Revision EGUSPHERE-2025-5065

Point by point response to the reviewers:

First of all, we would like to thank the editor and the reviewers for the positive and constructive comments. We carefully revised and improved the article. The followings are response to the comments of reviewers. The line number below is indicated based on the **clean version.**

Reviewers #1:

General Comments

The manuscript presents valuable insights from a two-year measurement campaign of CO_2 fluxes in a tea plantation in China. The study compares plots subjected to different intercropping treatments, providing an interesting perspective by distinguishing emissions from tea rows and inter-row spaces. The discussion is comprehensive; however, additional experimental details would enhance the reader's ability to interpret the results. Aside from this, I have only a few minor comments (see below). Overall, the paper falls within the scope of *Biogeosciences* and merits publication after these minor revisions are addressed.

Response: Thank you very much for your positive comments. We have revised the manuscript and answered the questions point by point. The line number below is indicated based on the clean version.

Specific Comments：

Abstract

1. Lines 28–31: These absolute values are difficult to interpret without broader context regarding tea plantation emissions. Readers will likely be more interested in relative changes compared to control plots, as mentioned in line 41. Please provide relative changes for the total flux as well (see comment on line 41).

   Response: Thank you for the comments Your viewpoint is indeed more accurate. We have removed the average values and replaced them with the relative changes in average fluxes. We revised the description (Lines 29–32).

"Average tea-row fluxes were 8.7% and 9.5% lower under SM and HM, respectively, compared to CK, indicating emission reductions with intercropping. In contrast, average inter-row fluxes increased by 19.4% under SM and 7.7% under HM, demonstrating pronounced spatial contrasts."

2. Lines 32–33: Specify for which plots midday peaks occurred.

   Response: Thank you for the comments. While diurnal variations differed slightly between tea rows and inter-rows and among different treatments, it is worth noting that, overall, the peak fluxes predominantly occurred around midday. We revised the description (Lines 32–35).

   "Diurnal patterns generally exhibited midday peaks (12:00–14:00), especially in summer and autumn across all tea-rows, and short-term CO_2 pulses were triggered by field operations such as fertilization and pruning."

3. Line 41: The relative changes reported do not correspond to the values in lines 28–31. Be more precise which aggregates are shown and used for the relative changes.

   Response: Thank you for the comments. The reported percentage changes are based on the total annual emissions (derived from the fluxes), rather than on the average flux values alone, and have been revised accordingly as suggested. We revised the description (Lines 41–43).

   "Compared to CK, intercropping reduced tea-row emissions by 7.1–7.9% but increased inter-row emissions by 12.7–28.9% based on the two years cumulative emissions, continuous intercropping significantly decreased overall inter-row emissions over time."

4. Lines 40–45: This section is unclear. Tea-row and inter-row fluxes appear similar in magnitude (e.g., 8.12 CK (tea-row) vs. 9.07 CK (inter-row)). Tea-row emissions decrease by 7–8%, while inter-row emissions increase by 13–29%. How does this support the conclusion that intercropping is a climate-smart management strategy?

   Response: Thank you for the question. This question is of great significance. In fact, the comparisons in the text should be understood within the correct frame of reference. Whether for the tea rows or the inter-rows, the emission data are relative to "tea plantations with no fertilization." For traditional agricultural economic tea plantations, the amount of fertilizer applied is huge. Most importantly, the overall emissions from the "green manure intercropping" tea plantation remain significantly lower than those from conventionally fertilized tea plantations. This demonstrates that intercropping, as an integrated system, has a clear emission reduction effect.

Furthermore, and more importantly, evidence on the temporal scale shows that over the two-year period, emissions from the tea rows continued to decrease, while emissions from the inter-rows dropped significantly in the second year compared to the first. This powerfully indicates that the emission reduction benefits of green manure intercropping require time to stabilize and fully manifest across the entire system, including the inter-rows, highlighting the critical importance of sustained implementation for achieving long-term and stable emission reductions.

5. Add to the abstract: measurement method (flux chambers), campaign duration, and dataset size.

   Response: Thank you for the comments. We revised the description (Lines 23–27).

   "We employed the static chamber method over a two-year period, with sampling conducted weekly, to investigate how intercropping with *Vulpia myuros* C. (SM) and a legume–nonlegume mixture of *Lolium perenne* L. and *Trifolium repens* L. (HM) influenced spatial CO_2 flux dynamics compared with a no-intercropping control (CK) from tea rows and inter-row zones in a subtropical tea plantation.**"**

Experimental Setup (Lines 164 ff.)

1. Provide more details: plantation size, distances between plots and replicates, age of plantation and tea plants, etc.

   Response: Thank you for your valuable and professional comments. The detailed information has been added to Section 2.1 (Lines 165–169) and Section 2.2 (Lines 178–181), respectively.

In Section 2.1 (Lines 165–169):

"The tea plantation was established in 2015; the tea plants are 8–10 years old and arranged in a single-row planting pattern with a row spacing of 150 cm and a plant spacing of 40 cm."

In Section 2.2 (Lines 178–181):

"The experimental tea plantation covered an area of approximately 1000 m². For each treatment, three representative tea rows were selected as three replicates. Adjacent treatments were separated by two tea rows (~3 m), and replicate areas within the same treatment were spaced approximately 5 m apart."

2. Consider adding a schematic (with dimensions) to Figure 1. Clarify whether tea plants were inside the chambers.

Response: Thank you for your constructive comment. Figure 1b is a field photo of the experimental setup. The silver chamber shown is the flux chamber, which fully enclosed the tea plant. We have revised the figure by adding the specific dimensions of the flux chamber next to it in the image. (A photo of the chamber placed in an inter-rows location has also been added to panel b.)

