Dear Editor,

We appreciated the comments by the reviewers and yourself which certainly helped us to improve the manuscript. We addressed all comments and suggestions carefully, and revised our manuscript. Our one-by-one responses to the reviewers' comments are attached directly to the following text. Please don't hesitate to contact us if any open questions do remain. Thanks a lot!

Best regards,

Sincerely yours,

Zhisheng Yao and coauthors

Response to reviewers' comments:

Reviewer #RC1 (Remarks to the Author):

This manuscript addresses the current limitations in the understanding of biogeochemical carbon and nitrogen cycles in urban green spaces and the relatively low accuracy in estimating greenhouse gas (GHG) budgets. To this end, 56 representative sampling sites with diverse vegetation types and landscape positions were selected within urban parks to conduct long-term, seasonally cross-sectional observations of greenhouse gas fluxes. Through systematic measurements of soil methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) fluxes, the study reveals the dynamic patterns and driving mechanisms across temporal and spatial scales. Based on the observational data, the random forest (RF) model was developed to predict the probability of GHG hot spots and/or cold spots. The findings provide critical data support for a deeper understanding of carbon and nitrogen cycling processes in urban ecosystems, and lay a scientific foundation for improving the accuracy and predictive capability of GHG budget models for urban green spaces. Although the manuscript presents some valuable findings, I do not believe the authors are adequately prepared for this manuscript to be published. The manuscript contains numerous basic errors that require careful revision and correction. The main issues are outlined below:

1. Figure and Table Issues: The figures and tables need to be redrawn and improved in terms of visual clarity and design. Additionally, detailed descriptions should be provided in the figure and table legends to clarify the information they contain.

Response: Thank you for this comment. We have carefully revised the figures and tables to improve their visual clarity and overall design. Specifically, we redrew the figures to enhance readability and reformatted the tables for better presentation. In addition, we expanded the figure and table captions to provide more detailed explanations, ensuring that all contents are clearly described and the information they contain is easier to understand.

2. Figure 1: This figure contains a large amount of irrelevant information, such as street names. It is recommended that the figure be revised to remove such unnecessary details and enhance its scientific presentation.

Response: Thank you for this helpful suggestion. Following this comment, we have revised Figure 1 by simplifying the background map, removing unnecessary labels and visual elements to enhance readability and emphasizing the spatial distribution of sampling sites. Please see the revised Figure 1 below.

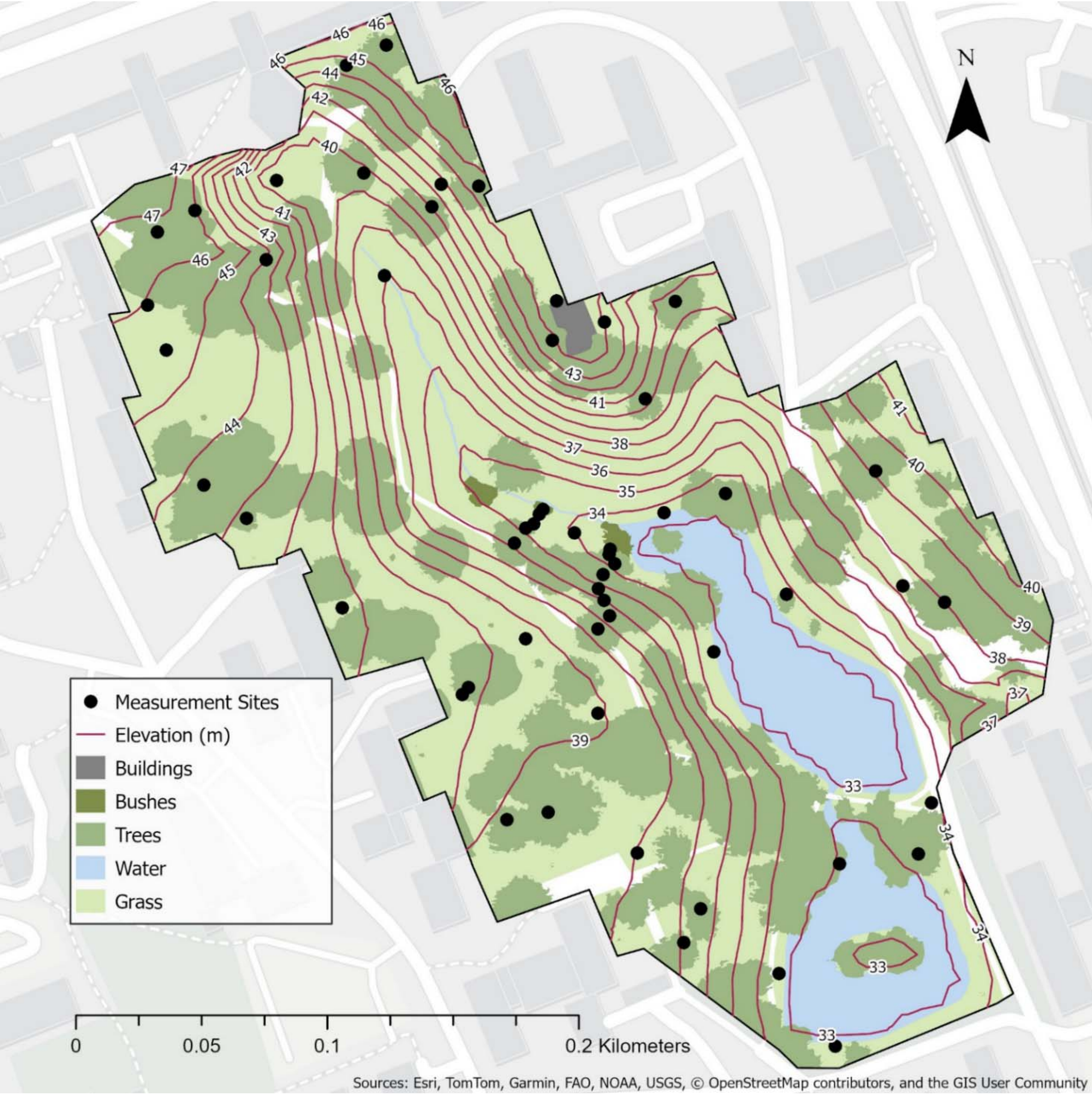

Figure 1: The map showing the land cover types and the locations of the sampling sites across a city park at Aarhus University.

3. Figure 2: The visualization is poor, and it appears that a significant amount of data is missing during the sampling period. The authors should clearly explain the reasons for these data gaps.

Response: Thank you for the comment. To clearly illustrate the temporal variations of these GHG fluxes, we added the dynamics of daily mean fluxes alongside the observation time in a supplementary figure. The figure caption explains why some measurements are missing during the observation period. Please see the supplementary figure below:

