nature portfolio

Peer Review File

Climate change and deforestation in the Amazon: A recipe for extremely dangerous heat stress exposure

Web links to the author's journal account have been redacted from the decision letters as indicated to maintain confidentiality.

7th May 21

Dear Dr Oliveira,

Your manuscript titled "Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon" has now been seen by 2 reviewers, and I include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. In particular, we ask that you address the concerns regarding discussion of the population analysis and the appropriateness of the applied equation for estimating indoor WBGT. Please highlight all changes in the manuscript text file.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter) and the completed checklist:
[link redacted]
** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

We understand that due to the current global situation, the time required for revision may be longer than usual. We would appreciate it if you could keep us informed about an estimated timescale for resubmission, to facilitate our planning. Of course, if you are unable to estimate, we are happy to accommodate necessary extensions nevertheless.

Please do not hesitate to contact me if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Clare

Dr Clare Davis

Associate Editor
Communications Earth & Environment

www.nature.com/commsenv/
@CommsEarth

EDITORIAL POLICIES AND FORMATTING

We ask that you ensure your manuscript complies with our editorial policies. Please ensure that the following formatting requirements are met, and any checklist relevant to your research is completed and uploaded as a Related Manuscript file type with the revised article.

Editorial Policy: Policy requirements

Furthermore, please align your manuscript with our format requirements, which are summarized on the following checklist:
Communications Earth & Environment formatting checklist

and also in our style and formatting guide Communications Earth & Environment formatting guide .

*** DATA: Communications Earth & Environment endorses the principles of the Enabling FAIR data project (http://www.copdess.org/enabling-fair-data-project/). We ask authors to make the data that support their conclusions available in permanent, publically accessible data repositories. (Please contact the editor if you are unable to make your data available).

All Communications Earth & Environment manuscripts must include a section titled "Data Availability" at the end of the Methods section or main text (if no Methods). More information on this policy, is available at http://www.nature.com/authors/policies/data/data-availability-statements-data-citations.pdf.

In particular, the Data availability statement should include:
- Unique identifiers (such as DOIs and hyperlinks for datasets in public repositories)
- Accession codes where appropriate
- If applicable, a statement regarding data available with restrictions
- If a dataset has a Digital Object Identifier (DOI) as its unique identifier, we strongly encourage including this in the Reference list and citing the dataset in the Data Availability Statement.

DATA SOURCES: All new data associated with the paper should be placed in a persistent repository where they can be freely and enduringly accessed. We recommend submitting the data to discipline-specific, community-recognized repositories, where possible and a list of recommended repositories is provided at http://www.nature.com/sdata/policies/

repositories.

If a community resource is unavailable, data can be submitted to generalist repositories such as figshare or Dryad Digital Repository. Please provide a unique identifier for the data (for example a DOI or a permanent URL) in the data availability statement, if possible. If the repository does not provide identifiers, we encourage authors to supply the search terms that will return the data. For data that have been obtained from publically available sources, please provide a URL and the specific data product name in the data availability statement. Data with a DOI should be further cited in the methods reference section.

Please refer to our data policies at http://www.nature.com/authors/policies/availability.html.

REVIEWER COMMENTS:

See attached files for Reviewer Comments.

Reviewer #2 (Remarks to the Author):

Congratulations to the authors for this good work. The paper presents an evaluation of the WBGT as a result of current and future climate conditions, considering Amazon savannization and global climate change scenarios. It was tested representative concentration pathways (RCP) 4.5 and 8.5 scenarios, with simulations until the end of this century. The method was chosen for WBGT estimation depends on the variables air temperature, relative air humidity, wind speed, and radiation. Knowing that air temperature and humidity exert a very important role in heat stress evaluation, the results of this paper present great scientific gain. This is because the savannization simulation has shown increased temperature and decreased humidity, and therefore, this study reveals that there is no compensation of the increased temperature by decreased humidity, resulting in increased WBGT under two scenarios considered.

Daniel Bitencourt

Review for "Effects of Deforestation and Climate Change on Heat Stress Risk Exposure in the Brazilian Amazon"

Summary: This paper presents results from a set climate modelling experiment where different land use changes in the Brazilian Amazon were combined with various greenhouse gas emissions scenarios. The authors use these experiments to describe the impacts of deforestation, climate change, and the combination of both on WBGT, a metric of occupational and environmental safety. A population analysis reveals the impacts of different scenarios on the population within the study regions. The climate modelling component of this paper is solid (though I do have a suggestion to clarify presentation of the results), and the population analysis makes an extremely important contribution to the existing literature on tropical deforestation. I have some questions about the methodology (particularly the population analysis) but in general I think these authors have produced a valuable piece of work. My experience is in climate science and not human health/population health; I think the climate modelling in this piece is rock solid, but was very confused by the discussion of the last two figures. I think the authors could do a better job of explaining and presenting the results.

I recommend that this paper be accepted once these revisions are complete. My comments are in black. Long stretches of text from the paper are in blue.

Major Suggestions:

1) Some of the discussion of the various model experiments are difficult to understand, I would strongly suggest the authors adopt some kind of naming convention so that each experimental result is explicitly identified. One example of this could be the following "XY" where X is the greenhouse gas scenario (H – historical, 45 – RCP4.5, and 85 – RCP8.5) and Y is the land use scenario (F – forested, S – Savannah). Thus HS would be the historical greenhouse gas scenario run with the savannah land use pattern and 85F would be the RCP8.5 greenhouse gas scenario run with the forested land use pattern. This would be particularly helpful in the Figure captions. "Difference historical" is not really descriptive of the experiments you're subtracting from one another, I think a naming convention would help the readers quite a bit.
2) There's virtually no discussion of the population analysis, which makes the second half of the "Amazon savannization and heat stress" section a bit challenging to understand or offer comments on. I don't think anything needs to be added to the main text here, but a discussion of the population analysis is basically essential for interested readers to understand how Figs. 3 and 4 were generated.

