Assessing the Vulnerability and Adaptation Potential of Sugarcane Production to Water Stress Across Southern Africa

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“Climate change is the single greatest threat to a sustainable future but, at the same time, addressing the climate challenge presents a golden opportunity to promote prosperity, security and a brighter future for all.”

Ban Ki-Moon, Former Secretary-General of UN
Take Home Messages

• Sugarcane is vulnerable to water stress arising from amplified precipitation variability due to a changing climate.

• Increased climate variability is causing corresponding increases in drought frequencies resulting in yield declines throughout southern Africa.

• Amplification of inter-annual precipitation variability will increase the exposure of sugarcane to water stress.

• Adaptation interventions have to be adopted as a matter of urgency to minimize vulnerabilities and build resilience.
Sugarcane in Southern Africa
Sugarcane in Southern Africa

Livestock → Animal feed manufacturers → By-products → Sugar Producers, Millers and Refineries → Export Sugar Market

Downstream Industrial Sector → Local Sugar Market

Wholesalers → Retailers → Consumers → Direct Sector
Sugarcane in Southern Africa
• The sustainability of sugarcane production is under threat due to the increased frequency of extreme hydrological events that include prolonged droughts and extreme floods (IPCC, 2019; Hennessy et al., 2022).

• The crop is grown under a highly variable hydroclimatic environment, characterised by high temperatures resulting in high evaporation rates and substantial water requirements punctuated by low rainfall-to-runoff conversion ratios and high evaporation rates.

• Inter-annual precipitation variability is the primary determining factor in the exposure of sugarcane to water stress and, ultimately, the viability and sustainability of rainfed and irrigated sugarcane production.
Mean Annual Precipitation, Runoff and Evaporation across Southern Africa and the world
• Owing to these hydroclimatic dynamics, sugarcane is often exposed to water stress and, out of necessity, is grown under a combination of rainfed, supplementary and full irrigation regimes.

• Sugarcane is a water use intensive crop with an ET of over 1 800mm.annum\(^{-1}\) for a full canopy crop, requiring 850mm of water per growing cycle for sustainable rainfed production.

• Sugarcane yields are therefore highly sensitive to water stress and any shortages have serious implications for the sustainability of the sugar industry especially in a changing climate.
IPCC AR4 Scenario, Mean deviation (%) 2080-2099, ensemble models

Social futures 2050
7000 → > 9000 km³/yr

Water scarcity index in 2050 (median)

Policy challenges

Uncertainty change present day to 2050

Stable Increase
Small-scale growers face limitations including access to finances, current climate data and information, crop modelling, climate forecasting tools and current sugarcane varieties.

For these reasons, small-scale growers in the region are historically more vulnerable to the impacts of climatic extremes compared to their large-scale commercial counterparts.

The region lacks an assessment of the vulnerability of sugarcane to inter-annual dry periods over sufficient temporal scales to understand the vulnerability and adaptation potential of the sugarcane industry.
Study Objective

Assess the vulnerability and adaptation potential of sugarcane production to climate and management-related water stress in six mill areas across southern Africa, and recommend viable adaptation strategies to ensure the sustainability of the sugarcane production industry.
Study Aims

1. Assess the long-term observed sugarcane water use with the purpose of defining the current and potential vulnerability of sugarcane production to water stress resulting from extended dry conditions.

2. Identify the hydrological parameters and agronomic management practices which may influence the vulnerability of sugarcane production to water stress caused by extended dry conditions.

3. Define the adaptation potential or adaptation ‘space’ for outgrowers and commercial sugarcane producers.
Study Sites

Six Mill Areas:

1. Eston Mill, South Africa
2. Union Mill Cooperative (UCL), South Africa
3. Noodsberg Mill, South Africa
4. Big Bend Mill, eSwatini
5. Nchalo Mill, Malawi
6. Kilombero Mill, Tanzania
## Study Sites

