Simulating wheat adaptation to climate change in Europe using an ensemble approach with impact response surfaces (IRS2)

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CropM

MACSUR Science Conference, April 2015, Reading, UK

Introduction

- Adaptation (A)
  - can reduce CC risks to crop production
  - is best analyzed at local scales
- Uncertainty (U) is due to
  - climate projections
  - downscaling
  - imperfections of crop models
- Approach: Combination A+U
  - A: exploiting the potential of GxMxE
  - U: CROP MODEL **ENSEMBLE+IRS**→projections informed with uncertainty

Objectives

- Study:
  - to explore the adaptation potential of rainfed winter wheat at Lleida (NE Spain) in a water-limited environment, as a 1st study case

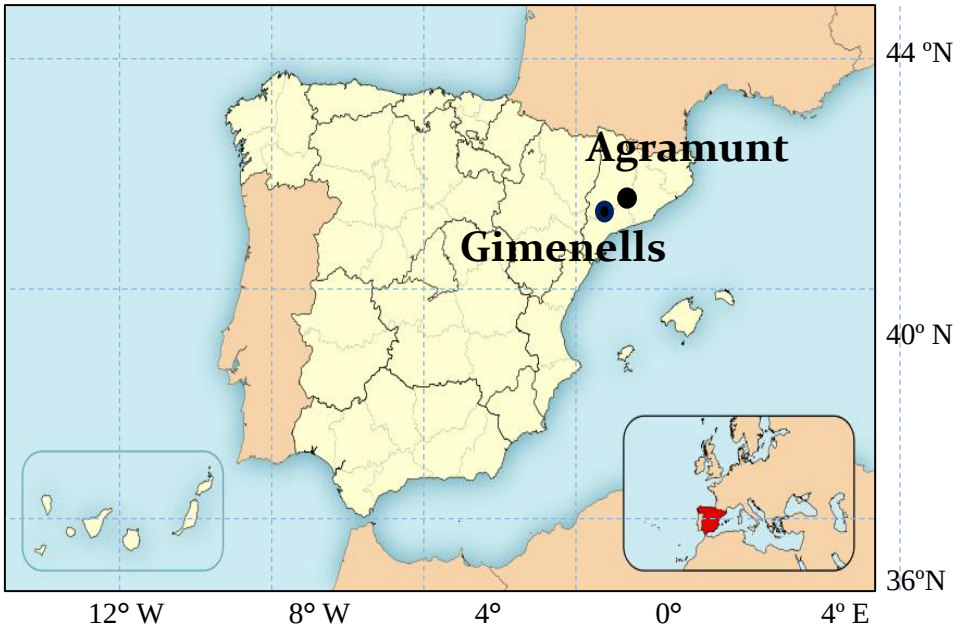
  → Feasible adaptations

- Today:
  - to present
    - the methodology that constructs **IMPACT RESPONSE SURFACES** (IRSs) from an ensemble of crop models for IRS2
    - preliminary results

Methodology I:

Study site and crop

- NE-Spain: IRS1-LLEIDA (Gimenells and Agramunt)
- Soils
  - Gimenells, 109 cm
  - Agramunt, 180 cm
- Climate
  - P:361 mm
  - T: 14.8 ºC
- Rainfed winter wheat:
  - Sowing date: 29 Oct
  - Flowering occurs in May
  - Harvest date: by June
- Experimental data: Cartelle et al. (2006) and Abeledo et al (2008)



Methodology II

- Following Pirttioja et al. (under review)→IRS1
- Simulation experiment
  - Baseline period: 1981-2010 (as in IRS1)
  - Management: water-limited, optimal nutrients
  - Soil: 2 actual profiles
  - Climate
    - **3 LEVELS OF CO_2,** for 20-year time slices centered on 1995 (360 ppm), 2030 and 2050 (A1B)
    - Delta change (Harris et al., 2010) + seasonal pattern
      - 64 combined changes to baseline T and P (1981-2010):

