Slutrapport

Odlingssystemens effekter på kolinlagring i jordbruksmark – kunskapsbank och modellering

Projektnummer:
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Del 1: Utförlig sammanfattning

Resultat från metaanalyser i vår studie visar att kolinlagringspotential (kg kol per hektar och år) i matjorden avtar i följande ordning: vall (520) > stallgödsel (410) > fånggrödor (330) > N-gödsling (230) > halmåterföring (120) > direktsådd (<100). Kolinlagringspotentialen i alven som undersöktes på några av de svenska långliggande fältförsöken (LF) skiljer sig mellan platserna. Fortsatt arbete behövs för att förstå orsaken till denna variation. Data från ett stort antal LF analyserades för att ta fram nya parametrar och skatta osäkerhet i kolbalansmodellen ICBM. Vår hypotes att ovanjordiska växtrester bidrar mindre till mullbildning jämfört med rötter kunde inte förkastas. För att studera nedbrytning av organiskt material testades Tea Bag Index i försök över hela landet, och det visade sig vara en användbar metod för framtida modellutveckling. ICBM integrerades i *Odlingsperspektivet*, ett rådgivningsverktyg som är lätthanterligt och flexibelt. Resultaten från detta projekt har både bidragit till processförståelsen om markkolsdynamik och gjorts tillgänglig för användning av jordbrukaren. Den kunskap vi tagit fram används också i utredningar om växthusgasbalanser relaterade till den svenska livsmedelsstrategin. Vi fördjupade också vårt samarbete med Norge och Kanada som nu använder ICBM-modellen i sina rådgivningsverktyg och de har visat intresse av att använda den för sin klimatrapportering.

Projekt har fått finansiering genom:

Stiftelsen Lantbruksforskning

Del 2: Rapporten (max 10 sidor)

Background and aim of the project

Soil organic carbon (SOC) is the major determinant for physical and biochemical soil properties, fundamentally defining both the fertility and sustainability of agroecosystems. As the total quantity of SOC in world's soil is largely exceeding the amount contained in the atmosphere and all vegetation combined, even small changes in SOC can influence atmospheric CO_2 concentrations. Compared to their initial status before conversion into agricultural land, many soils today have lower SOC contents, and in theory, it is possible to re-store and thereby sequester C in agricultural soils (Paustian et al. 2016). SOC sequestration is the net removal of CO_2 from the atmosphere through photosynthesis and the subsequent transfer into pools of SOC with longer turnover times. These principles are in the agenda for assessing national and farm-scale greenhouse gas (GHG) budgets, which is achievable by using different SOC models. Since SOC stocks are changing very slowly over time, results from long-term field experiments (LTEs) are essential for studying the influence of different management practices on SOC sequestration rates, and for calibrating models (Kätterer et al. 2012). This project was aiming at gathering and using the knowledge from the Swedish LTEs for determining SOC stock change rates (SCR) for different management practices, including considerations for changes in subsoil SOC. Another objective was to incorporate new concepts related to SOC dynamics through a multi-site calibration of the ICBM model using the data from these LTEs, and to integrate ICBM within the Swedish extension services farmer decision-tool *Odlingsperspektiv*. We were also testing a new concept for studying SOC decomposition dynamics *in situ*, the tea bag index (TBI).

Materials and methods

Soil sampling and analysis in LTEs (top- and subsoil C stocks & gravel and stones)

We sampled selected treatments in 5 LTEs for assessing changes in SOC stocks in deeper soil layers. In 2016, the Lanna site in southern Sweden, which is part of the humus balance series. Lanna has two parallel experiments (R3-0020 & R3-0021), one with a continuous spring cereal rotation and the other one with a continuous 4-year clover/grass ley rotation. Sampling was made for the most contrasting N treatments of each experiment (receiving no N and the highest rates), and only in the spring cereal monoculture plots with no straw removal because it is the most common management practice in the region. In 2017, we sampled Högåsa in central Sweden, which is one of the experiments in the soil fertility series (R3-9001). For this site, sampling took place in four treatments (0PK-0N, 0PK-N, PK-0N, PK-N) for both the rotation with- or without manure applications. We sampled two sites 2018 from the experimental series monocultures in northern Sweden (R8-74), Ås and Röbäcksdalen supported by SITES (the Swedish Infrastructure for Ecosystem Science). At each of these two sites, sampling was made allowing us to compare a spring barley monoculture rotation with a continuous ley, both having a mineral fertilization vs combined mineral fertilization and manures treatment.

For these 5 LTEs, sampling of soil profiles down to 50- or 60-cm depth were made, using small depth intervals around the intersection with the plough layer (i.e., 0-20, 20-22.5, 22.5-25, 25-27.5, 27.5-30, 30-35, 35-40, 40-50 and 50-60 cm). We were analyzing all samples for whole soil C and N contents by dry combustion, and conducting measurements of dry soil bulk density (BD) with triplicate cylinders (7.2-cm diameter) for the arable soil layer (5- to 15-cm depth). We were also re-analyzing historical soil samples for whole soil C and N from the two LTEs in northern Sweden. Furthermore, in 2017 and 2018, we were measuring stones and gravel *in situ* for 6 LTEs of the soil fertility series on gravely soils in central (Fors, Högåsa) and southern (Borgeby, Ekeby, Fjärdingslövsgården, Orupsgården) Sweden. Allowing us to account for particles > 2-mm to correct the whole soil SOC stocks that are determined on soil < 2-mm (Fig. 1).

Fig. 1. Excavation and sieving of arable soil (40 x 40-cm quadrats 20-cm depth) disregarding larger stones *in situ,* and sieving out gravel in the laboratory, obtaining samples for different fractions (> 32-mm, 16- to 32-mm, 8- to 16-mm and 2- to 8-mm) of whole soil. Ekebo site.

