Reviewer 1

In regions that take climate change mitigation seriously, research on ecosystem carbon cycling and greenhouse gas GHG emissions is of high relevance, with soils, particularly nutrient-rich soils with high carbon content, being one of the key focuses for nature based climate stakeholders. By investigating soil GHG emissions, this paper contributes to filling existing knowledge gaps on this matter. The study is particularly relevant by addressing less studied drivers of soil emissions, specifically the impact of feral pigs, thereby providing insight into a less explored aspect of ecosystem functioning. The results offer valuable empirical evidence demonstrating that feral pigs significantly affect soil conditions and GHG emissions, drawing attention to an important issue.

The introduction of the paper successfully and concisely establishes the topicality of the study, provides useful context on the role of invasive ungulates such as feral pigs in tropical Australian ecosystems, and very briefly introduces current understanding of their impacts on GHG emissions. However, the overview of existing knowledge on soil GHG emissions appears somewhat disproportionate and could be slightly expanded.

The amount of sampled data is not explicitly stated and appears relatively limited compared to typical soil GHG emission studies. Nevertheless, this limitation is justified by the specific study conditions, including the remoteness of the area and its inaccessibility or safety constraints during large parts of the year. These constraints do not detract from the overall quality of the study or manuscript. The paired study design, with parallel measurements at disturbed and relatively undisturbed sites, is appropriate and allows for a meaningful assessment of disturbance effects.

The results are sufficient to support the interpretations and conclusions, and the applied methods are generally valid. However, transparency of the Methods section should be improved, particularly by providing more detailed explanations of underlying assumptions, site conditions, and technical aspects of data collection and processing. This would enhance traceability and reproducibility.

Overall, the study is well presented, clearly structured, and written in fluent language. The title accurately reflects the content of the paper.

Specific comments

25: The abstract states that animals significantly affect the "carbon cycle"; however, the information presented in the abstract and results indicate that impacts extend beyond the carbon cycle to greenhouse gas emissions more broadly. This could be specified more precisely.

True, we have changed the term "carbon cycle" to "greenhouse gas fluxes"

L24: "This study provides another compelling example of how animal populations can significantly impact greenhouse gas fluxes at the landscape scale"

L311: "..they also increase soil CO_2, CH_4, and N_2O emissions, confirming that feral pigs pose a serious threat to soil carbon and other biogeochemical cycles (O'Bryan et al., 2021)."

30: "climate change and human impacts", climate change is attributable to human activities; the wording can be adjusted accordingly.

Agree, we have added "other human impacts" to clarify that climate change is a human impact:

L28: "As climate change and other human impacts on landscapes intensify, multiple approaches are needed to decrease greenhouse gas emissions"

30: "one such solution is the restoration", while restoration is strongly promoted as a climate mitigation measure, empirical evidence remains equivocal, particularly when accounting for spatial and temporal dimensions of uncertainties. The sentence can be adjusted accordingly.

We have added the adjective "potential" to acknowledge the uncertainty:

L30: "One potential solution is the restoration and improved management of wetlands."

33: "These potent greenhouse gases are emitted in large quantities in wetlands from tropical climates", this is observed in all climates and can be adjusted accordingly.

We have removed the term "tropical climates"

L33: "These potent greenhouse gases are emitted in large quantities in wetlands, mostly when they are polluted (Rosentreter et al., 2021; Saunois et al., 2020)"

75: "increase in soil decomposition", the implied linkage between decreasing oxygen availability and increased soil decomposition appears counterintuitive. The sentence may be split into separate sentences addressing different gases for clarity, if necessary.

Good point- we have rewritten the predictions as follows:

L69: "We predict that nitrogen inputs will increase due to animal excretion (Krull et al., 2013), and that soil oxygen (and thus its reduction-potential or redox) will decrease due to the removal of vegetation and increased microbial activity (Doupé et al., 2009; Liu et al., 2020). We expect these changes to result in increased soil CH_4 emissions and incomplete nitrification-denitrification, which increases N_2O emissions (Anderson & Levine, 1986)."

120: The soil horizon or sampling depth (cm) used for soil sample collection should be specified.