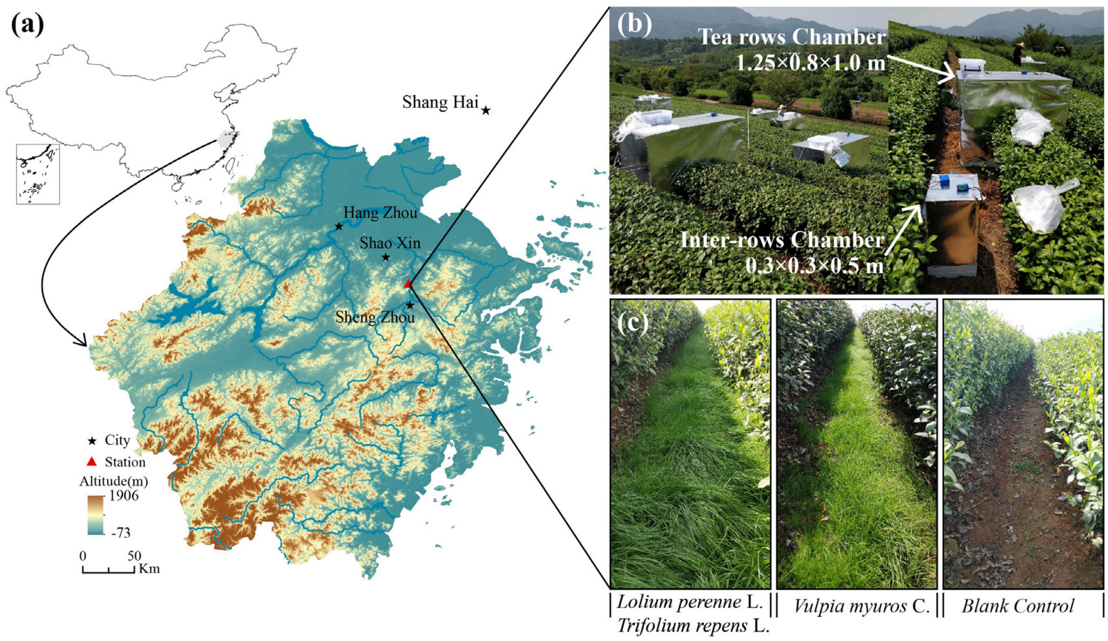


Figure 1. (a) Geographic location of the study area in Shengzhou City, Zhejiang Province, China; (b) field layout of the tea plantation experiment; (c) photos of *Lolium perenne* L. and *Trifolium repens* L. plot, and *Vulpia myuros* C. plot, the blank control plot, respectively.

3. According to lines 183–184, one measurement included four samples every 7 minutes: indicate when the first sample was taken after chamber closure and how long (overall) a single experiment took. How high were the CO_2 concentrations at the end?

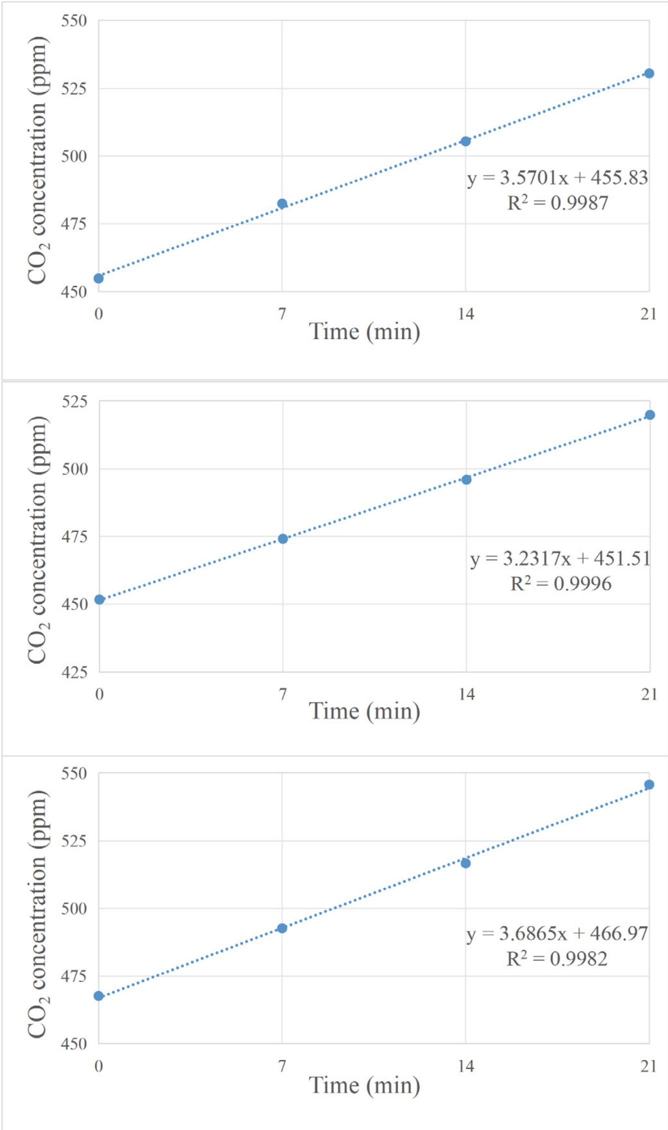
Response: Thank you for your questions. This comment covers several issues; we have addressed each of the points raised below in a point-by-point manner:

We collected four gas samples during the 21-minute period after chamber closure to calculate the flux at each point. The CO_2 concentration of the final gas sample is provided in the representative data table below. Data shown are means ± SE.

Type	Spring (ppm)	Summer (ppm)	Autumn (ppm)	Winter (ppm)
CKT	559.38±9.04	603.10±27.82	586.91±10.10	506.64±5.33f
HMT	550.06±9.72	569.38±23.78	574.68±8.07	507.70±4.94
SMT	550.44±8.61	583.63±24.70	575.51±8.85	503.52±4.85
CKG	705.94±26.25	705.93±30.60	662.62±16.00	563.34±6.88
HMG	719.34±24.49	725.38±34.82	681.12±15.92	559.16±10.55
SMG	740.50±27.08	757.70±36.72	708.70±19.18	581.16±11.75

Include an example showing the 4 measured CO_2 concentrations over time (perhaps in the appendix) and illustrate how fluxes were calculated. Was a linear fit applied to the four data points? How linear was the CO_2 increase? How consistent were the three replicates?

Response: Thank you for your questions. Fluxes were calculated by determining the linear slope from four gas concentration measurements. We added the formula in Appendix 1. All fitted slopes selected for flux calculation exhibited high linearity, with $R^2 > 0.95$. To ensure data reliability, outliers and points with large standard deviations were excluded during quality control. The resulting consistency across replicates is reflected in the standard deviations of the mean fluxes, as shown in Fig. 2b, c. The following figure illustrates the slope of the linear regression of CO_2 concentration over time.



Were all six plots always sampled simultaneously? Did you ever observe decreases in CO_2 concentrations? Figure 2 shows only positive fluxes.

Response: Thank you for your questions. Sampling was conducted sequentially across the six treatments, and each full sampling cycle was typically completed within one hour. Dark chambers covered with aluminum foil were used to measure respiratory fluxes. No significant decline in CO_2 concentration was observed during long-term flux measurements. However, a limited number of negative flux values were recorded during diurnal observations in spring and winter, as detailed in the diurnal variation section.

Include an uncertainty analysis for flux determination.

Response: Thank you for your comments. We added it (Lines 217–224).

"During the tests, the deviation between the calculated regression values of CO_2 and the nominal mole fractions was 0.37 μmol mol^{-1}. The linear fit between the instrument response values and the nominal mole fractions achieved a correlation coefficient (R^2) of 0.9999. Furthermore, the standard gases used were calibrated in multiple rounds by the Greenhouse Gas Laboratory of the Atmospheric Observation Center of the China Meteorological Administration using primary standard gases, ensuring traceability to the World Meteorological Organization primary standards."

Figure and Table Captions

1. Add a condensed explanation of your three letter codes to the different figure/table captions: Something like: CK = control, SM and HM = intercropping types, T = tea row, G = inter-row.

   Response: Thank you for this helpful suggestion. We agree that adding a condensed explanation of the letter codes to the figure and table captions will significantly improve their clarity for readers. Accordingly, we add the following note to all relevant captions: "CK for control; SM and HM for intercropping types, T for tea row, G for inter-row."

