BIKE BIOFUELS PRODUCTION AT LOW - ILUC RISK FOR EUROPEAN SUSTAINABLE BIOECONOMY

BIKE is a Horizon 2020 project whose objective is to support uptake of the low ILUC-risk concept for biofuel feedstocks. This series of Briefing Notes seeks to explore issues in the EU policy sphere which may impact low ILUC-risk value chains, and identify opportunities for fostering an enabling policy environment.

Soil sampling and soil organic carbon across agricultural landscapes

BIKE pilot site in Northern Greece.

Soil organic carbon (SOC) is a key indicator of soil health and agricultural productivity; optimising carbon uptake by soils through careful agricultural management also represents a significant opportunity for greenhouse gas mitigation[i]. SOC can be estimated by soil sampling and by models which have been validated against experimental data. However, SOC dynamics are sensitive to several factors, such as climate, vegetation, soil type, and the kinds of agricultural practices undertaken; consequently, the outcomes of on-farm interventions can be highly variable and difficult to predict. Moreover, spatial and temporal variability at the field scale also introduce complexities in measuring carbon stocks, especially in the short-term: it is only over long periods of consistent agricultural practices that signals can be reliably discerned from the noise.

EU policy initiatives have sought to overcome these hurdles, in order to promote agricultural practices identified as effective in building soil carbon and to reward farmers for demonstrating improved soil carbon performance (see the policy discussion in BIKE Briefing Notes #7 and #8[ii]). In this Briefing Note, we introduce soil sampling methods, and tools for modelling SOC over time and across landscapes. We highlight some limitations of EU policy protocols for monitoring and crediting SOC, and provide recommendations to make these protocols fairer and more robust. These changes are intended to incentivise more farmers to adopt climate-friendly land management practices.

SOC estimation and measurement

Recent years have witnessed local, national and global efforts to quantify stocks of carbon in soils, as well as the potential for soil carbon sequestration to offset greenhouse gas emissions in other sectors of the economy. Such efforts must distinguish between 'ephemeral' and 'lingering' soil carbon, as only the latter is a suitable multi-decadal carbon sink. SOC levels can be estimated via analysis of physical samples, remote sensing (both on- and off-field), modelling of soil dynamics, or a hybrid of all three[iii]; we consider these in turn.

Conventional soil measurements require in-situ collection and laboratory testing of soil samples (normally a few milligrams): this gives an accurate snapshot of SOC and other soil properties at the location and soil depth in question; but it can be time-consuming and expensive. Recent development of on-field and aerial/satellite sensing devices using spectroscopic techniques has allowed for rapid measurements, more cheaply and at scale[iv,v]. However, these new technologies are at present not considered adequate to give reliable results for long-term carbon stocks[vi] – in large part because they only probe the soil surface. Since this topsoil matter is more readily available for decomposition, its 'ephemeral' carbon is susceptible to rapid re-emission if conditions or management practices change. Subsoil (below 30 cm) on the other hand has a greater amount of stable 'lingering' carbon. The fact that remote sensing cannot penetrate to this layer has not prevented some carbon offsets companies from adopting remote sensing solutions for soil carbon assessment.

Soil survey campaigns

To build a fuller picture of the soil properties and SOC in a given area, a sampling strategy must be implemented. The design of the strategy will depend on the objectives of the project at hand: some surveys aim to minimise sampling costs; others aim to provide high three-dimensional resolution by sampling a number of soil depths; others prioritise spatial coverage of the target field, while taking into account environmental factors and soil properties known to influence SOC stocks.

At the EU scale, the LUCAS (Land Use and Coverage Area Frame Survey) project is the most extensive sampling effort to date, and has created a consistent dataset of soil properties across Europe[vii]. These include physical bulk properties such as moisture, density, structure, and soil particle size distribution; chemical properties such as organic / inorganic carbon content and concentration of nutrients; electro-chemical properties such as cation exchange capacity; and biodiversity at the macro and micro scales. LUCAS sampling focusses predominantly on topsoil (0-30 cm), with limited to no samples from the subsoil.

Soil modelling

Recent decades have seen the development of soil modelling tools for research and decision-making. These models rely on existing high-resolution databases of SOC measurements, which form the basis for extrapolation over larger areas. The literature now boasts a variety of modelling frameworks with different domains of applicability in terms of geographical coverage, SOC pools, soil depth increments, soil types, and land management practices.

Soil models can further be classed as mechanistic or statistical, depending on whether they are built upon a scientific understanding of soil dynamics, or use machine-learning methods to infer relationships within large datasets of soil measurements. These operate at a number of scales – from integrated global models used to inform carbon inventories and climate impacts (e.g. from the IPCC[viii]), to higher-resolution models more sensitive to local conditions, which can account for management changes at the field scale (e.g. CENTURY, RothC, DAISY).

