Response to Referee #2

The authors thank the referee for the overall positive response, the time and attention spent on the review and the helpful comments. Our answers to the comments are given point by point in blue text colour.

Comments on " Downscaling of climate change scenarios for a high resolution, site-specific assessment of drought stress risk for two viticultural regions with heterogeneous landscapes" by Hofmann et al.

Overall, this paper represents an advancement in our knowledge of the impact of climate change on viticulture albeit in this case for two very specific regions in Germany. Specifically, the authors incorporate site specific soil information into a vineyard water balance model to assess drought stress against the backdrop of climate change. I recommend acceptance subject to the following revisions.

Major Concerns:

1. While the paper focuses on drought stress, I strongly urge the authors to consider heat stress as well. They have all the information at hand, so it should be relatively straight forward to consider in tandem both drought and heat stress. Moreover, the authors should go into more detail as to what specifically is driving ET changes in the future. Right now the description is rather vague between temperature and solar radiation.

Response: Thank you for this suggestion. Heat stress is a very interesting topic, but we think that a different methodology would be needed to address this topic in its entirety. Estimating heat stress on an individual vineyard basis would require the coupling of drought stress, stomatal closure, and the resulting changes in canopy energy balance. We opted to add this component in the future. In a first step, we wanted to identify possible "drought hot spots" because of the large heterogeneity of the terrain. Additionally, a different downscaling or bias correction method of the climate simulations would probably be needed for this type of analysis. The weather generator we used is well suited for reproducing the statistical structure of observed long time (30 years) weather recordings but less suited for reproducing frequencies of extremes, like record-breaking temperature events. In addition, up to now, heat stress is not a common stress factor of viticulture in Germany, even though hot days (Tmax > 30 °C) have been observed to increase in summer. The highest temperature recorded in Geisenheim (Rheingau, since July 1884) was 39.4 °C (on July 25th 2019). As stated above, we would need a refined energy balance model which would also need to include the energy balance of the soil and realistically, this would require additional validation runs a.s.o and would exceed the scope of the paper.

Concerning the question what is specifically driving ET changes, we would add this to the revised paper.

2. There is no consideration of the importance of rooting depth on the water balance calculation. I see this as a potential serious deficiency. Given the wide range of soil types and the lack of irrigation, what is the range of root depths across the region? How sensitive are the calculations to vine age/rooting depth? At a minimum a sensitivity analysis should be performed for a realistic range of root depths and not just some average value.

Response: The calculations were made on the assumption that grapevine roots have access to the full available water capacity (AWC). These data are available up to a depth of 2.0 m for the entire regions. If the rooting depth is limited because of shallow soils for example, this would largely be reflected in the AWC data. It is known that grapevine roots can reach deep (> 6 m) soil layers, but 80 % of the roots are usually found within the upper 1.0 m (Smart et al., 2006). Many studies have shown that the water status of established grapevines (older than approximately 5-6 years) can be described quite well based on the water balance of the upper 1.5-2.0 m. Among these was also a study on vastly different vineyard sites within the experimental region (Hofmann et al., 2014). From this, we concluded that the available data on AWC was a proper estimate for the total transpirable soil water grapevines can maximally extract from the soil and we would outline this more clearly in the manuscript.

Young grapevines, especially in the first three years, would need an additional investigation. Yet, since vineyard renewal is in the order of 30-45 years, the proportion of surface area falling in this category would be between 6-10 %. We propose to add more details concerning the rooting depth in the revised manuscript. We could add a sensitivity analysis for cases of concern, i.e. individual vineyards with low available AWC and varying rooting depth, but it would be difficult to apply to the situation of the region.

Smart, D. R., Schwass, E., Lakso, A., and Morano, L.: Grapevine Rooting Patterns: A Comprehensive Analysis and a Review, Am J Enol Viticult, 57, 89-104, 2006.

Specific comments.

1. Lines, 20, 79, 86, etc. Why were the Rheingau and Hessiche Bergstrasse chosen for this study? I can understand the Rheingau as one of the world's most renowned wine regions, but why Hessiche Bergstrasse versus say the Mosel, the Pfalz or the Nahe? The reasoning as stated is not very convincing.

