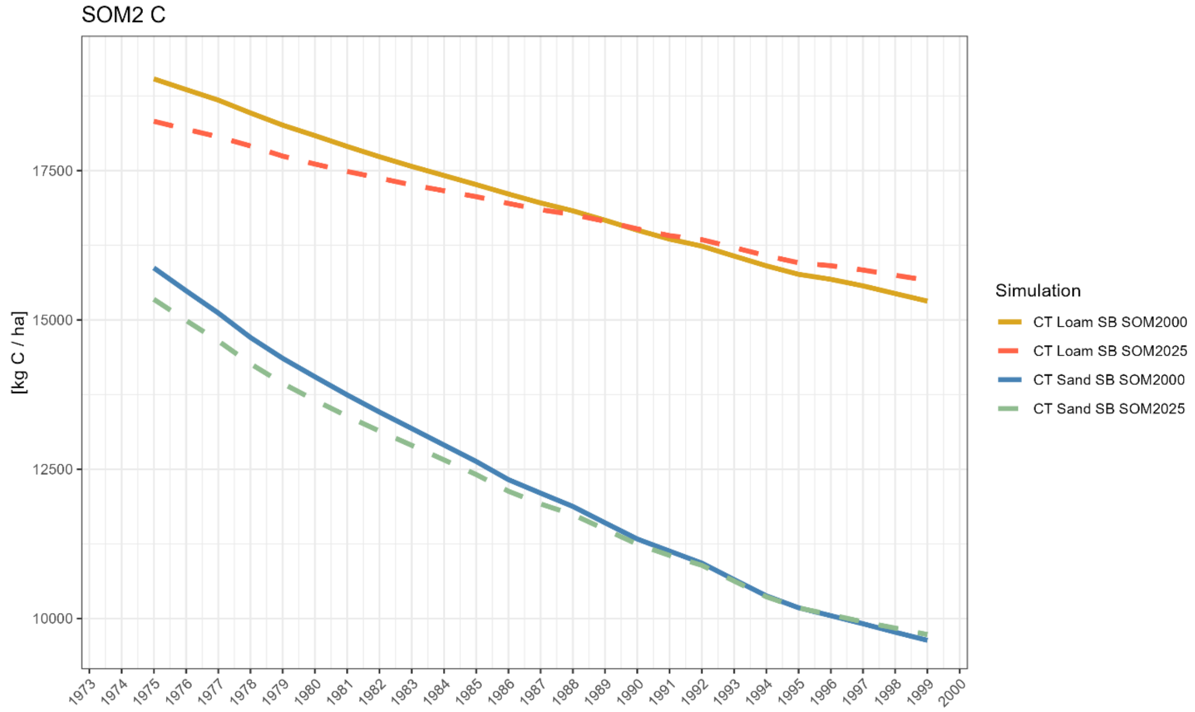

Figure 4: C content in the SOM2 pool for Test1.

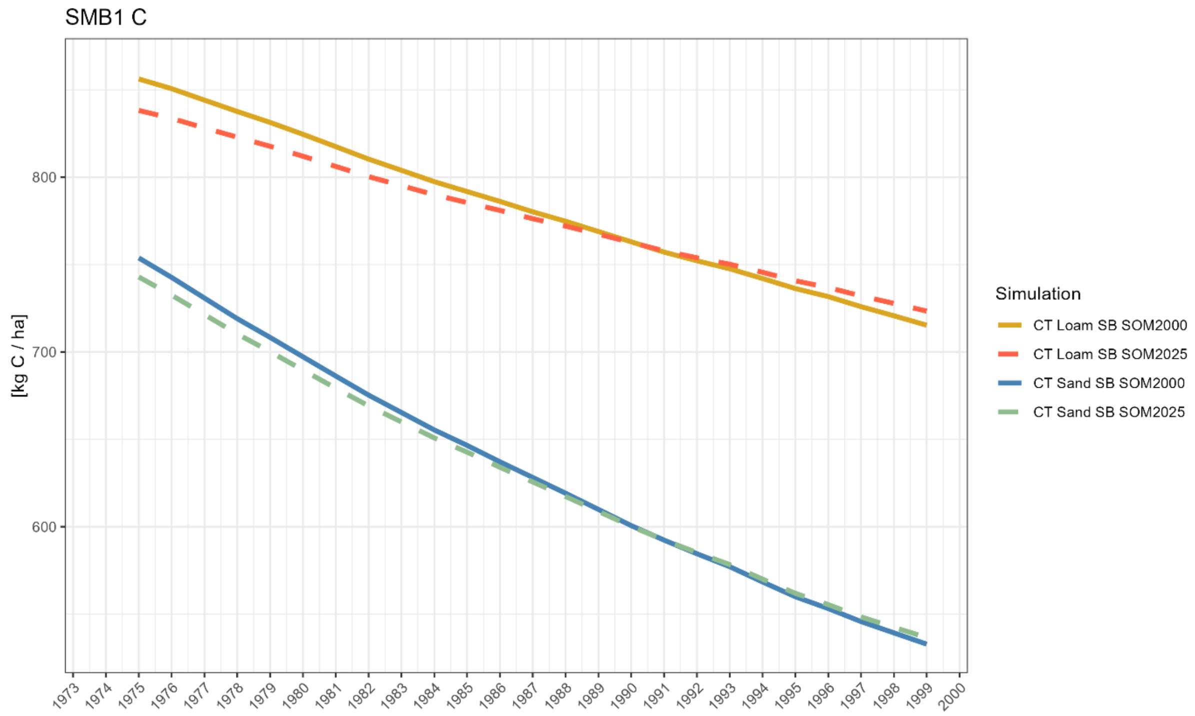

Figure 5: C content in the SMB1 pool for Test1.

