SHORT NON-REFEREED PAPER

CLIMATE CHANGE WILL IMPACT THE SUGARCANE INDUSTRY IN AUSTRALIA

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Abstract

Climate is a key driver of sugarcane production and its by-products. Given the significant contribution of sugarcane production to economic growth and development in Australia, it is critical to understand how this production system will be impacted by climate change. This project investigated the impact climate change will have on productivity and harvest practices. The project team assessed the change in projected climate across the Australian sugarcane industry on a grid as small as 5 x 5 km. This was pertinent to Australia's sugarcane-growing regions, as local topography can change rapidly. Projections for the period 2046 to 2065 considered a high (A2) and low (B1) illustrative emissions scenario and were compared to the baseline period of 1961 to 2000. Down-scaling from global circulation models of climate change showed that climatic variables within a given region are not uniform and are affected by local topography. Adaptation strategies may therefore need to vary within a region. Projections of yield varied between climate change scenarios. Harvest disruption projections should be considered closely with yield projections and rainfall projections either side of the harvest window. In the face of competing solutions and finite resources, the findings from this project can assist policy makers not only in Australia but around the world with developing robust adaptation strategies for a changing climate.

Keywords: sugarcane, harvesting, climate, GCM, productivity, sustainability

Introduction

Given the challenges of delivering sustainable solutions to employing, feeding and fuelling an increasing global population, it is necessary to understand the impact of climate change on sugarcane production. Climate change studies are usually based on climate data generated from general circulation models (GCMs) for a range of illustrative emission scenarios (Nakicenovic and Swart, 2000). Projections from GCMs are often downscaled for impact studies where geographic features at a finer scale influence climate. Downscaling is important for the sugarcane-growing regions of Australia where climate is influenced by the close proximity of mountain ranges in the west and the coastline on the east.

The '2007 Climate Change in Australia' technical report (Pearce *et al*., 2007) considered low, medium and high emissions for 2030, 2050 and 2070. Under a high emissions scenario Pearce *et al*. (2007) suggested that, although there would be an increase in maximum and minimum temperatures by the year 2050 across coastal Queensland, radiation and rainfall were not considered likely to change. Change was considered as 'likely' if agreement exceeded 66% between the 23 GCM models used. Several studies have investigated climate change impacts on rainfall, but relatively few studies have extended this research to address harvest downtime due to high intensity rainfall.

Several recent studies have looked at climate change impacts on sugarcane around the world, including Swaziland (Knox *et al*., 2010), Brazil (Marin *et al*., 2013) and Australia (Biggs *et al*., 2013). Knox *et al*. (2010) and Marin *et al*. (2013) projected mean yields to increase under a high emissions scenario (A2; CO_2 conc. 745 ppm) for the year 2050. Biggs *et al*. (2013) considered projections to the year 2030 using a CO_2 concentration of 437 ppm. This resulted in an increase in biomass yields under low and moderate climate change conditions but a reduction with strong climate change. These studies differ in the way that the CO_2 effects have been incorporated into the modelling procedure. However, all three papers incorporate direct and indirect benefits of increased CO_2 concentrations.

This communication reports on the results of a recent climate change study funded by the Sugar Research Association (SRA) of Australia. The project aimed to estimate how climate change will affect key atmospheric variables relevant to sugarcane crop production (Everingham *et al*., 2013; Sexton *et al*., 2013), estimate the impact of climate change on harvest disruptions due to rainfall (Sexton *et al*., 2014), and project crop productivity for possible future climates (Everingham *et al*., 2014; Stokes *et al*., 2014).

Methodologies

An extensive desktop modelling approach was undertaken to deliver the project's outputs and outcomes. Desktop modelling activities involved: (i) processing downscaled climate outputs from the GCMs, (ii) generating radiation data that was not available from the downscaled models, (iii) converting rainfall projections to a harvestability index, (iv) implementing a sophisticated statistical yield estimation routine and (v) developing a robust statistical procedure to communicate model consensus of climate and yield outputs for initiating industry discussion.

Daily rainfall, and maximum and minimum temperature projections were obtained for 11 GCMs for the reference period 1961 to 2000 and future period 2046 to 2065 from the CMIP3 database (Meehl *et al*., 2007). High (A2) and low (B1) illustrative emission scenarios were considered. Current global emissions are tracking near or above the A2 illustrative scenario. Data were downscaled to an approximate 5 x 5 km grid for sugarcane-growing regions in Australia using the method of Timbal *et al*. (2011). Radiation data were not available and were estimated based on daily temperature and rainfall data (Sexton *et al*., 2013). The paired differences in mean modelled projections were computed between future climates (2046 to 2065) and the historical baseline (1961 to 2000) scenarios for each climate variable.

Bootstrapped confidence intervals produced for the 25th, 50th and 75th percentiles of spatio-temporal mean projected differences were used to assess whether a regional change could be considered plausible or highly plausible, following Everingham *et al*. (2013). For example, an increase in temperature was considered plausible if a bootstrapped 95% confidence interval on the 50th percentile of 11 GCM paired differences was greater than zero and highly plausible if a bootstrapped 95% confidence interval on the 25th percentile was greater than zero. Spatial variation within each region was also investigated.

