A healthy soil contains a myriad of living organisms.

Photos: Georgina Smith/CIAT

THE ROLE OF SOIL CARBON IN MITIGATING CLIMATE CHANGE – LOST CAUSE OR TRIPLE-WIN?

Carbon is the major building block of soil organic matter. And this in turn forms the basis of soil fertility. In this article, our author explains just how closely soil fertility and climate change are linked, the role that the former French Minister of Agriculture's „4 pour 1,000" (4 per 1,000) initiative can play in the context, and what all this means for food security und resilience of small farmers.

By Rolf Sommer

What distinguishes soil from "dirt" is its biology and functionality. A healthy soil contains a myriad of different bacteria, fungi, insects, earthworms and other organisms. Thriving, these consume and produce organic material – humus, or as scientists say, soil organic matter. Humus is what determines a soil's fertility and resilience to a large extent. It can persist in a soil for decades, centuries or even millennia, but it is basically in constant turnover – humus being decomposed and lost as carbon dioxide (CO_2), and new humus being formed. Soils rich in humus can absorb and hold more water, and are usually more productive than soils that have been degraded.

Most of such soil degradation is caused by people and agricultural land use. Degraded soils are often associated with (physical) erosion, unprotected topsoil being washed away by rainstorms and leaving behind barren land. However, in Africa, loss of soil organic matter contributes significantly to soil degradation, which is evident for instance when rangelands are no longer lush and green, or crops don't grow as well as they used to, producing meagre crop yields. This so-called biological or chemical soil degradation is also anthropogenic. Decades of unsustainable land management practices in Africa have rendered many formerly productive soils infertile. Many of the African soils are very old and weathered to start with, and nutrients have been leached over the years. Soil fertility, productivity and soil organic matter are tightly interlinked in these cases.

A HUGE POTENTIAL

What does this have to do with soil carbon and climate change? First of all, needless to say, carbon (C) is the major building block of organic matter. This means that when we talk soil organic matter we talk soil (organic) carbon at the same time. Globally, soils contain a lot of carbon: about 1,500 gigatons (Gt), or billion tons, to a depth of 1 m and 2,400 Gt to 2 m. This is three times the amount of carbon that we currently find as CO_2 in the atmosphere (~830 Gt C), at least four times the amount of all biomass on our planet (~400–600 Gt C), and 240 times the current annual fossil fuel emission (~10 Gt C). Given this massive stock, if we were able to increase the net soil C storage globally only a little bit each year, this would represent a substantial C sink! The potential of the soil to sequester carbon can lessen the intensity of climate change and become a critical mitigation measure, if it is well leveraged. However, as yet, this potential is not well enough tapped.

At least since states agreed the Kyoto Protocol in 1997, combating climate change by reducing net greenhouse gas emissions has been high on the agenda. CO_2 is by far the biggest contributor to these emissions.

THE 4 PER MILLE INITIATIVE – A REALISTIC VENTURE?

What is the potential to sink carbon in soils? Our most recent, optimistic rates (0.9-1.85 Gt C) range between 9–18 per cent of all annual emissions caused by fossil fuel burning. Other scientists are even more optimistic: Two years ago, French scientists defined the aspirational goal to mop up a significant share of all newly emitted CO_2 through soil organic carbon sequestration and halt the annual increase in atmospheric CO_2. To achieve this, the C-stock of the top 40 cm of all soils (~820 Gt) would have to increase by approximately 4 per mille (0.4 %) each year, equal to 3.5 Gt of carbon sequestered. Hence the name of this initiative: 4 per 1,000 (which also budgets-in concurrent natural sinks – oceans – and measures, namely reducing emissions from land use change – deforestation – to zero). It was launched by the French Minister of Agriculture at the 2015 United Nations Climate Change Conference in Paris, and without doubt, has since gained tremendous momentum and global interest.

Not to be misunderstood from the start: 4 per mille is a game-changing initiative and deserves our full support. But, as is often the case, the devil lies in the details.

First of all, not all soils on this planet are the same, and soils are exposed to different climates and land uses. Carbon stocks in soils depend on how much organic matter is added to the soil each year, e.g. by retaining crop residues or adding compost, and how much is lost by microbial breakdown of humus, which is a factor of climate, land use and soil properties. To increase soil carbon, either organic inputs need to be augmented or humus breakdown reduced. But soils under pristine forests, for instance, may have reached an equilibrium, i.e. they cannot easily be hoodwinked into sequestering more carbon; management options to do so are limited or absent. This applies similarly to high latitude grassland or tundra soils.

CIAT LONG-TERM TRIALS IN KENYA

Since 2004, the International Center for Tropical Agriculture (CIAT) has maintained two long-term trials in Western Kenya in which the impacts of improved land management practices on the yields of maize and soil fertility are tested. These experiments are very valuable, as trials of this kind conducted long-term in Africa are hard to find, and as it takes longer time spans to be able to evaluate how sustainable certain management practices really are. Two cropping systems – Integrated Soil Fertility Management and Conservation Agriculture – are being tested. Both have in common that organic matter is retained or brought back to the soils to sustain long-term soil fertility. Results indicate that, depending on the amount of organic matter recycled, soils under these systems can mitigate the emission of between 0.25 and 0.7 tonnes of carbon per hectare and year. That sounds little but is enough to offset the amount of carbon emitted by one economy return flight ticket from Nairobi to New York.

Focusing on annual cropland soils therefore seems a good entry point to address the issue.