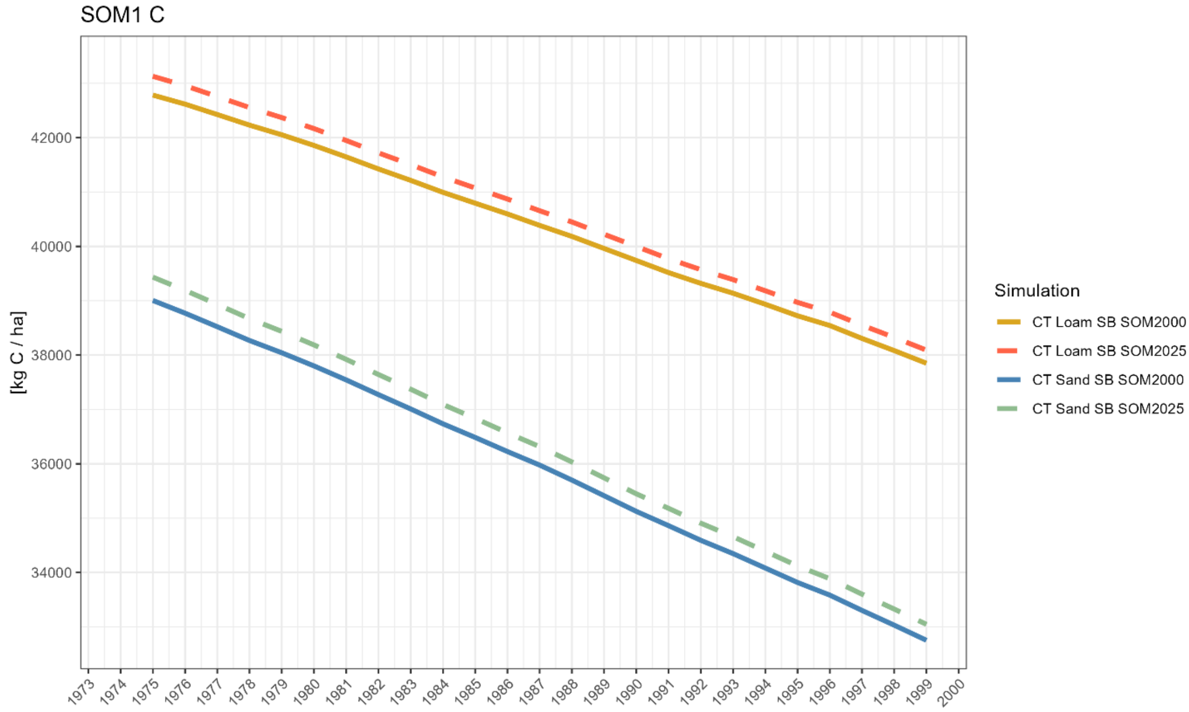

Figure 6: C content in the SOM1 C pool for Test1.

Table 5: Mean and standard deviation (sd) of harvested C for Test1 over the 25 years.

Soil	Crop	SOM parameter	Harvested C [Kg C/ha]	
			Mean	Sd
Loam	Spring barley	SOM2000	3524	955
Loam	Spring barley	SOM2025	3519	952
Sand	Spring barley	SOM2000	1843	992
Sand	Spring barley	SOM2025	1847	994

Similar to the C content in the soil (Figure 1) the organic N content (kg N ha^{-1}) in the soil (0-200 cm) decreases in the 25-year period, but slightly less for the SOM2025 parameterization compared to the SOM2000 parameterization (Figure 7). The mineral N shows a higher yearly dynamic (be aware of the different y-axis) but a general decrease (Figure 8). For the sandy soil the mineral N content is the same for the two parameterizations, but for the sandy loam soil the SOM2000 parameterization results in a higher mineral N content compared to the SOM2025 parameterization. However, the dynamic for the two are similar. The level and dynamic of mineralization is similar for the two parameterizations, but the immobilization is higher and more dynamic (again be aware of the different y-axis) for the SOM2025 parameterization compared to the SOM2000 parameterization (Figure 9 and Figure 10). Overall, the simulations give a similar amount of harvested and leached (below 200 cm) N for the two parameterizations, but with slightly higher N leaching for the SOM2025 parameterization on the sandy loam soil (Table 6 and Figure 11).

We thus argue that the C and N trends and dynamics are comparable for the two parameterizations for conventional tillage and spring barley.

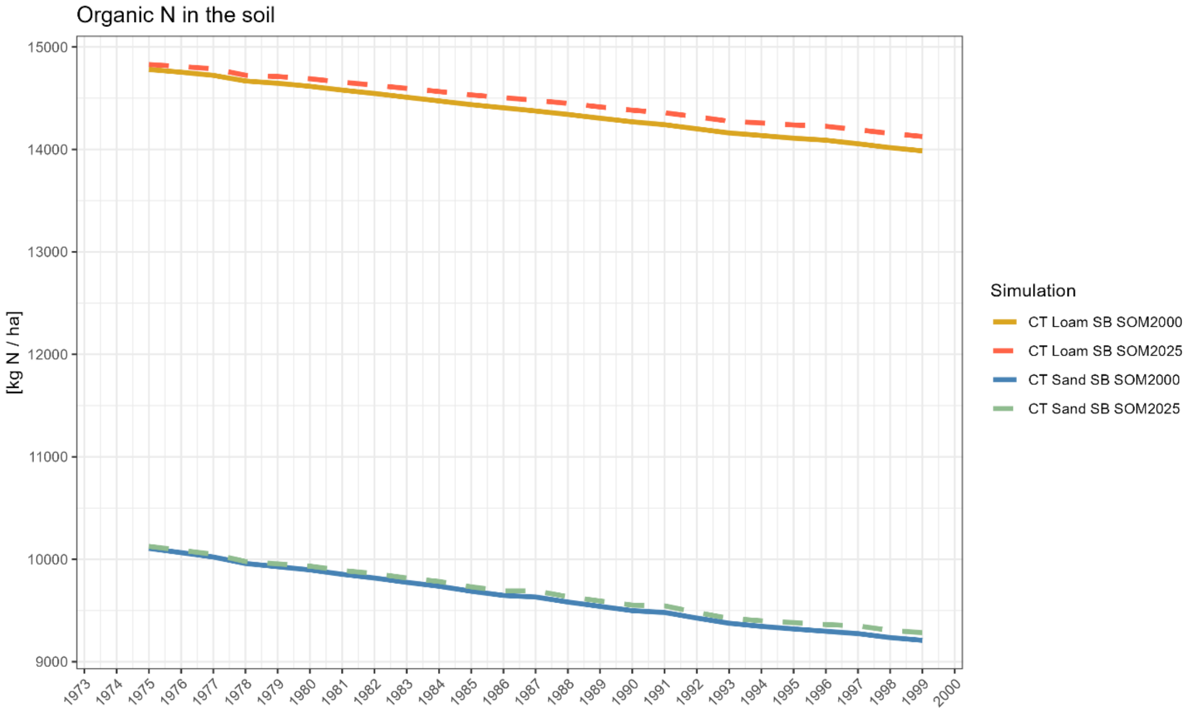

Figure 7: Organic N in soil for Test1.

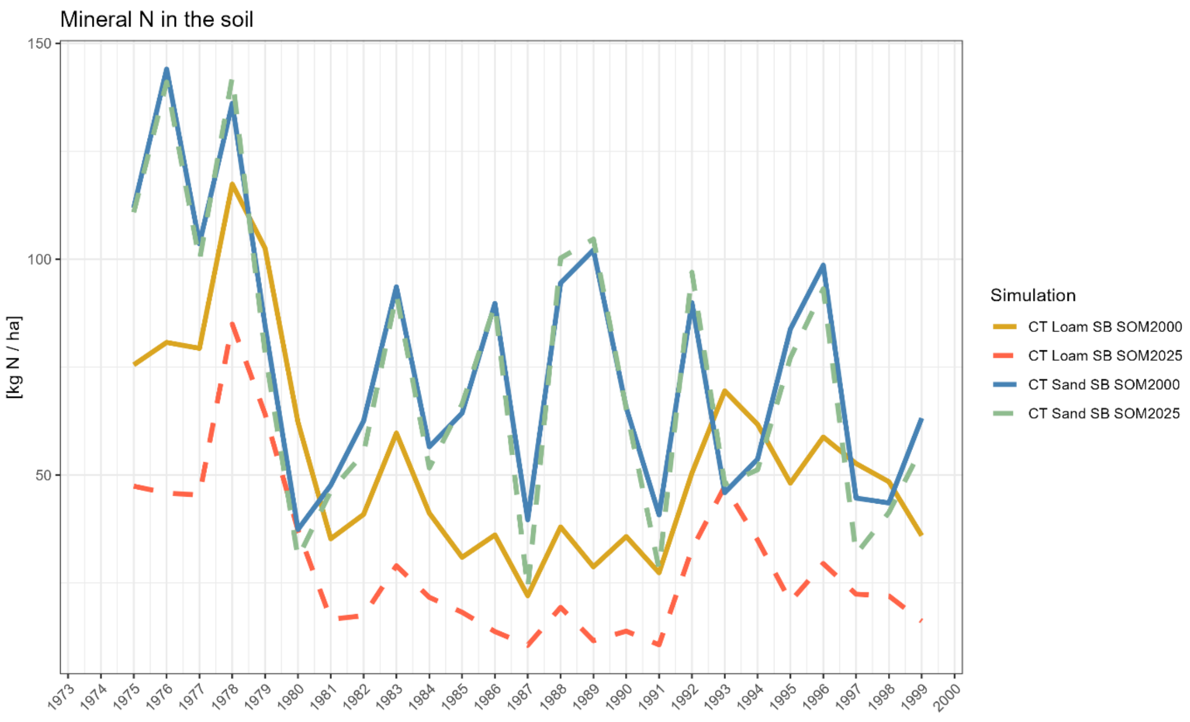

Figure 8: Mineral N in soil for Test1.

