Carbon farming, Result-based schemes and NIVA indicators

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NIVA POLICY BRIEF No. 5

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The NIVA project provided an opportunity to develop several environmental indicators aimed at measuring the impact of agricultural practices on the environment. They focus on carbon storage in soils, the risk of nitrate leaching and the impact on biodiversity.

The objective of this policy brief is to present the carbon storage indicator in connection with carbon farming and result-based scheme perspectives.
It turns out that the last day of the NIVA project (30 November 2022) is also the day on which the Commission published its proposal for carbon farming regulatory framework (see below the paragraph titled "European legislation on carbon farming"). This is obviously a coincidence, but this one is mentioned just to highlights the importance of this issue.

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1. Context

The climate emergency

Year after year, heat and drought records are broken all over the world, with 2022 being dramatic in Europe. Water resources may be lacking, weakening agricultural production and impacting biodiversity. Extreme, destructive and deadly climate events occur, including storms, fires and floods.

These climatic disruptions originate from global warming which is due to the significant increase of greenhouse gases in the atmosphere, with CO_2 in the first place. One of the challenges of preserving the planet is to reduce the concentration of CO_2 in the atmosphere. This can be done on the one hand by reducing GHG emissions and on the other hand by 'capturing' and storing carbon, in particular in the soil and biomass thanks to the photosynthetic activity of plants.

The climate emergency is now a priority, as the European Parliament recalled in its recent communications. In 2021, the EU made a legally binding commitment to reach climate neutrality by 2050, while setting a target to reduce net greenhouse gas emissions by at least 55 % by 2030.

The Green Deal

On 14 July 2021, the European Commission communicated on the Green Deal. The Green Deal is the European Union's action program in response to the climate emergency aiming in particular to reach the goal of GHG emission reduction: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en. All sectors of society are concerned: housing, transport, industry, energy, finance, management of natural spaces, but also agriculture.

The Farm to Fork Strategy

In this context, the Farm to Fork Strategy (https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en) is the European Commission roll out for Green Deal in the agriculture sector.

With 430 million tons of CO_2 released in Europe, the agricultural sector accounts for 10 % of European greenhouse gas emissions. But, agriculture is also a sector that offers huge opportunities for climate mitigation, for instance through surface albedo management and carbon storage in the soil. As a matter of fact, soil is one of the largest carbon reservoirs, along with the oceans, but decades of intensive agriculture have dramatically reduced the amount of organic matter in arable soils. Hopefully, this tendency can be reversed through carbon farming practices (e.g. cover crops, including temporary grasslands in the crop rotations, organic amendments, biochar, agroforestry, crop diversification…) and therefore

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arable lands have a high potential for storing carbon. That is why at the COP21, **the "4 per 1000" initiative** was presented which aims at increasing the amount of carbon stored in soils on average by 0.4 % every year globally. It would allow maintaining global warming below 1.5°C at the end of the century but whether or not this target can be reached has since been the subject of much debate. Yet, soils rich in organic matter are more fertile, which increases food security, they decrease the need of chemical fertilizers, irrigation and they limit the risk of soil erosion.

Carbon farming represents all agricultural practices which allow to preserve and increase the soil organic carbon stocks. For France, a study[1] conducted by INRAE in 2019 at the request of the French Ministry of Agriculture and Ademe (The French Agency for Ecological Transition) has identified the most promising practices to store carbon in the soils, it also has quantified their potential and their cost-effectiveness. Given their efficiency, their potential surface area of implementation and their moderate cost of implementation**, cover crops present the best potential to store carbon in the arable soils**.

Carbon market and carbon farming

Under the Kyoto Protocol, the European Union has established a mandatory "carbon market". It requires companies in highly carbon-emitting sectors to purchase "quotas" (entitlement to emit CO_2) in order to offset their over emissions. In addition to this mandatory carbon market, there is a voluntary carbon market which allows other companies and individuals on a voluntary basis to offset their emissions by buying carbon credits. This voluntary market is supplied with carbon credits by companies or groups of individuals that have developed carbon storage projects. These projects are evaluated based on scientific based certified and auditable methods.

In the field of agriculture, such projects aiming to generate carbon credits already exist. These projects, generically called "carbon farming", allow farmers to get a financial support when they adopt certain agricultural practices that contribute to carbon storage in the biomass and/or in the soils. Several methods (e.g. based on in-situ soil sampling, soil or coupled plant/soil models) exist to quantify biomass and/or soil organic carbon (SOC) stock changes caused by such projects[2].

[1] https://www.inrae.fr/actualites/stocker-4-1-000-carbone-sols-potentiel-france

[2] Smith, P., Soussana, J.-F., Angers, et al. (2020) How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal, Global Change Biology, 26, 219–241,

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Certification and labels for carbon farming

Whatever the method used, it must certified. For this, several certification bodies exist (e.g. Verra, Goldstandard…). For instance, the VM0042 methodology from Verra aims at quantifying the greenhouse gas (GHG) emission reductions and the SOC stock changes resulting from changes in agricultural land management practices (e.g. carbon farming practices).

In France, the Low Carbon Label (Label Bas Carbone) was launched in 2019 by the French Ministry of the Environment that approve three methods to quantify GHG reductions and carbon storage for animal farming, arable crops and hedges/orchards. Once a project is accepted and certified, farmers can receive support from funders: local communities, companies, or associations can purchase the carbon credits generated by the project as part of a voluntary approach to offset their own CO_2 emissions.

