Benefits of increasing soil organic carbon to reduce drought stress in maize under climate change

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Challenges of a changing climate to agriculture: increase in drought events and intensity

While in normal climate conditions a soil with "poor" structure can supply the plant with the water and nutrients necessary for its development, a severe drought event can compromise an entire year of production if the soil is not able of adequately retain and release water to the plants (Figure 1). A better soil structure can be attained with the adoptions of several management options, (e.g. cover cropping, compost application) which most commonly will lead to an increase in soil organic carbon.

Figure 1 – Schematic representation of the effects of an event of drought in two different soils

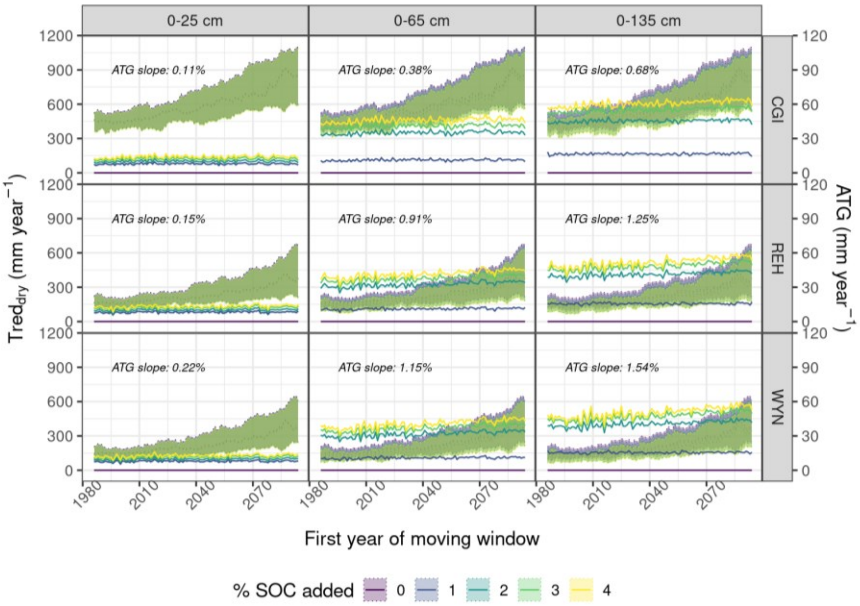

Figure 2 – Transpiration reduction due to drought stress (Tred$_{dry}$) (left axis, green band) for actual and future climate conditions considering different levels of SOC increase in the soil at different effective soil depths; and average transpiration gain, ATG, (right axis, colored lines) between 0 and 4% addition of SOC. Climate projections considered the RCP8.5 pathway and were averaged for every 10 years. The green shaded area of Treddry refers to the values between (dotted) quantiles $q_{0.05}$ and $q_{0.95}$ of the climate projections. ATG is interpretable as average seasonal gain in transpiration due to SOC increase, and ATG slope refers to the slope of the ATG line between 0 and 4% SOC addition.

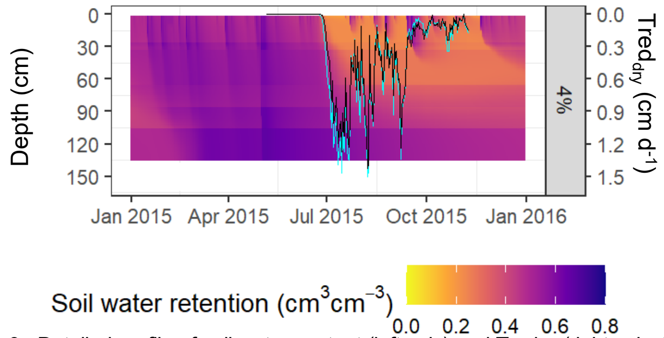

Figure 3 –Detailed profile of soil water content (left axis) and Tred$_{dry}$ (right axis, black lines) with the addition of 4% SOC. The blue line represents Tred$_{dry}$ for the original soil profile (0% SOC).

Modelling approach

We tested how different levels of soil organic carbon (SOC) at varying soil depths influence in the transpiration reduction caused by drought stress (Tred$_{dry}$) in maize under current and future climatic conditions (Figure 2).
The model was validated utilizing information from a long-term lysimeter for a typical Swiss soil and applied at three distinct climatic regions: Changins (CGI), Wynau (WYN) and Reckenholz (REH). A pedotransfer function (PTF) was used to indirectly assess the effects of SOC on soil hydraulic properties that affected the drought stress during the crop growing period. average transpiration gain between the management scenarios was calculated as the Tred$_{dry}$ difference between the scenario with no addition of SOC (0%) and the one with the maximum addition of SOC (4%).

Summary

The addition of SOC resulted in an increase on the ability of the soil to retain water, which improved the drought stress, specially at the onset of drought (Figure 3).
We found that adding at least 2% SOC down to at least 65 cm depth could increase transpiration annually, by almost 40 mm. Beyond this threshold, additional crop transpiration benefits of sequestering SOC are only marginal.
The benefits of adding SOC only at the topsoil were marginal (Figure 2), indicating that SOC increases in subsoils can play a supporting role in mitigating drought impacts in rain-fed cropping in Switzerland.