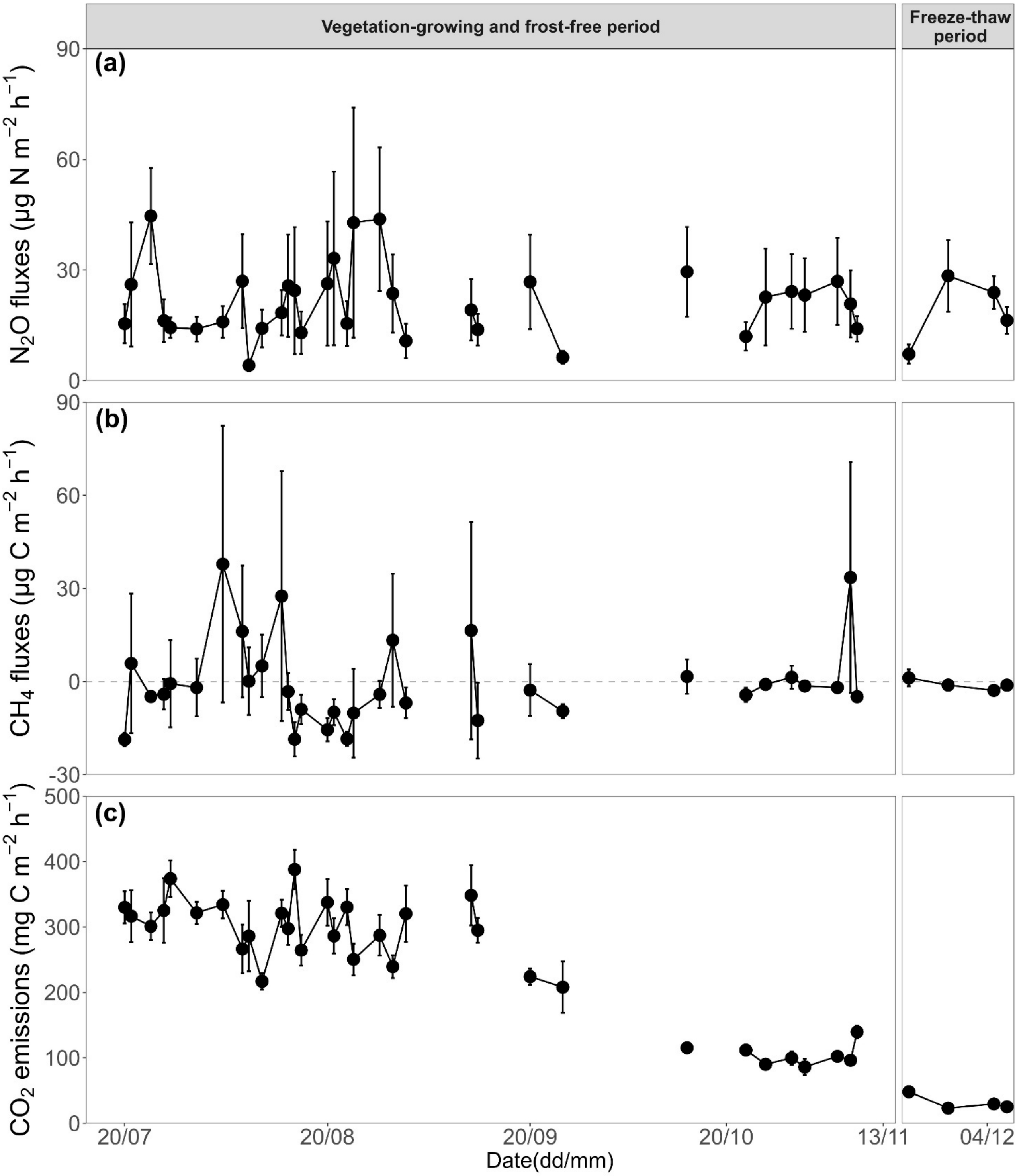

Figure S4: Seasonal variations in daily mean nitrous oxide (N_2O) (a), methane (CH_4) (b) and ecosystem (i.e. soil and plant) respiration (CO_2) fluxes (c) for the urban park over the entire observation period from July to December, 2023.The vegetation-growing and frost-free period spans from 20 July to 21 November, 2023, while the freeze-thaw period spans from 22 November to 31 December, 2023. The data shown are means ± standard errors (n=56). The data gaps between September 20 to October 20, for example, are due to logistical and operational constraints.

Additionally, we split Figure 2 into two new figures to improve visual clarity and readability. Please see the figures below:

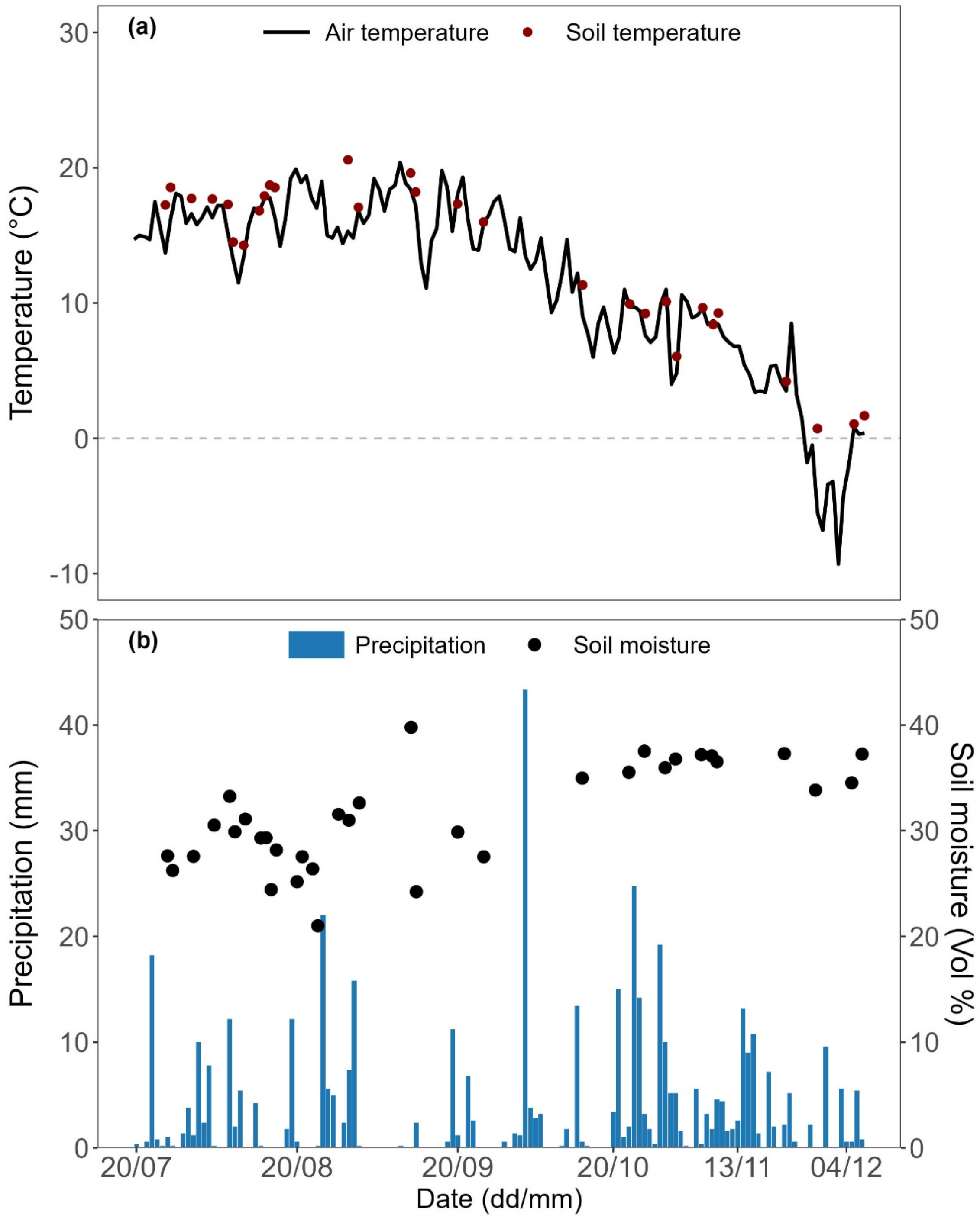

Figure 2: Seasonal variations in daily mean air (source Danish Meteorological Institute, 2025) and soil (5 cm) temperature (a) and daily precipitation (source Danish Meteorological Institute, 2025) and

mean volumetric soil (0-5 cm) moisture content (b) over the entire observation period from July to December, 2023.