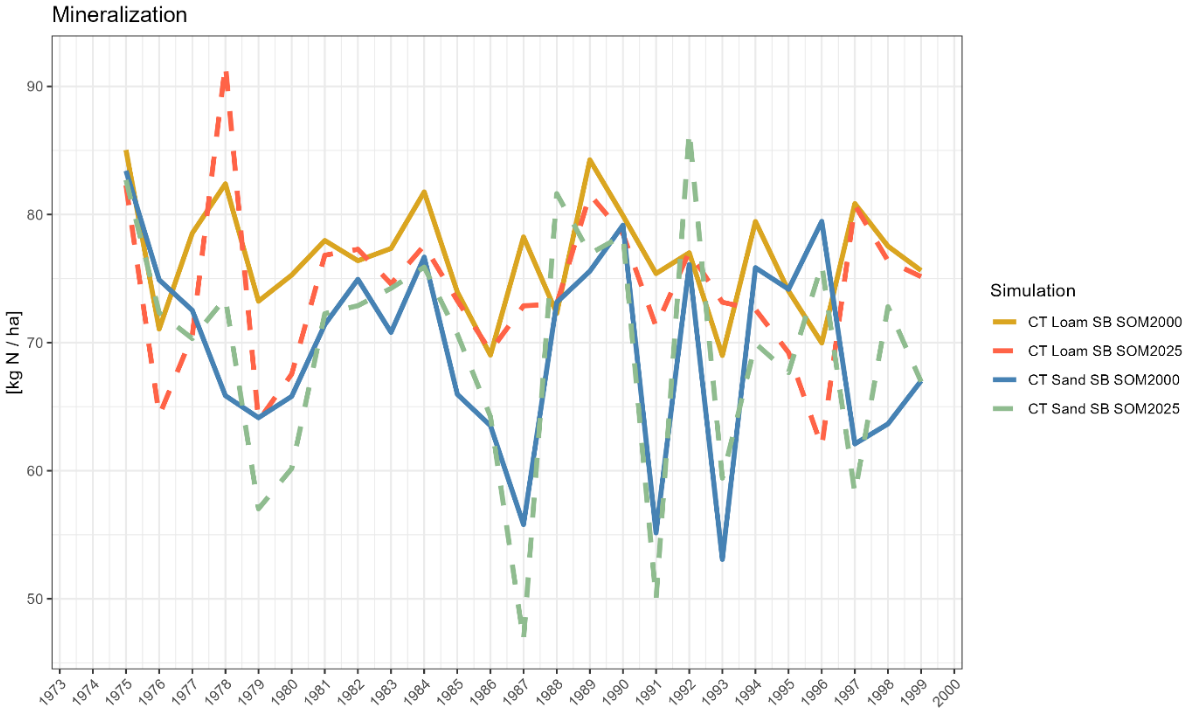

Figure 9: Mineralization for Test1.

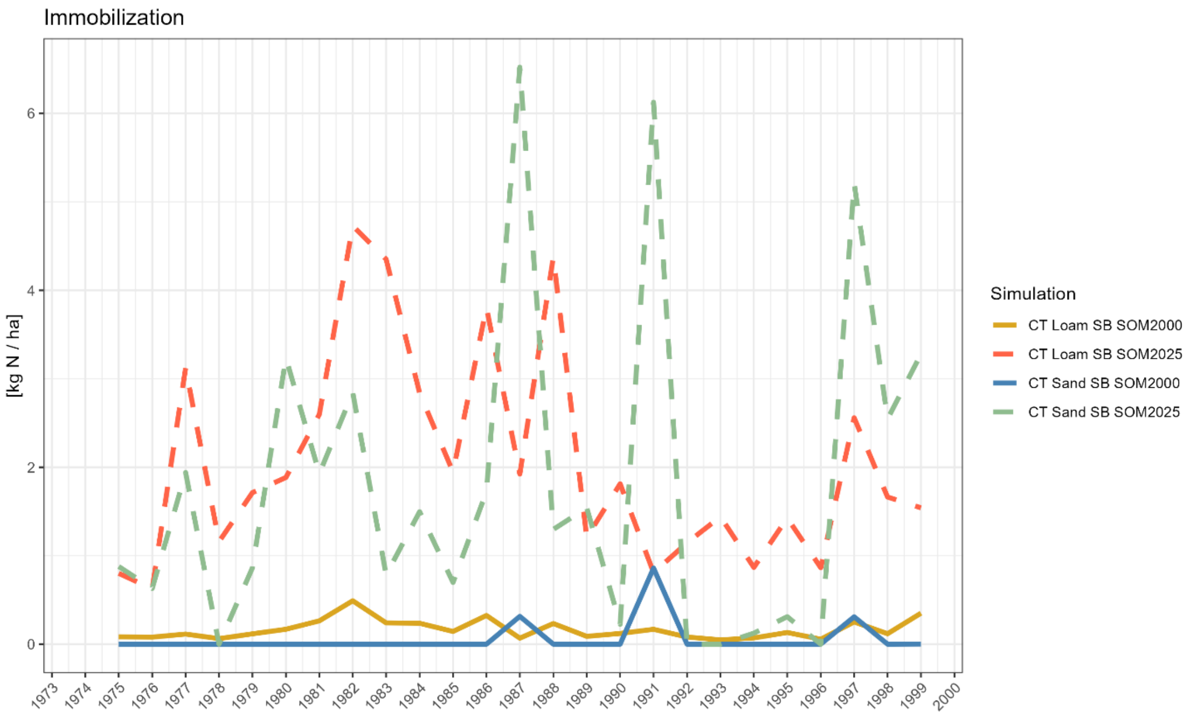

Figure 10: Immobilization for Test1.

