



Peer Community In Animal Science

Provision of optimal shade for ewes: a question of choice

Birte L Nielsen  based on peer reviews by **Pol Llonch**  and **Matteo Chincarini** 

Cécile Ginane, Mickaël Bernard, Véronique Deiss, Donato Andueza, Camille Béral (2025) Shade use, welfare and performance of ewes grazing in temperate silvopastures differing in tree density. Zenodo, ver. 4, peer-reviewed and recommended by Peer Community in Animal Science. <https://doi.org/10.5281/zenodo.10974491>

Submitted: 23 April 2024, Recommended: 13 March 2025

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Published: 13 March 2025

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As the world slowly (or not so slowly) warms, the ability to regulate heat becomes even more pertinent for livestock kept in enclosed areas. Trees are not always present on land grazed by sheep, and when the pasture has some forestation, the coverage will provide varying degrees of shade. In this study by Ginane et al. (2025), ewes kept in enclosures with different levels of tree cover were observed at different times over a period of three years to investigate the extent to which the animals chose to spend time in the shade. By using fields with very different provision of shade (approximately 1, 40, and 81% shade, respectively), the authors wanted to test the hypothesis that ewes would actively seek out tree shade when the combined temperature and humidity increased – especially if the conditions reached levels associated with heat stress. Even at the lowest provision of shade, which consisted of a single tree in the paddock, all ewes could fit within the shade cast by the tree; but if the distribution of ewes or groups of ewes were random, i.e. independent of shade, the likelihood of these ewes being in the shade by chance was effectively 1%. By factoring in the element of chance, the authors found that mean shade use was greater than the tree canopy cover for the low and medium shade treatments, whereas it didn't differ from chance for the densely forested treatment. Across treatments, all ewes spent just under 60% of the observation time grazing, and the ewes with the low and medium level of shade actively selected shade for foraging activity, whereas the ewes with over 80% canopy cover avoided it. Across treatments, shade was used primarily for resting and ruminating.

Tree cover affected the availability of forage in a negative manner, with more biomass available for ewes in the low shade treatment and significantly less in the high treatment, although this did not translate into significant differences in live weight or body condition score. Using this information, Ginane et al. (2025) calculated the optimal level of tree cover to be somewhere between the low and medium cover, at roughly 30

trees per hectare – preferably spread out over the area to offer different locations of shade and to encourage a natural spread of manure.

This longitudinal study of shade use by ewes provides novel and useful information on the positive and negative effects of tree cover in paddocks used to rear ewes with lambs. The authors raise the limitation of the study themselves, and they would have liked to also include observations on non-sunny days, to be able to eliminate place preferences independently of shade availability. But the clever calculation of active shade-selection makes this study easily applicable for use in the assessment of paddock suitability for pregnant ewes.

References:

Cécile Ginane, Mickaël Bernard, Véronique Deiss, Donato Andueza, Camille Béral (2025) Shade use, welfare and performance of ewes grazing in temperate silvopastures differing in tree density. Zenodo, ver.4 peer-reviewed and recommended by PCI Animal Science
<https://doi.org/10.5281/zenodo.15001481>

Reviews

Evaluation round #2

DOI or URL of the preprint: <https://doi.org/10.5281/zenodo.10974491>

Version of the preprint: 3

Authors' reply, 11 March 2025

Dear recommender,

Please find the revised version of our preprint entitled "Shade use, welfare and performance of ewes grazing in temperate silvopastures differing in tree density", for peer-review evaluation.

The preprint is accessible at <https://doi.org/10.5281/zenodo.15001481> and the metadata, data files, scripts and appendices by following the private URL: <https://entrepot.recherche.data.gouv.fr/privateur1.xhtml?token=1c5da6a3-b89e-4a63-a690-a8a48018f55d>

We thank you for the comments made on the manuscript, which we modified accordingly. Explanations of the changes are given in the file "PCI_AnimSci#303_Responses_to_comments_onV2_Submitted.pdf" and appear in blue after each comment.

We hope that these changes will make the manuscript acceptable for publication in the Peer Community In Animal Science Journal.

Best regards,

Cécile Ginane, on behalf of the authors

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Decision by Birte L Nielsen , posted 27 February 2025, validated 03 March 2025

The revised version is much improved, and the only further revision needed is mainly typographical.