        P: -50 % AND +20 %

        T: 0 °C AND + 7 °C

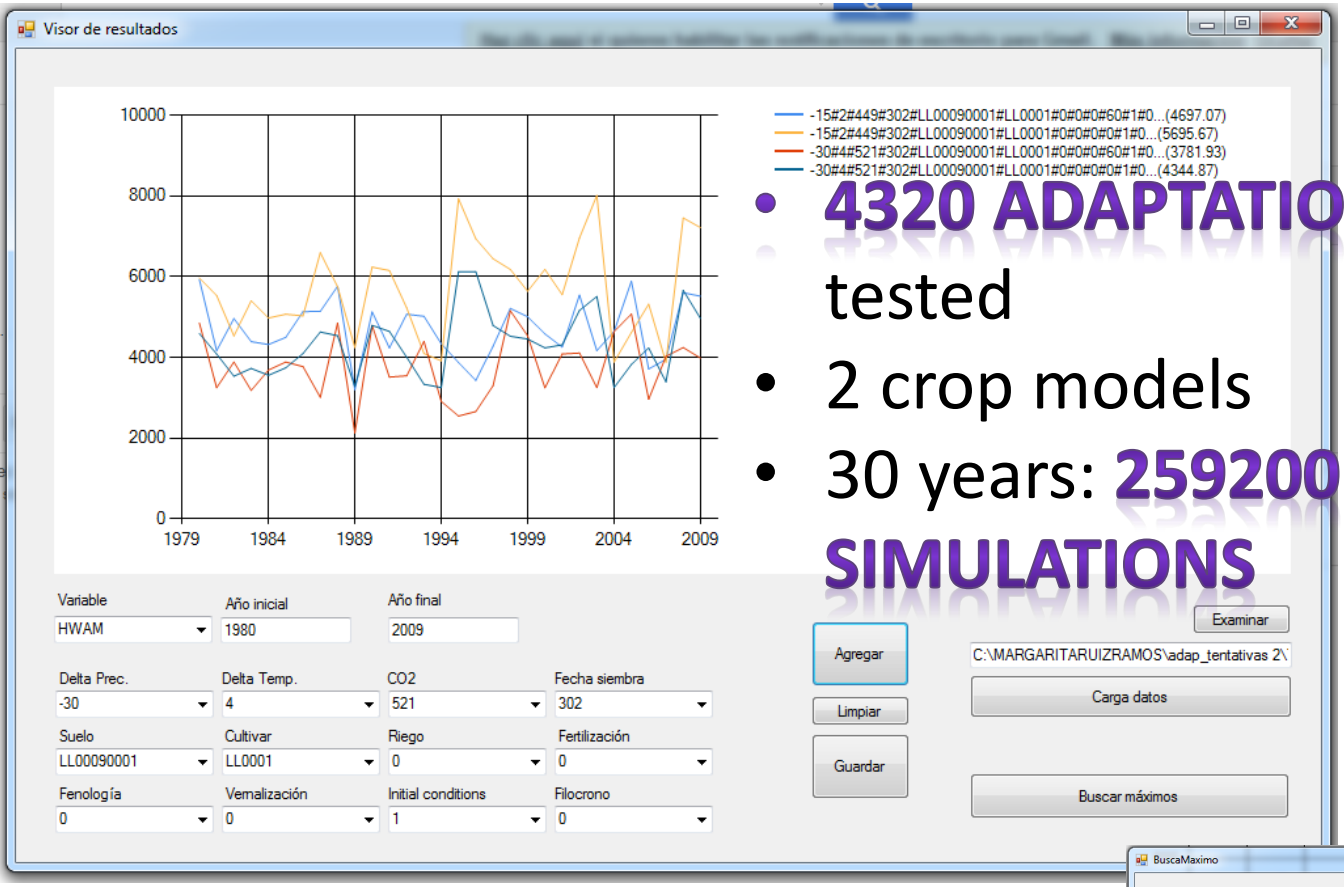
Methodology III

- Adaptations:
  - Sowing date: 15 days shifts
  - Phenology: thermal and vernalisation requirements
    - eg. -10%, +10%, +15%, +20%...of the TSUM thresholds
  - Supplementary irrigation: eg. at flowering
- Phase I
  - Recalibration
  - Pre-selection of a limited number of effective adaptations
  - Ranges supported by literature
  - **CERES, SIRIUSQ**