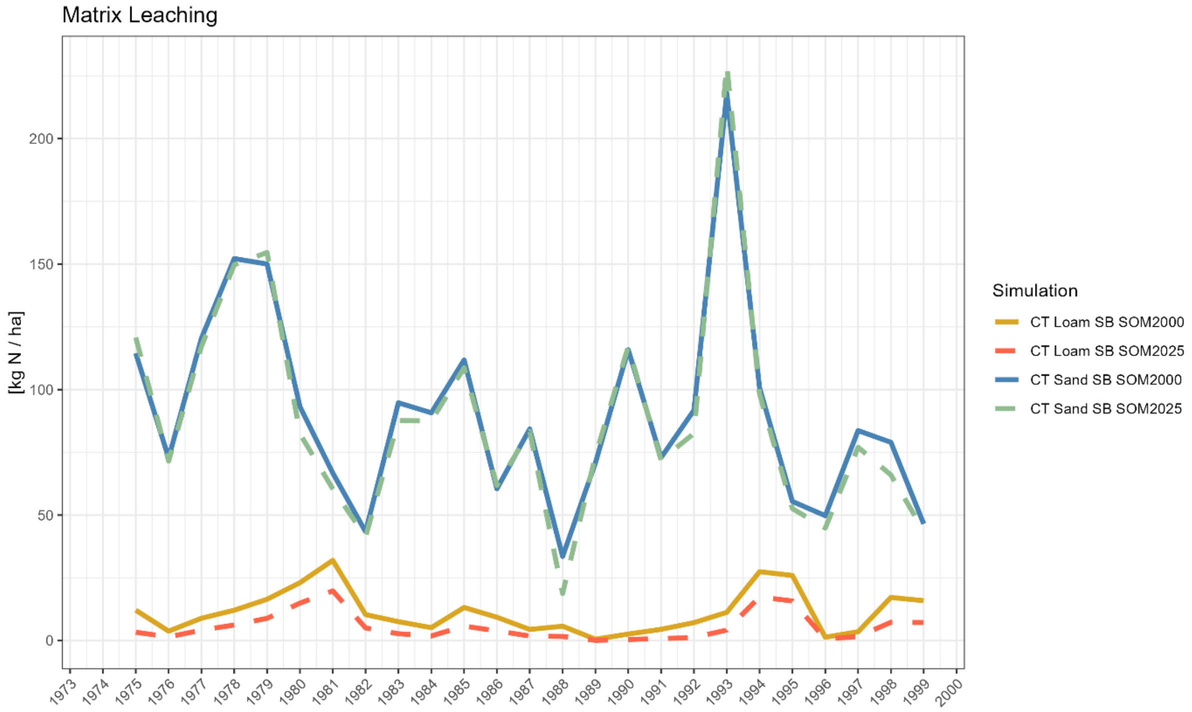

Figure 11: Matrix leaching for Test1.

Table 6: Mean and standard deviation (sd) of harvested N for Test1 over the 25 years.

Soil	Crop	SOM parameter	Harvested N [Kg N/ha]	
			Mean	Sd
Loam	SB	SOM2000	129	13
Loam	SB	SOM2025	127	11
Sand	SB	SOM2000	78	31
Sand	SB	SOM2025	79	31

3.2 Test 2: Conventional tillage and no tillage, crop rotation and loam

Test 2 compares C dynamics in and on (in the mulch layer) a sandy loam soil for crop rotations with high input of organic matter (cover crops and stem and leaves left on the field) in a system with conventional tillage (CT) and a system with no tillage or other soil cultivation (NoT). The high input of organic matter results in an increased C content (kg C ha^{-1}) in and on the soil (0-220 cm) for CT both parameterized with SOM2000 and SOM2025 (Figure 12). The C content for NoT with the SOM2000 parameterization shows less variation and no increase in C content compared to the SOM2025 parameterization. When no soil cultivation is simulated, C is only incorporated in the soil by bio-incorporation and with the SOM2000 parameterization 50 % of the added material is lost by this process, which result in less increase in C content compared to the SOM2025 parameterization and CT. Thus, if simulating systems without or with reduced soil cultivation (such as conservation or regenerative agricultural systems) we recommend using the SOM2025 parameterization or a similar user defined parameterization.

For the NoT simulations the difference in C content are already present before the simulations starts, because the parameterizations affect the initialization of the SOM pools and due to the 5 year warm up period (see more on initializations of the SOM pools in Appendix 9.2 and Appendix 9.3).

The variation and trends in the total C content are a result of a decrease in C content in the SOM1 (slow) pool and an increase in the SOM2 (fast) pool (Figure 13 and Figure 14). The increase in SOM2-C is similar between CT and NoT for the SOM2025 parameterization but differs for the SOM2000 parameterization. In the NoT SOM2000 simulation the SOM2 content increases slower due to the high earthworm respiration rate. A similar pattern is seen for the C content in the SMB1 pool (Figure 15). For the SMB2 pool the C content is higher for both CT and NoT with the SOM2025 parameterization compared to the SOM2000 parameterization (Figure 16), again due to no earthworm respiration and a higher recycling of decayed material from the SMB2-pool (60%).

Despite these differences the harvested C is similar for NoT and CT with the two parameterizations (Table 7).

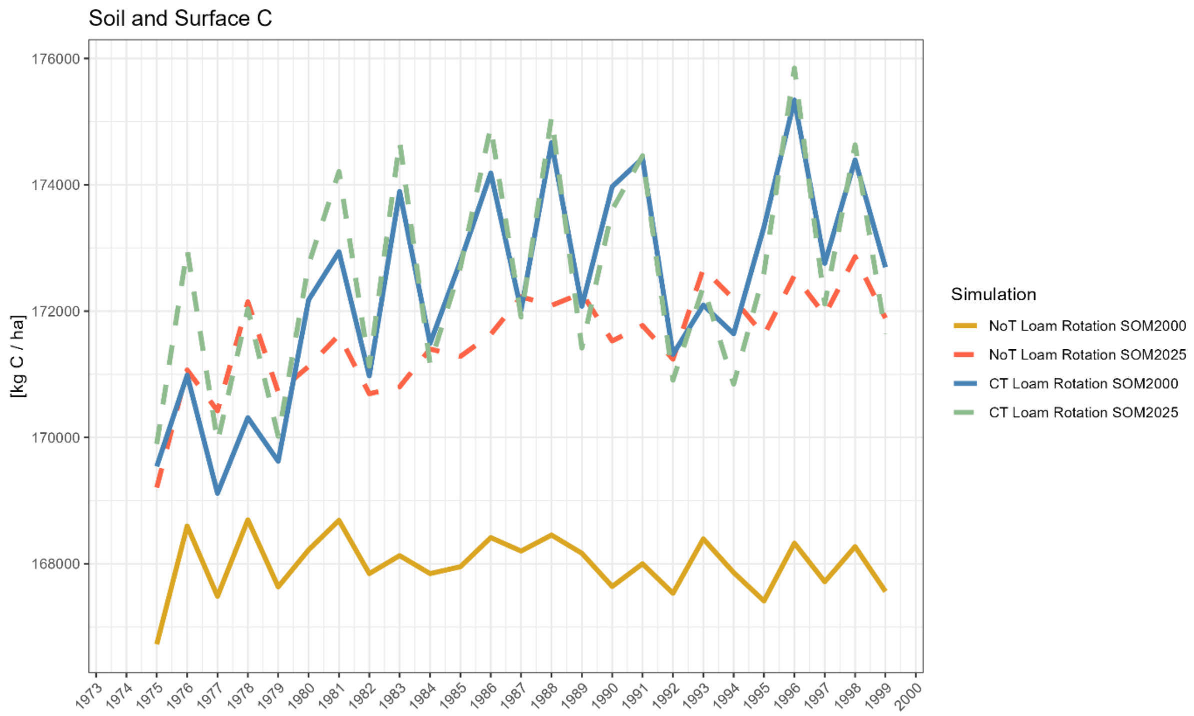

Figure 12: Total C content in and on the soil for Test2.