Results

1. Line 243: Explain what the uncertainties represent.

Response: The uncertainty mentioned here refers to the standard deviation. We have added a clarification regarding the flux data presentation in the text (Line 261) as follows: “Data shown are means ± standard error (SE).”

2. Line 245: Specify the significance level for “significantly higher.”

   Response: Thank you for your suggestion. We have added the notation "($p < 0.05$)" in the “2.3 Data Processing” section (Lines 261–262).

   “In all statistical tests, the level of significant differences and correlations was set at $p < 0.05$.”

Figures and Tables

1. Figure 2: Clarify whether error bars indicate uncertainty of a single flux measurement or standard deviation across duplicates.

   Response: Thank you for your comments. The error bars represent the standard error of the mean among repeated measurements. We have added the relevant description in the Figure 2.

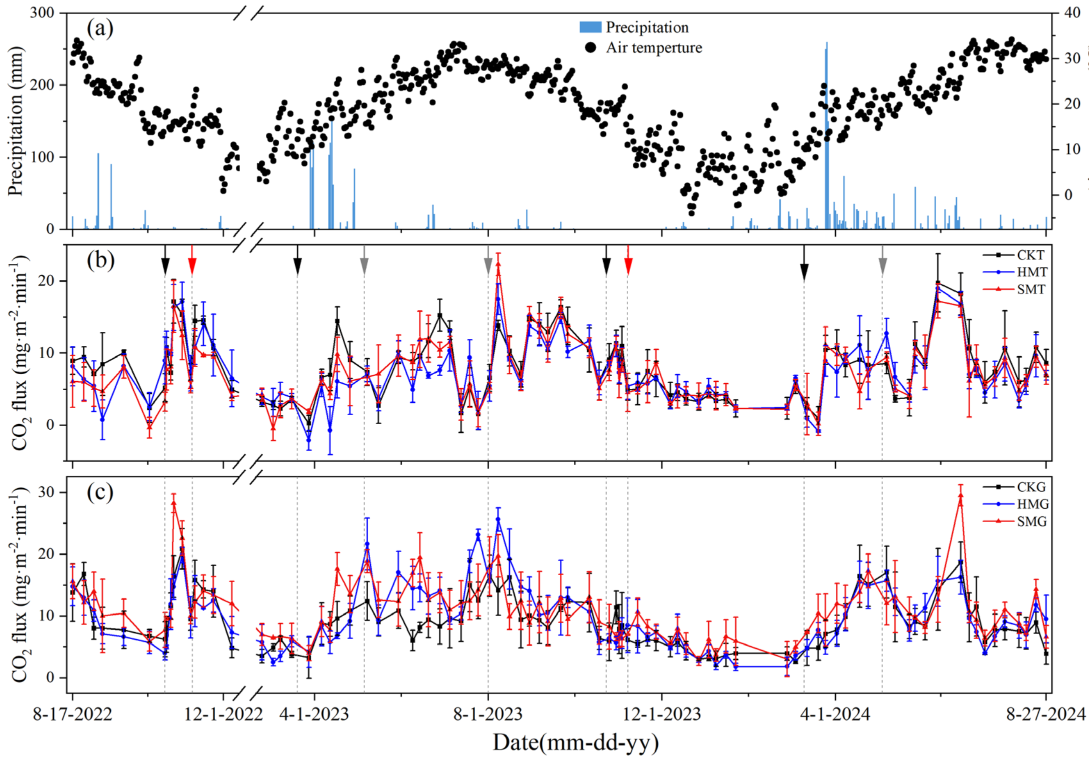
2. Table 1: Explain ± values and superscript letters.

   Response: Thank you for your comments. In this study, data are presented as mean ± standard error (SE). The use of SE is preferred when making inferences about the population mean or comparing the differences between group means. The superscript letters indicate significant differences between seasons and treatment types, as determined by two-way ANOVA. Different letters denote statistically significant differences ($p < 0.05$). we added the descriptions in Table 1.

3. Figure 2: Use a different color for precipitation vs. temperature. Confirm whether negative CO_2 fluxes were ever observed. Were tea plants present in the chambers?

   Response: Thank you for your comments. We have revised Figure 2. Measurements were predominantly conducted on clear mornings, with net CO_2

emissions observed in the majority of cases and only weak negative fluxes recorded at a few time points. The tea plant was enclosed inside the measurement chamber during sampling; it can be seen in revised Figure 1b.



4. Figure 3: Explain superscript letters and error bars. Add "T" for tea row and "G" for inter-row in the legend.

Response: Thank you for your comments. In this study, data are presented as mean ± standard error; superscript letters denote significant groupings based on two-way ANOVA with Tukey's post-hoc test. We added it (Lines 919–920).

"Data shown are means ± SE. Different superscript letters denote statistically significant differences (p < 0.05). CK for control; SM and HM for intercropping types, T for tea row, G for inter-row." in the Figure 3 legend.

Results

1. Lines 354 ff.: The consistent differences in soil properties are surprising given the short distances. Provide more detail on plantation history and intercropping duration. When did the intercropping practices start?

Response: Thank you for your comments. The CKG and SMG treatments were spatially separated by three tea rows (approximately 5 m). Green manure intercropping was maintained for two years, with sowing conducted each November and decomposition occurring by August of the following year. Under the SM treatment, which involved continuous coverage of *Vulpia myuros* over two years, hence changes in soil properties were observed. The presented data represent the two-year averages of soil ammonium-N and nitrate-N concentrations. We added more detail on plantation history and intercropping duration. (Lines 166–169; 176–181; 184–190).

"The tea plantation was established in 2015; the tea plants are 8–10 years old and arranged in a single-row planting pattern with a row spacing of 150 cm and a plant spacing of 40 cm."

"The experimental tea plantation covered an area of approximately 1000 m². For each treatment, three representative tea rows were selected as three replicates. Adjacent treatments were separated by two tea rows (~3 m), and replicate areas within the same treatment were spaced approximately 5 m apart."

"Tea plantation followed standard management practices, including fertilization, pruning, and tillage. Every late October, after trenching and soil turning between the tea rows, rapeseed cake (975 $kg \cdot ha^{-1}$) and compound fertilizer (375 $kg \cdot ha^{-1}$) were applied as basal fertilizer. Green manure sowing was carried out in early November: *Vulpia myuros* C. (SM) was sown at a seeding rate of 6 $kg \cdot ha^{-1}$; *Lolium perenne* L. and *Trifolium repens* L. (HM) were sown as a mixed culture at seeding rates of 18 $kg \cdot ha^{-1}$ and 4 $kg \cdot ha^{-1}$, respectively."

Conclusions

1. Line 587 refers to the mitigation of carbon losses. Quantify overall CO_2 emission reductions when summing tea-row and inter-row fluxes for HM, SM, and CK. Data (e.g. in abstract, see my comment there) do not support it and Figure 3 suggest reductions only for HM in the second year. If mitigation exists, contextualize its

potential impact at larger scales.