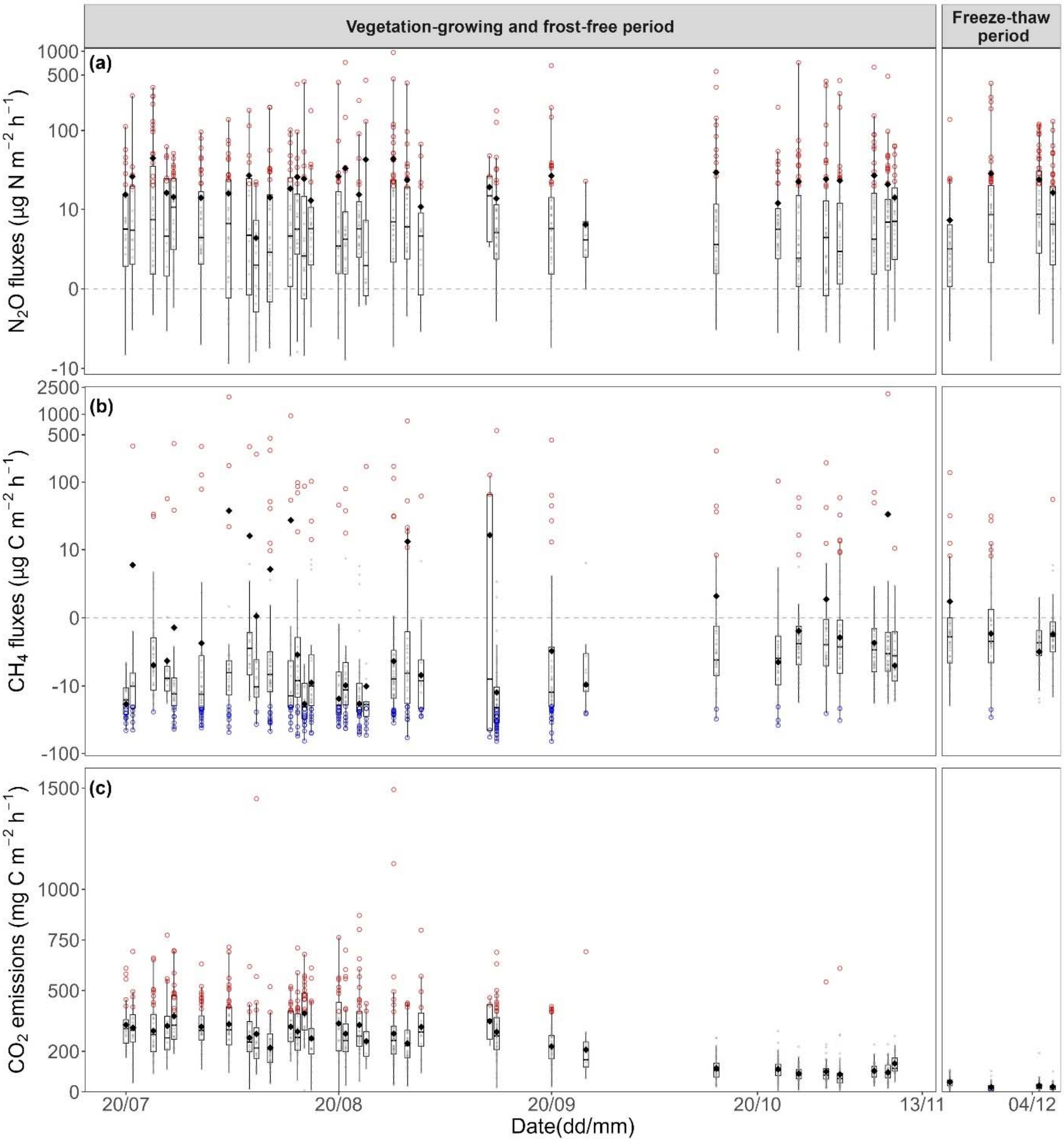

Figure 3: Fluxes of soil nitrous oxide (N_2O) (a), methane (CH_4) (b) and ecosystem (i.e. soil and plant) respiration (CO_2) (c) over the entire observation period from July to December, 2023.The vegetation-growing and frost-free period spans from 20 July to 21 November, 2023, while the freeze-thaw period spans from 22 November to 31 December, 2023. In panels a-c, the black solid diamonds and lines inside the box represent the mean and median value, respectively. The box borders represent the 75th and 25th percentiles, and the whisker caps represent the 95th and 5th percentiles. The red and blue circle points represent hot spots and cold spots, respectively, and grey circle points represent neither hot spots nor cold spots of observation data. The definition of hot and cold spots can be found in the Materials and Methods section. To improve visualization across the wide range of flux values, the y-

axes are displayed using a pseudo-logarithmic scale; this transformation was applied only to the y-axis for visual clarity and does not affect the original data values or statistical interpretation.

4. Page 101, Methods Section: The authors state that sampling was conducted once per week; however, this frequency is not reflected in Figure 2. A detailed explanation is required to clarify this discrepancy.

Response: Thank you for your comment. During the observation period, we conducted gas sampling at least once per week, unless interrupted by logistical (holidays) and operational (e.g. instrument breakdown) constraints. Specifically, from July7 to September 1, 2023, we measured fluxes one to three times per week. For the rest of the observation periods, the sampling frequency was reduced to once per week. We rewrote the description of the sampling frequency as above mentioned for clarity (Lines 131-135). As we also replied in response to the former comments, we added Figure S3 to clearly show the temporal dynamics of gas fluxes.

5. Figure 3: In figure 3a, the hotspots of N_2O are presented as point-based distributions, which may be inconsistent with the appropriate visualization principles for such data. The validity of this representation should be re-evaluated.

Response: For the spatial N_2O estimation in figure 3a (now Figure 4a in the revised manuscript), we used the distance to nearest tree as an indicator (see Supplementary Figure S4). The overlaid dots in Figure 4a indicate the exact locations of the tree trunks, but not the observed N_2O hot spots. As following this comment, we have added a description of these overlaid points denoting the tree locations to the caption of Figure 4a for clarity (Lines 283-284).

6. Figure 3: In figure 3b, a clear emission hotspot is observed near the stream. However, based on the sampling point distribution in figure 1, the number of plots located around the stream is limited, which raises concerns about the accuracy of this result. A similar issue is also present in figure 3d. The authors are advised to re-examine the data and verify the accuracy of the results.

Response: Thank you very much for the comment. To conveniently compare the estimated hot/cold spots with the in-situ flux observations, we added a supplementary figure showing the observed hot/cold flux frequency compared to the area with overall mean probability of estimated hot/cold spots. Please see the supplementary Figure S5 below:

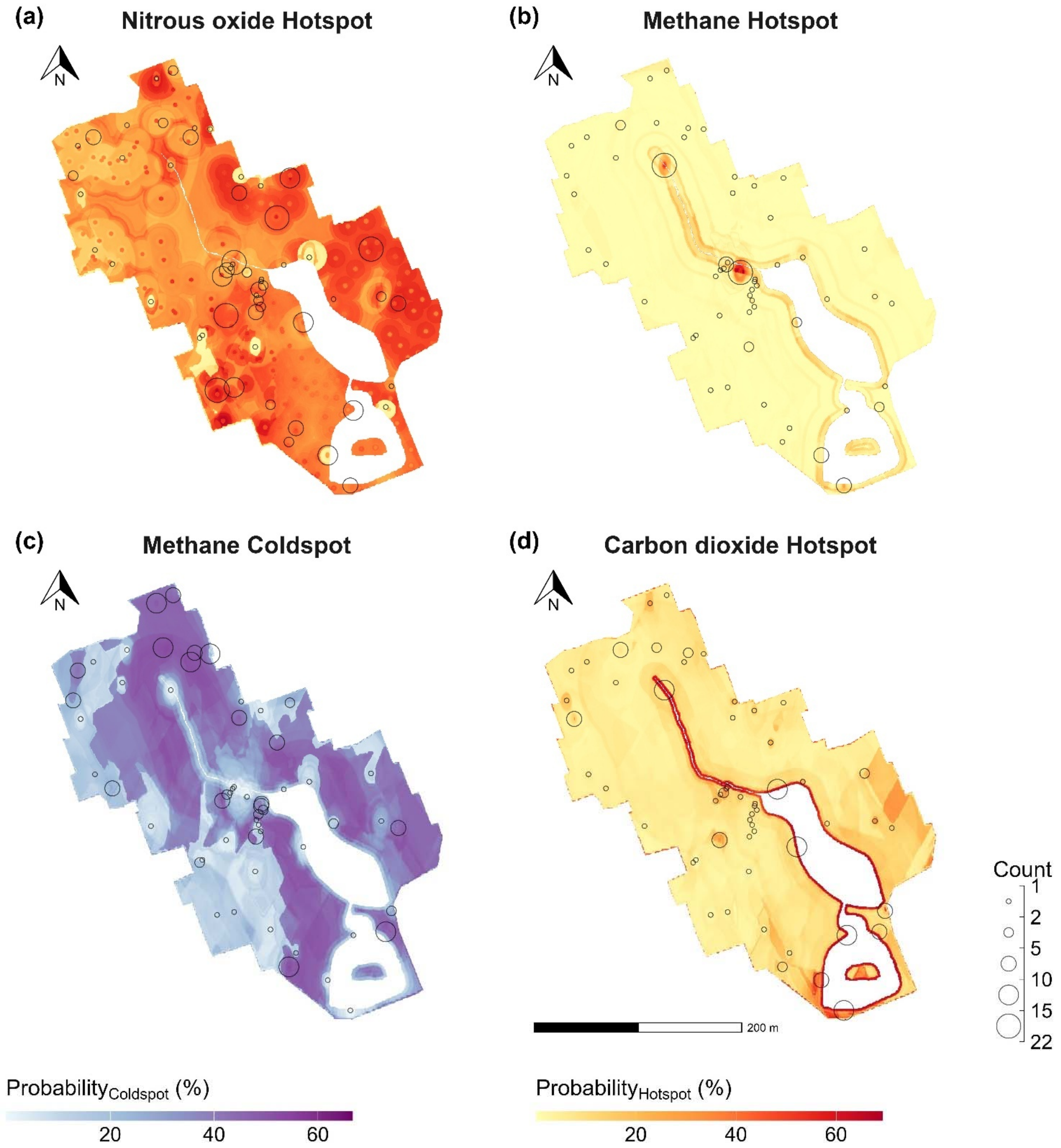

Figure S5: Shown are observed hot/cold flux frequency compared to the area with the highest overall mean probability of being classified as nitrous oxide (N_2O) emission hot spots(a), methane (CH_4) emission hot spots(b), CH_4 uptake cold spots(c) and carbon dioxide (CO_2) emission hot spots(d). The definition of hot and cold spots can be found in the Materials and Methods section. The circle size ("Count") indicates the frequency of observed hot/cold fluxes based on the in-situ measurements.

