Soil Organic Carbon in Boreal Agricultural Soil

Tillage interruption and its effect on Soil Organic Carbon

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Abstract

Farmers have been disrupting the carbon cycle ever since humans started converting forests to agricultural lands. But are there farming practices that can be applied to increase the carbon storage in the soil and subsequently counteract increasing carbon dioxide levels in the atmosphere? In this study I investigate if soil organic matter (SOM) and soil organic carbon (SOC) change with longer interruption between tillage events. The study was conducted by studying SOM concentrations and SOC pools in eight fields with different time since tillage (1 to 14 years). I found that SOM concentrations increased in the O horizon of the studied soil in response to increased time since tillage. Here, SOM concentrations were on average around 13 % one year after tillage, while fourteen-year-old farmland had a concentration around 15 %. In similar, SOC pool increased from around 0.1 kg C m^{-2} in the O horizon of 1 year old soil to 0.33 kg C m^{-2} 14 years after tillage. While both SOM concentrations and SOC pools increased in the O horizon over time since tillage, the SOM concentration and SOC pools decreased in the subsoil. I found no net sequestering of SOC in response to less frequent tillage in comparison to more frequency tillage. My conclusion is that limiting tillage to 14-year cycles is not enough to increase carbon sequestration.

Key words: soil organic carbon, agriculture, tillage interruption, carbon sequestration

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1 Introduction

Ever since humans became farmers, we have disrupted the balance between atmospheric carbon dioxide and carbon stored in plants and soil (Lal et al. 2011; Janzen 2004; Foley et al. 2005). Even though combustion of fossil fuels is the main source of greenhouse gases, such as carbon dioxide, to the atmosphere (Brennan & Owende 2010). Therefore, the impact from agriculture should be considered in the global carbon balance (IPCC 2022). Our exploitation and change of land use where photosynthesis and 'pumping' of carbon to soils are disrupted by harvest and tillage operations also contribute to a reduced atmospheric uptake (sequestering) of carbon (Laganière, Angers & Paré 2009; Foley et al. 2005; Lal et al. 2011).

Agriculture may have been the first example where humans affected greenhouse gases in the atmosphere of our planet (Paustrian et al. 2016). The clearing of natural ecosystems, such as forests to agricultural lands releases CO_2 into the atmosphere and it has been suggested that early farming initiated a 20 ppm rise in the middle of the Holocene (Lal et al. 2011; Ruddiman 2017). Plenty of C is stored overground as plant biomass but also in the soil as Soil Organic Carbon (SOC) (West et al. 2010). When forests are converted to agricultural lands, it has been estimated that about 20-50% of the SOC storage is lost (Yoo et al. 2011). This is mainly due to removal of plant biomass and reduced inputs of organic matter to the soil (Laganière, Angers & Paré 2009). The soil storage of SOC is controlled by plant production (inputs of C) and, decomposition and leaching generating outputs from the soil (Esteban, Jobbágy & Jackson 2000). Afforestation can increase the SOC content, but this depends on which types of trees are planted (Laganière, Angers & Paré 2009). But our needs for productive agriculture will remain as we have a growing demand for food as the world's population is increasing (Bronick & Lal 2005). In other words, afforestation of farmlands seems like an unlikely universal solution to rising CO_2 levels in the atmosphere. Agricultural ecosystems have the potential to be a carbon sink and sequester CO^2 from the atmosphere if the land management is changed and improved (Lal et al. 2011). One of these tools for mitigation is the improving and modification of tilling (Reijneveld, van Wensem & Oenema 2009).

Agricultural lands can sequestrate carbon from the atmosphere and can in turn help mitigate the climate crisis. SOC stocks depend on plenty of functions such as plant productivity, soil texture, density, hydrology, and position of the landscape (Richaed et al. 2011). Other factors are also climate conditions and the age of the land (Dang et al. 2023; Jenny 1943). Furthermore, carbon sequestration essentially relies on the presence of perennial vegetation and their photosynthesis (Wander & Nissen 2004). The vegetations root biomass plays an important role in the sequester of carbon under the vegetations growth (Subedi, Ma & Liang 2006). This is due to rhizodeposition where the roots releases carbon into the soil. Roots, however, also release C to the atmosphere by microbial respiration and decomposition of soil biota and sometimes even primes decomposition of SOC (Grover et al. 2015; Dijkstra, Zhu & Cheng 2021). Reduced impact from tillage, and by that root disturbance, have shown positive effects on carbon sequestration in soils (Paustrian et al. 2016). This is mainly because soil aggregate structure, formed by clay and silt, has capacity to protect the SOC from being decomposed (Taghizadeh-Toosi & Olesen 2016). Reduced tillage has also been shown to decrease the decomposition rates which can increase SOC stocks (Paustrian et al. 2016).

