



Soils can help mitigate CO₂ emissions, despite the challenges

Julie Loisel^{a,1}, John P. Casellas Connors^a, Gustaf Hugelius^b, Jennifer W. Harden^c, and Christine L. Morgan^{a,d}

In their opinion piece, Amundson and Biardeau (1) argue that “values system opposition” between farmers and scientists complicates the use of soils as long-term carbon stores. They imply that storing carbon in agricultural soils is an unrealistic climate mitigation strategy. We agree that implementing restorative soil management practices across the world’s >500 million active farms is a formidable challenge. But we fear that the authors are overly dismissive of the broader motivations for, and benefits of, building carbon in our soils. Furthermore, we assert that current agricultural practices are contingent upon, and will be shaped by, transitions in the global energy systems. Therefore, continued soil-restoration efforts may not only contribute to climate mitigation, but may also play a role in supporting energy transitions as well as climate adaptation.

Soil organic matter (SOM) content contributes to soil health and function by supporting crop performance and ecosystem services (2). Soils with higher SOM content tend to be more productive and more capable of retaining water (3); they are also inhabited by more diverse micro- and macrobiomes (4). Although farmers may not describe these processes using the same terminology as scientists, farmers in many locations have long leveraged practices that cultivate soil fertility, beneficial soil–plant–water processes, and intergenerational health of soils (5).

The soil security framework (6) recognizes soil as a primary resource for fundamental human endeavors, which goes beyond “climate-smart soils” (7). Humans are managing over 75% of the global land area, contributing to the decline in soil function in many regions (8). The soil security framework establishes the relationships

among soil health, economic value, stakeholders, and environmental sensitivity. This framework draws from growing knowledge of soil systems to posit that practices that restore SOM add value to agricultural lands. This approach bridges social and biophysical sciences, highlighting the importance of policy and legal frameworks pertaining to soil use.

Contemporary farming practices rely on the heavy use of fertilizers, excessive soil tilling, and heavy machinery; these practices are detrimental to soil health and carbon storage, and entrain soil erosion, losses of SOM, and other externalities (9). Despite this, many programs still incentivize such practices. Instead, crop insurance and other programs could base their guarantees and rates on data that reflect soil health, such as SOM enrichment and aggregate stability (10). While federal and global institutions have incentivized energy-intensive agriculture, transformations of energy systems may greatly change this trend. Reducing the reliance on fossil fuel inputs now is important to facilitate broad energy transitions.

Focusing on soil security and actionable valuation of soil benefits such as SOM and carbon accumulation may accelerate soil-health-promoting practices, add economic value in terms of soil performance, maintain food security, and reduce energy needs in agriculture. Institutional obstacles to rapid, wide-scale implementation of altered soil management practices may currently prevent farm-based carbon sequestration as a global climate mitigation strategy, but it provides a framework for considering the variable ways that soil management bridges an array of concerns from the scale of the farm to the planet.

1 Amundson R, Biardeau L (2018) Opinion: Soil carbon sequestration is an elusive climate mitigation tool. *Proc Natl Acad Sci USA* 115: 11652–11656.

2 Lal R (2004) Soil carbon sequestration to mitigate climate change. *Geoderma* 123:1–22.

3 Harden JW, et al. (2018) Networking our science to characterize the state, vulnerabilities, and management opportunities of soil organic matter. *Glob Change Biol* 24:e705–e718.

4 Jackson R, et al. (2017) The ecology of soil carbon: Pools, vulnerabilities, and biotic and abiotic controls. *Annu Rev Ecol Evol Syst* 48: 419–445.

^aDepartment of Geography, Texas A&M University, College Station, TX 77843; ^bDepartment of Physical Geography, Stockholm University, SE-106 91 Stockholm, Sweden; ^cDepartment of Earth System Science, Stanford University, Stanford, CA 94305; and ^dDepartment of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843

Author contributions: J.L., J.P.C.C., G.H., J.W.H., and C.L.M. wrote the paper.

The authors declare no conflict of interest.

Published under the [PNAS license](#).

¹To whom correspondence should be addressed. Email: julieloisel@tamu.edu.

Published online May 14, 2019.

