Response to comments by referee #1 on the manuscript egusphere-2024-2348

We, the authors, thank the editor for handling the paper and the reviewer for their comments and suggestions. We value the careful feedback provided, and we believe this is important for improving the quality of our review paper. We provide a table with detailed responses to each separate comment. We hope that the revisions align the manuscript's objectives with the reviewer's expectations.

Sincerely,
Renata Moura da Veiga (on behalf of all co-authors)

Reviewer's comments	Answers
I think the Abstract would benefit with more detail and the key take-away messages. For instance, it is not clear that, amongst the papers that evaluated fire emissions, most were on a global or continental scale and there were only 2 papers that explicitly analysed fire emissions in the Cerrado. This severe lack of literature on the issue (especially compared to other ecosystems, as the authors reinforce), is one of the key take-aways of the paper in my opinion. Could also mention that most of these studies were conducted by international teams and a considerable number did not include Brazilian authors nor institutions based in the Cerrado biome.	We have fully revised the Abstract to include the suggestions made by the reviewer. The Abstract now reads: "Estimating fire emissions in the Brazilian Cerrado requires integrating fire parameters, mitigation strategies and policies. Despite the Cerrado's significant contribution to global fire emissions, research in this area is still overlooked when compared to other savanna ecosystems. Here, we provide a comprehensive understanding of the Cerrado's fire emissions within the global carbon budget by examining how fire dynamics, management and policy shape emissions. We systematically reviewed 77 papers, of which 57% address fire dynamics, management and policy. While these are key to providing a holistic understanding of fire emissions, linking them to estimates is challenging, especially due to the difficulty in valuing the qualitative aspects of fire. This review only identified two papers that explicitly analyze fire emissions in the Cerrado, and found that 17% of papers are led by institutions located within the Cerrado biome area. These numbers reinforce the urgent need for further investigation into the topic. Most papers employ different methods to achieve their results. Evidence suggests growing

	interest in fire emissions in the Cerrado, reflected in the rising number of studies over the years. More research is required to provide a more comprehensive understanding of fire emission in the Cerrado, understand fire dynamics and emissions, and identify potential mitigation measures that could help reduce the Cerrado's contribution to the global carbon budget. This could be achieved by better accounting of emission parameters across the Cerrado's vegetation types and fire regimes, and by including fire management representation in land surface models and using observational data to constrain and assess their utility."
Line 12: I suggest changing "countries" to "ecosystems".	"Countries" changed to "ecosystems"
Line 12: I think it's missing a phrase stating what this study is proposing to do (e.g. "Here, we propose to bridge this gap by (…)"), to precede results on the following sentence "Of 77 systematically reviewed papers (…)".	Sentence added: "**Here, we provide a comprehensive understanding of the Cerrado's fire emissions within the global carbon budget by examining how fire parameters guide emission estimates and mitigation strategies**. We systematically reviewed 77 papers, of which 57% address fire dynamics, management and policy."
Line 12: "papers" is duplicated.	"Papers" deleted.
Line 12: Is the 54% correct? Lines 290-291 state 46 papers for "fire dynamics" and 12 for "management and policy" (that is, 58 total for both categories). If some of these are double counted, then this number should figure somewhere in the manuscript for clarification.	Thank you for your comment. It is in fact 57% (58 papers out of 101, due to double counts). This is made clearer in the text in lines 273-277: "Of the 77 papers reviewed, 46 relate to fire dynamics parameters used to estimate emissions, 43 report the amounts of fire emissions, and 12 report fire management and policy. It's worth noting that 24 papers are related to more than one topic. These numbers indicate that most papers are not related to reporting emissions but provide information to support the understanding and estimation of fire emissions **– 57% (double counts included) of papers address fire dynamics, management and policy."**
Line 13: I suggest "While these are key to provide a holistic (…)".	"Drivers" deleted, and the sentence now reads "While these are key to provide"...