Other initiatives or labels exist in Europe: e.g. Healthy Soils for Healthy Food (SPAR/WWF), UK Woodland Carbon Code, MoorFutures.

European legislation on carbon farming

For now, the European Commission defines carbon farming as "a green business model" that rewards farmers for setting up carbon sequestration practices, coupled with significant biodiversity benefits. However, the details of such a scheme remain to be clarified, starting with a joint agreement to certify the storage capacity of the soil but also the rules in terms of additionality and the sources of financing (e.g. public through CAP subsidies, private through the voluntary carbon market).

The European Commission issued on the 30th of November 2022 a "Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a Union certification framework for carbon removals".

https://climate.ec.europa.eu/document/fad4a049-ff98-476f-b626-b46c6afdded3_en

This regulation gives a large place to carbon farming and aims to guarantee the removals by proposing an EU certification framework based on four quality criteria (called QU.A.L.ITY): **QU**antification of carbon removal, **A**dditionality of removals against basic requirements, **L**ong-term storage (removals) and sustainabil**ITY** as regard other environmental and climate objectives.

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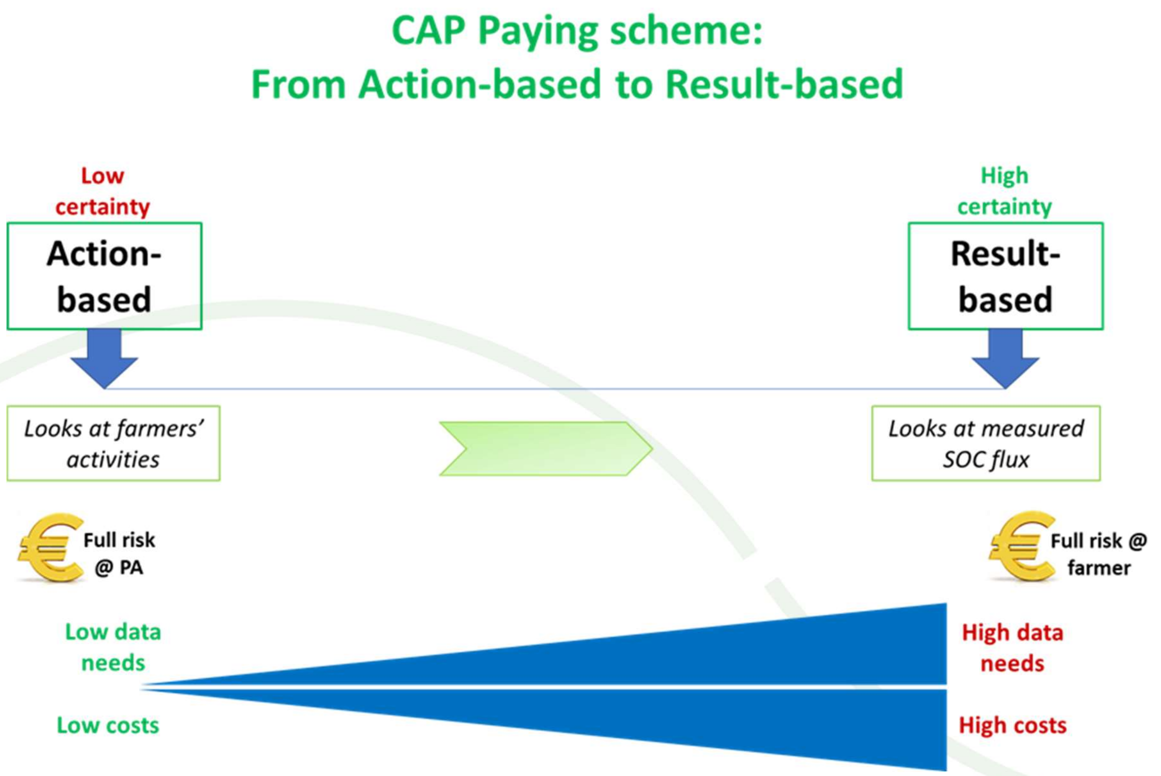
2. CAP subsidies and carbon farming: action based versus result based schemes.

Given the climate situation, and the fact that the CAP is now performance-driven it would be relevant to base support measures on result rather than on actions. This part presents a discussion on this topic by taking the example of carbon farming.



Action based

An *action based*-scheme (farming practices) is relatively easy and cheap to monitor. We know which farming practices are likely to restore SOC (soil organic carbon). Policy makers can suggest these farming practices and monitor whether they are followed up. An action-based scheme can be based on indicators that Paying Agencies already use.

> If a policy maker focuses on checking whether farmers do certain practices, we call that an *action-based* scheme.
> The results of land management practices are not measured in an action-based scheme.

The drawback is that if we only look at farmers' activities, we have no evidence that organic carbon is stored in the soil. The Paying Agency pays but gets no guarantee that SOC has increased.

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➢ Promising farming practices

To monitor an action-based carbon farming scheme, one needs to decide on a set of actions or practices for land-owners, assuming that these will increase SOC. Interreg published in-depth report on carbon farming practices in 2020[3] and a short report with the five most promising carbon farming methods in 2021[4]. The five most promising practices (indicators) are:

1. Use cover crops
2. Enrich crop rotations
3. Add compost and solid manure
4. Improve grassland
5. Introduce agroforestry

These carbon farming practices can be used as direct monitoring indicators. These fit in an action-based scheme, where farmers and land owners get CAP payments depending on whether they carry out these practices. It is not measured whether they actually managed to store carbon in the soil.

