Probabilistic assessment of adaptation options from an ensemble of crop models: a case study in the Mediterranean


MACSUR Science Conference 2017, Berlin
Introduction and Objectives

• Adaptation is needed for dealing with climate change
• Adaptation has to be done at local scale and informed with uncertainty
• Study objectives:
  – to explore adaptation potential of rainfed winter wheat in a water-limited environment, using Adaptation Response Surfaces (ARSs)
  – to estimate the likelihood of the effect of adaptations using Probabilistic Projections (PPs) of climate change
What is an ARS?

- IRS are plotted surfaces showing the response of an impact variable (here $Y$) to changes in two explanatory variables (here $P$ and $T$).

- By analyzing adaptation variables such as changes in crop yield ($\Delta Y$, $\%\Delta Y$) when an adaptation option is simulated, these can be interpreted as the adaptation response to potential changes of $P$ and $T$, i.e. ARS.

 Ruiz-Ramos et al., 2017
What are Probabilistic Climate Projections?

- Probabilistic Climate Projections are climate projections in the form of probability distribution functions (PDFs).
- They provide climate projections with associated uncertainty values.

Joint probabilities of Temperature and Precipitation changes for the next century. Data from: Hadley Centre
Coupling PP and ARS for probabilistic assessment

Ensemble of Crop Growth Simulation Models

Response Surfaces

Probabilistic Projections of Climate Change

Bilinear interpolation

Selection of a threshold

Likelihood

Cumulative distribution of the effect

Cumulative distribution (%)

Yield (Mg ha\(^{-1}\))

Delta Temp. (°C)

Delta Prec. (%)
The modelling study

- **Crop and study site:** Winter wheat at NE-Spain (Lleida)

- **Models ensemble:**
  - 17 members (14 models)
  - Calibration performance:
    - “Good” according to (Jamieson et al., 1991)
    - %RMSE yield & biomass < 20
    - %RMSE phenology < 11

- **Simulation experiment:**
  - **Baseline period:** 1981-2010
  - **Standard management:** water-limited, optimal nutrients
  - **Soil:** 2 actual profiles (shallow and deep)
  - **Climate**
    - **Baseline** (360 ppm) + 2 levels of CO₂ (447 and 522 ppm)
    - Delta change + seasonal pattern
      - 72 combined changes to baseline T and P (1981-2010):
        - P: -40 % to +30 %
        - T: -1 °C to + 7 °C
Methodology: Adaptations to be tested

Based on preliminary runs aimed at narrowing the number of simulations

• Vernalisation:
  – Standard: Winter
  – Spring wheat

• Sowing date
  – Standard: 302 DOY, 28th October
  – Sowing at -15d (earlier)
  – Sowing at +30d (later)

• Phenology
  – The standard cultivar
  – A cultivar with a crop cycle 10% shorter, for WW and SW
  – A cultivar with a crop cycle 10% longer, for WW and SW

• Irrigation
  – Standard: Rainfed (R)
  – Supplementary irrigation (SI) with 40 mm at flowering
  – Full irrigation (I as a reference)
ARS combined adaptations: RAINFED

CO₂ 522 / Shallow soil / Rainfed

ARS: percentage of median yield change (%) with adaptation

SW/early SD/Shorter cv

SW/early SD/Longer cv

Ruiz-Ramos et al., 2017
ARS combined adaptations: Suppl. Irr.

CO₂ 522 / Shallow soil / Supplementary Irrigation

ARS: percentage of median yield change (%) with adaptation

SW/early SD/Longer cv

WW/early SD/Std cv

Ruiz-Ramos et al., 2017
## Adaptation potential: Qualitative assessment

<table>
<thead>
<tr>
<th>Water mgnt</th>
<th>Cultivar</th>
<th>Sowing date</th>
<th>Shallow</th>
<th>Deep</th>
<th>Recommendations</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adaptation</td>
<td>Recovery</td>
<td>Adaptation</td>
</tr>
<tr>
<td>WW</td>
<td>R</td>
<td>None</td>
<td>None</td>
<td>-</td>
<td>None</td>
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<tr>
<td></td>
<td>cv1</td>
<td>Earlier</td>
<td>1,2,3,4,5</td>
<td>1,2,3,4</td>
<td>1,2,3,4,5</td>
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<tr>
<td></td>
<td>cv0</td>
<td>All</td>
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<td>1</td>
<td>1,2,3,4,5</td>
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<tr>
<td></td>
<td>cv2</td>
<td>None</td>
<td>None</td>
<td>-</td>
<td>None</td>
</tr>
<tr>
<td>SW</td>
<td>R</td>
<td>cv1</td>
<td>Earlier</td>
<td>1,2,3,4,5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>cv2</td>
<td>Standard &amp; earlier</td>
<td>1,2,3,4,5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>sl</td>
<td>cv1</td>
<td>Earlier</td>
<td>1,2,3,4,5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cv0</td>
<td>Standard &amp; earlier</td>
<td>1,2,3,4,5</td>
<td>1,2,3,4,5</td>
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<tr>
<td></td>
<td>cv2</td>
<td>Standard &amp; earlier</td>
<td>1,2,3,4,5</td>
<td>1,2,3,4</td>
<td>1,2,3,4,5</td>
</tr>
</tbody>
</table>

Abbreviations: rainfed (R), supplementary irrigation (sl), shorter, standard and longer crop cycle duration (cv1, cv0 and cv2 respectively), cultivar without vernalization requirements (SW), winter wheat (WW), management (mgnt), not considered because of lack of adaptation response (−).
Likelihood of adaptation