Tea Bag experiments

We used a new and innovative approach for studying the decomposition of organic materials *in situ*, the TBI, following the procedures described by Keuskamp et al. (2013). It consists of burying tea bags of two different brands (Green tea and Rooibos) with different degrees of decomposability into the soil and retrieving them after various time-periods (Fig. 2).

Fig. 2. Tea Bag Index (TBI) measurements made by inserting tea manufactured by Lipton in the topsoil (8-cm depth) of LTEs, using four teabags each of Green tea and Rooibos per experimental unit within a 2 x 2 m grid and retrieving them after different time-periods (15, 30, 60 and 90 days).

For this purpose, we selected contrasting treatments from three different categories of Swedish LTEs located in regions with variable pedo-climatic conditions; humus balance (Röbäcksdalen, Säby, Lanna, Lönnstorp) and soil fertility (Röbäcksdalen, Högsåsa, Vreta Kloster, Borgeby, Ekebo) series, and tillage systems (Säby, Ultuna, Lanna) experiments for a total of 13 LTEs. The contrasting treatments were spring cereals vs. ley, high fertility (manures plus full N) vs. low fertility (no manures and no N), and no-tillage vs- ploughing or shallow cultivation. We were using 4 teabags of each brand in each experimental plot and for each date of retrieval (i.e., 88 plots x 4 teabags x 2 brands x 4 dates= 2816 teabags). The ash content was determined on a pooled-sample of the 4 teabags used for each experimental plot and date of retrieval to correct for contamination by mineral soil particles.

The data- and knowledge-base

We were constructing a data- and knowledge-base following each treatment in the LTEs on an annual basis for two purposes. Firstly, the assembling of the data necessary for modelling SOC dynamics (soil (<2-mm) organic carbon content through time including initial values, texture, bulk density and gravel & stone content (>2-mm), crop types and crop residue management and yields, amounts of organic amendments) was needed for the model development and improvement in this project. Secondly, it also allowed us to extract the long-term effect of specific management practices on SOC stocks in order to calculate linear SOC stock change rates (SCR). In this project, by combining data from the Swedish LTEs with those from other temperate regions, we specifically addressed the issue of tillage practices (Meurer et al. 2018), and the effect of crop residues, cover crops, manures and nitrogen fertilization (Bolinder et al. *Submitted*).

Model development and improvement

The objective of this work was addressing the following two main issues. First, there was a need to thoroughly testing our previous findings that root-derived carbon contributes more to the stable SOC pool (Kätterer et al. 2011), as well as verifying the coefficients used for calculating the carbon inputs from roots. Secondly, there was a need for making a new calibration of the latest ICBM version, as presented in Kröbel et al. (2016) which we have now been including into the farmers' decision-tool *Odlingsperspektiv*. For these two purposes, we were using the data assembled in the previous section for different Swedish LTEs. For the first objective, we used a multi-site approach and Bayesian calibration with the RothC model as described in Dechow et al. (2019). Using RothC, which is another process-oriented model like ICBM, allowed us considering data from a larger number of LTEs with pedo-climatic conditions representative for Sweden. In total, 439 time series of data for SOC from 36 LTEs in central and northern Europe were included in this analysis; among those were included data from 10 of the Swedish experiments in the soil fertility series. For the second objective, we were also selecting a Bayesian approach for calibrating the latest version of ICBM. The first version of ICBM was developing from the LTE in Ultuna Sweden, with a time-series of data from 1956 to 1991 (Andrén and Kätterer, 1997), now we were using an updated time series of data from this LTE ending in 2017, and by including experimental data (1996-2017) from a sister LTE at Lanna in southern Sweden (Menichetti et al. *In preparation*). For these two LTEs, we were using an equivalent soil mass approach but no correction for gravel and stones were necessary because it is representing less than 0.2%.

Farmers' decision-tool version of ICBM
It was decided the most appropriate and efficient to incorporate ICBM using the existing Excel-based program within *Odlingsperspektiv* because it is already a user-friendly decision-tool for farmers (www.greppa.nu). *Odlingsperspektiv* comprises a module designed for calculating and advice farmers about SOC balances and soil fertility issues (*Mullhalt och bördighet*). We were incorporating the latest version of ICBM into this module. This version integrates the latest findings from the Swedish LTEs, having a separate humification coefficient for above- and belowground carbon inputs from crop residues, as described in detail by Kröbel et al. (2016). Another major change (compared to the previous calculator used for calculating SOC balances) was the inclusion of new coefficients used for calculating the carbon inputs from roots. We were basing this on results from Bolinder et al. (2007, 2015), including an update of literature data from European and Scandinavian data (Bolinder, unpublished data). Hans Nilsson and Emma Hjelm (Swedish Board of Agriculture) were the main actors from extension service organizations for including ICBM into *Odlingsperspektiv* and for the promotion of the new tool. Göte Bertilsson, a consultant (GREENGARD) from the agribusiness sector was working with the background to the farmer decision-tool including testing on data from LTEs in southern Sweden.

Results & Discussion

Top- and subsoil C stocks & gravel and stones in LTEs
The SOC concentrations were significantly higher for the continuous ley treatments at the Lanna LTE compared with the cereal monoculture rotation, while the effect of N fertilization was only significant for the cereal monoculture rotation. This was comparable to what we found in an earlier sampling for another site in the same series of LTEs at Lönnstorp (Fig. 3).

