

['Reply on RC1/RC2'](#), Andreas Hense, 07 Dec 2023

Having read the manuscript and the two reviewers comments it is clear that the manuscript need major changes. I would suggest to the author team to concentrate upon the central problems issued by both RC1&RC2: (a) the reorganisation/streamlining of the manuscript including the introduction (or at least a clarification) of a "take-home-message", a strengthening of the connections between the subchapter on hydrology and the remaining parts and (b) the introduction of some sort of a reference in time to allow an evidence based estimation of the reported levels of forest damages. If these points can be successfully implemented the manuscript would indeed constitute a nice review on the desired topic. Also, please consider the extensive list of specific comments by RC1 although some of those may become obsolete after revision acc. to (a) and (b). After submission of the revised manuscript RC1/RC2 will be asked to rereview the text.

Authors: We thank the reviewers and the editors for their helpful comments. We have changed the manuscript substantially according to the comments and addressed each of the major points.

**RC1:** ['Comment on egusphere-2023-1463'](#), Anonymous Referee #1, 01 Sep 2023

#### **General comments**

This paper covers a very important topic, and provides a thorough review of drought and heat events across four climate zones and 20 European countries. This is a monumental task given the inconsistencies in data availability and documentation and challenges associated with translation across at least 15 languages. The paper itself might benefit from additional tables or figures and less text to help facilitate comparisons across regions. Also a greater emphasis on how the results compare to a reference period (prior to 2018?) would help the readers better access how truly extraordinary (or not) the results are. The organization of the paper was generally good, but there were sections that were disconnected from previous sections. For example, the description of groundwater was very general and poorly linked with drought until the following page. Also, the section about dryland mechanisms was not well integrated into the paper and only discussed hydrophobicity. In fact, I'm not convinced this section is necessary (might flow better from future trends to policies without the section on hydrophobicity) but if the authors want to include it they should more comprehensively review the most important mechanisms that mitigate drought stress. The paper is generally well-written, with only minor typographical errors, which are documented below.

#### **Authors:**

We thank the reviewer for the comments. We agree that a clear definition of a reference period previous to 2018 would be very helpful to illustrate how unusual our focal period was (starting 2018). Given that another severe drought occurred in 2015 (e.g. Hoy et al. 2017, Laaha et al. 2017) we used the period 2010-2014 as a

reference period. Additionally, we streamlined the manuscript and addressed the sections that were mentioned to break the flow. Former Table 3: Forest fires in the Alpine countries was removed /added to the supplement

### **Specific comments**

L79-80. The sentence could benefit from expanding upon “essential ecosystem services”.

Authors: Some essential ecosystem services were added (with a reference).

L84. Explicitly state the level of political boundaries referred to in the data (i.e. country-level or county-level).

Authors: We state now that it is country-level.

L98-100. Providing definitions for atmospheric processes mentioned would improve accessibility here. For example, “periods of blocking”, “positive North Atlantic Oscillation”, and “double jet stream configuration”.

Authors: Done as suggested.

F1. Comparison between two columns seems ill-suited, as the second column (Spring and Summer) includes data from the first column (Summer). It would be more apt to compare Spring and Summer. This figure should also be discussed further in the text.

Authors: Done as suggested.

L125. It would be good to include more information about how SPEI was calculated. What was the reference period and time scale?

Authors: Additional information was added in the caption and in the paragraph above (including references).

T2. The data in this table seems like it would be better represented graphically (multiple line graph) as it is difficult to follow the trends in which country experienced the highest insect damage. List the full names of the countries since you have the space. Perhaps change the units to minimize zeros?

Authors: the table has been replaced by a graphical representation.

L418. These tree felling statistics come off as less impactful, given that the previous sentence indicates that the annual productivity is still over double the volume felled. Also, you don't provide a reference level of felling so we can't assess the % increase.

Authors: Now, we provide a reference level for the period 2010-2014. We also added a sentence that there are no long-term consequences of the drought in Norway.

L426. How was “unfavorable condition” determined? Is this condition due to pests and disease or is it that the forest is in an unfavorable condition to resist pests and disease?