7. Figure 4: The results in figure c and e show opposite trends, yet the authors have not provided a sufficient explanation for this inconsistency. Furthermore, the notation "$p \leqslant 0.01$" should be corrected to conform to standard scientific writing conventions ("$p<0.01$").

Response: We apologize for the ambiguous description. In this study, we used the term 'CH_4 emission' to refer to a source of atmospheric CH_4, and the term 'CH_4 uptake' to refer to a sink of atmospheric CH_4. Therefore, both 'CH_4 emission' and 'CH_4 uptake' are expressed as positive values in these figures. In Figure 5c, the y-axis represents 'CH_4 uptake', and in Figure 5e, the y-axis represents 'CH_4 emission'. Based on this comment, we added the information about these terms in the Materials and Methods section for clarity (Lines 162-163). Additionally, we corrected "$p \leqslant 0.01$" to "$p < 0.01$" throughout the manuscript.

8. Supplementary Materials: The supplementary tables S9 and S10, mentioned in the main text, are not found in the provided supplementary files. Moreover, some tables in the supplementary materials appear to be duplicated. The authors should review and organize the supplementary content accordingly.

Response: We apologize for the incorrect numbering of the supplementary tables. Following this comment, we carefully checked the supplementary materials and renumbered all the tables. In this study, we used a similar analytical framework for different dependent variables (e.g. N_2O, CH_4 and CO_2 fluxes). This resulted in duplicated appearances. To avoid confusion, we have carefully revised all supplementary tables for clarity.

9. Model Parameters: The manuscript does not clearly indicate the parameters used for the different GHG models. In particular, figure S3 lacks essential information such as the coefficient of determination (e.g., R^2) and statistical significance (e.g., p-values), which are critical for assessing model performance.

Response: The random forest models used in this study were implemented as classification models, rather than regression models, to predict the probability of GHG flux hotspots and cold spots. Therefore, we assessed the model performance using the standard and widely accepted classification model metrics area under the receiver operating characteristic curve (AUC) and log loss. In response to the comment, we have explicitly added the model performance metrics to the caption of Figure S4 and provided a clearer description of model parameters and predictors in the manuscript and supplementary material.

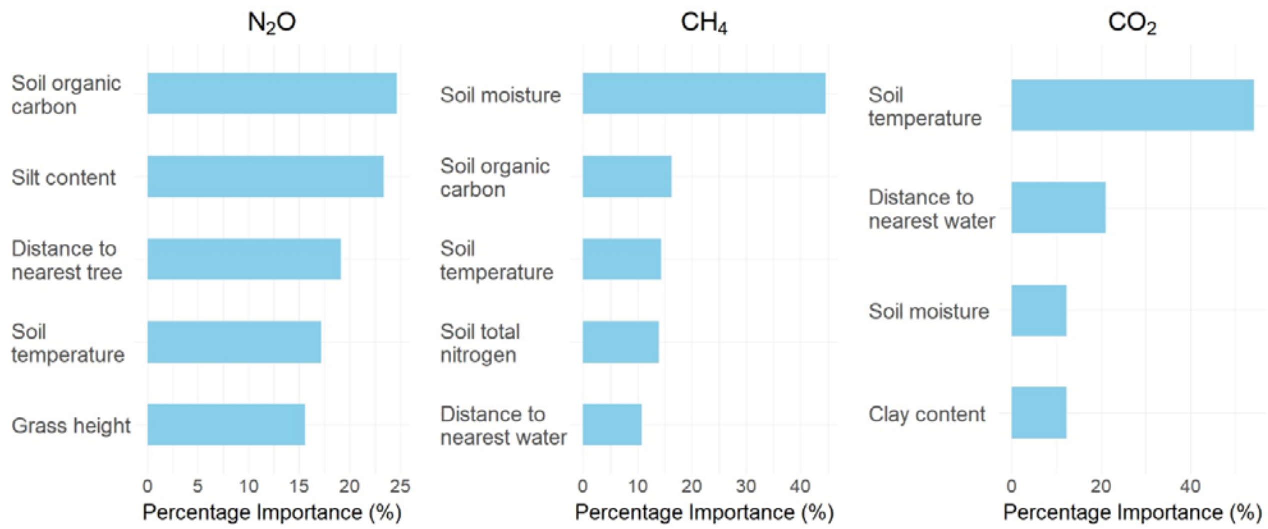

Figure S4: Predictors variables importance plots showing the relative importance assigned by the random forest algorithm to predictor variables in the final models for soil nitrous oxide(N_2O), soil methane (CH_4), and ecosystem respiration (carbon dioxide, CO_2). Model performance was evaluated using the area under the receiver operating characteristic curve (AUC) and log loss (see Tables S6-8).

10. Discussion Section: It is recommended that "Discussion" be thoroughly revised and restructured.

Response: Thank you for this comment. We have incorporated your suggestion, e.g. renaming the subtitles of the Discussion (Lines 325-326, 370, 411 and 438) and adding a comparison between our observed results from human-induced urban greenspaces with natural grassland and forest ecosystems, which indeed improves the clarity of this section (Lines 330-334, 376-380 and 415).

Reviewer #CC1 and #RC2 (Remarks to the Author):

The manuscript, titled "Spatial and temporal variability of CO_2, N_2O and CH_4 fluxes from an urban park in Denmark", examines the spatiotemporal variations in soil N_2O and CH_4 fluxes, as well as ER-CO_2 in an urban park. It also employs a random forest (RF) classification approach to map the hot and cold spots of greenhouse gas fluxes with high spatial resolution. Importantly, this study considers CO_2, N_2O and CH_4 fluxes from urban green spaces together, and attempts to link chamber-based measurements to spatially explicit maps that could be useful for management purposes. The field dataset is valuable, and the combination of chamber measurements with RF modelling is promising. However, there are several comments that need to be tackled before the manuscript can be accepted for publication:

1. Line 33: The phrase "such as parks, gardens, street trees, grassy lawns and wooded areas" mixes urban greenery types (parks, gardens, street trees as locations) with vegetation types (grassy lawns, wooded areas). I suggest revising it to "such as urban parks, residential gardens, street trees and small wooded patches" to keep all examples at the same categorical level.

Response: Thanks. We have incorporated your suggestion and changed those types to "such as urban parks, residential gardens, street trees and small wooded patches." (Lines 33-34)

2. Line 38: The word 'Unlike' in the sentence beginning "Unlike natural forests, grasslands, and managed agricultural systems…" feels somewhat categorical. A more neutral alternative, such as "In contrast to…" or "Compared with…" would read more effective.

Response: Thanks. We have replaced "Unlike" with "Compared with" for clarity (Line 39).

3. Line 44: I would avoid using the verb "found" in this context. More cautious alternatives such as "reported", "observed" or "shown" would be preferable.

Response: Thanks. We have incorporated your suggestion and replaced "found" with "reported" (Line 45).

4. Line 50: It would be helpful to add a closing sentence to this paragraph that explicitly links urban green spaces to climate impacts, for example, "This suggests that, although urban green spaces are often overlooked, existing studies indicate that they can influence climate by increasing N_2O emissions and reducing CH_4 uptake."

Response: Thanks. We incorporated your suggestion and added the sentence as a closing statement (Lines 51-52).

5. As a significant portion of the analysis is based on the RF modelling, it should briefly outline the RF approach (or similar machine-learning methods) and cite a few relevant studies that have used RF to analyze GHG fluxes or hot/cold spots in the Introduction section.

Response: Thank you for this suggestion. We have added a brief paragraph in the Introduction outlining the background of using random forest models for analyzing greenhouse gas fluxes and identifying hot/cold spots. The added sentences read as follows:

"Nonetheless, machine learning approaches such as random forest models can be used to effectively identify the key environmental factors driving the spatiotemporal variability of soil GHG fluxes.

Many studies have used random forest models incorporating soil, climate and management factors to predict GHG flux dynamics various ecosystems, such as grasslands (Barczyk et al., 2024), wetlands (Ying et al., 2025), and agricultural fields (Saha et al., 2021)." (Lines 59-63)

6. Line 81 and Fig. 1: Although Fig. 1 shows the locations of the 56 sampling sites, it remains unclear how these sites were selected and whether they represent different vegetation compositions and land-use types (e.g. low-management urban forest vs. heavily used open lawns). Some points near the lake appear highly clustered, while others are more scattered. Please briefly explain the site-selection strategy and whether different vegetation and land use types were explicitly included.