Minor Suggestions:

Abstract:

I would remove the distinction between indoor and outdoor heat stress values in the abstract, as they may be unfamiliar to non-expert readers and instead introduce this subtlety in the second main section (see *** below).

First you say savannization and climate change *will* lead to XYZ, then the next sentence says the effects *might* lead to XYZ. Since the land use change applied to the climate model to represent savannization in this paper is fairly extreme, I would stick with *could* or *might* rather than implying that the results presented here are a forecast.

Introduction:

~~in the midst of a global health crisis due to the COVID-19 pandemic~~

"These latter two regions present the highest projected air temperature increases due to global warming in Brazil." I think you could say "A recent study[5] found that these two regions have the largest projected air temperature changes driven by XYZ climate models."

Between August 2019 and July 2020, **total** deforestation in the Brazilian Amazon **experienced the single highest year-to-year increase since 2010 (nearly 1,000 km^2)**"

"The Paris Agreement **(aimed at limiting global warming to 1.5-2.0˚C)"**

The area deforested in 2020 is much larger than the commitment specified in Brazil's(?) National Policy"

Direct and indirect implications – I don't understand the difference here. I would say "…will aggravate the effects of heat exposure on human adaptation, work activities, leisure…"

~~**Human Health Implications Due To Heat Stress:**~~
Heat Stress Impacts on Human Health:

~~by contrast,~~ in environments with high humidity (and low wind speeds), this mechanism is ~~reduced~~ less effective and the body's heat balance can be compromised. Outside of environmental factors, clothing, physical activity, and acclimatization can also effect heat stress.

*** "Based on indoor/in-shade and outdoor WBGT values…" These two sentences that end the section are very unclear and do not adequately describe the metrics you're using to quantify heat stress later in the paper. In particular, a description of why indoor and outdoor values are different (and an explicit discussion of how these are calculated in the methods section) is essential for readers to understanding the primary metric in this paper. For example, in Fig. 1 you show values of indoor/in-shade WBGT; the reader should understand why this is before you get there. There are equations in the methods, but no real explanation of i) why there are different metrics and ii) who uses which ones for which purposes would be helpful.

Amazon savannization and heat stress:

Fig 1S, 2S, 3S – see comment on naming convention above. I think that it will be extremely helpful here because sometimes it's not clear which land use change or greenhouse gas experiment you're discussing. It would be particularly helpful for Fig. 1, because there are so many panels (the with/without naming convention is not clear). I would also mention somewhere here that these scenarios are a worst case scenario where the *entire* Amazon rainforest is replaced with savannah. That's clear from the methods, but not in the text and is pretty important for interpreting the results.

Sometimes you refer the land use change as *savannization* and sometimes it's called *deforestation*. I think that based on what you right in the methods section is should be the former all the time.

***"Figure 2 shows histograms of the distributions of the daily maximum indoor/in-shade and outdoor WBGT values, highlighting the heat stress exposure risk thresholds, as influenced by savannization and the climate change scenarios in the Amazon Basin." Again, maybe this distinction is obvious to a small subset of your readers, but a motivation for showing these two metrics (especially when you only showed one of them in Fig. 1) would be helpful here, even it's just a pointer to your description in the methods section. Also, I'm personally a bit confused by the different thresholds you point to in the caption to Fig. 2. I'm not very familiar with indoor/outdoor WBGT, so I think an explanation why the thresholds presented are the same for different values of WBGT would be important.

"The data show that under indoor/in-shade conditions, replacement of the current forest cover with savanna-type vegetation during the baseline/historical period could lead to a daily maximum WBGT distribution equivalent to that predicted by the RCP8.5 climate scenario at the end of the century." There's already some observational evidence of this happening in the Amazon, see Vargas Zeppetello *et al* 2020 *Environ. Res. Lett.* **15** 084012.

~~most severe effect of climate change~~ climate changed forced by unmitigated GHG emissions.

"Under these conditions…" Which conditions? Another place where a naming convention would be helpful.

~~Climatic~~ climate

"In the context…" See major comment 2 above. There's no discussion of how any of this is calculated, and some of the discussions of Figs. 3 and 4 are not clear to me. I think some discussion of how these population calculations were done need to be in the methods section. In Fig. 3, how long are these populations exposed for? 1 day/week/month per year?

In Fig. 4, I'm not sure if the difference is between the historical forested simulation and the RCP8.5 with savannah or forest. I'm also unclear of what's being plotted here, and the text isn't very clear. What are the different dots? What's on the x-axis and what are the important differences between the three plots? Since there's no obvious correlation between WBGT changes and vulnerability index, maybe there's a better way to display this information.

Materials and Methods:

I would combine the observational data and the WBGT bias correction sections, as that seems to be the only place where these observational data are used. I'd also be curious to see how much the bias correction matters to the analysis. Some before/after bias correction figure would make an interesting way to show how well the model represents WBGT.

Review of **Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon**

Congratulations to the authors for this good work. The paper presents an evaluation of the WBGT as a result of current and future climate conditions, considering Amazon savannization and global climate change scenarios. It was tested representative concentration pathways (RCP) 4.5 and 8.5 scenarios, with simulations until the end of this century. The method was chosen for WBGT estimation depends on the variables air temperature, relative air humidity, wind speed, and radiation. Knowing that air temperature and humidity exert a very important role in heat stress evaluation, the results of this paper present great scientific gain. This is because the savannization simulation has shown increased temperature and decreased humidity, and therefore, this study reveals that there is no compensation of the increased temperature by decreased humidity, resulting in increased WBGT under two scenarios considered.