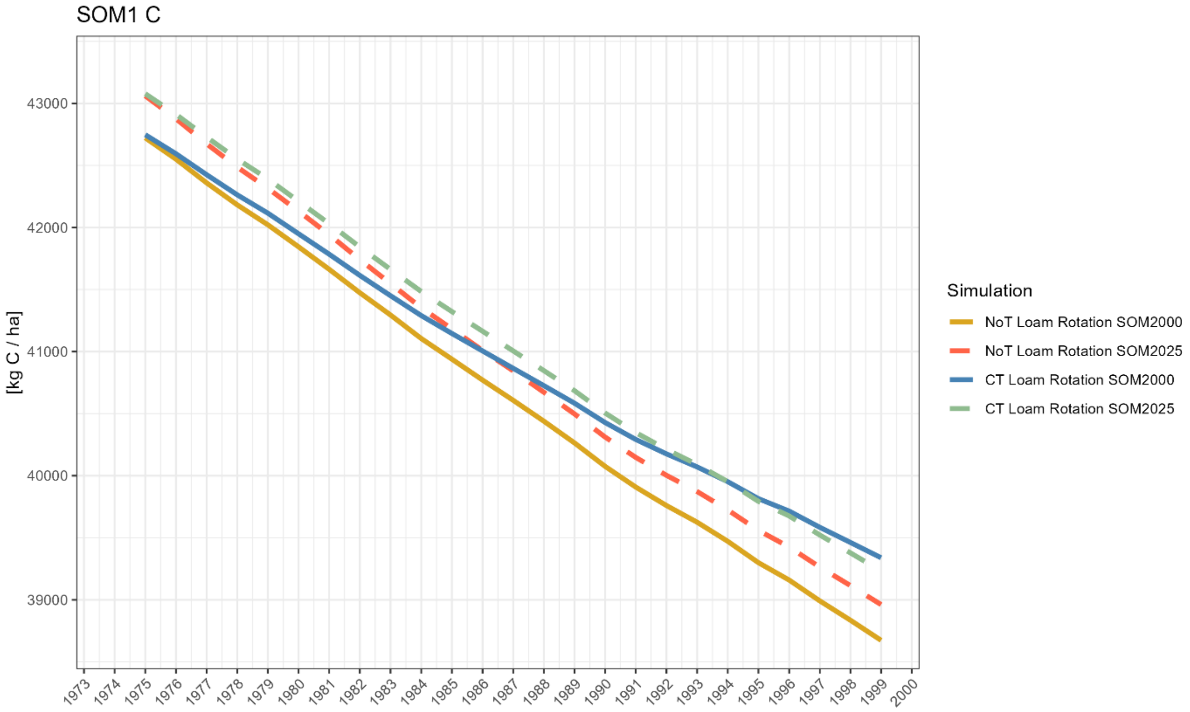

Figure 13: C content in the SOM1 pool for Test2.

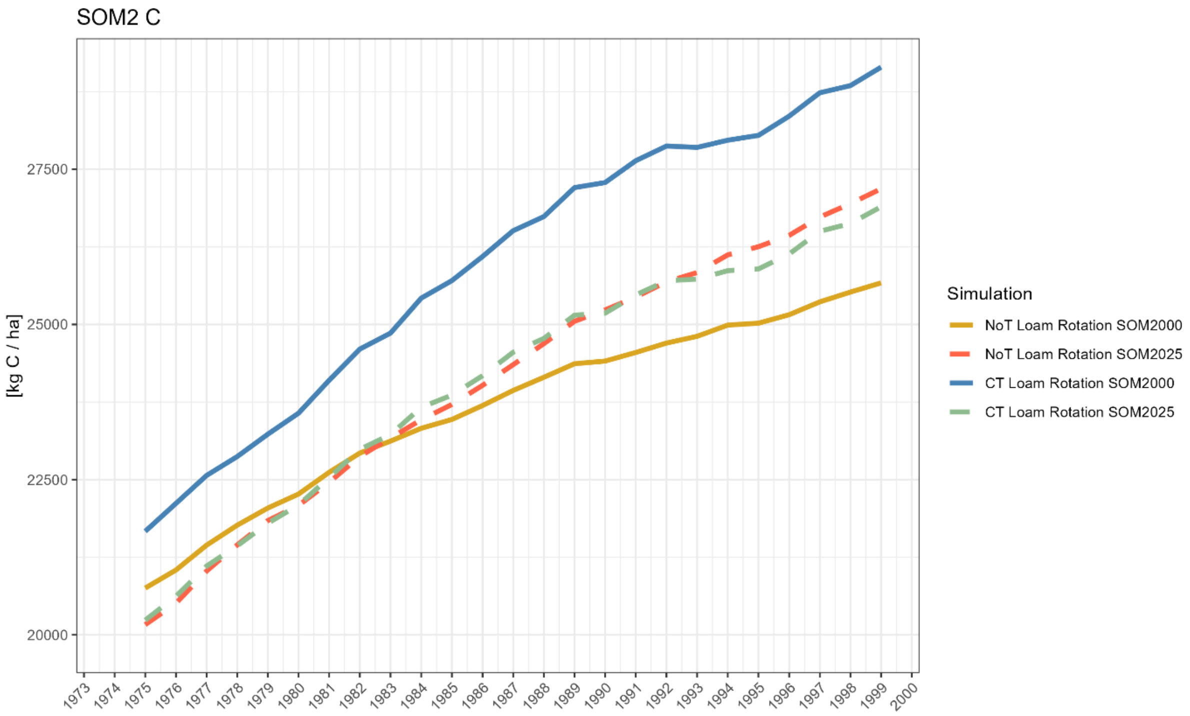

Figure 14: C content in the SOM2 pool for Test2.