In the Abstract (and because it is in the abstract) you refer to '*even on low stressful days*', which should be replaced by '*even on days with lower TRH*' - or words to that effect, as you did not measure stress directly.

In Figures 2 and 4, there are some stray arrows and treatment names on the right-hand side. And in Figure 7, there is a down-pointing arrow missing in the top left-hand graph.

Evaluation round #1

DOI or URL of the preprint: <https://doi.org/10.5281/zenodo.10974491>

Version of the preprint: 1

Authors' reply, 20 February 2025

Dear recommender,

Please find below the answer to the comments made by you and the two other referees. The answers appear in italics below each comment.

Best regards

Cécile Ginane, on behalf of the authors

Revision round #1

Decision for round #1: Revision needed

Request for revision

Comments and suggestions from Birte Nielsen:

Lines 22-23: As also highlighted by one of the reviewers, shade-seeking can be to prevent heat stress. I am also confused why active shade seeking would increase with decreasing tree-density; is that because they may be in the shade by chance otherwise? Please have a think about what this sentence is actually saying.

Beyond the abstract, to address more clearly this question of active search (motivation to get shade) that would increase as the availability of the resource (tree density) decreased, we calculated the Jacobs' selectivity index. This index allows analysing the selection of a resource relative to its availability in the environment. With this index, that stands between -1 (never used) and 1 (exclusively used), we show that shade selectivity was indeed greater for Tlow ewes (0.93) than for Tmed ewes (0.59) than for Thigh ewes (0.12). These new data and analysis have been added in the main text and the results are evoked in the abstract.

Lines 33-35: As this is in the Abstract, it needs to be easily understood, but I am struggling to understand. Perhaps it is the use of 'versus' which could be replaced with 'with'. In effect, if 50% of an area is shaded, and the sheep spend 50% of their time there, we cannot know if they seek/avoid shade, or not). You are saying that the sheep spend more time than by chance under shade in treatment T1 and T+, but in T++ it corresponds to the area, so could have happened by chance.

Yes, you are wright. We corrected the sentence to make it clearer and included the results from the selectivity index explained in the response of the previous comment.

I agree with one of the reviewers that the treatments could be better named. Perhaps T1, T60 and T150? It is also not immediately clear if the three areas of study were of the same size.

The name of the treatments has been changed to Tlow, Tmed and Thigh instead of T1, T+ and T++.

Regarding the areas, this is specified more clearly.

Lines 40-41: As highlighted by one reviewer, I suggest changing this wording to: "Active shade seeking is therefore an indicator of increasing thermal load". You do not know if this is "before physiological changes occur" as you did not measure this.

We removed the initial sentence and added the proposed one a little bit earlier in the text for a better integration.

Line 42: suggest deleting 'globally' or replace with 'Overall ewe performance...'

Done.

Line 43: Not clear what 'penalized sward biomass' is.
Modified by "the lower sward biomass"

Line 56: Replace 'exploring' with 'exploratory'.
Done

Line 58: Replace 'withdraws' with 'drawbacks'
Done

Line 84-86: Please see my comments to lines 22-23, and adjust wording here as well.
Done

Line 88: This end of sentence is very difficult to follow. Can you reword it?
We have reworded the sentence and hope that it is clearer now.

Line 93: suggest replacing 'with a risk of heat stress for the animals' with 'with increased thermal load on the animals'.
Done

Line 101: To make it clearer for the reader, I suggest the following adjustment: "...three pastures of similar size (mean = 0.82 ha, SD = 0.034)".
Done

Line 109: the addition of 'for ethical purpose' is somewhat abrupt and casual. Are you allowed to keep sheep in pastures without access to shade? If yes, and you had chosen a field with no trees, how would you have observed active shade seeking? I suggest moving the ethical committee's approval to be more visible.

According to the council directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes, it is stated that "Animals not kept in buildings shall where necessary and possible be given protection from adverse weather conditions, predators and risks to their health". For experimental purposes and considering the appropriate endpoints, we could have kept sheep without shade as a control treatment for some data (performances, time budget or respiration rate), but you are right, this would have prevented us to analyse shade use when shade availability is low.

We moved the ethical committee's approval to the Materials and Method section and we reformulated the sentence where the plots are presented.

Line 112: Replace 'implanted' with 'planted'
Done

Line 118: Replace 'excepted' with 'except'
Done

Line 119: insert 'on average' after 'weighed'
Done

Line 120: Replace '1st' with 'first'
Done

Line 12: Replace 'lactating' with 'suckling'

Done

Line 122: Please indicate when the marking of the sheep was done relative to the observations, and if it had to be refreshed.

