POLICY BRIEF

November 2021
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Water use efficiency and carbon sequestration potential of indigenous crops

A recently completed Water Research Commission (WRC) funded project investigated the water use efficiency and carbon sequestration potential of indigenous crops.

Background

South and sub-Sahara Africa, in general, are water scarce and should use the limited available water efficiently. Collaborative thinking is central to mitigate climate change and improve water use efficiency in agriculture by adopting strategies that enhance long-term storage of carbon in the soil, and cultivating crops and varieties that utilize water efficiently.

Most smallholder farmers in South Africa stay in regions that have limited water availability and marginal soil fertility to achieve meaningful agricultural productivity. This project sought to explore ways of using crops that are readily available to local farmers to simultaneously cope with unfavourable water supply while improving soil fertility and mitigating against climate change.

The project further sought to enhance soil water storage by using selected local crop varieties that have enhanced capacity for soil carbon sequestration and efficient utilization of limited water supply. Increased carbon sequestration ultimately improves the water and nutrient holding capacities of the soil.

In pursuant of the objectives, several meetings, trainings and two stakeholder workshops involving team members were held to select the most appropriate sites for conducting project trials, experimental designs, guidelines for data acquisition and analyses. The preliminary project activities were deemed to be more suitable on well-monitored research facilities at the University of KwaZulu-Natal (UKZN)'s greenhouses and Ukulinga research farm.

The series of investigations carried out established that water usage and carbon varied significantly among maize, wheat, sorghum and pearl millet. There were also variations within each plant species dictated by genotypic differences among varieties. The variations were concomitant with variations in biomass productivity.

These differences have implications on soil carbon sequestration since it is achieved primarily via two processes i.e. decomposition of plant matter and rhizo deposits. In this regard, sorghum, which produced 31.5 Mg ha-1 of biomass compared to 24.9 and 13.4 Mg ha-1 produced by maize and wheat, respectively, had the highest potential for carbon sequestration based on biomass production.

However, carbon sequestration is also influenced by the quality of biomass, defined by its C: N ratio. In terms of recalcitrance, maize was the most recalcitrant due to its high C: N ratio, showing that its biomass C had the longest mean residence period in the soil.

Sorghum biomass was more susceptible to microbial decomposition and would thus have the least residence period in the soil, which reduces its carbon sequestration potential. Wheat straw appeared to be even more recalcitrant (highest C: N in shoots) than maize stover.

Aims and objectives

The project objectives were to:

- Evaluate water use efficiency and soil carbon sequestration potential of sorghum varieties in comparison with maize and wheat varieties.
- Assess the effect of crop residue incorporation on soil biological properties (microbial biomass, enzyme

activity, C pools, mineralizable N and P).
- Build capacity of post-graduate students and smallholder farming communities on water-use efficiency and soil C dynamics.
- Build a multidisciplinary team of soil scientists, crop breeders and hydrologists/climatologists.
- Identify the contribution of crop production to global carbon credits.

Major outcomes

The project team interacted with various stakeholders to develop results from participatory activities that included all stakeholders. Several highlights were identified from the project.
- Smallholder farming communities in Sub-Saharan Africa in general and South Africa, in particular, are a very important stakeholders in formulating intervention strategies for sustainable agriculture. Their production of indigenous crop varieties that have largely been ignored in mainstream agriculture in favour of commercial crops such as maize and wheat offers entry points for carbon emission mitigation, water conservation and food security.
- Crops such as sorghum, pearl millet and maize had higher biomass productivity and water use efficiency compared to wheat. This was attributed to genetic differences, with maize, sorghum and pearl millet being C4 species, which have higher capacity to regulate their water potential under harsh environments and maintain higher biomass productivity and carbon sequestration potential compared to C3 species such as wheat.
- Water relations are influenced by the environment, crop species, soil properties and agricultural management, so these should be taken into consideration to ensure sustainable crop production.
- Carbon sequestration potential of a crop variety is determined by the amount of biomass produced, the chemical composition of the biomass, the soil and environmental conditions.
- Databases of water use efficiency and carbon sequestration potential of different crops were developed.
- The project has successfully equipped students with different skill sets required to build a strong foundation in understanding WUE and soil C dynamics and their impact on agriculture in South Africa and the world. The students were developed in their individual capacity and as a collective to be able to work in diverse teams.

Observed needs from the project

The project identified the following as areas of further research:
- Further development of the DSS to fully incorporate all agroecological zones in South Africa.
- More experimentation and resilience assessment of longer-term CRA practice options, such as agroforestry, rangeland management, landscape rehabilitation and erosion control.
- Working with a smallholder farmer-level decision support process for implementation of baskets of Climate Resilient Agriculture practice options works extremely well in terms of learning and adoption. This approach needs to be further tested and improved in different agroecological zones.
- Research into institutional and implementation options through existing governance structures and or recommendations for implementation models across a range of stakeholders

A focus on soil and water conservation, microclimate management (e.g., shade house structures and Conservation Agriculture), soil organic matter and rainwater harvesting is crucial in underpinning improved productivity and production. Attempting to expand on conventional agricultural practices in this context is not feasible, given the already extreme conditions and intense competition for dwindling water resources in these types of catchments.

Major findings

The conclusions derived from this study suggest that more still needs to be understood on the main factors controlling water use efficiency and carbon sequestration in crops. There are many interactions between crop water use efficiency and carbon sequestration in relation to agronomic practices such as fertilizer application, irrigation scheduling, tillage system, planting dates, and plant architecture.

Such interactions could not be investigated in the framework of the present study but present important grey areas for further research. Such an improved understanding of the links between plant characteristics, water use efficiency and soil carbon storage may open opportunities for plant breeding and improved agronomic practices with climate change mitigation in mind. Research on stover management strategies that address farmer needs while enhancing soil caron is also needed.

There is a need to do a cost benefit analyses for carbon sequestration between accumulating high biomass compared to having more favourable biochemistry such as high C: N ratio, high lignin and high cellulose contents to increase recalcitrance of plant residues.

The biochemistry of crop residues and carbon deposits have huge implications for microbial populations in the soil that affect the stability and mineralization of the deposited carbon. It will be imperative to conduct assessment on changes in microbial population in the soil following incorporation of different crop residues and determine carbon sequestration potential in that regard.

The main limitation of the study was that the carbon fluxes in the soil were estimated from planting to harvest in a single season. Carbon sequestration in the soil is a long-term process and may be difficult to accurately quantify over short periods. Conducting multiple year experiments should possibly provide a more accurate estimation of soil carbon sequestration by crops.

Recommendations

At advanced stages, it was recommended that the project be upscaled to smallholder farms where communities would provide some of their most preferred and locally available varieties for inclusion in the screening and breeding stages. In addition, the smallholder farmers would participate in future projects to stay reasonably informed on progress and key decisions derived from the project.

The research was done as on-station experimentation, where plant growth conditions are ideal and controlled. More research needs to be done on-farm to see the performance of the different crop varieties under real field conditions that the farmers are experiencing.

Related report:
Water use efficiency and carbon sequestration potential of indigenous crops (**WRC Report No. 2721/1/21**).
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