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# *Interactive comment on* "$CO_2$ fertilization effect can cause rainfall decrease as strong as large-scale deforestation in the Amazon" *by* Gilvan Sampaio et al.

**Gilvan Sampaio et al.**

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We take this opportunity to genuinely thank the work done by the two anonymous reviewers, which has substantially improved this new version of our manuscript.

Obs: line numbers mentioned in the referee's comment refer to line numbers in the previous manuscript version, whereas the line numbers mentioned in the response to each comment refer to line numbers in the new manuscript PDF file.

IMPORTANT STATEMENT When attempting to respond to the referees' comments we realized that some of the variables requested to be shown in the article were not



saved or stored properly. As such we had to carry out new simulations such that we could properly save and show the requested variables. In that process we noticed that there were some differences in the Deforestation scenario results, especially regarding rainfall anomalies (which instead of -0.8 mm d-1 is in fact -0.5 mm d-1), and minor numerical updates in the other variables [although average precipitation reduction in the Physiology scenario is stronger than in the Deforestation scenario, the variability range of anomalies in both scenarios do not indicate a significant difference between the two mean values (as can be seen in Fig. 3a) and because of that we keep the article's title and conclusion]. We attribute this confusion regarding changing values in the Deforestation scenario to a recent substitution of processing blades at INPE's (Brazil's National Institute for Space Research) supercomputer, where these simulations were carried out. The new model runs do not change in any way the previous conclusions of the article and in fact are more trustworthy, for example in regard to the obtained changes in radiative balance and accompanying surface temperature changes which are now more consistent in the deforestation scenario. We sincerely apologize for the inconvenient.

Anonymous Referee #1

1. "This study compares the idealized physiological and deforestation simulations. In reality, both rising CO2 and deforestation are influencing precipitation, so we are more interested in the compound effect of them. Although rising CO2(x1.5CO2) and deforestation reduce precipitation of a similar magnitude (12-13%), their mechanisms are different, and may amplify or attenuate each other. Here an interesting question arises: would the combination of rising CO2(x1.5CO2) and deforestation cause more or less than 25% of precipitation reductions? I am not sure how long it takes to run another scenario, but it is definitely worth a try."

R: This point was also raised by Referee #2 and is indeed relevant for this article. One should notice however that if we have 100% deforestation and eCO2, the physiological effects of eCO2 would be acting upon grassland vegetation, and not on the forest any-more, which was not the original aim of the article of assessing the comparative effects of the physiological effects of eCO2 on the forest and of an extreme deforestation scenario on rainfall in the Amazon region. In that sense, to not change the original concept of the article but attending the reviewers' suggestion we now present a scenario with eCO2 (in fact RCP8.5 which has a CO2 increase rate similar to what was employed in the Physiology and Deforestation scenarios) and 100% deforestation altogether as a supplement of this manuscript (Figs. S1-S4). In such a scenario (RCP8.5+Def) the changes in all variables are in between those obtained in the Deforestation and Physiology scenarios, except for the spatial pattern of rainfall change which is comparatively more pronounced in west Amazon; and also the circulation change pattern, in which the increase of Easterlies across the Amazon stronger than in Deforestation, apparently due to the combined effects of eCO2 on plant physiology and radiative balance of the atmosphere. Explicit mentions to this scenario and a brief discussion of its results in comparison to the Physiology and Deforestation scenarios are now made respectively in the main text lines 123 (Methods), and 307 (Discussion).

2. "Section 3.1: add some statistical analyses of changes in stomatal conductance, leaf area index, transpiration, and atmospheric specific humidity in the physiological and deforestation scenarios."

R: Statistics on stomatal conductance, leaf area index, transpiration and atmospheric specific humidity (this latter the atmospheric vertical profile over the Amazon) are now presented in section 3.1 (see lines 176-190), as well as in the newly included Table 2 (attached), that presents summarized statistics for all the variables analyzed in the article.

3. "Fig 5: To show how circulation changes impact moisture convergence, please also include moisture convergence changes in the physiological and deforestation scenarios in this figure."

R: We thank the reviewer for this very good suggestion. Fig. 5 now presents a spatially



explicit map of changes in moisture convergence overlaid by the anomalies in atmospheric circulation at 850 hPa (see Fig. 5 attached). We understand that the inclusion of such information in Fig. 5 makes it clearer the role of different circulation anomalies in driving the similar changes in the region's moisture budget. A mention in the sense is now made in line 206 (Results – 3.2 Atmospheric Circulation).

