

Interactive comment on “Differential effects of extreme drought on production and respiration: synthesis and modeling analysis” by Z. Shi et al.

Anonymous Referee #2

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The paper by Shi et al. seeks to synthesize across-study findings about how ecosystem production and respiration respond to droughts, and attempts to examine underlying mechanisms with a terrestrial ecosystem model applied to represent four grassland sites. The paper is topically appropriate for the special issue, and it might make a suitable contribution but offers disappointingly little in the way of new insights despite the paper's bolder claims. I have the following concerns.

1) **Synthesis Is Not New:** A significant part of the set-up for the manuscript is about synthesis of past work. Unfortunately, the presentation does not take us beyond the basic conclusion that ecosystem productivity declines more than respiration in response to drought, and that extreme droughts cause larger responses. There are no substantive insights about how responses vary by ecosystem types aside from the notable

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difference in rainforests.

2) **Interpretation of Different Effects of Reduced Amount or Reduced Frequency is Overstated:** It is suggested that the effect of drought differs depending on how drought is delivered, either by fewer events or smaller events of the same number. However, the results of the model experiment and the analyses presented do not support this interpretation and conclusion. First of all, the graphical presentation makes it difficult to compare the two cases. More importantly, statistics are not presented to evaluate if these treatment effects do, in fact, differ significantly. Even if they are statistically different, the magnitudes are very similar and the direction of their unique effect sizes varies across sites, if their effect sizes are in fact different. Thus the results section describing this (section 3.2, lines 232+) needs to be revised. Also the discussion should be revised to remove claims about these differences (section 4.3, Lines 339+) and corresponding implications (section 4.4, Line 361+) for future experiments.

3) **Mechanisms Not Really Revealed:** The second objective of the study is to use an ecosystem model to examine mechanisms that may underlie differential sensitivity of production and respiration. The analysis of the model output does not examine mechanisms, except to show the long-term change in soil carbon and this is not sufficient to illuminate the causes. The basic idea is not all that new: Rh is supplied partly by slow-changing soil carbon sources whereas GPP (and to some degree by extension, NPP) results from short-term physiological response closely tied to weather, and this causes Rh to have a milder response to drought that then accumulates with continued exposure. The fact that this emerges in a model that simply works this way is not especially revealing. Furthermore, the analysis presented does not make much of the details that are available from modeling. The luxury of modeling is that you can look at everything. For example, to what degree is Rh sensitive to the reduced supply of photosynthate imposed by drought as opposed to the declining soil C stocks, and how does this relative importance shift over time with continued exposure? What are the partial roles of soil water limitation, soil temperature, and carbon availability in driving

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changes in Rh in response to drought, and how does their relative importance shift over time with continued exposure? It is disappointing not to see better use of the data on hand.

4) Limitations of Using a Model to Assess Long-term Responses to Drought: Models may well miss ecological processes that become important at longer time scales, such as acclimation, mortality, and species shifts, all influencing the physiological capacity of the ecosystem and potentially causing it to respond differently to continued forcing. Given that such processes are either absent or parameterized with limited observational information, it is not clear that the modeling experiment shown here is justified as a tool for diagnosing effects of long-term exposure to drought. This might need further, more open discussion as a limitation, particularly regarding conclusions about the long-term decline in soil C and corresponding long-term decline in the differential drought-sensitivity of productivity and respiration (Lines 311+).

5) Complexity is Not Demonstrated Clearly: The fourth implication mentioned in section 4.4 does not emerge clearly from what is presented. What is shown to motivate macro-scale global change experiments? What is shown to suggest cross-scale interactions? What is shown to suggest differential sensitivities (a little is here maybe)?

6) Across Ecosystem Synthesis Collapses to Grasslands When Examining Mechanisms: If not in the results, then at least in the discussion, it would be valuable to have conjecture about how the inferred mechanisms and long-term response patterns might change for the case of droughts in other ecosystem types, for example a range of forest types. This is not imperative, and you can't do everything of course, but the paper's set up is rather grand leaving the reduced emphasis to grasslands a little disappointing.

More Mechanical Concerns:

1) Methods section 2.2.3 presents Fig 1 and Table 2 but these should be presented in the Results section at the front end of the modeling application.

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2) L121: just rainfall or all precipitation forms?

3) L80: Change "We" to "It has been..." because not all of the authors of the manuscript were involved in this hypothesis.

4) L86: Is it drought that is manipulated, or rainfall / throughfall that is manipulated? Please reword.

5) L70: To suggest that there has been no synthesis across sites in search of possible general patterns overlooks some work of this sort, including Schwlam et al. 2010, which certainly does perform such a synthesis.

6) L243: "annul" to "annual"

7) L299: to suggest that soil carbon content is stable seems to be poorly worded. The idea is rather that there are small changes to a large pool, and that the flux acts on the large pool, so it is only until the small changes accumulate that the effect grows to its maximum. Basically, there is a lag in response to a semi-continuous forcing.

8) L296: this interpretation seems to miss the role of reduced photosynthate and associated exudates and/or reduced C inputs (litter).

9) L335: "...two [reduced-]rainfall treatments..."

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