Projections of harvest disruptions due to rainfall for the Australian Sugarcane industry under future high and low emission climate scenarios

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The Sugar Industry in Australia
The Sugar Industry in Australia

- 3rd Largest raw sugar exporter
- 3 Million tonnes of raw sugar
- 80% exported
- 4000 Cane Farming businesses

$1.5 - $2.5 billion production

Current value of raw sugar (sugar#11)

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<tbody>
<tr>
<td>US /lb</td>
<td>19.7</td>
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<tr>
<td>AUD /kg</td>
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<tr>
<td>AUD $/T</td>
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</table>
Where is Sugar Grown?

- Heterogeneous Landscape
- Spatially variable rainfall
- Seasonally variable rainfall

Seven regions Considered
1. Tully
2. Herbert
3. Burdekin
4. Mackay
5. Bundaberg
6. Rocky Point
7. New South Wales
The Crop Cycle

Grand Growing

planting

Grand Ripening

harvesting

Tillering

rainfall (mm)
Modelling Harvest Disruptions: “Wet days” Rule
Wet days rule

- Work with industry to define how much rain causes a disruption

- Disruptions due to rainfall “wet days” (Muchow, et al. 1996)
  - If rainfall for day $i \geq 10\text{mm}$ and $<20\text{mm}$ then day $i$ is defined to be a wet day.
  - If rainfall for day $i \geq 20\text{mm}$ and $<40\text{mm}$ then day $i$ and $i+1$ are defined to be wet days.
  - If rainfall for day $i \geq 40\text{mm}$ then day $i$, $i+1$, $i+2$ are defined to be wet days.

- Used in climate variability impact studies (Everingham, et al. 2001).
Data:
Climate Scenarios, GCMs and Downscaling
Climate Scenarios

- Compare two Time Frames
  - 1961 – 2000
  - 2046 – 2065

- Comparison between simulations using three Climate Scenarios
  - 20C3M (1961-2000)
  - B1 (2046 – 2065)
  - A2 (2046 – 2065)
General Circulation Models

- 200Km to 400Km
- Spatial trends vary between and within regions
- Maintain spatial trends
- Can downscale data to more appropriate size
- 0.05 x 0.05 decimal degrees
General Circulation Models

- 200Km to 400Km
- Spatial trends vary between and within regions
- Maintain spatial trends
- Can downscale data to more appropriate size
- 0.05 x 0.05 decimal degrees

Total Annual Rainfall (mm)

Downscaling

- Rainfall data downscaled using Analogues Methodology
  - Statistical downscaling methodology (SDM)

- Developed for Bureau of Meteorology (Timbal et.al, 2011)

- Based on 10 climate regions in Australia

Methodology
Methodology

Downscaled Climate Scenario Rainfall

Apply Harvest Disruption Rule

- Identify number of Unharvestable days
- 0.05° x 0.05° pixels
- Winter and Spring
- 11 GCMs

Analysis

Bias Analysis
- 20C3M – AWAP
- 1961 – 2000
- PDF
- Identify spatial trends

Climate Change
- B1 – 20C3M
- A2 – 20C3M
- 2046-2065 1961-2000
- Boxplots
- KW test for significance
- Identify spatial trends
"I REJECT YOUR REALITY
AND SUBSTITUTE MY OWN"

-Adam Savage (Mythbusters)
Model Bias

- Historical simulated data (20C3M) compared to “baseline” data (AWAP)

- Probability density functions compared
  - Individual GCMs (11)

- Bias analysed spatially
  - Temporal average of 11 GCMs
Results:
Regional and Spatial analysis
Regional Analysis

- General shifts between time periods noted for each climate scenario

- Paired Wilcoxon test used to check for significant shifts in distribution

- Differences between historical and future projections analysed spatially
Change in Unharvestable days: A2

Winter
A2-20C3M

Change in Unharvestable days

Change in Unharvestable days: A2

Change in Unharvestable days: A2

How can industry adapt?

- Start harvest early
  - Modifying harvest window can improve farmer profits (Everingham et al. 2011)
- Expand harvest regions
How can industry adapt?

- Upgrade harvesters
  - Wet Harvesters used in 2010 Season

Track harvester – Ingham, tracks offer advantage of less soil compaction under wet conditions.