The study is addressed to Brazil and, therefore, I think that it should include some bibliographic references about this issue "WBGT" conducted for this country. Follow below some papers and books how suggestions:

Bitencourt, D.P. (2019) Maximum wet-bulb globe temperature mapping in central–south Brazil: a numerical study. Meteorological Applications, 26, 385–395. https://doi.org/10.1002/met.1769

Bitencourt, D.P., Maia, P.A. and Roscani, R.C. (2019) The heat exposure risk to outdoor workers in Brazil. Archives of Environmental & Occupational Health, 74, 1–8. https://doi.org/10.1080/19338244.2019.1633991

Bitencourt, D.P., Ruas, A.C. and Maia, P.A. (2012) Análise da contribuição das variáveis meteorológicas no estresse térmico associada a morte de cortadores de cana-de açúcar. Cadernos de Saúde Pública, 28, 65–74. https://doi.org/10.1590/S0102-311X2012000100007.

Bitencourt, D.P., Alves, L.M., Shibuya, E.K., Cunha, I.A., and Souza, J.P.E. (2020) Climate change impacts on heat stress in Brazil—Past, present, and future implications for occupational heat exposure. International Journal of Climatology, 41, 2741-2756.

Roscani, R.C., Bitencourt, D.P., Maia, P.A. and Ruas, A.C. (2017) Risco de exposição à sobrecarga térmica para trabalhadores da cultura de cana-de-açúcar no Estado de São Paulo. Cadernos de Saúde Pública, 33(3), e00211415. https://doi.org/10.1590/0102-311x00211415.

Maia, P.A., Ruas, A.C. and Bitencourt, D.P. (2015) Wet-bulb globe temperature index estimation using meteorological data from São Paulo State, Brazil. International Journal of Biometeorology, 59, 1395–1403 https://doi.org/10.1007/s00484-014-0949-7.

Nobre, C.A., Marengo, J.A. and Soares, W.R. (2019) Climate Change Risks in Brazil, 1st edition. Cham, Switzerland: Springer International Publishing, pp. 67–129.

Nassis, G.P., Brito, J., Dvorak, J., Chalabi, H. and Racinais, S. (2015) The association of environmental heat stress with performance: analysis of the 2014 FIFA world cup Brazil. British Journal of Sports Medicine, 49, 609–613. https://doi.org/10.1136/bjsports2014-094449

WBGT is an index widely used around the world for heat occupational exposure. Therefore, it is important some comments on the main features that legally regulate this exposure in Brazil. Recently, in December 2019, the norm was modified through document SEPRT Nº 1359 (http://www.normaslegais.com.br/legislacao/portaria-seprt-1359-2019.htm). The new regulation assigns to heat occupational exposure two other aspects very important, in addition to environmental heat stress which is quantified with WBGT: (1) worker´s clothing and (2) Laboral activity. This last implies for worker metabolic rate. In my opinion, it is important the authors show those issues in the introduction text.

WBGT has two equations, one applied for outdoor workspace WITH solar radiation and another applied for indoor workspaces OR outdoor workspaces WITHOUT solar radiation. In this study, where the WBGT is estimated from atmospheric variables, the equations would be applicable only for outdoor workspaces WITH and WITHOUT solar radiation. My suggestion is to replace "indoor/in-shade WBGT" with "in-shade WBGT" in the entire text of the paper.

Why the results of figures 1 and 4 were shown only for WBGT without solar radiation?

Material and Methods:

- I suggest replacing "observational data" with “meteorological data” or "atmospheric data". "Observational data" can indicate to the reader that it is data from the weather stations.

- Does "b" is the equation proposed by Bernard (1999)? I suggest citing the Bernard (1999) paper again when the equation is presented not to confuse with the original equation of WBGT without solar radiation. Also, the author could justify why did not use the same method from Liljegren et al. (2008) for the situations with and without solar radiation. If Liljegren et al. (2008) have made the estimation of T_{nbw} e T_g, those temperatures could be used in WBGT original equation without solar radiation (WBGT = 0,7 T_{nbw} + 0,3 T_g). In addition, it is important to treat air temperature always with the same variable name. In the text appear other variables names such as “Temperature of the dry” and “Atmospheric bulb”.

Reviewer 1

Major Suggestions:

1) Some of the discussion of the various model experiments are difficult to understand, I would strongly suggest the authors adopt some kind of naming convention so that each experimental result is explicitly identified. One example of this could be the following "XY" where X is the greenhouse gas scenario (H – historical, 45 – RCP4.5, and 85 – RCP8.5) and Y is the land use scenario (F – forested, S – Savannah). Thus HS would be the historical greenhouse gas scenario run with the savannah land use pattern and 85F would be the RCP8.5 greenhouse gas scenario run with the forested land use pattern. This would be particularly helpful in the Figure captions. "Difference historical" is not really descriptive of the experiments you're subtracting from one another, I think a naming convention would help the readers quite a bit.

Response: We agree. The legend captions have been changed to be easier to understand. We have taken the reviewer's suggestion and placed it in the introduction of the results section to help the readers.

