Info Note

Building soil carbon stocks to enhance adaptation and mitigate climate change in climate-smart landscapes, Southern Ethiopia

Preliminary results from climate-smart agriculture practices in Doyogena district

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Key messages

- Loss of soil carbon and accelerated organic matter decomposition from agroecosystems due to unsustainable land management undermines crop productivity.
- Integrated climate-smart landscape management reverses soil carbon loss, rehabilitates degraded agroecosystems, and builds synergies between adaptation and mitigation co-benefits for food security.
- Agroforestry practices and technologies have the potential of building soil carbon stock in landscapes.
- Longer duration of implementation of CSA interventions contributes significantly to enhancing soil carbon stocks with benefits towards climate change mitigation and resilience in landscapes.

Introduction

Climate change is a major challenge, particularly for Ethiopia's rural populations who depend on rainfall for subsistence farming and are therefore more vulnerable to climate-related risks. Agriculture accounts for more than 40% of Ethiopia's gross domestic product (GDP) (UNDP, 2015), and contributes significantly to greenhouse gas (GHG) emissions (FDRE, 2015). In Ethiopia, annual GHG emissions were estimated to be 150 Mt CO_2e in 2010, with 50% of emissions coming from agriculture, and another 37% from forestry sectors — mainly agriculture related deforestation (FAO, 2016). Furthermore, the capacity of Ethiopia's agricultural, forest, and grassland sectors to act as carbon sinks is decreasing rapidly due to unsustainable agricultural practices. Since 2011, the federal government of Ethiopia has embarked on implementing the Climate Resilient Green Economy (CRGE) strategy. CRGE has ambitious commitments in its Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC), to "climate-proof" Ethiopia's Growth and Transformation Plan (GTP) by curbing its GHG emissions by more than half by 2030, while also building resilience against climate risks and future climate change. As set forth in the second GTP, reaching this goal will require boosting agricultural productivity by introducing climate-smart technologies and practices that include integrated watershed management, conservation agriculture, as well as nutrient and crop management across agroecosystems and landscapes with the potential to reduce GHG emissions by 40 Mt CO_2e in 2030 (CRGE, 2011).

Farmers in Doyogena district of the Southern Nations, Nationalities, and Peoples' Region (SNNPR) face different climate-related risks. These include increasing rainfall intensity and variability, water stress, soil erosion, deforestation, severe land degradation and fragmentation, declining soil fertility, shortage of livestock feed, and increased incidence of crop and livestock diseases and pests. To address the challenges in this hotspot, a development partner, Inter Aide, started a pilot project in several villages in 2006. Subsequently, a USAID funded project known as Africa Research in Sustainable Intensification for the Next Generation (Africa

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RISING) was initiated in the community in 2012 targeting additional villages (ILRI, 2015). Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security—particularly for women and children—and conserve or enhance the natural resource base.

Methods

To be able to assess the effect of the CSA interventions on soil carbon, a study was undertaken in Tula-Jana landscape in April 2018. The landscape has an annual rainfall ranging from 1,000 to 1,400 mm. It has a bimodal season where the short rainy season (*Belg*) is from January to March, and the long rainy season (*Meher*) spans June to October. The altitude ranges from 2420 to 2740 meters above sea level. Temperature ranges from 12°C in the cold periods to 28°C during the warm periods, respectively.

Soil sampling was done in three replicates from five different land uses: business as usual (BAU) under conventional management; cropland under CSA practices; agroforestry that involves enset *(Ensete ventricosum*) plantations; grasslands; and community forests established for 14 years with mainly *Acacia decurrens* trees. In addition, the topsoil of an undisturbed indigenous forest was sampled as a comparison. With this rationale, a soil sample (0-15cm) was taken from this land use as the baseline scenario for the current study. Cropland included annual field crops: wheat, barley, potatoes, and faba beans. Specific CSA practices included soil-water conservation structures (soil bunds) strengthened by grasses — desho grass (*Pennisetum pedicellatum*) and elephant grass (*Pennisetum purpureum*) — hedgerow planting, crop residue management, crop rotation with legumes and restricted grazing on croplands.

