

## Response to reviewer

---

### Reviewer # Questions and our responses

**We extend our deep appreciation to Reviewer for the constructive comments and suggestions toward improving our paper.**

#### **Reviewer:**

In the latest (second) revision, the authors have done a good job of responding to my comments. They improved their methods significantly by (a) excluding grid cells that changed aridity classes and (b) refining their pasture-cell exclusion rule. Additionally, they have made great improvements in terms of explaining their analyses. As a result, I suggest this paper be *published after minor revisions*.

**Response:** Thanks for your encouragement. We extend our deep appreciation to you for constructive comments and suggestions toward improving our paper.

Point-to-point responses to all the comments are given below.

#### 1. Pasture vs. rangeland

You masked based on the LUH2 “managed pasture” layer, but most grazing land by area is actually rangeland—see below for 2010. Please consider the exclusion based on the total pasture+rangeland area. (I’m sorry, I should have caught this in the first revision!) Alternatively, there may be an argument that rangeland doesn’t need to be excluded, as might be considered less intensely grazed. If you want to go that route, mention it in the text

Response: Thanks for the detailed and constructive suggestion. We agree with that rangeland is considered less intensely grazed, while there is a strong anthropogenic disturbance in managed pasture. To reduce the interference effects from human activity, we only removed the grids with the fraction of managed pasture over 10% in this study. We added more detailed explanation as below:

“There is a weak anthropogenic disturbance in rangeland, while managed pasture is intensely grazed by livestock. To remove pasture area with strong anthropogenic disturbance, we obtained land-use forcing data from Land-Use Harmonization (LUH2) to map the distribution of managed pasture data from 2001 to 2015 (Hurt et al., 2020).”  
(See Revision, Page 14, Lines 338-341)

2. Include temperature and “other factors” as “climate factors”

At L557-64, the authors seem to consider only precipitation and radiation as “climate change” factors. The numbers from that result in a pretty good correspondence to the results from Zhu et al. (2016), but I would be surprised to learn that those authors included only precipitation and radiation in their analyses. Later in that paragraph, the authors talk about temperature, but it’s unclear why it was not included before. Finally, “other factors” (wind speed and relative humidity) are not mentioned at all, but these are also climate factors. The authors should rewrite this paragraph to include all climate factors together in the initial analysis. (The final sentence is a good summary but should also mention “other factors.”)

Response: Thanks for the constructive suggestion. We rewrote this paragraph to include all climate factors and added more explanation about the “other factors” in the revised manuscript.

“At the grid cell scale, as shown in Figures 8b and 8d, temperature, radiation, precipitation, and other climate factors (humidity and wind speed) dominate the long-term trend of carbon stocks over two thirds of global grid cells. At the global scale, climate factors explain 17.55% and 10.72% of long-term trend in LVBC and WVBC,

respectively (Figures 8a and 8c). LVBC and WVBC variations driven by climate factors are ultimately offset by spatially compensatory effects, which dampens the response of the carbon stock to these factors at the global scale (Jung et al., 2017). Thus, contributions of precipitation and radiation to the variability of LVBC and WVBC are relatively low at the global scale, and the effects of humidity and wind speed on global carbon stock are minor. This spatially compensatory effect of climate changes is consistent with a previous analysis (Zhu et al. 2016) which found that climate changes explain only 8% of the increasing trend in carbon storage of foliage at a global level but that they dominate the trend over 28.4% of global land area. Results show that trends in temperature drive historical long-term trends in the potential carbon stocks, with faster increases and considerable variation occurring by grid cell. Thus, our results reveal that temperature dominates the long-term trends of carbon stock among climatic drivers, while a relatively strong compensatory effect exists in the global change in the carbon stock induced by precipitation, radiation, humidity, and wind speed.” (See Revision, Page 28, Lines 557-571)

### 3. “Grids”

In almost all instances, the authors should replace “grid(s)” with “grid cell(s).” “Grid” is more appropriate when describing the overall setup (e.g. “grid resolution” is fine), but for referring to individual 0.5° boxes, “grid cell” is what should be used. In “Minor suggestions and technical corrections,” I’ve noted some places this should be fixed, but not all places.

Response: Corrected.

4. L82-4: This sentence is still confusing. “Global warming” seems to speak directly to temperature, but Keenan et al. (2017) found that slower temperature growth meant MORE C sequestration on land (due to lower ecosystem respiration). The Madani et al.