We have clarified that the soil measurements and soil samples were taken from the surface:

L120: "At each plot, surface (0 -2 cm deep) reduction-oxidation potential (redox; 3-5 measurements) and soil temperature were determined with a redox meter (HQ 11d ORP- meter, Hach, calibrated against ZoBell's Solution)."

L122: "Three surface (0- 5 cm) soil samples of a known volume were taken at each plot, weighed, and oven-dried at 50°C"

135: The equation 1 appears to be derived from the ideal gas law; therefore, the temperature used should correspond to the chamber headspace (gas) temperature rather than soil temperature. If headspace temperature was not measured, please state this explicitly and discuss the potential *uncertainty associated with using soil temperature as a proxy. Soil depth for temperature measurements is not specified.*

We have recalculated all the emissions using the air temperature instead. Differences were ≤ 5% of the previous calculations. We have clarified as follows:

L120: “At each plot, surface (0- 2 cm deep) reduction-oxidation potential (redox; 3-5 measurements) and soil temperature were determined with a redox meter (HQ 11d ORP- meter, Hach, calibrated against ZoBell’s Solution).”

L150: “Fluxes (F) were calculated per hour from the net changes in gas concentrations (N, mol) during the incubation time (t, hours), per volume of the chamber (V, m3), at a given air temperature (T, °K), assuming a pressure of one atmosphere”

145-150: Section 2.4. Root sampling depth is not specified. In disturbed plots, measured root-derived emissions likely reflect decomposition processes rather than active respiration. A more accurate approach would therefore be to define these emissions as decomposition rather than respiration. In addition, it is unclear how roots (both dead and living) collected at the reference plots were interpreted in the analysis, whether all measured emissions were assumed to represent decomposition and comparable with estimates from disturbed plots. Furthermore, as soil flux measurements were also conducted at reference sites with undisturbed, vegetated soil, it remains unclear how aboveground autotrophic respiration was treated in the study.

155: “Fluxes of CO2 were also included by correcting for respiration using the differences in emissions (%) from vegetated and unvegetated plots”. The purpose of this data manipulation remains unclear at this point in the manuscript. Clarification is required regarding which fluxes were corrected and whether the correction was applied to the reference plots to account for the presence of living biomass. It is not straightforward to correct part of the dataset by calculating differences between two datasets that are not directly comparable. Specifically, disturbed plots include fluxes from soil organic matter decomposition and decomposition of remaining dead root biomass, whereas reference plots include soil organic matter decomposition, decomposition of roots from natural mortality, respiration of living roots, and respiration of aboveground vegetation. Hence, the purpose of the correction is not clear. Further clarification is therefore needed as to why a simple difference between reference and disturbed plots was not used, and, if root respiration and/or root decomposition emissions were measured, why these data were not applied in the correction.

At line 265, it becomes clear that the correction was applied to exclude root emissions; however, the correction procedure should be explained more clearly earlier in the manuscript (section 2.5).

We have changed the term “soil respiration” to either “root respiration” or “soil decomposition”. We have also included the details of the correction earlier in the Methods, as well as the caveats of this calculation:

L159: “Soil CO_2 fluxes are a combination of the decomposition of organic matter and dead roots and the respiration of live roots, the latter contributing up to 79% of the total (Krauss et al. 2012). To test the contribution of root respiration to soil CO_2 emissions, we compared CO_2 emissions from the unvegetated and vegetated plots measured during the Kunumeleng season. Additionally, we measured root biomass at each reference and disturbed plot by sampling the surface (top 10cm) with a soil corer (7.3 cm diameter).”

L167: "We acknowledge the limitations of this approach, as root respiration was measured once roots were extracted from the soil, without accounting for the effects of the aboveground vegetation and the soil profile vegetation, which could consume CO_2 through photosynthesis and other non-photosynthetic pathways (Rodriguez et al 2025). Furthermore, direct root respiration cannot be distinguished with certainty from organic matter decomposition without the use of additional tracers, such as ^{14}C (Trumbore et al 2006). Thus, our estimations on root respiration contributions to CO_2 emissions should be interpreted as a first-step calculation."

