Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2020-407-AC2, 2020

Biogeosciences
Discussions

Interactive comment on "The decline of alpine lichen heaths generates atmospheric heating but subsurface cooling during the growing season" *by* Peter Aartsma et al.

Peter Aartsma et al.

peter.aartsma@usn.no

Received and published: 18 December 2020

We thank Reviewer 2 for his/her time to review our manuscript and for his/her valuable comments. Below are our answers on his/her comments.

Reviewer comment: This paper investigates the differences between lichen and shrub cover for alpine tundra microclimates. The authors measured vegetation and microclimate data at a site in Norway in two consecutive years. The research gap that they are aiming to investigate is well-framed and interesting for the field of tundra ecology in a wider scope. The article is well-written, especially the discussion and methods are overall clear. The main strength of the paper in my view is that it introduces meticulous

measurements on an understudied aspect of this field. However, I propose major revisions to this paper before acceptance. The authors should reframe the conclusions of their study in accordance to the size and caveats of their experiment and improve on their analysis of the results.

Author response: We thank the Reviewer for his/her positive words about the framing of the research gap and the writing style of the manuscript. We understand his/her point concerning the size and caveats of our experiment and will elaborate on this in the next version of the manuscript. We will in particular frame our experiment, which is based on one study area, in the context of ecosystem-wide change over the Northern Hemisphere. Below we will expand on our additional thoughts about the size of our experiment and the analysis of the results by addressing the more specific comments.

Reviewer comment: The paired plot set-up, and the plot selection not being random, risks the introduction of a selection bias. Despite their thorough methodology it remains unclear as to how their plots where actually selected. Was selection bias prevented through radial/cardinal walking?

Author response: For the plots of 2018, we selected randomly 10 locations in the study area using ArcMap. Subsequently, we selected the lichen plots within a radius of 50 meters around each random location that fitted the criteria in Table 1. In case we found multiple lichen plots that fitted these criteria, we selected the lichen plots with the highest percentage of lichens. Subsequently, we selected the shrub plots within a radius of 50 meters around each selected lichen plot that fitted the criteria in Table 1. In case we found multiple shrub plots that fitted these criteria, we selected the shrub plot with the highest percentage of shrubs. The location of the plots of 2019 were selected subjectively, but still fulfilled the criteria of Table 1. Since the location of the plots of 2019 were selected subjectively, we decided to include only the measurements of 2018 in the mixed effects models and in the Wilcoxon test and therefore bias was prevented in these analyses. We agree that we did not specify the plot selection adequately in the text and will explain this more detailed in the next version of the manuscript.

Reviewer comment: How was a plot determined to be on a ridgetop, and how was a slope <10% determined?

Author response: The ridgetops in our study area are well distinct from the midslopes and the snowbeds (see Appendix A of the manuscript for a picture of the study site). The ridgetops were determined based on their vegetation characteristics and the low or absent slope angle. We obtained the slope of each plot with a clinometer. We will specify this in the methods section of the new version of the manuscript.

Reviewer comment: Why was this area picked in general, does it represent the landscape that they want to study in a particularly good way?

Author response: We selected this area since it has a high abundance of lichens and the landscape is representative for an alpine landscape in Scandinavia. We will elaborate on this in the section "Study area" in the new version of the manuscript.

Reviewer comment: The authors successfully performed very high-detail measurements for both radiation and soil parameters. The measurements where however always on different days for different plots, and there was no revisiting of same plots, not even in 2019 when they revisited the study site. This limited amount of measuring days, measured plots and no revisiting of plots increases the risk of the results being affected by unaccounted variability. 2018 for instance was a very warm and dry year that could influence many processes in the ecosystem. Please expand on the potential consequences of these limitations and why the experiment design was changed in 2019.

Author response: The initial sample design for this study contained only measurement of one field season (2018). However, 2018 turned out to be a warm and dry year and therefore we chose to include measurements of 2019 in this manuscript to show that the measurements of 2019 show a similar pattern (lichen plots having a higher soil temperature and soil heat flux than shrub plots during warm days, despite having a lower net radiation). Unfortunately, we could not revisit the same plots of the field

season of 2018, since the vegetation was disturbed after taking soil samples, and this affects the measurements (especially radiation) substantially. The reason for a change in experimental design was that we wanted to measure the plots for a longer period to gain insights in the variability in the microclimatic conditions over time. In the next version of this manuscript, we will elaborate more on the consequences of the warm and dry field season for our study in the discussion. Moreover, we will give our reasons for a change in experiment design (in Lines 132-135).

