Modelling the Impacts of Precision Irrigation on Sugarcane Yield, Water and Energy Uses in Sub-Saharan Africa

Second Year Student Progress Report

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By

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1. Research Context Background

Sugarcane production trends in Africa, over the past sixty years, indicate an overall average increase of over one million tons/year. However, there has been an average crop yield reduction of 0.03 t/ha per year over the same period - indication that the yearly increase in total production tonnage is due to expansion of overall harvested area (about 18600 ha/year). Irrigated sugarcane yield is about three folds higher than the yield from rain-fed. Thus, irrigation is a requirement for improved sugarcane crop yields. Sugarcane takes up to 12 months to reach maturity, requiring water throughout the period. With an average water requirement ranging between 18,000 m^3/ha and 20,000 m^3/ha, sugarcane is a high-water requirement crop. Thus, the expansion of harvested area to increase cane production has implications that are more significant on water resources availability compared to the increase due to improved crop productivity. Holding other factors constant, the total volume of irrigation water, required to meet crop water demand, increases with the cultivated area. Hence, expansion of cultivated area means an increased volume of irrigation water requirements. The water volume requirements increase even more, where irrigation water management is poor and irrigation efficiencies are low. This would mean less water for other competing uses at catchment level including environmental flows to support aquatic ecosystems, hydropower generation and other downstream users.

Although SSA is not considered water poor since it stocks about 9% of the world's freshwater resources, irrigated cane production has great potential to alter local water balances, thus impacting on the dynamics, quality, and quantity of water supplies for competing uses at catchment scale and beyond. India, for example, the world's second-highest sugarcane producer, irrigated production had led to extreme water shortages affecting the long-term sustainability of the country's sugar industry. Competition for same water source, the Shire River in Malawi, has seen sugarcane irrigation at Nchalo estate lose out to hydropower generation for the national grid during low flow regimes. Sugar production is a major consumer of freshwater resources, as both sugarcane production and sugar processing have significant impacts on water resources with an estimated water consumption of about 209 m^3/ton. Thus, expansion of the cultivated area to increase sugarcane production is not sustainable.

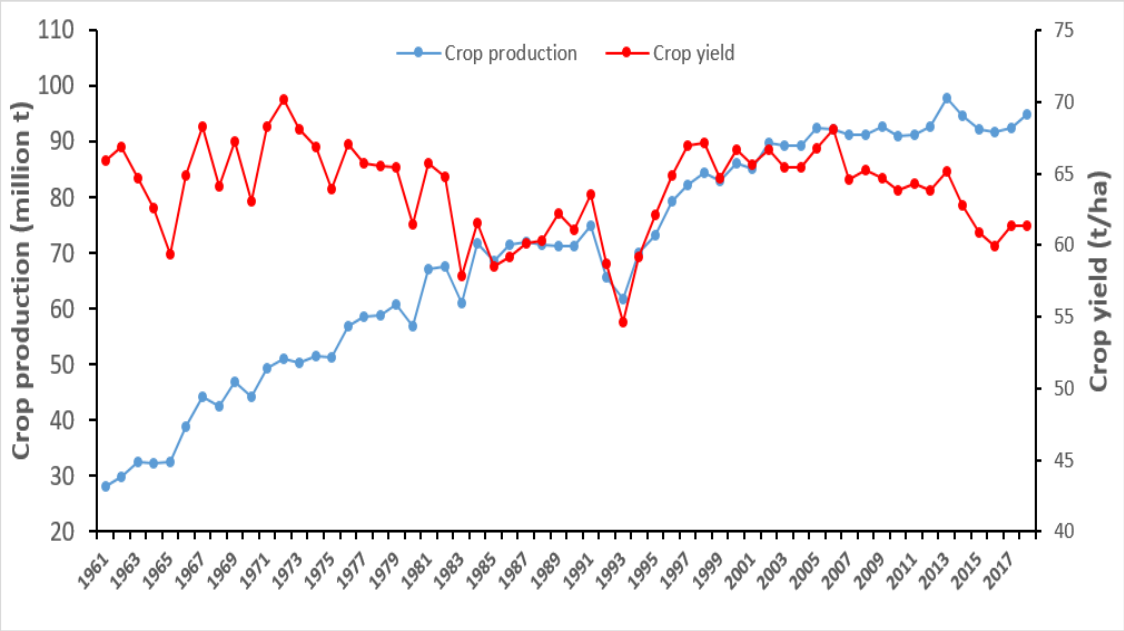

Figure 1: Sugarcane production (t) and yield (t/ha) trends in Africa (1961 to 2018) adapted from FAOSTAT (2020).

