IN DEFENSE OF SOIL CARBON SEQUESTRATION

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Introduction and Background.

There are reports that disparage the use of biological carbon sequestration practices. Soil carbon sequestration has multiple functional roles in food production, soil and planetary health, sustainability of food and fiber (trees) and, in reducing concentrations of the greenhouse gas, atmospheric carbon dioxide. These benefits are widely accepted throughout the world and the mitigation potential is significant. https://scholar.princeton.edu/sites/default/files/tsearchi/files/paustian_et_al._response_to_wri_soil_carbon_blog_.pdf

Major reasons for naysayer complaints seem to be grounded in various interpretations of aspects of legitimate carbon accounting", including an inability to measure soil carbon, and a mistaken impression that there are insufficient precedents to provide confidence that carbon accumulation is being done with best scientific practices. There also seems to exist a major misunderstanding of the word permanence as it applies to sequestered carbon, and a fundamental distrust for the concept of carbon offsets. During this global warming emergency, it is time for humanity to gather, envision, learn, and take actions that collectively reduce emissions as well as reduce greenhouse gases (GHG) already present in the atmosphere. It is my hope that my comments will clarify some of the misunderstandings.

Regarding precedents. There are currently (as of Sept. 2020) over 570 registered land-based carbon farming projects in Australia, covering **more than 47 million hectares**, (equivalent to nearly twice the entire land area of the State of Oregon). These contracted projects are in the process of generating 144 million tons of carbon dioxide abatement equivalent to erasing 2.4 years of ALL of Oregon's GHG emissions. These projects will inject more than $1.7 billion into rural, regional and remote Australian communities. https://climatefriendly.com/new-investment-in-carbon-farming/ Furthermore, as **leading soil scientists have already noted,there are hundreds of long-term field experiments across the world** (cited in **https://scholar.princeton.edu/sites/default/files/tsearchi/files/paustian_et_al._response_to_wri_soil_carbon_blog_.pdf)**

including several in California – that document how practices like cover cropping, tillage reduction, and diverse crop rotations increase soil carbon stocks. https://calclimateag.org/regenerative-agricultures-climate-mitigation-potential-a-california-perspective/

There are Rules in the carbon market including the need to validate and verify that carbon dioxide sequestration is occurring. In 2014 the U.S. **Supreme Court ruled (again) that EPA can regulate greenhouse gas emissions, with some limits, from stationary sources.** https://www.washingtonpost.com/politics/supreme-court-limits-epas-ability-to-regulate-greenhouse-gas-emissions/2014/06/23/c56fc194-f1b1-11e3-914c-1fbd0614e2d4_story.html Since the flow of carbon dioxide in the U.S. as a pollutant is regulated through the Federal Clean Air Act, it provides empowering incentives for landowners, corporations, and individuals who want to do the "right thing"(i.e., offset their carbon footprint) , to make sure third party companies are involved to validate and verify the amounts of carbon claimed to have been sequestered as a means of due diligence.

Carbon market brokers that bring farmers, polluters, and carbon buyers together (like Nori, Indigo Ag, and others) insist that due diligence be involved to assure the carbon has been sequestered, it is not being sold twice, it's been properly measured, etc. https://www.offsetguide.org/high-quality-offsets/ A condition of farmer acceptance into a carbon market sequestration program usually includes assurances that

farming practices implemented are new to their operation, i.e., are in addition (are different) to what had previously been carried out prior to the startup of carbon sequestration measurements. https://nationalaglawcenter.org/considering-carbon-overview-of-carbon-market-composition/ Some carbon marketplace companies may pay for previously adopted carbon-sequestering practices but only for a limited number of years of practice. https://agecon.ca.uky.edu/carbon-markets-101 The third-party company will verify practices by going through a thorough history of farmer land management records.

Offsets. A simplistic definition of offsets is: GHG *emission reductions* or *removals* that compensate for CO_2 emissions. If an industry cannot reach its regulatory requirements to lower pollution of GHG emissions, there are often opportunities to offset this pollution by purchasing a specific amount of soil carbon through the carbon market that a land owner may have previously sequestered into forests or agricultural soils. Surveys show reasons many land owners are hesitant to join a carbon marketplace program despite all their co-benefits include: a need for more information on conducting the practices, start-up costs of project validation, and not knowing how to join a commercial marketplace.

The purposes of this commentary is to attempt to clarify the nature of the carbon sequestration “problems” and to reassure interested readers that soil carbon sequestration provides a credible opportunity because it has been happening naturally over geological periods of time, it can be quantified using the basic laws of chemistry and physics and carbon persists within the soil and is not lost in significant amounts even after occasional physical soil disturbances to control weeds.