Authors: The first is the case (“due to pests and disease”). We rewrote the sentence.

L530. This paragraph should connect these disturbances to drought, as drought is not mentioned in the paragraph. Providing context for prevailing rates of disturbance prior to the drought would also be helpful.

Authors: We agree and this paragraph has been expanded with two sources that illustrate the connection of these disturbances to drought. A source comparing the period before the drought phase was also given.

L531-536. In Germany you described the climate, but you didn't do that in the other countries (see L516 where you just jump right to forests). It would be good to be consistent across countries.

Authors: The 2021 climatic description has been deleted.

L764-809. The description of groundwater and monitoring of groundwater is very long, compared to the very small section on how the drought affected groundwater (L793-798). Perhaps it could be shortened or the impacts expanded upon.

Authors: The groundwater section was strongly revised and shortened.

L822-835. This section starts with a discussion of groundwater, but I would think that seedling establishment is more influenced by surface/soil water and not groundwater. Maybe a section on surface moisture should precede this section on establishment.

Authors: The reviewer is correct. We change the naming of the subsections to emphasize this aspect. We also added a reference to a recent manuscript that addressed this topic in detail and to a previous section in which we address the topic of soil moisture.

L845-847. This paragraph about climate change effects on pests seems out of place when the above paragraph only discusses observations. It would be good to be consistent across the paragraphs in this section.

Authors: We understand this comment as such, that this paragraph contains too many quantitative results so that it does not match the style of the other paragraphs in this section. We followed the request of the reviewer and modified this paragraph.

L884. I'm not convinced the survey is relevant. Just because people thought they should plant more trees, does not mean that the drought damage was clearly noticeable to visitors.

Authors: Agreed and the text was deleted.

L1045-1089. The heading was about dryland mechanisms but they only discussed one: hydrophobicity. I'm not sure this section is needed, but if included, they should more comprehensively review the most important mechanisms that mitigate drought stress.

Authors: This section was deleted. Relevant text about mechanisms that mitigate drought stress were moved elsewhere (at the end of the chapter 5.2 Future trends and biophysical feedbacks of forest cover changes). Content about soil hydrophobicity was moved to chapters 3. Damages to forests and 4.3 Drought legacy effects in forests – the accumulation of long-term damages.

L1125-45. It might be better to describe the forest damage first and then discuss mitigation (i.e. switch the order of the first two paragraphs in the conclusion. Conclusions about the relative differences between regions might be helpful to include here

Authors: The order of the paragraphs was switched as suggested.

L1036. You suddenly switched from discussing soil temperature to albedo. Better transition?

Authors: We have rearranged and rewritten three sentences in this part of the manuscript and thus created a more comprehensive statement.

L1067. Increasing bare patches reduces (not increases) connectivity of vegetation, but maybe you were referring to hydrologic connectivity. It would be good to clarify your statement.

Authors: The section was deleted and the respective sentence with it.

## Technical comments

L42. Which “large European data sets”? What variables are being considered?  
Climate vegetation?

Authors: We rewrote that part: ... with Europe-wide data sets such as tree cover loss, burnt forest areas, crown defoliation or damaged wood by insects.

L47. What do you mean by superimposed? Just driven by?

Authors: That part of the abstract was rewritten and the word ‘superimposed’ is not used anymore.

L49. Why do you say “can still be observed”? Why still? Is the Southern zone affected? That’s what you are describing in the other zones.

Authors: The word ‘still’ was deleted.

L51. This inventory or all inventories.

Authors: This Inventory was meant. However, the sentence was removed for clarity.

L65-67. Wording is a little vague. How long is this trend?

Authors: This trend refers to a period of 42 years.. The sentence was revised accordingly.

L73-74. This sentence seems out of place.

Authors: We removed this sentence.

L77. I would say forest ecosystems, rather than these

Authors: Revised as suggested.

L85. “The insight of” is awkward.

Authors: The sentence was revised.

L86. Repace “assessing the” with “for the assessment of”

Authors: Revised as suggested

L88. It’s not clear why the context is needed only for the Southern region.