Result based

Setting up a result-based carbon farming scheme includes quantifying SOC stock changes in the soil.

A result-based carbon farming scheme based on in-situ soil sampling has proven to be time consuming, costly and difficult to almost impossible to monitor (e.g. because of soil properties and biomass inputs spatial-temporal variability), especially if changes are small, which is the case when they are measured over a short period of time (i.e. 1-3 years)[5]. Because of the costs and time involved, we do not think it is realistic to take physical soil samples to measure SOC on farms all over Europe. Note that methods based on proxy (e.g. on tractors)/aerial sensors (drones) or on remote sensing only allow to map superficial soil organic carbon content but do not allow to quantify SOC stocks (as organic matter is distributed along the soil profile with patterns that may differ greatly according to the pedoclimatic conditions/current and past practices).

If a policy maker focuses on *measuring changes in SOC*, we talk about a *result-based* scheme.
In a result-based scheme, farming practices are not taken into account.

[3] Paulsen, H.M., Inventory of techniques for carbon sequestration in agricultural soils. 2020: Interreg North Sea Region.
[4] Interreg, Five promising measures to protect the climate by Carbon Farming. Short report. Interreg North Sea Reagion Carbon Farming. European Regional Development Fund. European Union. 2021
[5] Smith, P., et al., How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Global Change Biology, 2020. 26(1): p. 219-241.

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Other approaches to quantify SOC stock changes in the soil are based on soil or coupled plant/soil models. They are typically used for NDCs[2] or for the voluntary carbon market (e.g. French Label Bas Carbone). Such models often require detailed information on farming practices and recent plot/farm specific soil analysis as inputs for the models. A major drawback is that they often fail to account properly for the spatial-temporal variability in crop/cover crop biomass development and of the resulting biomass inputs into the soil that impact SOC stock changes in the first order.

Indicators

A result-based payment scheme needs different monitoring indicators. According to COWI et al indicators should be[6]:

- linked to a desired outcome at farm/plot scale;
- consistently measurable using a simple technology;
- sensitive to changes in agricultural- or land management within a reasonable time frame;
- unlikely to be influenced by external factors beyond control of land manager.

These requirements are rather qualitative, they differ per farm and seem harder to meet than for action-based indicators. These requirements also demonstrate that some factors are outside the control of the farmer or land manager.

Risk and certainty

COWI et al. mention two critical factors that determine the *feasibility* of a result-based scheme:

- Risk of non-delivery due to external factors. Non-delivery means that no increase in SOC is measured, due to a dry season for example.
- Ease of measuring SOC and degree of certainty.

The risk of non-delivery in a result-based scheme is fully concentrated at the land-owners' side. In an action-based scheme it is concentrated at the Paying Agency.

Alternative Carbon Farming schemes

We concluded that a large scale result-based scheme is out of reach with the current methodologies (soil sampling, current models) and that an action-based scheme doesn't satisfy the need for evidence. Either we need new approaches for quantifying SOC stock

[6] COWI, Ecologic Institute, and IEEP, Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU. DG Climate Action, under Contract No. CLIMA/C.3/ETU/2018/007. COWI, Kongens Lyngby. 2021.

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changes at large scale meeting the requirements listed by COWI et al., or we need something in the middle between action-based and result-based schemes or that combines both approaches (see hybrid schemes here below). In the meantime, we decided in NIVA to develop a new generation of tools to produce agro-environmental indicators and some of them could be used for result based schemes (e.g. tools for carbon indicator TIER3).

➢ Hybrid scheme

A hybrid scheme is a scheme where a farmer will get a part of the payment based on actions to restore carbon in the soil, and bonus payments based on result (a measured increase in carbon). In such a hybrid scheme, the farmer and policy body share the risk of non-delivery. In a result-based scheme, the farmer bears the full risk and in an action-based scheme the policy body does. In a hybrid scheme, the action-based and the result-based approach together form the full payment. So the land-owner commits to the desired practices, plus there is an incentive to do more and use creativity to store more carbon in the soil.
Note that the price of the ton of CO_2 on the voluntary carbon market is currently too low to compensate for the price of implementation of the carbon farming practices[1]. It would therefore not be shocking to consider the possibility of additionality of carbon credit through the voluntary carbon market and subsidies that would be paid through the second pillar of the CAP for practices contributing to store carbon in arable soils. Ideally, the same monitoring tool should be used for both the payment based on action and results to ensure consistency in the hybrid scheme. So note that the TIER3 Carbon indicator tool developed in NIVA could answer this need.

➢ Convinced-based scheme

A *convinced-based* scheme would be a scheme based on the conviction (underlined by scientific research) that some actions increase the amount of organic carbon in the soil. Practices to restore carbon can be the same as in an action-based scheme, but this scheme uses a mathematical model to calculate changes in SOC (see for instance TIER 2 Carbon indicators tool here below). These calculations are based on land management practices in combination with external effects. Such model could use for instance satellite imagery and farm data.

➢ Agro-environmental indicators for alternative schemes?

