*Climate Mitigation Potential of Regenerative Agriculture **is** significant!*

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In a recent World Resources Institute (WRI) blog post entitled *"Regenerative Agriculture: Good for Soil Health, but Limited Potential to Mitigate Climate Change"*, Ranganathan et al. (2020), dismiss the potential for regenerative agriculture to contribute to the "large-scale emission reductions" and CO_2 removal needed to hold global warming below the 2 °C threshold in the Paris Accords. We believe their blog post merits comment and critique. Given the severity of the climate change challenge and the urgent need to decarbonize the global economy, while also actively drawing down CO_2 concentrations in the atmosphere, all viable options are needed to help solve the problem. We believe that the science is clear that regenerative agriculture can in fact contribute significant emission reductions and CO_2 removal, as well as improve soil health. Unfortunately, we believe the WRI post confuses rather than clarifies the scientific and policy issues concerning the role and potential of regenerative agriculture to contribute to climate change mitigation.

First, the WRI piece poorly characterized the practices and principles comprising the suite of conservation management practices that are often referred to as "regenerative agriculture". These principles are widely understood to include: 1) maintaining (to the degree possible) continuous vegetation cover on the soil, 2) reducing soil disturbance, 3) increasing the amount and diversity of organic residues returned to the soil and 4) maximizing nutrient and water use efficiency by plants. Broadly these attributes are designed to more closely mimic native (e.g. prairie) ecosystems which we know maintain much higher soil C stocks than conventional annual croplands. In general, these practices work to increase soil C by increasing the amount of C added back into the soil and reducing the relative C loss rates via soil respiration and erosion. For annual cropland, these practices include reduced tillage/no-till and cover crops (as mentioned by WRI), more diverse crop rotations with higher frequency of perennial crops, but also grassed waterways and buffer strips, agroforestry (e.g., hedgerows, windbreaks), integrated livestock management with improved grazing management, and conversion of marginal lands (poorly suited to annual cropping) to perennial grasses and trees. There is an extensive literature and literally hundreds of long-term field experiments across the globe that document the capability of these practices, e.g., cover crops, (Abdalla et al. 2019, Poeplau and Don 2015), tillage reduction (Ogle et al. 2005, Franzluebbers 2010, Kravchenko and Robertson 2011), perennials (Conant et al. 2016, Ogle et al. 2005, Guo and Gifford 2002) to increase soil C contents. Hence the field experimental evidence that regenerative agricultural practices can significantly increase soil C stocks is unequivocal. Of course, results vary for different combinations of climate and soil types and management systems but in general we understand the variability in responses from region to region and we can design regionally-appropriate climate-smart regenerative agroecosystems.

“Faulty carbon accounting” is stated as another reason for discounting the capability of regenerative ag practices to store C and reduce greenhouse gases. One of the examples given, of the impact of organic amendments (e.g. manure) that is imported from off-farm sources, is correct in that the addition of that (imported) carbon does not by itself represent a net sequestration from the atmosphere. Assessing the net impact of such practices requires a broader life cycle assessment that goes beyond the farmgate boundaries and may (Ryals et al. 2015) or may not result in a net reduction of GHG emissions. However, estimates of global soil C sequestration potential (e.g., Fuss et al. 2018, Griscom et al. 2018, Lal 2004, Paustian et al. 2016, Smith et al. 2008, Sommer and Bossio 2014), based on field experimental data (as described above), generally don’t include organic amendments in the suite of practices considered in estimating soil C sequestration potential.

Further, the WRI blog post speculates that adoption of regenerative practices might cause significant yield declines compared to conventional agriculture, and therefore increase pressure to convert forests to crop production, resulting in large C emissions from the liquidated forest biomass stocks. We don’t believe there is strong evidence to support that assumption and indeed it is more likely that in the long run, regenerative practices will reduce soil degradation and improve yield stability (Oldfield et al. 2019, Schjønning et al. 2018), resulting in *less* pressure for land use conversion. In fact, one of the more attractive features of using soils as a CO_2 removal strategy is that additional C can be stored in the soil, *without* land use/land cover change. In contrast, land conversion is recognized as one of the major constraints against scaling up other CO_2 removal approaches involving tree biomass sinks, including afforestation and bioenergy with carbon capture and storage (BECCS) (NASEM 2019).

Finally, the argument is made that building soil organic matter (SOM) requires the concomitant storage of both carbon and nitrogen at a ratio (C:N) of ca. 10-12. Indeed, this characteristic stoichiometry of SOM is well known and soil scientists agree that practices to build up SOM stocks will generally-speaking entail building up stocks of organically-bound nitrogen as well! However, we reject the implication that any increase in organic matter storage will require an additional proportional increase in the use of synthetic nitrogen fertilizer. If this were the case, then it would be true that the large “embodied emissions” associated with industrial fertilizer production as well as increased N_2O emissions could render moot any climate benefit from C sequestration. However, in most annual croplands in the industrialized world, there is an excess of nitrogen and in fact one of the key functions of cover crops (an important regenerative ag practice) is to capture nitrogen that otherwise could be leached to aquatic systems or lost in gaseous forms. Hence stabilizing that nitrogen in organic matter stocks via cover crop adoption and improved crop rotations is a *positive* benefit! When N is not in excess, legume (cover) crops can promote N input via biological N fixation. There are many long-term experiments which demonstrate the capacity of improved crop rotations and cover crop adoption to increase SOM stocks, while maintaining or increasing yields, *without* requiring additional nitrogen inputs compared to conventional management (e.g., Dick et al. 1998, Abdalla et al. 2019). Hence, with proper management, regenerative agriculture practices can build up soil organic C and N stocks, while reducing N losses and “tightening up” the N cycle in our agroecosystems.

The WRI blog closes with an excellent analysis showing the potential to reduce agricultural greenhouse gas emissions through a variety of practices including reducing food waste, shifting towards more plant-based diets, improving crop N use efficiency, reducing on farm energy use and other land management changes. These are all changes that are fully compatible with the management practices associated with regenerative agriculture. Indeed, we believe it is not productive to create artificial silos that seemingly decouple non-CO_2 GHG emission reductions from CO_2 removal and soil sequestration. We submit that adoption of conservation practices that comprise regenerative agriculture can – and must – do both. Ironically, this is implied in the first part of the title of the WRI blog "*Good for Soil Health*…" Most soil scientists would agree that the main mechanism for the improvement in soil health with adoption of regenerative agricultural practices is due to the increase in soil organic matter!

Climate change as well as food security, climate resilience, biodiversity and soil health are all interrelated parts of a new global imperative. That imperative is for humanity to fundamentally re-imagine our agricultural landscapes, designing them to provide not only sustaining services (food and fiber) but environmental services as well, including climate change mitigation and adaptation capacity. The science is clear that regenerative agricultural practices have the biophysical capability to contribute significantly to both soil health **and** climate change mitigation! There are no single solutions to achieving GHG emission reductions and CO_2 removal and by now it is universally accepted that many solution 'wedges', each contributing a modest (5-10%) part of the solution, are required. We believe the preponderance of evidence is that regenerative agriculture has the potential to be such a wedge. The challenge, however, is whether socio-economic and political barriers can be overcome to bring that transformation to scale. Thus, it is more important than ever that the scientific community project a clear, data-driven message that can inform policy makers and the general public about the potential for positive change via a new agricultural revolution.

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