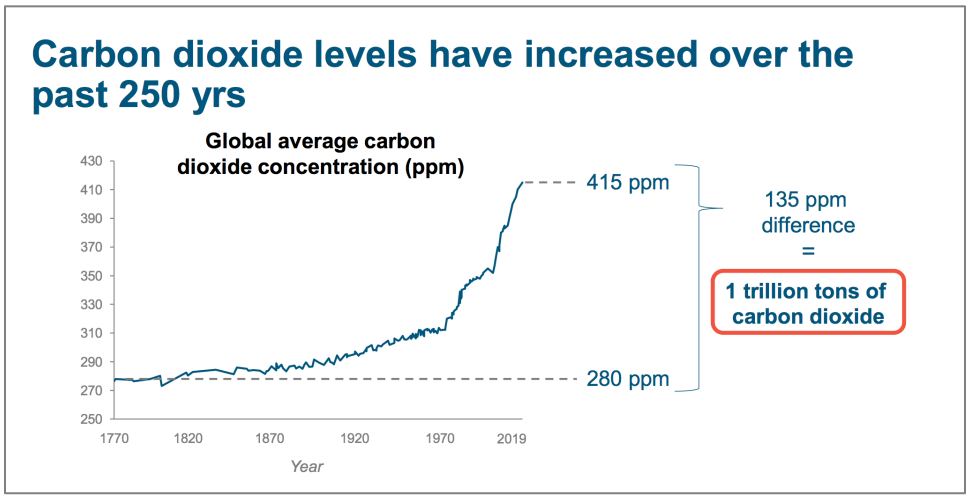
The Terraton Initiative™: supporting calculations

Objective

This document provides background on the calculations underlying the Terraton Initiative™. We lay out this math for transparency and to invite scientific partners and journalists to join us in thinking through this foundational but complicated topic. For a broader overview, please see our Press Release.

We have a teraton problem

Atmospheric concentrations of carbon dioxide have been rising significantly since the Industrial Revolution. In April, the Mauna Loa Observatory in Hawaii reported an average monthly level of carbon dioxide above 415 ppm for the first time in recorded history.[1] This is the highest level in the last 800,000 years.[2] **This accumulation of carbon dioxide represents an additional 135 ppm in the atmosphere since the Industrial Revolution which equates to 1 trillion tons[3] of carbon dioxide, or 1 teraton.[4]**



Soil provides a "terraton" opportunity

Soil represents the third largest pool of carbon on the planet, after the ocean and fossil fuels,[5] holding approximately 1.5 teratons of organic carbon down to a 1 m depth, equivalent to 5.5 teratons of carbon dioxide.[6,7,8] This pool of soil organic carbon is 5.5 times larger than the 1 teraton of carbon dioxide that has accumulated in atmosphere over the last 200 years.[9]

The total weight of agricultural soils at a 70 cm depth is approximately 14 teratons, based on a 1.33 g/cm^3 average bulk density.[10,11,12] The size of the carbon pool in cropland soils, representing 3.64B acres globally,[13] is estimated at 0.12 teratons of organic carbon, equivalent to 0.45 teratons of carbon dioxide, down to a depth of 70 cm.[14] This equates to an estimated average concentration of ~1% organic carbon across all cropland soils.[xi]

In nature, multiple ecosystems and soil types have accumulated soil carbon to levels above 3% at comparable depths. Uncultivated soils (e.g., forests) are documented to have soil organic carbon levels over 3% down to a 70 cm depth.[15] Undisturbed forest soils contain an average of 3 times the level of soil organic carbon found in cropland soils of the same soil type.[16] The conversion of pastureland acres to cropland production has reduced soil organic carbon by a factor of 2-4 times in arid and humid climates.[17]

Sequestering 1 teraton of carbon dioxide is possible by increasing the amount of carbon in the soil by approximately 0.27 teratons.[18] **This sequestration would amount to an increase in soil organic carbon levels from 1% to 3% across all cropland,** which is in line with the above estimates of the carbon content in uncultivated soils.[19] If grazing and rangeland acres were included in addition to cropland acres, then soil organic carbon levels on these 12B global acres[xii] would only need to rise by approximately 0.5% to sequester 1 teraton of carbon dioxide.[20]

For additional background reading, please see a list of resources below.