155: The manuscript notes that instantaneous fluxes are extrapolated to annual fluxes per hectare; however, the study design does not allow for accurate annual extrapolation. This should therefore be avoided, or the formulation should be reframed to clearly indicate that the reported values represent instantaneous fluxes expressed in units of t ha $^{-1}$ yr $^{-1}$, with explicit clarification of whether these were obtained by averaging the measurements. An alternative approach could be to present relative reductions in emissions without implying that these can be extrapolated to annual values.

We have removed the annual extrapolations from the results and are now presenting only hourly rates. Following the Reviewer 2 request, we provide a broad calculation in the Discussion of potential annual reductions based on our results and supported by published data.

L367: "We cautiously estimate annual emissions from pig disturbance using our data, supplemented by published estimates of emissions during flooding (Bass et al. 2014). We consider emissions from flooded Melaleuca swamps to be representative of reference sites and open-water areas without vegetation to represent sites damaged by pigs. Seasonal differences were included in our estimations, considering that the wet seasons Kudjewk and Bangkerrent seasons span from 20 Dec-30 April, the cool seasons, Yekke and Wurrkeng, from 1st May- 15th August (data from this study), and the hot dry seasons, Kurrung and Kunumeleng seasons, span from 16th Aug to 19th December (data from this study). We estimate that annual emission reductions by comparison (reference vs disturbed) are 13.2 Mg CO_2 ha^{-1} yr^{-1}, 1.1 Mg CH_4 ha^{-1} yr^{-1}, and 0.004 Mg N_2O ha^{-1} yr^{-1}, equivalent to reductions of 43.4 Mg $CO_{2\text{-eq}}$ ha^{-1} yr^{-1}. We can then extrapolated these emissions to the Kakadu and adjacent river floodplains (See Fig 1; 356,800 ha, Ward et al. 2014) considering that about 10% of the area is disturbed by pigs (unpublished data). We estimate emissions of 0.47, 1.04, and 0.04 Mt $CO_{2\text{-eq}}$ yr^{-1} for CO_2, CH_4, and N_2O, respectively, or a total of 1.5 Mt $CO_{2\text{-eq}}$ yr^{-1}. These levels of emissions are equivalent to 5.6% of the Northern Territory's emissions in Australia, or 57.4% of the Territory's agricultural emissions. Although we have acknowledged the limitations of our calculations and the challenge of removing the thousands of pigs inhabiting these wetlands, it is clear that there is significant potential to reduce greenhouse gas emissions through feral pig control."

230-235: It is unclear what exactly is being compared. Please clarify whether all data are aggregated or whether the comparison still retains subgrouping by disturbance.

We have clarified in this legend and in the legend of Figure 4 and 5:

Figure 3…The box plots show the mean and standard error for five chambers at five plots within five sites

Figure 4….. Violins represent the distribution of the average of five chambers of three plots within three sites (Djabulukgu, Mamukala, and Munmarlay).

Figure 5….Violins represent the distribution of the average of five chambers at three plots within three sites (n = 3; Djabulukgu, Mamukala, and Munmurlay-Coolaboo).

205; 220;230: CO2 emissions were lower at reference plots during Yekke (8–14 June 2023) but higher during Kunumleng (25–30 October 2023). In addition, CO2 emissions during the cooler Yekke period were higher than during the hotter, pre-monsoon Kunumleng period. Can this be explained by seasonal vegetation dynamics? It may be so if by the Kunumleng period, vegetation at reference plots may have developed greater biomass, leading to increased autotrophic respiration and consequently higher CO2 emissions. If so, this would imply that the observed differences reflect not only soil processes but also seasonal variation in vegetation activity. If this is plausible, adding some information on vegetation dynamics may be valuable. At the same time, can the lower CO2 emissions observed during Kunumleng, despite higher temperatures, be related to drier soil conditions, which can limit microbial activity and soil respiration (this was confirmed at discussion)? In this case, adding information on meteorological conditions during the study periods would therefore improve the interpretation of the observed CO2 dynamics.

