RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

Info Note

The potential of soil organic carbon sequestration for climate change mitigation and food security

Integrated assessment model shows that increasing soil organic carbon sequestration in the agriculture sector could contribute significantly to climate change mitigation and food security

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Key messages

- Soil organic carbon (SOC) sequestration on agricultural land decreases the costs of climate change mitigation while promoting increased food security.
- SOC has the potential to sequester up to 3.5 $GtCO_2eq/yr$ by 2050 in a scenario consistent with 1.5 ºC warming. In total, the SOC sequestration potential in 2050 could offset around 7% of total emissions in 2010 (IPCC, 2014).
- SOC sequestration would occur mainly through improved cropland and grassland management, but restoration of organic soils and degraded lands is also significant.
- SOC sequestration could reduce the negative food security impacts of a carbon tax of 190 $\$/tCO_2eq$ by as much as 65%, compared to a scenario without SOC sequestration.
- Under a carbon price policy, farmers would generate revenue from providing SOC sequestration. Hence, farmers contributing SOC sequestration would remain competitive producers in a high carbon price context.

Soil organic carbon sequestration: a climate change mitigation strategy that could benefit agriculture

SOC sequestration on cropland and grassland is an important mitigation option with potentially significant co-benefits for food security. At a carbon price of 20 $\$/tCO_2eq$, Paustian et al. (2016) identified a technical mitigation potential of 3-8 $GtCO_2eq/yr$ related to improved cropland and grassland management, biochar application, enhanced root phenotypes, and restoration of degraded lands and organic soils. Realizing this potential could offset 6-16% of current greenhouse gas (GHG) emissions.

Nevertheless, the mitigation potential of SOC sequestration is currently not considered in climate stabilization scenarios by the integrated assessment models used by the Intergovernmental Panel on Climate Change (IPCC).

To fill this gap in information, we analyze the potential contribution of SOC sequestration on agricultural land to climate change mitigation and food security using the economic, bottom-up land use model called Global Biosphere Management Model (GLOBIOM). Three mitigation scenarios were built incrementally:

1. A default scenario, where SOC mitigation options were not considered for achieving climate targets (no SOC).
2. A mitigation scenario, where improved cropland and grassland management and restoration of organic soils and degraded lands increased SOC sequestration based on Smith et al. (2008) (SOC).
3. An optimistic mitigation scenario, where the effects of increased SOC plus the effects of increased SOC on yields were considered (SOC+).

Contribution of SOC sequestration on climate change mitigation

Figure 1 presents the implications of considering SOC sequestration in the mitigation portfolio to achieve decreasing radiative forcing levels from 6.0 W/m^2 up to 1.9 W/m^2, the latter level considered necessary to limit global warming to 1.5 ºC.

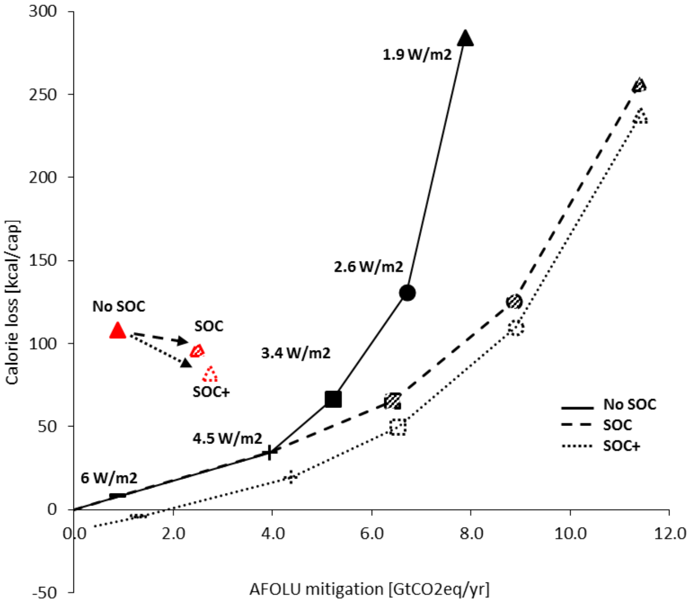

Figure 1. Trade-offs and synergies between annual land sector mitigation and dietary energy consumption by 2050 under a uniform carbon price across sectors consistent with certain climate targets. *Global annual mitigation potential in GtCO$_2$eq/yr in 2050 vs. loss in daily dietary energy (kcal per capita and per day) consumption, compared to a baseline scenario without mitigation efforts. The convex lines represent policies where all countries participate in the mitigation effort for different SOC scenarios. For a 1.5°C scenario (1.9 W/m^2), implications of a regional mitigation policy are shown where only developed countries & China (red triangles) participate. Arrows indicate the impact of including SOC sequestration measures in the climate policy (Frank et al., 2017).*

