In the following, we have numbered our answers as AARC2-n, where n is the answer number (Author Answers to RC2). This allows referring to our answers in this document as well as in the answers to the other reviewers.

In this manuscript Loubet et al. present the first case study of SOC stock measurements with the ICOS protocol at the French crop site FR-Gri in 2019 and compute the soil stock evolution from 2005 to 2019. Overall, the paper is of a good scientific quality and stresses some important issues like digging deeper than 30cm when monitoring soil organic carbon stocks (unlike e.g., LUCAS or the LULUCF inventory which limit themselves to 30cm). There are however a few issues that need to be addressed before the manuscript can be accepted for publication.

A clear carbon balance should be included in this manuscript. Table 1 includes the imports and exports but no overall balance is calculated. Also is the mineralization rate known of this field? The outcome of the balance could be directly related to the SOC stock loss

AARC2-1. We thank the reviewer 2 for his constructive comments. This first comment is very important indeed. Table 1 and the whole paper does not include a full carbon balance because this would imply computing the net ecosystem exchange (NEE) over the whole period 2005-2019. While in principle we have all the data to do such a carbon balance, we should stress that during that period the instrumentation have changed from pre-ICOS to ICOS standard, and in particular the InfraRed Gas Analyser (IRGA) has changed from open path (Licor 7500) to close path (Licor 7200). The flux computation has also changed from using EDIRE to using EDDYPRO. As a consequence, there might be changes over the whole period that could be due to instrumental or computational changes and lead to erroneous conclusions. This is the reason why we would like to first recompute the historical data with a homogenised processing, and the latest standards prior to using these data. We acknowledge that this would bring more information to that paper but this process is also slow and we consider this should come with a later publication.

The differences between the sampling campaigns are very important and should be discussed into more detail. E.g., the difference in sampling depth intervals, the selection of the reduced sampling area.

AARC2-2. We thank the author for this comment which corresponds to RC1 comments. We provide additional analysis of the spatial variations of soil characteristics in the field that shows that the 2005 campaign and the 2019 "reduced area" sampling points correspond to the same soil type (see detailed answer AARC1-4 and Figure R2). We additionally checked that there was no significant differences between the soil characteristics of the samples (e.g., carbon content, density, rock fraction) from the 2019 reduced area and the 2019 sampling points that were in the 2005 sampling area (see detailed answer AARC1-4 and Figure R2). We also compared the only comparable parameter between the two-sampling campaign (the rock fraction), which showed no significant differences (Figure R3). This additional information provides additional confidence that the choice of the reduced sampling zone in 2019 corresponded to the soil characteristics of 2005.

How was the measurement of the bulk density executed? Which protocol? Was the soil moisture content similar at the time of sampling in 2005 and 2019

AARC2-3. The bulk density was measured by weighing the dry mass of the bulk sample obtained from a mechanical corer. The soil was first dried at room temperature prior to fractionating the fine soil, rock and roots fractions, then the rocks and roots were dried at 70°C prior to measuring the weight of rocks and roots. The remaining fine soil was subsampled and dried to 105°C to determine the remaining water content fraction which was used to correct the dry mass of fine soil.

The soil sampling was in December in 2005 and in mid-march in 2019. The surface moisture at these times were : 32.4% in 2005 and 39% in 2019 averaged over the 0-30 cm profile over the month.

The ICOS site focusses on arable land but in the introduction the effect of crops and crop type on carbon sequestration is hardly mentioned. The same for tillage type and the difference between inversion and non-inversion tillage which could lead to a redistribution of the carbon present in the soil.

AARC2-4. We tried to give a short overview of these effects which may have not been sufficiently put forward? We propose to rephrase the introduction to better emphasize on these aspects:

"Intensive farming based on monoculture and soil tillage with high external inputs (e.g. fertilizers) per-formed throughout the 20th century is expected to aggravate climate change (Autret et al., 2016) by increasing CO2 emissions through soil heterotrophic respiration and destabilising carbon by releasing mineral-associated or aggregate-protected carbon (Autret et al., 2016; Six et al., 2012; Schmidt et al., 2011). In contrast, conservative agricultural practices, like persistent vegetative cover, high or-ganic inputs, cover cropping, and increased inclusion of high C:N plants in crop rotations, are promoted to partially restore SOC and mitigate climate change (Lal, 2004; Poeplau and Don, 2015) by increasing C inputs and improving its persistence in soil (Xu et al., 2019). However, carbon losses may still occur in conservative system when high organic inputs, particularly from nitrogen-rich sources, trig-ger the priming effect (Zheng et al., 2024). Minimum and no-tillage have been also promoted to restore SOC stocks since the 2000s, but growing evidence shows that this may not be the case (Chenu et al., 2019)."