Response: Thank you for your comments. The values mentioned are relative to the CK treatment, and we have added "compared to the CK" in line 629. We also recognize that the net mitigation effect at the small plot scale over a two-year period may be limited. The mitigation effect is primarily manifested as a significant reduction in emissions from the tea-row zone, which offsets the initial increase observed in the inter-row area. The clear declining trend in inter-row emissions under the HM treatment in the second year suggests that the initial emission pulse was likely a transient response to soil disturbance during the green-manure establishment phase, and that its mitigation potential strengthens over time. Future management could be optimized to maximize emission reduction in tea rows while minimizing disturbance in inter-row areas, thereby enhancing the overall net benefit.

2. Add general considerations on intercropping: benefits and drawbacks (costs, labor, temperature effects, soil compaction, aeration, etc.). Large-scale adoption depends on whether benefits outweigh additional costs.

Response: We thank the reviewer for raising this important perspective. We agree that the widespread adoption of any agricultural technology depends on its net benefits. We revised the description (Lines 638–647).

"Continuous green manure intercropping over two years significantly reduced inter-row CO_2 emissions, and the HM treatment suppressed fertilization-induced emission peaks. These findings demonstrate that green manure intercropping, particularly mixed legume and non-legume combinations, can effectively alter the spatial pattern of CO_2 emissions and mitigate carbon losses. Moreover, this practice provides significant co-benefits like improved soil aeration and fertility, reduced chemical fertilizers, weed suppression, and promoted tea plant growth, thereby offsetting the extra costs in labor and seeds. Therefore, green manure intercropping emerges as a practical and multifunctional strategy for reducing carbon emissions in agroecosystems."

Reviewers #2:

General Comments

This study focuses on a subtropical tea plantation and utilizes the static chamber–gas chromatography method to conduct long-term monitoring of CO_2 emission fluxes under different green manure intercropping treatments. It systematically reveals the short- and long-term trends and differences in CO_2 fluxes across different areas of the tea garden, including between tea rows, and analyzes the impact of key environmental drivers such as soil temperature, moisture, and organic carbon on carbon emissions. The findings provide important insights into the carbon cycling mechanisms in tea plantations under green manure intercropping and hold significant practical value for promoting low-carbon management in tea cultivation. The experimental design is reasonable, the analysis and discussion are thorough, and the structure is clear, making the paper suitable for publication in this journal. The following minor revisions are recommended:

Response: Thank you very much for your positive comments. We have revised the manuscript and answered the questions point by point. The line number below is indicated based on the clean version.

Specific Comments：

1. Lines 153–154: The baseline physicochemical properties of the soil in the study area are not provided. It is recommended to include initial soil characteristics.

   Response: Thank you for the comments. We have supplemented a detailed table of the basic physicochemical properties of the six treatment soils before the experiment (now Table 1) in Sec. 2.1 Lines 169–171.

   "The soil type of the tea plantation is classified as red soil (Ultisol), a typical soil type in this region, and the initial basic physicochemical properties of the six treatment soils are shown in Table 1."

2. Line 171: In addition to the green manure treatment, please specify the type and application rate of fertilizers used.

Response: Thank you for your comment. Regarding the fertilizer treatments mentioned on lines 185-187, the specific types and application rates are as follows:

On October 21, 2022, rapeseed cake was applied as base fertilizer at a rate of 300 kg per mu after trenching and soil turning between the tea rows. On October 28, 2023, base fertilizer consisting of rapeseed cake (65 kg per mu) and compound fertilizer (25 kg per mu) was applied following trenching and soil turning in the tea row inter-rows.

3. Line 185: For consistency, please express time in 24-hour format. Replace "between 9:00 and 11:00 a.m." with "between 09:00 and 11:00 (local time)."

   Response: Thank you for the comments. We revised it (Line 207).

4. Line 198: What was the soil sampling depth? This significantly influences soil physicochemical properties. Sampling across multiple soil layers would be more appropriate.

   Response: Thank you for the suggestion. The soil sampling depth was 0–20 cm. The core focus of this study is the impact of green manure treatments on soil carbon processes in tea plantations. Since the root systems of green manure and their incorporation primarily concentrate in the 0–20 cm soil layer, sampling at this depth most directly reflects the treatment effects. To avoid destructive deep-layer sampling that could harm the root systems of productive tea plants and to ensure the continuity of long-term observations, this biologically active layer was selected as the representative depth, which is also a commonly adopted standard in comparable studies both domestically and internationally. We recognize the value of stratified sampling and will aim to refine this aspect in future research.

5. Lines 216–217: The method for calculating CO_2 fluxes is not clearly described. Please provide details.

   Response: Thank you for the comments. The description of the CO_2 flux calculation method has been added in the Appendix 1.

6. Lines 308–310: On what basis were the growth stages of green manure defined? Please clarify.

   Response: Thank you for the comments. The growth stages of green manure are divided as follows: early growth stage (from mid-November to early April of the following year, primarily functioning for soil surface coverage and water-soil conservation), vigorous growth stage (from mid-April to late May, when biomass and nutrient retention peak), wilting stage (from early June to late July, as the plants naturally wither and prepare for incorporation), and decomposition stage (during August each year, when residues rapidly decompose and release nutrients). This division is based on field phenological observations and biomass dynamics, clarifying the functional transition of each stage within the tea garden ecosystem—from growth and accumulation to incorporation and decomposition—to precisely align with the nutrient management needs of tea garden soils.

7. Lines 498–499: The decrease in cumulative emissions between rows in the second year is attributed to "reduced human disturbance," which is insufficiently supported. Please elaborate with references to relevant literature.

   Response: Thank you for your comments. Yes, attributing the decrease in CO_2 emissions simply to "reduced anthropogenic disturbance" is overly general. In this study, the cumulative CO_2 emissions from the inter-row areas in the second year were lower than those in the first year across all treatments, with a more pronounced reduction observed in the green manure treatments (HM, SM). We believe this change is closely related to the gradual attenuation of the priming effect caused by initial soil disturbance and the continuous improvement in soil structure facilitated by green manure growth. We added more discussion in Sec. 4.2 (Lines 537–549).

   "The decrease in emissions can be attributed to the gradual attenuation of the carbon priming effect induced by soil disturbance during the initial experimental phase (Zhou, 2025), coupled with the long-term positive effects of green manure on enhancing soil physical structure and ecosystem stability (Gui et al., 2024). The increase in green manure biomass in the following year indicates that the green manure system is transitioning from an initially disturbed and unstable state toward a more productive and carbon-sequestration-enhanced stable state (Figure A1). This trend not only reflects the improved functioning of the soil ecosystem and drives further carbon sequestration in the tea plantation, but also provides crucial support for the significant reduction in inter-row CO_2 emissions observed in the following year, which closely aligns with the hypothesis that green manure intercropping promotes the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase."

8. Line 541: The discussion on the SOC threshold lacks adequate references. Additional literature should be cited and discussed.