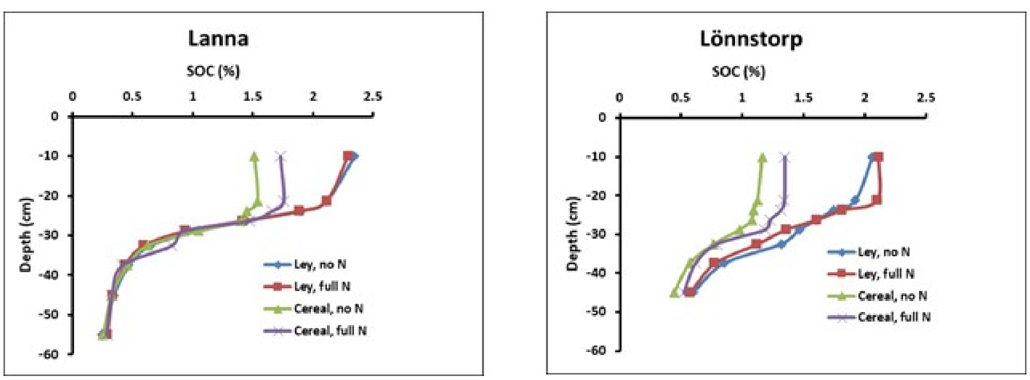

Fig. 3. Soil organic carbon (SOC) concentration in soil profiles for Swedish LTEs at two locations comparing continuous spring cereal with a continuous ley, receiving no or full application of N (adapted from Börjesson et al. 2018).

After correcting SOC stocks for gravel and stones and using an equivalent soil mass approach, compared to the cereal rotation, the linear SCR for leys in the topsoil (0 to 20-cm) were 0.36 and 0.59 Mg C ha^{-1} yr^{-1} for Lanna and Lönnstorp, respectively. Contrary to Lönnstorp, we did not find any differences in subsoil C at the Lanna site. However, for the LTE we sampled at Högåsa there were differences in SOC contents extending down to the upper subsoil (30 to 40-cm). In particular, the SOC content was higher in the treatment with full N and PK (PK-N) compared to the unfertilized treatment (0PK-0N) for the rotation without leys and manures. A similar observation was made earlier for another site of the soil fertility series at the Fors LTE (Kirchmann et al. 2013). We found no differences in subsoil SOC at the two experiments we sampled in northern Sweden.

The percentage of gravel and stones (particles > 2-mm) by volyme at Fors, Borgeby, Fjärdingslövsgården, Högåsa, Ekebo and Orupsgården were representing 1.7, 3.0, 3.7, 4.0, 5.4 and 8.7%, respectively. Calculations of SOC stocks for a given soil depth and area are done using the product of C concentration measured on whole soil samples < 2-mm and BD. We were using a correction for the content of gravel and stones, following the approach described by Poeplau et al. (2017), applying it to the initial SOC content of the whole soil at each site. Results show that when considering gravel and stones, these corrections are reducing the SOC stocks (0 to 20-cm depth) by 2.7% (Fors) to as much as 12.8% (Orupsgården). In future work we will apply this approach for a larger number of the Swedish LTEs, in both the model parameterization and for determining more precise linear SCR. An identical difference in percentage SOC content, when applied on a smaller SOC stock is reducing SCR. We were using this approach for the two sites when calculating changes in subsoil SOC stocks (Fig. 3). However, it only affected the results at Lönnstorp where gravel and stones were about 6.5%. Gravel and stones are negligible at Lanna (<0.2%).

Tea Bag experiments
The mass of the two brands of teabags remaining after 90 days in the soil allows calculating the standard TBI, which consists of two parameters. A decomposition rate parameter (*k*) and a stabilization factor (*S*), where *k* represents short-term dynamics of new input to the soil, while *S* is representing an indicator for longer-term storage of SOC (Keuskamp et al. 2013). Our results are showing the standard TBI parameters are possibly obtainable with a shorter time-period of 60 days under Swedish pedo-climatic conditions, and pointing out that correcting for contamination of soil particles is important, particularly for increasing time-periods and for green tea (Fig. 4A).

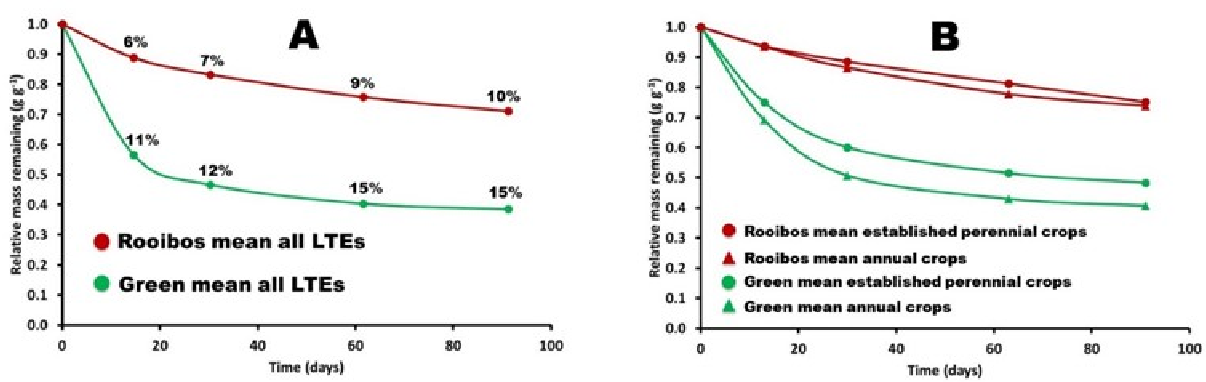

Fig. 4. Relative mass remaining of Rooibos and Green tea (A) mean values from all the thirteen Swedish LTEs where numbers on the graph indicates the ash content (B) mean values from the four LTEs comparing annual crops versus ley (Data from Olle Åkesson, 2017, M. Sc. thesis).

Using the standard TBI (90 days), Åkesson (2017, M. Sc. thesis) were showing that the effect of tillage on the decomposition rate parameter (k) was not consistent but full inversion tillage with ploughing slightly reduced S. Similarly, soil fertility had no effect on k but there was a trend indicating lower S-values in the unfertilized plots. However, a much clearer trend was noticeable when comparing annual crops with leys, where the annual cropping systems resulted in significantly lower S-values, as shown by large differences in the relative mass remaining for Green tea (Fig. 4B). Furthermore, the decomposition rate parameter k showed a pattern of being lower for leys. Combining air temperature and precipitation in a synthetic climate index (i.e., temperature x precipitation) resulted in a better correlation with S (R^2=0.33, N=88), rather than using these variables separately. The parameter k also correlated with several soil properties, where clay content and whole soil C/N ratios explained 13 and 19% of the variance, respectively.