Authors: The following explanation was added: “This study examines forest damage spanning 2018-2022, only the exceptional forest fire damage in 2017 in Southern

Europe is included, as it provides context for subsequent damage. Post-2017, significant measures were implemented in Southern Europe to mitigate forest fires, affecting subsequent damage trends. Forest damage of other zones is not discussed for 2017 as it was comparatively minimal.”

L93-94. State which European countries are not included in the research.

Authors: We provided a list of the countries not included in the text as requested.

L119. Change “Britain/Scandinavia” to “Northern” to keep naming convention consistent.

Authors: Corrected as suggested.

Table 1. But earlier you said countries were assigned to one zone (L84).

Authors: We corrected this statement and additionally, specified in the text and the table caption as needed.

L131-32. Include a citation here, as this longer-term drying trend is once again alluded to without reference.

Authors: We added a suitable references.

L141. It’s not clear why it’s a “however”.

Authors: The sentence was revised for clarity.

L159. This sentence makes a definitive statement based on results from a climate model. Replace “is going to” with “is projected to”.

Authors: Revised as suggested.

L160. Seasons are not capitalized.

Authors: Corrected as suggested.

L166-67. Definitive language on our future climate emissions, even though there is great uncertainty surrounding projections. Replace “As soon as we” with “If we”.

Authors: Corrected as suggested.

L167. Should refer to the transition from the current state in future tense. Replace “is slowly” with “will slowly”.

Authors: Corrected as suggested.

L173. You should again address the uncertainty in the future climate system. Replace "once" with "if".

Authors: Revised as suggested.

L182. You wouldn't start this sentence with despite as what you describe seems to be the logical conclusion. As it is difficult to reconcile... therefore there are few studies.

Authors: We revised the sentence for clarity as requested.

L194. Climate models project possible future climates, therefore there is inherent uncertainty. These models shouldn't be used to "confirm" results. Replace "are confirmed in" with "match results from".

Authors: Corrected as suggested.

L204. You didn't tell us about Sweden first "as Sweden did". Omit?

Authors: This part has been rewritten and now includes more information about different years.

L211. "fires" not "Fires"

Authors: Corrected as suggested.

L221. What period of time are the climate models projecting more concentration ppt?

Authors: The time period and other information are included now into this sentence.

L235. What do you mean by "last place in Europe"? Do you mean sufficient water sources?

Authors: We changed it into: "...is one of the places in Europe with the lowest water resources"

L240. Omit "shortage"

Authors: We omitted "shortage".

L245. Why is 2015 the reference period here?

Authors: 2015 was used here to highlight that 2019 - despite being less bad than 2018 - was worse than the 2015 drought which was the worst drought in recent history until then. We added "(as 2015 was the worst drought until 2018)" for clarification.

L271. Than all the other countries?

Authors: Italy was affected less by the 2018 drought compared to central and northern European countries. This point is now in the text.

L291. Alters rather than reflects?

Authors: We changed to "The drought conditions add impact on water storage..."

L307. Change to "greater risk of embolism, which can cause..."

Authors: Corrected as suggested.

Figure 2. The colors in graphs b and c do not match, leading to possible misinterpretation.

Authors: The graphs have been completely revised.

L316. Need to define and expand on "moderate to severe defoliation". Figure caption is difficult to interpret.

Authors: We added in the figure caption the definition '> 25% needle/leaf loss, i.e. moderate to severe defoliation'.

Figure 3. The legend should state that it's only severe wildfires. Also, this figure should be included after the first time it is mentioned in the text, which is currently L514.

Authors: The entire section on forest fires was completely revised and other data that can clearly be assigned to forest fires was also used to generate new figures. The graphic (Figure 4) was also inserted where it was first mentioned in the text.

L357. But we can't always limit disturbance damage, just be understanding it.

Authors: The reviewer is correct and we modified the sentence to emphasize this point.

Figure 4. Replace "E" with "ESP" to remain consistent in naming convention. Figure does not include a title, while the previous figure does. Similar to the previous figure, Figure 4 should be included after the first time it is mentioned in the text, which is currently L739. Does Figure 4 include tree cover loss from wildfires, wind and pests? It would be good to list the disturbances monitored.

