REPLY TO WANG AND D'ODORICO:

On the sustainability of large-scale desert plantations as a partial solution for climate change

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We thank Wang and D'Odorico for their letter (1), "Water limitations to large-scale desert agroforestry projects for carbon sequestration."

We agree entirely that water resources are vital for the sustainability of desert plantations. However, the focus of this work (2) is not water quantities per se, but the rainfall enhancement process and regional potential. As such, it complements essential multidisciplinary studies. We refer readers to 2 of our feasibility publications on desert agroforestry (3, 4). The first investigates feasibility of jojoba and other crops in the United Arab Emirates, and the second showcases large *Jatropha curcas* plantations in desert regions. Both consider water and other resources in quantitative analyses. The latter study estimates a carbon accumulation of ~17 to 25 Gkg C·y^{-1}, and both studies indicate that coastal regions are preferable given their proximity to water sources. Theory aside, profitable jojoba plantations of 2 to 3 km^2 have already been operational for decades, for example, in Israel (5), and we envisage that scaling up by approximately an order of magnitude is quite feasible and sustainable.

We accept that generating a net water gain from rainfall enhancement is a big "ask," and we are careful not to make such claims. Indeed, we use the term "significantly reduce irrigation water demand" within the paper (2). Even so, rainfall quantities are significant, and even a moderate offsetting of irrigation is valuable. But this is "academic" to a certain extent, because to assess potential based solely on water balances is to oversimplify the system. Rain enhancement is only one potential of plantation systems, and the following factors [as given in the publication (2)] must also be included: carbon storage and carbon trading; viability as a negative emission technology; irrigation offsetting; valuable oils and bioenergy; growth of dryland economies; and soil protection, flushing, and reversal of desertification.

To illustrate this systems thinking, an example tradeoff would be that carbon emissions offsetting would "pay" for marine desalination. Ultimately, unpacking such complexity will probably require life cycle assessment or similar analyses.

Therefore, we emphasize that rainfall amounts do not necessarily have to balance or exceed irrigation quantities for the overall system to represent a net benefit.

Another observation by Wang and D'Odorico (1) is that our ideal global locations differ from those of the global tree restoration study of Bastin et al. (6). This is perhaps not surprising, given the differing requirements for plantations and rainfed deciduous/coniferous forest (assumed in most "afforestation" scenarios). An exception to this may be high-elevation semiarid forests (7).

In summary, we agree with the concerns raised by Wang and D'Odorico (1) and emphasize that multidisciplinary sustainability research is vital, and ongoing, with various studies already published. Together with this impact study, we should now be able to identify sustainable locations for plantations which enhance rainfall. The combined findings indicate that large swathes of arid coastline exist with high atmospheric potential—particularly around the Sahara, Arabian Peninsula, Pakistan, and Namibia. If sufficient resources can be found there, those regions represent more than enough area to contribute significantly to a wider afforestation strategy.

1 L. Wang, P. D'Odorico, Water limitations to large-scale desert agroforestry projects for carbon sequestration. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 24925–24926 (2019).

2 O. Branch, V. Wulfmeyer, Deliberate enhancement of rainfall using desert plantations. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 18841–18847 (2019).

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The authors declare no competing interest.

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