This information is added in the text.

Line 145: Please indicate that the observations were made on days when no other disturbances were observed or planned (e.g. the sward measurement, weighings etc.) if that was the case.

Done

Line 195: It would be clearer with 'a synthetic' (rather than 'the').

Done

Line 204: It is interesting that the TRH value correlates with higher temperature but lower humidity. It makes sense, but the thermal load would increase with higher humidity – this may be worth noting in the Discussion.

Our calculation of TRH is based on our local microclimatic data. The fact that it increases with lower humidity is related to that our location is in a temperate climate. This is added at the start of the discussion.

Line 214: As you had observations during periods of no sun, and would know if the area chosen by any ewe would have been in the shade or not, this would allow you to assess if the areas were chosen for other qualities than shade, e.g. softness, elevation etc. It may not require a complete re-analysis of your data, but could be an additional analysis to answer one of the questions from the reviewers.

This would be an interesting data to analyse. However, the only information we have about the areas chosen by the ewes, other than whether they were in the shade or the sun, is their position relative to trees, i.e. whether they were in open areas or under the tree crowns. Unfortunately, we have no information about any geolocation of the ewes within the plots (North/South, elevation, etc.) so it is not possible to qualify their position relative to some plot's characteristics.

Line 240: It is not clear why the respiration per animal per day were not used as a behavioural measure to assess the thermal load on the animals? Why did you resort to one value per year for each animal? Are these not the values used in Figure 7?

You are right that respiratory rate (RR) is commonly used to assess the thermal load on an animal. We decided to analyse these data on an annual basis rather than on a daily basis because we did not always manage to get several data measurements on each individual each day, and because we observed large variability between measurements on a given animal and day. To make this transparent, we have included in the data file the mean RR for each individual on each day, as well as the number of measurements for that mean and the associated standard deviation. We feel that we should have more data to analyse RR on a daily basis. The values used in the Figure 7 (now Figure 6) are the annual data for each individual.

Line 245: CP data were...

Done

Line 255: But the increase of shade use with increasing shade availability would have happened by chance – was the proportion of shade available adjusted for in the analysis? You appear to do this later (line 263 and Table 3) but not here? Also, was there enough shade available in Treatment T1 to give all animals a choice?

You are right that the increase in shade use with shade availability is logical and could have happened by chance. The proportion of shade available was not adjusted for in the analysis as it is considered in a qualitative way in the

model (one value per treatment). To assess whether shade use was active (rather than by chance), we performed Wilcoxon signed-rank tests comparing shade use with tree canopy cover (as a proxy for shade availability) (Table 3).

In Tlow, the estimate of tree canopy cover was approximately 65m². This was sufficient for all ewes and their lambs to be in the shade at the same time (our own observations). In addition, this 65 m² is about twice the area required for 10 ewes and their twin lambs, according to the legislation. We added a sentence in M&M section to specify this.

Line 279: "The ewes from T+ and T++ never differed in their selection of shade." But does this not mean that the T+ ewes were choosing and/or the T++ ewes were avoiding shade, given they had different shade areas available?

Actually, if we look at the selection for shade relative to shade availability, for the main activities (feeding, ruminating and resting) by using Wilcoxon signed-rank tests, it appears that for the resting and ruminating activities, the ewes from all treatments actively chose shade. For the feeding activities, Tlow and Tmed ewes chose shade whereas Thigh ewes avoided it. We added these results in the text.

Line 288: As also suggested by one of the reviewers, if this is the only animal welfare measure, this would be better included under the animal behaviour heading.

Done

The Discussion is relatively long so if you can, please simplify and reduce some sections as that would improve the readability of the article (even splitting into more paragraphs would make it easier to read). The revised Discussion should also take in aspects raised above (that shade use is not the same as heat stress, and the differences between shade availability in your treatments).

The discussion has been reworked. We modified the section on shade use as an indicator of heat stress. We stated the limits of the study in terms of quantification of shade while highlighting the fact that the 3 treatments were very contrasted.

When possible, we split the discussion in more informative sections. We shortened the section with the respiration rate but we acknowledge that the discussion is still a bit long because we added a section on the optimal tree coverage, as requested.

