Response to reviewers' comments:

Reviewer #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."

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.

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".

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.

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. For example, many studies have used random forest models to predict GHG flux dynamics across various

ecosystems, including grasslands (Barczyk et al., 2024), wetlands (Ying et al., 2025), and agricultural fields (Saha et al., 2021)."

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 reads 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 and the lake in order to capture the spatial heterogeneity in vegetation types, microtopography and soil moisture conditions effectively. 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."

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.

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.

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

I.e. "In addition to measuring gas fluxes, soil temperature, and volumetric water content at a depth of 5 cm, a combined temperature and moisture sensor was used to simultaneously record these measurements in the direct vicinity of each sampling chamber site."

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.

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. That is:

"The coefficient of variation (CV) was calculated as the ratio of the standard deviation (SD) to the mean (μ) of the flux measurements, expressed as a percentage ($CV = SD / \mu \times 100$)."

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 will add this information in our revised manuscript.

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.

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.