   Response: Thank you for the comments. We added more discussion in Sec. 4.3 (Lines 595–602).

   "Studies in different climatic zones of China have revealed that SOC thresholds are influenced by factors such as climate and soil type. In the maritime monsoon climate zone, dual thresholds for NO_3^--N and extractable iron (Fe) have been identified, beyond which their marginal effects on SOC shift significantly. In the continental monsoon climate zone, SOC content increases markedly once a critical threshold of TN is exceeded (Cui, 2025). Additionally, research in alpine ecosystems has shown that SOC components vary along elevation gradients and exhibit distinct thresholds (Zhang, 2025)."

9. Table 1: Please clearly note "Values are mean ± SE" in the table caption or footnote.

   Response: Thank you for the comments. We noted "Data shown are means ± SE." in the table 1 footnote.

10. Root biomass data are lacking. The contribution of green manure roots to soil respiration has not been quantified, which may affect the interpretation of CO_2 flux

sources.

Response: Thank you for your important comment. We have added Figure A1 in Appendix 1, which presents the green manure biomass (including above ground parts and root systems) for the HM and SM treatments. The biomass was measured as fresh weight immediately after sampling and as dry weight after oven-drying at 65°C to constant weight. We added more discussion in Sec. 4.2 (Lines 537–549).

"The decrease in emissions can be attributed to the gradual attenuation of the carbon priming effect induced by soil disturbance during the initial experimental phase (Zhou, 2025), coupled with the long-term positive effects of green manure on enhancing soil physical structure and ecosystem stability (Gui et al., 2024). The increase in green manure biomass in the following year indicates that the green manure system is transitioning from an initially disturbed and unstable state toward a more productive and carbon-sequestration-enhanced stable state (Figure A1). This trend not only reflects the improved functioning of the soil ecosystem and drives further carbon sequestration in the tea plantation, but also provides crucial support for the significant reduction in inter-row CO_2 emissions observed in the following year, which closely aligns with the hypothesis that green manure intercropping promotes the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase."

11. Within the closed chamber environment, temperature and humidity change over time, potentially influencing CO_2 flux measurements. Further analysis on this aspect is recommended.

Response: Thank you for the comments. The static chamber method has an inherent limitation: changes in the chamber micro-environment (temperature, humidity, air pressure) during measurement may affect the calculated CO_2 flux. To minimize this impact, the following measures were taken in this experiment:

1. Controlled measurement duration: The chamber closure time was strictly limited to 21 minutes for each measurement to reduce accumulated deviation in the chamber environment.

2. Standardized operation: Measurements were conducted during periods of stable weather. A fan was installed inside the chamber to mix the air, while the exterior was wrapped with aluminum foil and sponge to prevent rapid internal temperature rise due to direct sunlight during sampling.

3. Linear relationship verification: We ensured that the CO_2 concentration showed a strong linear relationship with time within the selected measurement window ($R^2 > 0.95$), indicating that changes in respiration rate due to chamber environmental variations were not significant during the measurement period.

12. The study does not explore how different green manure treatments regulate microbial activity or the mechanisms by which soil microbial communities drive carbon sequestration. If relevant measurements were not included, this could be addressed in future research.

Response: Thank you for the comments. We fully agree that elucidating how green manure treatments drive soil carbon sequestration by regulating microbial activity and community structure is a crucial component for a complete explanation of the ecological mechanisms involved. The current study primarily focuses on the response relationships among green manure, soil physicochemical properties, and CO_2 emission fluxes. Due to limitations in research design and duration, it did not include measurements related to microbial community structure and function. Follow-up research will place greater emphasis on investigating the role of soil microorganisms.

13. The language throughout the manuscript should be further refined to avoid repetitive statements, particularly in the Results and Discussion sections.

Response: Thank you for the comments. We have refined the language throughout the manuscript to improve conciseness and eliminate repetitive statements. The revisions have focused on consolidating redundant descriptions, employing more precise and varied phrasing, and strengthening the logical flow of the argument.

Reviewers #3:

This manuscript examines how green manure intercropping with grasses and grass–legume mixtures influences spatial and temporal patterns of soil CO_2 fluxes in a subtropical tea plantation, with a focus on contrasts between tea-row and inter-row zones. The dataset appears extensive, and the field effort is clearly substantial. However, based on the current framing in the introduction, the broader scientific importance and implications of the study would benefit from further clarification and strengthening before the manuscript is ready for publication.

Response: Thank you very much for your positive comments and valuable suggestions. Your professional opinions have significantly enhanced the overall professionalism and clarity of our thesis. We are very glad that you can offer such professional guidance on the revision of our work. Based on your valuable comments, we have thoroughly revised the manuscript. Improvements have been made in the background introduction of the paper, the grasp of the theme, the clarity of the method introduction, the description of the result calculation, and the depth of the discussion. The paper is more accurate and in-depth as a whole. We are also very satisfied that the results of our hard work and research have finally been better presented. Thank you very much for your guidance. Below are our provided detailed point-by-point responses to all the questions raised. All line numbers cited below refer to the clean version.

The introduction places the study within the context of greenhouse gas emissions, but this framing would benefit from greater conceptual precision. In agricultural systems, soil CO_2 fluxes are not necessarily equivalent to net GHG emissions, as their climatic relevance depends strongly on C origin. CO_2 derived from root respiration or recent plant inputs is part of the short-term carbon cycle rather than a net climatic forcing. Clarifying whether the measured CO_2 fluxes represent autotrophic respiration, heterotrophic respiration, or their combination would greatly improve interpretation of the results and help align the study more clearly with its stated climate relevance.

Response: Thank you for this insightful comment. This point was indeed not expressed clearly in our article. Thank you for pointing it out. We fully agree that distinguishing between autotrophic and heterotrophic respiration is crucial for accurately interpreting the sources of CO_2 fluxes and their climatic implications. The static chambers used in this study covered tea plants, green manure, and the rhizosphere soil, and thus the measured CO_2 fluxes represent the combined flux of autotrophic respiration (roots of tea plants and green manure) and heterotrophic respiration (soil microorganisms). We focused on investigating how green manure inputs drive the variation trends of fluxes by influencing heterotrophic respiration, including the decomposition of fresh residues and native soil organic carbon. We added more descriptions in Section 2.3 (Lines 246–249).

"Static chambers were placed to cover tea plants, green manure plants, and the topsoil (0–15 cm). The monitored CO_2 fluxes represent the total ecosystem respiration of the tea plantation, including autotrophic respiration from plant roots and heterotrophic respiration from soil microorganisms."

In addition, although N_2O emissions are mentioned in the introduction, they are not included in the study, and refining the scope of the introduction to better match the measurements would improve coherence.

Response: Thank you for your professional suggestions, which are precise and highly consistent with the research logic. This research took a considerable amount of time and involved a large amount of work and data. This study mainly focuses on the main processes of soil CO_2 fluxes and carbon cycling in tea plantations, the observation system and data collection were designed centering on this core theme, and relevant observation indicators for N_2O emissions were not included for the time being. Thus, no relevant analysis was conducted in this study. Certainly, we will add relevant observations of nitrous oxide emissions in subsequent research to further improve the studies on greenhouse gas emissions from tea plantation soils. We have removed the introduction related to N_2O in the background and strictly limited the scope of the introduction related to the article topic.