Authors:

- All country codes are now consistent using ISO3 codes through the entire document and all graphs: Finland: FIN, Sweden: SWE, Norway: NOR, United



Kingdom: UK, Ireland: IRL, Poland: POL, Czech Republic: CZE, Switzerland: CHE, Austria: AUT, Germany: GER, Netherlands: NLD, Belgium: BEL, France: FRA, Italy: ITA, Spain: ESP, and Portugal: PRT.

- Figure titles are revised throughout the whole manuscript, all graphics are inserted, where they are mentioned first in the text.
- The disturbances are listed in the revised manuscript:  
Tree cover loss may be the result of human activities, including forestry practices (e.g. timber harvest or deforestation), natural causes (e.g. diseases or storm damage, and fire events).

L363. Replace "2.2" with "3.2". You might want to recheck the numbering of your section headings throughout.

Authors: We replaced it and a general recheck of numbering was conducted.

L367. Expand on historic forest damage directly coming from drought.

Authors: We added more information about the past damages.

L377. I'm not sure if it's a steady increase if it omits 2019.

Authors: This part has been rewritten and updated.

L389. Comparison between volume harvested and total area confusing as metrics are different. Especially confusing as the unit for volume ( $m^3$ ) looks very similar to  $m^2$ .

Authors: All usages of " $m^2$ " were removed from the text. .

L393. Replace "thus over than" with "thus over"

Authors: Corrected as suggested.

L427. Ash should not be capitalized. Accordingly should start a new sentence.

Authors: Corrected as suggested.

L421. Forest Research should be capitalized. August should be too.

Authors: Corrected as suggested.

L435. Omit harsh to avoid sensationalizing. Replace with large?

Authors: revised as suggested.

L436-37. Provide further context. Is 15-30,000 ha burned in a year a lot? What is the historic average?

Authors: We added the mean value for 2011-2022 to provide context.

L438. Punctuation issue. 1.323 instead of 1,323. If you prefer to use the European decimal notation, keep this consistent throughout the paper as you change between the two.

Authors: Corrected and made consistent throughout the whole manuscript.

L445. What about the other 88%? Is it grassland?

Authors: A sentence was added to explain the other 88%, i.e. "The rest of the wildfires took place across all other land covers including built-up areas, gardens, and grassland."

L448. Add from, as in "suffers from"

Authors: Revised as requested.

L477. Replace "2.3" with "3.3"

Authors: We replaced it and conducted a general recheck of numbering.

L478. Remove "has"

Authors: Revised as requested.

L486. Entire hectares? A hectare isn't that big.

Authors: We revised this sentence.

L504. Why is there a parenthesis before 2018?

Authors: The whole sentence was rewritten and rearranged.

L504. It was what?

Authors: The whole sentence was rewritten and rearranged.

L505. I think you need another and before "a decrease"

Authors: Revised as suggested.

L509. The Krotoszyn Plateau could use a reference.

Authors: We added a reference for the Krotoszyn Plateau (Danielewicz, 2016).

L513. Was this the only factor behind the relatively good situation in Poland compared to geographic neighbors? If so, you should provide evidence.

Authors: This comparison to geographic neighbors was deleted.

L524. Change to "Damaged wood infected almost exclusively with..." for clarity.

Authors: Revised as suggested.

L525. Add "the fire" as a new sentence, rather than using "it".

Authors: Revised as suggested.

L553. "Caused in the periods of heat" is awkward. Perhaps "had an outbreak during a period of heat...".

Authors: Sentence was rewritten as: "In Germany, outbreaks of European spruce bark beetle (*Ips typographus*) have inflicted widespread damage on forests, particularly during episodes of heat and drought"

L574. I don't think it's necessary to remind us that Austria and Switzerland are also described in the alpine section. You told us this at the beginning. It would also be helpful to provide criteria about how you assigned the zones.

Authors: Deleted as requested.

L579. Replace "for tree" with "of tree"

Authors: Revised as suggested.

L582. Replace "for the" with about

Authors: Revised as suggested.

L583. I think you just need to tell us "but the results have not been published".

Authors: We agree and added in the text that the current inventory will be completed in 2026.