Other minor comments:

4. "Title: 'CO2 fertilization effect' -> 'CO2 physiological effect' "

R: Suggestion accepted.

5. "Lines 138-140: temperature increases are due to reduced evaporative cooling effect in the physiological and deforestation scenarios, rather than precipitation decreases."

R: Referee #1 is correct. It is the reduction in evapotranspiration that causes both the reduction in rainfall and increase in temperature. The mentioned sentence now reads (line 160):

"As expected for a tropical region where variations in precipitation and temperature are tightly coupled, the reduction in evaporative cooling leads to an increase in regional temperature (...)"

6. "Lines 145-148: I think the logic here is that reductions in evapotranspiration and moisture convergence lead to precipitation decreases. More analyses of how land surface changes (physiology and deforestation) modify atmospheric processes and thereby impact moisture convergence and precipitation are needed here."

R: We thank Referee #1 for indicating this point for improvement in the article. In fact the concept of moisture convergence employed here is a well-known simplification of the mass continuity equation applied to the specific humidity mass of an atmospheric volume:

S = P – E (1)

Where S is the storage of water vapour, P is precipitation and E is evapotranspiration (Banacos and Schultz 2005). We now make this information explicit in the article text when moisture convergence is first mentioned in the text and changed the phrasing to (line 171):

"The reduction of evapotranspiration (Physiology: -0.35 mm d-1; Deforestation: -0.22 mm d-1) is associated with a reduction of moisture convergence [precipitation minus evapotranspiration (Banacos and Schultz, 2005)] alongside with decreased precipitation in both Physiology and Deforestation model scenarios. Reduction in moisture convergence is 59% more pronounced in the Physiology scenario (Fig. 3a) owned namely to a stronger decrease in horizontal transport of humidity by east winds. The mechanisms associated with these changes are explained next."

While this specific section of text is just part of the opening of the Results section, the "analyses of how land surface changes (physiology and deforestation) modify atmospheric processes and thereby impact moisture convergence and precipitation" is provided in the subsequent subsections of the Results section, namely in subsections "3.1 Provision of humidity" and "3.2 Atmospheric circulation". In any case we make it explicit in the opening of the Results section that further explanation will be provided in the oncoming subsections (see line 175).

7. "Lines 196-198: as total evapotranspiration (transpiration+evaporation) is reduced, the decrease in soil water should not be due to increases in temperature and evaporation, but rather because of precipitation declines."

R: Referee #1 is correct and the mentioned sentence now reads (line 274):

"Stomatal closure driven by eCO2 is related to higher water use efficiency (the amount of water used [in transpiration] per unit of carbon assimilated through photosynthesis), but even so the net effect is a small decrease ($\sim$2%) of available soil water in the Physiology scenario, due to the decrease in precipitation."



Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2020-386/bg-2020-386-AC1-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-386, 2020.