Methodology IV

- Phase II
  - Selected adaptations evaluated combining IRSs and probabilistic projections of CC
  - **ALL CROP MODELS**
    - Calibration: nRMSE<= 20% ("Good"according to Jamieson et al., 1991)

Current status: Results Phase I

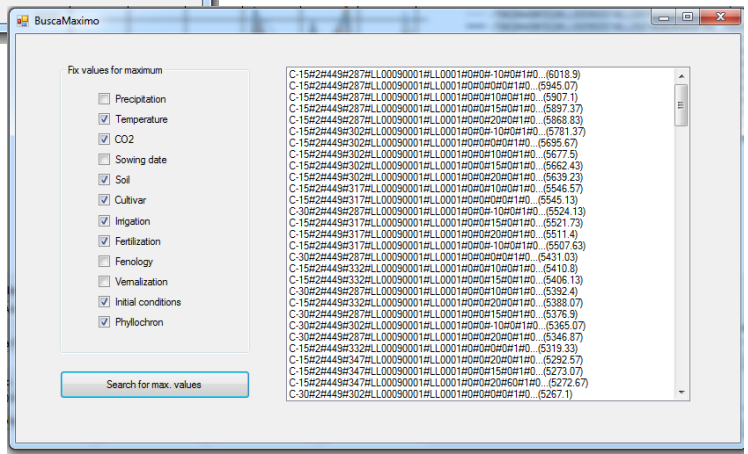


- **4320 ADAPTATIONS** tested
- 2 crop models
- 30 years: **259200 SIMULATIONS**

- P 3
- T 3
- CO_2 3
- Soils 2
- Sowing 5
- PH 4
- V 2
- Irri 2

A combination browser:

→ Plots and searching for maximum means



- Adaptations with CERES-GIMENELLS (109 cm)

Blue indicates little differences between options

Small T&P changes // Large T&P changes

ADAPTATION COMBINATION				SELECTED OPTION	HIGHEST YIELD
SOWING DATE	PHASE DURATON	VERNALISATION	SUPPL. IRRIG.	Sow (d), phen (%), V, I	
x	-	YES	-	-15 d	x
x	-	NO	-	-15 d	
x	x	YES	-	-15d, 0%//0,-10%	
-	-	NO	-	NO	
-	-	YES	x	OK	
x	-	YES	x	+15//+45	
x	x	YES	x	-15 d, -10%	xx
x	-	NO	x	NO	

- Adaptations with CERES-AGRAMUNT (180 cm)

(Option in brackets) indicate further yield gain

ADAPTATION COMBINATION				SELECTED OPTION	HIGHEST YIELD
SOWING DATE	PHASE DURATON	VERNALISATION	SUPPL. IRRIG.	Sow (d), phen (%), V, I	
x	-	YES	-	+45 d	
x	-	NO	-	-15 d	
x	x	YES	-	+45 d, -10% (No V)	x
-	-	NO	-	SW	
-	-	YES	x	OK	
x	-	YES	x	+45 d	
x	x	YES	x	+45d, -10% (No V, -15d)	
x	-	NO	x	-15d	xx

Adaptations with CERES

GIMENELLS
SOWING -15 d
IRRIGATION AT FLOWERING
NO SW
PHENOLOGY -10%

Baseline yield hardly recovered

AGRAMUNT
SW
SPRING WHEAT SOWN -15 d
WINTER WHEAT SOWN +45 d
IRRIGATION AT FLOWERING
PHENOLOGY -10%

Baseline yield recovered and exceeded by *ca*. 10%c

- **GIMENELLS:** Irrigation> sowing date> phase duration> vernalisation
- **AGRAMUNT**: Vernalisation> Irrigation> sowing date> phase duration

40%----------→1%

Range of yield change

- Adaptations with SIRIUSQ –GIMENELLS (109 cm)

Blue indicates little differences between options

ADAPTATION COMBINATION				SELECTED OPTION	HIGHEST YIELD
SOWING DATE	PHASE DURATON	VERNALISATION	SUPPL. IRRIG.	Sow (d), phen (%), V, I	
x	-	YES	-	+30d	
x	-	NO	-	-15 d	
x	x	YES	-	30 d,+15%	
-	-	NO	-	SW	x
-	-	YES	x	OK	
x	-	YES	x	+30 d	
x	x	YES	x	30 d,-+10 %, 0%	
x	-	NO	x	-15d	xx