With impacts of tillage regimes in mind, it is easy to understand that effect on SOC storage comes via several complex processes that needs to be considered when managing our

agricultural soils. Even if reduced tillage has been shown to generate a positive effect on carbon sequestration as SOC (Abdalla et al. 2013), conventional tilling (CONT) with events of ploughing is still common. Conservation tillage (CT), aim for a minimal soil disturbance and is practised as eco-tillage, minimum tillage, mulch tillage, reduced tillage, zone tillage or no-tillage (Abdalla et al. 2013). However, reduced tillage might not be enough. Agricultural soils that go through cultivation with a few years interruption contain more carbon than soils that are cultivated every year (Freibauer et al. 2004). Swedish agriculture, especially the north, is interesting since the boreal climate poses challenges for the cultivation. Since the vegetation period is shorter than in southern Europe, the time between tillage and harvest are also shorter which may affect the potential for sequestration.

In this study I will investigate the importance of tillage frequency for SOC storage in agricultural lands. The aim was to improve our understanding about tillage interruption, rather than no tillage at all, and its effect on SOC and carbon sequestration. This study focused on the following research questions:

- Do the SOM concentrations increase with a longer interval between tillage?
- Does the SOC stock increase with a longer interval between tillage?

My hypothesis is that longer intervals or interruptions between tillage events will increase the SOM and SOC content. Furthermore, tillage interruptions as a method to increase carbon sequestration will be discussed.

2 Method

2.1 Study area

The study was conducted in central Jämtland county, Sweden (63°0'30.3"N 14°43'20"E) (Figure 1). The sites studied consist of eight different agricultural lands, that have all been used to produce roughage for cattle and as pasture for at least two decades. Areas of the agricultural lands vary from 0.29 to 2.59 hectare (Table 1). The soil has a typical boreal build up with a thin O horizon, topsoil, and sub soil. O horizon are built up by vegetation, litter, and roots. Topsoil goes as deep as the plough cuts and at the bottom there is a clear border where the soil profile turns into the sub soil. The study area lies on an elevation of approximately 400 m.a.s.l. and a yearly precipitation and temperature average of 643.43 mm/year and 2.83 C° (www.SMHI.se). These agricultural lands belong to a farm where small-scale and noncommercial producing of meat occur. The farm fulfills the requirements to be classified as organic farming. Organic agriculture in this context means that no artificial/ harmful pesticides or herbicides are used on the harvests. Same goes for the fertilization where the only one used is the manure from the cattle. Soils are cultivated in cycles and not every year. This is done by tillage with ploughing followed by harrowing before sowing also known as CONT.
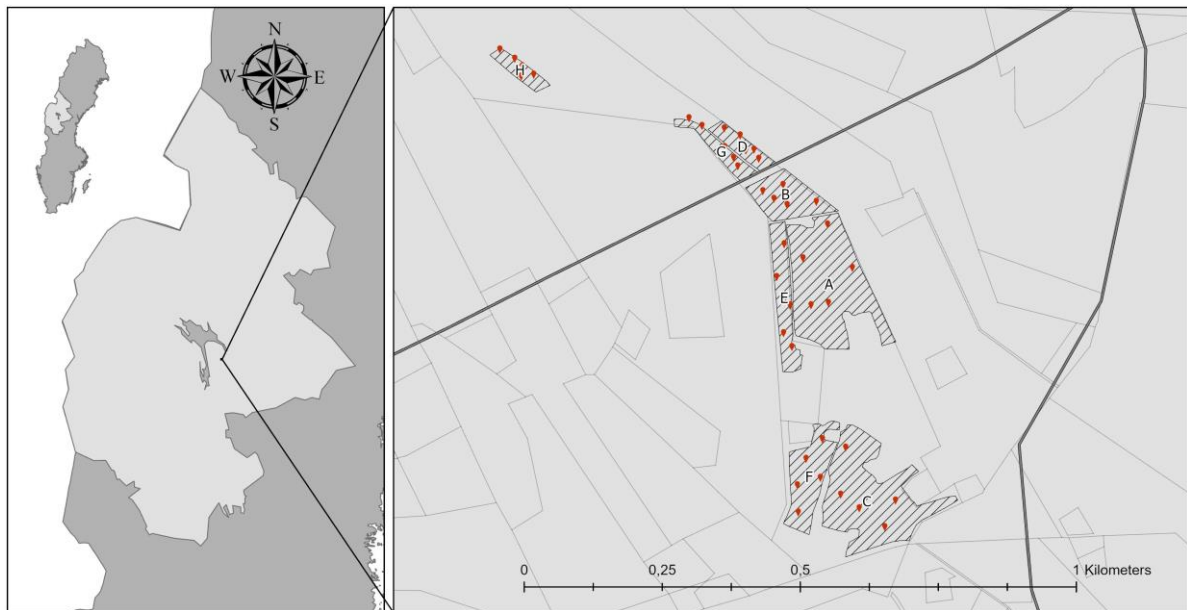
Figure 1. Map over study area. To the left, showing Jämtland county and where in Sweden the study area is located. The right map shows the study area and its sites. Striped areas display the different agricultural lands. Study sites are striped and labeled from A-H. Red points display the location of every pit dug. Gray lines show property boundaries. The darker lines display roads. At the bottom is a scale bar showing distance in kilometers. Coordinate system: SWEREF 99 TM. Data sources: Lantmäteriet© and Natural Earth©.