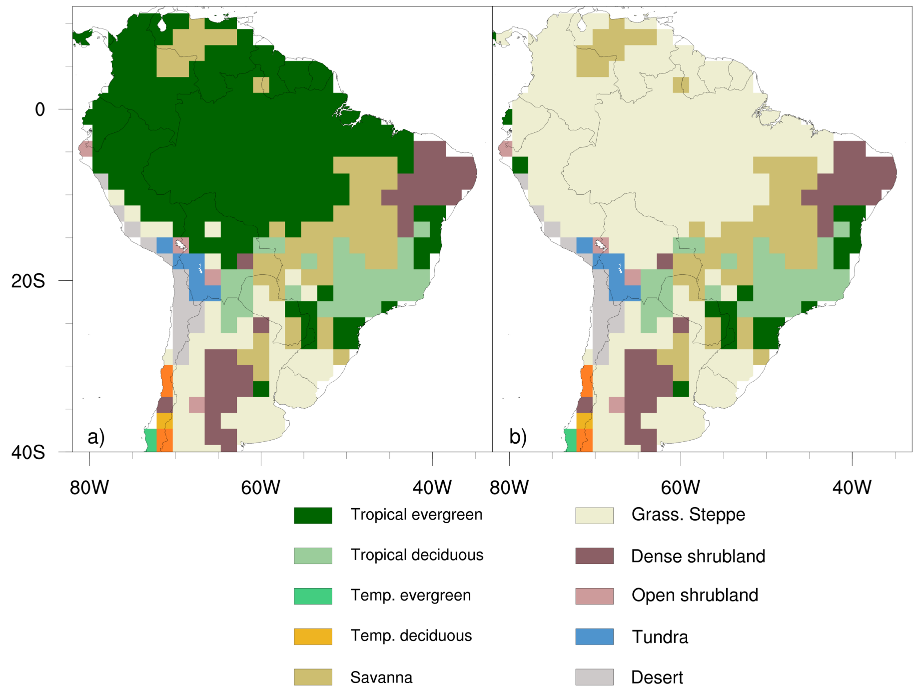


**Fig. 1.** Vegetation maps used in (a) Physiology and (b) Deforestation modelling scenarios. Vegetation type grass. steppe in the Amazon region is composed of C4 grass, representing tropical pasturelands.



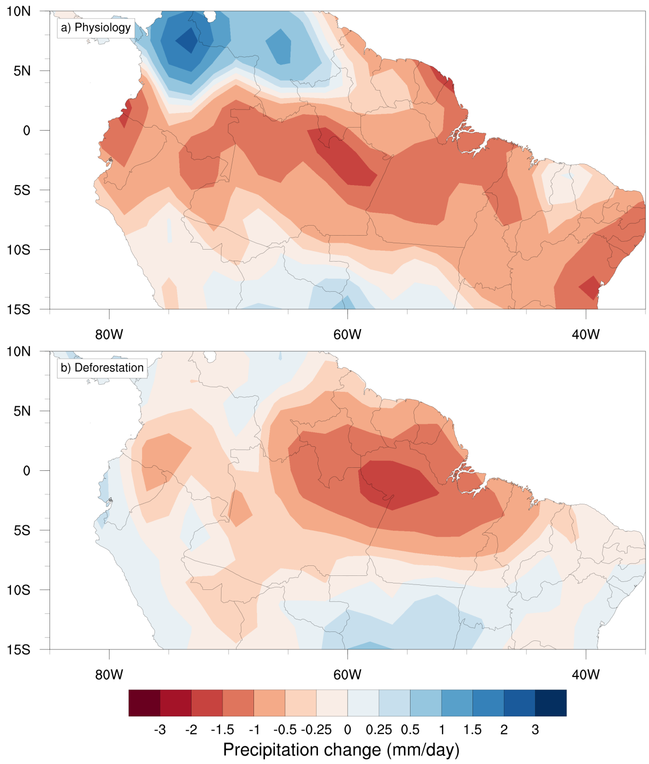


**Fig. 2.** Annual mean precipitation change relative to control simulations using the CPTEC-BAM in tropical South America under (a) an atmospheric CO2 concentration of +200 ppmv (1.5xCO2) affecting solely surfac

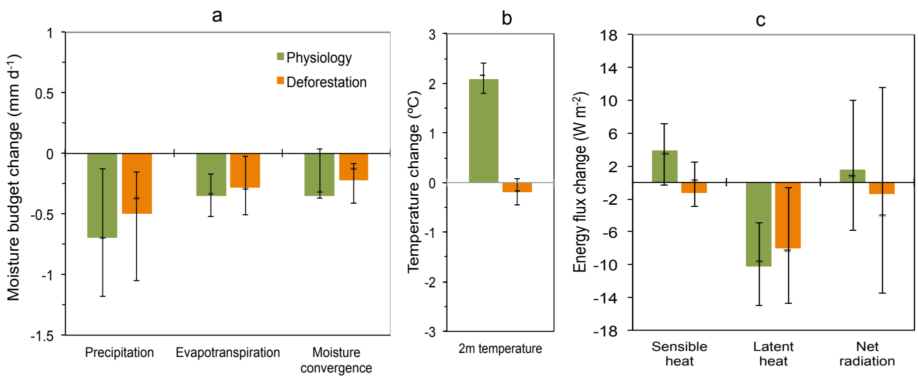


**Fig. 3.** Mean annual changes in (a) moisture budget, (b) 2m-air temperature and (c) energy balance from the CPTEC-BAM over the Amazon region (black line square area in Fig. 5) under an atmospheric concentratio