(2020) bit is weird as well. Maybe “found that plants productively with water stress show a negative response to temperature rise in tropical zones” should be changed to “found that productivity showed a negative response to temperature in tropical zones due to increasing water stress”?

Response: Thanks for the suggestion. We corrected this paragraph following review’s suggestion. (see Revision, Page 3, Lines 83-84)

5. L222: “10% **of** non-structural”

Response: Corrected. (see Revision, Page 8, Line 222)

6. L262,6: “tree” should be “trees”.

Response: Corrected. (see Revision, Page 10, Line 262 and Line 266)

7. Fig. 1: I’m glad to see the newly-excluded grid cells marked in white in this figure. Please add an indication to the legend and/or caption pointing this out.

Response: Thanks, we added more explanation of the white grid cells in the caption of Figure 1.

“The white grid cell was not assigned hydrological category.” (see Revision, Page 12, Figure 1)

8. L332-3: “vegetation grid cells” doesn’t really make sense. Suggest changing “We defined vegetation grid cells as those whose largest component” to “We included grid cells whose largest vegetation component”. Also, refer to Fig. A6 here.

Response: Corrected. (see Revision, Page 14, Lines 332-333 and Page 34, Line 639)

9. L345: “grids” should be “grid cells”.

Response: Corrected. (see Revision, Page 14, Line 346)

10. L355: “We declare that” is unnecessary and can be deleted.

Response: Corrected. (see Revision, Page 14, Line 347)

11. L367: “showed” should be “shown”.

Response: Corrected. (see Revision, Page 16, Line 368)

12. L427, 433: “grid” should be “grid cell”.

Response: Corrected. (see Revision, Page 20, Line 428 and Line 435)

13. L428: “dominated” should be “dominant”.

Response: Corrected. (see Revision, Page 20, Line 429)

14. L430-2: “zones” should be “grid cells”... Unless the analysis looks at area (i.e., hectares or whatever), in which case it should say “land area” or something. “Zones” is confusing because it can also be used to refer to latitudinal bands. (I know you’re not referring to latitudinal bands because with 10 bands all your results would be multiples of 10%.)

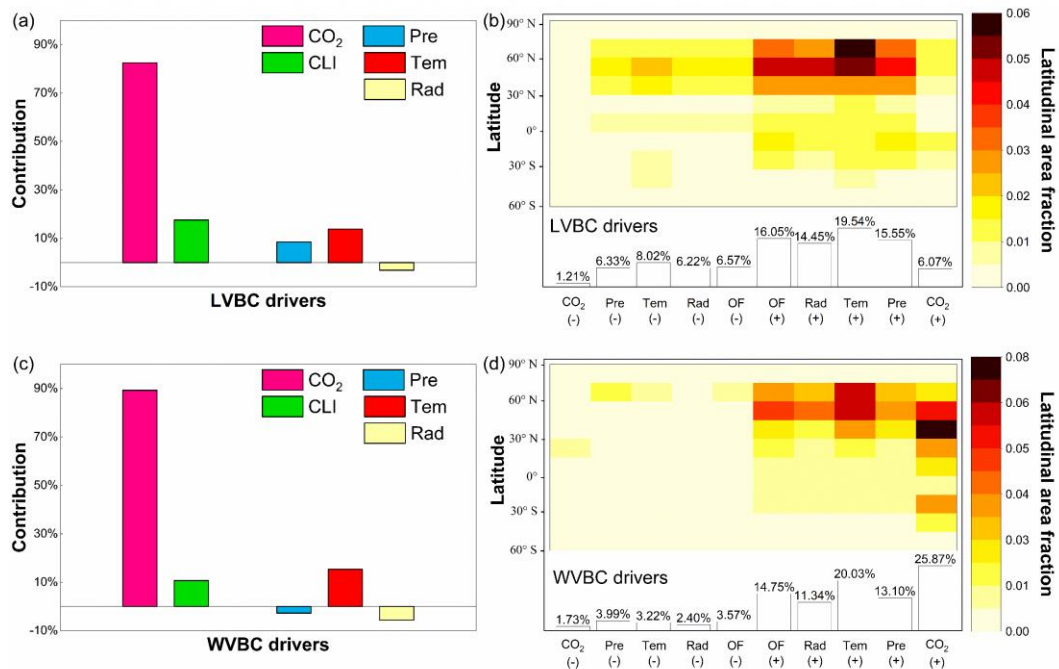
Response: Corrected. (see Revision, Page 20, Lines 433-434)

15. Fig. 8:

Now that you've improved the description, I understand what you were going for with panels B and D. The labels indicating the fraction of grid cells in each category (1.21%, 6.33%, etc.) should actually be changed back to how they were previously. “-1.21” etc. is confusing because it doesn't have the percentage symbol, and incorrect because - 1.21% of global area is impossible. Sorry for my confusion before.