The eight different study sites range in areas from 0.29 – 2.77 hectare. The oldest one was cultivated in 2008, while the most recent one was cultivated 2022. This area was ploughed in early spring this year and the sampling occurred the same fall (Table 1).

Table 1. Information about the study sites, with area size (in hectares) and what year they were cultivated last.

Site	A	B	C	D	E	F	G	H
Area (hectare)	2.77	0.86	2.59	0.37	0.77	1	0.36	0.29
Cultivated year	2022	2021	2020	2019	2018	2017	2015	2008

2.2 Sampling

Samples were collected between the 10th and 14th of October 2022. I applied a stratified sampling approach with random data points, where the boarder of each field defined each stratum. All eight sites were chosen based on what year they had been cultivated. For each site, five pits were excavated with a shovel. The location for the pits were randomly stratified to cover as much of the site as possible. The tool used for sampling was a steel cylinder with a volume of 220.89 cm³. This cylinder was hammered into the soil with a sledgehammer. At each pit, one soil sample was taken from both the topsoil and the sub soil for the analysis at depths of approximately 10cm and 20cm. To ascertain the soils compaction, bulk density samples were taken from the topsoil and sub soil by hammering in the same steel cylinder. Bulk density will then be used to estimate each horizon's pool and by that a percentage for SOM concentration and SOC content could be calculated. The O horizon was sampled by measuring the depth and cutting out a piece which area then were measured, and volume calculated. All samples were kept in zip-bags and then stored in freezing temperatures until mars when the analysis started. At each study area the stoniness

was estimated by hammering down a rebar until a stone was reached or the rebar went down deeper than 60 cm, this was repeated ten times at each area.

In summary, five samples from the O horizon; five soil samples and five bulk samples were taken from the topsoil and subsoil. Making up a total of 200 samples, 120 for carbon analysis and 80 for bulk density.

2.3 Lab work

Firstly, all samples were dried in 37°C for seven days. This was to ensure that the samples could be stored at room temperature without being spoiled and to remove excess moisture. All samples were prepared by being dried in 105 °C. Carbon content in the samples were analyzed by loss on ignition (LOI). Dried samples of soil and O horizons were put in crucibles and weighted. They were then inserted into an oven with a temperature set to 550 °C and burned for five hours. After a few hours of cooldown, the crucibles with its content were weighed again and a difference could be calculated. The loss of weight is considered as SOM. After the bulk density samples were dried, the content was weighted. Soil samples were analyzed without being sieved. The bulk density was also calculated without being sieved since most of the matrix was less coarse than 2 mm and homogenous.

A few selected samples (N=12) were analyzed by an EA-IRMS at Swedish University of Agricultural Sciences (SLU). These were prepared by being sieved by a 2mm mesh. Samples were then encapsulated into aluminum tins and weighted. From this analysis the mass fraction of C; ωC / % were retrieved and with these values the actual carbon content could be obtained.

