SHORT, NON-REFEREED PAPER

SUGARCANE PRODUCTIVITY AND WATER USE IN SOUTH AFRICA UNDER A FUTURE CLIMATE: WHAT CAN WE EXPECT?

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Abstract

Reliable predictions of sugarcane crop response to climate change are necessary to plan adaptation strategies for the South African sugarcane industry. The objective was to estimate expected changes in sugarcane yields, water use and irrigation requirements due to climate change for existing and potential new production areas in South Africa (SA).

The DSSAT-Canegro model was used to simulate dryland (non-irrigated) and fully-irrigated crops for 1967 catchments using actual weather data for the period 1971-1990 (past) and projected weather data (from three climate models) for the period 2046-2065 (future).

Temperatures are expected to increase by about 2°C. Rainfall projections are less certain with a possibility of slight increases in annual total rainfall, especially in the northern parts of the industry.

Most dryland yields are expected to increase due to accelerated canopy development and increased water use efficiency. Increases vary from 11% in current warm areas to 33% in current cool areas. Irrigated yields are expected to increase marginally (1-5%) in current high potential areas, while larger increases are expected for current marginal areas. Crop water use and irrigation requirements are expected to increase by 8% to 11%, respectively. Areas in northern Limpopo, north-eastern parts of the Eastern Cape, and high-lying areas in KwaZulu-Natal and Mpumalanga are likely to become suitable for sugarcane production as temperatures increase.

A database was generated for areas in SA where sugarcane can potentially be grown. The database comprises estimated sugarcane yields, water use and irrigation requirements, at sub-catchment level, for the past and the future climate. The information should be useful for the planning and future management of sugarcane production in SA.

Keywords: crop water use, irrigation, weather data, rainfall, temperature, climate change, Canegro, cane yield.

Introduction

Reliable predictions of sugarcane crop response to climate change are necessary to plan adaptation strategies for the South African sugarcane industry. Although previous studies provide tentative predictions (Schulze and Kunz, 2010; Singels *et al*., 2014; Jones *et al*., 2015), recent scientific and methodological advances provide new opportunities to refine these.

The objective of this study was to estimate expected changes in sugarcane yields, water use and irrigation requirements due to climate change for existing and potential new production areas in South Africa (SA), using the best models and data available.

Methods

An upgraded version of the DSSAT-Canegro model (Jones and Singels, 2018) that includes revised calculation of thermal time to account for the limiting effect of very high temperatures, and improved algorithms for simulating tillering, photosynthesis, respiration and water stress responses, was used in the study. Eighteen seasons of dryland (non-irrigated) and fully-irrigated crops, harvested in April and October in the periods 1971-1990 (past) and 2046-2065 (future), were simulated for each of 1967 quinary catchments (QCs, Schulze and Horan, 2011). QCs were selected based on their deemed suitability for sugarcane production under past and future conditions in terms of temperature regime, annual rainfall and expected yield according to a simple yield relationship (fully described by Lumsden, 2016). For dryland crops, growing season duration for both periods was determined from annual thermal time, and varied from 12 to 23 months. For irrigated cane, crop cycle duration was set at 12 months. A row spacing of 1.2 m was assumed for all runs.

Weather data for the past and future periods were derived from empirically downscaled projections of three general circulation models (CSIROmk3.5, GFDLcm2.1 and MPI-ECHAM5) developed by the Climate Systems Analysis Group (CSAG) of the University of Cape Town. These projections were adjusted to better represent conditions in the QCs using the approach described in Schulze *et al*. (2011). The soils information was derived from the QC database (Schulze *et al*., 2011).

Each simulation produced 18 values each of cane yield, water use and irrigation demand. These were ordered from low to high and the difference between the past and future values expressed as a percentage of the past value. The average and standard deviation of these differences are reported.

A Microsoft Excel-based visualiser tool was developed for assisting stakeholders in viewing and analysing the data and maps generated in this study.

Results and Discussion

Temperatures are expected to increase by about 2°C. Rainfall projections are less certain with a possibility of slight increases in annual total rainfall, especially in the northern parts of the industry.

Simulation results suggest that most dryland yields are expected to increase due to accelerated canopy development (due to higher temperatures) and increased water use efficiency (a result of elevated atmospheric CO_2 concentration). Average increases vary from 13% in warm areas to 19% in cool areas (Table 1). The magnitude of the increase is a function of altitude, with high-lying areas showing increases as high as 40% (Figure 1). Sucrose yield increases due to climate change were lower than cane yield increases (not shown) because increased temperatures would accelerate structural stalk growth rate at the cost of sucrose accumulation. Yield increase ratios calculated in this study mostly seem lower than the range of 30-100% reported by Schulze and Kunz (2010, Figure 12.11, p 79).

Results suggest that new areas may become suitable (mean cane yields exceeding 35 t/ha) for dryland production, such as the northern coastal areas of the Eastern Cape, and high lying areas in Kwazulu-Natal and Mpumalanga that lie to the west of the current production areas.

Irrigated yields are expected to increase marginally (1-5%) in current high potential areas, while larger increases are expected for current marginal areas (e.g. 17% for the Midlands) (Table 1), given adequate water supply. Expected yield increases for current production areas are substantially lower than the 15% increase predicted with Canegro by Knox *et al*. (2010) for Swaziland, and the 10% increase predicted with Canegro by Jones *et al*. (2015). This could be ascribed to the refinements to the Canegro model made since 2010 (Jones and Singels, 2018).