The caption says that the fractions are of global area, but in the text it sounds more like fractions of grid cells. (See comment above for L430-2.)

Response: Corrected. (see Revision, Pages 20-21)



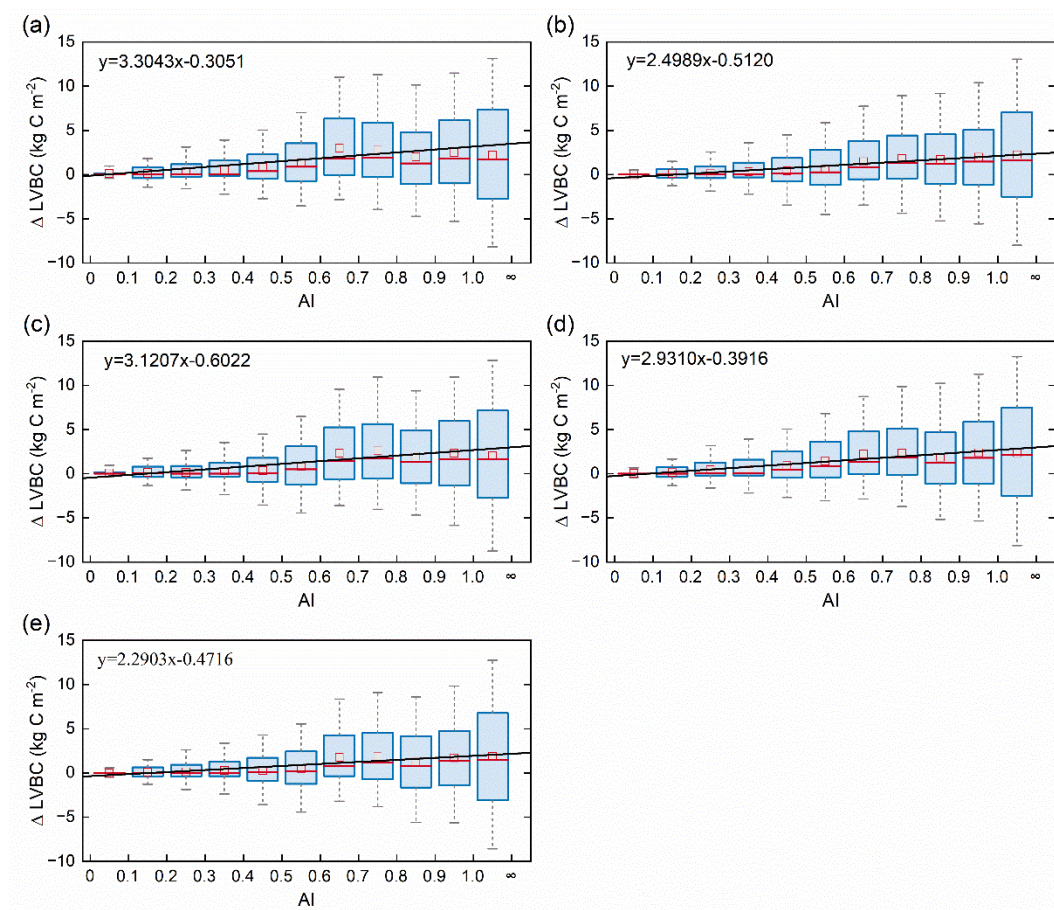
**Figure 8. The proportion of changes in vegetation biomass carbon stocks attributed to driving factors.** Ratios of the driving factors of CO<sub>2</sub> fertilization effects (CO<sub>2</sub>), climate change effects (CLI), precipitation (Pre), temperature (Tem), radiation (Rad) for LVBC (a) and WVBC (c) are calculated by the Mann-Kendall and Sen's slope estimator statistical tests. Attribution of LVBC (b) and WVBC (d) dynamics to driving factors calculated as averages along 15° latitude bands. At the local scale, the driving factors include CO<sub>2</sub>, Pre, Tem, Rad, and other climate factors (OF). The fraction of global grid cells (%) that is predominantly influenced by the driving factors is showed at the bottom of the bar. The '-' symbol before fraction indicates a negative effect of the driving factor on carbon stock, and vice versa.