> *"The various model experiments were explicitly named using the following legend: greenhouse gas scenario (H – Historical, 45 – Representative Concentration Pathways 4.5 – RCP4.5, and Representative Concentration Pathways 85 – RCP8.5); and land use scenarios (F – Forested, S – Savannah). For instance, HS represents the historical greenhouse gas scenario with the savannah land use pattern and 85F indicates the RCP8.5 greenhouse gas scenario run with the forested land use pattern."*

2) There's virtually no discussion of the population analysis, which makes the second half of the "Amazon savannization and heat stress" section a bit challenging to understand or offer comments on. I don't think anything needs to be added to the main text here, but a discussion of the population analysis is basically essential for interested readers to understand how Figs. 3 and 4 were generated.

Response: Thank you for your helpful review. As recommended, we included the population analysis in the methodology.

> *"**Population analysis.** Bias-corrected WBGT indices were used to calculate indicators of extremes, such as mean daily highs. Thus, from the WBGT hourly data, the maximum daily values were selected, forming a series of 10,266 days for each experiment. From this series, the monthly climatology of the WBGT daily maximums was calculated. The warmest month of this climatology was linearly interpolated for the reference geographic location of the 5,565 municipalities in Brazil and related to their populations, according to the number of inhabitants in each municipality as reported for 2019. The vulnerability of Brazilian municipalities and their populations exposed to heat stress conditions was evaluated using the Social Vulnerability Index (SVI)[31]. This index combines 16 indicators to define multiple dimensions of vulnerability, i.e., human capital, urban infrastructure, and income and work, thereby providing a scientific basis for understanding the vulnerability of Brazilian municipalities. Each indicator is represented by a normalized value on a scale that varies between 0 and 1, where 0 corresponds to the ideal or desirable situation. The*

SVI and its components can be categorized as follows: low or moderate social vulnerability (SVI: <0.400), high social vulnerability (SVI: 0.401 - 0.500), and very high social vulnerability (SVI: 0.501 - 1.000)[31].

Minor Suggestions:

Abstract:

I would remove the distinction between indoor and outdoor heat stress values in the abstract, as they may be unfamiliar to non-expert readers and instead introduce this subtlety in the second main section (see *** below).
Response: We have eliminated this distinction in the abastract text (Thank you!).

First you say savannization and climate change will lead to XYZ, then the next sentence says the effects might lead to XYZ. Since the land use change applied to the climate model to represent savannization in this paper is fairly extreme, I would stick with could or might rather than implying that the results presented here are a forecast.
Response: We agree. Thus, we have changed this in the text.

Introduction:
~~in the midst of a global health crisis due to the COVID-19 pandemic~~
Response: We have eliminated this sentence from the introduction section.

"These latter two regions present the highest projected air temperature increases due to global warming in Brazil." I think you could say "A recent study5 found that these two regions have the largest projected air temperature changes driven by XYZ climate models."
Response: Thank you! We have adjusted this point in the text, according to the suggestion.

Between August 2019 and July 2020, total deforestation in the Brazilian Amazon experienced the single highest year-to-year increase since 2010 (nearly 1,000 km2)" .
"The Paris Agreement (aimed at limiting global warming to 1.5-2.0˚C)"
The area deforested in 2020 is much larger than the commitment specified in Brazil's(?) National Policy"
Response: The portions in the text have been modified based on this recommendation.

Direct and indirect implications – I don't understand the difference here. I would say "…will aggravate the effects of heat exposure on human adaptation, work activities, leisure…"
Response: This portion of the text has been removed to increase readability.

~~Human Health Implications Due To Heat Stress:~~
Heat Stress Impacts on Human Health:
Response: As recommended, we have modified this subtitle in the principal text.

~~by contrast,~~ in environments with high humidity (and low wind speeds), this mechanism is reduced less effective and the body's heat balance can be compromised. Outside of

environmental factors, clothing, physical activity, and acclimatization can also effect heat stress.

Response: Thank you! We feel that this suggestion improved and ensured the fluidity of this portion of the text.

*** "Based on indoor/in-shade and outdoor WBGT values…" These two sentences that end the section are very unclear and do not adequately describe the metrics you're using to quantify heat stress later in the paper. In particular, a description of why indoor and outdoor values are different (and an explicit discussion of how these are calculated in the methods section) is essential for readers to understanding the primary metric in this paper. For example, in Fig. 1 you show values of indoor/in-shade WBGT; the reader should understand why this is before you get there. There are equations in the methods, but no real explanation of i) why there are different metrics and ii) who uses which ones for which purposes would be helpful.

Response: We have added more details about the WBGT index to reflect exactly this highlighted point.

> *"There are different heat exposure stress indices that can be measured such as rational indices (through calculations involving heat balance equation), empirical indices (based on objective and subjective strain), and direct indices (involving direct measurement of environmental variables)19 Direct indices are more applicable, as these indices are based on monitoring environmental variables. Among these indices, the Wet Bulb Globe Temperature (WBGT) is the most used, especially in military training, work safety, sports medicine and leisure activities[22–24].*
>
> *The WBGT heat index incorporates the natural wet bulb temperature (Tnwb), the black globe temperature (Tg), and air temperature (Ta), which can be estimated meteorological variables (temperature, humidity, wind speed, and solar radiation) for both in-shade environments (without solar radiation exposure) and outdoor environments (with solar radiation exposure). This index is properly adjusted for actions in work environments with rest/work cycles recommended based on various metabolic rates defined in international[22] and national[25,26] standards, which recommend an hourly rest period during heavy work when the WBGT exceeds 26°C and suspension of work activities when the WBGT reaches 34°C. Under more extreme conditions, e.g., a WBGT greater than 40 °C, exposure may compromise survivability in heat-vulnerable groups[2,27].*
> *."*

Amazon savannization and heat stress:

Fig 1S, 2S, 3S – see comment on naming convention above. I think that it will be extremely helpful here because sometimes it's not clear which land use change or greenhouse gas experiment you're discussing. It would be particularly helpful for Fig. 1, because there are so many panels (the with/without naming convention is not clear). I would also mention somewhere here that these scenarios are a worst case scenario where the entire Amazon rainforest is replaced with savannah. That's clear from the methods, but not in the text and is pretty important for interpreting the results.