Models can be used to predict future trends, to establish counterfactual baselines (e.g., for estimating the impact of new management techniques), and to fill measurement gaps in time-series data. It is critical, however, that model estimates are systematically validated against direct measurements, because accuracy is known to deteriorate rapidly as the scope of investigation deviates from the training dataset.

Soil sampling in RED II

The European Commission has established a protocol for soil sampling under RED II in its Implementing Regulation for voluntary certification schemes[ix]. Biofuel feedstock producers may use this protocol to demonstrate soil carbon accumulation in their fields, so that reduced life-cycle emissions can be claimed for the final fuel product via the 'e_{sca}' term. This term is calculated from an estimate of soil carbon accumulation after at least ten years of consistent management practices, averaged over the period of cultivation. The RED rules do not include any assessment of the stability of soil carbon stocks at the end of this period: this suggests that the Commission both regards ten years as being sufficient time for significant soil carbon changes to manifest, and assumes that at least some of this carbon will remain sequestered even after the project period has elapsed and agricultural management practices are allowed to change.

The RED II Implementing Regulation protocol requires an initial 'baseline' soil measurement, followed by repeat measurements at least every five years; in the intervening periods, models approved by the voluntary certification schemes may be used to predict the SOC accumulation for a given project. These models must be re-calibrated to align with field measurements as they become available.

The regulation thus attempts to find a balance between the use of models and measurements that gives a degree of confidence about the claimed e_{sca} credits while moderating the burden on operators. The level of sampling required is less than would normally be considered adequate for research work, but still enough that some operators have expressed concerns about the cost. Whether this balance between model-based and measurement-based estimation offers sufficient accuracy is open to discussion, and the level of uncertainty on reported e_{sca} values will depend on the details of the project and the model in question. The Implementing Regulation does offer a safeguard in case measurements suggest systematic over- or under-estimation of modelled e_{sca} over the previous five years, as the e_{sca} credit in subsequent years must be adjusted (either debited or credited) to make up for any discrepancy.

Farmers and economic operators seeking to claim e_{sca} must comply with the Implementing Regulation's sampling requirements. The Implementing Regulation stipulates that[x]:

> *"a sample of 15 well distributed sub-samples per every 5 hectares or per field, whichever is smaller (taking into account the heterogeneity of the plot's carbon content), shall be taken."*

The regulation further states that samples are to be taken from the top 30 cm of soil, and include measurements of bulk density as well as SOC. Since SOC levels in this soil layer are known to be dynamic, the above-quoted requirement to "take into account the heterogeneity of the plot's carbon content" is welcome. It would be useful for implementation if the text were augmented with Commission-approved principles or indicative thresholds for assessing heterogeneity, as well as guidance on how to adapt the sampling strategy in response to high/low heterogeneity (at present this is left to the discretion of whoever is authorised to take the samples)[xi]. The Commission could consider whether leeway could be given to certification bodies to allow reduced sampling requirements in certain specific cases – for example where low heterogeneity is demonstrated through an initial pre-sample.

The associated benefits and costs of changing agricultural practices and claiming e_{sca} must be assessed on a case-by-case basis. There is, nevertheless, an opportunity for more systematic study to identify more generally the kinds of projects for which e_{sca} would make it worthwhile for operators to implement soil carbon measurement.

Biochar as a soil amendment

Incorporating biochar into (sub-surface) soils is attractive from both agricultural and climate perspectives: on the one hand it improves soil health, water retention, and structure; on the other, it offers a relatively stable store of carbon. Moreover, under favourable circumstances (and over the span of many years), biochar can create an indirect 'multiplier effect' by enhancing biological and biochemical processes which build soil carbon stores far beyond the initial biochar application[xii].

The SOC impact of a biochar amendment can thus be thought of as the sum of two time-dependent contributions: (i) the amount of 'recalcitrant' (lingering) biochar carbon that will remain in the fields (as opposed to its 'labile' (ephemeral) carbon component that quickly re-enters the carbon cycle); and (ii) the pedogenic carbon that builds in the soil matrix as a result of the 'multiplier effect'. To varying degrees, these are both sensitive to the type of biochar applied (meaning its feedstock- and process-dependent physical and chemical characteristics, which can be well characterised in the lab before it is applied to the field). They are also sensitive to field characteristics such as the initial soil SOC, pH, the local climate, and land management practices. But they differ in the immediacy of the SOC impact: recalcitrant carbon is present in the soil from the moment of biochar addition, whereas pedogenic carbon may take six to ten years to reliably manifest in measurements[xiii].