Shallow soil/Spring Wheat/std SD and CV/Rainfed

Likelihood: 1.00
Median adapt. resp: 11.3%

Likelihood: 1.00
Median adpt. resp.: 15.1%

PP: HADCM3 A1B (Harris et al. 2010)
ARS: percentage of median yields change (%) with adaptation
Likelihood of recovery

**Shallow soil/Spring Wheat/std SD and CV**

**Likelihood: 1.00**  
**Median recovery: 21.8%**

**RRS:** % of median yields recovery with adaptation  
**Recovery:** difference between median yields with adaptation and baseline reference yield

**Likelihood: 0.97**  
**Median recovery: 22.2%**
## Adaptation potential: Quantitative assessment

<table>
<thead>
<tr>
<th>Water mgnt</th>
<th>Cultivar</th>
<th>Sowing date</th>
<th>Median Likelihood (%)</th>
<th>Median Likelihood (%)</th>
<th>Median Likelihood (%)</th>
<th>Median Likelihood (%)</th>
</tr>
</thead>
</table>
| **WW** | sl Short Earli...
Adaptation potential: Quantitative assessment

<table>
<thead>
<tr>
<th>Water mgnt</th>
<th>Cultivar</th>
<th>Sowing date</th>
<th>2020-2040 (447 ppm)</th>
<th>2040-2060 (522 ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Adaptation</td>
<td>Recovery</td>
<td>Adaptation</td>
</tr>
<tr>
<td>WW</td>
<td>sl</td>
<td>SS</td>
<td>LIK LI Med</td>
<td>SS</td>
</tr>
<tr>
<td>WW</td>
<td>Std</td>
<td>Earlier</td>
<td>1.00 8.1 0.98 10.0</td>
<td>1.00 7.4 0.95 10.5</td>
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<tr>
<td>WW</td>
<td>Standard</td>
<td>Earlier</td>
<td>1.00 18.8 1.00 22.6</td>
<td>1.00 19.6 0.95 18.6</td>
</tr>
<tr>
<td>WW</td>
<td>Standard</td>
<td>Standard</td>
<td>1.00 20.2 1.00 22.2</td>
<td>1.00 22.4 0.97 20.4</td>
</tr>
<tr>
<td>WW</td>
<td>Standard</td>
<td>Longer</td>
<td>1.00 13.8 0.96 13.5</td>
<td>1.00 15.7 0.92 10.8</td>
</tr>
<tr>
<td>SW</td>
<td>R</td>
<td>SS</td>
<td>LIK LI Med</td>
<td>SS</td>
</tr>
<tr>
<td>SW</td>
<td>Std</td>
<td>Earlier</td>
<td>0.98 5.7 0.97 14.5</td>
<td>0.99 8.7 0.78 12.4</td>
</tr>
<tr>
<td>SW</td>
<td>Standard</td>
<td>Earlier</td>
<td>0.88 5.8 0.86 10.3</td>
<td>0.99 9.0 0.78 7.3</td>
</tr>
<tr>
<td>SW</td>
<td>Standard</td>
<td>Standard</td>
<td>1.00 19.6 0.98 22.2</td>
<td>1.00 14.9 0.89 19.0</td>
</tr>
<tr>
<td>SW</td>
<td>Standard</td>
<td>Longer</td>
<td>1.00 11.3 1.00 21.8</td>
<td>1.00 15.0 0.97 22.2</td>
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<td>SW</td>
<td>Std</td>
<td>Earlier</td>
<td>0.98 6.7 0.89 11.3</td>
<td>1.00 9.7 0.79 7.8</td>
</tr>
<tr>
<td>SW</td>
<td>Standard</td>
<td>Earlier</td>
<td>0.88 5.0 0.98 13.6</td>
<td>0.98 9.2 0.93 11.7</td>
</tr>
<tr>
<td>SW</td>
<td>Standard</td>
<td>Standard</td>
<td>1.00 30.6 1.00 27.4</td>
<td>1.00 37.5 1.00 27.1</td>
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<tr>
<td>SW</td>
<td>Standard</td>
<td>Longer</td>
<td>1.00 22.0 1.00 40.5</td>
<td>1.00 24.3 1.00 40.1</td>
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<tr>
<td>SW</td>
<td>Standard</td>
<td>Longer</td>
<td>1.00 12.2 1.00 26.3</td>
<td>1.00 14.9 1.00 27.0</td>
</tr>
</tbody>
</table>
• **Adaptation is possible!**

• **A wide scope for adaptation exists when considering combined adaptations**
  - There are few feasible options for rainfed (but not NONE)
    - Based on SW, std/longer cycle and earlier SD (Adapt. Resp.: likelihood 100%, median up to 20%; Recovery: likelihood 98%, median 22%)
  - There are many feasible options for SI
    - SW, std/longer cv and earlier SD (Adapt. Resp.: likelihood 100%, median up to 37%; Recovery: likelihood 100%, median 40%)
    - Also for WW (Adapt. Resp.: likelihood 100%, median up to 22%; Recovery: likelihood 97%, median 20%)

• **The methodology can be useful for planning and supporting decisions**
  - ARSs provide a qualitative assessment of the performance of adaptations
  - ARSs and probabilistic projections of CC integrates the information by providing quantitative values and informing on uncertainties
Thank you!

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