Sometimes you refer the land use change as savannization and sometimes it's called deforestation. I think that based on what you right in the methods section is should be the former all the time.
Response: We have standardized the legends of the scenarios to increase readability based on this suggestion. In addition, we have mentioned that this is the worst scenario in this results section.

***"Figure 2 shows histograms of the distributions of the daily maximum indoor/in-shade and outdoor WBGT values, highlighting the heat stress exposure risk thresholds, as influenced by savannization and the climate change scenarios in the Amazon Basin." Again, maybe this distinction is obvious to a small subset of your readers, but a motivation for showing these two metrics (especially when you only showed one of them in Fig. 1) would be helpful here, even it's just a pointer to your description in the methods section. Also, I'm personally a bit confused by the different thresholds you point to in the caption to Fig. 2. I'm not very familiar with indoor/outdoor WBGT, so I think an explanation why the thresholds presented are the same for different values of WBGT would be important.

Response: We have added two paragraphs to provide additional details about the WBGT index in the "Heat Stress Impacts on Human Health" section, and we hope that this point will be clearer. Furthermore, we have removed the risk thresholds of heat stress from the "Materials and Methods" section justifying the limits considered in this study.

> *"In this study, to describe the spatial distribution of heat stress condition, the daily risks of heat exposure are defined as moderate (WBGT ≥ 26°C and < 30°C), high (WBGT ≥ 30°C and < 34°C), and extreme (WBGT ≥ 34°C) for work activities (workability), sports, and leisure practices22. These tolerance values are similar to the permitted limits of labor scale (work/rest) for intense occupational activities22 and international sports training[24] in non-cooled places. Under more extreme conditions, exposure to WBGTs greater than 40°C might compromise survivability in heat-vulnerable groups[2,27]."*

"The data show that under indoor/in-shade conditions, replacement of the current forest cover with savanna-type vegetation during the baseline/historical period could lead to a daily maximum WBGT distribution equivalent to that predicted by the RCP8.5 climate scenario at the end of the century." There's already some observational evidence of this happening in the Amazon, see Vargas Zeppetello et al 2020 Environ. Res. Lett. 15 084012.
Response: We have included this reference in the discussion of the results (Thank you!).

~~most severe effect of climate change~~ climate changed forced by unmitigated GHG emissions.

"Under these conditions…" Which conditions? Another place where a naming convention would be helpful.
Response: We have added a new name for this scenario to clarify these conditions.

~~Climatic~~ climate

"In the context…" See major comment 2 above. There's no discussion of how any of this is calculated, and some of the discussions of Figs. 3 and 4 are not clear to me. I think some discussion of how these population calculations were done need to be in the methods section. In Fig. 3, how long are these populations exposed for? 1 day/week/month per year?

Response: We have added a topic in the "Materials and Methods" section about population analysis. In addition, we have included an example about the exposure time in the highlighted text.

> *"For instance, these populations would be exposed to WBGT thresholds for at least one hour per day based on the monthly climatology of the daily maximum values."*

In Fig. 4, I'm not sure if the difference is between the historical forested simulation and the RCP8.5 with savannah or forest. I'm also unclear of what's being plotted here, and the text isn't very clear. What are the different dots? What's on the x-axis and what are the important differences between the three plots? Since there's no obvious correlation between WBGT changes and vulnerability index, maybe there's a better way to display this information.

Response: We have completely re-written the description of Figure 4 in accordance with your suggestions, and we believe it has vastly improved the focus and clarity of this result. Furthermore, we have changed the figure legend to be more interpretable and understandable.

> *"Of the total of 5565 Brazilian municipalities, 16% (887, inhabited by 30 million people) might be impacted (i.e., increased in-shade WBGT) by the savannization of the Amazon Forest in the RCP8.5 scenario (Figure 4). Of the impacted population, 42% reside in the northern region of Brazil, which is dominated by municipalities with low population density (with the exception of Manaus, which has a population of more than two million people) and very high social vulnerability. Of the impacted population in the northern region (12 million), 50% live in areas with low resilience and high social vulnerability (IVS≥0.400), reflecting a low capacity to respond and adapt to the combined effects of climate change and deforestation (the impacts of outdoor conditions are presented in the Supplementary Material).*
>
> ***Figure 4. Municipalities impacted by Amazon savannization RCP8.5 global warming scenario (2073–2100), according to the social vulnerability index (SVI) components**. Legend: The impacted municipalities were defined as those with a difference between the average daily maximum of the in-shade WBGT in the hottest month (85S – 85F scenarios) higher than 0.2. The SVI was classified: 0.3 to 0.4: moderate vulnerability (dashed yellow line); 0.4 to 0.5: high vulnerability (dashed orange line); greater than 0.5: very high vulnerability (dashed red line). The impacted population comprised 29,648,362 people, of which 42% reside in the northern region, 35% in the southern region, 16% in the southeastern region, and 7% in the midwestern region."*

Materials and Methods:

I would combine the observational data and the WBGT bias correction sections, as that seems to be the only place where these observational data are used. I'd also be curious to see how much the bias correction matters to the analysis. Some before/after bias correction figure would make an interesting way to show how well the model represents WBGT.

Response: As recommended, we have combined this content into one section namened "Atmopheric data and WBGT bias correction".