Line 16: “Methodological techniques” seems redundant (also on the legend of Figure 5). I suggest “Most papers employ different methods (…)”. Line 18: I suggest rephrasing to “More research is required to understand fire dynamics and emissions in the Cerrado and identify potential mitigation measures (…)”. Line 19-21: While I agree that land surface models would benefit from including fire management, I’d say it’s more urgent that the scientific community works to properly quantify emission factors for Cerrado’s vegetation types and across fire types (more/less intense fires, EDS/LDS fires, etc).	Sentence in the abstract changed to “most papers employ different methods” ... “Techniques” deleted from Figure 5 (line 308 and figure legend) Sentence rephrased: “More research is required to understand fire dynamics and emissions in the Cerrado, and identify potential mitigation measures that could help reduce the Cerrado’s contribution to the global carbon budget.” Sentence updated: “This could be achieved by better accounting of emission parameters across the Cerrado’s vegetation types and fire regimes, and by including fire management representation in land surface models and using observational data to constrain and assess their utility.”
I think the Introduction is quite big and could be slightly summarized and re-organized. I propose to relocate the following paragraphs: paragraphs from lines 55 to 77 could follow the first paragraph (lines 23-30), characterizing the Cerrado biome and fire activity. Then, keep paragraphs from lines 31-54, discussing fire emissions in Cerrado. And finally, paragraphs from lines 78-104.	We appreciate your comment. We have reorganized the paragraphs according to the reviewer’s suggestion.
Line 24: I suggest “Around 49% of Cerrado (965,783 km2) is covered (…)”. Line 37: “However” seems misplaced. There is no contradiction. Line 38: This phrase is confusing as is. I suggest something along the lines of “Thus, understanding the contribution of each of these greenhouse gases, especially CO2, in fire emissions is essential, especially in fire-prone ecosystems such as Cerrado.”. Line 40: I suggest rephrasing this sentence, deleting “immediate emissions” and “fire participates”. Something along the lines of “Beyond emissions, fire interacts with several components of the carbon cycle, shaping complex interactions and carbon	“48.66%” changed to “around 49%” “However” deleted. Sentence rewritten: “Thus, understanding the contribution of each of these gases, especially CO2, in fire emissions is essential, particularly in fire-prone settings such as the Cerrado. Sentence rephrased: “Beyond emissions, fire interacts with several components of the carbon cycle, shaping complex processes over time.”

balance over time.”.	
Lines 42-44: Needs a reference.	We have included the reference: Bond WJ, Woodward FI, Midgley GF (2004) The global distribution of ecosystems in a world without fire. New Phytologist, 165(2):525-37. https://doi.org/10.1111/j.1469-8137.2004.01252.x
Line 70: Define IPCC.	Definition added for IPCC and UNEP: “Working Groups I and II of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6 WGI/WGII; IPCC, 2021, 2022) and the United Nations Environment Programme “Spreading like Wildfire" report (UNEP, 2022)
Line 78: As it’s the first time this term is used in the article, and because it has not been said yet that this is one of the categories identified in the study, it is not clear what “fire dynamic parameters” is. I propose changing to “understanding fire dynamics provides grounding (…)”.	“Fire dynamic parameters” changed to “fire dynamic”
Lines 80-82: Is this not a result?	Sentence deleted and paragraphs joined together: “In this context, understanding fire dynamics provides grounding for assessing fire emissions in the Cerrado, and the interaction between these is essential for uncovering the factors that influence the Cerrado's role in the global carbon budget and the broader implications for national and international policy. Linking fire dynamics to estimated emissions also guides mitigation by identifying aspects for potential intervention”...
Line 80: I suggest changing “cycle” to “budget”.	“Carbon cycle” replaced by “Carbon budget”
Line 84: GHG is not defined.	Definition added: “greenhouse gases (GHG)”
Lines 87-88: Reference?	Reference added: Griscom et al., 2020
Lines 89-91: I believe this belongs in Discussion.	Sentence moved to Discussion: lines 529-641.