The motivation for the study currently appears to rest primarily on the limited number of prior studies examining soil CO_2 dynamics in tea plantations with green manure intercropping. While this system-specific focus is valuable, the manuscript would be strengthened by more clearly articulated scientific questions and testable hypotheses that highlight the underlying processes or mechanisms being investigated. As written, the study is largely descriptive, and the novelty would be clearer if the authors explicitly stated what new conceptual or mechanistic insights are expected beyond documenting spatial and temporal flux patterns.

Response: Thank you for your insightful and constructive comments, which have greatly guided us to improve the scientific rigor and innovation of this manuscript. We have added more explanations in the Introduction and discussion to highlight the hypothetical expectations and deep-seated goals of the study to enhance the novelty of the article (Lines 143–153, 537-549, 594-602).

"We propose the following hypotheses: intercropping tea plantations with green manure will alter the spatiotemporal pattern of CO_2 emissions by regulating the soil microenvironment and carbon input dynamics, thereby driving the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase. This study quantifies the dynamics of CO_2 fluxes in tea rows and inter-row areas under different green manure intercropping patterns, analyzes their key influencing factors, and aims to reveal how the green manure system transitions from an initial disturbance phase to a long-term stable phase of emission reduction, thereby elucidating the underlying mechanisms by which green manure intercropping regulates carbon fluxes in tea plantations and providing support for the development of low-carbon tea plantations and sustainable regional agriculture."

"The decrease in emissions can be attributed to the gradual attenuation of the carbon priming effect induced by soil disturbance during the initial experimental phase (Zhou, 2025), coupled with the long-term positive effects of green manure on enhancing soil physical structure and ecosystem stability (Gui et al., 2024). The increase in green manure biomass in the following year indicates that the green manure system is transitioning from an initially disturbed and unstable state toward a more productive and carbon-sequestration-enhanced stable state (Figure A1). This trend not only reflects the improved functioning of the soil ecosystem and drives further carbon sequestration in the tea plantation, but also provides crucial support for the significant reduction in inter-row CO_2 emissions observed in the following year, which closely aligns with the hypothesis that green manure intercropping promotes the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase."

"Conversely, in SOC-rich soils, nitrogen fertilization may enhance microbial metabolic efficiency and increase microbial residue production (Ling et al., 2025). Studies in different climatic zones of China have revealed that SOC thresholds are influenced by factors such as climate and soil type. In the maritime monsoon climate zone, dual thresholds for NO_3^--N and extractable iron (Fe) have been identified, beyond which their marginal effects on SOC shift significantly. In the continental monsoon climate zone, SOC content increases markedly once a critical threshold of TN is exceeded (Cui, 2025). Additionally, research in alpine ecosystems has shown that SOC components vary along elevation gradients and exhibit distinct thresholds (Zhang, 2025)."

Similarly, the role of green manure would benefit from clearer definition and context. It is not always clear whether green manure refers to cover crops or other intercropping practices.

Response: Thank you sincerely for the insightful comments. We further provided a clearer description of the management methods of green manure and other aspects. In this study, the green manure system is implemented as an "intercropping system conducted between tea rows, with ecological coverage as its primary function." Here, "intercropping" describes its spatial arrangement and cropping system, while "cover crop" refers to its management as a perennial living mulch, characterized by the key practice of avoiding artificial incorporation, thereby enabling it to perform sustained ecological covering functions.

We have made important additions in Sec. 2.2.

“The experimental tea plantation covered an area of approximately 1000 m². For each treatment, three representative tea rows were selected as three replicates. The experiment followed a completely randomized block design, with individual treatment plots measuring 20 m in length and 3 m in width. Adjacent treatments were separated by two tea rows (~3 m), and replicate areas within the same treatment were spaced approximately 5 m apart.” (Lines 176–181).

“Green manure sowing was carried out in early November: *Vulpia myuros* C. (SM) was sown at a seeding rate of 6 kg·ha^{-1}; *Lolium perenne* L. and *Trifolium repens* L. (HM) were sown as a mixed culture at seeding rates of 18 kg·ha^{-1} and 4 kg·ha^{-1}, respectively. As intercropped cover crops, both green manure treatments were allowed to grow naturally, lodge, and cover the soil surface without artificial incorporation. Topdressing was applied in late February of the following year, with urea used at a rate of 300 kg·ha^{-1}. Tea leaves were harvested at the end of March, and pruning was normally conducted in May and July.” (Lines 187–194).

Relevant literature on how green manure influences soil C cycling could be more fully integrated.

Response: Thank you for this valuable suggestion. We have incorporated a synthesis of relevant literature on how green manure influences soil carbon cycling (Lines 130-135).

“Previous studies have shown that green manure can alter soil organic carbon turnover by inputting plant residue carbon sources into the soil (Li et al., 2024), and may comprehensively influence carbon cycling and CO_2 emissions in agricultural ecosystems through pathways such as regulating the microbial carbon pump function and reducing the carbon priming effect (Gui et al., 2024; Zhou et al., 2025).”

Statements regarding green manure introducing soil disturbance would also benefit from additional explanation or supporting evidence.

Response: Thank you for your valuable comment. Other reviewers also proposed the support for the literature description. We have searched for and added more literature descriptions that support the impact of green manure on soil characteristics. At the same time, we have also added the data results of green manure biomass and placed them in the attached Figure A1 to explain the impact of green manure on soil in combination with the literature research. We have added the manuscript to provide a more nuanced explanation (Lines 537–549).

"The decrease in emissions can be attributed to the gradual attenuation of the carbon priming effect induced by soil disturbance during the initial experimental phase (Zhou, 2025), coupled with the long-term positive effects of green manure on enhancing soil physical structure and ecosystem stability (Gui et al., 2024). The increase in green manure biomass in the following year indicates that the green manure system is transitioning from an initially disturbed and unstable state toward a more productive and carbon-sequestration-enhanced stable state (Figure A1). This trend not only reflects the improved functioning of the soil ecosystem and drives further carbon sequestration in the tea plantation, but also provides crucial support for the significant reduction in inter-row CO_2 emissions observed in the following year, which closely aligns with the hypothesis that green manure intercropping promotes the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase."

The Materials and Methods section would benefit from substantially more detail to allow readers to fully evaluate the experimental design and reproduce the study. Important information that should be clarified includes the timing of green manure planting and termination, planting rates, termination methods. Plot layout and size, the presence of buffer zones between treatments.