Figures are fuzzy and difficult to read

AARC2-3. We apologize for this inconvenience that was due to a wrong setup of adobe acrobat on the very last version of the pdf submission with minor changes. All figures have been modified to improve the quality and were uploaded as an author response the 21 may 2025 "**AC1**: 'High quality figures to ease the reader', Benjamin Loubet, 21 Mar 2025".

We will for sure take much care of the figure quality in the revised version

Small remarks

L54: High organic matter inputs can lead to nutrient leaching. Important drawback.

We agree and appreciate your comment. We actually mentioned in the discussion section the evaluation of the organic and inorganic carbon leaching as measured by Kindler et al. (2011) (L542-544), which indeed showed that DOC leaching may be an important term in the overall carbon balance. *"Dissolved organic carbon leaching was evaluated to contribute to the overall organic C loss from the field to around 10% (Loubet et al. 2011)."*

We propose to specifically mention in the revised manuscript the potential negative feedback related to high organic matter inputs (e.g., effect-priming → soluble C → leaching). *We propose to add the following sentence in the discussion section (see detailed answer AARC1-11): "In terms of soil processes, SOC stock declines during that period may reflect an unbalance between SOC mineralization and immobilization rates likely trigged by a priming-effect through fresh organic matter inputs - mainly from legumes, plants with low C:N ratio, organic amendments, and nitrogen-rich fertilization (193 kg N ha^{-1}) (Ceschia et al., 2010; Loubet et al., 2011; Bernard et al., 2022)."*

L175: Add the number of the strata to the figure. Why not limit the reduced sampling area to the strata that show overlap with the sampling area of 2005?

This is a very good comment which we have addressed in detail in our answer to the reviewer 1 comments (see answer AARC1-4). In short, we used as many strata as possible to increase the statistical significance. We showed in our answers to reviewer 1 that choosing the strata that overlapped 2005 did not change significantly the soil properties and SOC stock when compared to the reduced area that we choosed in the original manuscript.

L185: Which soil characteristics are similar? Explain into more detail.

This is a very good comment which we have addressed at length in our answer to the reviewer 1 comments (see answer AARC1-4). The only similar characteristics that we can compare are the rock fraction, but using 2019 measured soil characteristics we identified groups of similar soil characteristics that correspond to the choice of reduced area retained in the analysis. And also, we showed that all the soil characteristics measured in 2019 were not significantly different in the reduced area and in the overlapped area (see previous answer).

L190: Root fraction >1mm in diameter?

The removal of roots larger than 1 mm in diameter aimed to facilitate the subsequent steps of soil preparation. After separating all soil fractions, the remaining roots were added to those previously measured (∅ >1 mm).

L230: How deep was the reduced tillage practice applied? Was decompaction verified by e.g., penetration resistance measurements?

Thanks for this good question. Tillage was usually at most 15 cm after 2004, except in 2010 (25 cm) and 2012 (40 cm). However, soil decompaction was not verified by direct technique, but was clearly shown by observed changes in soil bulk density at the surface (see Figure R7 in answer to RC1, reproduced below). We propose to insert the following paragraph concerning soil management in the Material and Method section after Figure 1:

"In 2004, as part of the implementation of reduced tillage and the crop rotation system, the soil was scarified to a depth of 50 cm. Since then, most tillage operations have been restricted to the superficial layer (0–15 cm), using a stubble cultivator or clod crusher. Two additional deep tillage operations occured: one in 2010 (to a depth of 25 cm) and another in 2012 (to a depth of 40 cm). Furthermore, the soil is disturbed to a depth of 5 or 10 cm during seeding."