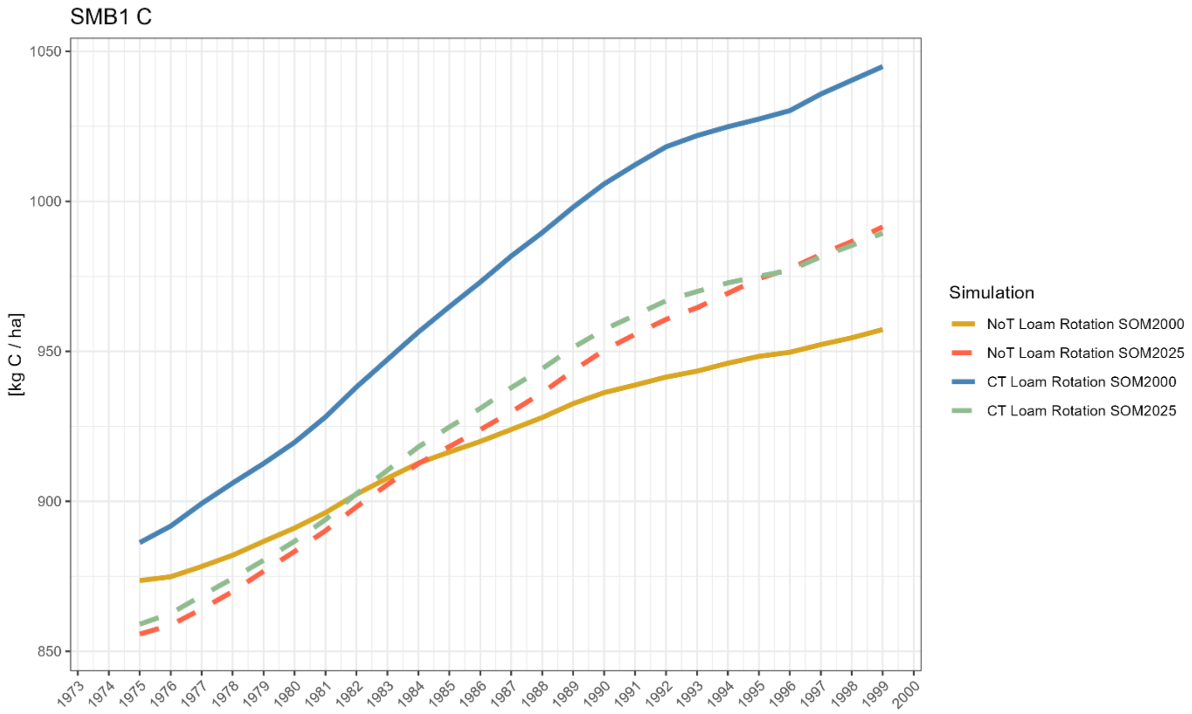

Figure 15: C content in the SMB1 pool for Test2.

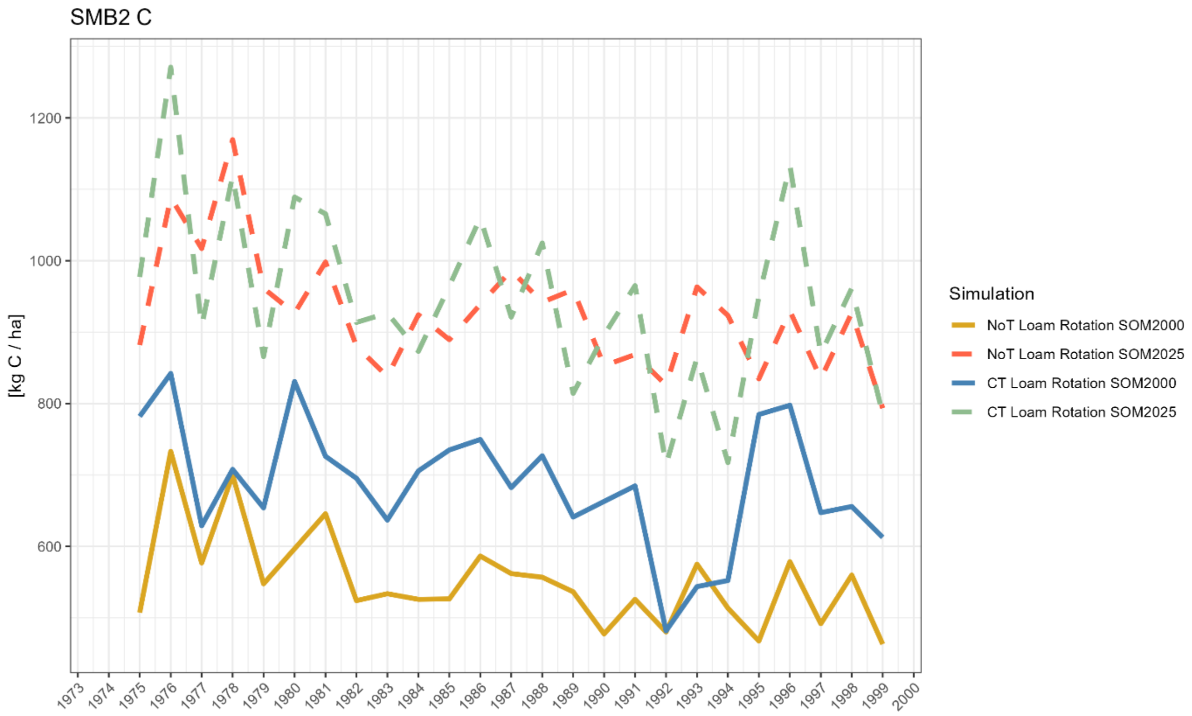

Figure 16: C content in the SMB2 pool for Test2.

Table 7: Mean and standard deviation (sd) of harvested C for Test2 over the 25 years.

Soil	Crop	SOM parameter	Harvested C [Kg C/ha]	
			Mean	Sd
Loam	Spring barley	SOM2000	2856	760
Loam	Spring barley	SOM2025	2870	757
Loam	Winter rape	SOM2000	1375	820
Loam	Winter rape	SOM2025	1365	811
Loam	Winter wheat	SOM2000	2140	300
Loam	Winter wheat	SOM2025	2083	293

The content of organic N (kg N ha^{-1}) in and on the soil (0-200 cm) (Figure 17) follow the trends of the total C content (Figure 12), with a higher content and increase for CT with both SOM2000 and SOM2025 and NoT with SOM2025, but no increase in the organic N content for NoT with SOM2000 parameterization. For the CT simulations the organic N increases more with the SOM2000 parameterization, where 60% of the decomposed material from the SMB2 pool is transferred to the SOM2 pool, compared to the SOM2025 parameterization where only 40% is transferred to the SOM2 pool and 60 % is recycled to the SMB2 pool.

The mineral N in the soil and on the surface varies over the period, depending on the fertilization and crop uptake in the crop rotation. The content for the CT simulations is similar for the SOM2000 and SOM2025 parameterizations, whereas clear differences are seen for the NoT simulations, where the SOM2025 parameterization in general results in lower mineral N content and a less variation in mineral N. This is a result of the general lower mineralization in the NoT SOM2025 simulation compared to the NoT SOM2000 simulation (Figure 19). In addition, some immobilization is simulated for NoT SOM2025, but not for NoT SOM2000 (Figure 20). The difference in mobilization and immobilization dynamics in the NoT simulations are a result of lost C due to the earthworm respiration in the SOM2000 parameterization, resulting in a different C/N-relationship for the organic matter entering the SMB2-pool in the NoT SOM2000 compared to the NoT SOM2025 simulations. The immobilization for the CT SOM2000 and CT SOM2025 simulations are similar, whereas there are some variations in the simulated mineralization but none of the parameterizations result in constantly higher or lower mineralization (Figure 19 and Figure 20).

These differences in N dynamics result in slightly different N leaching (below 200 cm), with the SOM2025 parameterization resulting in lowest N leaching for both NoT and CT.

The harvested amount of N is similar for the two parameterizations for the CT simulations, whereas for the NoT simulation the SOM2025 parameterization in general leads to lower harvested N amounts.