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Location</th>
<th>Area (km²)</th>
<th>MAP Range (mm)</th>
<th>MAE Range (mm)</th>
<th>Water Management</th>
<th>Area Under Sugarcane (Ha)</th>
<th>Annual Output* (tonnes/annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mgeni</td>
<td>KwaZulu-Natal, South Africa</td>
<td>4 474</td>
<td>700 - 1 550</td>
<td>1 570 - 1 740</td>
<td>Irrigated and Rainfed</td>
<td>25 300</td>
<td>3 546 256</td>
</tr>
<tr>
<td>Ubombo</td>
<td>Lubombo, Swaziland</td>
<td>5 502</td>
<td>500 - 710</td>
<td>2 000 - 2 200</td>
<td>Irrigated</td>
<td>10 981</td>
<td>1 303 750</td>
</tr>
<tr>
<td>Kilombero</td>
<td>Morogoro, Tanzania</td>
<td>17 736</td>
<td>1 000 - 1 800</td>
<td>1 600 - 1 800</td>
<td>Irrigated and Rainfed</td>
<td>21 800</td>
<td>1 200 000</td>
</tr>
<tr>
<td>Shire</td>
<td>Cikhwawa, Malawi</td>
<td>18 000</td>
<td>1 100 - 1 300</td>
<td>1 500 - 1 800</td>
<td>Irrigated and Rainfed</td>
<td>19 520</td>
<td>1 680 000</td>
</tr>
</tbody>
</table>

*Average raw sugarcane crushed by mills between the 2010-2017 production cycles.*
Methodology (Summary)

1. Use the AquaCrop model to simulate the maximum potential yields that would be achieved under ideal agronomic growing conditions for each mill area,

2. Use observed sugarcane yields from the selected mill areas to determine the annualized actual sugarcane water use.

3. Derive an annualized ‘Crop Productivity Ratio’ (CPR) based on the relationship between annualized sugarcane water use and observed rainfall to assess potential water stress during individual growing cycles.

4. Perform a qualitative assessment that relates the proposed CPR with simulated and observed yields to ascertain the positioning of each mill area within a particular “Adaptation Space”.
Methodology (Summary)

INPUT
- environmental conditions
- historical or future weather conditions
- crop planting date
- soil fertility
- irrigation management
- soil profile
- groundwater

OUTPUT
- biomass and crop yield for given environmental conditions
- effect of climate change on food production
- understand crop responses to environmental changes
- optimise Water Use Efficiency
- yield gap analysis

Graphs showing data trends over time.
Results

Long-term mean (LTM) sugarcane water use (wu) in relation to mean annual precipitation (MAP) for individual mill areas.
LTM observed and simulated yields for the South African and Big Bend mill areas and annualized water use per growing cycle.
LTM observed and simulated yields for the Nchalo and Kilombero mill areas and annualized water use per growing cycle.
Sugarcane Productivity Ratios

Long Term Mean (LTM) Crop Productivity Ratios (CPR) for the South African and Big Bend Mill Areas

A CPR = 1 is the benchmark and differs for each mill area.
Long Term Mean (LTM) Crop Productivity Ratios (CPR) for the Nchalo and Kilombero mill areas relative to observed and simulated yields.

A CPR = 1 is the benchmark and differs for each mill area.
Adaptation Recommendations

1. Improve the understanding of the impacts of climatic extremes across the sugarcane value chain, i.e. from planting to cultivation to processing and retail.

2. Share (updated) research outputs regarding drought and pest-resistant sugarcane varieties particularly with outgrowers.

3. Grow multiple sugarcane varieties within a single mill area to create a ‘yield buffer’ to negate the effects of water stress during prolonged dry periods.

4. Explore the use of biotechnology (i.e. genetically modified hybrid sugarcane varieties) to limit the exposure of sugarcane to biotic and abiotic stresses.

5. Increase investments in efficient irrigation technologies that use limited volumes of existing water resources to increase yields.

6. Engage in multi-cropping to increase soil organic matter which can potentially increase the water holding capacity of soil thus enhancing plant available water for every season.
Adaptation Recommendations…continued

7. Reversing stigmatizing policies that relegate sugarcane production to a secondary crop or a crop that threatens national water resources (e.g. the SFRA law in South Africa). While this position may have been true once, significant progress has been made in improving water use efficiency in the industry. These policies need to be revised to reflect the current status of sugarcane production.

8. Considering changes to cropping dates to limit the impact of increasing rainfall seasonality particularly in the Nchalo and Kilombero mill areas.

9. Improving in-field technologies that reduce soil degradation and enhance water holding capacities.

10. Reducing practices such as burning prior to harvesting and burning sugarcane trash which increase the emission of greenhouse which ultimately exacerbate climate change. While burning enables hand-cutting which creates seasonal employment, self-trashing varieties can limit the need for burning while not compromising livelihoods.
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Thank You For Listening