POSITION PAPER

Soil organic carbon certificates – potential and limitations for private and public climate action

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1 Description of problem

Climate-smart use of soils for arable crop production encompasses all efforts leading to adaptation to climate change and to mitigation of greenhouse gas (GHG) emissions from soils and land use. Increasing soil organic carbon (SOC) using agricultural measures, as reviewed by Merante et al. (2017) and Wiesmeier et al. (2020), is regarded as a negative emission technology (Lal, 2019; Smith, 2016; 4 per Mille, 2020). It is also relevant for ensuring sustainable soil fertility and for saving mineral N-fertilisers and related emissions. Thus, upcoming benchmarking systems, such as 'C-footprint' and 'C-neutral production', of arable products (Stoessel et al., 2012), for farms and businesses are gaining interest as part of agro-ecological concepts (Saj and Torquebiau, 2018). A number of initiatives were developed world-wide in recent years (CarboCert, 2020; Carbon Farmers of Australia, 2020; ÖkoregionKaindorf, 2020; Zero Foodprint, 2020; Wesseler, 2020) acting as agencies for private and, so far, regional trade in SOC-certificates sold on the private market for offsetting individual or business GHG-emissions. However, questions remain about their consideration in country-level GHG-accounting in relation to mitigation targets. Governments are obliged to report SOC-changes within the sector 'Land Use and Land Use Change' (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and the European Union (EU) climate change mitigation policy (European Parliament and the Council of the European Union, 2018[5]). Moreover, all emissions (CO_2-C losses from C-sinks) and removals (increases in C-sinks) in arable land, grassland and forestry count towards the 'no-debit' target of the LULUCF-Regulation from 2021 onwards (i.e. no increase in GHG-net-emissions, including C-removals in the LULUCF sector). In their national reporting duties, many countries claim that the SOC-stock in arable soils is stable. National soil monitoring programmes, e.g. 'National Soil Inventory' (Thünen Institute 2020a, 2020b) in Germany, are improving current methodologies by replacing stable SOC-stocks assumptions with values measured at regular intervals and/or estimated by dynamic modelling.

Farmers play an important part in reducing GHG-emissions from the agriculture and LULUCF sectors.

Recently, in a German publication, Wiesmeier et al. (2020) proposed minimum sampling schemes and analytical standards to evaluate long term SOC changes and discussed opportunities and challenges arising from possible measures to increase SOC. Further, the authors elaborated

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on general limits of SOC-related CO_2-certificates for climate protection (e.g. leakage effects, spill-over effects, reversibility, and translocation). However, they also commented on the positive role of CO_2-initiatives and of payments to support farmers' initial activities. Thamo and Pannell (2016) also assessed permanence, additionality and leakage as crucial areas of uncertainty and were sceptical about the success of long-lasting policy design to promote SOC-sequestration.

With this paper we pursue this discussion by further evaluation of practical limits for proper SOC-reporting and accounting. We examine the potential for sensible positioning of SOC-initiatives in national GHG-accounting.

2 General challenges with soil organic carbon certificates

Key challenges with a trade in SOC-based private certificates arise from the natural realities of SOC-storage and its detectability, leakage effects and other limitations.

One important challenge is the 'reversibility' of SOC-storage. The dynamics of SOC-sequestration are well understood (see e.g. Minasny et al., 2017; Smith, 2004). The sequestration of SOC follows a simplified 'slow in–fast out' pattern (e.g. Poeplau et al., 2011), meaning that SOC-increase takes time and that measures need to be applied continuously. Otherwise, the C accumulated will be lost and emitted as CO_2 and the long-term net GHG-mitigation effect will be zero. Moreover, the quality of SOC is important, since SOC-compounds that are labile to microbial mineralization are more prone to loss than stabile SOC-compounds (von Lützow et al., 2006). Certification schemes thus need to establish a soil management system for reaching and maintaining a new SOC-equilibrium, i.e. new steady state of C-input and CO_2-C loss (e.g. Kell, 2012) over a long time through continued improved soil management, including the period after increase when no new certificate (no further SOC-increase) is generated. On a field scale, this requires measures that can be monitored over time. Promising measures, such as long-lasting changes in crop rotations (e.g. integration of multiannual green-forage crops, cover crops, deep-rooting crops), require know-how transfer, social support (Demenois et al., 2020) and moderate monetary investments depending on regional circumstances (e.g. Pellerin et al. (2017) reported a mean cost of 38 Euro ha^{-1} yr^{-1} for cover crop cultivation in France). Measures on landscape scale which establish permanent and protected ecosystems (hedgerows, grassland) or permanent land-use types (e.g. fibre-woods, berries, nuts, paludiculture) are still reversible but not as easily as agronomic measures. Thus, such landscape measures are more reliable for long-term 'C-sequestration' (not restricted on SOC). In the 'Carbon Farmers of Australia' (2020) SOC-scheme, these landscape measures are listed as further options for C-certificates. Hedgerows and permanent grassland have positive effects for the entire ecosystem (protection against erosion, increased biodiversity, varied landscape), but may compete with crops for water and nutrients (Sudmeyer et al., 2012) or cause leakage effects (see below) which need to be considered. However, in contrast to field-scale measures, landscape-scale measures can be better monitored and controlled to ensure a long-term implementation. However, such fundamental changes in land-use bring a change in products harvested and would need large financial incentives, at least initially.