Response: Thank you for this helpful comment. We clarified the site-selection strategy in the Methods section. The 56 sampling sites were selected using a stratified random approach to capture spatial heterogeneity in vegetation types, microtopography and soil moisture conditions across AU Park. Specifically, the revised paragraph read as follows:

"To better understand the spatial and temporal variability of CO_2, CH_4 and N_2O fluxes, 56 sampling sites were selected across AU Park using a stratified random sampling design. The sites were stratified based on their landscape position and proximity to ponds to effectively capture spatial heterogeneity in vegetation types, microtopography and soil moisture conditions. For example, more sampling sites were established in areas with apparent topographic changes, while fewer sampling sites were set up in areas with flat and homogeneous vegetation." (Lines 87-92)

7. Line 100: "During the vegetation and frost-free period (20 July to 9 November 2023) and the freeze–thaw period …", the choice of these start and end dates is not explained.

Response: The start and end dates of the vegetation-growing and frost-free period (20 July to 9 November 2023) were determined based on daily mean air temperature conditions, during which temperatures remained consistently above 0 °C. The freeze–thaw period was defined by the onset of repeated temperature fluctuations around 0 °C, resulting in alternating freezing and thawing conditions. Following this comment, we added the information on how to define these two periods in the Materials and Methods section (Lines 112-116).

8. Line 104: "On each sampling day (08:00–16:00), we used a chamber closure time of 5–7 min …". Because temperature and other drivers can vary substantially over the course of a day, fluxes measured at different times may differ considerably, which is why many studies restrict measurements to a narrower morning time (8:00-10:00). If the 56 sites were measured at different times of day, how did you account for potential diurnal variation? Alternatively, do you have any diurnal measurements showing that daily variability is small compared with seasonal variability?

Response: We admit that it is better to finish the flux measurements between a narrower time (e.g. 8:00 am-10:00 am) to minimize the effect of diurnal temperature variation. However, logistically it is impossible to finish the flux measurements for all 56 sampling sites in such a short time period. To minimize the potential impact of sampling, the sampling sites were monitored in a random order on each sampling date. We added this information for clarity (Lines 119-120).

9. Line 113: "Soil temperature and volumetric water content at a depth of 5 cm" It should be clearly stated whether soil temperature and soil moisture were measured simultaneously with the gas fluxes. Given that these variables can change over the day, non-simultanous measurements may introduce

additional uncertainty.

Response: Thanks. During the observation period, soil temperature and volumetric water content at 5 cm depth were measured simultaneously with the gas flux measurements at each sampling site. We added this information in the Methods section for clarity (Lines 134-136).

10. Line 135: There seems to be a conceptual problem with the definitions of hot and cold spots in Eqs. (2)–(3). As the authors written, the thresholds based on the median and IQR do not clearly match the verbal description of "hot spots" (high-emission tails) and "cold spots" (high-uptake tails), and it is not obvious whether signed or absolute flux values were used. I strongly recommend that the authors carefully re-check these equations, explicitly state how hot/cold/normal classes were defined, and ensure that the formulas in the Methods correspond exactly to the classification actually used in the analysis.

Response: Thank you very much for this comment. We used signed fluxes to define hot and cold spot thresholds. We also verified the equations (Line 159).

11. Line 192: "The temporal coefficient of variation (CV) for N_2O fluxes was 45.6% during the measurement period." Please add an equation or short description in the Materials and Methods explaining how CV was calculated.

Response: Thank you for this suggestion. We have added a brief description of the definition of the coefficient of variation (CV) in the Materials and Methods section (Lines 194-195).

12. I suggest adding a figure showing the observed GHG fluxes (or observed hot/cold/normal classifications) at the 56 sites. It would be very valuable to compare directly with the RF prediction maps; otherwise, it is difficult to judge how well the model reflects the actual measurements.

Response: Thank you for this suggestion. As we replied to the Reviewer #RC1, we added Supplementary Figure S5 to show the frequency of observed hot and cold spot fluxes.

13. Given that both N_2O and CH_4 fluxes were measured, it would be very interesting to calculate a combined non-CO_2 climate metric in CO2-equivalent units. For example, the areas with low CH4 uptake but high N_2O emissions might have high non-CO_2 climate forcing, whereas north-western areas with both low N_2O emissions and strong CH_4 uptake might show low non-CO_2 climate forcing. Even a simple non-CO_2 analysis would enhance the practical value of the results.

Response: Thanks. We have incorporated a metric of non-CO_2 GHG flux by calculating the global warming potential (GWP) of soil N_2O and CH_4 fluxes expressed in CO_2-equivalents.

Specifically, we calculated the 100-year GWP of N_2O and CH_4 fluxes using the latest IPCC assessment (IPCC, 2021), according to:

$$GWP = 273 \times N_2O + 27 \times CH_4$$

We added this information in our revised manuscript (Lines 197-200).

14. Many sentences in the Discussion and Introduction are very long and contain multiple clauses with shifting subjects, which makes the argument difficult to follow. Besides, issues such as "all above-ground biomass were trapped…" (should be "was"), "ranging from 45.6% and 259%" (should be "to") indicate that a thorough language edit would be beneficial.

Response: Thanks. The Introduction and Discussion sections have been carefully edited to improve clarity and readability (Lines 129, 324, 336, 396 and 402).

15. The quality of all the figures needs to be improved

Response: The quality of all figures has been carefully improved in the revised manuscript.

Reviewer #RC3 (Remarks to the Author):

In this manuscript, authors applied an opaque chamber to measure fluxes of three major greenhouse gases (GHGs) within an urban park in 2023. Authors also developed a random forest model to 1) explore the relative importance of different environmental factors to GHG fluxes and 2) map the hot/cold spots of GHGs over the whole park. The dataset collected in this study is unique and most of the presentation is scientifically valid. Authors highlighted their findings in urban ecosystems, but discussion on how different their findings compared to natural ecosystems is missing. This manuscript shall be improved to add more discussion that addresses this issue.

1. Line 19: Calculation of CV is based on weekly/monthly/annual mean fluxes?

Response: Thank you for the comment. To assess spatial variability, the coefficient of variation (CV) was calculated using cumulative GHG fluxes for individual sampling sites over the vegetation-growing and frost-free period. Regarding temporal variability, the CVs were calculated using daily mean GHG fluxes. For clarity, we have incorporated these descriptions in the revised manuscript (Lines 194-197).

2. Line 72: What is the total area of the park?

Response: The total area of Aarhus University Park is about 8.2 hectares. This information has been added to the manuscript (Line 78).

3. Line 100: "During the vegetation and frost-free period" what does "vegetation" mean here?

Response: In this study, the ‘vegetation and frost-free period’ was defined as the period when the daily mean air temperature was consistently above 0 °C (Lines 112-116). Thus, here ‘vegetation’ means ‘vegetation-growing’. For clarity, we have corrected ‘vegetation and frost-free period’ to ‘vegetation-growing and frost-free period’ throughout the whole manuscript.

4. Line 110: "chamber area" is ambiguous. Shall be clarified. How about "the area of the chamber top face"?

Response: Thank you for the suggestion. We have revised it for clarity (Line 126).

5. Line 131: "In this study, the observed GHG fluxes were classified into three categories" shall be "In this study, the different subsections of park were classified into three categories based on the relative magnitude of observed GHG fluxes"

Response: Thanks. We replaced the original sentence with the recommended description (Lines 152-153).

6. Line 137: "M is the median and Q3 – Q1 is the interquartile range of the measured fluxes". Please clarify the temporal resolution of measured fluxes used for calculating M, Q3 and Q1? Instantaneous value, weekly mean or something else?

Response: Thank you for the comment. In this study, the median (M) and interquartile range (Q3–Q1) were calculated based on daily GHG fluxes from individual sampling sites during the vegetation and frost-free period. We added this information in the revised manuscript for clarity (Lines 160-161).

7. Line 144: Need to rephrase this paragraph. I suggest to revise as follow but also expect authors to

double check and make sure that the revised text has identical meaning: "First, the counts of hot, cold, and normal spots varied substantially across the three gases, with the normal spots category being predominant. This imbalance could potentially introduce biased sample numbers of training data under different categories, thus causing the RF model favoring the majority class and failing to accurately identify the minority classes. To address this issue, the minority categories were oversampled during training. We used an ad hoc, iterative approach to identify the most effective inflation factor of oversampling for each GHG (Tables S1-S3).

Response: Thank you very much for editing. We replaced the original sentence with the recommended description (Lines 169-174).

8. Line 154: In Table S5. There are three numbers in each row. What do they mean respectively?

Response: The different numbers for each hyperparameter correspond to the different combinations of hyperparameters we used over a grid search. That is, for the combination between each individual number, we have run the RF model and derived the performance metrics. The best performing model was selected as the final model. To improve clarity, we have added a detailed explanation of the hyperparameter values and their role in the grid search procedure to the caption of Table S5.