Line 390: Can you apply thresholds from another species? What was the wool length/cover of your sheep?

It is questionable to apply index formulas and thresholds developed for one species to another. For this reason, we decided to calculate our parameter to qualify the climate on the days of observation in our experiment. Nevertheless, in the bibliography, some indices are classically used, including in sheep studies, to characterise the local climate in relation to the risk of heat stress. For the sake of comparison, we considered it useful to provide the values of these indices applied to our climatic data and to position the days of observation using the thresholds developed in another ruminant species (beef cattle or dairy cows) from classical indices.

Unfortunately, we did not specifically measure the length and cover of the wool. In return, the ewes from all treatments and all years were conducted in the same way. They have been shorn once, in the spring, two months before entering the experimental plots, and were not shorn afterwards during the grazing season.

Line 473: In this section I am missing information on what the optimal tree cover would be under your circumstances. How many trees are needed to allow shade to be available for 10 ewes and 20 lambs, and how big an area of unshaded grass land is needed to ensure sufficient roughage when no supplement is provided? This information would allow the reader to compare your results with an ideal situation under the same circumstances. You allude to it in your conclusions but a more detailed estimate in the Discussion would be great.

A section in the discussion is now dedicated to this information.

Table 4: The line numbers appear to have infiltrated the Table.

This is corrected

by Birte L Nielsen, 31 Jul 2024 13:18

Manuscript: <https://doi.org/10.5281/zenodo.10974491>

version: 1

Review by Pol Llonch, 09 Jul 2024 11:28

The manuscript investigates the use of shade in sheep during sunny days, according to different tree density in a temperate region. The manuscript is very relevant, especially due to the lack of evidence in this matter in the literature. However, the manuscript has several minor flaws, which are described below, but one major aspect that needs careful consideration. This is about the experimental design, which omits a control treatment, which should be the distribution of sheep under trees in non-sunny days. I strongly believe that this should be included in the experimental design but I would like to see the rationale of authors behind this decision.

Title and abstract

The abstract should include the numerical results and not only whether a variable was lower or higher..

Numerical data have been added in the abstract.

Introduction

The introduction does not mention what is the expected effect of shade for animal welfare and behaviour. There is literature in other species such as cattle, that addressed this, and authors are suggested to include this.

Done

Materials and methods

Are the methods and statistical analyses appropriate and well described? [] Yes, [x] No (please explain), [] I don't know

· Line (L) 107 Treatments should receive alternatives acronyms. I suggest using Tlow, Tmedium and Thigh, to highlight the tree density of each treatment.

We agree and modified the names of the treatments accordingly.

· L108: The experimental design should include observation during non-sunny days, as a control group. Otherwise, sun (and temperature) cannot be taken as the fixed effect.

Our objective was to study the use of shade by the ewes, depending on shade availability, and in a range of climatic conditions (variable risk of heat stress). We did not aim to compare the use of trees in sunny vs non-sunny days. Consequently, we focussed as much as possible on sunny days: out of the 19 days of observations, only two had less than 30% of sunny scans, and on these days, beyond the fact that they weren't 100% sunless, some thundery rains have occurred in the afternoon making these days not valuable as a control (the ewes could spend time under trees to protect from rain). Furthermore, to study the use of shade, our main variable of interest is the position of the ewes relative to shade, which is different from the position relative to tree crowns, due to the shadow cast that evolves with sun position. We actually recorded the positions of the ewes relative to tree crowns but decided not to present the data as the length of the manuscript was already important. As an illustration, over all the days of observation (n=19), the average proportion of scans on which the ewes were observed under shade was:

Tlow: 0.37 (SD 0.18) / Tmed: 0.72 (SD 0.10) / Thigh: 0.79 (SD 0.12). On the same days, the average proportion of scans observed under tree crowns was:

Tlow: 0.21 (SD 0.14) / Tmed: 0.44 (SD 0.11) / Thigh: 0.57 (SD 0.13).

We recognise the importance of asking why the animals use the proximity of trees, to assess whether it is for shade or for some other reason. Our design was not intended to answer this question, but the need for knowledge on this point now appears in the perspectives.

· In L112, is the tree crown of different treatments providing the same shade. Please provide evidence of this.

We did not make precise measurements on the quality of shade provided by the trees in the different treatments, and we acknowledge this limit. We aimed to analyse the system in a more global way, as a first approach, by considering very contrasted tree densities and by choosing pasture plots each planted with mature deciduous trees (more than 25 years). We agree that future studies will need to characterise shade, both qualitatively and quantitatively to better understand the animals' responses relative to it in various climatic conditions.