A problematic issue for proper and justifiable certification of SOC-stock changes is the 'difficulty in detectability': A change in SOC needs time to reach a level that can be detected by current soil sampling and laboratory protocols. There are high expectations for new sensor-based technologies, including small-scale sensors and remote sensing. So far, these provide higher resolution, but are not sensitive enough to detect changes in SOC-stocks (Stevens and van Wesemael, 2008; Stevens et al., 2008). Moreover, these methods have higher uncertainties, which can prolong the period until significant SOC-stock changes can be detected. Soil sampling and analysis should be conducted by well-trained personnel and using standardised protocols concerning replicates per field, depth and time of sampling. These requirements all add to high costs. To protect farmers from the case that SOC-increases are not detected and, thus, 'SOC-duties' arise, contracts between farmers and providers of SOC-certificates should extend over long time-scales, e.g. 20 years. This would also increase the duration of measures, which is needed to ensure SOC-increase and GHG-mitigation effects. Since the effect of a measure on SOC is neither guaranteed nor verifiable in advance, we question the fairness of the current practice of issuing SOC-certificates in advance of real and detectable effects.

A SOC-change detectable within five years, a period often used in current SOC-certification schemes, can only be achieved by extremely high C-inputs from external sources (Blanco-Canqui and Lal, 2007; Maillard and Angers, 2014). German croplands have an average SOC-stock of 60 Mg ha^{-1} in the top 30 cm and an average SOC-content of 1.5 % (Jacobs et al., 2018). As a theoretical example, this means that an increase of 0.1 % SOC, which is the minimum needed to detect any changes on accounting for small-scale variability and uncertainty of analysis, needs raising the SOC-stock by 4 Mg ha^{-1}. Retention coefficient (proportion of added C retained as SOC in Mg Mg^{-1}) for straw and farmyard manure is usually found to reach a maximum of 0.15 and 0.3, respectively (e.g. Kätterer et al., 2011). Thus, the SOC-increase of 0.1 percentage points requires an average per-hectare addition of 27 Mg straw-C (60 Mg straw dry mass) or 12 Mg farmyard manure-C (133 Mg fresh farmyard manure). The SOC-certification scheme of ÖkoregionKaindorf (2020) defines 'success' as an increase of the SOC-content by 0.3 percentage points within five years. This can certainly be reached only by extremely high amounts of C-input concentrated on a small area.

The above is one example of the 'dilemma of translocation and dilemma of leakage'. If the application of transportable SOC-sources, e.g. farmyard manure or compost, is concentrated on selected fields, a net GHG-mitigation effect will not be achieved, since SOC-inputs will be suspended in other fields because the overall amount of organic fertilisers available will not increase. Using internal, farm-own, organic fertilisers to stabilise SOC is obviously appropriate and part of good agricultural practice. However, over-application using translocated external sources to reach certification goals is inappropriate and needs to be excluded from SOC-certification schemes. Moreover, measures to increase SOC may have negative side-effects, e.g. nitrogen leaching, increased nitrous oxide emissions, or a shift of GHG-emissions to other sources (e.g. when expansion of grassland is followed by an increase in number of ruminants and related emissions). Such side-effects should be prevented by stringent planning and documentation of measures to increase SOC through ex-ante impact assessments. They should at least be taken into account in quantification of GHG-mitigation (e.g. MoorFutures, 2020).