These results are supporting the climatic factor of the ICBM model, which is using the interacting effects of climatic variables in combination with soil properties, and where decomposition rates for leys are set to a lower value compared to that of annual crops (Andrén et al. 2008; Bolinder et al. 2012). However, there is a need for analyzing this further on a much larger data set. We have submitted our TBI data (90 days measurement) for participating in the creation of a global map of litter decomposition rates, which we then will subsequently use for validating the ICBM climatic parameter. So far, researchers have been submitting data from about 3000 locations across the world and a collective article of this global map is in preparation; where we are also contributing to another synthesis article following the latest TBI workshop in Umeå 2019 (http://www.decolab.org/tbi/).

The data- and knowledge-base

In Bolinder et al. (*Submitted*) we summarized and analyzed results for the effect of selected management practices from review articles, often applying meta-analysis statistical methods, including research papers if they analyzed an important number of LTEs for a given type of comparison. Meurer et al. (2018) were conducting a worldwide meta-analysis on the effect of no-till vs. conventional tillage using an equivalent soil mass approach focusing on boreo-temperate regions (Fig. 5).

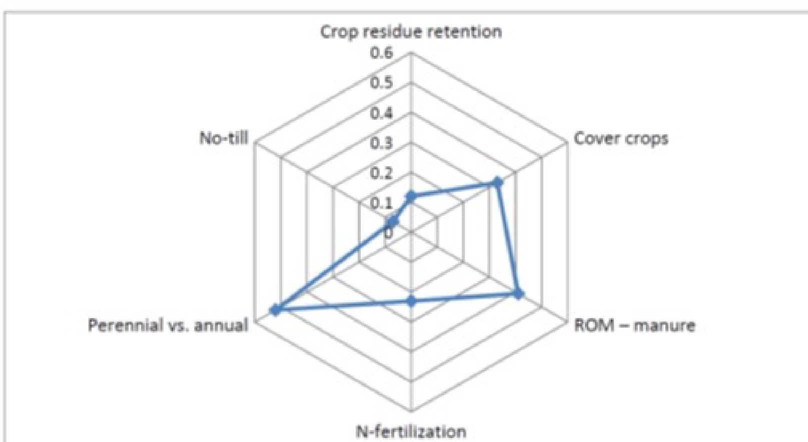

Fig. 5. The overall average effect of different management practices on mean stock change rate (SCR; Mg C ha^{-1} yr^{-1}) weighed by the number of paired comparisons (*N*) used in each review; crop residue retention (*279*), cover crops (*176*), ROM-manure (*217*), N-fertilization (*183*), Perennial vs. annual (*15*) and No-till (*101*).

Results were also discussed in relation to a previous publication we made (Kätterer et al. 2013) addressing the effect of rotations with high or low frequency of perennial crops. Our work clearly shows that a high frequency of perennial leys in crop rotations and application of recycled organic material (ROM) such as manures are the management practices that increase SOC the most, followed by the use of cover crops, N-fertilization and aboveground (e.g., straw) crop residue retention. No-tillage is the least efficient management practice regarding SOC management. This synthesis also shows that results are not always consistent among reviews and that interaction with texture and climate remain inconclusive.

The primary data from the Swedish LTEs are managed officially at SLU in a digital database (and associated archives), and users can have access by making a formal request (www.ffe.slu.se). The data we were generating and compiling in this project in a more useful format (for modeler's) are also available upon request. Furthermore, some of the results we were analyzing within this project, notably those in Meurer et al. (2018) are associated with a Systematic Map guiding researchers for sourcing data from LTEs including those from Sweden (https://eviem.se/en/projects/soil-organic-carbon-stocks/). We have been communicating our findings from the knowledge-base on linear SCR for use and discussion on various Swedish governmental committees (e.g., Government Offices of Sweden, Department of Environment and Energy), and to the Swedish Board of Agriculture (e.g., Markensten et al. 2018).

Model development and improvement

In the multi-site calibration (Dechow et al. 2018), we were clearly showing that the relative contribution from belowground carbon inputs to SOC was indeed higher than that from aboveground crop residues. Furthermore, by comparing the Bolinder et al. (2007) coefficients used for calculating the carbon inputs from roots to those from Franko (1997), we could show that both approaches were underestimating annual carbon inputs to soil from belowground and from the stubble component of aboveground crop residues. Generally, both approaches were similar, their respective influence on model calibration were varying depending on crop types and with subgroups of LTEs. The uncertainty in estimates for belowground carbon inputs to soil remains high.

Model calibration on the two Swedish LTEs by Menchetti et al. (*In preparation*), were yielding slightly higher humification coefficients for below- and aboveground crop residues (0.385 to 0.395 and 0.146 to 0.197, respectively), compared to the default values (0.310 and 0.125, respectively) we were presenting in Kröbel et al. (2016). However, we are still fine-tuning this calibration and validating them on selected treatments from other Swedish LTEs. An advantage with these Bayesian-based calibration methods is the feasibility of quantifying the uncertainty of model predictions, as exemplified in Fig. 6. We could expand this concept including simulations we are executing with ICBM within future versions of *Odlingsperspektiv*. We are also including this new calibration within the Swedish national climate reporting system, where ICBM is used for assessing SOC stock changes for mineral agricultural soils.

