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Interactive comment on "Water availability limits tree productivity, carbon stocks, and carbon residence time in mature forests across the western United States" *by* Logan T. Berner et al.

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Anonymous Referee #2 This is a nice study demonstrating the regional relationship between water availability and productivity, C stocks and residence time in forests of the western US. An impressive data set based on both forest inventory and satellite data were used to establish these relationships. I am not a specialist in estimating forest NPP or C dynamics, but the methods used and assumptions made seem reasonable and the authors are experts in these ecosystems.

Their results indicate that mature forests in the western US were strongly sensitive (across spatial gradients) to changes in water availability. This is not a surprising result, but the scale and scope of this analysis makes this a publishable study. Where I

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Discussion paper

take issue is the inference drawn from this analysis. The authors conclude that their analysis suggests that projected climatic change over the coming century could reduce productivity, biomass and carbon residence time in many parts of this region. Indeed, they justify their study by noting that “Changes in ecosystem structure and function along spatial climatic gradients can provide insight into long-term ecosystem response to climatic change”. While this makes sense in the broadest terms, using spatial relationships (based on average values derived from long-term data) to make predictions about temporal changes in (or the differential sensitivity of) ecosystems to a climate change is risky at best.

We have long known that large scale spatial relationships between NPP and precipitation (or water availability) have a slope that is determined by combined changes in water availability, biogeochemistry and the plant community. But the temporal dynamics over which each of these factors will change in the future will vary dramatically. . .from decades to centuries to even millennia. Thus, spatial models of NPP vs. water are not good predictors of expected temporal dynamics in ecosystems...particularly in forests that have long-lived trees and where communities may turnover very slowly (hundreds of years?). Please see the three references below. Combined, they do a nice job of covering many of the well-known problems inherent in substituting spatial models for temporal models when projecting a future with directional and chronic climate change.

Thus, while I am in favor of publishing this analysis, the conclusions drawn that “projected warming and drying over the coming century. . .could have important impacts on ecosystem structure, function, and services. . .” are really not that noteworthy. Nonetheless, a well-done confirmatory message is much better than much of the introduction and discussion which repeatedly references “sensitivities to changes in water availability” in the context of climate change. As presented, the implication that there is climate change relevance in this analysis is really quite misleading. . .given that spatial sensitivity does not equate to temporal sensitivity – except perhaps for sign. This is true under today’s environment, and spatial relationships such as those derived here will likely be even poorer surrogates for predicting the future as the varying time scales of change (climate vs forest community turnover vs. biogeochemistry) lead to novel functional relationships.

Thus, at the very least the authors should point out the limitations of their analysis and approach with regard to its relevance to future temporal C dynamics. Specifically, because the slopes (sensitivity) of temporal relationships between NPP and water are almost always less steep than slopes from spatial models, the authors need to recognize that the sensitivity implied by their analysis will likely not be manifest.

Estiarte, M., Vicca, S., Peñuelas, J., Bahn, M., Beier, C., Emmett, B. A., Fay, P. A., Hanson, P. J., Hasibeder, R., and Kigel, J.: Few multiâĂŘyear precipitationâĂŘreduction experiments find a shift in the productivityâĂŘprecipitation relationship, Global change biology, 2016.

Gaitan et al. 2014. Vegetation structure is as important as climate for explaining ecosystem function across Patagonian rangelands. Journal of Ecology 102: 1419-1428.

Wilcox 2016. Does ecosystem sensitivity to precipitation at the site-level conform to regional-scale predictions? Ecology 97: 561-568.

RESPONSE: We appreciate your critique of our manuscript, as well as the references that you suggested. We revised our manuscript to better acknowledge that the eco-climatic relationships we observed reflect long-term climatic constraints on ecosystem structure and function, which are shaped by gradual shifts in community composition and population size (Jin and Goulden, 2014). Consequently, these ecoclimatic relationships are not sufficient to predict ecosystem response to near-term changes in climate. We re-wrote the introduction, de-emphasizing observed and projected climate change, while emphasizing how this study seeks to confirm earlier observation at a larger scale. Furthermore, we remove the "Climate change implications" section (4.5) from the discussion and replaced it with section called "Predicting ecosystems response to environmental change" that reads (starting on line 475):

"Water availability is projected to decline in much of the western US over the coming century, in part due to higher temperatures increasing atmospheric evaporative demand (Dai, 2013; Walsh et al., 2014; Cook et al., 2015). Predicting the timing, magnitude and extent of ecological response to regional climate change remains a challenge. Our study showed that water availability is a key determinant of forest structure and function in the western US, broadly suggesting that chronic reductions in regional water availability could reduce the NPP, BIO, and CRT of mature stands. Nevertheless, it is problematic to predict the temporal response of extant forest communities to near-term climatic change based on ecoclimatic relationships derived from spatial data. For instance, recent studies found that the slope of the NPP-precipitation relationship was much steeper when derived from spatial data than when derived from the temporal response of NPP to interannual variation in precipitation (Jin and Goulden, 2014; Wilcox et al., 2016). Near-term effects of climate variability depend on the physiological characteristics of species in the extant plant community, yet ecoclimatic relationships derived from spatial data reflect gradual adjustment of community composition and population size to climate over long periods of time (Jin and Goulden, 2014; Wilcox et al., 2016). Furthermore, ecoclimatic models derived from spatial data cannot account for other ecophysiological impacts of environmental change, such as (1) enhanced plant water use efficiency from CO2 fertilization (Soulé and Knapp, 2015); (2) increased likelihood of tree mortality due to hotter drought (Adams et al., 2009); or (3) novel changes in disturbance regimes (Dale et al., 2001; Hicke et al., 2006). Consequently, predicting ecological response to environmental change over the coming century will require the use of mechanistic ecosystem models that account for physiologic, demographic, and disturbance processes at fine taxonomic and spatial scales (Hudiburg et al., 2013; Law, 2014). Although spatial models may not be suitable for near-term projection of ecosystems change, they do provide insight into long-term ecosystem adaptation to local climate and, furthermore, can be used to validate and refine mechanistic models if constructed from a representative sample of forestlands."

We also modified the Summary and Conclusions section to read (starting on line 519):

"The pronounced increase in tree productivity, biomass, and carbon residence time between the driest and wettest areas illustrates the gradual adjustment of ecosystem structure and function to long-term variation in water availability; however, the observed ecoclimatic relationships are not suitable for near-term projections of future ecosystem response to regional drying. Predicting near-term ecosystem response to drying and other environmental change (e.g., increased CO2) will require mechanistic ecosystem models, which can be evaluated against ecoclimatic relationships developed using inventory sites from a representative sample of forestlands (e.g., Forest Service inventory sites). Overall, our results indicate long-term water availability is a key determinant of tree productivity, live biomass, and carbon residence time in mature stands ranging from dry woodlands to coastal temperate rainforests, underscoring that additional efforts are needed to anticipate and mitigate the impacts of projected warming and drying on forest ecosystems in the western US and elsewhere around the world."

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