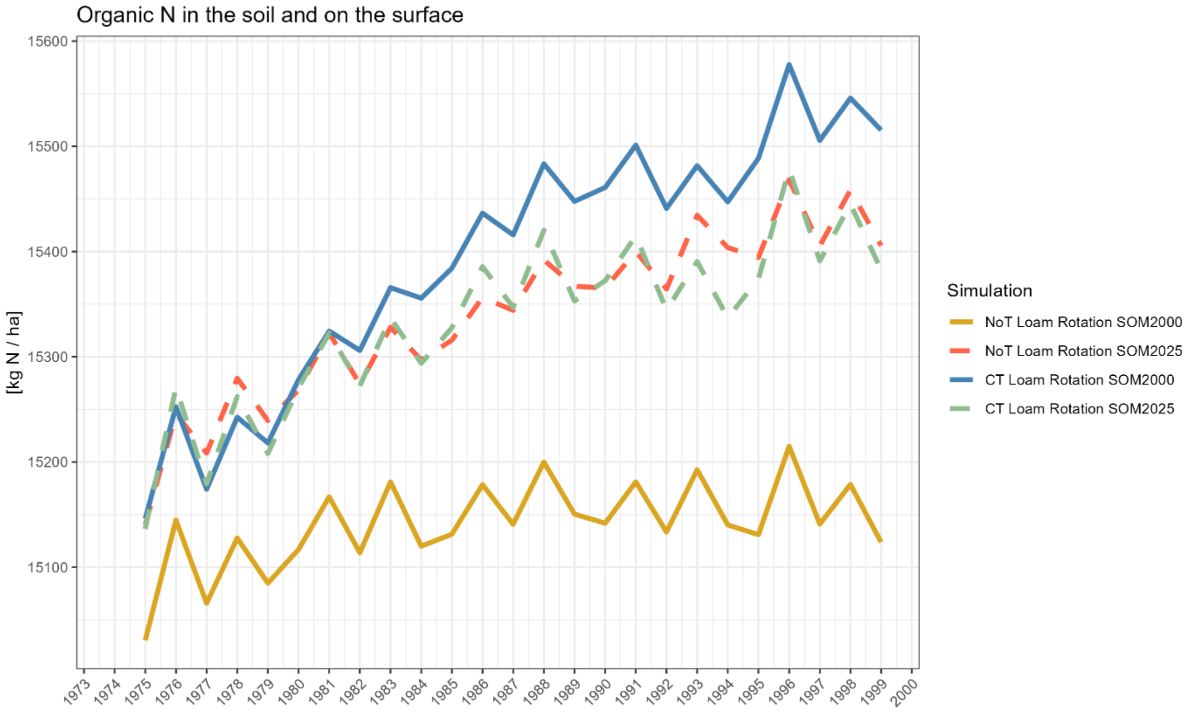

Figure 17: Organic N in the soil for Test2.

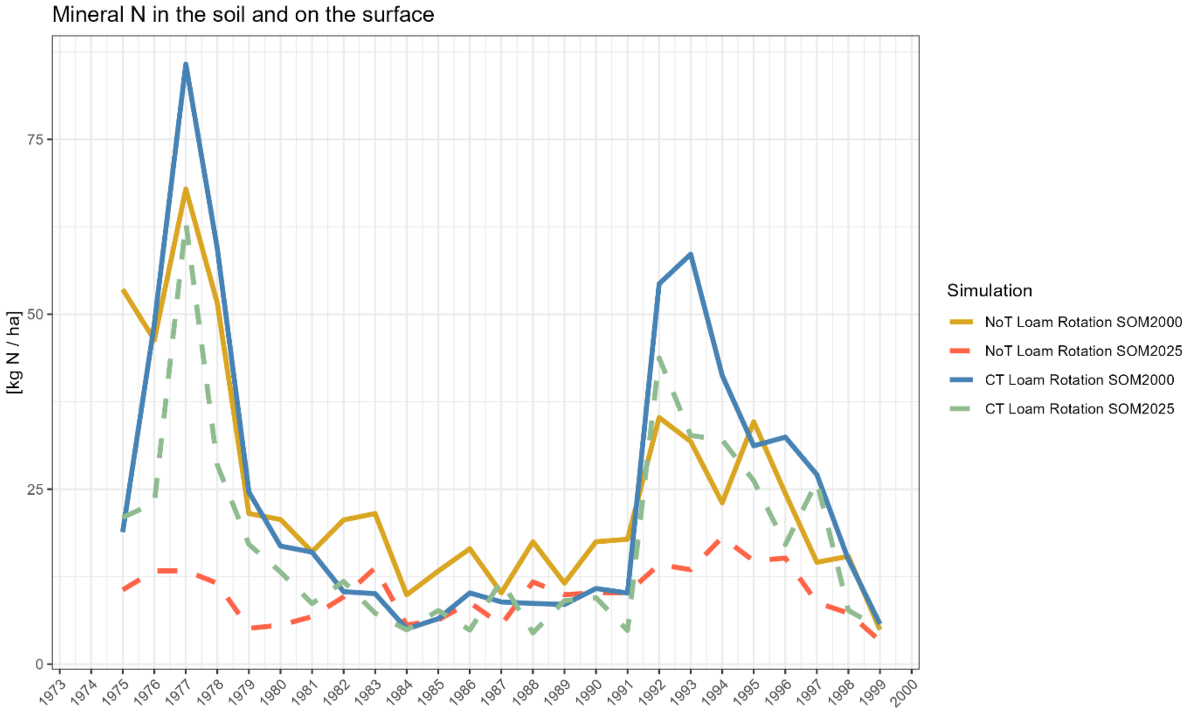

Figure 18: Mineral N content in the soil for Test 2.

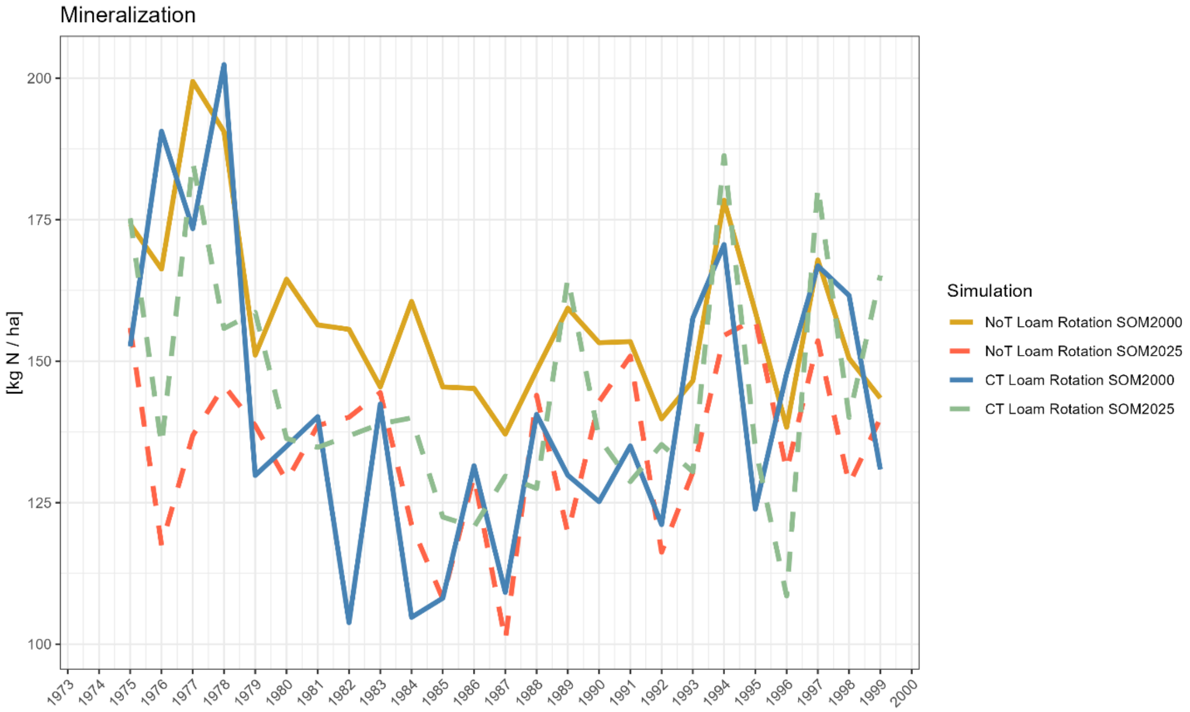

Figure 19: N mineralization for Test2.