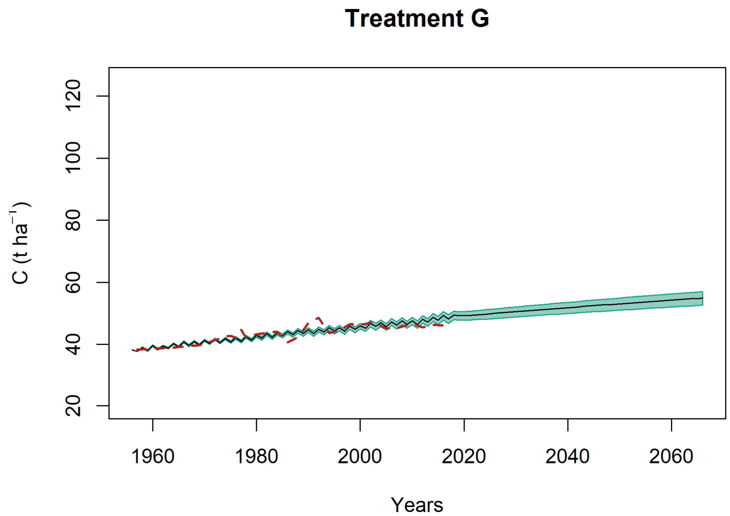

Fig. 6. Example showing the calibrated model (colored area) versus the experimental data (red dashed line) for the treatment G (i.e., representing the most common agricultural practices) in Ultuna. The extended colored area are representing the uncertainty in predictions after 2017, when ICBM version two was running with average annual C inputs and climatic data calculated on all previous years (from Menichetti et al. *In preparation*).

Farmers' decision-tool version of ICBM

Generally, the Swedish extension scientists and farmers seem to appreciate the new version of *Odlingsperspektiv,* which now includes the ICBM model for calculating changes in SOC stocks. The results are focusing mostly on relative differences in SOC stocks between different scenarios, comparing two management alternatives, such as the present versus a new (improved) rotation (Fig. 7). It is also possible assessing trends in the evolution of SOC stocks through time for a given scenario, although this requires the user to provide information that is more detailed (e.g., at least some measurements of SOC contents in the fields).

There are several improvements needed to be implemented in the future. However, now when the basic structure of ICBM is in place, incorporating new knowledge and refinements in parameter values is easy. Some of the challenges are including the following. The coefficients used to calculate the carbon inputs from roots for forage crops are mostly valid for shorter-term ley rotations (not more than 3 years of ley), they need to be refined for assessing SOC dynamics in rotations having more permanent leys. In this project, we were specifically testing ICBM mainly on some of the Swedish LTEs in the southern part (*Skåne* County). This was revealing that the climatic factor of ICBM was sometimes not adequately representing the expected differences in decomposition rates between annual crops and leys. Consequently, an adjustment of the former was necessary in this application, although an adjustment by lowering the humification coefficient for aboveground crop residues is equally possible. Further research on a larger number of LTEs will disentangle the appropriateness of and the balance between such adjustments. We were also testing *Odlingsperspektiv* on the two experiments we sampled in northern Sweden, where it performed well for several treatments (Lina Wu, 2018, M. Sc. thesis).

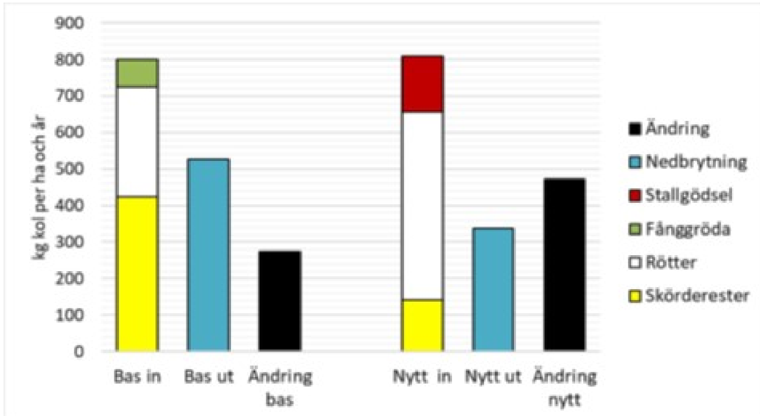

Fig. 7. Example of output from the Farmers' decision-tool version of ICBM (*Odlingsperspektiv*). Showing results (kg C ha^{-1} yr^{-1}) for a present (*Bas*), compared to a new (*Nytt*) rotation. Where the change (*Ändring*) is the simulated difference with ICBM, inputs (*in*) are from manures, cover crops, roots and crop residues (*stallgödsel*, *fånggröda*, *rötter* och *skörderester*); outputs (*ut*) from decomposition (*nedbrytning*) represents a relative difference between the two former.

Furthermore, the climatic factor in ICBM that we implemented in *Odlingsperspektiv* has a quite low spatial resolution. It uses average values for each of the eight agricultural productions regions accordingly with values presented by Andrén et al. (2008). Through our participation within the SMED (*Svenska MiljöEmissionsData*) consortium, we have access to detailed climatic data from 22 weather stations (1970-2016) in Sweden as well as to gridded climatic data (1990-) by county. Presently, this information is not publicly accessible but a web application has been recently created by a researcher in our group (Lorenzo.Menichetti@slu.se), where the user can either ask us to calculate the climatic parameter for a specific location, or doing that themselves with their own climatic records.

