Water limitations to large-scale desert agroforestry projects for carbon sequestration

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Vegetation and soils take up 20% of global anthropogenic greenhouse gas emission (1), and vegetation also plays an active role in regulating global water cycle (2). In PNAS, Branch and Wulfmeyer (3) conduct a detailed regional-scale simulation to show that agroforestry can significantly enhance rainfall in some desert regions and therefore could provide an effective biological engineering approach to sequestrate carbon (3). They also identify arid zones that have potential for desert agroforestry to enhance rainfall. The zones are mostly outside of the proposed areas available for potential tree restoration in a recent global analysis (4). This is an important finding. However, we argue that the conclusion misses an important piece of the puzzle: a comparison between plant water needs and water availability in these desert regions.

Deserts exhibit high atmospheric water demand relative to water supply. Even if agroforestry could increase rainfall, it is essential to compare the increased rainfall amount to water consumption by the planted trees to evaluate the sustainability of such a practice in desert regions. If plant water consumption exceeds the generated rainfall, agroforestry will not be sustainable. Branch and Wulfmeyer (3) use the water-efficient plant species *Jojoba chinensis* in their simulation. Based on figure 4 of ref. 3, the average rainfall generation due to agroforestry within the study domain in 71 d is roughly 6 mm, about 0.08 mm/d. This is well below the typical rainfall range in which wild *Jojoba* populations are found (0.18 to 1.2 mm/d) (5). Therefore, irrigation would be unavoidable.

Besides water consumption, the water sources accessible to the planted vegetation need to be considered. These plants can rely on either soil water or groundwater. Soil water in the deserts is transient, and some deserts have stable shallow groundwater resources (6). However, groundwater in the dry environments has a very low recharge rate, representing only 0.1 to 5% of long-term mean annual rainfall (7). When utilizing groundwater as a major water source, desert plantations serve as a "biological water pump" and unsustainably deplete the limited desert groundwater resources (8).

The use of agroforestry to prevent dryland degradation has been adopted worldwide over the last several decades. Particularly, to fight desertification and desert expansion, China has planted billions of trees over the past 4 decades. An area close to the size of Ireland is planted with tree seedlings every year (9). These past activities have generated important insights into such practices. For example, because many of the introduced plant species consume large amounts of water, the afforested areas experience reduced river flow and groundwater recharge, thereby triggering water shortages for humans (9).

Branch and Wulfmeyer (3) provide a unique perspective on using desert agroforestry to sequestrate carbon and enhance local rainfall. While the idea is interesting, caution is needed in accounting for vegetation water consumption, water availability, and water sources, as noted in the case of large-scale bioenergy plantations (10). Without an assessment of plant water consumption and local water availability, it is not possible to make sustainable plans on the use of desert agroforestry to sequester carbon and combat global warming.

Acknowledgments

We acknowledge support from Division of Earth Sciences of National Science Foundation (Grant EAR-1554894) and from the Agriculture and Food Research Initiative program (Grant 201767013-26191) of the US Department of Agriculture National Institute of Food and Agriculture.

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Author contributions: L.W. designed research; L.W. and P.D. performed research; L.W. and P.D. contributed new reagents/analytic tools; and L.W. and P.D. wrote the paper.

The authors declare no competing interest.

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First published November 26, 2019.

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