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Reply on RC1

Iris Johanna Aalto et al.

Author comment on "Strong influence of trees outside forest in regulating microclimate of intensively modified Afromontane landscapes" by Iris Johanna Aalto et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-261-AC1, 2022

Reply to Reviewer #1

"Strong influence of trees outside forest in regulating microclimate of intensively modified Afromontane landscapes" - Aalto et al.

General comments:

This paper aims to examine the effect of canopy cover on microclimate in an intensively modified Afromontane landscape in Taita Taveta, Kenya. The authors studied microclimate sensors under different canopy covers, and land surface temperature (LST) from Landsat 8 thermal infrared sensors and combined these data with high-resolution airborne laser scanning data to disentangle combined effects of topography and canopy cover on microclimate. This is an interesting comparison of temperatures across canopy cover changes, forest types, and elevational gradients to help understand thermal regulation by forests and microclimates that buffer species and local climate against warming.

A strength of the study is that it utilizes multiple temperature datasets (in situ and remote sensing) and that it includes study sites along an elevational gradient with CC changes. The study shows a strong negative relationship between canopy cover and temperature, with the strongest effect on maximum temperature. Results are well reported with good figures. The main weakness of the paper is that it does not carefully describe the different physical measurements, what they actually measure, and how they related and interact. The link between microclimate and LST is not clearly established.

Reply: We would like to thank the reviewer for the excellent comments and suggestions. We have addressed each of the comments and made the suggested edits to the manuscript. Especially, we have tried to improve the link between microclimate and LST and explain these concepts more thoroughly. We believe the manuscript has greatly improved after the revision. Please find below detailed replies to all comments.

Main comments

Introduction

1. The flow and clarity of the manuscript could be improved. The second paragraph of the Introduction attempts to cover a large range of topics, spatial scales, and physical measurements and is confusing as written. It could be improved with better explanations and breaking it into two separate paragraphs. One paragraph could focus on forests, TOF, the goods and services they provide, and the land use factors impacting these systems. The second paragraph could focus on microclimates and improved description of other temperature measurements and how they relate.

Line 40-41 describes the values of Forests and TOF as "vital ecosystem services" which I think implies that they are source of many goods and services to humans (ie. That next sentence is redundant). When you say that forests and TOF are "also a source of goods for humans," are you actually referring to uses that degrade forests, such as logs for building or firewood gathering? This should be clarified because it can conflict with the ecosystem services you have just described. The tension between what forests provide when they are left standing, and how they are used for raw materials sets the stage for the existing condition of your study area.

On lines 97 to 102 of the Methods you describe this. But I think this is important background on TOF and helps readers understand why TOF are important (e.g. carbon storage and biodiversity). I recommend moving these lines to the Introduction to complete the TOF paragraph.

Reply: The second paragraph of the Introduction was split into two separate paragraphs as suggested. Text about ecosystem services in lines 40-41 was clarified. We expanded the description of TOF to highlight its importance.

2. Line 44-53: I recommend a new paragraph starting with the definition of microclimate. The description of microclimates is provided at a scale of centimeters to meters (line 45) which does not always seem congruent with your application of the term microclimate, and the spatial focus of the study. It seems that you are interested in microclimatic buffering capacity of forests at much larger scales? This may in part be a problem with definitions as microclimates can also be defined at very localized scales to describe unique thermal niches within context of the overall forest thermal environment. This seems different than the climatic conditions below forest canopies in general sometimes referred to as "microclimatic buffering". I recommend defining microclimate so that it incorporates the spatial domain of your study question.

For example, the De Frenne study states "…the local temperature experienced by living organisms (referred to as the ('microclimate')... While quite general, this definition includes the thermal regulation of forests across scales.

Reply: We created a new paragraph as suggested, containing the definition of microclimate and microclimatic buffering. We believe that a misunderstanding of the definition of these two terms might have caused confusion. The microclimate, as defined in our introduction, is our main interest, and not microclimatic buffering. We defined microclimatic buffering as the difference between the macroclimate and microclimatic conditions under the canopy (Ewers & Banks-Leite 2013). We therefore improved the manuscript to avoid this misunderstanding.

Ewers, R. M., and Banks-Leite, C.: Fragmentation Impairs the Microclimate Buffering Effect of Tropical Forests, PLoS One, 8, e58093, 2013

3. Lines 48-45: The authors compare understory microclimate variability to continental scale studies of spatial variability in LST measurements. LST is canopy temperature, a different physical measurement that indicates partitioning of solar radiation driven by transpirational cooling. I think you should add a sentence recognizing the differences in these physical measurements and that you are inferring a relationship between radiometric surface temperature and understory temperatures especially since the relationship between these various temperature measurements are not well understood.

Reply: We thank the reviewer for the comment. We edited the sentence to avoid misunderstanding and added a more detailed description of LST in the paragraph introducing it.

4. Line 56: Numerous studies have examined forests and moisture gradients using LST and thermal imagery from fine to moderate scales.