Average seasonal crop water use of dryland and irrigated crops is expected to increase by 8-11% due to increased atmospheric evaporative demand and accelerated canopy development under a future climate (Table 1). Irrigation requirements are also expected to increase by 5-11 % (Table 1). These values compare well with those predicted by Knox *et al*. (2010) and Jones *et al*. (2015), and are higher than those predicted by Schulze and Kunz (2010).

Results suggest that, under a future climate, areas in northern Limpopo, the northern-eastern parts of the Eastern Cape and in the Midlands could become high-potential areas (mean cane yields exceeding 90 t/ha), assuming adequate water supply.

Table 1. Simulated future long term mean annualised (LTM) cane yield (t/ha/annum), water use (mm/annum) and irrigation demand (mm/annum) for a representative catchment in each of the different agro-climatic regions of the industry. The expected long term mean increase from past to future (Δ, as a % of the past value) for each of these variables is also given.

Region	Cane yield		Water use		Irrigation demand	
	LTM	Δ	LTM	Δ	LTM	Δ
Dryland						
Zululand	77	13.2	876	8.3		
North Coast	80	16.6	777	8.1		
Midlands	76	18.8	747	10.4		
South Coast	80	14.9	755	9.8		
Irrigated						
Mpumalanga	142	0.7	1398	8.9	868	8.1
Pongola	139	5.3	1325	7.8	765	4.9
Zululand	132	5.4	1148	9.4	344	6.7
North Coast	139	9.8	1230	9.5	539	10.1
Midlands	128	17.0	1160	8.5	358	11.1
South Coast	132	13.4	1120	10.0	590	10.9

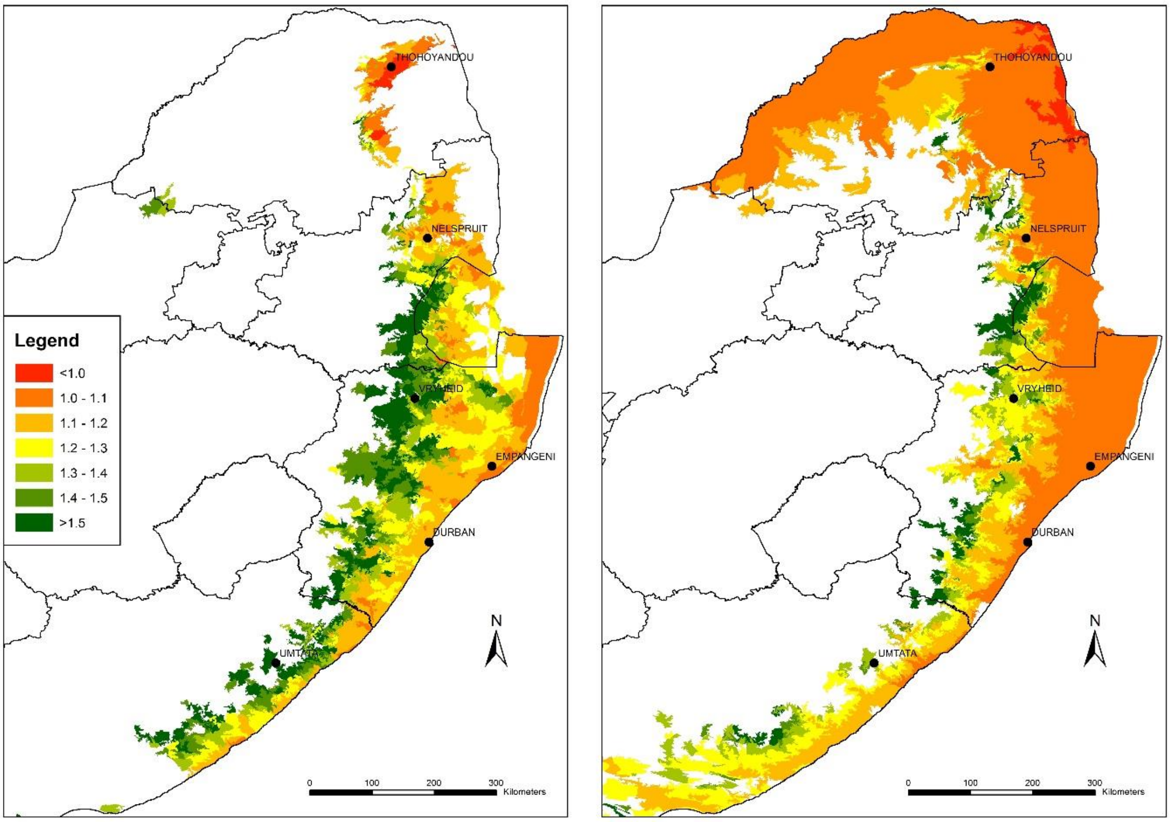

Figure 1. Changes in long term median cane yield from past to future, expressed as a ratio (future:past) for dryland (left) and irrigated (right) sugarcane production (map courtesy of South African Sugarcane Research Institute GIS office).

Conclusions

The study produced refined estimates of medium-term climate change impacts on dryland and irrigated sugarcane crops in SA. The database comprises of estimated yields, water use and irrigation requirements for the past and the future climate for areas where sugarcane can potentially be grown, at a quinary catchment level. The information is accessible in an Excel-based data and map viewer, and should be useful for the planning and future management of sugarcane production in SA.

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