Thank you for the ideas. The latter (dry soil conditions) may apply to this situation, as the Kunumleng period is very hot and dry. While the trees remain, understorey vegetation has mostly dried up, and soil humidity decreases. We have added this information, along with some meteorological conditions before sampling, to the Methods and Discussion.

L94: ". Both sampling trips were preceded by dry conditions with no precipitation for the previous 30 days and mean daily temperatures ranging from 33-36 °C during sampling in Yekke and 38-40 °C in Kunumeleng (Jabiru Airport Station, 14198, Australian Bureau of Meteorology)."

L327: "During this season, understorey vegetation and litter were scarcer, limiting organic carbon inputs into the soil and potentially causing reduced CO_2 fluxes compared to Yekke."

260: It is unclear which study period is represented by soil respiration in Table 4. Unclear why values in the table do not seem to match those represented in Figure 5.

We have modified this Table, first clarifying that the root respiration measurements were done during the Kunumleg season. We have also removed the soil CO_2 values from this Table to avoid confusion, as these were obtained with a different methodology and were not used for any further calculation in this study.

"Table 4. Root respiration and biomass from the top 10 cm during the Kunumeleng in reference and disturbed plots by feral pigs."

In addition, it is not explained in the methods how measured root emissions (probably "respiration+decomposition" or "decomposition" instead of "respiration" only) are expressed in mg m-2 hr-1.

We have clarified in the Methods how we converted root respiration to aerial rates.

L160: "To test the contribution of root respiration to soil CO_2 emissions, we compared CO_2 emissions from the unvegetated and vegetated plots measured during the Kunumleg season. Additionally, we measured root biomass at each reference and disturbed plot by sampling the surface (top 10cm) with a soil corer (7.3 cm diameter)."

L166: "Root respiration was converted to aerial emissions considering the area of root sampled (22.9 cm^2)."

335. This part of the sentence is confusing: " although it does not incorporate the potential absorption of CO2 as it travels from the sediment to the atmosphere." The hypothesis was not explicitly addressed in the results or discussion.

We have removed this statement and clarified the limitations of our estimations in the Methods section:

L167: "We acknowledge the limitations of this approach, as root respiration was measured once roots were extracted from the soil, without accounting for the effects of the aboveground vegetation and the soil profile vegetation, which could consume CO_2 through photosynthesis and other non-photosynthetic pathways (Rodriguez et al 2025). Furthermore, direct root respiration cannot be distinguished with certainty from organic matter decomposition without the use of additional tracers, such as ^{14}C (Trumbore et al 2006). Thus, our estimations on root respiration contributions to CO_2 emissions should be interpreted as a first-step calculation. "

Technical corrections

20: N2O typo

135-140: multiple typos, format as superscript where necessary. Use of terms "plots" and "sites" can be harmonised through the manuscript.

We have fixed the typos with adequate subscripts or superscripts and harmonized the terms "plots" and "sites".

Reviewer 2

Thank you for the opportunity to review the paper by Adame et al., titled 'Soil disturbance in wetlands by feral pigs increases greenhouse gas emissions", submitted to European Geosciences Union - biogeosciences.

This study investigates whether soil disturbance caused by invasive hoofed mammals in tropical wetlands of northern Australia enhances greenhouse gas emissions, specifically carbon dioxide, methane, and nitrous oxide. The authors combined field measurements of greenhouse gas fluxes with some laboratory incubations of soil and root respiration, alongside measurements of various environmental parameters, to determine the drivers of changes in fluxes. The study found that the highest emissions occurred near disturbed sites, suggesting that feral pigs have a measurable impact on wetland greenhouse gas cycling.

Overall, this is an interesting and timely study addressing an important and underexplored topic. The manuscript is generally well written and presents novel findings with potential implications for wetland management and greenhouse gas accounting. However, several methodological details require clarification, and some interpretations should be presented more cautiously.