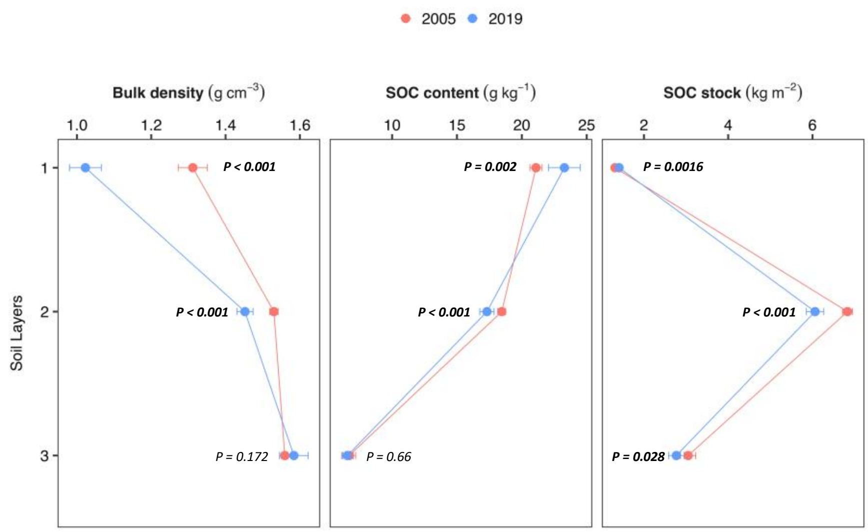

Figure R7. Mean of bulk density and soil organic carbon (SOC) contents and stocks with their corresponding confidence intervals (CIs) in the 2005 and 2019 campaigns across three soil layer (0-5, 5-30, 30-60 cm), computed using a design-based approach. Only the "Reduced Field" is presented.

L345: How are the stocks calculated in this figure? ESM?

This question was also raised by Reviewer 1. Regarding the harmonization of the two sampling campaigns, we fully agree that the ESM method is the reference method. This was maybe not sufficiently clear in the original manuscript, and we will clarify it in the revised manuscript. In the original manuscript we focused on the overall carbon stock estimated by the ESM technique over the entire profile 0-60 cm. In the revised version, we will provide additional information in the soil profile to the three coarsest layers of 2019: 0–5 cm, 5–30 cm, and 30–60 cm. The bulk density (BD), rock fragments, and carbon content were aggregated using a thickness-weighted mean, while SOC stocks and soil mass were calculated as cumulative sums across the respective layers. We will further include equivalent soil mass (ESM)-based SOC stocks calculated using two approaches from the SimpleESM function (Ferchaud et al., 2023). These methods converged to a C soil stock losses of 0.95 kg C m-2 in the 0-60 cm layer over time (see detailed answer AARC1-3 and Figures R6, R7 and R8 in response to RC1. R8 is reproduce below for clarity).

