



## REPLY TO LOISEL ET AL.: Soil in climate mitigation and adaptation

Ronald Amundson<sup>a,1</sup> and Léopold Biardeau<sup>b</sup>

We thank Loisel et al. (1) for their response to our article (2), which questions the ability of soil C sequestration to be the negative emissions strategy that has been widely advocated (ref. 3 and <https://www.4p1000.org/>). Loisel et al. acknowledge this but suggest we did not adequately articulate additional benefits. While this was not our focus, we did indeed acknowledge soil management as a climate adaptation strategy.

Loisel et al.'s letter (1) illuminates the chasm that exists between scientific conceptions of problems and the paths to their solutions (if they have one). Soil scientists have rolled both climate mitigation and adaption into a call for soil C sequestration. These are two different policy issues. Soil C sequestration for mitigation (globally) is likely a super wicked policy problem (4) because (i) it has urgency, (ii) it has no central authority, and (iii) those who seek to end the problem are also causing it. To physically achieve CO<sub>2</sub> reductions (ref. 3 and <https://www.4p1000.org/>) requires immediate international adaptation of practices maintained continuously for decades. In the United States (our focus), there is no serious policy discussion in progress that would implement such a program. This political challenge underscores the problems that natural scientists fail to appreciate when attempting to enter the policy arena (5).

Soil C management for soil health is a separate issue. Unlike mitigation, it lacks some of the immediate urgency but is a wicked policy problem (6, 7) because the "problem" has multiple definitions and no stopping point at a

definitive solution. We noted (2) that this indeed seems to be an important objective. For example, the 1985 US Farm Bill tied commodity support to the adoption of conservation practices. The result has been (along with the voluntary adoption of reduced tillage) a steady decline in the rates of soil erosion in the United States (8). Thus, we agree with Loisel et al. (1) that farm policy can be used as a tool, but social science and policy must determine the political climate that can institute them. The linkage of soil health to government programs is not, however, a climate mitigation strategy in disguise. It is a "faux paradigm shift," in which an eventual change in administrations can quickly dismantle the policy (4). For example, the rapid removal of land from the US Conservation Reserve Program in the past decade has reversed what initially appeared to be a paradigm shift in land management, due to economic changes.

Loisel et al. (1) set up a cardboard portrayal of modern agriculture (excessive tillage, erosion, etc.), which is at odds with the ways farming has been steadily changing by both technology and policy. While some C is already being sequestered by these changes, it is so small that it is insignificant to the climate system. We conclude that soil scientists are not effective at proposing policy, speaking policy-effective language (9), or anticipating the milieu of issues involved in this process, but they should instead work with and support the funding of experts (5) to more effectively continue the never-ending process (6, 7) to manage soil in a socially acceptable and beneficial way.

- 1 Loisel J, Casellas Connors JP, Hugelius G, Harden JW, Morgan CL (2019) Soils can help mitigate CO<sub>2</sub> emissions, despite the challenges. *Proc Natl Acad Sci USA* 116:10211–10212.
- 2 Amundson R, Biardeau L (2018) Opinion: Soil carbon sequestration is an elusive climate mitigation tool. *Proc Natl Acad Sci USA* 115: 11652–11656.
- 3 Lal R (2004) Soil carbon sequestration impacts on global climate change and food security. *Science* 304:1623–1627.
- 4 Levin K, Cashore B, Bernstein S, Graeme A (2012) Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sci* 45:123–152.
- 5 Grundmann R (2016) Climate change as a wicked social problem. *Nat Geosci* 9:562–563.
- 6 Rittel WJ, Webber MM (1973) Dilemmas in a general theory of planning. *Policy Sci* 4:155–169.
- 7 Game ET, Meijard E, Sheil D, McDonald-Madden E (2014) Conservation in a wicked complex world: Challenges and solutions. *Conserv Lett* 7:271–277.
- 8 Nearing MA, Xie Y, Liu B, Ye Y (2017) Natural and anthropogenic rates of soil erosion. *Int Soil Water Cons Res* 5:77–84.
- 9 Amundson R (2017) Whose security is important? Communicating environmental risk about soil to a diverse audience. *Global Soil Security*, Progress in Soil Science, eds Field DJ, Morgan CLS, McBratney AB (Springer, Cham, Switzerland), pp 383–387.

<sup>a</sup>Environmental Science, Policy and Management, University of California, Berkeley, CA 94720; and <sup>b</sup>Department of Agricultural and Resource Economics, University of California, Berkeley, CA 94720

Author contributions: R.A. and L.B. wrote the paper.

The authors declare no conflict of interest.

Published under the PNAS license.

<sup>1</sup>To whom correspondence should be addressed. Email: earthy@berkeley.edu.

Published online May 14, 2019.