Climate change and maize production in Zimbabwe

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Current climate variability...
Yield variability

Graphs showing yield variability over different years for various countries.
Frequency of mild to moderate droughts (2000-2011)
Current climate change

Each of the last three decades have been successively warmer than any preceding decade since 1850.
Climate change...
Impact of climate change on yields

![Graph showing the impact of climate change on yields for different regions and crop types.](IPCC AR5)
Projected impacts on maize production

- Andean region
- Brazil
- Southern Africa
- East Africa
- Central Africa
- Sahel
- West Africa
- West Asia
- Southeast Asia
- South Asia
- China

[Image showing bar chart with regions and corresponding production impacts.]

Adapted from Lobell et al. 2008
Climate projections

(a) RCP 2.6
Change in average surface temperature (1986–2005 to 2081–2100)

(b) RCP 8.5
Change in average precipitation (1986–2005 to 2081–2100)
Large increase in temperature

Global surface temperature change for the 21st century is likely to exceed 1.5 C relative to 1850-1900 for all scenarios except RCP2.6.
Breeding

Planning

Policies

Downscaled climate projections
Increase in maximum temperature

(19 GCMs, A2 scenario)

Cairns et al., 2013
## Rainfall changes

<table>
<thead>
<tr>
<th>Region</th>
<th>Season</th>
<th>Min</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>max</th>
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<tbody>
<tr>
<td>West Africa</td>
<td>Dec-Feb</td>
<td>-16</td>
<td>-2</td>
<td>-6</td>
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<tr>
<td></td>
<td>March-May</td>
<td>-11</td>
<td>-7</td>
<td>-3</td>
<td>5</td>
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<tr>
<td></td>
<td>June-Aug</td>
<td>-18</td>
<td>-2</td>
<td>2</td>
<td>7</td>
<td>11</td>
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<td></td>
<td>Sept – Nov</td>
<td>-12</td>
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<td>15</td>
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<tr>
<td></td>
<td>Annual</td>
<td>-9</td>
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<td>2</td>
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<tr>
<td>East Africa</td>
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<td>6</td>
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<td>June-Aug</td>
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<td>7</td>
<td>16</td>
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<td></td>
<td>Sept – Nov</td>
<td>-10</td>
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<td>7</td>
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<td>-3</td>
<td>2</td>
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<td>11</td>
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<tr>
<td>Southern Africa</td>
<td>Dec-Feb</td>
<td>-6</td>
<td>-3</td>
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<td>10</td>
</tr>
<tr>
<td>March-May</td>
<td>-25</td>
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<td>0</td>
<td>4</td>
<td>12</td>
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<td></td>
<td>June-Aug</td>
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<td>-23</td>
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<td>-12</td>
<td>-9</td>
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</tbody>
</table>

IPCC, 2007; Cooper et al. 2008
Changes in annual rainfall

Cairns et al., 2012
Rainfall changes

Cairns et al., 2013
Rainfall changes

Increase in seasonal rainfall in some areas, decrease in others

Dry lowlands rainfall will decrease during flowering. Delay in onset of short rainy season

General increase in rain, but delay in onset of rainy season

Cairns et al., 2013
Change in season length

Waha et al. 2013
Implications for maize production...
Changes in maize production

(MIROC GCM Projection)
<table>
<thead>
<tr>
<th>Country</th>
<th>Production (%)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CISRO</td>
<td>MIROC</td>
</tr>
<tr>
<td>Angola</td>
<td>-7.5</td>
<td>-14.0</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2.3</td>
<td>6.0</td>
</tr>
<tr>
<td>Kenya</td>
<td>4.0</td>
<td>20.0</td>
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<tr>
<td>Malawi</td>
<td>-5.8</td>
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<td>Mozambique</td>
<td>-9.0</td>
<td>-16.5</td>
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<td>Nigeria</td>
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<td>South Africa</td>
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<td>Tanzania</td>
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<tr>
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<td>5.0</td>
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<td>-8.3</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>-4.9</td>
<td>-11.1</td>
</tr>
</tbody>
</table>

Tesiaye et al. 2015
It's not all negative!
Implications for crop breeding...
Potential to increase yields