3 Soil organic carbon certificates and national greenhouse gas accounting

Private SOC-initiatives seek to generate market revenues by selling SOC-certificates as CO_2-certificates on the voluntary C-market, serving businesses and individuals in offsetting GHG-emissions. Voluntary C-certificates are not valid as offsets within the EU Emissions Trading System. Under most voluntary C-market standards (e.g. Gold Standard, 2020), SOC-certificates must comply with the quality requirement for 'environmental integrity'. This means that offsets have to be real, not double-counted, and must be additional compared with a projection without the offsetting activity (Gold Standard, 2020; Kollmuss et al., 2008; Ministère de la Transition Écologique et Solidaire, 2020). In particular, voluntary C-certificates must be additional to GHG-mitigation activities and targets set by government (Valatin, 2012). Under the Paris Agreement, the aspect of 'additionality' is more challenging than under the Kyoto protocol, as the Paris Agreement has global coverage and its ambition is to introduce global net-zero targets (United Nations 1998, 2015). Thus, the interrelations between private SOC-certificates, state policies and national GHG-mitigation targets need clarification, especially concerning the following four major dilemmas.

The 'dilemma of additionality' can be split into two aspects:

(a) 'Double-claiming of GHG-mitigation effects': The LULUCF-regulation requires member states to improve their GHG-emissions reporting, e.g. by measuring SOC-stocks regularly. Thus, relevant SOC-increases and losses, including those on fields under a private SOC-certification scheme, are reported in national GHG-inventories. As long as there is no mechanism for distinguishing between the effects of private and policy-induced activities, the national government will claim the GHG-mitigation as a contribution to national targets and private SOC-certificates will not make any additional contribution.

(b) 'Double-regulating and double-funding': Activities already included in good agricultural practice or supported by the EU's Common Agricultural Policy (CAP), e.g. catch crop cultivation, are not additional. Thus, the additional benefit of GHG-mitigation needs to be discussed thoroughly and stated in SOC-certification schemes (e.g. special cover crops not funded under the CAP).

The 'dilemma of lacking net GHG-mitigation effects': Assuming that the amount of organic fertilisers available today, e.g. compost from biowaste, does not increase and is used according to 'good agricultural practice', only organic fertilisers produced from additional biomass would provide additional GHG-mitigation. Otherwise, the overall amount of organic fertilisers will not increase but will simply be translocated. To cope with this dilemma, SOC-certification schemes need to achieve net-effects by excluding 'translocation and leakage' effects (see above).

The 'dilemma of reporting': Fields or areas participating in a SOC-certification scheme need to be integrated into existing harmonised, intensive and reliable national soil monitoring to cope with the 'difficulty in detectability'. Alternative methods for soil monitoring and GHG-reporting need to cover many details (e.g. management data for each field and information on the kind of certification scheme), resulting in high costs (e.g. setting-up the database for the SOC-scheme ÖkoregionKaindorf needed about 300,000 Euro (Forstner, 2019); see also above).

The 'dilemma of non-permanence and reversibility': When a soil or field is under a SOC-certification contract and SOC is lost some years later for some reason, the contract needs to stipulate beforehand which party will be accountable and bear the loss of investment costs. This makes SOC-certificates less reliable in the long-run than certificates based on yearly emission reductions (e.g. elevated groundwater level in organic soils).

4 Conclusions

All activities resulting in increases in SOC in agricultural soils must be encouraged, as there is global potential for additional CO_2-C-sequestration in soils. Moreover, maintenance of SOC has positive effects on soil fertility, as it improves biodiversity, water-holding capacity, plant nutrition, erosion control, soil structure stability, and yield stability. Sustainable SOC-management is becoming increasingly important especially in a context of climate change, since SOC-rich soils are more resilient to e.g. heavy rainfalls or drought periods. The pioneering spirit of SOC-certificate activities initiated world-wide can be of high value for the overall goal of fostering climate-smart agriculture and improving soil fertility. As long as SOC-certificates are not state-funded, farmers are free to 'sell' their achievements and to engage within local initiatives as part of their business operations.

The SOC-certificates could be kept exclusively as private sector initiatives and denoted 'Verified Emission Reductions for Voluntary Climate Action', which would require a more flexible interpretation of additionality. This would be in-line with similar initiatives, such as MoorFutures (2020), which are used for offsetting GHG-emissions of individuals, organisations or businesses according within corporate social responsibility schemes or similar. However, private SOC-initiatives might aim to expand to a broader scale, e.g. CO_2-compensation of flights or of large companies. To cope with this, the EU and its member states would need a policy decision on new mechanisms defining the relation between GHG-mitigation outcomes from private SOC-certification and national GHG-targets and accounting. Regarding the additionality of private SOC-certificates under the Paris Agreement, we recommend establishment of a new approach whereby countries, businesses and citizens take joint responsibility for national GHG-mitigation targets and welcome pioneering new activities.