> ***"Atmospheric data and WBGT bias correction.*** *The atmospheric data used in this study were from the reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5[42]. Hourly data fields (i.e., temperature, humidity, solar radiation, and wind speed) were linearly interpolated to match the spatial resolution of the BESM model. Historical period data from 1981 to 2010 was used for the indoor and outdoor environment WBGT calculations and as the current conditions for the bias correction of the model outputs. Observational hourly WBGT values from the reanalysis were used for comparisons with the simulation of the forested Historical period and bias correction procedures. The method used to correct the WBGT bias was based on variable normalization. The standard normal deviate-based scaling used in the experiment is a simple approach that matches only the first and second moments of the observations and model distributions[43]. The correction was applied separately for each time and month to account for possible seasonal and daily cycle changes in the climatological differences. For a given calendar month and time k and a given grid cell i, the scaling parameters are the WBGT (evaluated by 30 years) mean ($Mm_{i,k}$ and $Mo_{i,k}$ for model and observations, respectively) and the standard deviation ($Sm_{i,k}$ and $So_{i,k}$ for model and observations, respectively). For each model WBGT T_i from a particular month and hour (time subscript omitted), the scaled model T_i' is then given by $T_i' = (T_i - Mm_{i,k})So_{i,k}/Sm_{i,k} + Mo_{i,k}$. The means and standard deviations of the forested Historical experiment and the reanalysis were used to correct the computed WBGT bias for the deforestation and RCP experiments. The use of the forested Historic parameters to correct for bias in the deforestation and RCPs experiments is valid as the experimental boundary conditions, although the physics and dynamics of the model were not altered (Supplementary Fig. 6S).***"***

Reviewer 2

Review of Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon

Congratulations to the authors for this good work. The paper presents an evaluation of the WBGT as a result of current and future climate conditions, considering Amazon savannization and global climate change scenarios. It was tested representative concentration pathways (RCP) 4.5 and 8.5 scenarios, with simulations until the end of this century. The method was chosen for WBGT estimation depends on the variables air temperature, relative air humidity, wind speed, and radiation. Knowing that air temperature and humidity exert a very important role in heat stress evaluation, the results of this paper present great scientific gain. This is because the savannization simulation has shown increased temperature and decreased humidity, and therefore, this study reveals that there is no compensation of the increased temperature by decreased humidity, resulting in increased WBGT under two scenarios considered.

The study is addressed to Brazil and, therefore, I think that it should include some bibliographic references about this issue "WBGT" conducted for this country. Follow below some papers and books how suggestions:

- Bitencourt, D.P. (2019) Maximum wet-bulb globe temperature mapping in central–south Brazil: a numerical study. Meteorological Applications, 26, 385–395. https://doi.org/10.1002/met.1769
- Bitencourt, D.P., Maia, P.A. and Roscani, R.C. (2019) The heat exposure risk to outdoor workers in Brazil. Archives of Environmental & Occupational Health, 74, 1–8. https://doi.org/10.1080/19338244.2019.1633991
- Bitencourt, D.P., Ruas, A.C. and Maia, P.A. (2012) Análise da contribuição das variáveis meteorológicas no estresse térmico associada a morte de cortadores de cana-de açúcar. Cadernos de Saúde Pública, 28, 65–74. https://doi.org/10.1590/S0102-311X2012000100007.
- Bitencourt, D.P., Alves, L.M., Shibuya, E.K., Cunha, I.A., and Souza, J.P.E. (2020) Climate change impacts on heat stress in Brazil—Past, present, and future implications for occupational heat exposure. International Journal of Climatology, 41, 2741-2756.
- Roscani, R.C., Bitencourt, D.P., Maia, P.A. and Ruas, A.C. (2017) Risco de exposição à sobrecarga térmica para trabalhadores da cultura de cana-de-açúcar no Estado de São Paulo. Cadernos de Saúde Pública, 33(3), e00211415. https://doi.org/10.1590/0102-311x00211415.
- Maia, P.A., Ruas, A.C. and Bitencourt, D.P. (2015) Wet-bulb globe temperature index estimation using meteorological data from São Paulo State, Brazil. International Journal of Biometeorology, 59, 1395–1403 https://doi.org/10.1007/s00484-014-0949-7.
- Nobre, C.A., Marengo, J.A. and Soares, W.R. (2019) Climate Change Risks in Brazil, 1st edition. Cham, Switzerland: Springer International Publishing, pp. 67–129.

– Nassis, G.P., Brito, J., Dvorak, J., Chalabi, H. and Racinais, S. (2015) The association of environmental heat stress with performance: analysis of the 2014 FIFA world cup Brazil. British Journal of Sports Medicine, 49, 609–613. https://doi.org/10.1136/bjsports2014-094449

Response: We have included the following references in the "Concluding remarks" section – however, their inclusion depend on the editorial board:

> *"Bitencourt, D.P., Maia, P.A., Roscani, R.C. (2019) The heat exposure risk to outdoor workers in Brazil. Archives of Environmental & Occupational Health,74,1–8.*
>
> *Bitencourt, D.P., Ruas, A.C. and Maia, P.A. (2012) Análise da contribuição das variáveis meteorológicas no estresse térmico associada a morte de cortadores de cana-de açúcar. Cadernos de Saúde Pública, 28, 65–74..*
>
> *Bitencourt, D.P., Alves, L.M., Shibuya, E.K., Cunha, I.A., and Souza, J.P.E. (2020) Climate change impacts on heat stress in Brazil—Past, present, and future implications for occupational heat exposure. International Journal of Climatology, 41, 2741-2756.*
>
> *Roscani, R.C., Bitencourt, D.P., Maia, P.A. and Ruas, A.C. (2017) Risco de exposição à sobrecarga térmica para trabalhadores da cultura de cana-de-açúcar no Estado de São Paulo. Cadernos de Saúde Pública, 33(3), e00211415. https://doi.org/10.1590/0102-311x00211415.*"