L585. Put Flanders in parentheses instead to improve readability?

Authors: Revised as suggested.

L587. Remove "deciduous" as you then specify the inclusion of Norway spruce which is coniferous.

Authors: The sentence was revised for clarity.

L591. I think you could just add the definition of vitality in the next sentence “ of trends in vitality (e.g. loss of needles..”)

Authors: Revised as suggested.

L603 I would add “burned” after 659 ha.

Authors: Revised as suggested.

L607. Do you mean elevation?

Authors: Yes. Corrected as suggested.

L623. Evolved is not the best word to use here. Perhaps increased is sufficient.

Authors: Corrected as suggested.

L625. Replace “an increased defoliation” with higher defoliation rates.

Authors: Corrected as suggested.

L629. In instead of with would be better.

Authors: We reformulated the sentence.

L637. I'm not sure why you used the word balance.

Authors: We changed the wording accordingly.

L640. Replace wood with damage to be more specific

Authors: Revised as suggested.

L651. The years 2018 and 2022 seem out of place in that sentence.

Authors: The two years were better integrated into the sentence.

L659. Replace colon with semicolon

Authors: Corrected as suggested.

L660. Which disease? Citation?

Authors: Sentence was rewritten, naming the disease and its pathogen, the corresponding citation was added.

L670 The phrasing “2022 it is around” is awkward.

Authors: We changed it to ‘while in 2022 around one million m<sup>3</sup> were affected’.

L674 Too many modifiers. Rephrase to “in a week, consuming mainly broadleaved forests”...

Authors: Corrected as suggested.

L676. Omit situation. Just say Fires

Authors: Corrected as suggested.

L689. Damage, not damages

Authors: Corrected as suggested.

L697. I think you could combine this with the previous sentence- “increase in defoliation, forest mortality and leaf discoloration”...

Authors: Corrected as suggested.

L710. I don't think it's necessary to remind us that Italy is also described in the alpine section. You told us this at the beginning.

Authors: This sentence was deleted.

L812. Might be better to say “demographic processes” rather than just demography.

Authors: Revised as suggested.

L817. I would remove the term “long lasting” as I would argue that most of these examples are of short term legacies from drought.

Authors: We removed the term ‘long lasting’.

L855-857. The sentence about “an additional factor” seems out of place. Omit? Or improve the transition to this section on how easily forests can be attributed to climate change. It's been done by John T. Abatzoglou in the U.S. if you need a citation or want to discuss this topic more.

Authors: We rewrote the whole paragraph and added another paragraph about forest fire attribution to climate change in the U.S.

L860. Replace “literally no” with “very little” as there is a reduction from 7.8 to 7.6 to 6.0.

Authors: Corrected as suggested.

L878. You could omit “for example”

Authors: Revised as suggested.

L882. remove “also”

Authors: Removed.

L897. Replacing the phrase “Fort the forest damage...” would improve readability.

Authors: Sentence changed into: “The drought and heat of 2018 were the prerequisites for the forest damage caused in Central Europe in the period 2019-2020, while the main driver was an above-average water vapor pressure deficit ...”

L920. Add a reference for the statement about massive damage? Maybe you mean extensive rather than massive, as well.

Authors: A reference was added and the word ‘extensive’ was used instead of ‘massive’.

L922. The roots don’t have enough what?

Authors: The sentence was strongly revised for clarity.

L927. Add “the” main tree species

Authors: We added the missing word.

L939. You shift from discussing increases in diversity and say that means less conifers, even though those things are not necessarily relate. Either omit the “less conifers” or add an explanation.

Authors: We omitted the words “less conifers” as suggested.

L951. Because should be lower-case

Authors: Corrected as suggested.

L953. I think wildfires should replace the word systems

Authors: Corrected as suggested and we clarified the use of the terms “forest fire” and “wildfire”.

L968. Situation, not situatione

Authors: Corrected as suggested.

L975. Decay might not be the best word to use here. Decrease might be best.

Authors: Revised as suggested.

L979. You already stated that your results were in accordance with Gazol in L973. Omit this sentence?

Authors: Agreed. Sentence removed.

L987. Replace interpretation with interpreting.