What is soil organic matter (SOM)?

There probably isn’t any successful farmer or rancher that could not estimate the health of his or her soil by looking and sniffing it. Healthy, fertile soil is in that condition because of its increased soil organic matter content. Soil organic matter is derived from all living and dead materials present in the soil and on the soil surface including plant roots, shoots, leaves, living plant root exudates, microbes, worms, insects, arthropods and much more that are alive or recently died. But, all SOM is not the same.

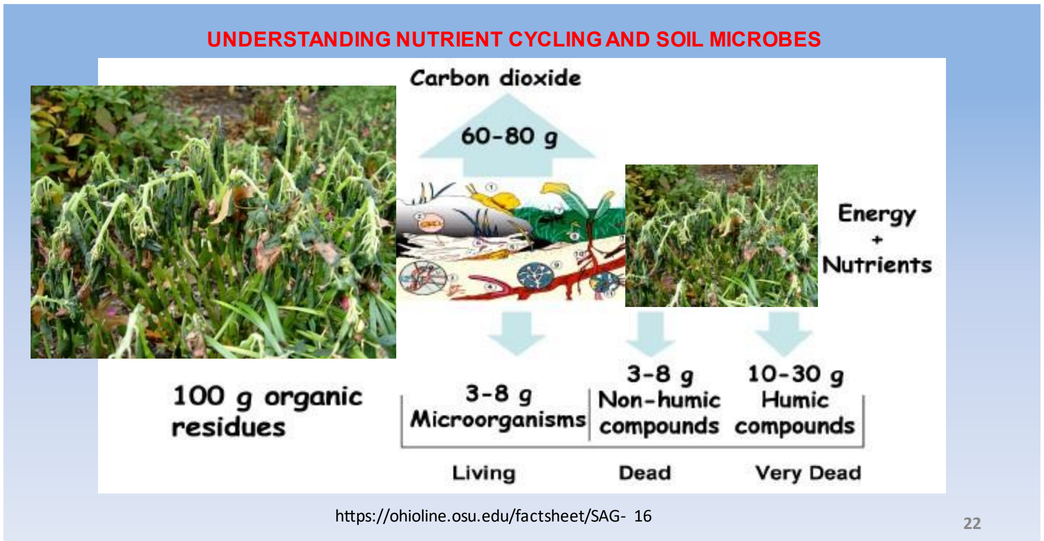
SOM contains about 58% carbon. The beginning source of this carbon was the atmospheric gas, carbon dioxide. That carbon now appears in the soil as organic matter converted from a gas into visible material through the processes of photosynthesis

Labile soil organic matter on the soil surface **can be readily decomposed**. It contains all the molecules and nutrients found within living organisms that have died including, nitrogen, minerals, and numerous proteins, DNA, RNA, complex cell wall components, water, and much more. Over time a significant percentage, approximately two-thirds or more, of these materials decompose within a few months to years (Figure 1). The relatively quick (months to 1-2 years) decomposition of recently dead **soil surface organic matter** has mistakenly led some to believe that soil carbon in general, is not stable. This labile surface material is NOT sequestered soil organic matter!

Every 1% of SOM weighs approximately 10 tons (20,000 lbs) per acre and most is found in the upper 7 inches (17.5 cm) of soil .This massive amount of carbon in soil (https://earthobservatory.nasa.gov/features/CarbonCycle) means that the processes of soil sequestration are a normal and integral part of the earth’s massive carbon cycling system, and have been occurring naturally over geological times. Notably, carbon dating studies have found SOM in soil thousands of years old.

Figure 1.Scientists understand and account for the fact the only 20-40 percent of the decomposing agricultural residues enter into the soil and become SOM. The larger component is decomposed and carbon re-enters the atmopshere as carbon dioxide. https://ohioline.osu.edu/factsheet/SAG-16 For example, each acre of corn residues (stover, without corn kernels) weighs approximately 6,000—9,000 lbs dry weight.When just 20% of these residues enter the soil, it adds approximately 1,200-1,800 lbs of

sequestered SOM.The remaing weight of the larger component (the 60-80%) has never been part of the soil carbon matrix and these residues re-enter the atmosphere as gaseous CO2 without ever having been "sequestered".



Soil Organic Matter Is Measurable.