Reviewer comment: The authors perform their statistics based on a sample size of 13, Wilcoxon is however not a parametrized method, and generally not suitable for small sample sizes. Significance of results based on these tests can't be concluded with so much certainty as the authors claim. Consider trying a paired parametric test. Be aware of confounding variables in the microclimate.

Author response: As suggested by the reviewer, we repeated the analysis with the paired parametric t-test and the paired permutation test. Both tests draw the same conclusion as the Wilcoxon test. However, in our view, the Wilcoxon test is the appropriate test to use here. The parametric t-test has the underlying assumption that the data has a normal distribution. Since we cannot test this assumption due to the low sample size, we decided to use the more conservative Wilcoxon test. Therefore, we still opt to report the results of the Wilcoxon test. Note: we analyzed the difference in the canopy and soil variables between the lichen and shrub plots (Fig. 3) for the plots of the field season of 2018 only, and therefore the sample size consists of 10 plot pairs. We will make this clear in the new version of the manuscript by adding "n = 10 plots per boxplot" in the caption of Figure 3.

Reviewer comment: Comments on figures: the amount of figures in the paper could be decreased.

Author response: We will move Figure 8 to the Appendix in the next version.

Reviewer comment: Fig. 3 needs better axis scaling to highlight their results.

Author response: We will change the scaling of the y-axis of this figure in the next version.

Reviewer comment: Fig. 5 could benefit from an r2 to indicate the strength of relationship.

Author response: We will determine the marginal and conditional r2 of each linear mixed-effects model as proposed by Nakagawa & Schielzeth (2013) and indicate these r-squares in Table 2. The marginal r-squared is the variation explained by the fixed effects and the conditional r-squared is the variation explained by the entire model. We chose to report these values in Table 2, since Reviewer 1 requested this information in this table. Moreover, we decided to remove the actual measurements from Figure 5 to be consistent with Figure 7, which makes the indication of the r2 in Figure 5 less necessary. In the caption of Table 2 we will state that Figure 5 shows the results of the mixed-effects models.

Reviewer comment: In Fig. 7 it is hard to read the confidence intervals due to overlapping the same colors.

Author response: We will make the confidence intervals more clearly in the next version of the manuscript.

Reviewer comment: There is serious cherry-picking in the 2019 graphs in fig. 8 and fig. 9. In 2019 only three plots were measured and then the authors select the one that support their conclusions the best to include in the paper. The supporting figures of the remaining 2 plots that were measured in 2019 don't show the same strong results as the ones that are included in the main paper.

Author response: We decided to move Figure 8 to the Appendix alongside the time series of the other two plots of 2019. The purpose of Figure 9 was to show that the difference in microclimatic conditions between the lichen and shrub plots is larger for clear, sunny days than for cold, cloudy days. Therefore, we chose a distinct warm,

sunny day and a distinct cold, cloudy day, as describe in the methods (Line 173-175).

Reviewer comment: Generally, it is a good study with only 13 plots over two years, and only a few consecutive days of measurements. 2018 was a very warm and dry year. Their plot selection could have introduced bias. The authors should make their claims according to the limits of their experiment. The same group of authors have published multiple papers focusing on slightly different aspects of this same site and experiment, further decreasing the novelty of the results presented here. My suggestion would be to extend the study by revisiting the sites in a different year, or performing the same experiment at a different site. The results would be very much strengthened by such an extension of the study and the scientific community would benefit from a more thorough investigation of this interesting experiment.

Author response: We thank the Reviewer that he/she acknowledges our study. The Reviewer is concerned about the amount of plots and years on which we base our conclusions. We would argue that our analysis shows that there is no sign of a significant bias, and that our dataset robustly supports our conclusion. Indeed, similar studies measuring with radiometers and soil heat flux systems (e.g. Blok et al. 2010; Juszak et al. 2016) have often measurements during one year and less plots. Studies with radiometers and soil heat flux systems like these are often limited by the amount of sensors. Therefore, it is hard to build proper replication into a sampling design. We would like to have measurements on more plots, however, this would also mean that we need to change plots more often, which would lead to less measurement days. We would also like to have more measurement days, but this would mean that we would have less plots. Therefore, we chose a hybrid solution with measuring one year multiple plots and less consecutive measurement days (2018) and the other year measuring less plots and more consecutive days (2019). Since our plot selection in 2019 was not random and the sample design was different for the field season of 2019 than for the field season of 2018, we chose to use only the plots of the field season of 2018 for the main analysis and use the plots of the field season of 2019 to support the results of