Response: Thank you for your constructive comment. We have added more detailed introductions such as the management of green manure, the conditions of the experimental area, and the management of artificial fertilization, enabling readers to have a clearer understanding of our experiments. Based on your opinion, our method section is indeed clearer and more accurate. The detailed information has been added to Section 2.2:

"The experimental tea plantation covered an area of approximately 1000 m^2. For each treatment, three representative tea rows were selected as three replicates. The experiment followed a completely randomized block design, with individual treatment plots measuring 20 m in length and 3 m in width. Adjacent treatments were separated by two tea rows (~3 m), and replicate areas within the same treatment were spaced approximately 5 m apart." (Lines 176–181).

"Green manure sowing was carried out in early November: *Vulpia myuros* C. (SM) was sown at a seeding rate of 6 $kg{\cdot}ha^{-1}$; *Lolium perenne* L. and *Trifolium repens* L. (HM) were sown as a mixed culture at seeding rates of 18 $kg{\cdot}ha^{-1}$ and 4 $kg{\cdot}ha^{-1}$, respectively. As intercropped cover crops, both green manure treatments were allowed to grow naturally, lodge, and cover the soil surface without artificial incorporation. Topdressing was applied in late February of the following year, with urea used at a rate of 300 $kg{\cdot}ha^{-1}$. Tea leaves were harvested at the end of March, and pruning was normally conducted in May and July." (Lines 187-194).

Whether chamber bases included vegetation.

Response: Thank you for the comments. We revised Figure 1, as shown in Figure 1b, the static chamber fully enclosed the tea plant and the soil beneath it, while in the inter-row spaces it enclosed the green-manure vegetation and the underlying soil.

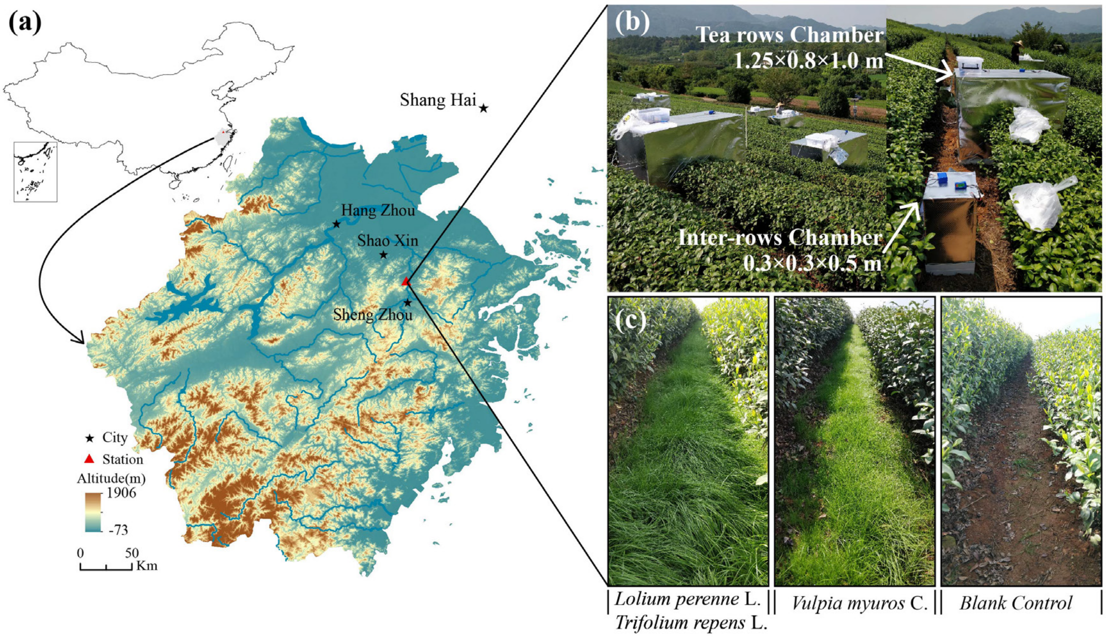


Figure 1. (a) Geographic location of the study area in Shengzhou City, Zhejiang Province, China; (b) field layout of the tea plantation experiment; (c) photos of *Lolium perenne* L., *Trifolium repens* L. and *Vulpia myuros* C. plot, the blank control plot, respectively.

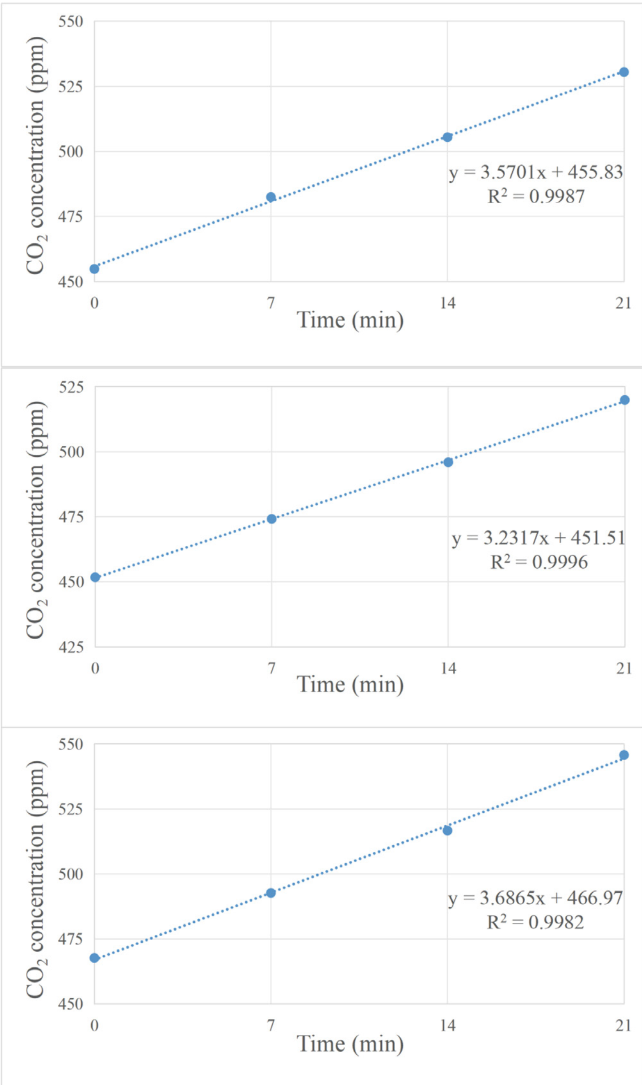
The rationale for diurnal monitoring, as well as how diurnal and seasonal variations were calculated, also needs to be more clearly explained.

Response: Thank you for the comments. Diurnal variation monitoring refers to intensive observations conducted at fixed sample points over a 24-hour period at two-hour intervals on representative sampling days within each season, we added the description (Lines 210-213). The primary aim is to directly reveal the dynamic variation patterns of CO_2 flux over a complete temperature-driven diurnal cycle.

"During these campaigns, gas samples were collected every 2 hours over a 24-hour period. After collection, samples were immediately placed in light-proof black bags, transported to the laboratory, and analyzed within 24 h using a gas chromatograph (Agilent 7890B, Agilent Inc., USA)."

