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April 24, 2019

## Natural Carbon Solutions Are Not Large- or Fast- Enough

Letter to Editor.

We thank Griscom et al. for their thoughtful letter to the editor, responding to our paper (Baldocchi and Penuelas 2018) and expressing the opinion ‘we need both natural and energy solutions to stabilize our climate’.

In formulating our essay, we took the perspective of treating the flows of carbon in and out of the atmosphere and ecosystem like a bath tub, which is regulated by the faucet and drain. We recognize that increasing the carbon sink is part of the solution, which is the point of Griscom et al. In fact, we express a similar point in our closing statement. But, we do so in a conditional manner, because we are more skeptical about how well and how realistically we can reduce carbon in the atmosphere with natural sinks.

One motivation for writing our piece stems from large-scale ecological solutions being proposed to the public that we perceive as being over optimistic to the uncritical eye; there have been calls to plant a billion and a trillion trees (Goymer, 2018). We are concerned that such projects may cause the public to ‘take our eye off the ball’, use it as an excuse to continue business as usual and assume the trees will save us

We also want to remind the reader that there is a big difference from planting vs growing a billion, or trillion, trees. Land will initially harbor a high number of small trees. But, as self-thinning occurs it will sustain a smaller number of large trees (Enquist, 2002). This occurs because energetic and resource scaling laws state there is only so much water and sunlight on a parcel of land. There are already examples of the unsustainability of large afforestation efforts in the arid and semi-arid regions of Inner Mongolia (Chen *et al.*, 2018).

Our take home point, based on long-term carbon flux data, remains that there are many carbon and water costs and unintended consequences associated with managing and regulating the uptake of carbon. Consequently, the rates and amount of net carbon uptake and accumulation are slow and low compared to the rates and amounts of carbon dioxide we release by fossil fuels combustion. Hence, we felt compelled to argue for the need to just reduce and even stop the emissions of carbon from fossil fuel combustion. We are optimistic about forward progress given the expanding availability of renewable energy in the form of wind turbines, solar panels, better battery technology and the growing adoption of electric cars.

We would be happy to admit we are wrong if natural solutions can be scaled up and reduce carbon dioxide in the atmosphere. But we feel we don’t have the luxury of waiting for the results for this one-off experiment. We add that our opinion that ‘natural carbon solutions are not enough’ has been now expressed in two more recent opinion pieces (Anderson *et al.*, 2019, Schlesinger & Amundson, 2019).

Dennis Baldocchi, Josep Penuelas

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