

## ***Interactive comment on “The rising productivity of alpine grassland under warming, drought and N-deposition treatments” by Matthias Volk et al.***

**Anonymous Referee #2**

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Biogeosciences bg-2020-322: The rising productivity of alpine grassland under warming, drought, and N-deposition treatments

General Comments

In their manuscript titled “The rising productivity of alpine grassland under warming, drought, and, N-deposition treatments”, the authors describe a novel experiment in which monoliths of soil and turf were transplanted across an elevational gradient combine with fertilization and water addition treatments. After four years of growth in the transplanted location, the authors describe how plant productivity in the monoliths responded to the interaction of different temperatures (comparing climate at the transplant location to the original site where the turfs were harvested from), fertilization, and increased moisture, as well as the interactive effects of these three treatments.

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The results of this study showed that intermediate levels of warming increased plant productivity, even in drier conditions. Increasing the precipitation received by some monoliths had only marginal effects on plant productivity, while fertilizing the plots with nitrogen solutions had no discernable effect on plant productivity.

While this experiment is truly novel in its use of monolith transplants to simulate climate change in conjunction with two additional global change treatments in order to understand how multiple facets of global change will impact productivity, I have several concerns regarding the framing of these treatments, the metrics used to communicate and aggregate results, and the overall clarity of the manuscript. In particular, while transplanting monoliths to new elevations does of course impact climate, and in some cases results in warming, characterizing this experiment as a “warming experiment” is disingenuous. I encourage the authors to refer to their experiment as is, a transplant experiment across an elevational gradient. Furthermore, it is also a misnomer to refer to the precipitation manipulation component of this experiment as a “drought treatment”, as water was added to some monoliths instead of removing precipitation, as when using rain-out shelters etc., to simulate drought. My detailed line comments below elaborate on these concerns as well as my suggestions and critique of the metrics that the authors chose to describe climate in this study.

Line Comments

34–“... to have beneficial effects”: Beneficial effects on what?

35-36: Clarify what you mean by “initial water supply”... Water resources at the beginning of the growing season are generally plentiful? But this would be the case only for plants that emerge early in the growing season, i.e. depends on phenology of plant species.

38–“kg N ha<sup>-1</sup> a<sup>-1</sup>”: These units are unconventional, instead of a<sup>-1</sup> (per annum?) I typically see yr<sup>-1</sup> when describing nitrogen deposition rates.

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45—"...showed a twofold productivity increase": In response to what treatment?

47—"...grasses were favored over forbs and sedges by drought and warmth": This seems unclear, what do you mean by "favored by drought and warmth"? Productivity of forbs and sedges increases with warming and drought?

61—"...if only a short or linear segment out of a larger range of biologically possible responses is represented in the data.": There is some indication that productivity relationships revealed in manipulative experiments actually encompasses even more variation than occurs naturally (see Jochum et al. 2020. Nature Ecology and Evolution).

67—I think that I am still confused by what you mean by "factor levels"... Does this refer to consideration of multiple global change factors, or does it refer to the magnitude of the global change treatment imposed by the experiments?

68—"Here, we present four-years of treatment results from a field experiment in the Swiss Alps.": This statement is an important introduction of your experiment, and as such, you should be more descriptive than "treatment results from a field experiment". What types of treatments specifically were involved in your field experiment, and were any of these treatments applied simultaneously to study interactive effects?

83—"monoliths (ML)": I do not feel that it is necessary to use an acronym for one word, and stating monolith regularly instead of ML will improve the clarity of your manuscript.

102-103: This sentence is rather unclear. What do you mean by standardizing harvests and the "zero-year" and "acclimation" distinctions? This aspect of your methods deserves an elaboration.

111-115: I find your naming convention, using the 'CS' designations, to be needlessly confusing. These are simply sites along an elevational gradient, so why not refer to them either by their numeric elevation (i.e. 2360 m) or simply as Elevation 1 (lowest elevation), Elevation 2.... etc., instead of introducing a less intuitive naming system.

116—"...6 CS, 6 MLs from each of the six sites of origin": I find your naming convention,

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using the 'CS' designations, to be needlessly confusing. These are simply sites along an elevational gradient, so why not refer to them either by their numeric elevation (i.e. 2360 m) or simply as Elevation 1, Elevation 2.... etc., instead of introducing a less intuitive naming system.

