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- Translating science into policy and practice

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Improving crop productivity and mitigating climate change by building up carbon stocks in soils of East Africa

Soil humus or organic matter consists of (organic) carbon compounds. Soil humus is essential for the soils' ability to hold water and supply the crops with the nutrients they need.

Food production and resilience to climate change depend on functional soils

There is substantial scientific evidence for improved soil fertility because of raised soil organic carbon (SOC) levels; even more so on degraded soils. Higher soil fertility means higher crop yields and higher resilience to climate variability (figure 1). In the reviewed literature, however, yield was rarely considered in the studies investigating soil carbon.

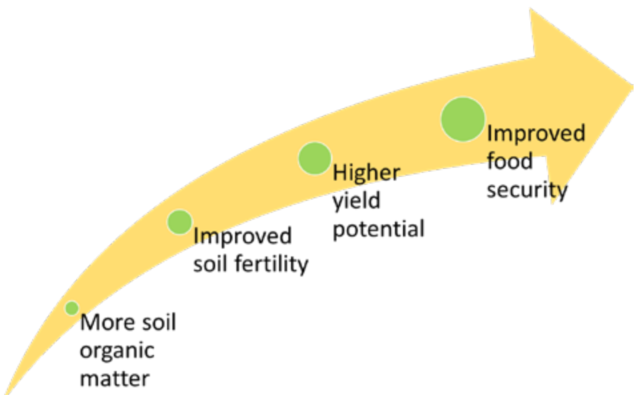

Figure 1. More soil organic matter improves soil fertility and has potential to improve yields and food security.

Key findings:

- Functional, fertile soils are the basis for food security – without carbon, soils do not function.
- Increasing carbon in soils can reduce atmospheric carbon dioxide levels.
- There is scientific evidence that we can affect topsoil carbon stocks in East African croplands by adopting appropriate management practices in the short-term (< 10 years).
- Returning crop residues back to the soil was consistently reported to increase soil carbon. Improved fallow with nitrogen-fixing trees, adding farmyard manure and inorganic fertilizer were also reported to increase soil carbon, but their impact was lower.
- East African grasslands cover large areas but the potential to sequester carbon in those areas is still unknown.
- Long-term spatially representative monitoring of soil carbon in both grasslands and croplands is recommended to remedy identified knowledge gaps.

Soil carbon levels can improve with appropriate management practices

In the short-term, the addition of crop residues was consistently reported to increase topsoil carbon stocks, while using fertilizers or farmyard manure had a positive effect on topsoil carbon stocks in three observations out of four.

In East African grasslands, however, the review could not find sufficient evidence to conclude that long-term land use, i.e. grazing, does impact soil carbon levels positively or negatively. Studies made from limited locations have shown that the average annual organic matter input (decaying grass biomass) into grassland soils is about double to that of cropped soils. This is largely a consequence of crop biomass usually fully removed and utilized as livestock feed, but is also due to perennial grasses producing more biomass in a year than most annual/seasonal crops. Grasslands subject to controlled grazing have higher soil carbon levels than grasslands exposed to unrestricted grazing. However, there is a notable scarcity of data on grassland carbon sequestration in Eastern Africa. Studies carried out elsewhere suggest that pasture improvements, including controlled grazing, fertilization and liming, and the use of more productive grass species and varieties, can generate sequestration gains between 0.1 and 0.3 tons of carbon per hectare and year. But grasslands, or rangelands in general, altogether are harder to manage. These are vast (and often inaccessible) land areas, sometimes, but not always, under communal management by pastoralists, who graze these lands in an opportunistic manner, based on seasonal availability of animal feed, accessibility and need. In Kenya and Tanzania, for instance, joint livestock and wildlife grazing is common. The negative impacts of overgrazing, i.e. the loss of above- and below ground carbon and soil erosion,

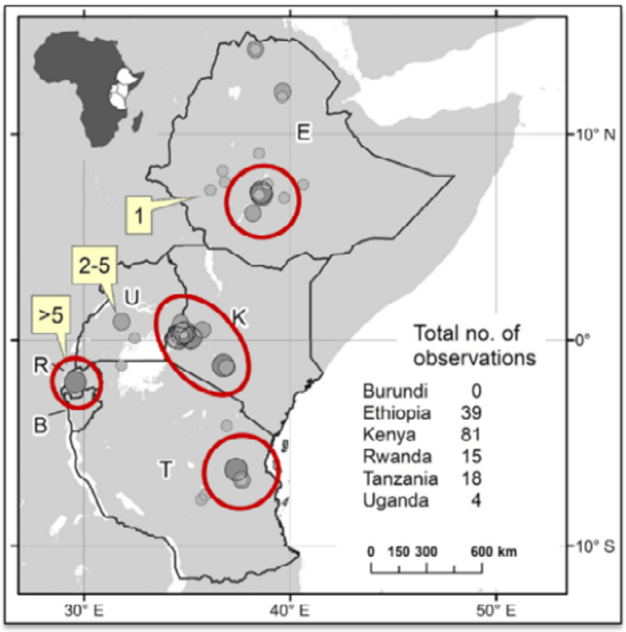

Figure 2. Hard data on effects of changes in management and/or land use on soil organic carbon content are spatially clustered to research hotspots.

