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Soil Carbon Restoration: Can Biology do the Job? Part One

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Key Points

- Weather anomalies are difficult to document, however, recent studies have found that mean temperature, precipitation and air moisture levels have all risen.
- Many scientists believe that unpredictable weather extremes are the result of human activity and an overwhelming percentage of climate scientist have concluded that human-caused climate change is happening.
- Deep ice core analysis has detected early spikes in atmospheric carbon dioxide and methane that correspond to agricultural expansion thousands of years ago in Mesopotamia and China.
- Lowering human emissions of greenhouse gasses is not enough, carbon must be extracted from the atmosphere and stored in a safe and stable environment.
- Storing atmospheric carbon in soil, where the carbon originally came from, has the potential to reduce atmospheric carbon to improve the quality, productivity and resilience of soils.

Introduction

A great deal of discussion in scientific and governmental circles continues to focus on how to deal with greenhouse gas emissions and the resulting weather extremes they create. Most analysts believe we must stop burning fossil fuels to prevent further increases in atmospheric carbon, and find ways to remove carbon already in the air if we want to reduce further weather crises and the associated human tragedies, economic disruption and social conflict that they bring.

Where, however, can we put that carbon once it is removed from the air? There is only one practical approach – to put it back where it belongs, in the soil. Fortunately, this is not an expensive process. But it does take large numbers of people agreeing to take part. Since few people will change what they are doing without a good reason, we have written this short paper. We hope it explains the problem of carbon dioxide build-up and climate change, how carbon can be taken out of the atmosphere and restored to the soil, and the advantages that can come to farmers and consumers from growing in carbon-rich soils.

Analysis

Climate Change

Weather anomalies are notoriously difficult to document. To do so requires good data over a long time, and clear standards for what constitutes an anomaly. Recently, however, as more and more people are interested in the topic, development of the data and standards has progressed. The key factors in extreme weather are excessive heat, precipitation, and air moisture. Recent studies have found that monthly mean temperature records, extreme precipitation events, and average air moisture content have all risen over the last 50 to 150 years. (Coumou)

Many scientists believe that the cause of such unpredictable extremes is the "anthropogenic" (originating in human activities) build-up of greenhouse gases in the atmosphere. Rigorous modelling studies and analyses of extreme weather events have found human-caused climate change to be a contributing factor in many such extremes. (Peterson) According to the American Association for the Advancement of Science, "Based on well-established evidence, about 97 per cent of climate scientists have concluded that human-caused climate change is happening.” (AAAS)

How Greenhouse Gases Cause Climate Change

Greenhouse gases, primarily carbon dioxide but also methane, ozone and nitrous oxide, have for millions of years been emitted from soil and water into the atmosphere by natural processes like animal respiration, swamp out-gassing and releases from nitrogen fixing bacteria. (EPA) Those gases are also broken down by natural processes and returned to their sources in a continual cycle. If the amount of greenhouse gases emitted and the amount returned to sources remain balanced, they will not cause climate change.

We need a certain level of greenhouse gases in the atmosphere. They trap solar radiation so that the earth reflects less of it back into space. This raises the amount of heat driving the planetary forces that cause weather. If we did not have some such gases, earth would be frozen year-round and far too cold for human life.

The level of a gas in the atmosphere is measured in units called “parts per million” (ppm). Nitrogen, Oxygen and Argon, the primary gases in our atmosphere, collectively account for 999,000 ppm. Throughout human history the atmospheric level of carbon dioxide has stayed at roughly 280 ppm, or less than 0.03 per cent.

Human Disturbance of the Carbon Cycle

Since the dawn of agriculture some 12,000 years ago, however, human caused deforestation, land clearings and crop tillage have released excess carbon dioxide. Using deep ice core analysis and techniques, scientists have detected early spikes in atmospheric carbon dioxide and methane that correspond to agricultural expansion thousands of years ago in Mesopotamia and China. (Amundson)

More recently, since about 1750, with the rapid increase in the burning of fossil fuels and the more recent industrialization of agriculture, the scale and number of human-caused sources of greenhouse gases have increased dramatically. With more coming out of the ground now, and less returning to it, the level of carbon dioxide in the air is growing and now stands at 400 ppm.

Scientists have estimated that we need to get the atmospheric carbon dioxide level back to about 350 ppm to avoid catastrophic climate change. (NASA) (Many researchers argue that a safer goal is closer to the pre-industrial level estimated at 275 - 280 ppm, but most public debate has settled on the 350 number.) One ppm of carbon dioxide in the atmosphere is equal to about 7.8 Gt of it. A molecule of carbon dioxide is mostly oxygen and the carbon in that molecule is only a little over a quarter of it (27.3 per cent to be precise). Thus, one ppm of atmospheric carbon dioxide contains 2.125 Gt of carbon (for purposes of illustration this is about the size of a cubic kilometre of solid graphite).