Response: The study was funded by the state government (Hesse) to which both wine regions belong. Also, the density and depth of available soil data is unique in Germany. Incorporating other wine regions would be very interesting but would be a topic for the future.

2. Line 50, canopy management is mentioned in passing here as a possible mitigation for climate change but never really followed up in the discussion at the end.

Response: We agree to take up this topic again in the discussion.

3. Please elaborate in more detail on issues with respect to access to water (e.g. the steep slopes) and water restrictions (e.g., appellation constraints).

Response: We agree to this suggestion and we would add more details concerning the access to water.

4. Line 86. There should be a fuller discussion as to the limits and uncertainties of downscaling at this scale.

Response: We agree that at this scale, characteristics such as climatic differences within an area covered by gridded climate model data become apparent, which should be discussed with more detail.

5. Line 107, what region?

Response: This refers to the Rheingau region, we would add this to the revised manuscript.

6. Page 4, bottom. Of the 10 weather stations considered, how many unique 25km RCM grid boxes are used?

Response: We used four grid boxes for the Rheingau and one for the Hessische Bergstraße. We would add this information to a more detailed description of the downscaling methodology (section 2.2.2) also suggested by Reviewer#1.

7. Line 160, it is not clear at all why the annual mean global temperature of MAGICC is used and not the annual mean global temperature of the GCM climate change projections?

Response: To use the mean global temperature of the GCM climate change projections, it would have been necessary to calculate this for each GCM (including calculating the mean of all grid boxes covering the earth of the GCM). The reduced complexity model of MAGICC greatly simplifies this approach.

8. Section 2.4: Again what is the sensitivity of these results as a function of root depth resulting from vine age, soil type, and site-specific water availability? What is the range of root depths across the region?

Response: We would add the assumptions made on the rooting depths to section 2.4.

9. Section 2.5: There is a missed opportunity here to also consider heat stress sensitivity when you have all the data at hand to so.

Response: Thank you for this suggestion. Please refer to our comments at the beginning of this response under the section – major concerns.

10. Section 3. The paper would benefit from more discussion at the end as to non-stationarity.

Response: This is a valid point we would follow up with more detail in the discussion. One possible already observed non-stationarity effect is mentioned in line 501-503 (“Due to increased temperature combined with relatively unchanged but still highly variable precipitation patterns (Fig. 8c), the occurrence of warm and wet conditions during the ripening period (September, October) has increased the risk for rot (Schultz and Hofmann, 2015).”). Non-stationarity effects could also be a point for future research directions.

11. Lines 232-33. Per 10 above, what does this sentence mean? Why are extreme events underestimated?

Response: The weather generator is capable to reproduce the statistical structure of long-time observational weather but underestimates frequencies of years with high solar radiation and high reference evapotranspiration. We will clarify the point in the revision.

12. Figure 2. Please show a power spectrum of the 30-year results not just the seasonal cycle and whisker plots.

Response: We agree to this suggestion. Reviewer#1 also suggested improving the statistical analyses.

13. Line 287. Please replace this and all subsequent uses of the word bandwidth. The most common use of bandwidth refers to a frequency range, for example when filtering a time series. Spread or range are much better.

Response: Thank you for noting this. We will correct this in the revised manuscript.

14. Lines 320-325, please detail what is driving these ET changes.

Response: We agree to analyse this with more detail and will discuss the causes in the manuscript.

15. Much like 13, please describe in greater detail what is mean by “ensemble change”

Response: We mean the spread of the ensemble. This will be corrected in the revised manuscript.

16. Line 429, please tease out what is driving ET

Response: We will add the individual contributions of the weather variables to ET changes.

17. Line 435, all the more reason to also include heat stress in this study not just drought stress

Response: Thank you again for pointing this out.

18. Line 501, please also discuss the potential role of canopy management

Response: We agree that canopy management, as potential adaptation strategy, should be discussed.