Wildlife and livestock grazing on grasslands in Central Kenya.

Smallholder farming landscape in Western Kenya.

can only be addressed by restricting access to these lands (exclosures), which often comes with significant trade-offs for the users of these resources.

Large knowledge gaps

There is very little quantitative knowledge on how soil carbon levels in East Africa are affected by management in the long run. These knowledge gaps are on the one hand simply a consequence of too few studies. On the other hand, changes are hard to trace, as soils are dynamic systems, where it can take decades after a management change until changes become apparent, and even longer until a new equilibrium is reached. To be able to clearly pinpoint in which direction soil carbon stocks are moving, it is necessary to observe soil organic carbon changes over longer times. But, such long-term studies in East Africa are rare.

The majority of research published in accessible scientific papers – and hence included in our literature study – on carbon in East African agricultural soils (annual or perennial crops and grassland) describes short-term studies, less than 10 years. Some of these are just one-time snapshots. Furthermore, most studies only consider the topsoil (15-20 cm soil depth). Long-term studies on soil sequestration in East Africa exceeding a period of 25 years are the exception. Not surprising, thus our understanding of long-term soil sequestration in East Africa is largely based on computer modelling with little supporting evidence to underpin these predictions. Also, published research studies are geographically clustered to a few intensively researched regions (see figure 2), which means that little is known on the effects under conditions prevailing in other regions, and only 20 % of the reviewed studies considered the implications on crop yield. We therefore recommend investing in representative long-term soil carbon monitoring where both carbon stocks and crop yields are measured in parallel.

Deep soils – future potentials to sink more carbon

Current knowledge about carbon in soils below 0.2 m depth is humble in the tropics, and East Africa is no exception. But, bringing carbon into deeper soil layers, e.g. by grasses with a deep-rooting system, offers significant potential to store substantial amounts of carbon, where it is less susceptible to fast turnover and loss in response to unsustainable land use. Past and present research carried out by scientists from the International Center for Tropical Agriculture (CIAT) in Latin America on the issue shows tremendous opportunities for capturing carbon in deep soils, while East Africa has received no attention in that regard so far.

Land use history – a major driving factor for how soils accumulate carbon

As our literature review and further field sampling of soils in strategic locations have shown: land use history matters a lot in terms of how much carbon a soil could sequester. There is usually a fast-downward trend of soil organic carbon happening the first few years after conversion of pristine land (forest, peatland) to agriculture. Our data from Western Kenya show that soils keep losing carbon after such land use change for more than 70 years. Adopting improved land management of such converted agricultural land – with the aim to sequester carbon – may still result in a loss of soil carbon over time, up to a point when soil carbon levels are stabilized after which net carbon sequestration is possible. Still, adoption of improved land management practices, even if not leading to a net sequestration, will still slow down losses of carbon considerably, the magnitude of which is a matter of the intensity of the conservation practice imposed.

Management decisions are made in a complex context

It is worth pointing out that recommendations on soil and agricultural management practices to farmers should not be based solely on their effect on soil carbon. The landscape and the farming systems are complex, and bio-physical and socio-economic aspects need to be considered before handing out recommendations or subsidizing specific management practices, not least the effects on crop yields and rural livelihoods.

Recommendations for increasing soil organic carbon in East Africa

- Return crop residues to the soil, introduce agroforestry and fallow with nitrogen fixing trees, tailoring recommendations to site-specific biophysical conditions and the farming system.
- Grasslands of East Africa are a big unknown altogether. We do not know whether these lands currently sequester or lose carbon, as data are extremely scarce. Further systematic field surveys are needed to address the issue, in combination with studies that quantify the potentials to sequester carbon in grassland after adoption of improved management practices.
- Invest in experiments or monitoring programs in eastern Africa designed to investigate long-term effects of agricultural management practices on soil carbon levels under different biophysical conditions! Effects on yield should be recorded in parallel.

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It is based on two reviews of scientific literature, focusing on the potential to improve soil carbon in East African croplands and grasslands.

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