There are four generally accepted ways to measure soil carbon. These are

1- Loss on ignition and combustion,
2- A chemical test called the Walkley-Black technique,
3- A spectral technique that uses near infrared technology.
4- A desk top approach to measuring soil carbon involves a nationally recognized computer model system called COMET-Farm. The raw data used to develop the computer program are derived from thousands of soil samples collected from nearly every county in the United States. COMET-Farm was developed through a partnership between the USDA Natural Resources Conservation Service and Colorado State University. There is more than a decade of model development experience reflected in COMET-Farm and it is the official greenhouse gas quantification tool of the USDA. The program estimates carbon sequestration amounts for a large number of agricultural practices for each county in the U.S. Nori corporation, a carbon marketplace company, allows land owners to estimate their carbon sequestration using the COMET program and does not require in field soil measurements.

https://comet-farm.com/#:~:text=COMET%2DFarm%20is%20a%20whole,including%20alternative%20future%20management%20scenarios.&text=is%20COMET%2DFarm%3F-,COMET%2DFarm%20is%20a%20whole%20farm%20and%20ranch,and%20greenhouse%20gas%20accounting%20system.

Figure 2 illustrates a full soil core showing the top mulch/organic material (black material) that sits on top of the soil, not within it. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9251.pdf Top mulch and any plant growth must be scraped off the surface soil layer before a soil core is taken for SOM analyses. This is not part of the "sequestered" soil organic matter. Soil specimens collected over time must be done consistently, preferably by the same person and use the same measurement technology. ***Comparison analyses of the physical/chemical methods (1-2 above) suggests that combustion, loss on ignition, and Walkley-Black function reliably in measuring soil carbon changes over time.***

There are projects under way to develop direct in the field measurements using Near Infrared spectroscopy and one prototype portable instrument called “Yard Stick” seems to be field ready and is coming to the market in 2022. See Figure 3. **Direct in the field measurements will likely increase convenience and speed of measurements and data acqusition at lower costs to the farmer.**
https://techcrunch.com/2021/02/17/yard-stick-provides-measurement-technology-to-combat-climate-change/.Agency.Energy
The resistance sensors on the probe calculate the density of the soil. With those two inputs, (soil density and carbon content) Yard Stick says it can calculate the amount of carbon sequestered in a particular area of soil.

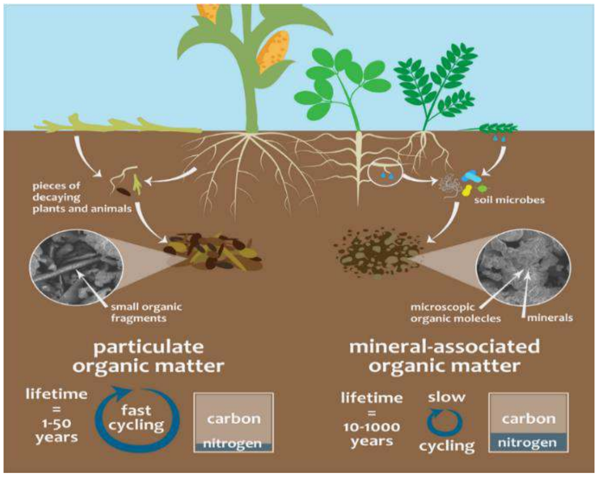
Figure 3. Yard Stick is a miniaturized technology used with a simple handheld drill. The tip of the probe contains a small camera that uses wavelengths to sense the presence of organic carbon the way our eyes sense differences in shades of blue when looking at the sky.

In separate studies, Kusumo and colleagues (2018) used infrared technologies (NIFR) to examine soil carbon taken from soil cores in New Zealand. The relationship between soil C measured by the conventional combustion laboratory method and predicted by Vis-NIRS technique showed a high correlation at all depths measured (down to 50cm).
https://iopscience.iop.org/article/10.1088/1755-1315/129/1/012023/pdf

When something is chemically measurable it is real, traceable, can be monitored, and therefore, can become verified as additional, and unlikely to be overestimated.

On the persistence of SOM.