Overall, our view is that separating private SOC-certificates properly from national GHG-reporting and accounting towards mitigation targets is very difficult. We advise governments not to interfere or provide financial support for private initiatives, but closely monitor their success and the ideas emerging. Governments could thereby identify opportunities for funding and establishing infrastructures for SOC-analysis and a SOC-audit scheme used by farmers and advisory services supporting 'C-neutral farming', or for building-up a network of farms to enhance communication and training on SOC-increasing activities.

REFERENCES

Blanco-Canqui H, Lal R (2007) Soil structure and organic carbon relationships following 10 years of wheat straw management in no-till. Soil Till Res 95(1–2):240–254, doi:10.1016/j.still.2007.01.004

CarboCert (2020) [online]. Retrieved from <https://www.carbocert.de/> [at 23 March 2020]

Carbon Farmers of Australia (2020) [online]. Retrieved from <https://carbonfarmersofaustralia.com.au/> [at 26 March 2020]

Demenois J, Torquebiau E, Arnoult MH, Eglin T, Masse D, Assouma MH, Blanfort V, Chenu C, Chapuis-Lardy L, Medoc J-M, Sall SN (2020) Barriers and strategies to boost soil carbon sequestration in agriculture. Front Sustain Food Syst 4:37, doi:10.3389/fsufs.2020.00037

European Parliament and the Council of the European Union (2018) Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU [online]. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0841-&from=EN> [at 23 March 2020]

Forstner S (2019) Humusaufbau und Zertifikathandel am Beispiel der Ökoregion Kaindorf [online]. Retrieved from <https://www.3-n.info/media/4_Downloads/pdf_NwsTrmn_3NVrnstltng_CarbonFarming_Hannover_Forstner.pdf> [at 10 July 2020]

Gold Standard (2020) [online]. Retrieved from <https://www.goldstandard.org/impact-quantification/certified-sdg-impacts> [at 26 March 2020]

Jacobs A, Flessa H, Don A, Heidkamp A, Prietz R, Dechow R, Gensior A, Poeplau C, Riggers C, Schneider F, Tiemeyer B, et al. (2018) Landwirtschaftlich genutzte Böden in Deutschland – Ergebnisse der Bodenzustandserhebung. Braunschweig: Johann Heinrich von Thünen-Institut, 316 p, Thünen Rep 64, doi:10.3220/REP1542818391000

Kätterer T, Bolinder MA, Andrén O, Kirchmann H, Menichetti L (2011) Roots contribute more to refractory soil organic matter than above-ground crop residues, as revealed by a long-term field experiment. Agric Ecosyst Environ 141(1–2):184–192, doi:10.1016/j.agee.2011.02.029

Kell DB (2012) Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: why and how. Philos Trans R Soc Lond B Biol Sci 367(1595):1589–1597, doi:10.1098/rstb.2011.0244

Kollmuss A, Zink H, Polycarp C (2008) Making sense of the voluntary carbon market. A comparison of carbon offset standards [online]. Retrieved from <http://mobil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/A_Comparison_of_Carbon_Offset_Standards_lang.pdf> [at 31 March 2020]

Lal R (2019) Conceptual basis of managing soil carbon: Inspired by nature and driven by science. J Soil Water Conserv 74(2):29A–34A, doi:10.2489/jswc.74.2.29A

Maillard É, Angers DA (2014) Animal manure application and soil organic carbon stocks: a meta-analysis. Glob Change Biol 20(2):666–679, doi:10.1111/gcb.12438

Merante P, Dibari C, Ferrise R, Sánchez B, Iglesias A, Lesschen JP, Kuikman P, Yeluripati J, Smith P, Bindi M (2017) Adopting soil organic carbon management practices in soils of varying quality: Implications and perspectives in Europe. Soil Till Res 165:95–106, doi:10.1016/j.still.2016.08.001

Minasny B, Malone BP, McBratney AB, Angers DA, Arrouays D, Chambers A, Chaplot V, Chen Z-S, Cheng K, Das BS, Field DJ, et al. (2017) Soil carbon 4 per mille. Geoderma 292:59–86, doi:10.1016/j.geoderma.2017.01.002

Ministère de la Transition Ècologique et Solidaire (2020) Label bas-carbone: récompenser les acteurs de la lutte contre le changement climatique [online]. Retrieved from <https://www.ecologique-solidaire.gouv.fr/label-bas-carbone> [at 30 June 2020]

MoorFutures (2020) [online]. Retrieved from <https://www.moorfutures.de/> [at 26 March 2020]

ÖkoregionKaindorf (2020) [online]. Retrieved from <https://www.oekoregion-kaindorf.at/> [at 23 March 2020]

