CIAT
International Center for Tropical Agriculture
Since 1967 ***Science to cultivate change***

Unlocking the potential of soil organic carbon in agricultural landscapes in Kenya and Ethiopia

Soils are a very important component of the global carbon cycle as they contain the largest sink of carbon in the terrestrial biosphere. At the same time, soil organic carbon (SOC) is the basis for soil fertility and the production of food to feed the growing global population. Healthy soils are not only important from an agricultural production point of view, but they also provide a multitude of other benefits that are critical to human well-being.

Benefits of increasing soil carbon

Climate change mitigation

Soils under **sustainable management** practices play an important role in mitigating **climate change** through **carbon sequestration** and reducing CO_2 **greenhouse gas emissions**

Improved nutrient cycling

Increasing **organic matter inputs** to the **soils** improves **nitrogen cycling** through **reducing nitrate leaching risks**

Enriched soil biodiversity

Soils that are **rich in SOC** support a wide variety of living **organisms** which are **essential** for the **cycling** of **ecosystem nutrients**

Improved water retention

Higher **SOC** improves **soil structure soil aeration,** and **water retention** thus **reducing the risk of soil erosion**

Improved food security

Soils rich in **SOC** have **high crop productivity**

Reduced agricultural production costs

Enhancing **SOC sequestration** can **reduce the long-term needs** for mineral fertilizer, i.e nitrogen

What practices improve soil organic carbon?

Adopting improved management practices that reduce soil disturbance and increase soil carbon inputs to the soils can contribute to sequestering SOC. Traditional farming practices such as continuous tilling in croplands have resulted in soil organic carbon decline. Some of the widely promoted soil management practices in the sub-Saharan Africa include: conservation tillage practices, such as no-till and minimum-till, crop residue retention, cover crops, adding organic matter, such as manure and compost, crop rotation or intercropping, and agroforestry.

MANAGEMENT	FUNCTION
Conservation tillage practices	Reduce soil disturbance and respiration from the soils
Crop residue retention	Increases organic matter inputs and soil nutrients, promotes soil water retention and reduces soil erosion
Cover crops and crop rotation	Cover bare ground during planting seasons, reduce erosion and prevent nutrient losses through leaching and runoff. Improve SOC through increasing above- and below-ground vegetation biomass
Fertilizer application	Improves the soil nutrient to maintain high crop productivity, which directly enhances SOC through increased biomass inputs
Manure and compost application	Enhances nutrient supply to improve the health of crops and soils. Organic amendments improve soil structure and the water holding capacity in soils
Intercropping	Intercropping cereal crops with legumes allows the crops to benefit from the nitrogen that is fixed by legumes. This increases crop production and enhances SOC through more above- and below-ground biomass transfer to the soils
Agroforestry	Incorporation of trees in agricultural systems increases the above- and below-ground organic matter inputs. Trees reduce soil erosion, enhance soil water retention, and increase the organic matter inputs to the soils

Evidence, decision tools and engagement to catalyse action for soil carbon

The multiple benefits and importance of improving soil carbon are recognized, but there is a need to turn this is into on-the-ground action through site-specific information, tools to guide decision-making, and engagement in key policy and program processes. An interdisciplinary team of researchers is working on understanding the biophysical aspects of SOC in agricultural systems in Kenya and Ethiopia, quantifying the biophysical and economic benefits of improved agronomic management practices, and assessing the socio-economic barriers that limit the adoption.

EVIDENCE GUIDING OUR RESEARCH

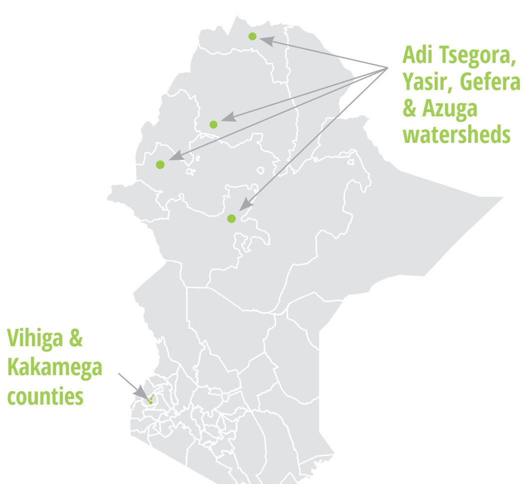
- Biophysical ability to sequester carbon in different contexts
- Socio-economic opportunities and constraints to farmers adopting soil carbon enhancing interventions
- Policy action for promoting soil carbon enhancement

DECISION TOOLS

- Watershed-level soil carbon hotspot mapping tools
- Biophysical models for targeting soil carbon enhancement interventions at local and national scale
- Ex-ante cost-benefit analysis tools for quantifying the economic benefits of soil carbon enhancement

ENGAGEMENT

- Global policy processes (e.g. UNFCCC, etc.)
- National policy and strategic guidance
- Regional program and project support



Examples from the field

Evidence guiding our research

SOC is influenced by many factors such as land use and management, soil texture, and climate. In cropland areas, the amount of SOC varies with the agronomic management practices. Although evidence from observed studies remains scarce, data gathered from published studies over the East Africa region show that SOC sequestration from crop residues retention, farmyard manure application, and inorganic fertilizers can be up to 19.7, 14.8, and 35 t C ha^{-1} yr^{-1} in the East African region.[1] However, to scale up the adoption of these practices, extensive research is still needed to quantify their SOC sequestration potentials and other co-benefits.

1 Namirembe S; Piikki K; Sommer R; Söderström M; Tessema B; Nyawira S. 2019. Soil organic carbon in agricultural systems of six countries in East Africa – a literature review of status and carbon sequestration potential South Africa Journal of Plant and Soil, in press.