9. Fig. 2: Authors need to improve this figure through resolving the following issues: 1) Layout is too tight, 2) precipitation and soil moisture shall use the same y axis scale, 3) air and soil temperature shall use the same y axis scale, 4) x axis labels are too crowd, consider reducing, e.g., can put 1 label for each month, 5) y axis scale (GHG fluxes) can be changed to logarithmic scale, 6) subplot id (a-e) can be moved inside the upper left corner of subplots and 7) too much gridlines inside the plot, but this can be improved after reducing x axis label and change y axis to logarithmic scale.

Response: Thank you very much for the comment and suggestion. To improve visual clarity and readability, we have split the original Figure 2 into two separate figures (now labeled Figures 2 and 3), please see them below:

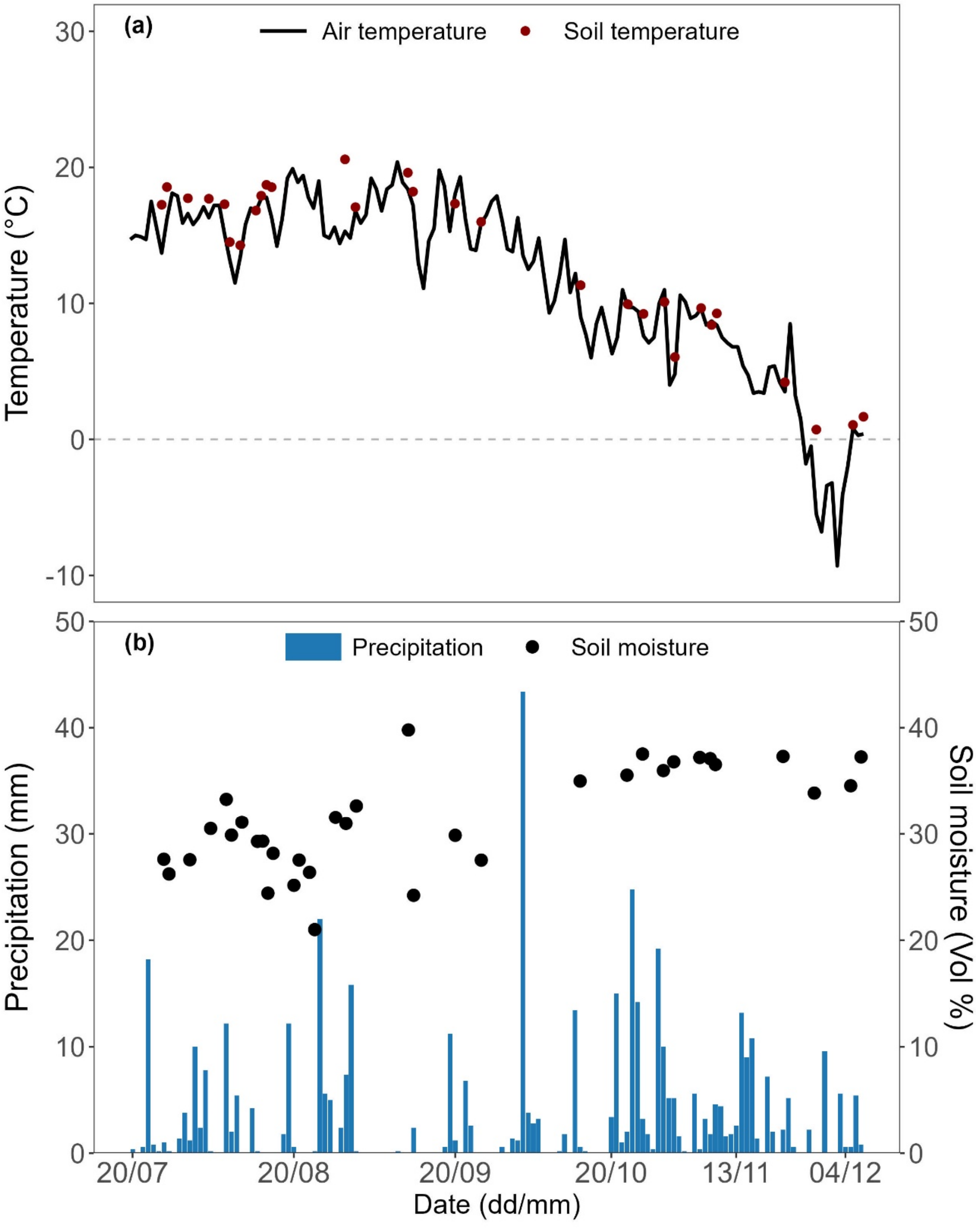

Figure 2: Seasonal variations in daily mean air (source Danish Meteorological Institute, 2025) and soil (5 cm) temperature (a) and daily precipitation (source Danish Meteorological Institute, 2025) and mean volumetric soil (0-5 cm) moisture content (b) over the entire observation period from July to December, 2023.

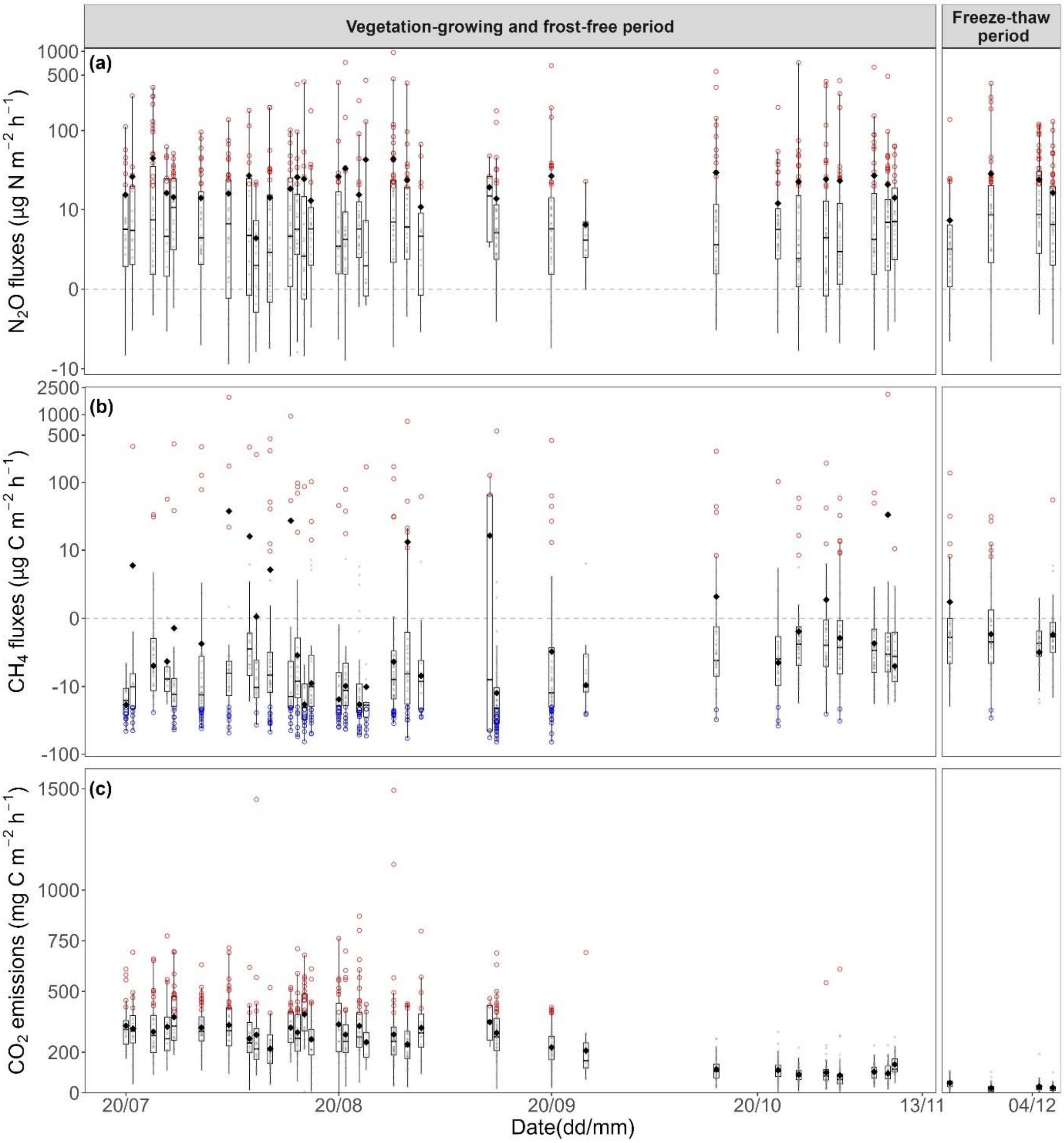

Figure 3: Fluxes of soil nitrous oxide (N_2O) (a), methane (CH_4) (b) and ecosystem (i.e. soil and plant) respiration (CO_2) (c) over the entire observation period from July to December, 2023.The vegetation-growing and frost-free period spans from 20 July to 21 November, 2023, while the freeze-thaw period spans from 22 November to 31 December, 2023. In panels a-c, the black solid diamonds and lines inside the box represent the mean and median value, respectively. The box borders represent the 75th and 25th percentiles, and the whisker caps represent the 95th and 5th percentiles. The red and blue circle points represent hot spots and cold spots, respectively, and grey circle points represent neither hot spots nor cold spots of observation data. The definition of hot and cold spots can be found in the Materials and Methods section. To improve visualization across the wide range of flux values, the y-axes are displayed using a pseudo-logarithmic scale; this transformation was applied only to the y-axis for visual clarity and does not affect the original data values or statistical interpretation.