the measurements of the field season of 2018. This means that we did not introduce bias in our main analysis due to plot selection. Indeed, 2018 was a warm and dry year and this was a reason to report the measurements of the field season of 2019 next to the analysis of the field data of 2018. As mentioned before, we will put emphasis on the limitations of our experiment in the next version of the manuscript. Moreover, we will elaborate on the consequences of the warm and dry field season of 2018 on our results. The Reviewer mentions further that we published a paper on a slightly different aspect of the same experiment. However, in this other paper (Aartsma et al., 2020) we measured the difference in albedo between lichen heaths and shrubs while in the current manuscript we study the effect of this difference in albedo on other microclimatic variables. Therefore, we think that this current manuscript brings sufficiently novel results to be published on its own. In the next version of the manuscript, we will introduce our findings and link the results of the previous paper (Aartsma et al., 2020) more thoroughly to the study of the current manuscript.

Reviewer comment: General comments: l.32 add a Norwegian or at least Scandinavian example?

Author response: We will add a Scandinavian example in the next version.

Reviewer comment: l.35 what about increased competition due to e.g. grazing?

Author response: Yes, grazing and trampling of lichens could lead to a decrease in abundance of lichens. We will add this in the next version.

Reviewer comment: l.42 does vegetation composition indicate the vegetation community, abundance, diversity?

Author response: In the sentence following line 42, we give examples on how the shrub increase alters the vegetation composition. We mention that a negative relationship between shrub and lichen occurrence is reported by multiple studies (line 43-44). We also mention that shrub patches have a lower lichen abundance and diversity than

areas without shrubs (line 43-44).

Reviewer comment: l.47 what other distinct characteristics other than albedo?

Author response: We will add more examples of the distinct vegetation characteristics between lichens and shrubs, for example their difference in vegetation height and the strong insulating capacity of lichens.

Reviewer comment: l.81 expand on insulating properties of lichens? Include differences between e.g. crustose and foliose lichens and indicate which type of lichen species were dominant in their plots?

Author response: We will expand on the insulating properties of lichens in line 47, in which we discuss the distinct characteristics of lichens and shrubs.

Reviewer comment: l. 108 'similar way, similar positions', explain how exactly?

Author response: We will explain this more accurately in the next version.

Reviewer comment: l.111 30cm above canopy. So much higher for shrubs with a much higher canopy? Consider other effects such a surface roughness and turbulence affecting this.

Author response: The radiometers were placed 30 cm above the vegetation canopy. Since these radiometers measured only the radiation terms (shortwave and longwave radiation), we think that these measurements are not affected by the surface roughness and turbulence. This would be different if we would measure the latent and sensible heat flux on this height, however, we did not measure these fluxes directly.

Reviewer comment: Tbl.2 move to supplementary information.

Author response: As proposed by Reviewer 1, we will add the slope and error of the fixed effects in Table 2. This provides more useful information for the reader. Since the table will increase in size when the slope and error of the fixed effects are added, we choose to report the output of the mixed models for the daily averages/totals in

the main text and move the output of the mixed models for the daytime and nighttime averages/totals to the Appendix.

References used by the author:

Aartsma, P., Asplund, J., Odland, A., Reinhardt, S., & Renssen, H. (2020). Surface albedo of alpine lichen heaths and shrub vegetation. Arctic, Antarctic, and Alpine Research, 52(1), 312-322.

Blok, D., Heijmans, M., Schaepman-Strub, G., van Ruijven, J., Parmentier, F., Maximov, T., & Berendse, F. (2011). The cooling capacity of mosses: controls on water and energy fluxes in a Siberian tundra site. Ecosystems, 14(7), 1055-1065.

Juszak, I., Eugster, W., Heijmans, M. M. P. D., & Schaepman-Strub, G. (2016). Contrasting radiation and soil heat fluxes in Arctic shrub and wet sedge tundra. Biogeosciences, 13(13), 4049.

Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining R2 from generalized linear mixedâĂŘeffects models. Methods in ecology and evolution, 4(2), 133-142.

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-407, 2020.