Figure 4. Sequestered carbon is not all the same. https://source.colostate.edu/soil-carbon-is-a-valuable-resource-but-all-soil-carbon-is-not-created-equal/



Fate of organic matter on and within the soil. Resistant, particulate and mineral-associated SOM (Figure 4) consists of approximately 80% of the soil carbon and decomposes over tens to fifty to thousands of years while living organisms (plant roots, microbes, invertebrates, plant root exudates) may comprise about 10% of the near surface soil organic matter. When SOM is added to the soil faster than it leaves, (e.g., every year), SOM will accumulate. **https://www.agric.wa.gov.au/measuring-and-assessing-soils/what-soil-organic-carbon**

Depending on environmental factors (temperature, moisture), around 30-50% of common crop residues left undisturbed on soil surfaces actively decompose within 12 months. Further accelerated decomposition (over months) continues after this time as well. These are surface residues and although the remaining remnants impact soil health, the CO2 released from surface residues over short periods since deposition (months to a year+/-), are **never part of the fraction deemed as soil organic matter**. This released carbon is ultimately considered to be part of the 60-80% of surface residues illustrated in Figure 1. The remnants (20-40%) of the partially decomposed residues comprise the particulate organic matter (Figure 4) and, after further weathering and living creatures moving organic matter further into the upper soil layers, it becomes components of mineral associated (formerly "humus") long-lived soil organic matter and the "resistant" organic matter. See Table 1 found here. https://www.agric.wa.gov.au/measuring-and-assessing-soils/what-soil-organic-carbon.

The papers of Conant and others (cited in Conant, et al. Dimassi et al., 2013), provide key information as to the relationships between organic matter actually within the soil and the consequences of physical disturbance of the soil (tillage, plowing).
https://controverses.sciences-po.fr/climateblogs/tillage/files/2012/04/07-Conant-impacts-of-periodic-tillage-on-soil-C-stocks-a-synthesis.pdf
For example, Conant, et. al. reviewed the science and found that **most (80%) of the soil carbon gains from no till (NT) treatments can still be realized when no till is coupled with biannual shallow cultivating or ripping for weed control.** " If those tillage activities are the most common in an otherwise long-term NT system, impacts on soil C stocks will be minimal". In other words, there will be no "massive" release of sequestered carbon. Factors impacting the amounts of soil carbon loss due to tillage are a function of the soil type, the frequency and intensity of tillage, depth of the tillage events, and the weather. https://environmentalevidencejournal.biomedcentral.com/articles/10.1186/s13750-017-0108-9 Other studies that showed an increased and "dramatic" release of "sequestered carbon" after tillage or plowing were likely due to high intensity soil treatment, and tilling or plowing at depths below 1-2 inches of the surface. https://environmentalevidencejournal.biomedcentral.com/articles/10.1186/s13750-017-0108-9

In separate studies, Sanderman, et al. noted through historical comparisons of agricultural land with native vegetation that only 14-28% of SOC loss occurred over the last 200 years due to industrial agricultural practices involving intense plowing and or yearly multiple deep tillage treatments that highly disturb the soil. https://www.pnas.org/content/114/36/9575#F1 Such data demonstrate that if a farmer was to abandon carbon sequestration and change back to industrial agriculture practices, there would not be sudden massive loss of previously sequestered carbon over the succeeding tens to 100 years. https://www.pnas.org/content/114/36/9575#F1

Further proof of SOM persistence has been demonstrated at the Rothamsted long-term agricultural experiment station, wherein farmyard manure was applied to a cereal cropping system for twenty years in the late nineteenth century and then stopped. Nearly 150 years later, this soil still contains about 2.5 times as much SOM as soil that never received manure (Johnston et al., 2009, cited in https://www.frontiersin.org/articles/10.3389/fenvs.2020.514701/full#Box1) Collectively all these studies have called into question the necessity for 100-year permanence requirements in the practices that sequester carbon. Some contracts currently allow 25 year periods of carbon sequestration efforts.

Fate of carbon dioxide in the atmosphere. A “quality” carbon offset credit, refers to the *level of confidence* that a landowner carbon credit issued for 1 ton GHG removed will fulfill the basic principle that their sequestration will completely *substitute* for (offset) 1 ton of GHG emitted by the polluter. But, scientists have estimated, using many different computer modeling systems, that following a “pulse” of carbon dioxide emission into the atmosphere by polluters, after 100 years, 75% of the GHG has left the atmosphere to continue its journey in the carbon cycle, perhaps even becoming photosynthesized again. Why should we ask and expect land owners to “permanently” sequester carbon when nature cannot do this? As stated above, to be put into perspective, after 200 years the amounts of SOM in soil may be overall reduced just 14-28% on average due to industrial agricultural practices, https://www.pnas.org/content/114/36/9575#F1 (see Figure 1a, solid black line.