Line 94: I suggest “what are the parameters used (…)”. Line 95: You mean “pyrogenic carbon”? If so, this term should be employed earlier in the text. Line 101: I suggest “describe fire parameters”.	“Fire dynamic” deleted and sentence now reads: “what are the parameters used”... Thank you for pointing this out. This sentence has been edited and now reads: “**Since carbon is a major contributor to atmospheric greenhouse gas levels**, this systematic review”... Aim (b) changed from “describe fire dynamic factors that support these estimates” to “describe fire parameters that support these estimates”
I think this section presents my only remaining disagreement with the authors: the use of “natural areas”. I disagree with the authors that “A focus on natural areas allows for a clearer evaluation of how fire interacts with ecosystem function, rather than being confounded by human-driven fire use.”, as fires in natural areas of the Cerrado are still, in their vast majority, human-driven (e.g. see Arruda et al. 2024: “Natural vegetation was the most affected, primarily due to human-driven ignition during the dry season”). Nevertheless, I completely agree with the point the authors make in “Knowledge Gaps in Fire Regimes and Emissions” and add that it should be included in the Discussion. However, I don’t think it justifies the use of “natural areas” in the study. I don’t think that including anthropogenic burning would change the scope of the article, as the study already considers anthropogenic burning. As mentioned before, ignitions in the Cerrado are overwhelmingly human and, as such, any discussion of fire and fire emissions in the biome will consider anthropogenic-driven fires, unless it specifically evaluates lightning-induced fires or “natural fire regimes”. Additionally, most papers found in the review process include burning in anthropogenic land covers and discuss the human components of fire. As there is no keyword in the review process for this, this is not explicitly accounted for throughout the manuscript. Moreover, there is no other	We understand the reviewer’s concern, and appreciate the discussion since we believe this has improved the paper. “Natural areas” indeed was not included as a keyword search. Thus, we reconsidered this methodological decision, and have clarified what we mean by fires in natural vegetation in the context of our review paper, stating that we did not include papers that explicitly use fire for anthropogenic land uses. The new paragraph and argument for this decision are in lines 122-129: “We applied four inclusionary criteria to identify relevant literature: papers had to be (1) published in peer-reviewed journals with an impact factor greater than 1; (2) encompass the Cerrado biome; (3) be published after 2003; and (4) be conducted in areas that do not explicitly include anthropogenic land uses. Although we acknowledge the role of anthropogenic fires and the importance of further research to integrate these to fully assess fire emissions in the Cerrado, we focus on fires that are not explicitly used for anthropogenic land uses – as land clearing for agriculture implementation – to provide a clearer ecological perspective on fire emissions in the Cerrado and their implications for the global carbon budget. Thus, identifying the key drivers of fire emissions in the Cerrado’s landscapes provides a strong basis for improving emissions estimates, understanding fire-climate feedback, and

mention of "natural areas" in Results or Discussion (except for the repetition of the research question). As such, I don't see the need to make this distinction, when this is not reflected in the Methods, Results and Discussion.	assessing long-term ecosystem resilience in the Cerrado." The research question and PRISMA diagram were also updated accordingly.
Lines 139-140: I wouldn't say "there is greater certainty", it's the yearly availability of these products that start in 2003.	Sentence changed to: "with full-year data available starting in 2003"
Lines 192-197: This information should come earlier in the Methods section, maybe after line 142.	Sentence moved to lines 143-149. Paragraph now reads: "The criteria led to the initial screening of 109 papers. Although we used keywords to conduct our review, the searches still returned papers not in English, or that did not mention fire emissions. 32 papers were excluded due to being duplicates, not in English, or not mentioning fire emissions. Review and perspective papers were included in this systematic literature review to contribute to a more complete analysis of fire emissions in the Cerrado. **Review and perspective papers analyze previously published studies by evaluating existing literature (review) or expressing opinions on a specific topic(perspective) while empirical studies provide new information based on observation or experiments. Although they do not focus on bringing original research, they supply the current knowledge of a specific topic and highlight pertinent published literature (Cronin et al., 2008).** We full-text screened the remaining 77 papers to confirm they met all the eligibility criteria. Figure 1 demonstrates the systematic literature review process through the PRISMA diagram."
Lines 192-197: Please clarify the different between Review and Perspective papers for the reader.	Thank you for your comment. The definition is already included in lines 144-146, and we have made these clearer: "Review and perspective papers analyze previously published studies by evaluating existing literature (review) or expressing opinions on a specific topic (perspective)"
Line 203: I suggest just using "fire	We have kept the term "fire dynamic

dynamics" instead of "fire dynamics parameters".	parameters" in this line and throughout the text. We believe this term better contemplates the discussions made in the manuscript, since we not only discuss the overall fire behaviour and how fire interacts with the environment and climate (fire dynamics), but also specific variables that describe aspects of fire dynamics (such as fire intensity, fuel load, and so on).
Line 203: I think the authors meant "research".	"topic of search" replaced by "topic of research"
Line 229: How was the trend estimated (linear regression, Mann-Kendall, etc)? This information should be added to Methods.	Sentence added to lines 139-140: " We evaluate the trend in the number of papers published over time using linear regression"
Line 237: There is no contradiction, as Mistry et al. (2019) also extrapolates from a smaller region to a larger.	"Conversely" changed to "Similarly"
Figure 4: Please upload with higher resolution.	Figure with higher resolution uploaded.
Line 291: I suggest rephrasing to "(…) policy. It's worth noting that 24 papers are related to more than one topic.".	"The total does not round up to 77 because 24 papers are related to more than one topic" replaced by "It's worth noting that 24 papers are related to more than one topic"
Lines 298-299: This sentence belongs in the Discussion.	Sentence moved to Discussion (now lines 695-696).
Line 301: Please clarify what "modelling" means in this context. Statistical modelling, process-based models?	We have now defined what we mean by modelling in the sentence: "In this study, we discuss 'models' in terms of the qualitative and quantitative characterizations of components within a system and their interactions (IPBES, 2016)."
Line 313-314: I think this sentence belongs in the Discussion and Conclusion.	This sentence was included as the first sentence of the Discussion. This sentence was already in the Conclusion in LINES 772-774 (now 753-755): "Based on our knowledge and search criteria, this is the first systematic literature