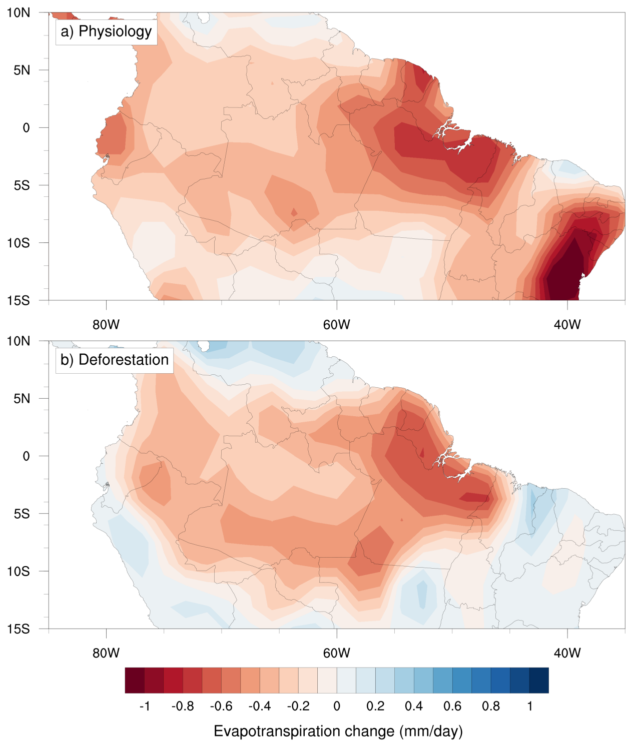


**Fig. 4.** Annual mean changes in evapotranspiration in tropical South America (a) under an atmospheric concentration of +200 ppmv (1.5xCO2) affecting solely surface vegetation physiology, and (b) with complete

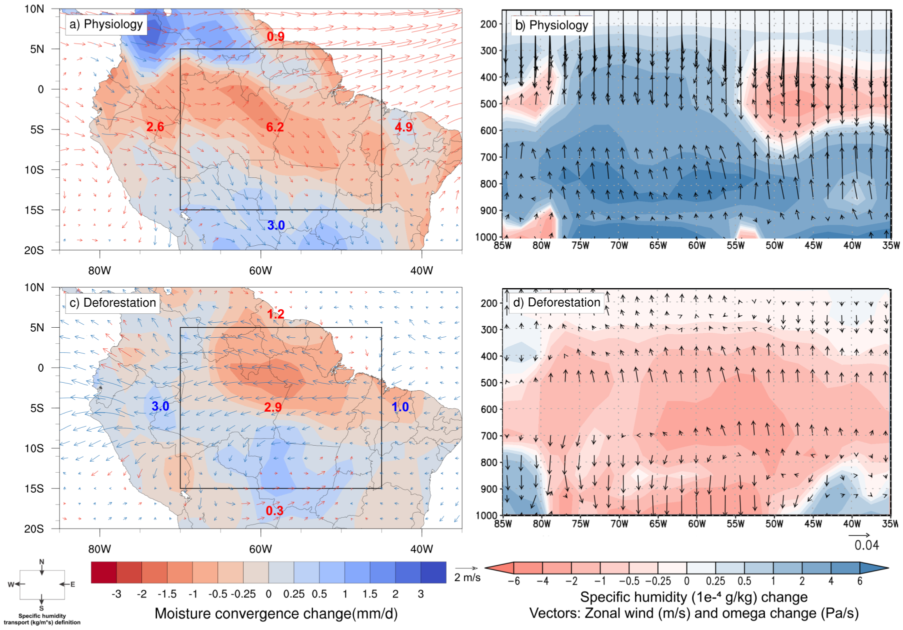


**Fig. 5.** Annual mean changes in 850hPa horizontal wind (a, c) and vertical profile of zonal circulation over the equator superposed on meridional mean specific humidity vertical profile (with pressure in hPa a