Further dissemination of these facts and education that addresses policy maker concerns may lead to broader support for adoption of carbon sequestration programs. https://www.frontiersin.org/articles/10.3389/fenvs.2020.514701/full#Box1

Putting science into action. Innovative field applications from the lessons learned from Conant and colleagues can be found within the Australian Carbon Farming Emissions program. A large sized device was built and tested for making healthy soil, called the “Soil Kee” Renovator (Figures 5-7). https://soilkee.com.au/Soilkee-Renovator/

This device simultaneously provides minimal tillage soil disturbance (perhaps upper 1 inch of soil) and a means for replanting of pasture, or row crops with a single pass over the field. **Minimum till** disturbance is achieved by widely spaced blades about 14 inches apart, (Figure 6). This process creates a **competition free seed bed** for **successful germination** and leaves around 80% of the pasture or field undisturbed (Fig.7). The undisturbed portion of the field acts as a **cover crop.**

Figure 5. The Soil Kee renovator/ Planting system used in Australia to facilitate carbon sequestration

Fig.6. Widely spaced blades on the Soil Kee

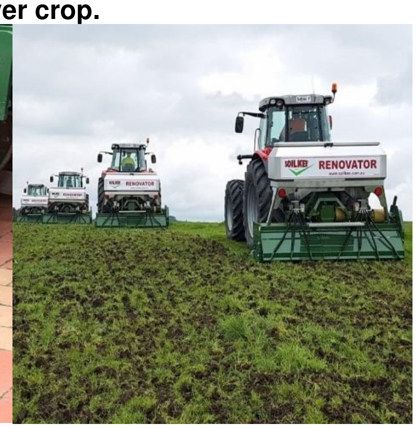


Fig. 7. Field perspective

Carbon sequestration projects are worthless without validation and verification.

Authentication of project transparency and integrity are key components for a land holder if they anticipate selling carbon credits publicly. Landholders should not be financially incentivized unless their project is verified and validated to comply with international standards for sale in the open market.

Third party verifiers offer the carbon purchasers a kind of due diligence in the assessment and identification of "good quality" offsets. This ensures offsetting provides the desired additional environmental benefits, and avoids reputational risk associated with poor quality offsets. https://en.wikipedia.org/wiki/Carbon_offset A successful verification provides reasonable assurance that the GHG assertion is without material misstatement file:///C:/Users/Owner/Downloads/ACR%20VV%20Guideline%20v1%201%20(1).pdf Third party verifiers like SCS Global Services or Aster Global, Inc. and others https://www.theclimateregistry.org/our-members/list-of-verifiers/ work closely with project land owners to provide third-party authentication which have already been used on hundreds of carbon sequestration projects.

It is critical that in any financially incentivized program that policy makers, land owners and polluters, be knowledgeable with these quality carbon sequestration requirements and the available rules that reference these issues. Easy reference and clear rules might facilitate the processes and encourage new carbon sequestration projects that really will help to mitigate the impacts of global warming on food production, soil sustainability, and financial health of the land.

SUMMARY: The science is clear that regenerative agriculture can in fact contribute significant agricultural emission reductions and CO_2 removal, as well as improve soil health. There is an extensive literature describing 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 content. 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 professionals can design regionally-appropriate climate-smart regenerative agroecosystems”. All citations here: **https://static1.squarespace.com/static/5c3780907c9327dc2a2e8c64/t/5edf6c3063b8cc74f6f4fff9/1591700528217/Response+to+WRI+-+FINAL.pdf**

The longer-term sequestered carbon in the form of SOM, persistently accumulates over time, keeping the soil fertile and healthy. The biannual gentle physical disturbance of the upper soil layer using light tillage to remove weeds, (like with the SoilKee) may remove a small percentage of the short-lived near surface SOM but not the deeper sequestered carbon.

If just 25% of Oregon’s 16 million farmed acres were to enter a carbon sequestering practice, the potential exists to remove about 6 million tons of CO_2 per year from the atmosphere, equivalent to approximately the total published Oregon agricultural emissions per year.. This assumes 0.4 tons as C is sequestered per acre per year, well within the average ranges reported in the literature for a variety of agricultural practices.*
https://drawdown.org/solutions/conservation-agriculture/technical-summary;
see page 31 and Appendix C here: https://www.chelseagreen.com/product/the-carbon-farming-solution/?
see pages 174-182 here https://www.goodreads.com/book/show/39027958-a-finer-future
*Calculations of carbon sequestration potential in Oregon: **25% X16 million (M) ac= 4 M ac X 0.4 t/ac as C=1.6 Mt C X 3.67 =5.9 Mt as CO2 equiv. removed from the atmosphere. THE VALUE OF THIS PROCESS IS $90 MILLION/YR IN THE CURRENT CARBON MARKEPLACE; funds would largely go to rural, underrepresented regions of the State of Oregon.**