We added this limit in the discussion.

· L124: Please provide the sanitary status of the flock

This information is now added in the text.

· L143: This is a very limited sample size. It should be clear whether results are presented as average per observation slot, or in a more granular manner. This is not clear in the current form.

A sentence is added for more clarity.

· L184: Was environmental data presented by observation slots or per day? Please confirm.

A sentence is added for more clarity.

· L209: Was this data presented by each animal per time, or by group of animals in total? Please explain better the outcome.

The data is analysed and presented per group of ewes in total. This is indicated when the statistical unit is defined and in the legend of the figures. Taking the group of ewes as the statistical unit aimed to prevent the consideration of individuals that are not independent in a group and express some degree of synchronicity.

· The ethics statement should be added.

Considering the comment on one of the other reviewers, the ethics statement now appears at the beginning of the Materials and Methods section.

Results

· L250: I suggest merging the section 'animal behaviour' and 'animal welfare' because animal behaviour is (in this case) an indicator of animal welfare.

Done

· L324: Was there any difference between biomass content between different paddocks?

This information is one of the results of the study and is reported in the Results section on pasture characteristics.

Discussion

Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? [] Yes, [x] No (please explain), [] I don't know

L451: I don't think shade use can be used as an indicator of heat stress because it may be performed as a strategy to prevent heat stress, even before it occurs. Therefore, as it is not directly associated with heat stress it cannot be used as a reliable indicator.

We acknowledge that heat stress is modified by the use of shade and that all our treatments provided shade, making the assessment of heat stress difficult. However, if we consider that shade is involved in improving the thermal comfort of the animal, we believe that shade use can be seen as an indicator of thermal discomfort and of a risk of heat stress if shade is no longer accessible. Of course, this would require verification that the animals are using the proximity of the trees for their shade, as you also pointed out (cf. previous comment and answer).

Review by Matteo Chincarini, 30 Jul 2024 15:19

The study addresses an interesting topic where the literature is scarce at the moment. The researchers investigated the use of shadow in sheep provided by natural resources. However, at this stage, the manuscript shows some limits in terms of statistics, references (mainly to other sheep) and a better explanation of the experimental design (for instance, why not use a latin square?).

I think that after an extensive review of the manuscript, the authors will be able to address all the questions highlighted below.

Please, see my specific comment below:

L 101: "device" could be changed with "setting"

Done

L 118 it is not clear to me how many animals were involved in the study. It seems that each year 10 ewes per group were used, plus the lambs. It seems that all ewes had twins, so for each group, there were 10 ewes plus 20 lambs. Is this correct? Can you rephrase it? Finally, it is important to report the sheep breed that was involved in the study.

Thanks for the remark. You are right. We now state the breed and provide more precisions about the number of animals each year.

L 143 Animal measurements: usually, when more than one observer is involved in assessments interobserver reliability should be performed to see the level of agreement between the observers. Did you do that? If not, how could this influence the results? This should be discussed.

You are right. Two main observers, experienced in recording animal behaviour, participated throughout the study. Together they carried out about half of the observations each year and trained the additional observers. However, we did not formally carry out the training in order to be able to assess interobserver reliability. This point was added in the discussion as one of the limitations of the study. In addition, within a classical observation day, the three observers changed groups of ewes at each time slot in order to limit an observer effect on the data.

L 144: "We observed the activity of all ewes on 4 days in 2016, 8 days in 2017 and 7 days in 2018." Please, could you describe how representative these observations are regarding the total period of each summer? Also, in which period of the year were the observations performed?

Thank you for this remark. The observations were performed between May and August each year. We have included this information in the text. Regarding the representativeness of the days of observation, in the first version of the manuscript, we provided a table (Table 2) that characterised the climate of the 3 experimental years, over the period May-September. In order to facilitate the comparison of the days of observation with the "classical" climate of the month, we have modified the Table 2 and provided the climate by month for each year. From this comparison, it is clearer that the days selected for the observations were located in the highest range for radiation and to a lesser

extent for temperature. This is consistent with our focus on the sunny days with a range of heat stress risk. This has been added in the text.

L 196 please, add the reference for each package of R that has been used, like FactoMineR

Done

L Results: as a general comment, add the effect size of all your comparisons when possible.