Furthermore, farmers often also require more information on the co-benefits of these practices, mainly yield benefits.

Data gathered from the literature and data-bases WOCAT (World Overview of Conservation Approaches and Technologies) and CIAT best-bet management practices provides useful information on some of the critical factors that determine the adoption of improved soil management practices. These factors can be broadly grouped into four categories: socioeconomic, plot-level, biophysical, and institutional. Using this data, statistical analysis shows that factors such as farm income, benefits vs. maintenance costs and access to technical assistance can negatively influence the adoption rate of the common improved agronomic management practices in Kenya and Ethiopia.[2] Therefore, in designing alternative management practices at the household level, it is important to consider the cost implications for farmers and the derived monetary benefits.

Policy interventions ensure that soil carbon is managed in sustainable ways. Our assessment of the existing agricultural policies in Kenya and Ethiopia reveals a need to formulate direct and specific policies to regulate the protection, utilization, and management of soil carbon. The existing indirect policies that impact on soil carbon are scattered across policy areas with disjointed implementation approaches. To develop effective and appropriate direct policy at regional and national level, policy makers need to be well informed of the importance of soil carbon, and extensive research is still needed to identify the priority areas and the effective management practices.

Decision tools

Hotspot SOC mapping approach

We have developed a new method for assessing the achievable SOC sequestration based on a non-linear boundary approach.[3] The method uses observed data on the current SOC and soil texture. The approach has also been extended using weather, soil and topographic data to enable us to predict achievable SOC at any location of interest. This approach quantifies the SOC that can be achieved by the farmers adopting the best management practices in the neighbourhood. We are using this approach for mapping the hotspots for SOC sequestration in selected watersheds in Kenya and Ethiopia.

SOC modelling tools

Models allow us to quantify SOC across complex landscapes and provide useful tools for assessing impacts of different management practices on SOC and the associated co-benefits. At the local scale in Kenya, we are using the CropSyst and DayCent models in Kenya to quantify the SOC changes that can be expected with farmers shifting from conventional management to improved practices. In addition, the RothC model is also being applied in Ethiopia to examine the impact of upscaling strategies of different land and agricultural management practices at the national level. An ex-ante cost-benefit analysis will be conducted to assess the feasibility of different improved management practices. In both countries, the SOC benefits associated with large-scale adoption of no tillage, residue retention and cover crops, and broadly conservation agriculture, are being assessed using the LPJ-GUESS global vegetation model. The modelling framework of LPJ-GUESS enables us to investigate the trade-offs between the agricultural ecosystem services, mainly crop production, water pollution, and carbon balance using yields, nitrogen leaching, and SOC as the key indicators, respectively. The effectiveness of these practices with climate change is also tested using the representative concentration pathways (RCPs) scenarios.

Socio-economic assessment survey tools

Detailed household level surveys have been developed to assess the physical characteristics of farmers' plots, rate of adoption of soil enhancing practices, such as agroforestry, mulching, manure and fertilizer application, and their income levels. The Evaluating Land Management Options (ELMO) tool is being used to assess how farmers perceive different land management options in terms of the required costs and inputs, their benefits and desired outcomes as well as how they gauge their advantages and disadvantages. The data gathered using the survey and the ELMO tool is critical for identifying the opportunities and constraints for adoption of soil enhancing practices in the case study areas in Kenya and Ethiopia.

Engagement

To disseminate our research and to be able to reach many beneficiaries, we are collaborating with two program partners: the Sustainable Land Management Programme (SLMP) in Ethiopia and GIZ in Western Kenya through the Soil Protection and Rehabilitation for Food Security Program. The tools developed and the knowledge acquired in various contexts within our work will help these programs in designing and implementing improved soil management practices for farmers. At the national level, our research will play a critical in guiding the implementation of policies to meet the targets set within the United Nations Framework Convention on Climate Change.

2 https://cgspace.cgiar.org/handle/10568/96175; https://hdl.handle.net/10568/105710
3 https://cgspace.cgiar.org/handle/10568/102387

CIAT's research is made possible by the multi-donor CGIAR Fund as well as by grants from many organizations, some of which are also Fund donors. This work is funded by the Federal Ministry for Cooperation and Development (BMZ), under the "Scaling up soil carbon enhancement interventions for food security and climate across complex landscapes in Kenya and Ethiopia" project. The project is undertaken as part of the CGIAR Research Programs on Water, Land and Ecosystems (WLE). We are grateful to all who support our efforts to build an eco-efficient future for tropical agriculture through high-quality science.

Socio-economic assessment framework

FOCUS GROUP DISCUSSIONS
(With farmers informed by literature review)

SUSTAINABLE LAND MANAGEMENT PRACTICE

Household surveys in farms

1. Barriers to adoption (biophysical, socio-economic and institutional)
2. Impacts of adoption on crop production

ELMO tool for assessing farmers' perceptions
(Ranking and scoring by farmers)

1. Benefits and desired outcomes (i.e. nutrition, cow feeds, incomes, crop yield, soil fertility)
2. Costs and inputs implications (i.e. labour requirement, seeds)
3. Advantages and disadvantages (e.g. soil erosion reduction, less technical knowledge)

Modeling framework

Conventional farmer practices
(e.g. tillage, no residues, little manure and fertilizer)

Improved management practices
(e.g. reduced tillage, with residues, increased manure and fertilizer)

Crop-soil models

Yield, SOC under farmer practice
(expected to be low)

Yield, SOC under improved practice
(expected to be high)

Farmer costs for conventional practices

Cost-benefit analysis
(Decision tool for feasible management practices)

Farmer costs for improved management practices

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SLU Swedish University of Agricultural Sciences
EIAR Ethiopian Institute of Agricultural Research
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