2.4 Calculations and analyses

SOM (%) were obtained by subtracting the weight of burned soil mass from the weight of dried soil mass. This value was then divided with the weight of dried soil mass to get a percentage SOM for each site. The actual carbon concentration for these soils was calculated using a regression analysis between SOM% and ωC / % retrieved from the EA-IRMS analysis of the same soil. From this regression the actual soil carbon concentration (%) was inferred. SOC stocks were calculated by first calculate the samples bulk density (kg m^{-2}) by following equation:

$$Eq.1 \; BD \; = \frac{mass}{volume}$$

Where the mass is the weight (kg) of the sample and volume (m^{-2}) is the amount. Both mass and volume were retrieved from the sampling with the steel cylinder. Further, SOC stocks (kg C m^{-2}) could be calculated by following equation:

$$Eq.2 \; SOC \; stock \; = SOC \; con \times BD \; (kg \; m^{-2}) \times depth \; (m) \times (1 - rock \; fragment \; fraction)$$

SOC concentration is the SOC in % divided with 100. BD is bulk density in kg m^{-2} (Eq.1). Depth is the depth, in m, of the actual horizon. Rock fragmentation fraction refers to stoniness. However, since stoniness was insignificant, this part of the equation was neglected. From that, an average and a summary for each site and horizon were calculated, together with standard deviation and standard error. Data resulting from the calculations were compiled in Microsoft Excel and then analyzed in R Studios. A Shapiro-Wilk´s test was conducted to test if the data had a normal distribution. Since all data were normally distributed, a regression analysis was used to test if: i) SOM increased with age and ii) if

SOC pools increased with age. Average SOM and SOC from each horizon and age were tested with regression tests performed in R Studios and had a confidence interval set to 95%.

3 Results

The regression analysis between SOM% and ωC / % suggested the following transfer function between SOM and SOC:

Eq.3 $y = 0.5015x - 0.8037$

Where y is the SOC in %, 0.5015 is the expected carbon content, or estimated slope, in SOM. X is SOM % and 0.8037 refers to the estimated intercept. The positive relationship between SOM and SOC was strong ($R^2 = 0.985$) and significant ($P = 1.47E^{-10}$) and suggested that approximately 50% of the SOM was carbon (Figure 2).
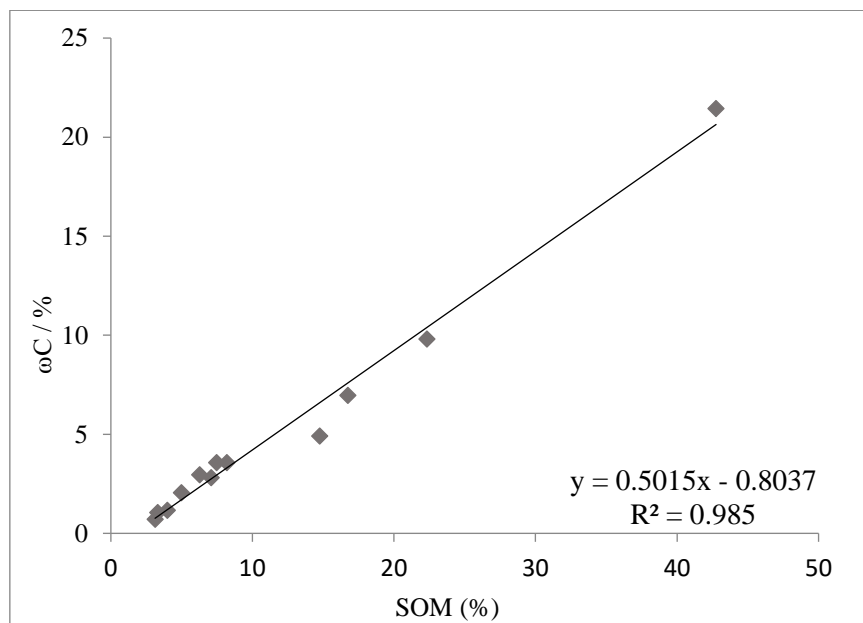

Figure 2. Regression between SOM% and ωC / %. Y-axis showing ωC / % and X-axis showing SOM%. Regression line with appurtenant R^2-value and formula. N=12. Confidence interval 95%.

3.1 Soil Organic Matter
SOM had the lowest values (3.08 – 3.83 %) in the sub-soil (Table 2). For the topsoil, the percentage of SOM were roughly double the amount compared to the subsoil. The topsoil, however, had a moderately wider range with values from 5.93 – 8.12 %. The site that contained the highest SOM concentration was site H with an average of 15.32% which also is the site which has gone the longest without tillage events. Site H also had the highest concentration of SOM in the O horizon. However, it also had the lowest concentration in both topsoil and sub soil (Table 2).

Table 2. Average SOM % for each site and horizon. For each site and horizon N=5. Age represents years since the last tillage event (from 2022). O = O horizon; TS = topsoil; SS = sub soil; TOT = average of O, TS, and SS together.