- Adaptations with SIRIUSQ –AGRAMUNT (180 cm)

Blue indicates little differences between options

Small T&P changes // Large T&P changes

ADAPTATION COMBINATION				SELECTED OPTION	HIGHEST YIELD
SOWING DATE	PHASE DURATON	VERNALISATION	SUPPL. IRRIGATION	Sow (d), phen (%), V, I	
x	-	YES	-	+15d,30 d	
x	-	NO	-	-15d//+15d	
x	x	YES	-	+30d, +10%//-10%	
-	-	NO	-	SW	x
-	-	YES	x	OK	
x	-	YES	x	30 d	
x	x	YES	x	30 d, -10%	
x	-	NO	x	0d	xx

Adaptations with SIRIUSQ

GIMENELLS
SPRING WHEAT SOWN -15d
WINTER WHEAT SOWN +30 d
SW
IRRIGATION AT FLOWERING

AGRAMUNT
SPRING WHEAT SOWN 0 CHANGE
WINTER WHEAT SOWN +30 d
SW
IRRIGATION AT FLOWERING

Baseline yield recovered and exceeded by *ca*. 10%

Vernalisation> Irrigation> sowing date> phase duration

40%----------→1%

Range of yield change

Common results CERES, SIRIUSQ

GIMENELLS

SW no clear advantage, -15d

WW, +30d, -15d ?

Phenology +10%?

Irrigation

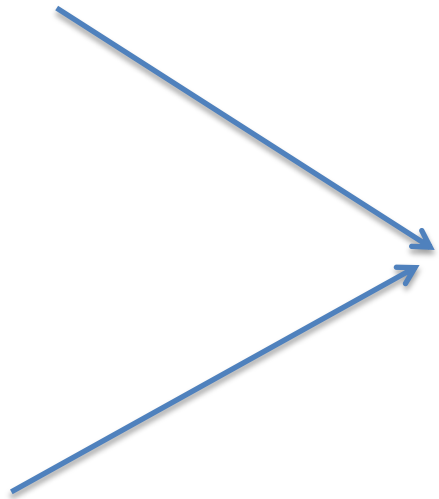
AGRAMUNT

SW -15 d

WW +30d

Phenology -10%

Irrigation



Redefinition

Selecting adaptations

- Common trends
  - feasible adaptations
- Similar calibration/validation results for both models
  - Different responses at Gimenells in the adaptation simulations→model uncertainty
  - Sowing dates and cultivar combination not conclusive
- Phenological changes have to be redefined

Selected Adaptations (for Phase II)

- GIMENELLS & AGRAMUNT
  - Vernalisation
    - SW
    - WW
  - Sowing date
    - -15d
    - 0 d
    - +30d
- Irrigation
  - Rainfed
  - 40 mm at flowering
  - No water limitation
- Fertilisation
  - No nutrient limitation
  - Farmer's fertilisation

2 x 3 x 2 x 1 = 12 adaptation options

2 x 3 x 3 x 2 = 36 adaptation options

<T-steps> X <P-steps> X <soils> X <CO2> X <adapt.> X <yrs> X <sites> X <crops> X <seas. cycle>
= 8 X 8 X 2 X 3 X 9 (8+1) X 30 X 1 X 1 X

Baseline without seasonal pattern

<T-steps> X <P-steps> X <soils> X <CO2> X <baseline> X <yrs> X <sites> X <crops> X <ann. cycle>
= 8 X 8 X 2 X 1 X 1 X 30 X 1 X 1 X 1

Next steps: Phase II

- Protocol and calibration data to be delivered in early May: SIMILAR SETTING THAN IRS1
- Sending back calibration results results by end of June
- Perturbed climate delivered in mid July
- Sending back perturbed simulation results by 30 September (extended if going for 36 adaptations)
- October-December analysing results
- March 2016 paper draft

Thank you!

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Subject: IRS2