119—"...were filled with soil to prevent air flow": Where did this soil come from? Bulk soil from each specific elevation/origin location?

121—"cross-factorial design": Full-factorial design? I'm unfamiliar with "cross-factorial" experimental designs.

153: This sentence is rather unclear... Temperatures were summed across one day?

154-156: This threshold seems particularly arbitrary, and I think that the use of a threshold in general is not necessary here. Why not simply present the mean growing season soil volumetric water content for each site/each season? This metric is much simpler and more intuitive for readers to understand and compare your results across the elevational gradient.

161-162: Why does the amount of precipitation added to each monolith vary between years?

168: Listing the chemical formula of ammonium nitrate is not necessary.

226: Is there some type of relationship between atmospheric N-deposition rates and elevation? Perhaps describe N-deposition rates across the entire gradient, not just at the middle and low points of your elevational gradient.

236: What does non-continuous mean? Non-linear?

239—"...only one third of the pre-harvest period was dry": It is definitely a misnomer to describe conditions of lower than 40% moisture content as "dry". In fact, in most alpine systems, 30% moisture content is considered ideal moisture conditions for optimal microbial activity (see Hawkes et al. 2017 PNAS for a relevant discussion related

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to respiration and soil moisture). I would highly suggest re-characterizing the way in which you describe soil moisture in this manuscript. Instead of creating a binomial in soil moisture conditions around an arbitrary 40% moisture content threshold, why not just describe average soil moisture across the growing season on a continuous scale, i.e. just state average growing season soil moisture for the pre-harvest period.

248-249: Because you describe soil moisture conditions in the previous section using percent dry days, we have no way of understanding how this transplantation effect on soil moisture conditions (described using VWC) might interact with your other treatments.

251: I would suggest that productivity is the more appropriate term, consistent with literature in this area of ecological research, to describe your response variable.

259: In order to show evidence to support this claim, I would like to see a figure and the related statistics that shows the relationship between the productivity effect size (productivity in transplanted monoliths - productivity in control monoliths that were re-installed at the same site / standard deviation of productivity across all monoliths) regressed against the temperature difference from the monolith's original climate and the transplanted climate. In other words, how much of the change in productivity is explained by change in temperature following transplantation?

260-261: What does "intermediate warming" mean here? Describing this result as "monoliths that experienced X-Y degrees of warming by being transplanted to warmer climates at lower elevations relative to climate at their original location showed increases in productivity".

262-264: This sentence is confusing. 2016 was the year in which productivity, on average, was highest, but this was only the case at two sites? These two statements seem to contradict one another.

298: The title of this section seems to not relate to the results described within the

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section. You already stated that each elevational site is characterized by different temperature and precipitation regimes in your methods and in previous sections of the results. Should this section describe the relationship between productivity and climate at each elevation?

325-326: Are there examples of other papers whose conclusions about the use of degree days instead of mean temperatures over the same time frame?

333-341: This section would benefit from a description of why the authors suspect that warming beyond "intermediate warming" was not associated with the same boost in productivity that was associated with intermediate warming.

337—"cockchafer (*Melolontha melolonth*) infestation: Please describe what this organism is and how it is relevant to variability in productivity.

347-349: Grammatical errors and diction in this sentence make it unclear.

358: I think this statement describes my point about eliminating your use of the "percent dry days" metric entirely... Your results, using this metric, prevent readers from relating the soil moisture conditions present in your experiment to soil moisture conditions elsewhere. Furthermore, describing soil moisture conditions less than 40% as "dry" is a misnomer.

380: What caused increased evapotranspiration at CS5? Is it possible that too much rainfall, either ambient or added as part of your irrigation treatment, could cause leaching of important soil nutrients, with higher VWC leading to lower productivity? This might be especially relevant in monoliths that received both an irrigation and fertilization treatment.

399-402: These are the only lines of this section of your discussion that reference your results directly. These sentences should be moved up in this section, and you should eliminate the references to other experiments with results that contradict what your experiment found, as this section is very unclear as currently written. Which of these

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citations and theories help explain your results? Remove the rest.

426—"This implies that subalpine grassland productivity has likely not increased during the past century warming": This statement is in no way supported by your results.

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