Thanks for the comment. We looked at how providing an indicator of effect size from our analyses. As the classical indicators, eta-squared or "f" of Cohen are both based on the sum of squares, which are not what is optimised in a mixed model, we provide instead the Fixed Effects Estimates and their associated standard errors. The main values are indicated in the text and the complete tables are provided as supplementary material in Appendix 3 so as not to make the manuscript too long, but this can be changed as requested.

L 254 "Square TRH was significant ($p = 0.046$)." What do you mean by this?

We used a quadratic model to take account of the curvilinear shape of shade use with TRH. The significance of TRH^2 reveals this curvilinear evolution and means that it is worth including this effect in the model when analysing the other factors.

L 288: here is the first time that you mentioned "animal welfare". I think that using only the respiratory rate as a measure of animal welfare is misleading. I would either include this parameter in the other paragraph or introduce more about why you focused on this parameter or animal welfare.

You are right. In accordance with the comment of the other reviewer, we included the data on respiratory rate within the "animal behaviour" section

L 363-368: you start the discussion by referring to the thermal stress indices used in cattle. Please, use literature on sheep and review your discussion accordingly

We are not sure to well understand the comment and we apologize if we do not answer to it correctly. In this section of the discussion the important point is that classical indices used in the literature to characterise the risk of heat stress have been developed in cattle, but not in sheep. This explains the citations of references on cattle. In a second time, we present which of these indices have been the most frequently used for sheep studies. In the other sections of the discussion, we tried to privilege references on sheep when they are available.

Introduction

Are the research questions/hypotheses/predictions clearly presented? No (please explain): The authors should include a clear hypothesis on what to expect from the variable the aim to collect.

We modified the presentation of the hypotheses at the end of the introduction and beginning of the discussion to make them clearer.

Materials and methods

Are the methods and analyses sufficiently detailed to allow replication by other researchers? Yes, No (please explain), I don't know

Are the methods and statistical analyses appropriate and well described? Yes, No ,please see my comments above I don't know

Results

In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)? Yes, No (please explain), I don't know

Are the results described and interpreted correctly? Yes, No, it will depend on the effect size and the

inferring of the period studied (the entire summer vs a few days of observations), [] I don't know
We have considered the effect sizes as elements of interpretation.

Discussion

Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? [] Yes, [x] No, they don't mention limitations [] I don't know
We have added the limitations of the study at the start of the discussion

Are the conclusions adequately supported by the results (without overstating the implications of the findings)? [] Yes, [x] No, please see my comments above and add references on sheep [] I don't know
We have considered as much as possible references on sheep when available.

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Decision by Birte L Nielsen , posted 31 July 2024, validated 09 August 2024

Request for revision

Dear authors,

This is an interesting study which has a lot of useful information worth publishing. Two reviewers have given their assessment and suggestions to how the manuscript can be improved, and they raise some important points. I have included my own suggestions and questions below.

I look forward to reading a revised version.

Best wishes,

Birte L Nielsen

Comments and suggestions from Birte Nielsen:

Lines 22-23: As also highlighted by one of the reviewers, shade-seeking can be to prevent heat stress. I am also confused why active shade seeking would increase with decreasing tree-density; is that because they may be in the shade by chance otherwise? Please have a think about what this sentence is actually saying.

Lines 33-35: As this is in the Abstract, it needs to be easily understood, but I am struggling to understand. Perhaps it is the use of 'versus' which could be replaced with 'with'. In effect, if 50% of an area is shaded, and the sheep spend 50% of their time there, we cannot know if they seek/avoid shade, or not). You are saying that the sheep spend more time than by chance under shade in treatment T1 and T+, but in T++ it corresponds to the area, so could have happened by chance.

I agree with one of the reviewers that the treatments could be better named. Perhaps T1, T60 and T150? It is also not immediately clear if the three areas of study were of the same size.

Lines 40-41: As highlighted by one reviewer, I suggest changing this wording to: "Active shade seeking is therefore an indicator of increasing thermal load". You do not know if this is "before physiological changes occur" as you did not measure this.

Line 42: suggest deleting 'globally' or replace with 'Overall ewe performance...'

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Line 101: To make it clearer for the reader, I suggest the following adjustment: "...three pastures of similar size (mean = 0.82 ha, SD = 0.034)".