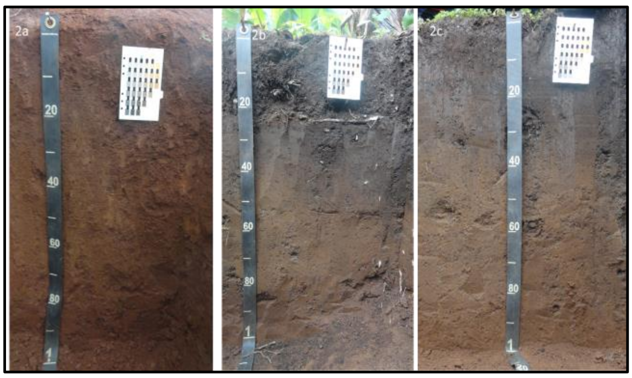

Figure 1. *Selected soil profiles showing land under BAU (2A) and corresponding project scenario agroforestry (2B), and crop land (2C) from Tula-Jana landscape. Photo: G. Ambaw (CCAFS)*

Soil samples were taken for distinct time periods of three years, six years and ten years to evaluate different stages of CSA practice implementation. Soil samples were taken from three depths in soil profiles: 0-15 cm, 15-45 cm and 45-100 cm — to adequately capture soil carbon accumulation in different layers of the soil profile. The samples were analyzed for soil organic matter using the Walkley-Black method for computation of soil carbon stocks. Soil carbon stock mean values were compared for the different land uses.

Soil carbon stock across different land uses

Agroforestry had the highest mean soil carbon stock of 312.1 t/ha that was statistically significant compared to other land uses (Figure 2). Agroforestry is mostly practiced around homesteads, instead of on crop fields, where farmers typically incorporate animal manure to improve soil fertility. This is due to the longer distances between the household and the farmlands. Cropland with CSA had the second highest soil carbon stock of 229.4 t/ha, attributed to crop residues. While cropland had statistically higher carbon levels compared to the community forest, it did not differ significantly from grasslands (208.9 t/ha). Grassland soil carbon stock is mainly a result of belowground carbon in roots and soil organic matter (Solomon et. al 2015). In addition, manure and urine from the animals play a key role in providing nutrients for grasses. Soil carbon stock in the community forest was much lower at 145.4 t/ha, compared to other land uses. This is because the area was highly degraded until restoration started in 2004. The area is characterized by steep slopes without soil and water conservation structures (exposed to higher erosion) and lack of biodiversity as it is mainly dominated by the black wattle (*Acacia decurrens*) tree species. All these factors could have contributed to the lower soil carbon stock in the community forest.

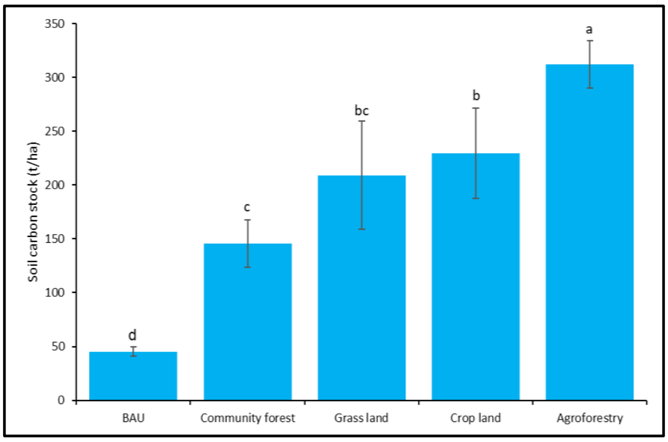

Figure 2. *Soil carbon stock variations at a depth of 100 cm in the different land management systems in Tula-Jana landscape.*

Time effect of CSA implementation within cropland on soil carbon stocks

The period of practicing CSA influences soil carbon stocks within one meter depth. Soil profile carbon stock buildup continued with time (Figure 3) and was statistically higher than BAU. The highest soil carbon stock was observed following ten years of practicing CSA (229.4 t/ha) compared to three years but did not differ significantly within the time series. In addition to mitigation benefits, a one ton increase in the soil carbon pool of degraded cropland can increase wheat yields by 20-40 kg/ha (Lal, 2004 and FAO 2017).