WBGT is an index widely used around the world for heat occupational exposure. Therefore, it is important some comments on the main features that legally regulate this exposure in Brazil. Recently, in December 2019, the norm was modified through document SEPRT Nº 1359 (http://www.normaslegais.com.br/legislacao/portaria-seprt-1359-2019.htm). The new regulation assigns to heat occupational exposure two other aspects very important, in addition to environmental heat stress which is quantified with WBGT: (1) worker´s clothing and (2) Laboral activity. This last implies for worker metabolic rate. In my opinion, it is important the authors show those issues in the introduction text.

Response: We have mentioned more details about the WBGT index and its workplace applications, including the national legislation.

> *"The WBGT heat index incorporates the natural wet bulb temperature (Tnwb), the black globe temperature (Tg), and air temperature (Ta), which can be estimated meteorological variables (temperature, humidity, wind speed, and solar radiation) for both in-shade environments (without solar radiation exposure) and outdoor environments (with solar radiation exposure). This index is properly adjusted for actions in work environments with rest/work cycles recommended based on various metabolic rates defined in international[22] and national[25,26] standards, which recommend an hourly rest period during heavy work when the WBGT exceeds 26°C and suspension of work activities when the WBGT reaches 34°C. Under more extreme conditions, e.g., a WBGT greater than 40 °C, exposure may compromise survivability in heat-vulnerable groups[2,27]. "*

WBGT has two equations, one applied for outdoor workspace WITH solar radiation and another applied for indoor workspaces OR outdoor workspaces WITHOUT solar radiation.

In this study, where the WBGT is estimated from atmospheric variables, the equations would be applicable only for outdoor workspaces WITH and WITHOUT solar radiation. My suggestion is to replace "indoor/in-shade WBGT" with "in-shade WBGT" in the entire text of the paper.
Response: Thank you for bringing this to our attention. We have replaced "indoor/in-shade WBGT" with "in-shade WBGT" in the text and figures of the paper.

Why the results of figures 1 and 4 were shown only for WBGT without solar radiation?
Response: As highlighted in the text and in Figure 2, the WBGT index estimation showed the most dramatic effects of the Amazon savannization on a regional scale and for in-shade conditions, and we decided to emphasize this result in the main text; however, we have included the outdoor WBGT results in the "Supplementary Material".

Material and Methods:
- I suggest replacing "observational data" with "meteorological data" or "atmospheric data". "Observational data" can indicate to the reader that it is data from the weather stations.
Response: "Observational data" has been replaced with "atmospheric data"

- Does "b" is the equation proposed by Bernard (1999)? I suggest citing the Bernard (1999) paper again when the equation is presented not to confuse with the original equation of WBGT without solar radiation. Also, the author could justify why did not use the same method from Liljegren et al. (2008) for the situations with and without solar radiation. If Liljegren et al. (2008) have made the estimation of Tnbw e Tg, those temperatures could be used in WBGT original equation without solar radiation (WBGT = 0,7 Tnbw + 0,3 Tg). In addition, it is important to treat air temperature always with the same variable name. In the text appear other variables names such as "Temperature of the dry" and "Atmospheric bulb"
Response: Yes, the in-shade WBGT index was calculated using the method described by Bernard (1999). We have cited the study again in the "b" equation to be more clear, and we have standardized the variable name of the air temperature variable in the text. In regards to the appropriateness of the applied equation for estimating the WBGT, we have used the method recommended Lemke and Kjellstrom (2012). According to the authors, the method of Liljegren et al. (2008) and the method by Bernard (1999) were recommended for estimating outdoor and in-shade WBGT from meteorological data, respectively. Moreover, the Bernard and Liljegren methods are close for estimating in-shade WBGT, but the equation used by Bernard (1999) has been extensively tested by Bernard and Pourmoghani (1999) while Liljegren did not test their formula for indoor environments. We have tested the method of Bernard (1999) and the outdoor WBGT during the night time (without solar radiation), and both methods were equivalent.

14th Jul 21

Dear Dr Oliveira,

Your manuscript titled "Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon" has now been seen by our reviewers, whose comments appear below. In light of their advice I am delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment under the open access CC BY license (Creative Commons Attribution v4.0 International License).

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

EDITORIAL REQUESTS:

Please review our specific editorial comments and requests regarding your manuscript in the attached "Editorial Requests Table". Please outline your response to each request in the right hand column. Please upload the completed table with your manuscript files.

If you have any questions or concerns about any of our requests, please do not hesitate to contact me.

SUBMISSION INFORMATION:

In order to accept your paper, we require the files listed at the end of the Editorial Requests Table; the list of required files is also available at https://www.nature.com/documents/commsj-file-checklist.pdf .

OPEN ACCESS:

Communications Earth & Environment is a fully open access journal. Articles are made freely accessible on publication under a CC BY license (Creative Commons Attribution 4.0 International License). This license allows maximum dissemination and re-use of open access materials and is preferred by many research funding bodies.

For further information about article processing charges, open access funding, and advice and support from Nature Research, please visit https://www.nature.com/commsenv/about/open-access

At acceptance, the corresponding author will be required to complete an Open Access Licence to Publish on behalf of all authors, declare that all required third party permissions have been obtained and provide billing information in order to pay the article-processing charge (APC) via credit card or invoice.