Specific comments to address:

Line 69 *– "Old disturbed" reads awkwardly and should be rephrased.*

We have changed the term "old disturbed" for "past disturbance" throughout the manuscript

Figure 1 *– Please indicate what the grey shaded areas represent.*

We have clarified as follows:

Fig 1. ”Grey areas represent the extent of the floodplain (modified from Ward et al. 2014) ”

Ward et al. 2014. Floodplain inundation and vegetation dynamics in the Alligator Rivers region (Kakadu) of northern Australia assessed using optical and radar remote sensing. Remote Sensing of Environment. 147, 43-55.

Line 120 *– It is not clear at what depth soil physicochemical characteristics were measured. Please provide more details on how these measurements were conducted. For example, were soil cores collected and redox measured along a depth profile? Soil redox potential changes substantially with depth, particularly in wetlands where soils transition from aerobic surface layers to increasingly anaerobic subsurface conditions. This redox gradient strongly influences the production and distribution of microbial greenhouse gases, meaning hotspots for CO2, CH4, and N2O may differ with depth. Please clarify whether soil redox potential values were adjusted relative to the Standard Hydrogen Electrode (SHE) and specify the reference electrode used. This information is important for interpreting the redox conditions associated with greenhouse gas production. Understanding where and how soil redox was measured is important for interpreting these results.*

Figure 6 *– As mentioned above, were soil redox potential values adjusted to a standard hydrogen electrode/reference electrode? Please also specify the depth at which redox was measured and indicate what the lightly shaded area represents.*

We measured surface soil redox, which was calibrated according to the instrument instructions with a ZoBell’s solution. We have clarified as follows:

L120: “At each plot, surface (0- 2 cm depth) reduction-oxidation potential (redox; 3-5 measurements) and soil temperature were determined with a redox meter (HQ 11d ORP- meter, Hach, calibrated against ZoBell’s Solution).”

Line 134 *– More methodological detail regarding greenhouse gas sampling is required eg: How much gas was removed from the chamber headspace at each sampling interval? Were vials over-pressurised? Please clarify whether ambient/background atmospheric samples were collected alongside chamber measurements as including atmospheric reference samples is useful for quality assurance of GC measurements, identifying potential contamination or instrument drift, and contextualising chamber concentrations relative to ambient greenhouse gas concentrations. This is particularly important for low-flux measurements and GHG ‘uptake’ measurements to see if your starting concentrations are near atmospheric (start measurement) and final concentrations (end measurement) ~below atmospheric levels. What were the precision and detection limits of the GC system used? Were any samples outside the calibration range? What is meant by “linearity of fluxes within each chamber was checked”? eg was an r^2 threshold used to reject poorly linear fluxes? If so, what threshold was applied? How are airtight seals with soil confirmed? When were chambers/collars installed? Eg were they pre-installed and revisited, or inserted immediately before measurements? Both approaches have important caveats that should be acknowledged. Long-term collar installation can alter soil biogeochemistry, whereas installing chambers immediately prior to measurements may disturb soils and release naturally accumulated gases, potentially altering measured fluxes. How was temperature measured for use in Flux Equation 1?*

We have clarified the requested information as follows:

L133: "Instantaneous gas fluxes (n = 5 per plot) were measured in dark, closed chambers (Hutchinson & Mosier, 1981) made of polyvinyl chloride (4L, 15 cm diameter and 30 cm in height; Fig. 2). The chambers were installed right before the measurements, hammered into the soil at least 3 cm deep, acknowledging some disturbance to the soil. After 15 minutes of deployment, gas samples were collected from the headspace of the chambers using a plastic 30 mL syringe and a 26G needle and transferred to 12mL vacuumed glass containers (flat bottom, 103 mm, diameter 15.5 mm, Labco Exetainer). The air samples were collected at 0 and 60 min at all chambers and at 0, 20, 40, and 60 min in one chamber per plot. During each sampling, the headspace was mixed with the syringe three times before the air sample was retrieved.