From the regulatory perspective, the European Commission developed a methodology for determining the accumulation of soil carbon which results from improved management practices. It states that:

> *"a continuous minimum period of 3 years from the application of the improved management practice shall be required before a claim can be made."*

This provision is presumably included with a focus on soil improvement practices which take time and must be applied continuously in order to build up a detectable SOC increment. However, such considerations may not apply in the case of biochar, which has an immediate measurable impact on SOC after a single application, often locked in through pairing with practices such as mulching and minimum-tillage that aim to avoid subsequent soil disturbance. There is therefore an argument for exempting biochar projects from the requirement for a three-year initialisation period, and for clarifying that the requirement for 'continuous application' can in this instance be satisfied by a single initial application.

There is also a case to be made that if a project seeks to claim only the SOC benefit from recalcitrant biochar carbon, then the soil sampling regime required by the Implementing Regulation is unnecessarily stringent. For such a project, modelling could be used to estimate the loss of labile carbon from a given biochar application. Provided there is robust auditing of the quality of the biochar applied and that the initial application is done correctly, it could then be appropriate to relax or even entirely remove the requirement for ongoing sampling. For projects seeking to also claim e_{sca} credit for pedogenic carbon formation, a sampling regime would still be necessary. Combining a relaxation of sampling requirements with a waiver of the three-year initialisation period would help make biochar application more attractive to biofuel feedstock farmers.

Future development and recommendations

Looking beyond the Renewable Energy Directive, the European Commission's proposal for a Carbon Removal Regulation[xiv] provides a basis for a future certification framework for 'carbon farming'. This recognition for farmers achieving SOC increases in their fields is welcome, and it addresses calls from the scientific community for a more uniform and robust standard for carbon removals[xv].

The Commission envisages that updates to its biofuel policies will align with the Carbon Removal Regulation and consider evidence from the field and the literature:

> *"The Commission may revise its methodological approach, as well as the caps applied to annual claims of carbon stock accumulation, based on [ongoing monitoring of implementation outcomes,] or with the aim to align with evolving knowledge or with new legislation in this area (i.e. EU carbon farming initiative)."*

Going forward, this Briefing Note makes the following recommendations.

1. The RED II's e_{sca} rules require a sampling depth within the top 30 cm of soil, but SOC below this level is more stable and may represent a larger proportion of stocks. Hence, there would be value in developing methodologies and certification schemes that assess SOC in the subsoil.

2. SOC monitoring at scale must take into account variability from factors such as soil type, land use, and management practices. The current rules acknowledge the issue of heterogeneity: there is now an opportunity to standardise the assessments of in-field heterogeneity by offering guidelines and baselines.

3. Biochar has the advantage of immediate stable carbon storage. For projects where recalcitrant carbon from biochar is the only SOC change being claimed, policy could be amended to apply a different incentive and monitoring regime for biochar. First, SOC increases could be claimed from year one rather than year four. Second, the soil sampling requirement could be relaxed, subject to an initial audit of the certifiable recalcitrant carbon in the biochar to be used.

I. IPCC, 2019, https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/.

II. BIKE Briefing Note #7, "Soil carbon crediting and the low ILUC-risk system"; and BIKE Briefing Note #8 "Sustainably delivering carbon farming and low ILUC-risk"; accessed from https://www.bike-biofuels.eu/briefing-notes/.

III. van der Voort et al., 2023, https://doi.org/10.1007/s13593-022-00856-7.

IV. Gehl & Rice, 2007, https://doi.org/10.1007/s10584-006-9150-2.

V. Coffield et al., 2022, https://doi.org/10.1111/gcb.16380.

VI. Smith et al, 2019, https://doi.org/10.1111/gcb.14815.

VII. Orgiazzi et al., 2018, https://doi.org/10.1111/ejss.12499.

VIII. https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf

IX. Commission Implementing Regulation (EU) 2022/996 (henceforth 'Implementing Regulation'), Annex V.

X. Quotations may be lightly edited, e.g. by omitting ellipses or changing the tense of a verb.

XI. Smith et al., 2020, https://doi.org/10.1111/gcb.14815.

XII. Schmidt et al., 2021, https://doi.org/10.1111/gcbb.12889.

XIII. Blanco-Canqui et al., 2020, https://doi.org/10.1111/gcbb.12665. Pulcher et al., 2022, https://doi.org/10.5194/soil-8-199-2022. Bi et al., 2020, https://doi.org/10.1016/j.chemosphere.2020.126881.

XIV. Commission Proposal for a Regulation COM 2022/672.

XV. Paul et al., 2023, https://doi.org/10.1016/j.jenvman.2022.117142.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952872.