The NIVA consortium is creating promising tools[7] to make IACS administration easier and to lower the administrative burden for the farmer and the Paying Agency (PA).
Some of the tools aim at producing agro-environmental indicators at large scale by combining IACS and remote sensing (Sentinel-2) data. This action was led by the French Paying Agency (ASP) and developments were based on research done at the French national research institute on Agronomy, Food and Environment (INRAe). Tools related to three indicators have been selected for development: 1) Soil Organic Cabon storage for arable

[7] More details about all tools can be found at www.niva4cap.eu.

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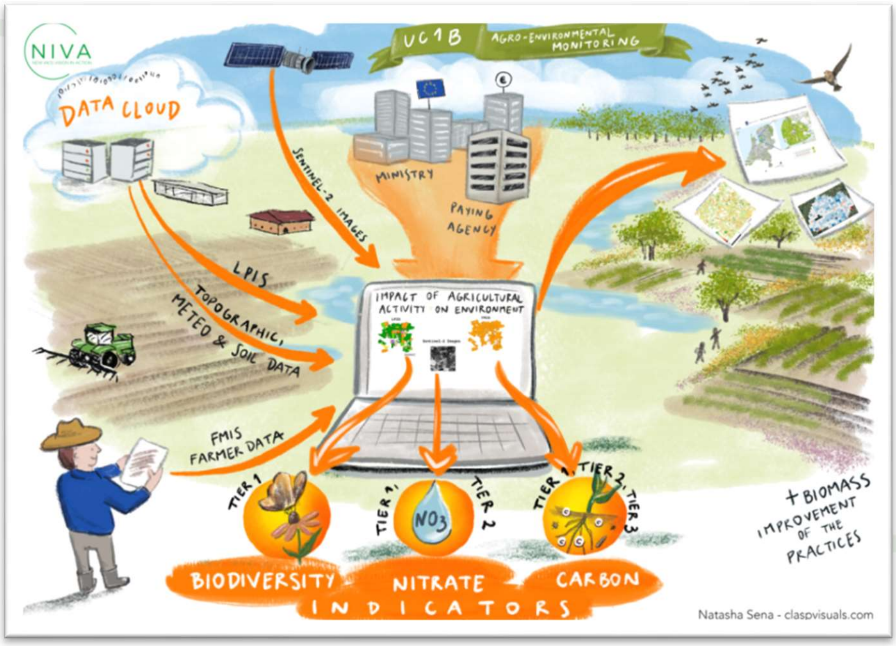
lands (related to climate change issues), 2) risk of Nitrate leaching (for water quality tackling environmental care) and 3) preservation of Biodiversity.

Work done and achievement on carbon budget are presented in the following part. Those tools could be part of the tool package used in the future for a more result-driven scheme and performance-driven policy. For the time being, the more advanced developments concern the carbon indicators, with three methods (TIERs) of increasing complexity. Yet for some of them validations/methodological improvements are still needed for accurate estimation of the soil carbon budget and systematic large scale application.

3. Carbon indicators – Work done and achievements

The indicators are calculated based on the data available in Europe such as LPIS data, satellite data (Sentinel-2), pan-European meteorological data (ERA-5 from the ECWF) and data from the farmers (collected through FMIS - Farm Management Information System).



Tools to produce the carbon indicators have been developed at different levels (*TIERs*) of complexity. The TIER approach (T1, T2 and T3) offers increasing level of precision, but also increasing complexity. The indicators are calculated for an agricultural year and they can be calculated at different levels: parcel or pixel (i.e. 10m).

Carbon indicators are calculated for arable crops. Annual carbon budgets represent how much organic matter has been lost or gained by the soil during a cropping year (typically between 1st October of year n and the end of September of year n+1). It is calculated by considering 1) the net annual CO_2 flux between the plot and the atmosphere during the cropping year, 2) how much carbon has been exported at harvest and 3) how much carbon has been brought as organic amendments.

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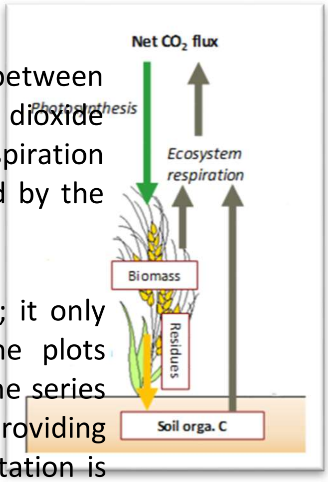
Carbon Tier 1



The methodology for TIER 1 estimates the net annual CO_2 fluxes between the parcels and the atmosphere: it takes into account the carbon dioxide emitted to atmosphere by the plants and the soil respiration (mineralisation of the soil organic matter) and the CO_2 absorbed by the plants through photosynthesis.

Carbon Tier 1 can easily be implemented at plot or pixel levels; it only requires IACS data (information about the crop type and the plots contours) and NDVI (Normalised Difference Vegetation Index) time series calculated from Sentinel-2 satellite data or from other satellites providing data with high spatio-temporal resolutions. The indicator computation is based on an empirical linear relationship between the net annual CO_2 flux and the number of days with active vegetation which is valid for most crop types in Europe (not rice). This relationship was established[8] based on measurements done at flux tower sites in Europe[9]. Using NDVI time series derived from Sentinel-2 we hypothesized that it is possible to determine the number days with active vegetation from remote sensing and therefore the net annual CO_2 flux.