16. Figs. 9, 10:

X-axis labels should indicate the range of values in each bin. This can be accomplished by either (a) changing each label to be, e.g., “0–0.1,” “0.1–0.2”, etc. or (b) moving the tick marks so that the tick to the left of a box shows its lower bound and the tick to the right shows its upper bound. I’d prefer (b), personally.

Suggest deleting “over the hydrological grid cells (Figure 1).” It’s poorly-worded and doesn’t really add anything.

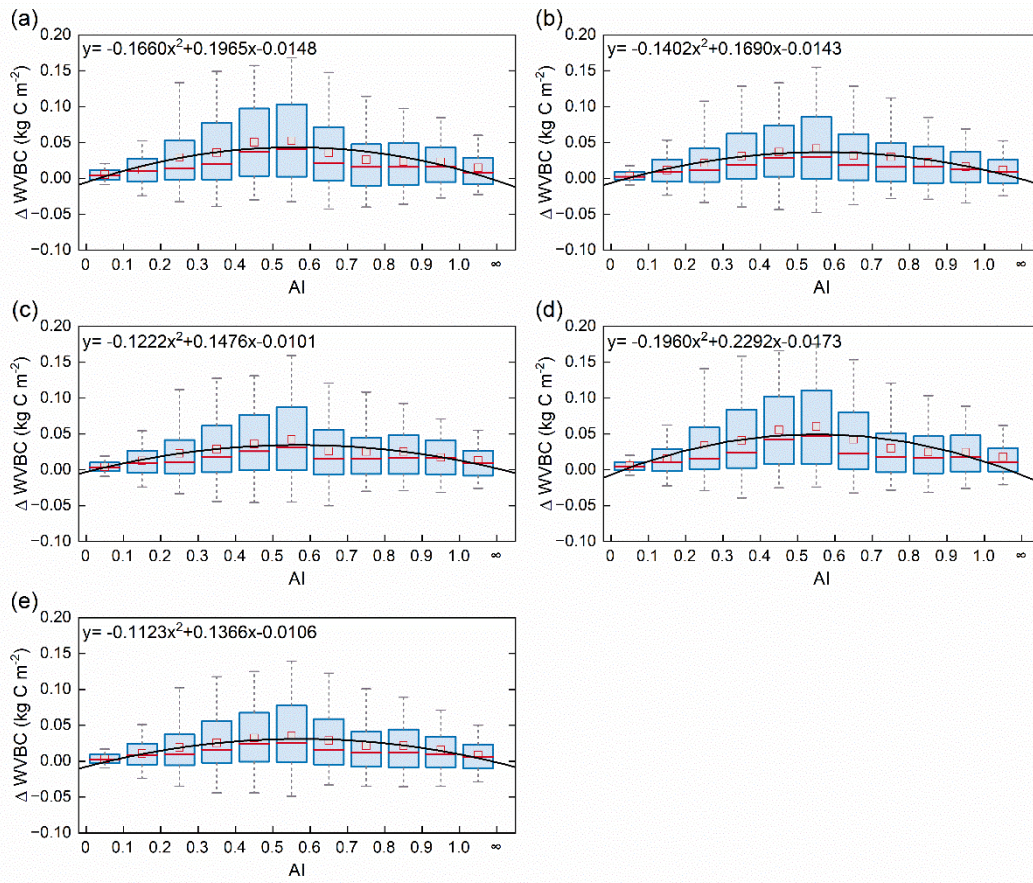
Response: Corrected.



**Figure 9. Relationships of the incremental change between AI and LVBC.** Magnitude of change in LVBC in the historical scenario S1 (a), CO<sub>2</sub> in scenario S2 (b), CO<sub>2</sub> + precipitation in scenario S3 (c), CO<sub>2</sub> + temperature in scenario S4 (d), and CO<sub>2</sub> + radiation in scenario S5 (e). The range of the box is 25%-75% of values; the range of the whiskers is 10%-90% of values; the small red square is average value; the red line is the median line; and the black line is the fitted curve. Positive value of the Y axis represents the magnitude of increased LVBC from 1916 to 2015 under

water-limitations conditions, and vice versa. AI of grid cells is calculated by multiyear average precipitation and multiyear average potential evapotranspiration in the period of 1916-2015. Categories of hydrological zones include: hyper-arid ( $AI \leq 0.05$ ), arid ( $0.05 < AI \leq 0.2$ ), semi-arid ( $0.2 < AI \leq 0.5$ ), sub-humid ( $0.5 < AI \leq 0.65$ ), and humid ( $AI > 0.65$ ).