Pellerin S, Bamière L, Angers D, Béline F, Benoit M, Butault JP, Chenu C, Colnenne-David C, De Cara S, Delame N, Doreau M, et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Environ Sci Policy 77:130–139, doi:10.1016/j.envsci.2017.08.003

Poeplau C, Don A, Vesterdal L, Leifeld J, Van Wesemael B, Schumacher J, Gensior A (2011) Temporal dynamics of soil organic carbon after land-use change in the temperate zone – carbon response functions as a model approach. Glob Change Biol 17(7):2415–2427, doi:10.1111/j.1365-2486.2011.02408.x

Saj S, Torquebiau E (2018) Climate-smart agriculture, agroecology and soil carbon: towards winning combinations. Montpellier:Cirad. Perspective 47:1–4, doi:10.19182/agritrop/00034

Smith P (2004) Carbon sequestration in croplands: the potential in Europe and the global context. Eur J Agron 20(3):229–236, doi:10.1016/j.eja.2003.08.002

Smith P (2016) Soil carbon sequestration and biochar as negative emission technologies. Glob Change Biol 22(3):1315–1324, doi:10.1111/gcb.13178

Stevens A, van Wesemael B (2008) Soil organic carbon dynamics at the regional scale as influenced by land use history: a case study in forest soils from southern Belgium. Soil Use Manage 24(1):69–79, doi:10.1111/j.1475-2743.2007.00135.x

Stevens A, van Wesemael B, Bartholomeus H, Rosillon D, Tychon B, Ben-Dor E (2008) Laboratory, field and airborne spectroscopy for monitoring organic carbon content in agricultural soils. Geoderma 144(1–2):395–404, doi:10.1016/j.geoderma.2007.12.009

Stoessel F, Juraske R, Pfister S, Hellweg S (2012) Life cycle inventory and carbon and water foodprint of fruits and vegetables: application to a swiss retailer. Environ Sci Techol 46(6):3253–3262, doi:10.1021/es2030577

Sudmeyer RA, Daniels T, Jones H, Huxtable D (2012) The extent and cost of mallee–crop competition in unharvested carbon sequestration and harvested mallee biomass agroforestry systems. Crop Pasture Sci 63(6):-555–569, doi:10.1071/CP12129

Thamo T, Pannell DJ (2016) Challenges in developing effective policy for soil carbon sequestration: perspectives on additionality, leakage, and permanence. Clim Policy 16(8):973–992, doi:10.1080/14693062.2015.1075372

Thünen Institute (2020a) [online] Retrieved from <https://www.thuenen.de/en/wo/projects/soil-protection-and-forest-health/projekte-bodenzustandserhebung/national-forest-soil-inventory-in-germany-data-quality-and-data-management/> [at 20 Nov 2020]

Thünen Institute (2020b) [online] Retrieved from <https://www.thuenen.de/en/ak/projects/agricultural-soil-inventory-bze-lw/> [at 20 Nov 2020]

United Nations (1998) Kyoto protocol to the United Nations framework convention on climate change [online]. Retrieved from <https://unfccc.int/resource/docs/convkp/kpeng.pdf> [at 03 Apr 2020]

United Nations (2015) Paris agreement [online]. Retrieved from <https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf> [at 03 Apr 2020]

Valatin G (2012) Additionality and climate change mitigation by the UK forest sector. Forestry J For Res 85(4):445–462, doi:10.1093/forestry/cps056

von Lützow M, Kogel-Knabner I, Ekschmitt K, Matzner E, Guggenberger G, Marschner B, Flessa H (2006) Stabilization of organic matter in temperate

soils: mechanisms and their relevance under different soil conditions – a review. Eur J Soil Sci 57(4):426–445, doi:10.1111/j.1365-2389.2006.00809.x
Wesseler S (2020) Startups aim to pay farmers to bury carbon pollution in soil [online]. Retrieved from <https://www.yaleclimateconnections.org/2020/01/startups-aim-to-pay-farmers-to-bury-carbon-pollution-in-soil/> [at 23 March 2020]
Wiesmeier M, Mayer S, Paul C, Helming K, Don A, Franko U, Steffens M, Kögel-Knabner I (2020) CO_2-Zertifikate für die Festlegung atmosphärischen Kohlenstoffs in Böden: Methoden, Maßnahmen und Grenzen. BonaRes Series 2020/1, doi:10.20387/BonaRes-F8T8-XZ4H
Zero Foodprint (2020) [online, formerly the Perennial Farming Initiative] Retrieved from <https://www.zerofoodprint.org/about> [at 4 Nov 2020]
4 per Mille (2020). Welcome to the "4per1000" initiative [online]. Retrieved from <https://www.4p1000.org/> [at 30 June 2020]