Conclusions

Our integration of data from LTEs concerning the effect of different cropping- and management systems on soil carbon sequestration are showing that the annual SCR are highest for perennial forage crops (0.52 Mg C ha^{-1}), followed by the use of cover crops (0.33 Mg C ha^{-1}). The use of recycled organic materials such as manures can also potentially increase SOC stocks (0.41 Mg C ha^{-1}), while the effect of nitrogen fertilization and of leaving aboveground crop residues shows intermediate SCR (0.23 and 0.12 Mg C ha^{-1}, respectively). The effect of no-tillage has the lowest SCR (<0.1 Mg C ha^{-1}). The sampling of selected treatments in some of the Swedish LTEs are showing that changes in SOC stocks can occur in deeper soil layers. However, results are highly variable among sites and consequently, more studies are needed for a better understanding of these effects. The sampling for soil particles >2-mm are indicating that corrections of actual SOC stocks for gravel and stones can be important for some LTEs and agricultural regions, allowing improved comparisons of SCR between sites. The multi-site calibration approach was confirming the hypothesis of higher humification coefficients for belowground (root-derived C) compared to C from aboveground crop residues. The latest version of ICBM was successfully incorporated into the farmer decision-tool *Odlingsperspektiv*. Overall, the model development and improvement are also showing that challenges remains in accurately estimating belowground carbon inputs to soil. In particular for crop rotations involving more than three consecutive years of forages. The new version of *Odlingsperspektiv* including the ICBM SOC model is a flexible approach, easily allowing an update for including new findings and parameter values. The TBI approach was useful for assessing the influence of climate and soil properties on decomposition, but the analysis will necessitate the use of larger databases for deriving appropriate information for inclusion in SOC models.

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Del 3: Resultatförmedling

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Meurer KHE, Bolinder MA, Andrén O, Hansson AC, Pettersson R, Kätterer T. 2019. Shoot and root production in mixed grass ley under daily fertilization and irrigation – Validating the N productivity concept under field conditions. Nutrient Cycling in Agroecosystems (in press).

Dechow R, Franko U, Kätterer T, Kolbe H. 2019. Evaluation of the RothC model as a prognostic tool for the prediction of SOC trends in response to management practices on arable land. Geoderma. 337: 463-478. DOI: 10.1016/j.geoderma.2018.10.001

Meurer KHE, Haddaway NR, Bolinder MA, Kätterer T. 2018. Tillage intensity affects total SOC stocks in boreo-temperate regions only in the topsoil – A systematic review using an ESM approach. Earth-Science Reviews. 177: 613-622. DOI: 10.1016/j.earscirev.2017.12.015

Börjesson G, Bolinder MA, Kirchmann H, Kätterer T. 2018. Organic carbon stocks in topsoil and subsoil in long-term ley and cereal monoculture rotations. Biology and Fertility of Soils. 54: 549-558. DOI: 10.1007/s00374-018-1281-x

Övriga publiceringar (populärvetenskaplig)

Thomas Kätterer. 2019. Porträtt av Lennart Wikström. Jordbrukets förmåga att binda kol är underskattad. Lantbrukets Affärer 4:2019.

Thomas Kätterer, Gunnar Börjesson och Martin Bolinder. 2019. Vallens effekt på markens kolbalans. Svenska Vallbrev. Nr 3. 2019.

Thomas Kätterer. Interviewed by Jens Blomkvist. 2019. Vall och rätt kvävegödsling gör svensk åker till kolsänka. Växtpressen 48(1): 8-11. April 2019

Rune Andersson, Lars Bergström, Martin Bolinder, Holger Kirchmann, Thomas Kätterer. 2019. Dagens svenska lantbruk är bra – men kan bli bättre. Debattartikel i Land Lantbruk 18 mars 2019.

Rune Andersson, Lars Bergström, Martin Bolinder, Holger Kirchmann, Thomas Kätterer. 2019. Viktigt att öka tillförseln av skörderester. Land Lantbruk 10 jan 2019.

Thomas Kätterer, Martin Bolinder, Lars Bergström, Holger Kirchmann, Rune Andersson. 2019. Viktigt att öka tillförseln av skörderester. Debatt i Land Lantbruk 10 jan 2019.

Martin A. Bolinder and Thomas Kätterer. 2018. Management strategies for soil carbon sequestration in cropland evaluated in long-term field experiments in northern Europe. International Conference on Negative CO2 Emissions, 22-24 May 2018, Chalmers University of Technology, Gothenburg. Conference proceedings paper, 12 pp.

Thomas Kätterer, Christopher Poeplau, Gunnar Börjesson, Martin Bolinder. 2017. Markens mullhalt ökar. Arvensis 06/2017, S. 30-31.

Holger Kirchmann, Lars Bergström, Thomas Kätterer, Rune Andersson. 2017. Så skapar vi ett ännu mer hållbart jordbruk. Debattartikel i Land Lantbruk 2 augusti 2017.

Thomas Kätterer, Lars Bergström, Holger Kirchmann, Rune Andersson. 2017. Vem kan man lita på i ekodebatten? GP Debattartikel 29 mars 2017.

Thomas Kätterer, Lars Bergström, Holger Kirchmann, Rune Andersson. 2017. Mycket känsla och lite förnuft i Livsmedelsstrategin. Debattartikel Göteborgsposten 16 mars 2017.

Holger Kirchmann, Lars Bergström, Thomas Kätterer, Rune Andersson. 2017. Ekologisk odling - framtidens lantbruk eller återvändsgränd? SLU faktablad. ISBN: 978-91-576-9468-3 http://pub.epsilon.slu.se/14196/

Craig Drury, Mark Liebig, Denis Angers, Michel Cavigelli, Rene Dechow, Roberta Farina, Rosa Francaviglia, Hero Gollany, Henry Janzen, Thomas Kätterer, Lars Munkholm, Gervasio Piñeiro, Charles Rice, Pier Roggero, Upendra Sainju. 2016. How Conservation Agriculture can mitigate greenhouse gas emissions and enhance soil carbon storage in croplands. Brochure from the Croplands Research Group/ Conservation Agriculture Network, Global Research Alliance on Agricultural Greenhouse Gases, 5 pages: https://globalresearchalliance.org/. https://globalresearchalliance.org/wp-content/uploads/2017/08/Conservation-Agriculture-Network-Brochure.pdf

Holger Kirchmann, Lars Bergström, Thomas Kätterer, Rune Andersson. 2016. Dreams of Organic Farming. - Facts and Myths. Fri Tanke förlag, Stockholm, 179 p. (e-book) ISBN: 9789187935718. Freely available as pdf-file Epsilon