The change in average number of unharvestable days, due to wet weather, was also investigated. A day was defined as unharvestable when >10 mm of rain fell, and where >20 mm fell in a single day, that day and the next were considered unharvestable. Finally, where >40 mm of rain fell in a single day, that day and the next two days were considered unharvestable (Sexton *et al*., 2014). This definition was designed for regions in north-eastern Australia where mechanical harvesting is practised. Plausible and highly plausible changes were identified and spatial variability was analysed.

A dual statistical ensemble methodology was used to assess the impacts of climate change on sugarcane productivity. Downscaled GCMs were used to simulate regionally averaged sugarcane yields for the base period 1971 to 2000. Projections of yield for 2046 to 2065 were simulated with and without elevated CO_2 concentrations. CO_2 concentrations were computed for the historic period 1970-2000 (345 ppm), and the 2046-2065 period for the B1 (493 ppm) and A2 (548 ppm) scenario. Stomatal resistance to gaseous diffusion was found to increase approximately 12% per 100 ppm increase in CO_2 concentration (Stokes *et al*., 2014), and potential transpiration was consequently reduced in the model according to the Penman-Monteith formula (Everingham *et al*., 2014). The confidence intervals described by Everingham *et al*. (2013) were used to identify plausible and highly plausible changes in regional yields.

Results and Discussion

Based on the modelling design, an increase in daily maximum and minimum temperature was considered highly plausible across all the Australian sugarcane-growing regions considered. Spatial variability was low for temperature data. For the high emissions scenario (A2), plausible and highly plausible decreases in radiation were projected for most regions and seasons. An increase in summer or spring rainfall was considered plausible for some northern regions, while a decrease in summer rainfall was considered plausible for the southern-most region investigated.

Under a high emissions future (A2) it is plausible for industry to plan for more harvest disruptions in spring (Ingham), and less harvest disruptions in winter and spring (Burdekin) and winter in Bundaberg. While projected changes were generally deemed subtle, individual GCMs projected increases of 5 to 21 unharvestable days in some regions. This would have a dramatic effect on harvest operations. Figure 1a shows the spread of projected unharvestable days for the most southern region (New South Wales).

Yield projections recognised an increase was plausible for three regions considered under the low emissions (B1) scenario and highly plausible for the most southern region under the high (A2) scenario (Figure 1b). These changes were only identified when CO_2 effects were considered in the simulations. Harvestability projections should be considered closely with yield projections, as an increase in yields and increase in harvest disruptions could lead to stand-over with negative impacts to profitability. Spatial projections revealed that changes within a region are not always uniform and adaptation strategies may need to vary within a region.

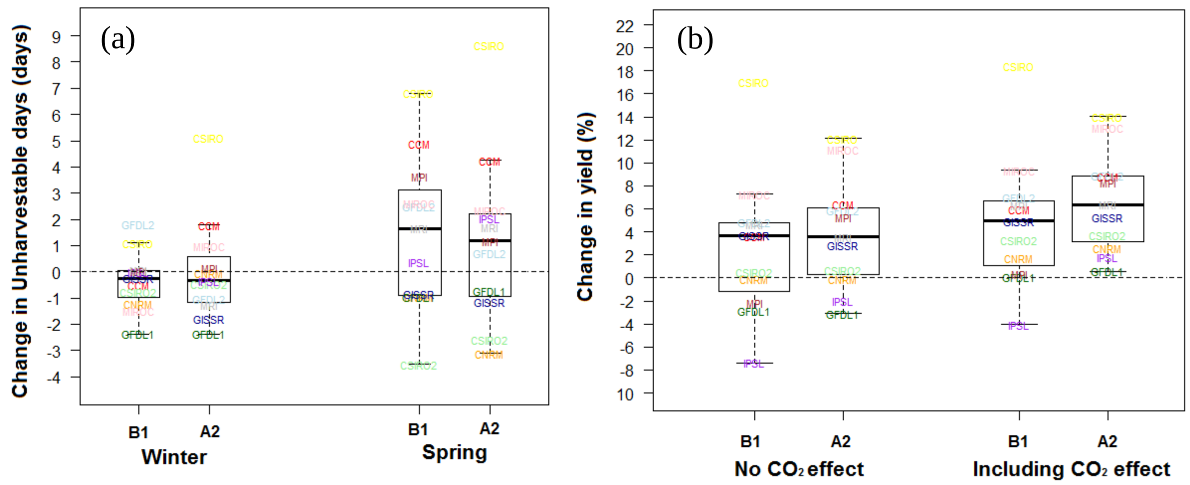

Figure 1. Projected change in (a) number of unharvestable days and (b) yield for the northern New South Wales sugarcane-growing region. Labelled points represent projections for each of 11 GCMs.

In the face of competing solutions and finite resources, the findings from this project can assist policy makers, not only in Australia, but around the world with developing robust adaptation strategies that will minimise risk and maximise opportunities in response to the challenges associated with a changing climate.

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