Authors: Agreed and corrected as suggested.

L1111. The sentence is very repetitive with L1004. Omit or alter the sentence.

Authors: The sentence was removed.

L1017. You could use a better transition after conditions. Semicolon or add "and therefore".

Authors: We added "and therefore".

L1033. It's not clear what you mean by your statement "not a robust feature".

Authors: The sentence was changed for clarity: "The multi-model mean shows a reduction of the annual amplitude of soil temperature over all European regions, although not all the models show this trend"

L1091. Replace sticking with another word. Complex?

Authors: Revised as suggested.

L115. Maybe rename to Issues of Data availability. I thought it was a statement about where your data will be made available (i.e. github).

Authors: We renamed the section title as requested.

**RC2:** ['Comment on egusphere-2023-1463'](#), Anonymous Referee #2, 23 Nov 2023

In this paper, Knutzen and colleagues present an in-depth assessment of the damages of the recent drought and heat events on European forests. They divided Europe into four regions with different climate backgrounds to account for regional specificities. This paper undoubtedly contains a lot of information, and I commend the authors for their thorough search across various information media. However, this strength of the paper is also one of its strongest weaknesses. The information remains raw and unprocessed, and many sections of the paper read like a succession of somehow related facts. As they advance with this manuscript, I strongly recommend the authors digest and sort through the information and try to see what key messages might emerge from their compilation.

Another area for improvement is that there is no point of comparison for the presented data. This synthesis would greatly benefit from having a reference against which most numbers from 2018-2022 could be compared. I couldn't help but wonder if the changes were slightly worse, way worse, or extremely worse. The reader needs a baseline to understand better how worse things got during those extreme years.

The structure of the paper could be refined as well. The information is only sometimes connected, making it difficult for a global picture to emerge. Some information is also repeated several times, like to which group each country belongs. It is said once at the beginning, and that's sufficient. What are the take-home messages for each region? For Europe? What results are specific to the study region, and what results are not? Some of these details are in the paper but must be more clearly visible. In theory, Section 5 should take all the previous elements together. In practice, it introduces many new elements whose added value often needs to be clarified. The conclusions of the paper are unclear.

Finally, the English needs to be improved. In particular, the punctuation could be more accurate because it is currently misleading in some places.

Overall, I support this manuscript, and it should become a significant contribution. However, it needs some serious remodelling and streamlining to become publishable. Improved structure and simplified language will also contribute to taking the paper to the expected level of a review paper.



Authors: We have changed the manuscript substantially according to the comments and addressed each of the major points pointed out. We acknowledge the need for refinement in the structure of the paper to enhance the clarity and coherence of the information presented. We agree that better connectivity between sections is essential to facilitate a clearer understanding of the global picture. Additionally, we recognize the repetition of certain details, such as the classification of countries into groups, and eliminated such redundancies to streamline the narrative.

The suggestion regarding the inclusion of clear take-home messages for each region and for Europe as a whole was performed. We strived to better delineate the specific results pertinent to the study region and distinguish them from broader findings applicable to Europe. In response to the comments, we would like to highlight some key insights derived from our study. During the 2018-2022 period, forests across all four zones (i.e. Europe) exhibited diminished vitality due to drought and elevated temperatures, albeit with varying severity. The Central zone experienced notable challenges exacerbated by bark beetle infestations, while some adaptive responses to heat and drought were discernible in the Southern zone. The Northern and Alpine zones showed comparatively lesser impacts. Furthermore, our analysis identified several key trends, including variations in defoliation rates among conifers and broadleaves across different zones, notable damage to wood from bark beetles in Central Europe and Sweden, and a significant increase in general tree cover loss across the Northern, Central, and Southern zones.

Moreover, we addressed the linguistic aspects, particularly punctuation, to ensure greater accuracy and coherence in the manuscript's presentation.

In response to your suggestions, we undertook a comprehensive remodeling and streamlining of the manuscript. We are confident that these revisions significantly enhanced the manuscript's readability, coherence, and overall quality, ultimately elevating it to the expected level of a review paper.

In conclusion, we sincerely appreciate the support for our manuscript and the constructive suggestions for its refinement.