Age	Site	O	TS	SS	TOT
1	A	29.49	7.13	3.62	13.41
2	B	21.78	7.42	3.19	10.8
3	C	28.36	7.41	3.83	13.2
4	D	22.59	7.11	3.35	11.02
5	E	27.23	7.41	3.14	12.59
6	F	25.88	7.86	3.41	12.39
8	G	31.65	8.12	3.76	14.51
14	H	36.98	5.93	3.08	15.32

The only horizon with a significant p-value (P = 0.03161) was the O horizon (Table 3). The O horizon hade the highest concentration of SOM with an interval ranging from 21.78 – 36.98 % (Table 2). For the total soil profile, the value 0.05375 is close to significant but still not small enough to be accepted as significant.

Table 3. Results from the regression tests from R Studios between horizons and SOM against years since cultivated last. O = O horizon; TS = topsoil; SS = sub soil; TOT = summary of O, TS, and SS. Confidence interval set to 95%.

	p value	Adjusted R^2	df	F
O	0.03161	0.492	1.6	7.78
TS	0.2311	0.09972	1.6	1.775
SS	0.3867	-0.01877	1.6	0.871
TOT	0.05375	0.4032	1.6	5.73

Only in this horizon the SOM concentration showed a significant (P = 0.03161) increase with longer time periods since tillage. Site B had the biggest deviation in standard error (Figure 3; Table 3).
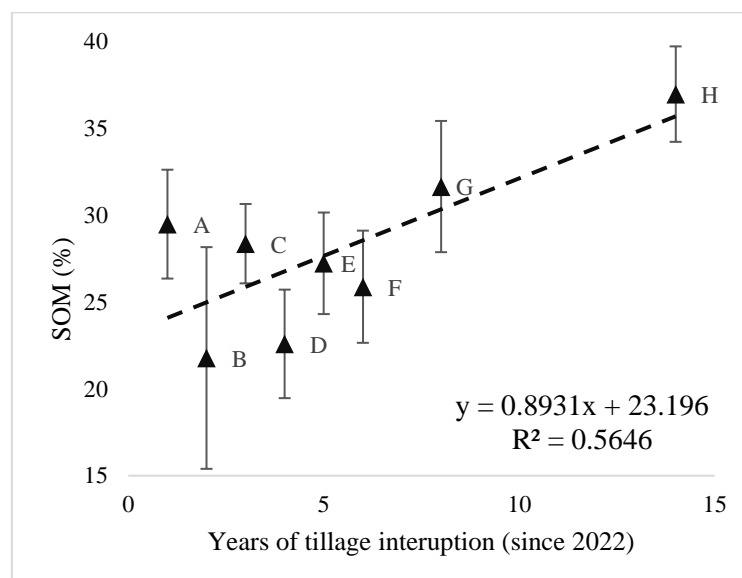

Figure 3. Results for the SOM concentration from the O horizon at each site. Triangles are the average value from each site. Y-axis showing % and X-axis showing years since last tillage (from 2022). Letters beside triangles represents each site. Vertical lines that intercept triangles display standard error. Dashed line is trendline with following equation and R^2 value. Confidence interval 95%.

3.2 Soil Organic Carbon

The O horizon had by far the lowest depth with depths of only mm to a few cm, and by that made up the smallest SOC pool ranging between 0.1 and 0.33 kg C m^{-2} (Table 4). As a comparison, SOC pool in the topsoil ranged from 5.06 kg C m^{-2} to 8.26 kg C m^{-2} while the sub soil ranged from 4.59 kg C m^{-2} to kg C m^{-2}. Also, for this analysis it was shown that site H stood for the greatest SOC pool in the O horizon but the smallest of all pools in both topsoil and sub soil. No effect was found (P>0.2311) of time since tillage on the sub-soil storage or the total SOC storage.

Table 4. Average storage of SOC kg C m^{-2} for each site and horizon. For each site and horizon N=5. Age represents years since the last tillage event (from 2022). O = O horizon; TS = topsoil; SS = sub soil; TOT = summary of O, TS, and SS.

Age	Site	O	TS	SS	TOT
1	A	0.10	7.31	7.01	14.42
2	B	0.13	6.42	4.77	11.32
3	C	0.12	8.26	8.78	17.15
4	D	0.25	6.87	6.01	13.14
5	E	0.17	8.02	5.86	14.06
6	F	0.16	7.64	6.04	13.84
8	G	0.27	7.06	6.42	13.75
14	H	0.33	5.06	4.59	11.07

Again, the O horizon was the only horizon that had a significant value (P = 0.03161; adjusted R^2 = 0.492) (Table 5). Also in this case, it was a positive correlation between increasing SOC and longer period since tillage (Figure 4).