	review to provide an integrated understanding of fire emissions in the Cerrado, where fire dynamics, management and policy emerge as crucial for estimating fire emissions".
Line 325: "emissions"	Corrected.
Line 379: Use the acronym previously defined for modified combustion efficiency.	"modified combustion efficiency" replaced by MCE
Line 382: Use the acronym previously defined for late dry season fires.	"Late dry season" replaced by LDS
Line 384: The values are so similar it is relevant to show the uncertainty range if there is one.	Vernooij et al. (2021) do not provide a uncertainty range.
Lines 385-386: It is said that the values are underestimated, and the following sentence says these are high. Seems contradictory.	Sentence rephrased: "These values are consistent with other savannas in the world"
Line 389: I suggest "(…) estimating emissions (…)".	"estimating fire emissions" replaced by "estimating emissions"
Line 428: This seems to entail that the previous studies did not use FRP as a measure of fire intensity, which is not the case.	We have deleted the word "also" as an attempt to remove this interpretation. The sentence now reads: "Fire intensity can also be measured through the fire radiative power (FRP)."
Lines 433-435: If FRE is not used in any study I don't see why its definition is needed here.	Sentence deleted.
Lines 448-452: I think this belongs to the Discussion.	We appreciate your comment. Although we agree that these sentences could fit the Discussion section, we have kept them where they were. We believe they introduce Figure 6, which follows this paragraph and summarizes all the predominant factors associated with fire emissions in the Cerrado mentioned in this section.
Figure 6: I now agree with the authors that the figure is essential to report findings. However, I still have reservations about the arrows, namely those going to Burned Area and Combustion completeness and then Fire emissions. You found in the literature that	We have modified Figure 6 to include the elements discussed in the text: combustion efficiency, FRP and emission factor. Together with burned area and combustion completeness, these now result in fire emissions. The legend was also modified

there are other parameters (e.g. FRP; emission factors) used to estimate Fire emissions. Why are they not considered here?	accordingly. We believe these changes address the reviewer's concerns, and make the Figure less confusing.
Legend of Figure 6: I don't think it's "fire spreads from forests to grasslands" but rather "fire spread increases from forests to grasslands".	Legend modified: "Figure 6: Variables associated with estimating fire emissions in the Cerrado found in the literature. The Cerrados's physiognomies, separated into forests, savannas and grasslands, increase in fine fuel load and decrease in fuel moisture from forests to grasslands. Microclimatic conditions also change across the physiognomies, with increasing wind speed and air temperature, and decreasing relative humidity from forests to grasslands. The Cerrado's seasonality is divided into wet and dry seasons. The wet season is characterized by high precipitation, lightning ignitions and accumulated biomass, whereas the dry season is characterized by low precipitation, anthropogenic ignitions and flammable biomass. Fuel characteristics (square boxes), climatic conditions (circle boxes) and ignition (hexagon boxes) interact (dashed lines) to determine the Cerrado's fire behavior. Two aspects of fire behavior are presented (numbers 1 and 2): 1) fire spread increases from forests to grasslands; 2) fire intensity increases in the dry season. The Cerrado's physiognomies, seasonality and fire behavior together (red solid square) interact to determine size of burned area, combustion completeness, combustion efficiency, emission factor and FRP. These (red dashed line) drive the resultant fire emissions (red dotted line). The image representing the Cerrado's physiognomies was adapted from the Brazilian Agricultural Research Corporation (Embrapa, 2024)."
Line 498: Is the 43% correct? Isn't it 43 papers out of 77?	43% is correct. It is 43 out of 101, given that 24 papers belong to more than one topic. This is made clearer now: "43% (43 papers, due to papers double counted)
Line 520: Acronym already defined previously.	Definition in parentheses "(Southern Hemisphere South America)" removed.