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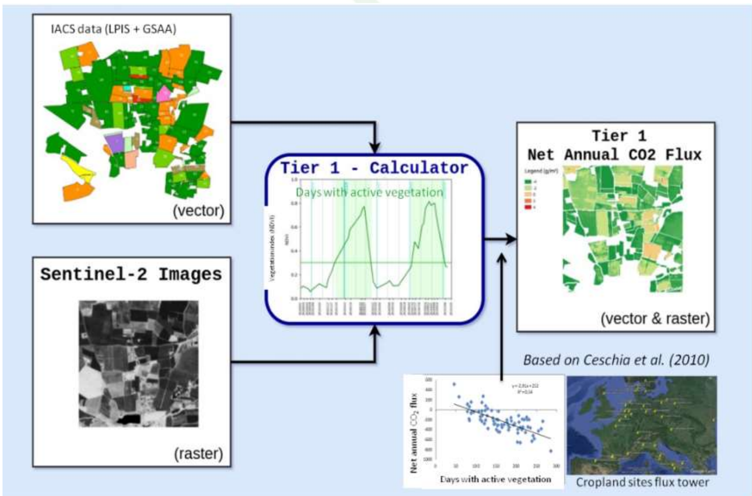
Stands alone tools (at parcel[10] and pixel levels[11]) are available at NIVA's Gitlab. A more advanced tool has been developed (integrating carbon TIER 1 algorithms in the IOTA2 software) to produce national level pixel scale indicators.



[8] Ceschia, E., Béziat, P., Dejoux, J.F., Aubinet, M., Bernhofer, Ch., Bodson, B., Buchmann, N., Carrara, A., Cellier, P., Di Tommasi, P., Elbers, J.A., Eugster, W., Grünwald, T., Jacobs, C.M.J., Jans, W.W.P., Jones, M., Kutsch, W., Lanigan, G., Magliulo, E., Marloie, O., Moors, E.J., Moureaux, C., Olioso, A., Osborne, B., Sanz, M.J., Saunders, M., Smith, P., Soegaard, H., Wattenbach, M., 2010. Management effects on net ecosystem carbon and GHG budgets at European crop sites. Agric. Ecosyst. Environ. 139, 363–383. https://doi.org/10.1016/j.agee.2010.09.020.
[9] http://www.europe-fluxdata.eu/home/sites-list
10 https://gitlab.com/nivaeu/uc1b_tier1_co2
11 https://gitlab.com/nivaeu/uc1b_indicators_tool

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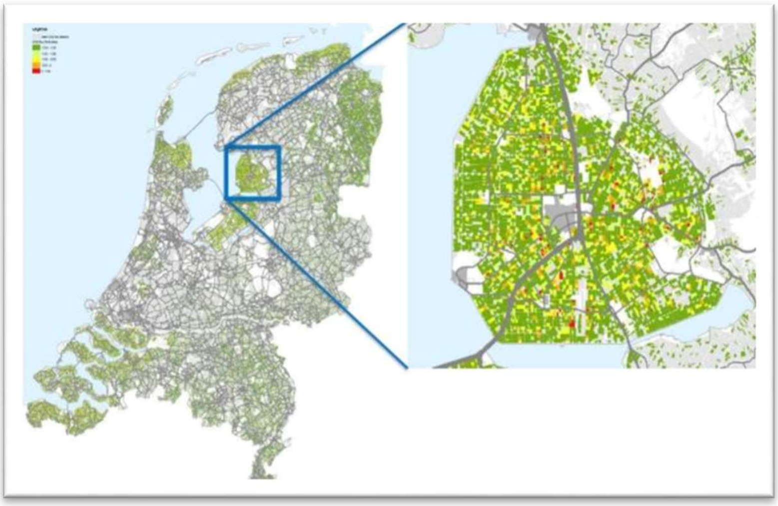
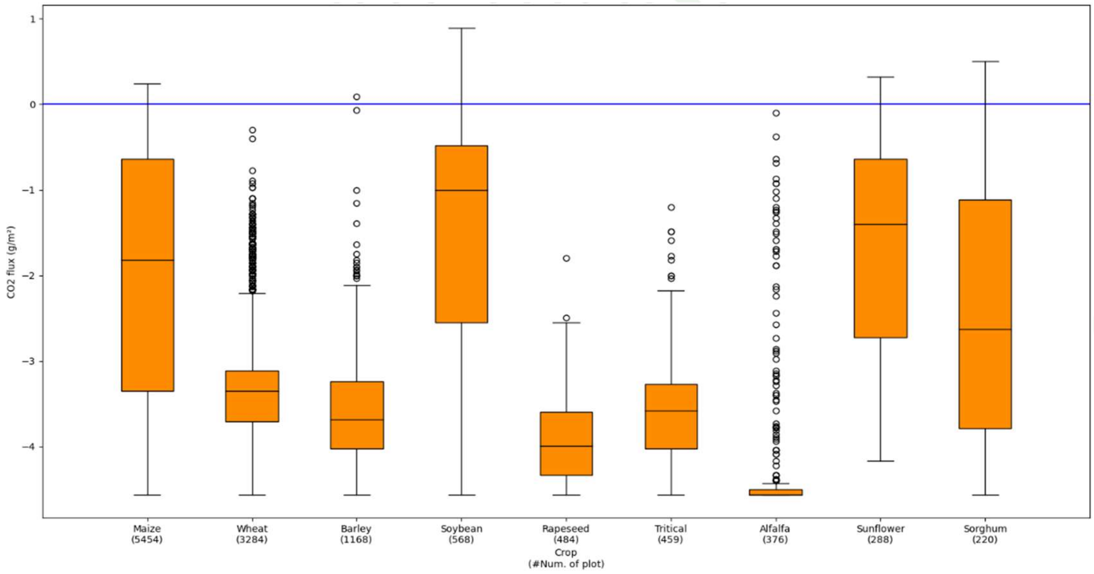
Carbon Tier 1 at parcel level has been tested in various areas in Europe: in France, Denmark, the Netherlands and in Spain. The tool is operational for large areas, i.e. it was calculated or the entire country in the Netherlands. The results in the form of a map are easy to interpret, for example one can recognize parcels that fix the CO_2 (in green on the figure below, left) and parcels that loose CO_2 (in red).