Table 5. Results from the regression tests between horizons and SOC against years since cultivated last.

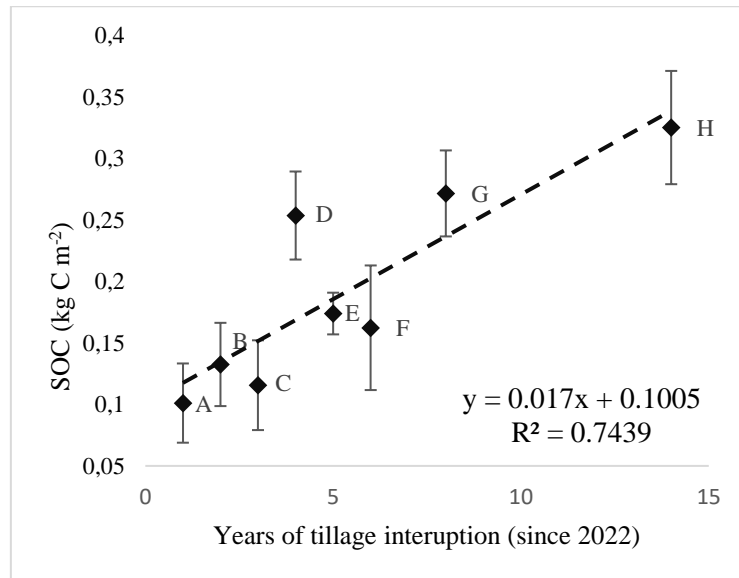|	p-value	Adjusted R^2	df	F
O	0.005845	0.7013	1.6	17.43
TS	0.0881	0.3096	1.6	4.14
SS	0.242	0.08904	1.6	1.684
TOT	0.2562	0.0759	1.6	1.575

Figure 4. Results for the SOC storage from the O horizon at each site. Triangles are the average value from each site. Y-axis showing kg C m^{-2} and X-axis showing years since last tillage (from 2022). Letters beside points represents each site. Vertical lines that intercept squares display standard error. Dashed line is trendline with following equation and R^2 value. Confidence interval 95%.

4 Discussion

I hypothesized that SOM and SOC would increase with longer time periods since tillage events. This was, according to my study, valid for the O horizons. However, for the whole soil profile, I found no effect of time since tillage on SOM concentrations or SOC pools. In other words, the effect of tillage in surface soil layers was either too small to be detected or counteracted by increased losses in sub soils. My results seem to contrast with other studies that have noticed that removal of vegetation leads to a rapid decrease in SOC levels since it reduces the organic carbon input (Taghizadeh-Toosi & Olesen 2016). Another reason might be that the effect of no-tillage is restricted to the topsoil layer and by that the SOM and SOC are not transported deeper down in the layer (Mondal et al. 2023).

An interesting observation was that the oldest site (site H) had the highest SOM concentration and highest SOC content of all sites in the O horizon. However, it also had the lowest SOM concentration and SOC content in the topsoil and subsoil of all sites. This could imply that tilling influences the downward transportation of carbon by soil mixing. Kyungsoo et al. 2011 showed that tillage reduced SOC in the upper layer of the soil while it increased SOC contents at the deeper layers. Earthworms and other burrowing soil organisms can also influence the downward transportation of SOC and an absence of these might lower the soil mixing process (Don et al. 2008).

4.1 Comparing findings with previous studies
I found that about 50% of the SOM was carbon. This was expected since SOC constitutes approximately 40-60% of the SOM (Pribyl 2015; Périé & Ouimet 2008). My conversion factor suggested that the SOC content in my soil was typically 12.9 % which led to SOC stocks ranging from 11.07 – 17.15 kg C m^{-2} in my soil. These SOC stocks can be compared to SOC stocks in German agricultural soils which are estimated to have SOC stocks of approximately 12.5 kg C m^{-2} (Poeplau et al. 2020). Danish agricultural soils have also been estimated to contain SOC stocks of around 14.2 kg C m^{-2} (Taghizadeh-Toosi et al. 2014).

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Both Denmark and Germany lie south of Sweden and have a warmer climate together with longer vegetation periods which could lead to a higher C sequestration and thus, higher SOC stocks. However, these boreal agricultural soils hold approximately equally SOC stocks. One of the reasons for that could be that in colder climates, the decomposition is slower and thus the carbon accumulation is more rapid than in warmer climates (Freibauer et al. 2004). Another reason could be organic farming, especially considering the way of using manure as fertilizer for the fields. Organic amendments such as manures from cattle have been shown to give a higher SOC sequestration in soils, than in soils with chemical fertilizers (Lal 2007).