10. Line 192: "recorded during both the vegetation and frost-free periods and the freeze-thaw period." Any snow cover during the freeze-thaw period? Please clarify.

Response: Yes, there was snow cover during the freeze–thaw period. According to data from the Danish Meteorological Institute (http://www.dmi.dk), the snow cover depth during this period ranged from approximately 0.1 to 13.1 cm. For clarity, we added this information to the revised manuscript (Lines 116-117).

11. Line 216: I'm a bit surprised that total N content is not one of the top predictors for N_2O flux. Please explain the reason.

Response: Thank you for the comment. Total N content was not significant, and was not used as one of the key factors controlling N_2O fluxes, we found that SOC was the key factor in predicting N_2O fluxes, which may also indicate the relative magnitude of microbial substrate availability. We have added this explanation in Discussion section (Lines 360-363).

12. Line 231: "Areas draining toward the artificial ponds showed the highest overall probability of becoming cold spots of CH_4 uptake over time" It's not likely that regions closer to ponds have stronger CH_4 uptake. Not sure if this finding is only indicated from RF model prediction, or reflected by the collected original samples. Since VWC is the major predictors of CH_4 flux, I suggest authors add every sample as dot to the map, with different colors showing either hot or cold spots, and plot VWC anomaly (actual VWC - mean) as basemap to support your finding.

Response: Thank you for this helpful comment. As we mentioned in our response to reviewers #RC1 and #RC2, we added the Supplementary Figure S5, which shows the frequency of observed hot and cold spot fluxes. As Figure S5 shows, our observations also revealed that the sampling sites near the artificial ponds sometimes functioned as sources of atmospheric CH_4, while at other times, they exhibited high CH_4 uptake. This variability is likely due to the fact that the magnitude of CH_4 fluxes is mediated by multiple factors such as soil moisture, bulk density, total N content and soil organic C as well as C/N ratio.

13. Fig. 4 & 5: Both figures show correlations between specific environmental predictors and GHG fluxes, so I suggest merging them together. Also, please put CO_2, CH_4 emission, CH_4 uptake and N_2O subplots in different rows for clarity purposes.

Response: Thank you very much for the suggestion. For the Figure 5, we mainly focus on the environmental factors controlling the spatial variability of GHG (N_2O, CH_4 and CO_2) fluxes. With regard to Figure 6, we tried to show the specific environmental factors in shaping temporal patterns of GHG fluxes. To show the differentiation, we separated these two figures. Nevertheless, according to the comment, we have harmonized the color scheme across Figures 5 and 6 for improving clarity and readability, i.e. using the same colors for the same dependent variables (i.e. N_2O, CH_4 and CO_2 fluxes). Please see the figures below:

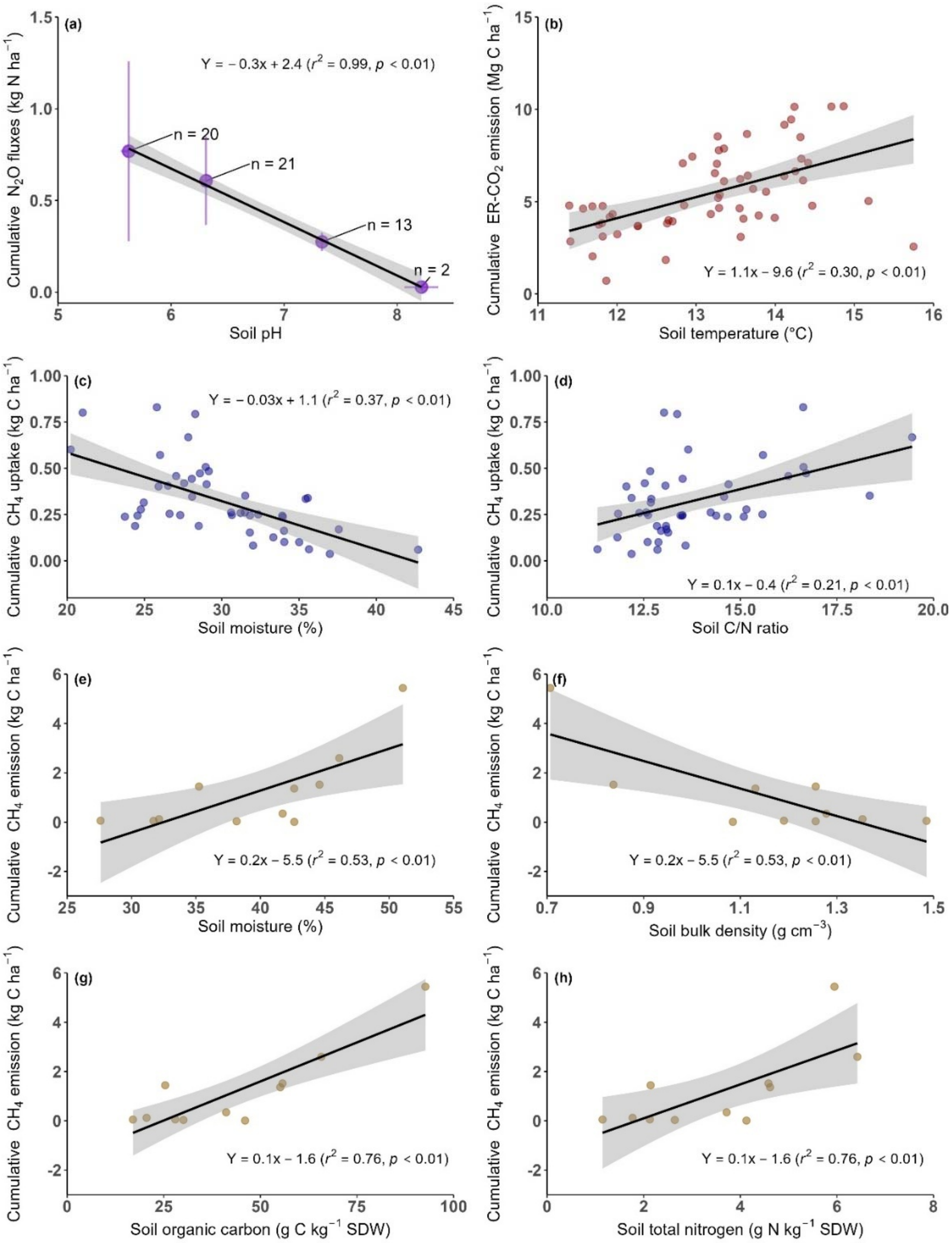

Figure 5: The relationships between cumulative nitrous oxide (N_2O) fluxes and soil pH (a), between cumulative ecosystem respiration (ER-CO_2) emissions and soil temperature (b), between cumulative methane (CH_4) uptake rates and soil moisture (c) and soil C/N ratio (d), between cumulative CH_4 emissions and soil moisture (e), soil bulk density (f), soil organic carbon (g), and soil total nitrogen (h) across all the sampling sites. In panel a, soil pH was binned at a step width of 1 (i.e. 5.0-6.0, 6.0-7.0, 7.0-8.0 and >8.0), and points are given as mean values ± standard error, with numbers referring to the number of observations. SDW: soil dry weight. The shaded area of each panel represents the 95% confidence band.