Understanding the impacts of future climate variability and drought risk on the reliability of water for irrigation, identifying appropriate technology and management options to improve water and energy efficiencies and evaluating the potential for implementing precision irrigation (PI) technologies to improve yields remain key challenges and priorities facing the agricultural sector in SSA. PI is a concept that encourages differential/variable application of water dictated by inherent field conditions. Application of PI concept in agriculture has potential benefits including increase in water use and economic efficiencies, improved uniformity in crop growth and quality and improved environmental sustainability. However, a review of the science literature shows gaps in knowledge on benefits and/or challenges for PI/VRI implementation in Africa.

At Nchalo estate, for example, the uniform prescription of irrigation application regardless of the infield soil variability is the day-to-day management of irrigation operations. Such approach is prone to water use inefficiencies, low yields due to non-uniform crop growth and development and poor environmental sustainability. Thus, this PhD research aims to bridge the knowledge gap by conducting a critical evaluation of the feasibility of implementing PI as a strategy for efficient water and energy management for the irrigated sugarcane industry in SSA. Among the knowledge gaps to be addressed would include developing an understanding and

quantifying potential agronomic benefits (increased yield), water use efficiency (improved water productivity), environmental benefits (nutrient losses/leaching, energy use) and economic benefits (increased revenues and crop quality) as a result of use of PI in sugarcane production in SSA.

2. Aims and Objectives

The aim of this PhD research is to evaluate the agronomic, environmental and economic impacts of precision irrigation on sugarcane production in sub Saharan Africa. Specific objectives include the following:

i. To critically review cane yield response to water, impacts of climate variability on productivity, and potential benefits of PI on water and energy use
ii. To identify opportunities for improving water and energy use and crop productivity by evaluating irrigation management practices across selected cane businesses in SSA using benchmarking techniques
iii. To simulate the impacts of precision irrigation on cane productivity and water use using a biophysical crop model
iv. To assess whether the implementation of PI technologies in sugarcane production is economically viable

3. Progress on Objective Accomplishment to date

The first two objectives have been fully accomplished, so far. In a nutshell, while the review of literature established that the benefits of PI are well articulated in most countries and states of Europe, USA, Australia and Asia; there is a gap in knowledge regarding the status of application and benefits of PI in sugarcane production in African countries.This finding has not only unravelled the status of the PI research in Africa, but also shaped and defined the direction of future research under the current area of consideration.

The benchmarking exercise (objective ii) revealed the water use and productivity trends and gaps in performance (within and between estates from season to season). For example, the water productivities observed in all the estates (between 2009 and 2019) fell below reported water productivities for corresponding countries. The establishment of the discrepancy between actual and potential water productivities is not only vital in the improvement of water productivity but also the

understanding of the reasons behind low water productivities. A science paper from the second objective has been drafted and should be ready for submission soon.

The third objective is being undertaken now and should be completed in the next couple of months. All the necessary datasets for the simulation of the impacts of precision irrigation on cane productivity and water use were collected and an appropriate biophysical simulation model was identified.

Figure 2: Irrigation system evaluation for furrow (A) and dragline (B) fields at Nchalo estate (November 2020)

The fourth and final objective will commence soon after accomplishing the third objective. However, the process of determining the dataset requirements for this objective is well underway.

4. Research Project Impacts

Overall, the research work is likely to be impactful to the sugarcane production industry, as it would help to bridge the knowledge gaps in the irrigation and water supply and management sector. Such knowledge would be necessary for the improvement of water productivity and efficient allocation of water resources, improving the catchment management and improving the profit margins for the business operations in the process. Further, the research outcomes will provide scientific evidence to justify tactical investments and improvements in irrigation water management across the sugarcane industry in SSA. The research will provide understanding on the impact of precision irrigation management on sugarcane yields

and water savings and energy use. This will benefit the local communities through enhanced economy in the regions where improved productivity and profitability of the sugarcane estates are achieved and also reduce water consumption for the growth of sugarcane ensuring long term environmental sustainability within the catchment area and water security for the local community in the process.

This research has been invaluable opportunity to me, as an individual. It has been an enabler for exposure and interaction with scientists and experts in the field of water resources management – an experience that will benefit me through my entire career. The knowledge and expertise acquired through this study would go a long way in promoting sustainable irrigated agriculture in Malawi and beyond through consultancies and outreach programs that I plan to embark on after completing the studies. Thus, this research and sponsorship from Sue White Fund has made me grow in my career! I am sincerely grateful to the Sue White Fund for affording me this lifetime opportunity.