Results show that incentivizing agricultural SOC sequestration under mitigation policies would increase the cost-efficient contribution of the agriculture, forestry, and other land use (AFOLU) sector from 7.9 GtCO$_2$eq/yr to 11.4 GtCO$_2$eq/yr by 2050. This assumes underlying carbon price levels of 190 \$/tCO$_2$eq, which is consistent with a least-cost achievement of the 1.5ºC target without SOC sequestration measures.

Results show that incentivizing agricultural SOC sequestration would also improve food availability in food insecure countries. More food would be available with SOC sequestration than with stringent mitigation without SOC sequestration policies because SOC sequestration policies would increase the value of carbon-enhancing production systems by paying farmers for providing carbon sinks, Hence, farmers contributing SOC sequestration would remain competitive producers in a high carbon price context and more food could be produced at lower costs, thereby benefitting food security.

Food security would increase further if the positive effects of SOC sequestration on crop yields were included, even while maintaining the level of GHG abatement. Impacts in the SOC+ scenario (+0.9% yield increase per tCO$_2$/ha sequestered) should be considered an upper limit, as yield increases are assumed to materialize on all cropland with SOC sequestration, and not on degraded lands only.

The importance of enrolling SOC sequestration options in mitigation policies and in reducing possible trade-offs between food security and climate change mitigation is more pronounced at regional scales. For example, if developed countries and China mitigated AFOLU emissions and sequestered soil carbon, the total abatement potential would almost triple, while decreasing the trade-off with food security (measured by calorie loss) by 20%, and even further when related increases in yields due to enhanced SOC sequestration are realized (Figure 1).

Trade-offs and co-benefits with food security

While Figure 1 presents the cost-efficient AFOLU mitigation potential for three different SOC scenarios that could be expected for carbon prices consistent with different climate targets (without SOC), Figure 2 shows the minimum AFOLU abatement required to meet the 2.0 ºC and 1.5 ºC climate stabilization targets (2.6 W/m^2 and 1.9 W/m^2, respectively).

Considering SOC sequestration in the mitigation portfolio considerably reduces the negative food security impacts of the 1.5 ºC global climate stabilization target because SOC sequestration delivers mitigation that would have been otherwise achieved through direct cuts in agricultural non-CO$_2$ emissions. In other words, with SOC sequestration, agricultural production levels and food availability are less impacted by climate change mitigation. With SOC sequestration, the total mitigation contribution from agriculture would increase from 2.7 to 3.5 GtCO$_2$eq/yr in 2050, yet loss in calories would be reduced from 285 kcal to 100 kcal per capita. This would bring down the expected increase in chronic undernourishment from up to 300 to 75 million people in 2050.

The carbon price for the AFOLU sector in the 1.5ºC scenario could drop from 190 \$/tCO$_2$eq to 50 \$/tCO$_2$eq due to the availability of SOC sequestration but still meet the expected mitigation of 7.9 GtCO$_2$eq/yr in the AFOLU sector in 2050.