We need, therefore, to be living with carbon dioxide at or below 350 ppm but it is already 400 and growing. What can we do?

Lowering Emissions

There is no question that humanity needs to stop releasing excessive amounts of greenhouse gas. It is estimated that about two thirds of those emissions are because of our burning of fossil fuels. (Ontl) We need to end our reliance on fossil fuels and develop alternative sources of energy. This is well known by governments. International groups have been established to further this goal. It is likely to be one of the hardest changes to make in human history, but we need to find the policies and mechanisms to make this happen if we want to survive. But that is not our only problem.

Hypothetically, if we could stop all emissions tomorrow, the greenhouse gas that we have already released into the atmosphere will continue to heat the globe for decades and perhaps centuries. That heating will melt ice and frozen soils, raising sea levels and releasing large quantities of greenhouse gas still frozen.

This is a potential problem in the arctic, for instance. There an abundance of frozen methane, a potent greenhouse gas, can be released into the atmosphere by melting. An enormous amount of carbon is also frozen in permafrost. A warming environment can expose this to digestion by microbes, in which case it will be exhaled as carbon dioxide. If that digestion happens where there is no oxygen, like a swamp or wetland, that carbon will be released by other microbes as methane. (NSIDC)

So, lowering emissions is not enough. Once we do that, we must also stop the rise in global temperature. If we are at roughly 400 ppm carbon dioxide now and want to get back to 350 ppm quickly, we need to take carbon out of the atmosphere and bury it somewhere. We need to find a long-term home for 50 ppm of carbon dioxide, which is 106.25 Gt of carbon. Can that be done?

Carbon Sequestration

We cannot safely store atmospheric carbon in the 70 per cent of the planet that is covered with water. Carbon dioxide dissolves in water and forms carbonic acid. For decades now we have been seeing the effects of a gradually increasing amount of carbonic acid in our oceans. Oceanic pH has been falling and acidification has been killing many forms of sea life, including shellfish, corals, and plankton. (NOAA)

Storing carbon in the soil, however, is a different story. That is where the carbon came from, and where it is needed. Scientists estimate that since the industrial revolution land clearing and cultivation for agriculture have released 136 Gt of carbon from the world's soil. (Lal 2004) So by our clearing land and tilling fields, soil has lost more carbon than we need to put back. How much carbon does the soil still contain? Vastly more. Again, scientists estimate that in the top 30 centimetres (about a foot) global soils contain around 700 Gt of carbon. If you count the whole top meter of soil (over 3 feet) that number more than doubles to about 1500 Gt. (Powlson) Clearly the soil, which once contained all this carbon, can do so again.

But before we try to answer the question about putting 106.25 Gt of carbon in the soil, let us understand the soil a little better.

Soil Carbon Hunger

Soil is literally alive. It is full of bacteria, fungi, algae, protozoa, nematodes and many, many other creatures. In a teaspoon of healthy soil, in fact, there are more microbes than there are people on earth. (Hoorman) Of course, as carbon-based life forms, this teeming community requires constant supplies of organic matter to survive. That organic matter (about 58 per cent of which is carbon) comes in the form of living organisms, their exudates, which are often simple sugars, and their residues, often carbohydrates like cellulose. These compounds are rich in energy, readily accessible to organisms, and rapidly assimilated by soil microbes. The half-life of simple sugars in surface soils, for instance, before they are consumed, can be less than one hour. (Dungait)

This tremendous appetite of soil organisms for carbon means that in healthy soil they quickly consume available organic matter. It is taken up into their bodies or is burned as energy and carbon dioxide is given off. Microbes in an acre of corn in fact exhale more carbon dioxide than do 25 healthy men at work. (Albrecht)

Once those microbes die the carbon in their bodies becomes available for other organisms to decompose and exhale.

The activity of soil organisms follows seasonal as well as daily cycles. Not all organisms are active at the same time. At any moment in time most are barely active or are even dormant. Availability of food is an important factor that influences the population and level of activity of soil organisms. (FAO)

Conclusion

In Part Two of this paper, Jack Kittredge discusses in detail the components of soil highlighting its complexity which is driven by the interrelatedness of these components and importance of the living components of soil, particularly the microbes. Part Two will include a description of the carbon cycle and introduces the topic of stable soil carbon which is discussed in Part Three.

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