Thomas Kätterer. 2016. Så kan åkermarken fånga mer koldioxid. In: Johansson B., Jonsell L., Prage L., Öbrink G. (Eds.) Jorden vi ärvde – vad gör vi med den? Uppsala Senioruniversitet, Rapport 20: 43-46. ISSN 1650-7207. http://www.usu.se/rapport-nr-20/

Thomas Kätterer, Gunnar Börjesson, Martin Bolinder. 2016. Sälja eller lämna? Arvensis 06-2016: 32-22. www.arvensis.se

Stefan Wirsenius, Elin Röös, Thomas Kätterer, Gustav Strandberg. 2016. Jordbruket måste ta sitt klimatansvar. Debattartikel i Tidningen Land, Lantbruk & Skogsland, 26 mars 2016. http://www.lantbruk.com/debatt/jordbruket-maste-ta-sitt-klimatansvar

Muntlig kommunikation

Thomas Kätterer, invited lecture at the seminar ”Vad vet vi om markkol idag” organiszed by Partnerskap Alnarp, Alnarp 17 June 2019.

Thomas Kätterer, invited lecture ”Kolinlagrin i mark från vallen – vad är det värt?” at Stenhammardagen, organised by SLU and Stenhammar godsförvaltning, Stenhammar 12 juni 2019 (ungefär 100 personer, inklusive Ers Majestät).

Thomas Kätterer, invited lecture ”Kolinlagring i mark och dess betydelse för att balansera jordbrukets klimatpåverkan” at the seminar organised by SLU for ”Gamla Gardets Socialdemokratiska Förening”, Uppsala 20 Maj 2019.

Thomas Kätterer, project presentaiton at the second global network meeting organised by SLU Global, Uppsala 14 May 2019.

Thomas Kätterer, invited lecture ” Mellangröda ger kolinlagring. Hur påverkar den livet i marken?” SLU Fältforsk:s seminarium om mellangrödor, Nässjö Hotell Högland, 2 maj 2019.

Thomas Kätterer, invited to Roundtable Discussion “Carbon Action” organized by “Race For The Baltic” which is an initiative of Zennström Philanthropies, Stockholm, 29 March 2019.

Thomas Kätterer. Invited lecture ”Kolinlagring i jordbruksmark” inom kursen ”Myt och verklighet - bruk och vård av naturen” för 60 jordbrukare, rådgivare och tjänstemen. Saturnus Konferens, Stockholm, 28 mars 2019.

Thomas Kätterer and Martin Bolinder. Invited contribution to workshop “Improving soil carbon reporting for Norwegian cropland”, NIBIO, Ås, Norway 14 Jan 2019.

Thomas Kätterer. Inverview SVT nyheter 10 feb 2019. https://www.svt.se/nyheter/vetenskap/plojningsfritt-jordbruk-en-koldioxidsug

Thomas Kätterer. Invited speaker at the seminar ”Så fångas koldioxid och lagras i marken”, IVA, Stockholm 29 jan 2019. https://www.iva.se/event/sa-fangas-koldioxid-och-lagras-i-marken/

Thomas Kätterer. Interview, P1, 13 Dec. 2018 i Vetenskapsradion. https://sverigesradio.se/sida/avsnitt/1199303?programid=406

Thomas Kätterer, invited lecture. Seminar ”Markanvändningen i vårt jordbruk – vad betyder den för maten och klimatet?”, Kungl. Skogs- och Lantbruksakademien, Drottninggatan 95 B, Stockholm, 5 Dec 2018.

Göran Bergkvist och Thomas Kätterer. Kvävedynamiken i marken. Oral presenteration by Bergkvist. Maltkornsmästar seminariet, Lantmannen, Linköping 20 nov 2018.

Thomas Kätterer. Invited contribution at roundtable discussion organized by SLU Skara “Kor och klimat”, Skara, 16 nov 2018.

Thomas Kätterer, Interview Kolotet, P1. 7 Nov 2018.
https://sverigesradio.se/sida/avsnitt/1178493?programid=3345

Thomas Kätterer. Interview i Vetenskapens Värld, P1, 23 Okt 2018.
https://sverigesradio.se/avsnitt/1169014#

Thomas Kätterer. Interview i Lantmannen. Extremväder skapar plötslig mikrobdöd. Lantmannen 11, 2018.

Thomas Kätterer. Invited lecutre. Kolbalanser och hur de påverkas av odlingsåtgärder. GREPPA Oldingsperspektiv, webinar 12 Oct 2018.

Thomas Kätterer. Rapportering av jordbruksrelaterte LULUCF utslipp i Sverige og pågående utviklingsprojekt. Invited lecture. Teknisk beregningsutvalg for klimagassutslipp i jordbruket, Det Kongelige Landbruks- og Matdepartement, Oslo, 11 Sept 2018.

Martin A. Bolinder. Interview in Syre, 10 Aug 2018.

Thomas Kätterer. Nationell forskning om kolinlagring i mark. Invited presentation at the KSLA seminar ”Så kan åkermark bidra till att fånga in mer koldioxid” Kungl. Skogs- och Lantbruksakademien, Drottninggatan 95 B, Stockholm, 27 april 2018.

Slu-news 7 Feb 2018. Jordbearbetningens betydelse för klimatet är överskattad.

Martin A. Bolinder. Interview i Vetenskapsradions Veckomagasin, P1, ”Jordbearbetningens betydelse för klimatet är överskattad”, 9 Feb 2018.

Thomas Kätterer. Så kan åkermarken fånga mer koldioxid. Invited lecture at Nordic Agro Summit http://nordicagrosummit.com/, Malmömässan, Malmö 7-8 Feb. 2018.

Thomas Kätterer. Interview in Expressen 3 Nov 2017.

Thomas Kätterer. Interview in Aftonbladet 25 Oct 2017.