Back in the laboratory, the CO_2, CH_4, and N_2O concentrations within each sample were measured in a gas chromatograph (Shimadzu GC-2010 Plus, DESITI, Queensland Government). The analyses had accuracies of 0.2%, 0.5%, and 1.5% for CO_2, CH_4, and N_2O , respectively. Air temperature next to the chambers was monitored throughout the experiment. The chamber with continuous measurements was checked for linearity using a regression of time for each gas within each plot. Coefficients for each regression are shown in Table S1; chambers with poor fit ($R^2 < 50$) were identified at sites with very low N_2O fluxes or very high CH_4 emissions. Because CH_4 is characterized by nonlinearity and spikes due to ebullition, outliers were retained in the calculations, although median values along with interquartile ranges were used to provide conservative estimates. Only one emission value of CH_4 in a disturbed site by pigs, which was three orders of magnitude higher than the rest of the chambers within the same plots, was removed from calculations (Coolaboo, chamber D, during Kunumeleng season). Fluxes (F) were calculated per hour from the net changes in gas concentrations (N, mol) during the incubation time (t, hours), per volume of the chamber (V, m^3), at a given air temperature (T, °K), assuming a pressure of one atmosphere"

Additionally, a new supplementary Table (S1) has been included with all the parameters of the regression equations for each plot. Finally, all data will be available to the public through as Supplementary Material to support accessibility and transparency.

Line 157 *– The manuscript extrapolates emissions to fluxes per hectare, but it may also be useful to cautiously estimate the impact per feral animal, or cautiously use reference satellite data, or published estimates to try upscale to the NT region and see what effect this disturbance could be having regionally or nationally. This could help contextualise the broader regional impact of feral pig disturbance.*

It may also be worthwhile to provide a preliminary estimate of the broader magnitude of these processes. As noted above, this could potentially be achieved by combining measured disturbance impacts with satellite imagery, aerial mapping, or existing estimates of feral pig disturbance extent across the region.

Thank you for the idea. We have included an estimate (acknowledging the limitations) of the potential of greenhouse gas reductions at the regional scale:

L367: "We cautiously estimate annual emissions from pig disturbance using our data, supplemented by published estimates of emissions during flooding (Bass et al. 2014). We consider emissions from flooded *Melaleuca* swamps to be representative of reference sites and open-water areas without vegetation to represent sites damaged by pigs. Seasonal differences were included in our estimations, considering that the wet seasons Kudjewk and Bangkerrent seasons span from 20 Dec-30 April, the cool seasons, Yekke and Wurrkeng, from 1st May- 15th August (data from this study), and the hot dry seasons, Kurrung and Kunumeleng seasons, span from 16th Aug to 19th December (data from this study). We estimate that annual emission reductions by comparison (reference vs disturbed) are 13.2 Mg CO_2 ha^{-1} yr^{-1}, 1.1 Mg CH_4 ha^{-1} yr^{-1}, and 0.004 Mg N_2O ha^{-1} yr^{-1}, equivalent to reductions of 43.4 Mg $CO_{2\text{-}eq}$ ha^{-1} yr^{-1}. We can then extrapolate these emissions to the Kakadu and adjacent river floodplains (See Fig 1; 356,800 ha, Ward et al. 2014), considering that about 10% of the area is disturbed by pigs (unpublished data). We estimate emissions of 0.47, 1.04, and 0.04 Mt $CO_{2\text{-}eq}$ yr^{-1} for CO_2, CH_4, and N_2O, respectively, or a total of 1.5 Mt $CO_{2\text{-}eq}$ yr^{-1}. These levels of emissions are equivalent to 5.6% of the Northern Territory's emissions in Australia, or 57.4% of the Territory's agricultural emissions. Although we have acknowledged the limitations of our calculations and the challenge of removing the thousands of pigs inhabiting these wetlands, it is clear that there is significant potential to reduce greenhouse gas emissions through feral pig control."

Table 1 *– There is a substantial soil temperature difference between reference and disturbed sites. I would have expected the opposite trend, where disturbed sites lacking vegetation cover would exhibit higher soil temperatures due to increased solar exposure and radiation heating bare/darker soil surfaces. Could this reflect a time-of-day sampling artefact? For example, were disturbed sites sampled in the morning and reference sites later in the day? Please consider and discuss.*

Line 291 *– Disturbed plots are colder? Are these soil temperatures or air temperatures? This is currently unclear. Was this time-of-day artefact? Seems counterintuitive.*

The plots affected by pigs were consistently colder as pigs tend to dig into the soil to access cool soil close to the water table, groundwater to avoid heat-stress. The plots (disturbed and reference) were measured simultaneously. See Discussion:

L106: "The disturbed plots were either "digging areas" that pigs use for finding roots and other underground food (e.g., turtles) or "wallows" which were deeper and are used by pigs to cover themselves with mud to avoid overheating (Bracke, 2011)."