Significant increases for SOM content and SOC pools as a function of time since tillage were only found in the O horizon. As mentioned previously, these soils are in the boreal climate zone with longer and colder winters than in temperate climate zones where most of the world agricultural soils occur (Gornall et al. 2010). Decomposition occurs more rapidly in temperate zones than in boreal zones. The slow decomposition in boreal zones results in an O horizon even for agricultural soils, which is not occurring in the agricultural soils in temperate zones (Yoo et al. 2011). The O horizon also contains a great rootbiomass which can be a source for SOM and SOC (De Deyn, Cornelissen & Bardgett 2008). Since the O horizons had a small range of different depths the volume of the layer varied between sites, in contrast to the topsoil and sub soil which had the same depth for all sites. The topsoil had a depth of 25 cm since this is the depth of which the plough cuts, and the sub soil had a depth of 60 since this was how deep the pits were dug. Variations in the O horizon's thickness depend on the buildup of vegetation cover. The longer the time of interrupted tillage, the more built up of vegetation covers and thus an O horizon which also will lead to an increase in root biomass. This might be a reason to why the SOM/ SOC increase with time of tillage interruption.

4.2. Implications of my findings

Longer intervals between tillage where the soil is ploughed did not generate a detectable impact in the whole soil. However, if my estimates for the O horizon is correct, extending time since tillage from 1 year to 14 years, can generate a net sequestering of 0.23 kg C m^{-2}. Considering that this effect occurred over a period of 14 years, it corresponds to an uptake of about 0.016 kg C m^{-2} yr^{-1}. Swedish farmlands amount to 3 001 800 hectare (2022), which is approximately 30 000 km^2 (The Swedish Board of Agriculture 2022). If assuming that my study would be representative for all farmland in Sweden, my finding suggests that reduced tillage frequency with 14 years could remove 480 000-ton C from the atmosphere each year.

As a comparison, CO_2 emissions in Sweden (2021) corresponds to about 47.8-million-ton year. About 14% of this carbon dioxide comes from the total agriculture (SCB 2023). In other words, the amount of SOC that can be retained in agricultural soil due to extended time between tillage is small compared to the total CO_2 emissions from Sweden but not insignificant. Interruption in tillage might not be the answer to higher carbon sequestration and thus increase of SOC in soils. As mentioned in the introduction, soil that has not gone through cultivation stores more carbon than soil that is cultivated every year. These benefits of interrupted tillage, however, are reduced after one tillage event that includes ploughing (Freibauer et al. 2004). From this, I assumed that this can be a reason to why there is no significant result for the topsoil, sub soil and, total SOM and SOC.

Tillage is a complex question when it comes to increasing SOC stocks. The buildup of SOM, which may occur with reduced tillage, can contribute to C sequestration (Abdalla et al. 2013) but will not increase the SOC transformation. The SOC transformation process

accelerates with an increase in vegetation cover which will increase net primary production (NPP) and organic C inputs. The decomposition of SOM will not accelerate this process (Dang et al. 2023). However, permanent changes and conversion to conservation tillage seems to be the best management for improving carbon sequestration (Bohoussou et al. 2022).

4.3 Conclusion

In conclusion my result showed that SOM (%) and SOC (kg C m^{-2}) increased with longer tillage interruptions, but only for the O horizon. However, no significant total effect was observed, either for SOM (%) or SOC (kg C m^{-2}). The boreal agricultural soils exhibit a near equally great SOC stock as in soil from temperate zones in Germany and Denmark. The relatively high content of SOC in this colder climate could be due to slower decomposition rates or organic farming. Worth noting is the p-value for the total SOM% is very close to being significant and maybe more replicates and/or more study sites would have given a significant result. I suggest that further studies should include more climate factors since the boreal climate zone make up for complex, but maybe positive features for carbon sequestration.