Comsin Harvesting owner Stephen Comelli with one of the new [Floatation] tyres he is using on some of his haul-out machinery. The tyres tread more lightly on farmers’ paddocks and are better for the environment. Peter Holt
Key Points

1. Some models perform better than others historically
   - Good models may not be “best” in future
   - Use multiple models

2. Downscaling allows precision results
   - Reproduce spatial patterns

3. Higher emissions = more down time
   - Later in the harvest season
Thank You.
Rainfall variability
The Crop Cycle

- Ratoon crop
- Planting
- Growing
- Harvest

Diagram showing the stages of crop development:

1. Germination & Establishment Phase
2. Tillering Phase
3. Grand Growth Period
4. Ripening Phase
Summary of Regional Analysis

- Simulated seasonal trends
  - Increases in spring
  - Decreases in winter
  - Burdekin decreased in spring

- Simulated significant trends
  - Tully: Increase (A2)
  - Herbert: Increase(B1, A2)
  - Burdekin: Decrease(A2)
Global Climate Scenarios

- Use Global Climate Models developed as part of World Climate Projects CMIP3 database
  - 11 GCMs
  - Developed around the world
  - Models used in Australian research previously
  - Daily rainfall data available for both time periods

<table>
<thead>
<tr>
<th>Group</th>
<th>Country</th>
<th>Acronym</th>
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<tbody>
<tr>
<td>Canadian Climate Centre</td>
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<td>CCM</td>
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<tr>
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<td>France</td>
<td>CNRM</td>
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AWAP predictands

Validation

11 GCMs 3 Climate Scenarios

NRR reanalysis predictors

Downscaled Climate Scenarios

ANALOGUE STATISTICAL DOWNSCALE MODEL

B1

A2

20C3M
The Harvest Period

- Harvest during drier months
  - June – November

- High rainfall during Harvest period can reduce sugar content of cane

- Disruptions can push harvest into wet season
  - December – February
Spring: Region 1
Differences in GTM Number of Unharvestable days
Overview

1. The sugar industry in Australia
2. Modelling harvest disruptions: ‘wet day’ rule
3. Data
   - Climate scenarios
   - Global Circulation Models
   - Downscaling
4. Methodology
   - Bias analysis
   - Change over time
5. Results
   - Regional change over time
   - Spatial patterns
6. How can industry adapt?
7. Key points
Summary of Bias

- Some GCMs reproduced PDFs better
  - Differed regionally and seasonally

- Spatial trends between and within regions
  - North/South trends between regions
  - East/West trends within regions
  - Evidence for over estimates in Tully
  - Evidence for underestimates in Herbert / Burdekin
## PDF Reproducing GCMs

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<thead>
<tr>
<th>Region</th>
<th>Global Climate Models</th>
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<tbody>
<tr>
<td></td>
<td>Winter</td>
</tr>
<tr>
<td>1. Tully/ Far North</td>
<td>MRI, GFDL1</td>
</tr>
<tr>
<td>2. Herbert</td>
<td>GFDL1, CCM</td>
</tr>
<tr>
<td>3. Burdekin</td>
<td>CSIRO, CNRM</td>
</tr>
<tr>
<td>4. Mackay</td>
<td>ISPL</td>
</tr>
<tr>
<td>5. Bundaberg</td>
<td>CNRM, MRI</td>
</tr>
<tr>
<td>6. Rocky Point</td>
<td>GFDL1, CNRM</td>
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<tr>
<td>7. New South Wales</td>
<td>MRI, GISSR</td>
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Summary of Bias

Winter
Difference in average Number of Unharvestable days

Spring
Difference in average Number of Unharvestable days

<table>
<thead>
<tr>
<th>Region</th>
<th>Direction of change in Number of Unharvestable days across 11 GCMs</th>
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<td>Winter</td>
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<tr>
<td>1. Tully</td>
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<td>4. Mackay</td>
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Sexton, Everingham, Timbal, Unpub (2012)
Summary of Spatial Analysis

- Shifts in Number of unharvestable days varied
  - Between regions
  - Within regions

- Northern and Southern regions were more variable than central regions

- Central area of Tully region showed higher increases than edges

- Burdekin region experienced least geographic spread