Scherrer, D. M. K-F. Bader, and C. Korner. 2011. Drought-sensitivity ranking of deciduous tree species based on thermal imaging of forest canopies. Agricultural and Forest Meteorology, 151, 1632-1640.

Kim, Y., Still, C.J., Hanson, C.V., Kwon, H., Greer, B.T. & Law, B.E. (2016). Canopy skin temperature variations in relation to climate, soil temperature, and carbon flux at a ponderosa pine forest in central Oregon, Agricultural and Forest Meteorology, 226, 161-173.

Mildrexler, D.J., Yang, J.Z., & Cohen, W.B. 2016. A Forest Vulnerability Index Based On

Drought and High Temperatures. Remote Sensing of Environment, 173, 314-325.

Reply: We agree with the reviewer that studies using LST to examine forests are abundant. However, studies focusing on the microclimate of tropical areas are still few: weather station data is still commonly used to study climate change effects. We have edited the sentence to highlight this.

5. Line 56-60: Consider that lines 103-107 of the Methods would make more sense added here. You are describing the climate mitigation potential of forests and TOF, so this would be a good place to highlight the projections for your study area that make this so important.

Reply: We thank the reviewer for the suggestion and have moved the lines from Methods to the Introduction.

6. 62-72: The background on LST and CC should also note the well-described negative relationship between LST and vegetation density. It is key to your study of fractional vegetation coverage (see references below for examples). This addition would be a good transition into the paragraph starting at line 68 that describes some of the commonly used vegetation indices used to study this relationship.

Nemani, R. R., and S. W. Running 1997. Land cover characterization using multitemporal

red, near-IR, and thermal-IR data from NOAA/AVHRR, Ecol. Appl., 7, 79–90.

Goward, S. N., Cruickshanks, G. D., & Hope, A. S. (1985). Observed relation between thermal emission and reflected spectral radiance of a complex vegetated landscape, Remote Sensing of Environment, 18, 137-146.

Goward, S. N., & Hope, A. S. (1989). Evapotranspiration from combined reflected solar and emitted terrestrial radiation: Preliminary FIFE results from AVHRR data., Advanced Space Research, 9, 239-249.

Reply: We thank the reviewer for the excellent suggestions. We have expanded the introduction of LST and included the references.

Methods and Results

7. Microclimatological field measurements: Is it common in microclimatological field measurements for Tair to be only 15 cm from the ground? It seems that measurements so close to the ground would be influenced by the surface temps. I am accustomed to Tair from weather stations where it refers to temperatures measured 1.5 meters above the ground surface as in:

Oyler, J. W., S. Z. Dobrowski, Z. A. Holden, and S. W. Running, 2016: Remotely sensed land skin temperature as a spatial predictor of air temperature across the conterminous United States. J. Appl. Meteor. Climatol., 55, 1441–1457

Reply: Weather stations that measure temperature at 1.5 meters cannot capture the microclimatic conditions. The 15 cm is already common in microclimatic measurements (see example references below). We used the acronym "Tair" to separate it from the two other measurement heights of the TOMST sensor (Tsoil and Tsurf), so the Tair here is not equivalent to the commonly used Tair of 1.5 m. We have clarified this in the text.

Wild, J., Kopecký, M., Maeck, M., Sanda, M., Jankovec, J., and Haase, T.: Climate at ecologically relevant scales: A new temperature and soil moisture logger for long-term microclimate measurement, Agr. Forest Meteorol., 268, 40–47, 2019.

Maclean, Ilya M. D et al.: On the Measurement of Microclimate, Methods in ecology and evolution, 12, 1397–1410, 2021.

De Pauw, Karen et al.: Forest Understorey Communities Respond Strongly to Light in Interaction with Forest Structure, but Not to Microclimate Warming, The New phytologist, 233, 219–235, 2022.

Doughty, Christopher E et al.: Forest Thinning in Ponderosa Pines Increases Carbon Use Efficiency and Energy Flow From Primary Producers to Primary Consumers. Journal of geophysical research. Biogeosciences, 126, 2021

Macek, Martin et al.: Elevational Range Size Patterns of Vascular Plants in the Himalaya Contradict Rapoport's Rule, The Journal of ecology 109, 4025–4037, 2021.

Vandvik, V., Halbritter, A.H., Yang, Y. et al. Plant traits and vegetation data from climate warming experiments along an 1100 m elevation gradient in Gongga Mountains, China. Sci Data 189, 2020.

8. Lines 150-175. The authors use a single channel method to derive LST as a work around to the stray light problem with TIRS band 11 on board Landsat 8. Can you report the uncertainties associated with this approach?

Reply: The uncertainty was addressed very briefly in the discussion, and we agree with the reviewer that it should be mentioned in the methods as well. We have corrected this and added the uncertainty estimate.

9. Figure 5: This is for mean temperatures. Why not show a similar scatterplot sequence for maximum temperatures?

Reply: We added a similar figure with maximum temperatures.