Results can be also presented and analyzed in a form of charts, for example by grouping the results per crop type and analyzing the capacity of a particular crop type to fix the CO_2 in a given region.



Results of Carbon Tier 1 at pixel level allow analysis of the heterogeneity of the indicator inside of the agricultural parcel (example on figure below).

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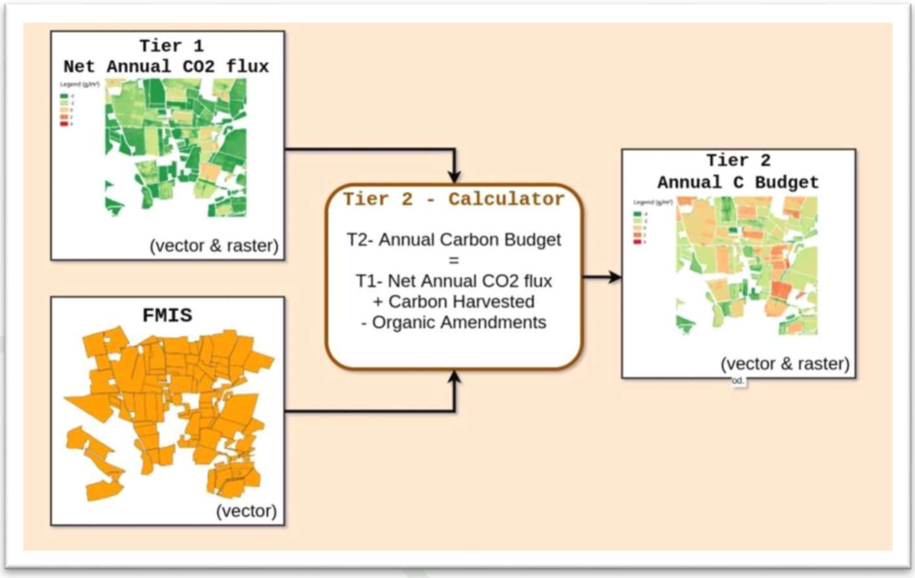
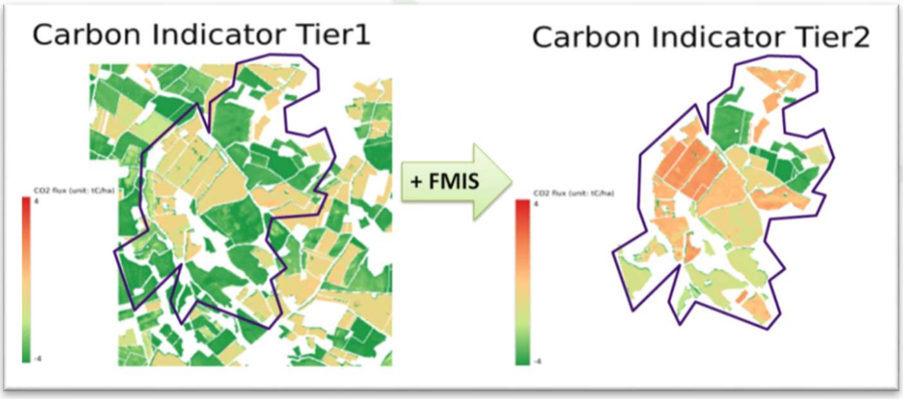
Carbon Tier 2

This indicator allows computing annual carbon budgets at plot level, which represents how much carbon has been lost or gained by the soil over a cropping year. The tool[12] uses the results from the Carbon Tier 1 indicator, combined with the farmer's FMIS data (the type and on amount of organic amendments, harvest). As for Tier 1, Tier 2 is based on an empirical approach and it can be applied to most crop species. The main challenge to produce this TIER2 indicator is access to farmer's FMIS data.



CT2 is assessing the carbon budget of crops, taking into account not only the CO_2 exchanges between the plot and the atmosphere but also the agricultural practices. The results on the figure below are presented only for parcels for which the FMIS data were provided allowing calculation of CT2. By comparing the results for Carbon Tier 1 and Tier 2, it can be observed that some of the plots that were close to CO_2 neutrality (in yellow on the left, CT1) become red on the right (CT2), meaning that their soil lost carbon when we account for the carbon exported at harvest.