Shiferaw et al. 2014
Potential to increase yields

(b) CZH0811 vs. SC513

(c) CZH0616 vs. SC513

Early maturity

Medium maturity

Tesfaye et al. in press
Maize mega-environments

Outputs of global climate models

## Changes in maize mega-environments

<table>
<thead>
<tr>
<th>Maize mega-environment</th>
<th>Current</th>
<th>2050</th>
<th>Change</th>
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</thead>
<tbody>
<tr>
<td>Wet upper mid-altitude</td>
<td>14</td>
<td>5</td>
<td>-60</td>
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<tr>
<td>Wet lower mid-altitude</td>
<td>27</td>
<td>11</td>
<td>-56</td>
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<tr>
<td>Dry mid-altitude</td>
<td>7</td>
<td>3</td>
<td>-52</td>
</tr>
<tr>
<td>Wet lowland</td>
<td>23</td>
<td>41</td>
<td>88</td>
</tr>
<tr>
<td>Dry lowland</td>
<td>26</td>
<td>38</td>
<td>57</td>
</tr>
<tr>
<td>Highland</td>
<td>2</td>
<td>1</td>
<td>-43</td>
</tr>
</tbody>
</table>
Changes in mega-environments

- No change in mega-environment assignment
- Currently a different mega-environment but will change to this mega-environment by 2050
- Currently this mega-environment but will become a different mega-environment by 2050
Potential changes in maize mega-environments
Potential changes in maize mega-environments
Potential changes in maize mega-environments
Summary: changes in mega-environments

Sonder et al. In prep.
Heat stress

Lobell et al. 2011
## Heat stress

<table>
<thead>
<tr>
<th>Entry</th>
<th>Pedigree</th>
<th>Grain yield (t ha⁻¹)</th>
<th>Rank under HEAT</th>
<th>WW</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>DS</td>
<td>DS+H</td>
<td>HEAT</td>
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<tr>
<td>2</td>
<td>[SYN-USAB2/SYN-ELIB2]-12-1-1-2</td>
<td>3.22</td>
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<td>251</td>
<td>La Posta Seq C7-F18-3-2-1-1</td>
<td>3.16</td>
<td>1.13</td>
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<td>190</td>
<td>CLQ-RCYQ40 = (CML165 × CLQ-6203)-B-9-1-1</td>
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<td>DTPYC9-F46-1-2-1-1</td>
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<tr>
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<td>CML444/CML442</td>
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<td>Trial mean</td>
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<td>1.13</td>
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<td>LSD₀.₀₅</td>
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<td>0.94</td>
<td>0.78</td>
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Cairns et al. 2013b
# Heat stress

<table>
<thead>
<tr>
<th></th>
<th>Drought</th>
<th>Drought (elevated temp)</th>
<th>Heat</th>
<th>Optimal</th>
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<tbody>
<tr>
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<tr>
<td>Drought (elevated temp)</td>
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<td></td>
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<tr>
<td>Heat</td>
<td>0.49</td>
<td>-0.07</td>
<td>-</td>
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<tr>
<td>Optimal</td>
<td>0.63</td>
<td>0.24</td>
<td>0.27</td>
<td>-</td>
</tr>
</tbody>
</table>
Heat stress

- Reduced pollen viability
- Reduced pollen shed
Heat stress

Mean

Grain yield (t ha\(^{-1}\))

Experimental hybrids

CH1315

CH1319

CH11367

CH1315

CH1318

C2H13

CH12236

CH11111

CH124794

Commercial hybrids

1

2

Magorokosho in prep.
Analogues of future climates
Exploit regional network

updated from Prasanna et al. 2013

- Drought* - 61 ha
- Low nitrogen - 48.5 ha
- Heat - 13.5 ha
- MLN - 17 ha

*Including CFT sites
Breeding for future or current environments?
Pest and diseases outbreaks?
Pest and diseases outbreaks?

2 QTL
- Chromosome 3
  - Max LOD - 28
  - R^2 - 38%
- Chromosome 6
  - Max LOD - 8
  - R^2 - 15%

GWAS
- Multiple leads
- 43 MABC projects
- Ongoing
- BC3F1:2 stage

GS methodology
- Cross validation prediction accuracy within AM panels
  - ~0.5

Gowda et al. 2015
Yield gains under drought: USA

Grain yield (t ha\(^{-1}\))

- **1985**: Average 6, Drought 5
- **1988**: Average 7, Drought 6
- **2012**: Average 10, Drought 8

Boyer et al. 2012
Product life cycles - USA

Average survival time (years)

- Conventional
- Herbicide tolerant
- Corn borer
- 2+ biotechnology traits

Magnier et al. 2010
Conclusions

GIS and modelling are essential to understand future environments.

Breeding programs need to be re-aligned to future environments.

Rapid varietal replacement has buffered other continents from the impacts of climate variability.
Thank you for your interest!

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