Discussion

10. The Discussion contains more grammatical problems compared to the rest of the manuscript. I encourage the authors to edit this section for grammatical consistency with the rest of the manuscript.

Reply: We thank the reviewer for the feedback and have revised the text for grammatical consistency.

11. Lines 320-322: States that results revealed trees on farms had the same effect on local temperatures as forests… Please refer to the figure or data specifically from the results that supports this finding.

Reply: We base this finding on the canopy cover model that showed the linear relationship between CC and temperature. Most of the canopy cover in the area consists of TOF. We have improved the text to clarify this.

12. Lines 323-325: Can you say on average how much cooler these moderately forested TOF sites in agriculture are vs. ag with no TOF?

Reply: See reply above.

13. Lines 327-328: This is a great link to local policy. Please state how much the difference in temperature 10% forest cover makes here.

Reply: We think that it is an excellent idea to add the numbers to the sentence and did as the reviewer suggested.

14. Lines 334-336: The link between forest and water for agriculture is important. You highlight fog drip here, but what about forests supporting clean water to farms, water retention through increased soil organic matter, and hydraulic redistribution? In other

words, try to strengthen this section.

Reply: We added a sentence about agroforestry's relationship with water as suggested by the reviewer.

15. Lines 337-338: It is not obvious to me why increasing the tree cover on farms would mitigate pressure on tropical forests from fuelwood collection. I presume that farms are private land, and fuel wood collection is not permitted by the general community, but I do not know. Please explain this.

Reply: Thank you for the very relevant comment that deserves clarification. According to Zschauer (2012), large part of the fuelwood in the study area is collected from people's own farms or other areas outside forests, such as bushland. Hence, agroforestry and tree planting in the farms are important for reducing pressure on fuelwood collection from remaining montane forests. The potential of agroforestry to reduce wood harvest pressures in sub-Saharan Africa are also more widely acknowledged (Iiyama et al. 2014).

Iiyama M, Neufeldt H, Dobie P, Njenga M, Ndegwa G, Jamnadass R (2014). The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. Current Opinion in Environmental Sustainability, 6, 138-147. https://doi.org/10.1016/j.cosust.2013.12.003

Zschauer K. (2012). Households energy supply and the use of fuelwood in the Taita Hills, Kenya. MSc thesis. University of Helsinki, Faculty of Science, Department of Geosciences and Geography. http://urn.fi/URN:NBN:fi-fe201201311271

16. Lines 349-351: topographic manipulation of the temperatures? Do you mean "accounting for the effect of topography on LST measurements…"?

Reply: The reviewer is correct that the formulation could be improved. We have changed this to what the reviewer suggested.

17. 354-355: Can you report an uncertainty estimate for the LST product?

Reply: See reply to 8.

18. 355-356: Here you state that LST may not be representative of understory conditions. Wasn't this part of your study? What did you find?

Reply: We thank the reviewer for the excellent comment. We have used both microclimatic measurements and LST to study CC and temperature and whether they are telling the same story in our study area. Previous research has not demonstrated the relationship between LST and the understory in dense canopies, and our results have shown that LST can be representative of the understory conditions. We have improved the manuscript to clarify this result.

19. 360: I recommend adding the following citation to this sentence:

Davis, K. T., Dobrowski, S. Z., Holden, Z. A., Higuera, P. E., and Abatzoglou, J. T. (2019a). Microclimatic buffering in forests of the future: the role of local water balance. Ecography 42, 1–11. doi: 10.1111/ecog.03836

Reply: We thank the reviewer for the suggestion and have added this reference to the sentence.

20. 369-370: At line 356 you questioned whether LST is representative of understory conditions and provided citations. Here you state that your results showed that LST can be used as a proxy for assessing the impacts of CC on microclimate. Do your results really show this? Or do they show that an increase in canopy cover results in a commensurate decrease in LST?

Reply: See reply to 18.

Other Specific Comments:

Line 140: delete "laying" so sentence reads "as the plot was outside of the ALS coverage."

Reply: We deleted the word "laying".

Line 191: Reword to: CC also affected temperature variability

Reply: We reworded the sentence.

Line 287: In additional to sensible heat flux, could some of the cooling effect be due to transpirational cooling?

Reply: We agree with the reviewer that the cooling effect is also due to this. However, the sentence did not mean to separate sensible heat flux and transpiration, and we have reformulated the sentence for more clarity.

298: Change discovery to finding.

Reply: We changed the word from "discovery" to "finding".

292: prevalent doesn't make sense here. Please clarify.

Reply: We changed "prevalent" to "ambient".

295: “One likely reason…”: isn’t another likely reason that on cloudy days there is less solar insolation at the surface, which has a disproportionately large effect on warming areas with low CC on sunny days?

Reply: We thank the reviewer for the remark and have added a sentence about this in the paragraph.

314: Change extent to magnitude

Reply: We changed “extent” to “magnitude”.

328: Can simplify sentence to “Soil and air temperatures impact crop productivity,…”

Reply: We simplified the sentence by removing “have an”.