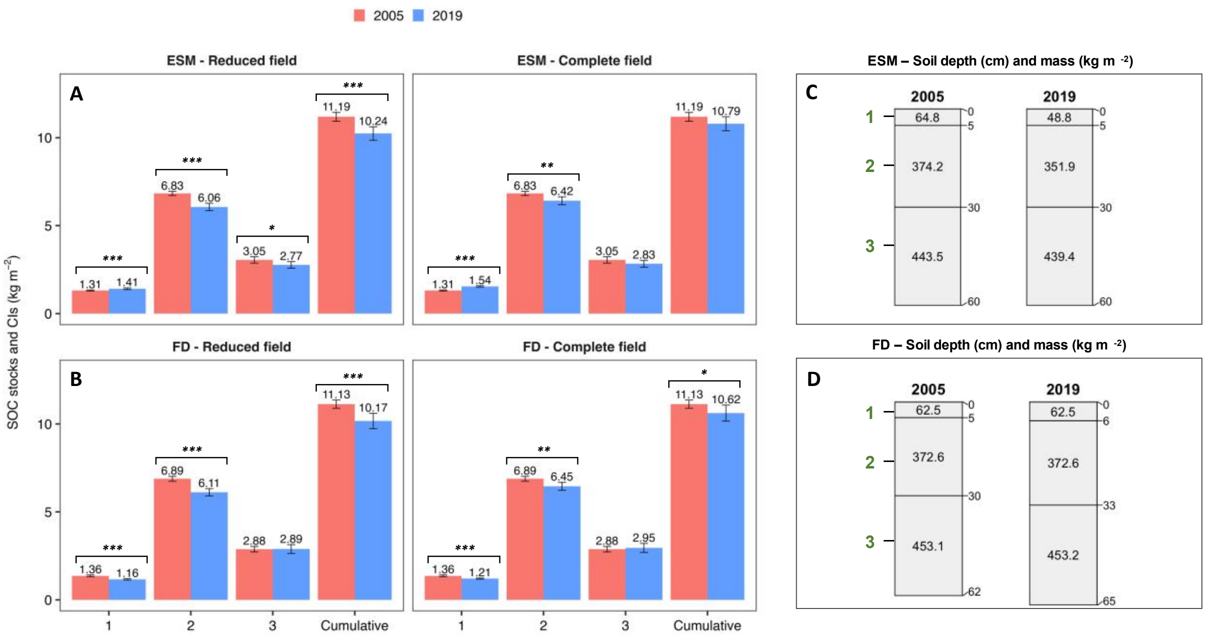

Figure R8. Mean soil organic carbon (SOC) stocks (kg m⁻²) estimated using the Fixed Depth (FD, Panel A) and Equivalent Soil Mass (ESM, Panel B) approaches, along with their corresponding confidence intervals (CIs), for the 2005 and 2019 campaigns. Estimates were computed using a design-based approach. Soil depth (cm) and fine soil mass (kg m⁻²) are also shown in Panels C and D. In the "Reduced Field" panels, seven strata from the 2019 dataset with pedological characteristics similar to the 2005 area were included. **, **, and *** stands for significance (p< 0.1, p < 0.01 and p< 0.001).*

L386: Which soil depth is used? 0-60cm?

The maximum soil depth in our study is 60 cm in 2005 and 100 cm in 2019. In the revised manuscript, we divided the soil profile into three aggregated layers: 0–5 cm, 5–30 cm, and 30–60 cm, and we removed the 60-100 cm when aggretating some soil variables and computing FD-based SOC stocks. Bulk density (BD), rock fragments, and carbon content were aggregated using a thickness-weighted mean, while SOC stocks and soil mass were calculated by summing values across layers. For the ESM calculation, we did not exclude the 60–100 cm layer from the 2019 data. Since the ESM approach adjusts both SOC stocks and layer depth limits, including the last layer is essential if the reference soil mass is not reached within the top 60 cm.

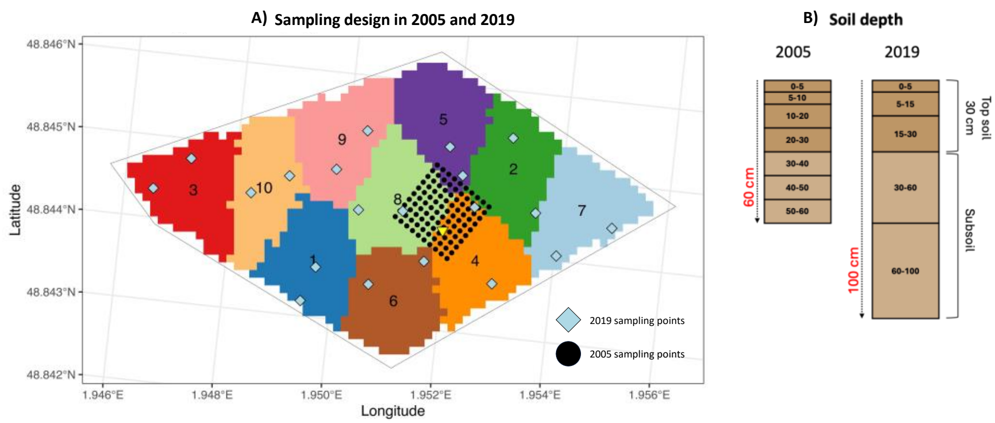

Figure R9. Sampling design in 2019 and 2005. (A) The numbers are the 2019 strata. The yellow triangle stand for the Eddy Covariance mast. The soil depths are shown in (B)

L387: kg ha-1 is preferred over g m-2 in my opinion

We have been harmonized the units in kg C m^{-2}, with additional presentation in Mg C ha^{-1} in parenthesis.