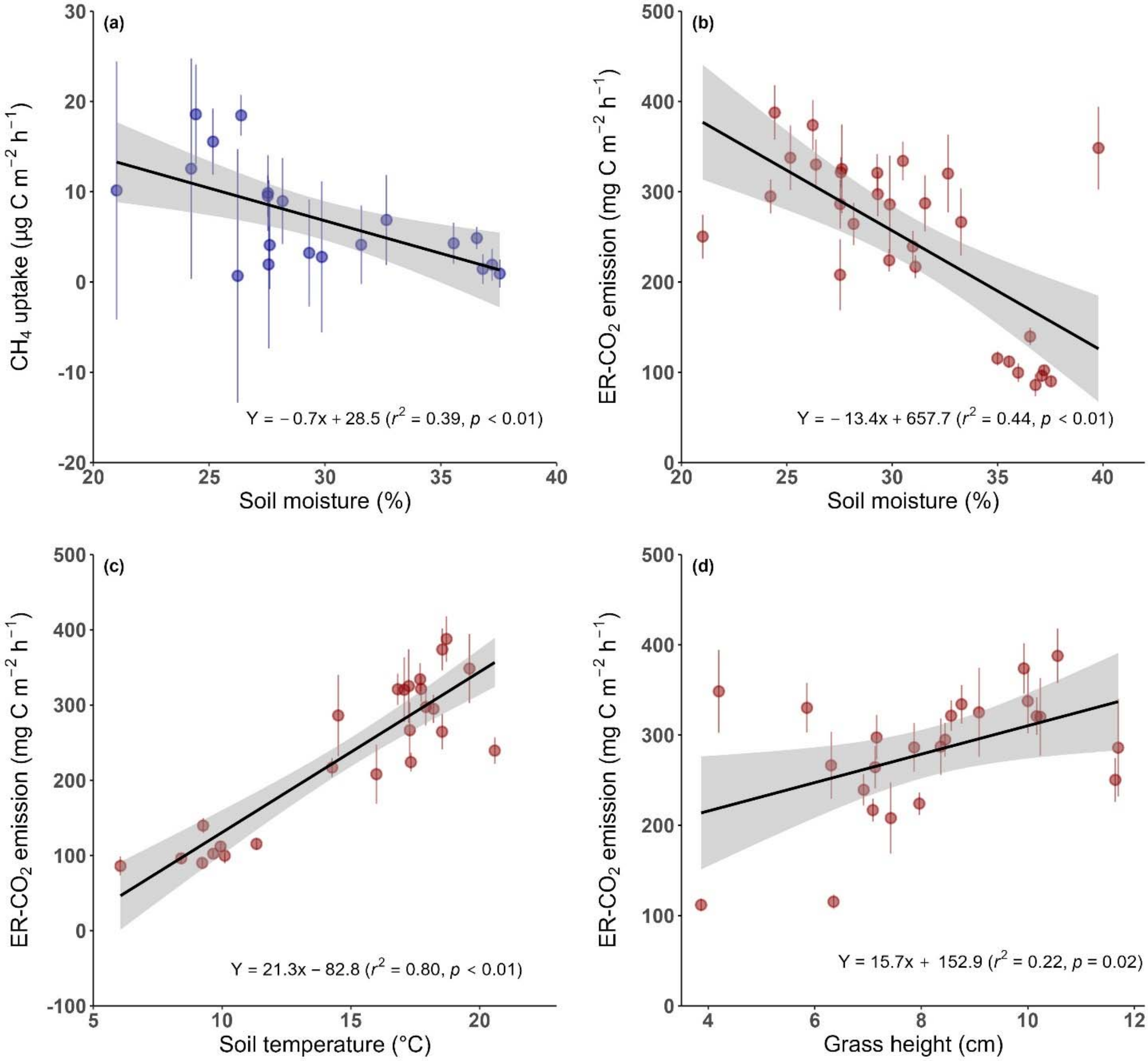

Figure 6: The relationships between methane (CH_4) uptake rates and soil moisture (b), between ecosystem respiration (ER-CO_2) emissions and soil moisture (b), soil temperature (c) and grass height (d) across the vegetation-growing and frost-free period. Points are given as mean values ± standard error across all the sampling sites at the same measurement time. The shaded area of each panel represents the 95% confidence band.

14. Line 363: "Moreover, the SOC decomposition process is constrained by anoxia, which restricts the release of nutrients necessary for CO_2 formation (Keiluweit et al., 2017)." If anoxia is important, I would suggest authors explore the correlation between water-filled pore space (WFPS) and CH_4 fluxes to corroborate your finding.

Response: Thank you for the suggestion. Regression analysis revealed a positive correlation between CH_4 fluxes soil water-filled pore space (WFPS) (see the figure below). This supports the presumption that the anoxia under high soil moisture conditions stimulates CH_4 emissions, while inhibiting aerobic CH_4 uptake and CO_2 emissions. We added this figure and the associated discussion to the revised manuscript (Lines 423-427).

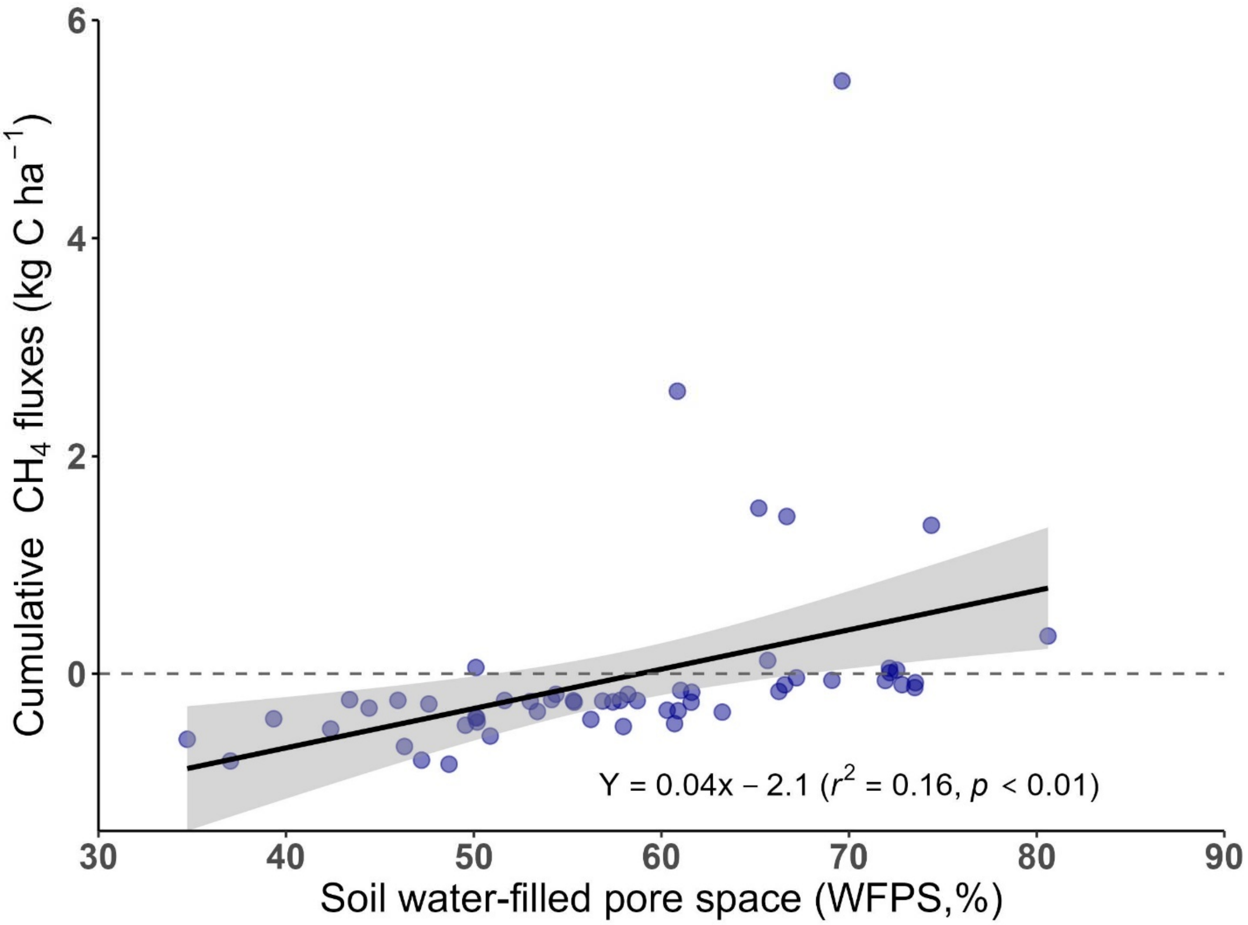

Figure S6: The relationships between cumulative methane (CH_4) fluxes and soil water-filled pore space across all the sampling sites. The shaded area represents the 95% confidence band.

15. In the discussion section, it is important to add a comparison between this study, which measured GHG fluxes over urban ecosystem, and other studies measuring the same fluxes from natural grassland, since it is one of the highlights of this work.

Response: Thank you very much for your suggestion. We added the discussion comparing the observed fluxes from urban greenspaces to those of natural grassland and forest ecosystems, which indeed improves the quality of this section (Lines 330-334, 376-380 and 415).