Acknowledgement

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Appendix
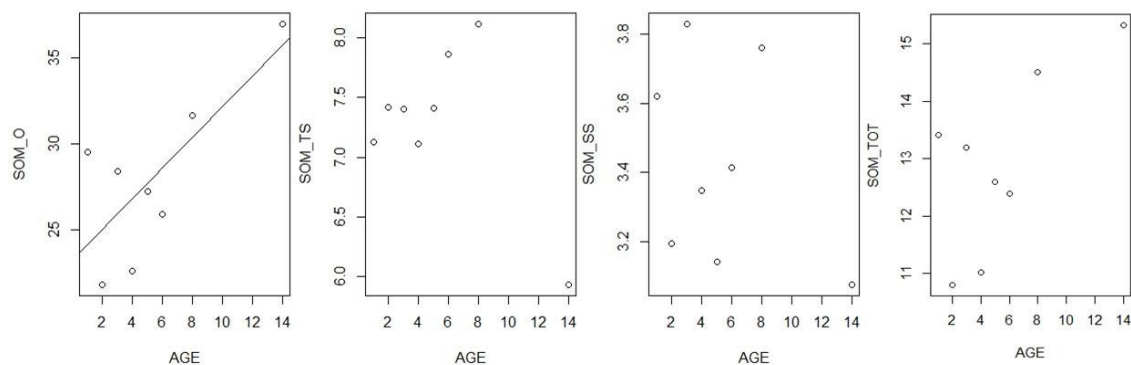
Results from regression between average SOM for each site and horizon: O, TS, SS and, TOT against age (years of tillage interruption since 2022). SOM in %. Regression line only plotted in the plot for O horizon since this is the only one with significant results.
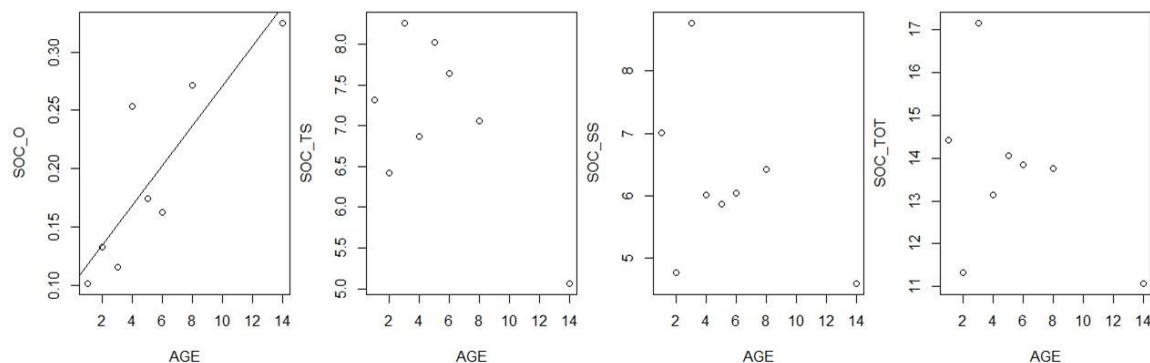
Results from regression between average SOC for each site and horizon: O, TS, SS and, TOT against age (years of tillage interruption since 2022). SOC in kg/m2. Regression line only plotted in the plot for O horizon this is the only one with significant results.

List of samples (first column) which were sent to SLU for an EA-IRMS analysis and its result ωC / % (second column) along with the same samples LOI% (third column). First letter and number in sample represent site. O = O horizon; TS = topsoil; SS = sub soil.

Sample	ωC / %	LOI %
A2TS	3.58	7.47
C4TS	2.82	7.08
E3TS	3.57	8.20
H3TS	2.96	6.26
A2SS	1.17	3.99
C4SS	2.06	4.97
E3SS	1.05	3.31
H3SS	0.71	3.12
B2O	4.92	14.76
D4O	6.97	16.75
E1O	9.81	22.33
H4O	21.45	42.76

Measured stoniness for each study site. At each study site 10 tests were conducted. The rebar used in these tests only went down to 60 cm.

A	(cm)	B	(cm)	C	(cm)	D	(cm)
1	38	1	41	1	30	1	60
2	36	2	23	2	32	2	60
3	60	3	53	3	32	3	60
4	33	4	61	4	60	4	60
5	60	5	52	5	47	5	60
6	22	6	39	6	44	6	60
7	30	7	56	7	57	7	60
8	38	8	47	8	25	8	60
9	43	9	49	9	40	9	60
10	60	10	26	10	23	10	60
E	(cm)	F	(cm)	G	(cm)	H	(cm)
1	30	1	38	1	53	1	60
2	60	2	20	2	55	2	38
3	24	3	23	3	42	3	60
4	44	4	13	4	11	4	38
5	43	5	60	5	26	5	60
6	38	6	58	6	55	6	60
7	23	7	35	7	45	7	22
8	15	8	52	8	55	8	11
9	52	9	43	9	18	9	42
10	58	10	52	10	38	10	60