L316: "The disturbed plots were also colder and filled with fresh groundwater, as pigs used some of these areas to wallow or coat themselves with mud to avoid overheating (Bracke, 2011)."

Figures 3 and 4 *– Nitrous oxide fluxes in Figure 3 range from approximately 200–800 µg/m2/h in disturbed sites, whereas Figure 4 appears mostly within ±5 µg/m2/h. This represents a difference of roughly two orders of magnitude, while methane and carbon dioxide fluxes appear comparable between figures. Please check whether this discrepancy is correct or due to an error.*

Figure 3 shows data from the Yekke season, while Figure 4 shows data from Kunumleng, where N_2O emissions were much lower. During Kunumeleng, pigs move closer to the waterholes, leaving behind highly anoxic soils where methanogenesis dominates over denitrification (see Fig. 7).

Figure 3. Greenhouse gas emissions (CO_2, CH_4 and N_2O) from reference plots (blue-left) and plots disturbed by feral pigs (red-right) for six sites across the floodplains during the Yekke season in Kakadu National Park

Figure 4. Greenhouse gas (CO_2, CH_4 and N_2O) fluxes of reference sites (REF- blue), sites previously used by pigs (PAST- orange), and recently used by pigs (RECENT-red). Violins represent the distribution of the average of five chambers of three sites (Djabulukgu, Mamukala, and Munmarlay) during Kunumeleng (pre-monsoon) season.

Line 306 *– "13δC" is incorrectly formatted and should be written as δ13C throughout. I also do not think the statement that "disturbed soils showed slightly reduced δ13C values" is fully supported by the data. Four out of six sites showed essentially the same/ non-significantly different δ13C values between treatments, while only two disturbed sites were statistically more negative, and only by a small fractionation (~2‰). Therefore, the broader claim appears overstated. Furthermore, bulk soil δ13C is only an indirect indicator of methanogenic processing and integrates multiple carbon pools and decomposition pathways. Small differences in δ13C could simply reflect pig disturbance-driven mixing of soil organic matter, altered litter inputs, or differences in carbon turnover rather than enhanced methanogenesis directly*

Good point, we have removed this statement and also corrected the formatting of $\delta^{13}C$

Line 303 *– The discussion regarding oxygen limitation in soils is also somewhat speculative because oxygen concentrations were not directly measured; only soil redox was assessed, and respiration rates and possibly only at the surface. This does not necessarily indicate that subsurface soils were aerobic too. Wetlands occupy low landscape positions and commonly feature shallow water tables, so deeper anaerobic conditions may still occur irrespective of surface measurements.*

Agree. We have clarified that our measurements are redox, not directly oxygen concentrations. We have also specified that we are referring to surface processes.

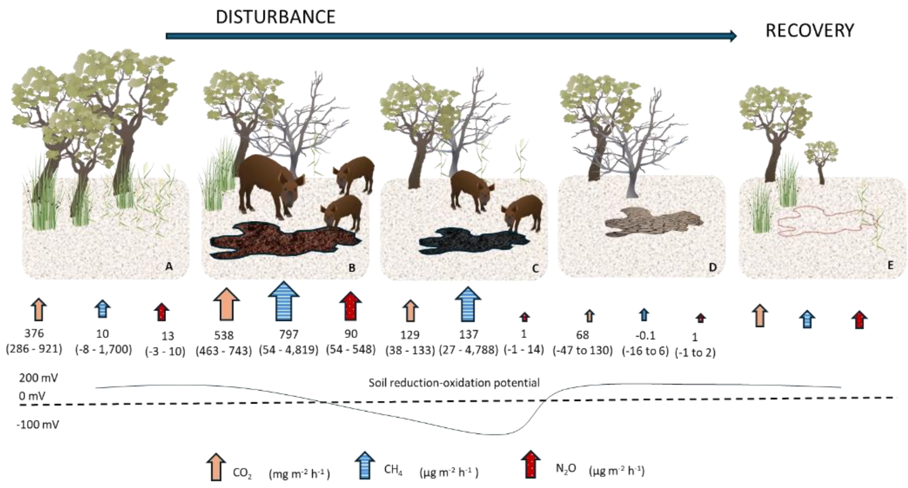
e.g.