Yet our research, carried out together with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in Western Kenya, shows that traditional farming practices like tilling the land have contributed to original carbon losses from the soil of 50-70 per cent in the last 30 to 100 years. While such losses illustrate a key challenge for the global community – that soil management is a major factor in whether our soils can sequester more carbon or not – they also show there is potential to "win back" carbon, if land use practices are changed and improved (see Box above).

> On current agricultural land, mitigation and adaptation interaction can be mutually re-enforcing, particularly for improving resilience to increased climate variability under climate change. Many mitigation practices implemented locally for soil carbon sequestration will increase the ability of soils to hold soil moisture and to better withstand erosion and will enrich ecosystem biodiversity by establishing more diversified cropping systems, and may also help cropping systems to better withstand droughts and floods, both of which are projected to increase in frequency and severity under a future warmer climate.
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> Rosenzweig and Tubiello, 2007

Second, even if we all agreed to implement practices that increase carbon in the soil, adoption of such management practices would take time. In other words, not all soils can be turned into carbon sinks tomorrow.

Third, a multitude of studies around the world show that increases in soil carbon over time are slow. In fact, the rate at which carbon can be requested usually slows down and even ceases altogether at some point – often 20 to 30 years after adoption of improved management practices. It is therefore reasonable to assume that the potential for soil carbon sequestration has its limits.

Fourth, the dilemma of a moving target and top-down calculations: unfortunately, greenhouse gas emissions are still on the rise. What constitutes a 4 per mille goal today may have to be bumped up to 5 per mille tomorrow to keep pace with the increases in emissions. Then, soils do not automatically sequester these amounts because the top-down calculated budget demands it. While it is reasonable to find out what a hypothetical increase of global carbon stocks by a certain amount or percentage each year would mean in terms of climate change mitigation, this needs to be backed by bottom-up estimates of sequestration amounts, taking into account the various site-specific factors – such as whether farmers will adopt them and what the incentive would be – as not all soils are the same, and the farmers are the ones that will need to implement changes.

Therefore, it is not surprising that the 4 per mille initiative has been criticised for largely simplifying the issue of carbon sequestration potentials and setting unreasonable aspirations.

HOW TO MEASURE SOIL CARBON

Unfortunately for book-keeping, nature is complex. Soil carbon is no exception. It varies significantly over space and time. Hence, it is not a trivial task to determine carbon in soils and its increase over time, large-scale. This is why scientists are working hard to find easy-to-measure and cheap indicators. While repeated actual soil sampling and lab-based carbon analysis may be the gold standard, indirect measures, such as the infrared spectra of soil properties, that are fast and cheap(er) to measure, or using satellite imagery to derive soil carbon status, can speed up this process of book-keeping.

Mathematical computer models can be leveraged to describe biophysical processes of carbon dynamics in soils, determining further potential to sequester carbon in soils.

Or, as David Powlson from Rothamsted Research in the UK put it: "The point we are making is that the rate of carbon accumulation in soil that is suggested, 0.4 per cent per year every year for 20 years, is almost certainly unattainable … It would therefore be unwise for policy-makers to rely on this rate of carbon sequestration across the globe. … However, no-one wishes to criticise the positive and laudable aims of the initiative."

In conclusion: despite all the simplifications, the 4 per mille initiative puts soil organic carbon sequestration as a means to mitigate climate change on the global agenda – where it belongs!

EVERY LITTLE BIT HELPS!

Even if we scale down expectations and move back to sequestration estimates that seem more reasonable and in line with previous estimates (e.g. that of Smith et al, 2008), the mitigation effect will be significant. Our 9-18 per cent estimates could help us make agriculture carbon neutral, as direct emissions from agriculture (excluding deforestation) add approximately this percentage of greenhouse gases to the global balance. Even a lower mitigation target by C sequestration in soils would be worth the effort, because there are no other silver bullet solutions lining up right now that could carry the bulk. Hence every little bit helps mitigate harmful emissions! And, this is only banking on climate change mitigation through soil carbon sequestration. For a centre like CIAT, food security and resilience of smallholder farmers in the tropics is a number one priority. Climate change mitigation is "only" a co-benefit. As outlined at the beginning of this article, the alarming loss of soil fertility is the real issue at hand. Smallholder farmers will benefit the most, and most immediately, by improving their natural resource basis (soils).

But farmers in developing countries are often resource-constrained, and forced to intensify their production, frequently depleting the fertility of their soils in the process. Sequestering carbon and receiving associated payments for this environmental service could help them make the shift a reality. It often takes very little to help farmers adopt more sustainable (and climate change mitigating!) measures, if they are provided with adequate information about the benefits of the shift. For example, microcredit schemes allow farmers to buy the right inputs, such as improved seeds, fertiliser, lime, etc., at the onset of the season, when cash is usually scarce. Providing the right tools (e.g. a shallow weeding tool that reduces tillage intensity and helps protect soils, or something as simple as a wheelbarrow to move compost) can catalyse adoption of practices such as conservation agriculture or integrated soil fertility management. Provision of crop insurance against drought allows farmers to adopt otherwise risky investments in sustainable intensification. In other words, a payment for an environmental service does not need to be a major income-generator, but only has to be big enough to catalyse change.

Bringing organic matter and hence carbon back into the depleted soils of the tropics addresses three climate-relevant issues: increased crop productivity, enhanced farming system resilience, and climate change mitigation. Such triple wins are hard to find in the development arena. Let us seize the opportunity!

While covering only about 3 per cent of the Earth's land area, peatlands hold roughly between 20 and 25 per cent of the world's soil organic carbon stock.

Photo: Berthold Steinhilber/laif

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