(see Revision, Pages 22-23)



**Figure 10. Relationships of the incremental change in AI and WVBC.** Magnitude of change in WVBC in the historical scenario S1 (a), CO<sub>2</sub> in scenario S2 (b), CO<sub>2</sub> + precipitation in scenario S3 (c), CO<sub>2</sub> + temperature in scenario S4 (d), and CO<sub>2</sub> + radiation in scenario S5 (e). The range of the box is 25%-75% of values; the range of the whiskers is 10%-90% of values; the small red square is average value; the red line is the median line, and the black line is the fitted curve. Positive value of the Y axis represents the magnitude of increased WVBC from 1916 to 2015 under water-limitations conditions, and vice versa. AI of grid cells is calculated by multiyear average precipitation and multiyear average potential evapotranspiration in the period of 1916-2015. Categories of hydrological zones include: hyper-arid ( $AI \leq 0.05$ ), arid ( $0.05 < AI \leq 0.2$ ), semi-arid ( $0.2 < AI \leq 0.5$ ), sub-humid ( $0.5 < AI \leq 0.65$ ), and humid ( $AI > 0.65$ ).

(see Revision, Page 24)



17. L467: “of historical” should be “of **the** historical”.

Response: Corrected. (see Revision, Page 23, Line 468)

18. L480: Is “maximum change magnitude of LVBC density” here saying the same thing as “fluctuation range” later? If so, define and use “fluctuation range” here.

Response: Thanks. The meaning of “maximum change magnitude of LVBC density” is same to “fluctuation range”. We corrected it and added the define of “fluctuation range”.

“Figure A7b shows that the fluctuation range (the difference between maximum value and minimum value in each factorial simulation) of LVBC density across all factorial simulation is  $1.202 \text{ kg C m}^{-2}$  in the hyper-arid regions for the 1916-2015 period. As shown in Figure A7f, the fluctuation range of LVBC density in humid regions is  $6.068 \text{ kg C m}^{-2}$  during the same period.” (see Revision, Page 23, Lines 481-484)

19. L486: “lived in aridity” should be “in arid”.

Response: Corrected. (see Revision, Page 23, Line 488)

20. L504-8: Where is it demonstrated that “aridity mitigation” is happening in semi-arid zones? This phrasing to me implies that semi-arid regions are becoming moister. I think what you mean is that semi-arid regions are less arid than hyper-arid and arid regions. Suggest rewriting: “Whereas LVBC decreases and WVBC increases in hyper-arid and arid regions (Figs. A7 and A8), causing a downward trend in LVBC:WVBC ratio, semiarid regions see an increase in LVBC.” Note that “in all factorial simulations” in several places in this paragraph is unnecessary; it doesn’t contribute anything to the analysis here.

Response: Corrected. (see Revision, Page 25, Line 505-507)

21. L508: “semi-arid **regions**”

Response: Corrected. (see Revision, Page 25, Line 510)

22. L538: Delete “are”

Response: Corrected.

23. L541-2: Suggest deleting this sentence. It doesn't add anything explanatory like what I was looking for.

Response: Corrected.

24. L547: “more dramatically” should be “relatively more” for clarity.

Response: Corrected. (see Revision, Page 27, Line 547)

25. L554: Please check whether “zonal” is correct here (referring to latitude bands) or whether “grid cell” should be used instead. (Similar: “zone” at L566.)

Response: Corrected. (see Revision, Page 27, Line 554 and Page 28, Line 569)

26. L558: Where does this “over one third” number come from? The weighted average of results from 8b and 8d? I think you should add panels C and E to show the total C effects (or maybe put this an Appendix figure).

Response: Thanks for the comment. Results show that climate factors dominated the variability of LVBC over 92.72% of the grid cells (Figure 8b) and dominated the

variability of WVBC over 72.40% of the grid cells (Figure 8d) in the past years. In the revised manuscript, we concluded that temperature, radiation, precipitation and other climate factors (humidity and wind speed) dominate the long-term trend of carbon stocks over two thirds of global grid cells. We think that readers can be able to understand the total contributions of climate factors to the variability of carbon stock at the grid cell scale based on Figure 8b and 8d. Meanwhile, we think that four numbers are too few to draw an Appendix figure. Thus, figures are not added in the revised manuscript.