L22: "Soil surface redox values were correlated with emissions in plots disturbed by pigs, with negative values associated with high CH_4 emissions."

L318: "The soil redox potential at all disturbed plots was significantly reduced, suggesting low oxygen conditions. Low redox soils favour microbial respiration through nitrification-denitrification when nitrate (NO_3^-) is available."

Figure 7 *– Consider adding an arrow indicating 'time' progression from left to right along the x-axis. Also consider using different colours or line styles for CO2 and N2O, as they are difficult to distinguish in black-and-white (and in colour) printing. It may also be worth discussing the concept of ecosystem recovery/re-establishment after disturbance as inset 'e'. While this was not directly investigated here, it could represent an interesting direction for future studies examining post-disturbance dynamics once feral pigs move on.*

Thanks for the idea. We have changed the format for each arrow to have a different pattern. We have also included a potential recovery panel and added an arrow to show progression with time.



Line 331 *– I recognise the body of Australian literature may be limited but are there additional recent studies in tropical wetlands beyond Iram et al. (2022) that support this claim that seasonal differences in GHG fluxes are low which could be discussed here? A couple of other relevant papers that could be considered on seasonal Australian wetland GHGs are:*

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023JG007556

https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.1002/lno.11158

https://link.springer.com/article/10.1007/s13157-014-0522-5

and this undulate research on Australian alpine wetland GHGs: https://www.sciencedirect.com/science/article/pii/S0301479723018224

Thanks for sharing, these are very helpful. We have incorporated them in our Introduction and Discussion. The data from Bass et al. (2014) were especially helpful to conduct the landscape extrapolation.

L34: "Emissions from wetlands increase when soils are disturbed, for example, by the trampling, grubbing, and digging of invasive ungulates or hoofed mammals (O'Bryan et al., 2021; Traby and Grover 2023)."

L332: "These results complement previous studies showing the effect of hoofed animals in increasing CH_4 emissions in wetlands (Treby and Grover, 2023)."

L349: "Emissions of *Melaleuca* wetlands during flooding periods in the region are higher for CH_4 but lower for CO_2 (Bass et al. 2014) and year-to-year variations in emissions are likely under different pre-flooding conditions, with lower emissions in floods preceded by dry periods (Jeffrey et al. 2019)."

L366: "We cautiously estimate annual emissions from pig disturbance using our data, supplemented by published estimates of emissions during flooding (Bass et al. 2014)."

Conclusion: *The introduction discusses national greenhouse gas accounting schemes or conservation programs to support feral pig exclusion as a mechanism to reduce greenhouse gas emissions. I suggest reconnecting this concept in the conclusion, albeit cautiously given this is the first study of its kind, nevertheless, it represents an important potential policy implication of this work.*

We have added a conclusion statement outlining the potential applications of this study; however, we have purposefully refrained from providing our opinion on management issues, as the Traditional Owners, who are co-authors of this manuscript, have requested to leave that topic to their own decision-making.

L382: “In conclusion, we demonstrate that feral pigs pose a significant threat to soil carbon integrity and significantly modify soil biogeochemical processes, leading to increased greenhouse gas emissions. These effects, measured in this study in tropical floodplains in Australia, are likely to occur in wetlands worldwide. Physical activity in the soil and the increase in nitrogen from pig excreta are significantly increasing emissions, especially of CH_4 and N_2O. Tackling these two potent greenhouse gases exacerbated by feral pigs has the potential to significantly contribute to climate change mitigation (Ocko et al., 2021), while also improving biodiversity and culture.”