Thomas Kätterer. Interview with http://fjardeuppgiften.se published on YouTube 20 June 2017.
https://youtu.be/VmwhhObYW_U

Thomas Kätterer. Odlingsåtgärder för att binda in kol i marken och hur dessa är implementerade i ICBM-modellen (Introductory Carbon Balance Model). Invited talk at Klimaseminar – Nordisk Ministerråd (Nordic Council of Ministers), Ålesund, Norway 27 June 2017.

Thomas Kätterer. 2017. Odlingssystemens effekt på mullförråd och kolinlagring i jordbruksmarken. Inbjuden föredrag inom 2-dagars utbildning för klimatrådgivare inom Greppa Näringen. Skövde, 19 januari 2017.

Thomas Kätterer. Management options for soil carbon sequestration in Nordic agroecosystems. Invited keynote, Climate policy and land use seminar, European Parliament, Brussels, 10 Jan 2017.

Thomas Kätterer. Invited lecture " Kan vi lagra mer kol i marken?" Future Agriculture Conference, Norra Latin, 26 October 2016.

Thomas Kätterer. Jordbruksmarken som kolkälla eller kolsänka. Invited lecture at Senioruniversitetet Uppsala 13 October 2016.

Thomas Kätterer. Odlingsåtgärder som leder till kolinlagring i marken. Oral presentation at a seminar organized by SLU and Greppa Näringen, 10 feb 2016 in Alnarp, attended mainly by farmers and representatives from farmer organizations (38 persons and an unknown number of people through video-link).

Studentarbeten

Lina Wu. 2018. Carbon sequestration in topsoil for forage-based cropping systems – an analysis of Swedish long-term experiments and SOC modelling. Agriculture Programme – Soil and Plant Sciences, Master's thesis, Uppsala 2018. Independent Project/Degree Project/SLU, Department of Ecology 2018:18. Online publication: http://stud.epsilon.slu.se

Olle Åkesson. 2017. Tea time for soils – decomposition experiments in Swedish long-term field trials. Agriculture Programme – Soil and Plant Sciences, Master's thesis, Uppsala 2017. Independent Project/Degree Project/SLU, Department of Ecology 2017:4. Online publication: http://stud.epsilon.slu.se

Övrigt (konferenser & workshops)

Meurer, K.H.E., Haddaway, N.R., Bolinder, M.A., Kätterer, T. Tillage intensity affects SOC stocks in boreo-temperate regions only in the topsoil. Oral presentation by Katharina H.E. Meurer at the ISTRO Conference, Paris, France, 24-27 September 2018.

Thomas Kätterer. Strategies for soil carbon sequestration in cropland evaluated in long-term field experiments. Keynote at the international symposium “Soil organic matter management in agriculture”, 29-30 May 2018, Thünen Institute, Braunschweig Germany.

Meurer, K.H.E., Haddaway, N.R., Bolinder, M.A., Kätterer, T. To till, or not to till – still an open question. Oral presentation by Katharina, H.E. Meurer at the BECC Science Seminar, Models and theoretical frameworks, Göteborg, Sweden, 29 May 2018.

Thomas Kätterer and Martin A. Bolinder. Management strategies for soil carbon sequestration in cropland evaluated in long-term field experiments in northern Europe. Oral presentation by Kätterer at the International Conference on Negative CO2 Emissions, 22-24 May 2018, Chalmers University of Technology, Gothenburg.

Thomas Kätterer. Systematic map and reviews of farming practices (e.g. tillage) affecting soil organic carbon. Invitet lecture at the East African experts workshop on soil carbon sequestration, ICIPE, Nairobi, 17-18 April 2018.

Taru Sandén, Martin Bolinder, Thomas Kätterer, Andreas Surböck, Jürgen Kurt Friedel, Andreas Baumgarten, Heide Spiegel. TeaTime4Long-Term Experiments: Investigating litter decomposition and stabilization affected by different improved agricultural management practices in Austria and Sweden. Oral presentation by Taru Sandén at the 6th International Symposium on Soil Organic Matter at Rothamsted Research in Harpenden, UK, 3-7 September 2017.

Meurer, K.H.E., Haddaway, N.R., Bolinder, M.A., Kätterer, T. To till, or not to till – still an open question. Oral presentation by Katharina H.E. Meurer at the 6th International Symposium on Soil Organic Matter at Rothamsted Research in Harpenden, UK, 3–7 Septemer 2017.

Meurer, K.H.E., Ghafoor, A., Haddaway, N.R., Bolinder, M.A., Kätterer, T. To till, or not to till – still an open question. Poster presented at EGU General Assembly, Vienna, 23-24 April 2017.

Bolinder, M.A., Åkesson, O., Kätterer, T. Sensitivity of the TBI to management practices in Scandinavian agro-ecosystems assessed within long-term field experiments. Poster presented at TBI workshop, Vienna, 1 March 2017.

Christopher Poeplau, Anke Herrmann, Thomas Kätterer. Effects of macro-nutrients on microbial metabolism drive soil organic carbon cycling. Oral presentation by Poeplau at the international workshop “SOMmic – Microbial Contribution and Impact on Soil Organic Matter, Structure and Genesis“. Leipzig, Germany, November 9-11, 2016.

Neal Haddaway, Katarina Hedlund, Louise E. Jackson, Emanuele Lugato, Ingrid Thomsen, Helena Bracht Jorgensen, Per-Erik Isberg, Thomas Kätterer. A Map and Reviews of Knowledge on Farming Practices Affecting Soil Organic Carbon. Oral presentation 100611 by Kätterer at the ASA, CSSA and SSSA International Annual Meeting in Phoenix AZ 6-9 Nov. 2016.

Thomas Kätterer. 2016. Integrated production of food and bioenergy on arable land – impacts on soil carbon sequestration. Oral presentation at network meeting "Effects of bioenergy production from forests and agriculture on ecosystem services in Nordic and Baltic landscapes", Jeløya, 4-5 April 2016.