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Conversions, Quantities, Calculations and Indulgences: A Primer

by Jack Kittredge, editor

Anyone attempting to make sense of calculations surrounding carbon cycling and soil carbon must first understand a little bit about quantities and conversion factors. Here are some basic facts you might find helpful.

Metric Conversions

First off, much of this literature uses the metric system of measurement. In case you forgot your high school lessons on the metric system, here are some useful conversions.

Length: one meter = 39.3701 inches; one inch (12 in. to a foot, 5280 ft. to a mile) = 2.54 centimeters

Area: one hectacre (10,000 square meters) = 2.4711 acres; one acre (43560 sq. ft.) = .40469 hectares

Volume: one liter (1000 cubic centimeters) = 1.0567 US quart (liquid); 1 US quart (liquid) = .94635 liters

Weight: one kilogram = 2.2046 lbs; one pound = .45359 kilogram

An additional complication concerns the use of the weight that derives from the ancient Germanic term for a large cask, or tun. In the US, one (short) ton = 2000 pounds. The non-US "conventional" system, however, uses the British Imperial (long) ton of 2240 pounds. Lastly, the metric tonne is 1000 kg or 2204.6 lbs, very close to the Imperial or long ton.

Temperature: one degree Celsius = 1.8 degrees Fahrenheit; 1˚F = .556˚C, water freezes at 32˚F or 0˚C.

Quantities

Carbon and Carbon Dioxide: The carbon atom has an atomic weight of 12. Carbon dioxide (CO_2) is a molecule composed of a carbon atom and two oxygen atoms. Since each oxygen atom has an atomic weight of 16, the total CO_2 molecule has an atomic weight of 44. Thus one carbon dioxide molecule weighs 3.67 times as much as a carbon atom, and carbon weighs .273 times as much as CO_2.

People are approximately 18% carbon by weight. Wood is roughly 50% carbon, and soil organic matter is about 58% carbon. Typical soils, depending on level of compaction, weigh between 1200 and 1600 kilograms per cubic meter.

Before the industrial revolution and burning of significant amounts of fossil fuels, scientists estimate that the level of carbon dioxide in the atmosphere was 280 parts per million. We are now at 393 ppm. Anything beyond 350 ppm is considered unsustainable as it will heat the earth (greenhouse effect) beyond tolerable levels. One part per million of CO_2 in the atmosphere is equal to 7.8 gigatons (GT or billion tonnes) of CO_2 or 2.125 GT of solid carbon (for illustration, this is about a cubic kilometer of graphite).

Methane: This is a gas with the chemical formula of CH_4. It is the main component of natural gas and a potent greenhouse gas, one unit trapping as much reflected sunlight as 25 units of carbon dioxide. It is produced by anaerobic respiration from bacteria, termites, and in the rumens of ruminant animals such as cattle.

Nitrous Oxide: This is a gas with the chemical formula of N_2O. It is known as "laughing gas" due to the euphoric effects of inhaling it. Nitrous oxide gives rise to NO (nitric oxide) on reaction with oxygen atoms, and this NO in turn reacts with ozone. Considered over a 100-year period, it has 298 times more impact (global warming potential) per unit mass than carbon dioxide.

Note: When encountering calculations involving Methane and Nitrous Oxide, some writers will automatically convert them into their CO_2 greenhouse gas equivalents (i.e. equate a methane molecule to 25 carbon dioxides, and a nitrous oxide one to 298 carbon dioxides). Be ready for these molecules to show up as CO_2 conversions, without clear explanation.

Calculations

We can now calculate how much carbon is contained in an acre of top soil when that top soil is 6 inches deep and has an organic matter of 1%. We can also calculate how much carbon dioxide that carbon is sequestering.

Taking an average soil weight of 1400 k/m^3, the top inch of a square meter of soil will have a weight of 1400 kilograms divided by 39.3701 (inches in a meter) or 35.56 kilograms, and the top six inches will have 6 times that much, or 213.36 kilograms. If the six inches of top soil in a square meter weighs 213.36 kg, by the magic of the metric system we see that the weight of a hectare of that top soil is 2,133,600 kg. But we want to know about an acre of it, so we divide by 2.4711 and find the answer is that 6 inches of top soil weighs 863,421.1 kg per acre. Now only 1% of that is soil organic matter (SOM), so we now have 8,634.211 kg of SOM. And only 58% of that is carbon, so we are down to 5,007.8 kg of carbon.

That is pretty close to 5 tonnes (metric tons) of carbon, so lets call it that. Since all that carbon was put there by the magic of photosynthesis – the plant using sunlight to combine carbon dioxide (CO_2) from the air with water (H_2O) from the soil to make carbohydrates (usually with the form $C_m(H_2O)_n$ where $_m$ could be different from $_n$) for the plant and giving back oxygen to the air – we know those 5 tonnes of carbon came from 3.67 times as much carbon dioxide. So the answer, dear class, is that the acre of top soil with 1% organic matter has sequestered 18.35 tonnes of carbon dioxide.

Indulgences

That's no slouch of a number. The average US citizen's share of emissions, with all our fossil fuel addictions, according to the United Nations is less than that much carbon dioxide annually (17.5 tonnes to be exact.) Of course the average Bangladeshi emits 0.38 tonnes, and your typical Zambian manages only 0.19. But if you are looking for a way to assuage your guilt and justify your lifestyle to posterity, building a percent more organic matter in the top soil of an acre of your field or yard or community garden every year is not a bad way to go about keeping your head held high!

How does this calculation hold up for the task at hand globally? Hold onto your hats!

If we are at 393 ppm CO_2 in the atmosphere now, and want to get back to the sustainable level of 350 ppm, we need to store 43 ppm somewhere. If each ppm is equal to 7.8 GT of CO_2, we need to store a total of 7.8 GT times 43, or 335.4 GT of CO_2. This may seem like a daunting task, even for organic farmers. But let's do the numbers.

The land area of the globe equals 149.4 million square kilometers. If you take the 38% of that which the World Bank says is agricultural land, you have about 56.8 million km^2. This, again by the magic of the metric system, is 5.7 billion hectares. One has to look up the conversion factor, of course, to find that this equals 14 billion acres.

If an increase in 1% of the organic matter of soil in an acre will sequester 18.35 tonnes of CO_2, then 14 billion acres could sequester 256.9 billion tonnes. This is more than three-quarters of the CO_2 that we need to sequester to get back to 350 ppm, the level of sustainability – all for increasing soil organic matter by one percent!

None of this, of course, would be easy. But isn't it nice to know that soil can do that? It even turns out that with proper practices much of that carbon can be stored for centuries as humus. And the best part of it is that doing all this will improve the fertility and water retention capacity of your fields, give you better crops and make you more productive as a farmer.