Seasonal variation reflects the overall trend of CO_2 flux at an annual scale, with the CO_2 flux for each season calculated as the arithmetic mean of flux values from all sampling days within that seasonal group. Diurnal variation is represented by the raw data from the 24-hour intensive monitoring, plotted as a trend graph of CO_2 flux values to illustrate the diurnal dynamics of CO_2 fluxes in the tea plantation ecosystem across seasons.

Other reviewers also raised questions about the calculation method. Based on your comments, we further added the detailed calculation method in Appendix 1. Diurnal and seasonal fluxes were calculated by determining the linear slope from four gas concentration measurements. All fitted slopes selected for flux calculation exhibited high linearity, with $R^2 > 0.95$. To ensure data reliability, outliers and points with large standard deviations were excluded during quality control. The resulting consistency across replicates is reflected in the standard deviations of the mean fluxes, as shown in Fig. 2b, c. The following figure illustrates the slope of the linear regression of CO_2 concentration over time.



Several methodological aspects would benefit from clarification, including gas sampling and storage procedures.

Response: Thank you for the comments. In addition to the added content in the previous method section, we have further included the description of gas sampling analysis and treatment. The detailed information has been added to Section 2.2 Lines 203–205 and 211–213.

"Four gas samples were collected at 7-minute intervals using gas sampling bags, which were pre-purged with nitrogen and maintained under vacuum to prevent background gas interference."

"After collection, samples were immediately placed in light-proof black bags, transported to the laboratory, and analyzed within 24 h using a gas chromatograph (Agilent 7890B, Agilent Inc., USA)."

Flux calculation methods.

Response: Thank you for your questions. Fluxes were calculated by determining the linear slope from four gas concentration measurements. We added the formula in Appendix 1. All fitted slopes selected for flux calculation exhibited high linearity, with $R^2 > 0.95$. To ensure data reliability, outliers and points with large standard deviations were excluded during quality control.

Whether fresh soil was used for total C and N analyses.

Response: Thank you for pointing this out. The soil samples used for total carbon (TC) and total nitrogen (TN) analyses were fresh soil. We added more details in Lines 236–240:

"Prior to the analysis of total carbon (TC) and total nitrogen (TN) by elemental analysis, as well as soil organic carbon (SOC) by the dichromate oxidation–spectrophotometry method, the stored samples were freeze-dried, ground, and sieved through a 100-mesh sieve to remove impurities and moisture."

The distinction between injected gas and carrier gas.

Response: Thank you very much for pointing out this lack of clarity in the description, which has helped us improve the methodological details. The injected gas refers to the sampled gas collected from the gas sampling bags, introduced via valve injection. The carrier gas is the high-purity nitrogen (99.999%) that carries the sample through the chromatographic column for separation. The detailed information has been added to Section 2.2 (Lines 215–217):

"Carrier gas was high-purity nitrogen (purity 99.999%), and valve injection was employed with a single injection volume of 30 mL and an injection flow rate of 250 $mL \cdot min^{-1}$."

In addition, management activities such as fertilization, grass cutting or termination, and tea pruning are discussed in the Results and Discussion but should be more fully described in the Methods.

Response: Thank you for the comments. We have further described human management measures, including fertilization, grass cutting or termination, and tea pruning (Lines 185–194).

"Every late October, after trenching and soil turning between the tea rows, rapeseed cake (975 $kg \cdot ha^{-1}$) and compound fertilizer (375 $kg \cdot ha^{-1}$) were applied as basal fertilizer. Green manure sowing was carried out in early November: *Vulpia myuros* C. (SM) was sown at a seeding rate of 6 $kg \cdot ha^{-1}$; *Lolium perenne* L. and *Trifolium repens* L. (HM) were sown as a mixed culture at seeding rates of 18 $kg \cdot ha^{-1}$ and 4 $kg \cdot ha^{-1}$, respectively. As intercropped cover crops, both green manure treatments were allowed to grow naturally, lodge, and cover the soil surface without artificial incorporation. Topdressing was applied in late February of the following year, with urea used at a rate of 300 $kg \cdot ha^{-1}$. Tea leaves were harvested at the end of March, and pruning was normally conducted in May and July."

The discussion is logically structured, but it would benefit from deeper engagement with underlying mechanisms and clearer links back to explicit hypotheses. Terms such as “human management” would be clearer if they were more precisely defined and contextualized, including what conditions are being compared before and after management interventions.

Response: Thank you for your valuable suggestions, which have been instrumental in enhancing the scientific rigor and analytical depth of this manuscript. In light of your comments, we have carefully revised the content: we further elaborated on the potential mechanisms underlying green manure-mediated regulation of tea plantation CO_2 fluxes and added an analysis linking the results to the core research hypothesis (Lines 544–552).

The comparison of human management is the comparison before and after management. We also provided a specific and precise definition of the term “anthropogenic management” in combination with the actual experimental practices, clarifying its connotations and the control conditions for this study, thereby improving the clarity of the presentation. We have added the following relevant statements to make the description clearer (Lines 184–194, 358-359).

“Tea plantation followed standard management practices, including fertilization, pruning, and tillage.”

“We conducted a comparison of the differences in CO_2 emissions before and after the implementation of different human management measures.”

“This trend not only reflects the improved functioning of the soil ecosystem and drives further carbon sequestration in the tea plantation, but also provides crucial support for the significant reduction in inter-row CO_2 emissions observed in the following year, which closely aligns with the hypothesis that green manure intercropping promotes the ecosystem from an initial disturbance phase towards a long-term stable emission reduction phase.”

Additional clarification on how high-frequency flux measurements were aggregated or transformed to generate the reported temporal patterns would also strengthen interpretation.

Response: Thank you for your valuable suggestions. These requirements have significantly enhanced the transparency of our data processing and the rigor of our result interpretation. Our data processing workflow is as follows: First, we removed anomalous data points caused by operational or instrument-related issues. Subsequently, for multiple replicate observations under the same treatment, we calculated the arithmetic mean flux value and represented the data dispersion with the standard error (SE). We added it in Appendix 1.

"Based on the daily mean flux values, we further divided the data according to the green manure growth stages and seasons, calculating the mean flux values for each stage and season. The calculation of the annual cumulative CO_2 flux was estimated based on linear interpolation between adjacent sampling days."

Overall, the main take-home message and the broader contribution of the study would be clearer with a more analytical and mechanism-focused discussion rather than a primarily descriptive one. Overall, the dataset has potential, but the manuscript would benefit from conceptual reframing, clearer hypotheses, improved methodological transparency, and a more mechanistically grounded discussion. Addressing these points would substantially strengthen the scientific clarity and impact of the study.

Response: We sincerely thank you for your meticulous review of our manuscript and the constructive comments provided. Your insightful observations regarding areas for improvement in our conceptual framework, hypothesis clarity, methodological transparency, and depth of mechanistic discussion are highly appreciated.

These suggestions have significantly enhanced the scientific rigor and logical coherence of this paper. Based on your professional opinions, the revised paper is indeed more accurate, clear and in-depth as a whole. We are also very satisfied that the results of our hard work and research have finally been better presented. Thank you very much.