Line 109: the addition of 'for ethical purpose' is somewhat abrupt and casual. Are you allowed to keep sheep in pastures without access to shade? If yes, and you had chosen a field with no trees, how would you have observed active shade seeking? I suggest moving the ethical committee's approval to be more visible.

Line 112: Replace 'implanted' with 'planted'

Line 118: Replace 'excepted' with 'except'

Line 119: insert 'on average' after 'weighed'

Line 120: Replace '1st' with 'first'

Line 12: Replace 'lactating' with 'suckling'

Line 122: Please indicate when the marking of the sheep was done relative to the observations, and if it had to be refreshed.

Line 145: Please indicate that the observations were made on days when no other disturbances were observed or planned (e.g. the sward measurement, weighings etc.) if that was the case.

Line 195: It would be clearer with 'a synthetic' (rather than 'the').

Line 204: It is interesting that the TRH value correlates with higher temperature but lower humidity. It makes sense, but the thermal load would increase with higher humidity – this may be worth noting in the Discussion.

Line 214: As you had observations during periods of no sun, and would know if the area chosen by any ewe would have been in the shade or not, this would allow you to assess if the areas were chosen for other qualities than shade, e.g. softness, elevation etc. It may not require a complete re-analysis of your data, but could be an additional analysis to answer one of the questions from the reviewers.

Line 240: It is not clear why the respiration per animal per day were not used as a behavioural measure to assess the thermal load on the animals? Why did you resort to one value per year for each animal? Are these not the values used in Figure 7?

Line 245: CP data were...

Line 255: But the increase of shade use with increasing shade availability would have happened by chance – was the proportion of shade available adjusted for in the analysis? You appear to do this later (line 263 and Table 3) but not here? Also, was there enough shade available in Treatment T1 to give all animals a choice?

Line 279: "The ewes from T+ and T++ never differed in their selection of shade." But does this not mean that the T+ ewes were choosing and/or the T++ ewes were avoiding shade, given they had different shade areas available?

Line 288: As also suggested by one of the reviewers, if this is the only animal welfare measure, this would be better included under the animal behaviour heading.

The Discussion is relatively long so if you can, please simplify and reduce some sections as that would improve the readability of the article (even splitting into more paragraphs would make it easier to read). The revised Discussion should also take in aspects raised above (that shade use is not the same as heat stress, and the differences between shade availability in your treatments).

Line 390: Can you apply thresholds from another species? What was the wool length/cover of your sheep?

Line 473: In this section I am missing information on what the optimal tree cover would be under your circumstances. How many trees are needed to allow shade to be available for 10 ewes and 20 lambs, and how big an area of unshaded grass land is needed to ensure sufficient roughage when no supplement is provided? This information would allow the reader to compare your results with an ideal situation under the same circumstances. You allude to it in your conclusions but a more detailed estimate in the Discussion would be great.

Table 4: The line numbers appear to have infiltrated the Table.

The manuscript investigates the use of shade in sheep during sunny days, according to different tree density in a temperate region. The manuscript is very relevant, especially due to the lack of evidence in this matter in the literature. However, the manuscript has several minor flaws, which are described below, but one major aspect that needs careful consideration. This is about the experimental design, which omits a control treatment, which should be the distribution of sheep under trees in non-sunny days. I strongly believe that this should be included in the experimental design but I would like to see the rationale of authors behind this decision.

Title and abstract

Does the title clearly reflect the content of the article? [x] Yes, [] No (please explain), [] I don't know
Does the abstract present the main findings of the study? [x] Yes, [] No (please explain), [] I don't know

- The abstract should include the numerical results and not only whether a variable was lower or higher..

Introduction

Are the research questions/hypotheses/predictions clearly presented? [x] Yes, [] No (please explain), [x] I don't know

Does the introduction build on relevant research in the field? [x] Yes, [] No (please explain), [] I don't know

- The introduction does not mention what is the expected effect of shade for animal welfare and behaviour. There is literature in other species such as cattle, that addressed this, and authors are suggested to include this.

Materials and methods

Are the methods and analyses sufficiently detailed to allow replication by other researchers? [x] Yes, [] No (please explain), [] I don't know

Are the methods and statistical analyses appropriate and well described? [] Yes, [x] No (please explain), [] I don't know

- Line (L) 107 Treatments should receive alternatives acronyms. I suggest using Tlow, Tmedium and Thigh, to highlight the tree density of each treatment.