“At the grid cell scale, as shown in Figure 8b and 8d, temperature, radiation, precipitation and other climate factors (humidity and wind speed) dominate the long-term trend of carbon stocks over two thirds of global grid cells.” (see Revision, Page 28, Lines 557-559)

27. L562-4: This sentence is confusing. Suggested rewrite: “This spatially compensatory effect of climate changes is consistent with a previous analysis (Zhu et al. 2016) which found that climate changes explain only 8% of the increasing trend in carbon storage of foliage at a global level but that they dominate the trend over 28.4% of global land area.”

Response: Corrected. (see Revision, Page 28, Lines 564-567)

28. L566-7: This sentence is unnecessary and opinionated; please delete.

Response: Corrected.

29. L567: Revert “we suggest” to “our results reveal” or “our results show” or something.

Response: Thanks, “we suggest” was changed to “our results reveal”. (see Revision, Page 28, Line 569)

30. L579-81: A critical aspect is not just that light competition is high, but that water limitation (competition) is low. Indeed, that’s what allows high competition for light—trees can grow in close proximity to each other (and thus shade each other) because there’s enough water to allow each tree as much as it wants. Please include this in your explanation here.

Response: Thanks for the constructive suggestion, we added more explanation about water competition as below:

“In sub-humid and humid regions, plants face low water limitations and intensified light-competition and have to invest as much non-structural carbon as possible into leaf and trunk.” (see Revision, Page 28, Lines 581-582)

31. L592-4: Description of Madani et al. (2020) is still too vague. What exactly did they show? Compare the vagueness here to the excellent summaries you give for Humphrey et al. (2021) and Ma et al. (2021) in the following sentences.

Response: Thanks for the comment, we added more explanation about water competition as below:

“Based on observations from satellite remote sensing, Madani et al. (2020) found that the constraining impact of water limitation determines whether global ecosystem productivity responds positively or negatively to the changes in climate factors.” (see Revision, Page 29, Lines 594-596)

32. L599: “process of terrestrial ecosystem” should be “of terrestrial ecosystems”.

Response: Corrected. (see Revision, Page 29, Line 602)

33. L617: You don't have any way of showing that the underestimate of CO<sub>2</sub> fertilization would be "slight." Unless you cite some other work showing that the N deposition effect is indeed slight, I would rewrite this to "which should cause an underestimate".

Response: Corrected. (see Revision, Page 30, Line 620)

34. Fig. A5: Much improved. Last thing: Please edit the legend labels to be "0–10%", "10–20%", etc.

Response: Corrected.

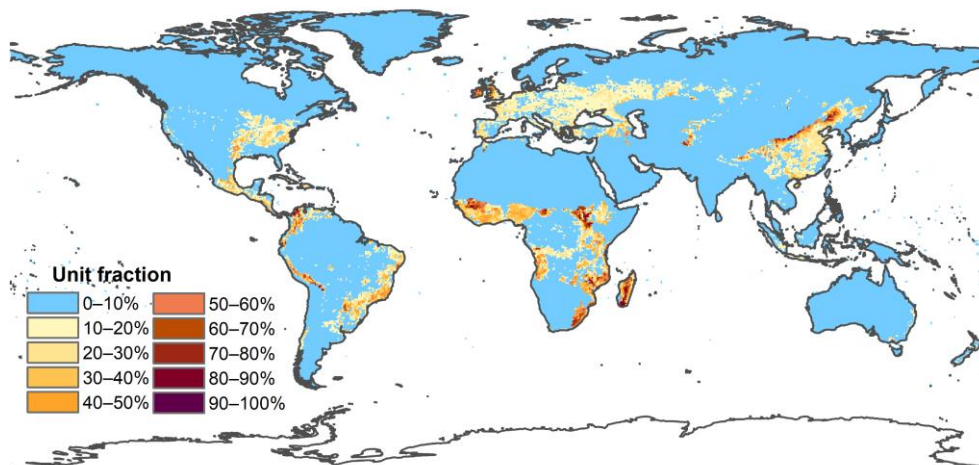


Figure A5. Spatial distribution of multi-year average fraction of managed pasture from 2001-2015 at  $0.5 \times 0.5$  arc-degree resolution.

(see Revision, Page 34)

**Thanks again for your time and efforts put on this manuscript.**