Lines 526-530: Seems Discussion to me.	Moved to Discussion: lines 634-639.
Table 2: I think it would be interesting a discussion on the similarity/disparity of the values found in the literature, and how they compare to broader estimates (from savannas in South America, for example).	We appreciate your comment and agree that a comparison with broader estimates could enrich the paper. However, we chose, in this section, to focus on studies explicitly dedicated to estimating carbon emissions from fires in the Cerrado. Expanding the discussion to include broader-scale estimates would, in our view, require a more extensive analysis. We believe that maintaining a focused approach allows for a more in-depth assessment of the Cerrado-specific dynamics and uncertainties.
Table 2: Please clarify that Gomes et al. (2020a) does not estimate emissions.	Observation on Gomes et al. (2020a), Table 2, changed to "The study estimates the amount of carbon released in combustion, used as a proxy for estimates of fire-associated emissions."
Line 579: Please remove "and even in the units". Gomes et al. (2020a) does not estimate emissions but rather the amount of carbon released in combustion, which is a parameter that can and will be used to estimate emissions.	Sentence removed and now reads: "The difference in values (Table 2) indicates"...
Lines 579-584 and 592-594: Seems Discussion to me.	Lines 579-582: We appreciate your comment. Although we agree that this paragraph fit the Discussion, we have kept it there because we think it provides a synthesis of Table 2, placed right before this paragraph. From our perspective, moving it to Discussion would hinder the flow of this analysis. Lines 592-594: moved to Discussion (lines 686-687).
Line 602: Define IFM.	Integrated Fire Management (IFM) defined, and acronym used in further mentions of the term.
Line 619: "small-scale"	Corrected.
Line 620: This section of the sentence is confusing: "fire regime characteristics of fire management activities". Maybe "(…) studies that estimate activities associated with fire management activities, such as prescribed	"Fire regime characteristics of fire management activities" replaced by "activities associated with fire management"

burning (…)".	
Lines 627-629: The results of Santos et al. (2021) are valid for which region? Better to mention.	Location clarified in the sentence: "Santos et al. (2021) also documents reduced burned area in the late dry season due to fire management **in two Indigenous Territories in the Cerrado**, which led to reduced fire intensity and reduced extreme wildfires, indicating a reduction in further fire emissions."
Lines 630-636: Please highlight that this is a result. That is, that this is what the papers cited discuss and inform.	Sentence included in the beginning of the paragraph: "The literature reviewed shows that"...
Lines 640-642: The authors mention a "broad and holistic understanding of the role of these emissions in the carbon budget on regional, national and global scales" however, up to this section of the manuscript, there has been no such discussion. As per my comment for Table 2, I suggest writing a paragraph on this.	Thank you for your comment. When we refer to a "broad and holistic understanding," we are referencing the multiple aspects identified in the literature that influence emission estimates—such as fire policy, fire management practices, and fire dynamic parameters—as well as the diverse methodological approaches used to estimate these emissions, as discussed in the earlier sections of the paper. We have made this clearer in the paragraph, which now reads: "To our knowledge, and according to our search criteria, this is the first systematic literature review to provide an overview of fire emissions in the Cerrado. By analyzing existing literature on fire emissions in the Cerrado, we identified key topics that contribute to a broad and holistic understanding of the role of these emissions in the carbon budget on regional, national and global scales. This understanding includes not only direct fire-related carbon emission, but also the underlying fire dynamic parameters, fire management practices, and fire policies, along with the various methodological approaches used to estimate these."
Line 658: I wouldn't say 31% of papers is "most".	"most" replaced by "many"
Lines 673-674: Slightly misleading sentence.	This sentence refers to Gomes et al. (2024)

Two papers were identified that estimate emissions in Cerrado. Even if only one goes back to 1985.	being the only paper found in the literature that evaluates net fire emissions. This was made clearer in the sentence: "This literature review identified one study that includes the removal of CO_2 by regrowth in the Cerrado, quantifying the net CO_2 emissions from the Cerrado fires from 1985–2020 (Gomes et al., 2024)."
Line 693: First time that pyrogenic carbon is mentioned in the text. If the authors want to use this term, I suggest using it earlier in the manuscript.	Term removed from sentence.
Line 714: Use the acronym previously defined.	"Integrated Fire Management" replaced by its acronym.
Line 724: I would also add to the discussing the findings of Andela et al. (2017; A human-driven decline in global burned area), where they found that a recent decrease in savanna fires worldwide is driven by human occupation.	Sentence added to Discussion (lines 706-707): "In fact, Andela et al. (2017) found a decreasing trend in fire activity driven by human activities worldwide"
Table 3: Shouldn't FRP be added to the column on the left?	Fire intensity added to Table 3.
I would suggest reinforcing the take-away messages in the Conclusion as well (similarly to the Abstract).	We have added two sentences in the Conclusion to reinforce the take-away messages: "From our literature review process, we found that research on fire emissions in the Cerrado is still overlooked when compared to other savanna ecosystems." "Thus, this review demonstrates that understanding the placement of fire emissions in the global carbon budget requires a holistic approach that draws together disciplines across fire science, especially in a distinct environment such as the Cerrado, **while reinforcing the urgent need for further investigation into the topic.**"