12 https://gitlab.com/nivaeu/uc1b_indicators_tool

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Carbon Tier 3

It is produced by the most advanced and complex tools[13,14] that we developed and calculations require intensive computing and large data storage capacities. Carbon Tier 3 is based on a modelling approach that has been tested and validated for straw cereals, maize, sunflower and cover crops. The method has been validated against in-situ data (flux tower measurements, data from the Regional Space Observatory[15]). The model simulates CO_2 fluxes (photosynthesis, plant and soil respiration), biomass and yield.
As an input, it requires IACS data (information on crops and plot contours), meteorological data, LAI (Leaf Area Index data derived from Sentinel 2 like satellites) to calibrate the model's phenology and photosynthesis capacity. As for Tier2, farmer's FMIS data on organic amendment and straw export is required to compute the carbon budget.

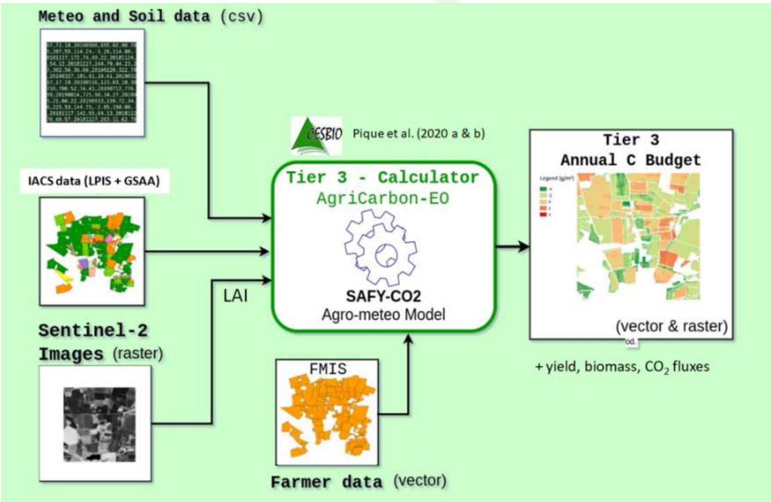
Carbon Tier 3 approach can be applied both to the voluntary carbon market in agriculture and to the CAP. Also, it can be validated against in-situ data.

➢ Carbon Tier 3 tools

There are two tools to calculate Carbon Tier 3:

1) SAFY-CO2 at parcel level allows calculations on a few thousands of plot land.
2) AgriCarbon-EO[16] at pixel level that allows simulations at pixel scale over several Sentinel 2 tiles.

The tools were tested in France and in Spain and validated against in-situ measurements[17, 18]. The AgriCarbon-EO tool produces high resolution results of the carbon budget components as well as their uncertainties.



13 https://framagit.org/ahmad.albitar/safye_co2.git
14 https://www.cesbio.cnrs.fr/agricarboneo/agricarbon-eo/
15 https://www.cesbio.cnrs.fr/la-recherche/activites/observatoires/l-observatoire-spatial-regional-osr/
16 https://www.cesbio.cnrs.fr/agricarboneo/
17 Pique G., Fieuzal R., Al Bitar A., Veloso A., Tallec T., Brut A., Ferlicoq M., Zawilski B., Dejoux J.-F, Gibrin H., Ceschia E. 2020a. Estimation of daily CO2 fluxes and of the components of the carbon budget for winter wheat by the assimilation of Sentinel 2-like remote sensing data into a crop model. Geoderma, 376, 114428.
18 Pique G., Fieuzal R., Debaeke P., Al Bitar A., Tallec T, Ceschia E. 2020b. Combining high-resolution remote sensing products with a crop model to estimate carbon and water budget components: Application to sunflower. Remote Sensing, 12, 2967

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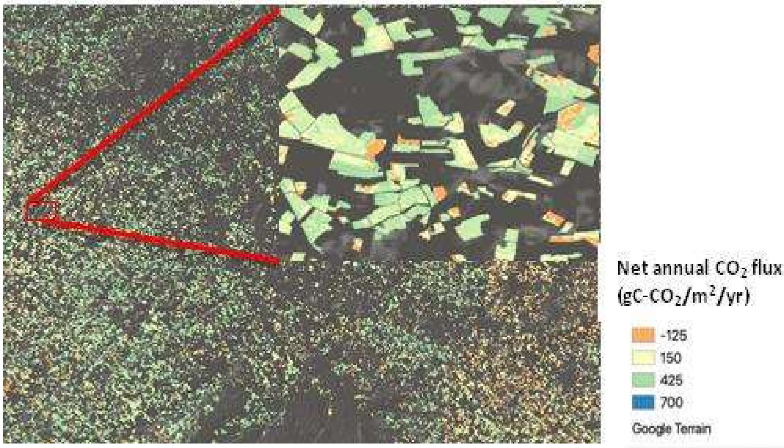
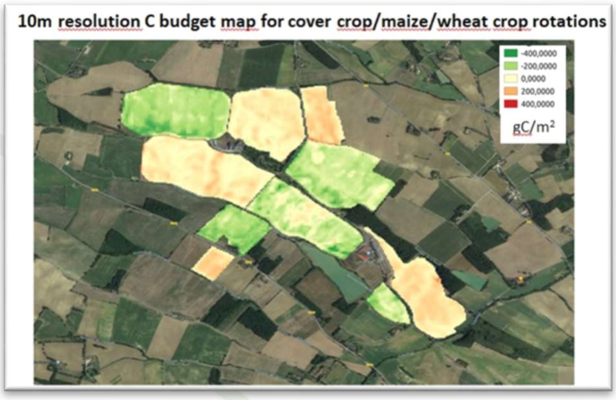
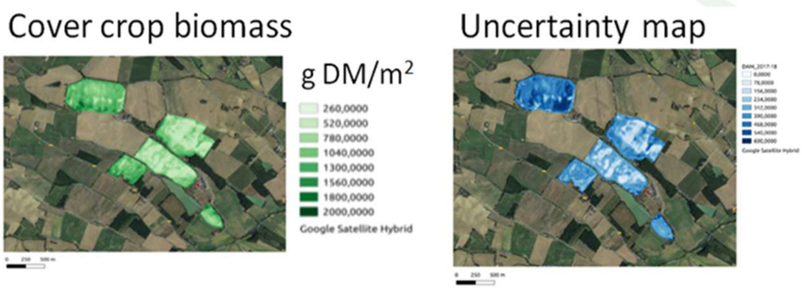
The image below shows 10m resolution net CO_2 flux map for straw cereals in South West France in 2018.