Resources

In addition to the publications cited in this paper, we want to acknowledge transformative studies, literature, tools, and global initiatives that have encouraged us to launch the Terraton Initiative™.

- Studies: Rodale Institute's 30-Year Farming Systems Trial, North American Project to Evaluate Soil Health Measurements (Soil Health Institute, Soil Health Partnership and The Nature Conservancy)
- Global Initiatives: Healthy Soils Program (California), The "4 Per Mille" Initiative
- Books and articles: Dirt to Soil, The Soil Will Save Us, Growing a Revolution, Kiss the Ground, The Carbon Farming Solution, Drawdown, Dirt: The Erosion of Civilizations, Gates Notes on soil carbon
- Tools: COMET Farm Tool, DeNitrification-DeComposition (DNDC) model

[1] National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, 2019.

[2] Snyder, C, Evolution of global temperature over the past two million years, *Nature*, 538(7624):226-228, 2016.

[3] Note: all references to tons are metric tons, not imperial tons.

[4] 1 ppm of carbon dioxide is equivalent to 7.8 billion tons of carbon dioxide. Reference: Le Quéré, C, et al., Global Carbon Budget 2016, *Earth Systems Science Data*, 8:605–649, 2016.

[5] National Academy of Sciences, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, *NAS Press*, 2019.

[6] Lal, R, Soil Carbon Sequestration Impacts on Global Climate Change and Food Security, *Science*, 304:1623, 2004.

[7] Zomer, R, Bossio, D, Sommer, R, Verchot, L, Global Sequestration Potential of Increased Organic Carbon in Cropland Soils, *Scientific Reports*, 7:15554, 2017.

[8] Note: the molecular weight ratio of carbon dioxide to carbon is 44/12, or 3.667.

[9] Scharlemann, J, et al, Global soil carbon: understanding and managing the largest terrestrial carbon pool, *Carbon Management*, 5:1, 2014.

[10] Geospatial analysis performed on SoilGrids250m dataset in; Hengl, T, et. al, SoilGrids250m: Global gridded soil information based on machine learning, *PLoS ONE* 12(2): e0169748, 2017.

[11] USDA NRCS, Soil quality indicators: Bulk Density, 2008.

[12] Manrique, L, Bulk density of soils in relation to soil physical and chemical properties, *Journal of Soil Science Society America*, 55:476-481, 1991.

[13] Lal, R, et. al, The carbon sequestration potential of terrestrial ecosystems, *Journal of Soil & Water Conservation,*73:6, 2018.

[14] Sanderman, J, Hengl, T, Fiske, GJ, Soil carbon debt of 12,000 years of human use, *Proceeding of the National Academy of Sciences of the United States of America.*, 114(36); 9575-9580, 2017.

[15] Batjes, N, A world dataset of derived soil properties by FAO-UNESCO soil unit for global modelling, *Soil Use and Management*, 13, 9-16, 1997.

[16] Buringh, P, *The role of terrestrial vegetation in the global carbon cycle*, Chapter 3: Organic carbon in soils of the world, John Wiley & Sons Ltd, 1984.

[17] Guo LB and Gifford RM, Soil carbon stocks and land use change: a meta analysis. *Global Change Biology* 8:345–360, 2002.

[18] The mass ratio of carbon dioxide to carbon is 44/12, or 3.667. So 1 teraton of carbon dioxide is equivalent to 0.27 teratons of carbon (or 270 gigatons).

[19] If current levels of carbon in the soil are .12 teratons and add 0.27 teratons of carbon, the net is 0.4 teratons of carbon in the soil. Divided by the total weight of global cropland (14.7 teratons), the result is ~3%.

[20] Assuming a bulk density of 1.33 g/cm^3 across cropland and rangeland.