- L108: The experimental design should include observation during non-sunny days, as a control group. Otherwise, sun (and temperature) cannot be taken as the fixed effect.

- In L112, is the tree crown of different treatments providing the same shade. Please provide evidence of this.

- L124: Please provide the sanitary status of the flock

- L143: This is a very limited sample size. It should be clear whether results are presented as average per observation slot, or in a more granular manner. This is not clear in the current form.

- L184: Was environmental data presented by observation slots or per day? Please confirm.

- L209: Was this data presented by each animal per time, or by group of animals in total? Please explain better the outcome.

- The ethics statement should be added.

Results

In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)? [x] Yes, [] No (please explain), [] I don't know

Are the results described and interpreted correctly? [x] Yes, [] No (please explain), [] I don't know

- L250: I suggest merging the section 'animal behaviour' and 'animal welfare' because animal behaviour is (in this case) an indicator of animal welfare.

- L324: Was there any difference between biomass content between different paddocks?

Discussion

Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? [] Yes, [x] No (please explain), [] I don't know

Are the conclusions adequately supported by the results (without overstating the implications of the findings)?

[] Yes, [] No (please explain), [] I don't know

- L451: I don't think shade use can be used as an indicator of heat stress because it may be performed as a strategy to prevent heat stress, even before it occurs. Therefore, as it is not directly associated with heat stress it cannot be used as a reliable indicator.

Reviewed by [Matteo Chincarini](#) , 30 July 2024

The study addresses an interesting topic where the literature is scarce at the moment. The researchers investigated the use of shadow in sheep provided by natural resources. However, at this stage, the manuscript shows some limits in terms of statistics, references (mainly to other sheep) and a better explanation of the experimental design (for instance, why not use a latin square?).

I think that after an extensive review of the manuscript, the authors will be able to address all the questions highlighted below.

Please, see my specific comment below:

L 101: "device" could be changed with "setting"

L 118 it is not clear to me how many animals were involved in the study. It seems that each year 10 ewes per group were used, plus the lambs. It seems that all ewes had twins, so for each group, there were 10 ewes plus 20 lambs. Is this correct? Can you rephrase it? Finally, it is important to report the sheep breed that was involved in the study.

L 143 Animal measurements: usually, when more than one observer is involved in assessments interobserver reliability should be performed to see the level of agreement between the observers. Did you do that? If not, how could this influence the results? This should be discussed.

L 144: "We observed the activity of all ewes on 4 days in 2016, 8 days in 2017 and 7 days in 2018." Please, could you describe how representative these observations are regarding the total period of each summer? Also, in which period of the year were the observations performed?

L 196 please, add the reference for each package of R that has been used, like FactoMineR

L Results: as a general comment, add the effect size of all your comparisons when possible.

L 254 "Square TRH was significant ($p = 0.046$)." What do you mean by this?

L 288: here is the first time that you mentioned "animal welfare". I think that using only the respiratory rate as a measure of animal welfare is misleading. I would either include this parameter in the other paragraph or introduce more about why you focused on this parameter or animal welfare.

L 363-368: you start the discussion by referring to the thermal stress indices used in cattle. Please, use literature on sheep and review your discussion accordingly

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Title and abstract

- Does the title clearly reflect the content of the article? [X] Yes,
- Does the abstract present the main findings of the study? [X] Yes,

Introduction

- Are the research questions/hypotheses/predictions clearly presented? No (please explain): The authors should include a clear hypothesis on what to expect from the variable the aim to collect.
- Does the introduction build on relevant research in the field? Yes, No (please explain), I don't know

Materials and methods

- Are the methods and analyses sufficiently detailed to allow replication by other researchers? Yes, No (please explain), I don't know
- Are the methods and statistical analyses appropriate and well described? Yes, No ,please see my comments above I don't know

Results

- In the case of negative results, is there a statistical power analysis (or an adequate Bayesian analysis or equivalence testing)? Yes, No (please explain), I don't know
- Are the results described and interpreted correctly? Yes, No, it will depend on the effect size and the inferring of the period studied (the entire summer vs a few days of observations), I don't know

Discussion

- Have the authors appropriately emphasized the strengths and limitations of their study/theory/methods/argument? Yes, No, they don't mention limitations I don't know
- Are the conclusions adequately supported by the results (without overstating the implications of the findings)? Yes, No, please see my comments above and add references on sheep I don't know