Please note that your paper cannot be sent for typesetting to our production team until we have received these pieces of information; therefore, please ensure that you have this information ready when submitting the final version of your manuscript.

Please use the following link to submit the above items:
[link redacted]
** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Clare

Dr Clare Davis
Associate Editor
Communications Earth & Environment

www.nature.com/commsenv/
@CommsEarth

REVIEWERS' COMMENTS:

Reviewer #2 (Remarks to the Author):

Dear authors,

I'm satisfied with the authors' response. I just would like to take a detail to your attention: The citation 26 (PORTARIA SEPRT No 1.359) don't set hourly rest period.

Review for "Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon"

The authors have addressed all of my concerns and have substantially improved their paper. I have a few minor comments, but this paper is essentially ready for publication.

Title: I think the title could be a bit more exciting. As the authors point out, the changes they find have serious social implications and this could be highlighted in the title. A suggested modification could be "Climate change and deforestation in the Amazon: A recipe for extremely dangerous heat stress exposure"

Introduction:

Suggested edit: "A recent study found that these two regions have the largest projected air temperature changes **driven by a global warming scenario** in the Eta…"

Heat Stress Impacts on Human Health:

Suggested edit: "The WBGT heat idex incorporates the natural wet bulb temperature (Tnwb),…which can be **calculated using standard meteorological observations…"**

Amazon savannization and heat stress:

Multiple references are made to the difference of 85S-85F, but this isn't shown in Fig. 1. I think there is probably just a typo here, but I'm not sure what comparison the authors are trying to make.

"it would be impossible to perform heavy outdoor activities for at least 1 hour/day" I think this probably means one day on average...but that really needs to be specified here, otherwise it's confusing to the reader.

"For instance, these populations would be exposed to WBGT thresholds" Which thresholds? With what frequency?

"Of the total 5565 Brazilian municipalities, 16% might be impacted" In what sense? It seems like most of the continent is impacted in 85S, so again I think it's important to be specific about the thresholds you're referring to.

Concluding Remarks:

"The 1.5˚C increase in the average global temperature…" Specify that these are global projections and not the ones you're making.

"In our projections, natural carbon sinks are preserved" I'm not sure what this means, but a suggested rewrite could be: "In our projections, the combination of land use change and global warming could further magnify the occupational risks…"

Reviewer #1

Review for "Effects of deforestation and climate change on heat stress risk exposure in the Brazilian Amazon"

The authors have addressed all of my concerns and have substantially improved their paper. I have a few minor comments, but this paper is essentially ready for publication.

Title: I think the title could be a bit more exciting. As the authors point out, the changes they find have serious social implications and this could be highlighted in the title. A suggested modification could be "Climate change and deforestation in the Amazon: A recipe for extremely dangerous heat stress exposure"

Response: We agree. The title has been changed to highlight the serious health impacts more interestingly. We appreciate your suggestion. Our new title is: *"Climate change and deforestation in the Amazon: A recipe for extremely dangerous heat stress exposure".*

Introduction:
Suggested edit: "A recent study found that these two regions have the largest projected air temperature **changes driven by a global warming scenario** in the Eta..."
Response: We agree. Thus, we have changed this in the text.

Heat Stress Impacts on Human Health:
Suggested edit: "The WBGT heat index incorporates the natural wet bulb temperature (Tnwb),...which can be **calculated using standard meteorological observations**..."
Response: We have adjusted this point in the text, according to the suggestion

Amazon savannization and heat stress:

Multiple references are made to the difference of 85S-85F, but this isn't shown in Fig. 1. I think there is probably just a typo here, but I'm not sure what comparison the authors are trying to make.
Response: Thank you! We have corrected the label of Figure 1.

"it would be impossible to perform heavy outdoor activities for at least 1 hour/day" think this probably means one day on average...but that really needs to be specified here, otherwise it's confusing to the reader.
Response: Thank you! We have adjusted this point in the text, according to the suggestion.

> *"In the 85S simulation, it would be impossible to perform heavy outdoor activities for at least 1 hour/day in 42% of the days studied (relative to WBGT ≥ 34 °C)."*

"For instance, these populations would be exposed to WBGT thresholds" Which thresholds? With what frequency?
Response: The portions in the text have been adjusted based on this recommendation.

> *"For instance, these populations would be exposed to high-risk of WBGT (≤ 34 °C) for at least one hour per day based on the monthly climatology of the daily maximum values.".*

“Of the total 5565 Brazilian municipalities, 16% might be impacted” In what sense? It seems like most of the continent is impacted in 85S, so again I think it’s important to be specific about the thresholds you’re referring to.
Response: Thank you! We have added more details for clarify this point.

“...(i.e., increase higher than 0.2 of in-shade WBGT in the hottest month)”

Concluding Remarks:
“The 1.5℃ increase in the average global temperature...” Specify that these are global projections and not the ones you’re making.
Response: The portions in the text have been adjusted based on this recommendation.

“The 1.5°C increase in the global average temperature based in the projections of HadGEM2 and GFDL-ESM2M climate models could represent 0.84%...”

“In our projections, natural carbon sinks are preserved” I’m not sure what this means, but a suggested rewrite could be:
“In our projections, the combination of land use change and global warming could further magnify the occupational risks...”
Response: Thank you! We have adjusted this point in the text, according to the suggestion.

Reviewer #2 (Remarks to the Author):

Dear authors,

I'm satisfied with the authors' response. I just would like to take a detail to your attention: The citation 26 (PORTARIA SEPRT No 1.359) don't set hourly rest period.
Response: Thank you – this was corrected.