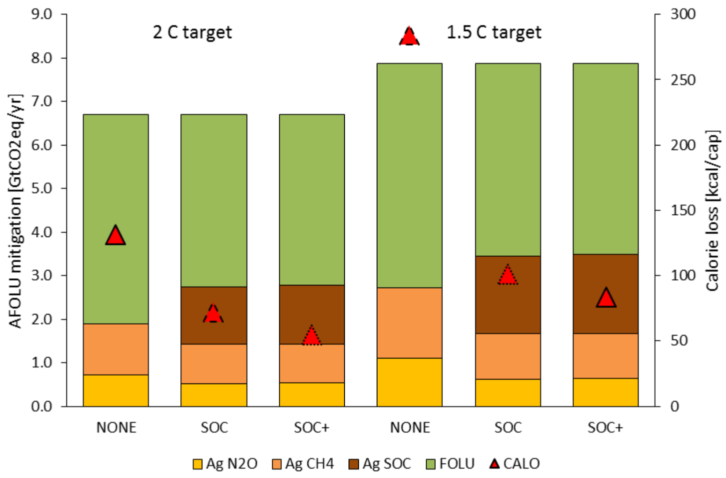

Figure 2. Global AFOLU mitigation option portfolio under two climate stabilization targets and trade-offs with daily dietary energy availability in 2050. *Required abatement is 2.6 W/m^2 for the 2.0ºC target and 1.9 W/m^2 for the 1.5ºC target. The sources of GHG mitigation potentials are: Ag N_2O – nitrous oxide mitigation from agriculture (yellow), Ag CH_4 – methane mitigation from agriculture (orange), Ag SOC – SOC sequestration from agriculture (brown), and FOLU – CO_2 mitigation from forestry and other land use (green). Estimated calorie loss is shown in the red triangles (Frank et al., forthcoming).*

Practical limitations and sensitivity analysis

SOC saturation and permanence of the carbon sink are two important potential limitations that must be taken into account. The sequestration rate of SOC-enhancing management practices decreases over time, as soil can store only finite amounts of carbon, and sequestration rates decline once approaching the new SOC saturation. Hence, most practices deliver additional SOC sequestration only over a limited time span of around 20-30 years (Paustian et al. 2016).

In addition, SOC practices need to be maintained even beyond the saturation point to keep the carbon stored in the soil rather than releasing it to the atmosphere. (Paustian et al. 2016, Smith 2016). Since recent studies show a potential overestimation of the mitigation potential of SOC sequestration, we also tested a scenario with a more conservative assumption on sequestration rates. Halving SOC sequestration rates from Smith et al. (2008) would – not surprisingly – reduce the GHG mitigation potential from SOC sequestration, but SOC sequestration remained an important mitigation option. Projections using half the SOC-sequestration rate in the 1.5ºC scenario would still reduce calorie loss from 285 to 130 kcal per capita in 2050, as compared to a mitigation policy without SOC sequestration. This decrease in calorie loss corresponds to a decrease in the number of chronically undernourished people in the 1.5ºC scenario from up to 300 to 100 million people.

Policy implications

Our analysis showed that by including SOC sequestration on agricultural land, target levels of GHG mitigation can be reached at considerably lower carbon prices and less calorie loss than mitigation scenarios that do not include SOC sequestration. Farmers and others who increase SOC sequestration on their lands will benefit from production subsidies under a carbon price scheme. These benefits will offset additional production costs levied by the same carbon price scheme, allowing these farmers to keep more cropland in production, thus serving to protect their livelihoods and benefit food security generally.

Stabilizing the climate, will require substantial efforts across sectors. Given a) the potential of SOC sequestration to mitigate climate change, b) that it is one of the few operational negative emission technology available today, and c) related co-benefits, further exploration of the possibilities for increasing SOC is warranted in any mitigation and adaptation policy portfolio. For example, in the voluntary ‘4 per 1000 Initiative’ (http://4p1000.org), countries and stakeholders aim to preserve and enhance soil carbon stocks.

SOC sequestration is a no-regret option that offers large co-benefits for soil health, resilience, and food security. Supporting the widespread adoption of these so-called win-win options is indispensable to achieve ambitious climate change mitigation targets with optimal cost-efficiency and tempered impacts to food security.

Further reading

- 4 pour 1000 initiative. http://4p1000.org/understand
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- Smith P 2016. Soil carbon sequestration and biochar as negative emission technologies. *Global Change Biology* 22(3): 1315-1324. Available from http://doi.org/10.1111/gcb.13178

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This series of briefs summarizes findings from the project "Identifying low emissions development pathways" (https://ccafs.cgiar.org/identifying-low-emissions-development-pathways), undertaken by researchers from the International Institute for Applied Systems Analysis in collaboration with the CCAFS Low Emissions Development flagship. Using IIASA's integrated assessment modelling, the project team developed scenarios to identify pathways and priorities for mitigation in the agriculture and land use sector. It is hoped that these results will bring attention to policymakers, donors, and other stakeholders, thereby contributing to the design of AFOLU mitigation policies around the world. The briefs are:

- *Carbon prices, climate change mitigation & food security: How to avoid trade-offs?*
- *Potential of soil organic carbon sequestration for climate change mitigation and food security*
- *Regional mitigation hotspots and sensitive mitigation pathways*

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CCAFS and Info Notes

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). CCAFS brings together some of the world's best researchers in agricultural science, development research, climate science and Earth System science, to identify and address the most important interactions, synergies and tradeoffs between climate change, agriculture and food security.

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