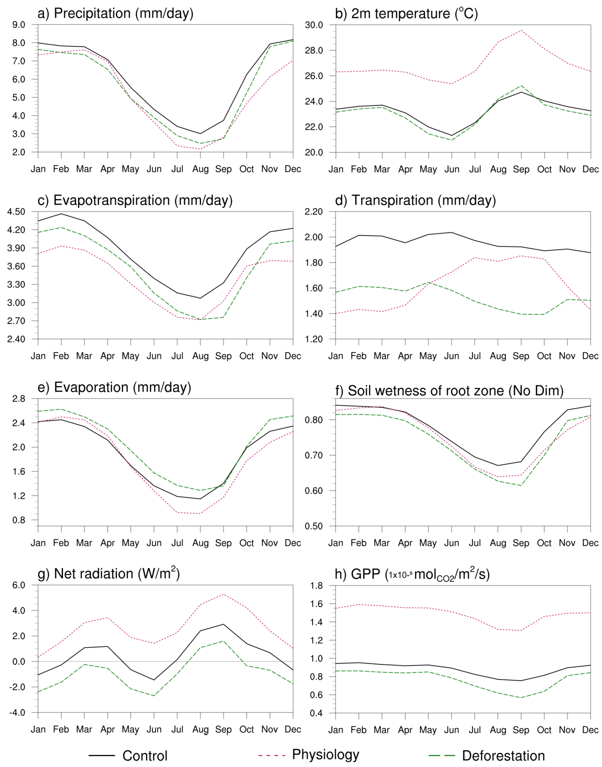


**Fig. 6.** Mean monthly precipitation, 2m-temperature, evapotranspiration, transpiration, evaporation, topsoil water content, net radiation and gross primary productivity in the Amazon region (black line square

**Table 1: Numerical experiments performed with CPTEC-BAM.**

| Experiment | Vegetation | CO2 concentration (ppmv) Atmosphere | CO2 concentration (ppmv) Land Surface | Deforestation |
|---|---|---|---|---|
| Control | Dynamic/Static* | 388 | 388 | No |
| Physiology | Dynamic | 388 | 588 | No |
| Deforestation | Static | 388 | 388 | Yes |
| RCP8.5+Def** | Dynamic | 588 | 588 | Yes |

*Control run with static vegetation was used for comparison with the Deforestation run.

** Results presented in Supplement.

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**Fig. 7.** Table 1



**Table 2: Mean annual changes and interquartile range (25th, 50th and 75th percentile values in parenthesis) of moisture budget, 2m-air temperature, energy balance, GPP, $g_s$ and LAI from the CPTEC-BAM over the Amazon region (black line square area in Fig. 5) under an atmospheric concentration of +200 ppmv (1.5xCO2) affecting solely surface vegetation physiology (Physiology), with complete substitution of the Amazon forest by pasture grasslands (Deforestation).**

| Variable \ Scenario | Physiology | Deforestation |
|---|---|---|
| Precipitation (mm $d^{-1}$) | -0.70 (-1.18; -0.70; -0.13) | -0.50 (-1.05; -0.37; -0.15) |
| Evapotranspiration (mm $d^{-1}$) | -0.35 (-0.52; -0.33; -0.17) | -0.28 (-0.51; -0.29; -0.02) |
| Transpiration (mm $d^{-1}$) | -0.35 (-0.53; -0.35; -0.19) | -0.42 (-0.66; -0.43; -0.19) |
| Moisture convergence (mm $d^{-1}$) | -0.35 (-0.37; -0.32; +0.04) | -0.22 (-0.41; -0.13; -0.08) |
| 2m temperature (ºC) | +2.07 (+1.80; +2.16; +2.40) | -0.20 (-0.45; -0.17; +0.08) |
| Sensible heat flux at surface (W $m^{-2}$) | +3.96 (-0.32; +3.46; +7.17) | -1.34 (-2.91; +0.23; +2.44) |
| Latent heat flux at surface (W $m^{-2}$) | -10.23 (-14.98; -9.60; -4.98) | -8.00 (-14.72; -8.27; -0.63) |
| Shortwave radiation at surface* (W $m^{-2}$) | +1.94 (+0.59; +2.23;+3.90) | +3.88 (+3.91; +5.08; +3.88) |
| Longwave radiation at surface* (W $m^{-2}$) | +2.75 (+2.24; +3.11; +3.85) | +6.9 (+4.84; +6.98; +9.26) |
| Net radiation (W $m^{-2}$) | -1.58 (-9.16; -0.79; +6.63) | +1.36 (-8.88; +4.02;+16.17) |
| Cloud cover (%) | -1.4 (-2.1; -1.4; -0.6) | -2.2 (-2.9; -2.3; -1.7) |
| Gross primary productivity (μmol$CO_2$ $m^{-2}$ $s^{-1}$) | +7.0 (+5.0; +9.0; +9.0) | -1.0 (-2.0; -1.0; 0.0) |
| Stomatal conductance (mol$H_2O$ $m^{-2}$ $s^{-1}$) | -0.10 (-0.10; -0.07; -0.05) | -0.02 (-0.02; +0.001; +0.003) |
| Leaf area index | +10.0 (+7.0; +12.2; +13.2) | -4.1 (-5.5; -5.5; -2.7) |

*Balance between incoming/absorbed and reflected/emitted radiation

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**Fig. 8.** Table 2