Reply to: Plant traits alone are good predictors of ecosystem properties when used carefully

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Reply to: Plant traits alone are good predictors of ecosystem properties when used carefully

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In a recent publication[1], we analyzed a long-term experiment to show that despite moderately strong links between traits and ecosystem properties within years, these links could not be used to accurately explain long-term variation in ecosystem properties. Hagan et al.[2] agree that "functional traits are not necessarily the panacea they are often considered to be". However, they also have concerns on our study, claiming that i) there is a mismatch between the functional traits and the ecosystem properties that we analysed and ii) that due to our study design, trait variation was limited in some plots. Below, we respond to both critiques.

First, Hagan et al. argue that when plant functional traits and ecosystem properties have mechanistic links, then plant traits should also be able to *predict* ecosystem properties[2]. While we agree that mechanistic links can help with predicting ecosystem properties, mechanistic links must not *always* lead to an adequate ability to predict ecosystem properties. Fluctuating environmental conditions (e.g. different weather patterns across years) in combination with context-dependencies can strongly hamper our predictive ability over longer time scales despite much stronger links between traits and ecosystem properties within years, as we also discussed in our original article[1]. Hagan et al. then argue that mismatches between the traits and the ecosystem properties we studied limited our capacity to predict rates of most ecosystem properties[2]. Their argument was that i) we analysed various ecosystem properties that are not well covered by other studies, and that ii) for those underrepresented ecosystem properties, we analysed different traits than should have been considered. While we agree with the first point, we believe that comprehensively studying multiple ecosystem properties is a strength. We disagree with the notion that we should have analysed a very different set of traits. By contrast and as outlined in our original article[1], we deliberately analysed a very broad set of traits, covering many plant parts typically underrepresented in other studies such as roots, stems, flowers and seeds, because of their hypothesized importance to various ecosystem properties. For example, based on other studies[3], we expected that pollinator abundance would be related to flowering duration, which is a trait rarely measured by other studies. However, we did not expect that each ecosystem property should be linked to each analyzed trait, even if we tested exhaustively for all possible relationships. While this might be problematic when one aims to increase a *mechanistic understanding*, the aim of our study was to maximize *predictive capacity*. In such cases, more pragmatic, explorative approaches are both effective[5], as well as widely used in ecology, including for remote sensing[6] and species identification[7]. Hagan et al. also mention additional traits we could have studied, such as the chemical properties of litter (as we also mentioned ourselves[1]). However, chemical litter properties are tightly correlated with the chemical properties of living plant tissues[8], so that such traits would likely not strongly complement the already existing set of traits we analysed. This is also supported by the asymptotic relationship between the number of traits analysed, and the proportion of explained variance that we found[1]. Hagan et al. interpret the finding that some (although certainly not all) of the aboveground, often plant-based ecosystem properties could be better explained by plant traits than most belowground properties as an indication that we studied aboveground plant properties more carefully[2]. We respectfully disagree and reiterate our original argument[1] that it is more likely that plant traits are inherently more strongly related to plant-based ecosystem properties than to the belowground ecosystem properties we analysed, which mostly reflected properties of higher trophic levels or abiotic conditions.

Hagan et al. also argue that the CWM and FD metrics that we analysed could not explain much variation in ecosystem properties in 40% of our plots[2]. Their argumentation is based on two points, namely that i) CWMs and FD cannot change over time in monoculture plots, and that ii) within (but not across) two-species plots, CWM and FD metrics of the same trait are perfectly correlated. While these are valid points, that could have been overcome by measuring traits for each species in each plot across each year, it is unlikely that such a massive undertaking would have strongly improved our predictive capacity, given that (as mentioned in our original article[1]) intraspecific trait variation in our experimental field is much smaller than interspecific trait variation[9].

To summarize, we agree that the selection of traits when studying their links with ecosystem properties should be done with care, although hypotheses based on mechanistic links are not crucial when a study aims at *predicting*, rather than *understanding*. Despite limitations in how plant compositions can change over time in biodiversity experiments, the ability to create even wider gradients in functional biodiversity than found in nature[10] makes them ideal to study the links between traits and ecosystem properties.

AUTHOR CONTRIBUTIONS

FvdP wrote an initial draft of the manuscript. All other authors (TS-G, AW, KB, SM, AA, RLB, NB, HdK, AE, NE, CE, MF, GG, AH, EK-F, SL, AM, LM, PAN, YO, CR, CS, MS-L, SS, BS, E-DS, VT, TT, WV, WWe, WWi & CW) helped editing the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

REFERENCES

1. van der Plas, F. et al. Plant traits alone are poor predictors of ecosystem properties and long-term ecosystem functioning. *Nat. Ecol. Evol.* **4**, 1602-1611 (2020).
2. Hagan, J. G., Henn, J. J. & Osterman, W. H. A. Plant traits alone are good predictors of ecosystem properties when used carefully. Submitted to *Nat. Ecol. Evol.*
3. Ogilvie, J. E., Griffib, S. R., Gezon, Z., Inouye, B. D., Underwood, N., Inouye, D. & Irwin, R. Interannual bumble bee abundance is driven by indirect climate effects on floral resource phenology. *Ecol. Lett.* **20**, 1507-1515 (2017).
4. Vasquez-Valderrama, M., González-M, R., López-Camacho, R., Baptiste, M. P. & Salgado-Negret, B. Impact of invasive species on soil hydraulic properties: importance of functional traits. *Biol. Inv.* 22, 1849-1863 (2020).
5. Shmueli, G. To explain or to predict? *Stat. Sci.* 25, 289-310 (2010).
6. Yuan, Q. et al. Deep learning in environmental remote sensing: Achievements and challenges. *Remote Sens. Env.* 241, 111716 (2020).
7. Wäldchen, J. & Mäder, P. Machine learning for image based species identification. *Methods Ecol. Evol.* 9, 2216-2225 (2018).
8. Wang, Z. & Zheng, F. Impact of vegetation succession on leaf-litter-soil C:N:P stoichiometry and their intrinsic relationship in the Ziwuling Area of China's Loess Plateau. *J. For. Sci.* 32, 697-711 (2021).
9. Roscher, C. et al. Interspecific trait differences rather than intraspecific trait variation increase the extent and filling of plant community space with increasing plant diversity in experimental grasslands. Perspect. Plant Ecol. Evol. Syst. 33, 42–50 (2018).
10. Jochum, M. et al. The results of biodiversity–ecosystem functioning experiments are realistic. *Nat. Ecol. Evol.* **4**, 1485-1494 (2020).