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Can biochar improve agricultural water use efficiency?

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To sustain and increase agricultural production under increasingly water-limited conditions, there is an urgent need to develop agricultural methods that balance water supply and demand while improving resilience to climate variability. A promising approach to address this need is biochar – a charcoal made from pyrolyzed organic material. Laboratory, pot-scale and some field studies have shown that biochar retains soil water and nutrients, supports root growth soil, and helps sequester organic carbon. However, does biochar improves soil water availability, plant water consumption rates and crop yields? To address this question, we synthesized literature-derived observational data and assessed how biochar affects evapotranspiration using a minimal soil water balance model.

Our data analysis showed that relative to control conditions, biochar additions increase the soil water holding capacity and have a variable but generally positive impact on soil water retention. Our modeling results demonstrated that biochar additions, by increasing soil water holding capacity, can increase long-term evapotranspiration rates, especially in dry regions. Empirical and model results support assertions that biochar generally improves water availability (and stability) for plants. However, biochar effects on plant productivity, crop yield, and water use efficiency are surprisingly variable. Empirical data showed that biochar amendments generally increased crop yields (75% of the compiled studies). In 35% of the cases, biochar simultaneously increased crop yield and improved water use efficiency. However, in some studies yield did not improve, and/or evapotranspiration rates increased (i.e., water use efficiency worsened). This suggests that less water might be available to plants in some biochar amended soils, or that some indirect (and poorly quantified) negative effects of biochar on plants can occur. Identifying the biochar properties that are most influential on improving soil moisture content (and subsequent yields) for crops, remains challenging, in particular due to the different variables being reported in the literature and low sample sizes.

Hence, while biochar amendments are promising, the variable impacts found in the literature highlight the need for targeted research on how biochar affects the soil-plant-water cycle. Specifically, at the pot or field scale, conservative tracers such as stable water isotopes ^{18}O and ^{2}H in combination with hydrometric measurements could be particularly useful to identify the effect of biochar on plant subsurface water sources, and how water is partitioned in the vadose zone.