Combined with FMIS data in France results show (see below), some high spatial variability in the carbon budget inside and between the plots. Yellowish plots are winter wheat that loose carbon while greenish ones are maize crops preceded by cover crops. The high spatial variability is mainly caused by differences in biomass inputs in the soil.



The model also produces high resolution agronomical variables such as cover crop dry biomass (DM) and the associated uncertainties (respectively on the left and on the right).



Where to find the tools and results?

- The tools are available on NIVA GitLab : https://gitlab.com/nivaeu/uc1b_tier1_co2 and https://gitlab.com/nivaeu/uc1b_indicators_tool
- French and Danish anonymous results from agro-environmental tools at Tier 1 are available openly at Zenodo platform: https://zenodo.org/communities/niva4cap

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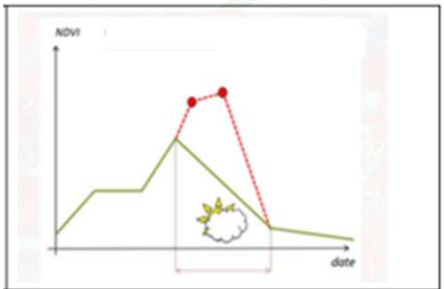
Opportunities and challenges (Discussion)

Interpretation, validity

Carbon Tier 1 is relatively easy to calculate, easy to interpret, but the results should be interpreted with caution: if the results highlight the effect of some management practices (impact the crop chosen, effect of cover crops) on the net annual CO_2 fluxes it does not account for the effect of other management practices (e.g. organic amendments) and it does not provide information on the carbon budget itself (only on one of the 3 components of the carbon budget is addressed).



Linear interpolation may be not valid

Apart from the intrinsic uncertainty associated to the empirical relationship used to calculate the indicator, the quality of the indicator depends on the number of satellite observations; for example cloud coverage increase the uncertainty on the estimate of the duration with active vegetation which impacts the results. For this purposes a note named "Quality Assessment of Carbon indicator Tier 1" can be found on the Zenodo platform (https://zenodo.org/record/7097103#.Y4oVvISZPIU)

Also the method is currently being improved by accounting for climatic variables. Indeed even if green vegetation is observed in the field by satellites, it may not be active on a photosynthetic point of view if solar radiation or temperature are limiting the plants metabolism. For this reason, the current method tends to overestimate the net CO_2 fixation of winter/cover crops. Next step will be to validate the improved methodology against ground truth (recent flux data concomitant with Sentinel 2 data).

Carbon Tier 2 is also rather easy to calculate but the main challenge is to access farmer's data through the FMIS (different formats) and to obtain their consent. This step requires conventions/agreements with farmer's or their representatives (e.g. agricultural councils, cooperatives). Also the process is costly and time consuming as the data quality/consistency must be checked. There are also privacy issues as the input data and the results cannot be shared openly or published. Note also that the uncertainty of the results combines the uncertainty of the TIER 1 approach with the uncertainty of the FMIS data. A dedicated validation procedure will have to be implemented to quantify the overall uncertainty of the approach. Tier 2 could be relevant for Convinced-based schemes.

Carbon Tier 3 is the most advanced approach but it requires significant IT infrastructure and addition of a new crop species/types in the modeling process requires a specific parametrisation/validation process which is time consuming. The main components of carbon budget calculation (biomass, yield, CO_2 fluxes…) are validated against ground truth data and this approach offers assessment of uncertainties on the variables simulated. This modeling approach can be applied both to the voluntary carbon market for cropland and for the CAP (eco schemes).

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4. Conclusion

Among the tools developed in the NIVA project for agri-environmental monitoring, the ones on carbon flux/budget are the most advanced. Three approaches (Tiers) of increasing complexity and precision have been developed. The tier 3 carbon indicator, which is based on an agro-pedo-meteorological model, makes it possible to quantify the carbon budget in the soil with good precision. This precision seems sufficient to base a carbon farming measure at least partly on the result, encouraging this way the performance.

At first sight this indicator seems compatible with the carbon farming requirements presented in the new coming Commission's regulation proposal.

Since the carbon indicator is developed at the scale of the pixel or of the agricultural plot, it informs the farmer about the performance of each of the plots but also on the intraparcellar variations resulting for instance from soil properties.

Some farmer's activity data are needed to calculate the tier 2 and tier 3 indicators. These data being usually already part of those present in the FMIS, calculating carbon indicator does not lead to an additional burden for farmers. Moreover, the results obtained can also be the subject of benchmark between farmers and allow agronomic advices promoting performance (e.g. precision farming).

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