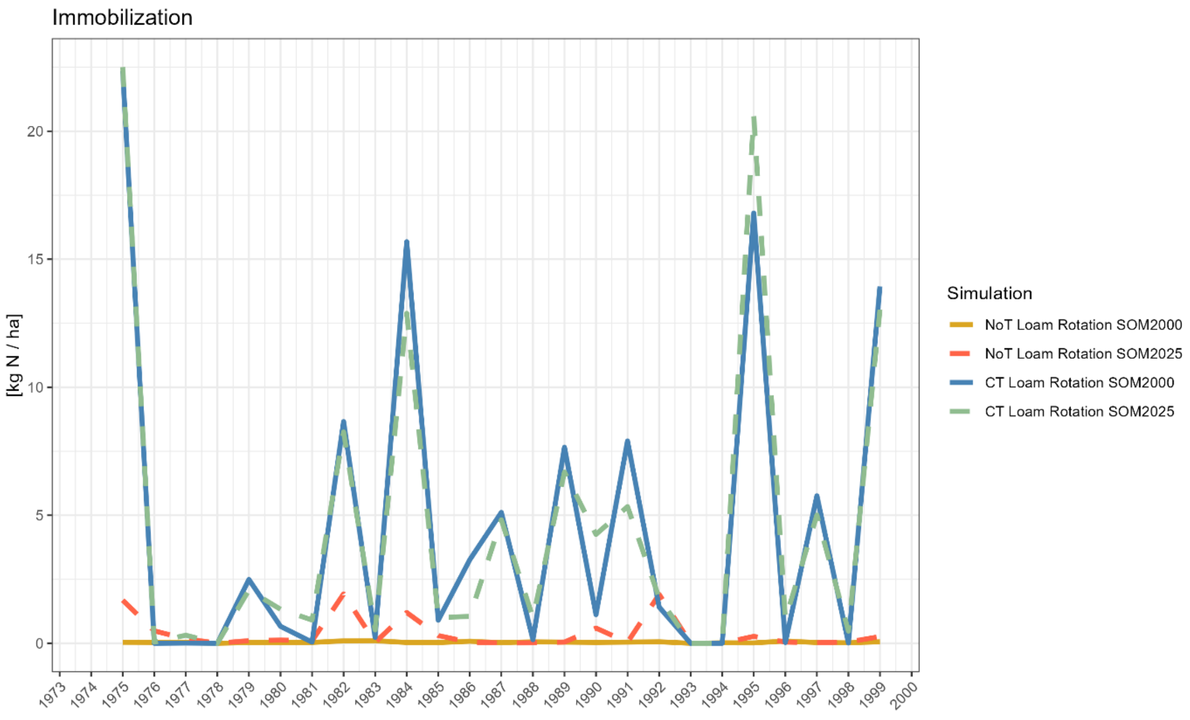

Figure 20: N immobilization for Test2.

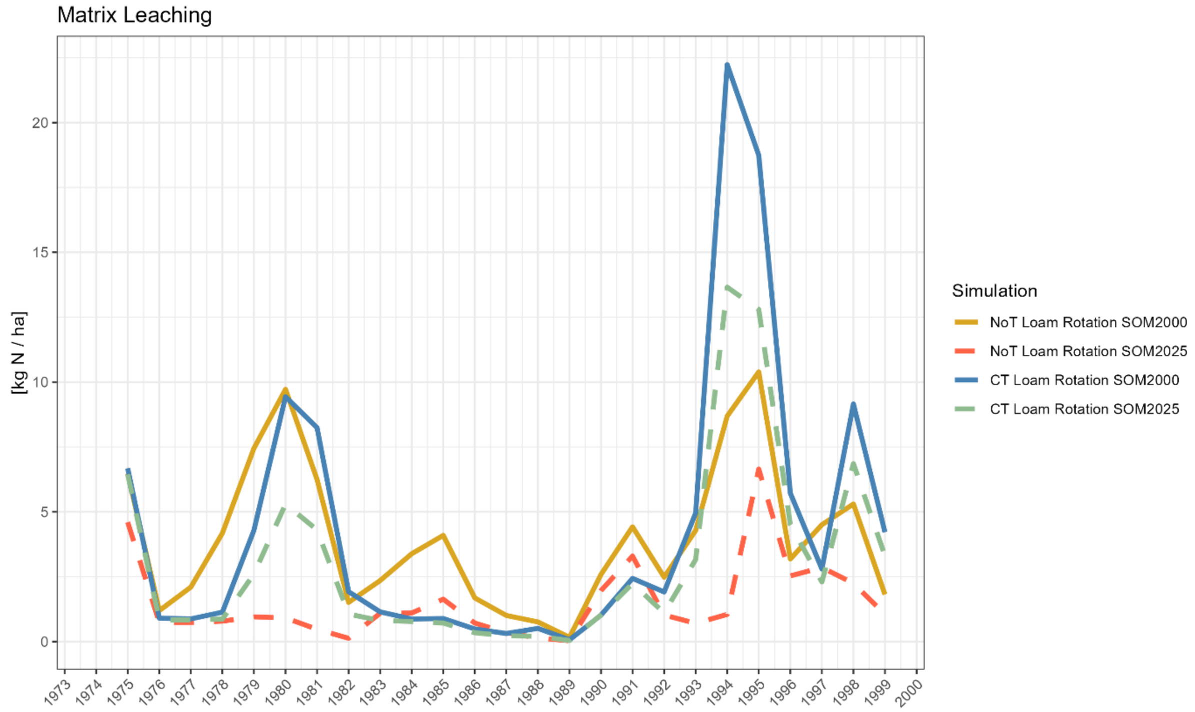

Figure 21: N matrix leaching for Test2.

Table 8: Mean and standard deviation (sd) of harvested N for Test2 over the 25 years.

Soil	Crop	SOM parameter	Harvested N [Kg N/ha]	
			Mean	Sd
Loam	Spring barley	SOM2000	100	15
Loam	Spring barley	SOM2025	99	15
Loam	Winter rape	SOM2000	95	15
Loam	Winter rape	SOM2025	90	16
Loam	Winter wheat	SOM2000	121	26
Loam	Winter wheat	SOM2025	117	30

4. Conclusions

In conclusion we argue that the C and N trends and dynamics in general are similar for the two parameterizations for the two conducted tests for conventional tillage. However, the differences in C and N dynamics seen for the NoT simulations call for further investigation of the parameterization of the SMB2 to SOM2 pathway and bio-incorporation. Especially, we in the Daisy group, wish to calibrate and test the SOM-module for non-tilled agriculture systems including mulch and dissolved organic matter dynamics (conservation and regenerative agriculture). Until then, we recommend to use the SOM2025 parameterization for future studies, in particular when simulating no-till systems, as it resembles the parameterization used in Bruun et al. (2003) and because we do not find it reasonable that 50 % of the bio-incorporated material should be lost twice (in the bio-incorporation process and by the AOM pool). On the other hand, a reduction of the respiration rate for bio-incorporation to 0 may not be the most correct representation of the conditions in the field. A recalibration of the SOM-module including bio-respiration, mulching, dissolved organic matter and additional evaluation of the SMB2 to SOM2 pathways is therefore needed in the future.

5. References

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