A YIELD GAP ANALYSIS TO ASSESS THE VULNERABILITY OF COMMERCIAL SUGARCANE TO CLIMATIC EXTREMES IN SOUTHERN AFRICA

Simphiwe Ngcobo
Centre for Water Resources Research
Monday, October 31, 2022
1. Sugarcane yield gaps remain high across southern Africa suggesting that the industry remains vulnerable and exposed to climatic extremes.

2. Yield gaps are attributed to the current crop management approaches currently being employed in mill areas as opposed to climatic regimes.

3. If sugarcane growers are to withstand the effects of extreme climatic events, they have to alter their crop management approaches and be actively included in current sugarcane production research.

4. Yield gaps can increase or decrease depending on the management and hydroclimatic conditions unique to each mill area.

5. Sugarcane growers may not currently be able to address the impacts of climate change on yields and yield gaps, however they can climate-proof the industry to reduce vulnerability.
Sugarcane is a strategically important commodity crop that supports the livelihoods of millions across southern Africa.

A water-use intensive crop that has come under increased scrutiny recently owing to increased frequency of extreme hydrological events.

Despite advances in new technologies, yields have been in consistent decline over the past 25 years across the region.

Climatic extremes and sub-optimum agronomic management have suppressed yields and resulted in increased yield gaps.

Critical to address these yield gaps to maintain the viability of the cane production industry.
Why Sugarcane?

Sugarcane harvested areas occupy approximately 785 000Ha across southern Africa.
<table>
<thead>
<tr>
<th>Country</th>
<th>MAP (mm)</th>
<th>ET (mm)</th>
<th>Water Use (mm/annum)</th>
<th>Area Harvested (Ha)</th>
<th>Average Yield (T/Ha/annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>1 050</td>
<td>1 400</td>
<td>285</td>
<td>13 000</td>
<td>38</td>
</tr>
<tr>
<td>DRC</td>
<td>1 534</td>
<td>1 300</td>
<td>315</td>
<td>16 500</td>
<td>42</td>
</tr>
<tr>
<td>Malawi</td>
<td>1 104</td>
<td>1 610</td>
<td>788</td>
<td>27 000</td>
<td>105</td>
</tr>
<tr>
<td>Mauritius</td>
<td>2 041</td>
<td>1 600</td>
<td>548</td>
<td>53 871</td>
<td>73</td>
</tr>
<tr>
<td>Mozambique</td>
<td>969</td>
<td>1 900</td>
<td>773</td>
<td>48 000</td>
<td>103</td>
</tr>
<tr>
<td>South Africa</td>
<td>497</td>
<td>1 943</td>
<td>598</td>
<td>325 000</td>
<td>63</td>
</tr>
<tr>
<td>Swaziland</td>
<td>788</td>
<td>1 904</td>
<td>1799</td>
<td>56 000</td>
<td>93</td>
</tr>
<tr>
<td>Tanzania</td>
<td>937</td>
<td>2 800</td>
<td>795</td>
<td>58 500</td>
<td>106</td>
</tr>
<tr>
<td>Zambia</td>
<td>1 011</td>
<td>1 818</td>
<td>795</td>
<td>39 000</td>
<td>106</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>652</td>
<td>1 750</td>
<td>1825</td>
<td>44 800</td>
<td>105</td>
</tr>
</tbody>
</table>

A demonstrably land and water resource intensive activity with a unique potential to be both high-benefit and high impact crop.
Mean annual precipitation (MAP) across Southern Africa highlighting the high spatial variability of rainfall across the region
Research Objectives

1. Develop a methodology of quantifying yield declines and yield gaps as a result of climatic extremes and management interventions and,

2. Offer recommendations to reduce the vulnerability of sugarcane to the effects of climatic extremes.
The AquaCrop Model

Methods...1

Transpiration
\[ Tr = Ks_{sto} Kc_{Tr} ET_o \]

WP*

Biomass (B)

HI

Yield (Y)

INPUT
environmental conditions

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

The AquaCrop Model

(a) canopy expansion
(b) stomatal closure
(c) early canopy senescence
(d) Harvest Index adjustment

FAO – Penman Monteith Equation

weather data

irrigation
rainfall
runoff
Methods...2

Pre-Input Data
- Access Observed Historical Climate Data.
- Access Reference Sugarcane Crop Coefficients
- Water resources management (rainfall and irrigation data)
- Field management best practices

Input Data and Model Modules
- Climate Module
  - Observed rainfall, T_max, T_min, ET_0
- Crop Module
  - Specify crop growth mode, crop and canopy development parameters, ET coefficients, water productivity, harvest index, and physiological stress parameters
- Management Module
  - Specify irrigation management. Set field management practices (i.e., mulching, runoff reduction and soil fertility parameters)
- Soil Module
  - Set soil surface and soil profile characteristics

Processing
- Non-Conservative Parameters.
  - Adjust the following:
    - Calendar days
    - Crop growth threshold temperature
    - Plant densities
    - Harvest Index
    - Crop Water Productivity
    - Net Irrigation Requirements
    - Specify response thresholds to water, temperature, salinity, and fertility stresses
- Conservative Parameters.
  - Keep the following static:
    - Canopy cover, growth and development coefficients
    - Flowering and yield coefficients
    - Soil water depletion coefficients
    - Flowering and stomatal opening
    - Salinity and fertility coefficients

Output
- Iterative Model Runs
  - (Based on Rainfall & Calendar Days)
- Production Output
  - (Potential) Yield
  - (Above-ground Biomass x Harvest Index)
Yield Gap Analysis

- Yield gap by water deficit ($Y_{GDW}$)
- Total yield gap ($Y_{GT}$)
- Yield gap by crop management ($Y_{GCM}$)

Yield level

Potential Yield ($Y_p$)

Potential Water-Limited Yield ($Y_w$)

Actual Yield ($Y_a$)
Model Verification

Ubombo Mill Area

South African Mill Areas

Observed Yield (t/ha) vs. Simulated Yield (t/ha)

Observed Yield (t/ha) vs. Simulated Yield (t/ha)
Results:

1. Sugarcane Yield Trends and Yield Gaps
Results:

2. Sugarcane Yield Trends and Yield Gaps
Yield Gap Analysis

- Potential Yield ($Y_p$)
- Potential Water-Limited Yield ($Y_w$)
- Actual Yield ($Y_a$)

Yield gap by water deficit ($Y_{GWD}$)
Yield gap by crop manage. ($Y_{GCM}$)
Total Yield gap ($Y_{GT}$)
Conclusions: 10 Key Lessons

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 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 cane 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.
Conclusions: 10 Key Lessons

6. Engage in multicropping to increase soil organic matter which can potentially increase the water holding capacity of soil thus enhancing plant available water for every season.

7. Reverse 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).

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

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

10. Reduce practices such as burning prior to harvesting and burning sugarcane trash which increase the emission of greenhouse which ultimately exacerbate climate change.
THANK YOU FOR LISTENING

3000 Stars in Westerlund 2.
25th Anniversary of the Hubble Telescope!!
(With Thanks to: NASA, ESA, Hubble Heritage Team and the Westerlund 2 Science Team, April 24th 2015)