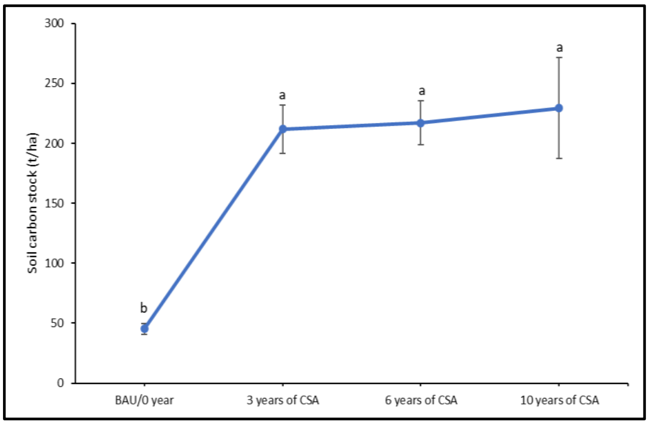

Figure 3. *Soil carbon stocks within one meter depth in relation to period (years under practice) of CSA implimentation in croplands in Tula-Jana landscape.*

Topsoil carbon stocks for different land uses

The topsoil carbon level from agroforestry land use was higher than the other land uses (Figure 4). This could be attributed to enset dominating the agroforestry land use, mixed with vegetables such as potato, cabbage, carrot, beetroot and garlic. Enset is a multipurpose perennial crop with high biomass production as compared to soil in its natural undisturbed state and is planted adjacent to homesteads. Enset has highly decomposable parts such as the leaf, pseudostem and the core that add organic matter to the soil. In addition, farmers deposit high amounts of household waste and animal manure near homesteads for soil fertility improvement which leads to higher soil carbon stock compared to the indigenous forest.

Grassland had a similar level of carbon stock compared to the indigenous forest. This finding shows that grasslands have the capacity to store carbon as much as soils in an undisturbed natural state. According to FAO and ITPS (2015), grasslands contain about 20% of the world's soil carbon stocks.

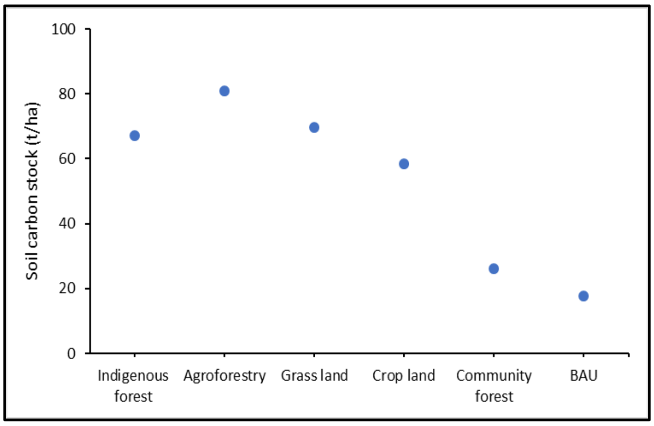

Figure 4*. Topsoil (0-15cm) carbon stocks of different land uses in Tula-Jana landscape.*

Conclusions and policy implications

The findings clearly demonstrate that CSA implementation has the ability to build up soil carbon stocks. For cropland, the soil carbon stock increases over time, implying that the sustainability of adopted technologies must be safeguarded in order to exploit the long-term benefits. Long-term mitigation benefits of CSA can only be realized when adopted technologies are properly managed and maintained.

Different land uses have different soil carbon stocking capacities, which indicates that a landscape approach, integrating CSA at the farm-level with other land use systems including agroforestry, grasslands and forests, needs to be considered to maximize soil carbon stock.

The soil is the largest terrestrial carbon pool. Therefore, storing carbon in soils has high relevance for Ethiopia's CRGE strategy as well as NDC. Given this context, the country needs to develop and implement policies that focus on promoting sustainable agricultural practices such as CSA at the landscape level.

Intervention projects are usually short lived. Therefore, inclusive systems and institutional arrangements need to be in place to ensure the continual use of CSA practices beyond project years.

Further Reading

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