Modelling European Agriculture with Climate Change for Food Security

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

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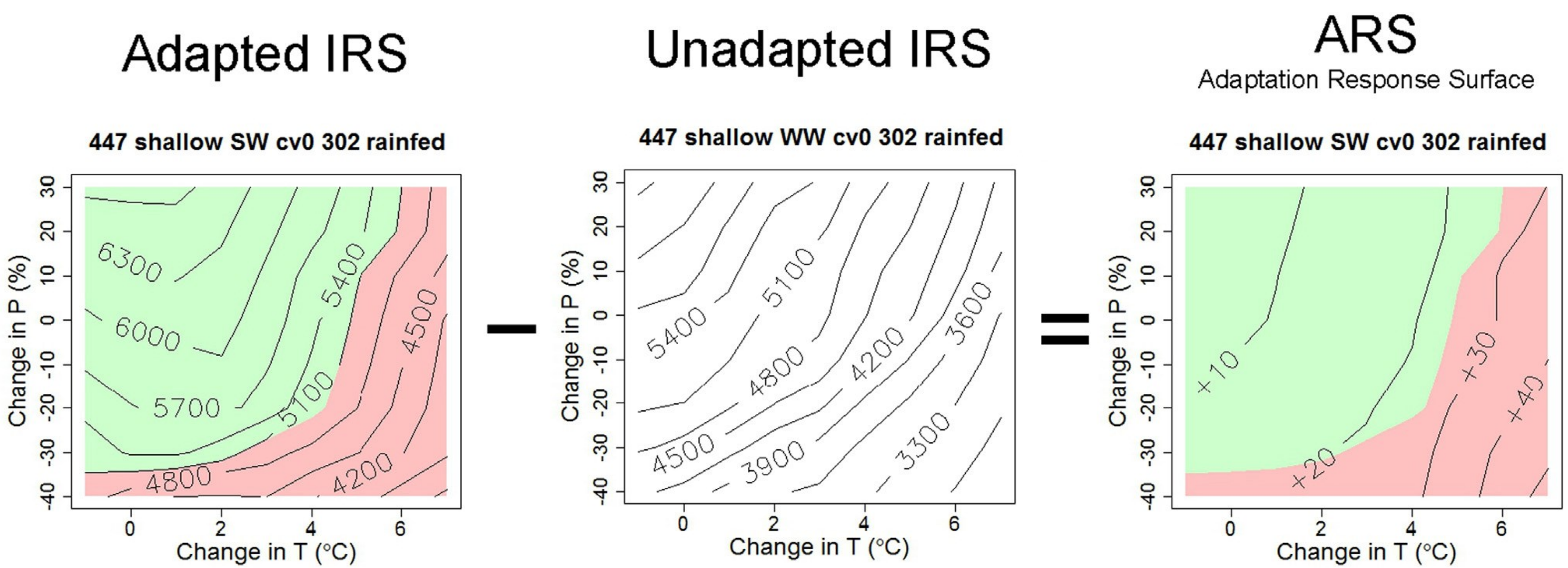
Introduction and Objectives

- 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 (ΔY, %ΔY) 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

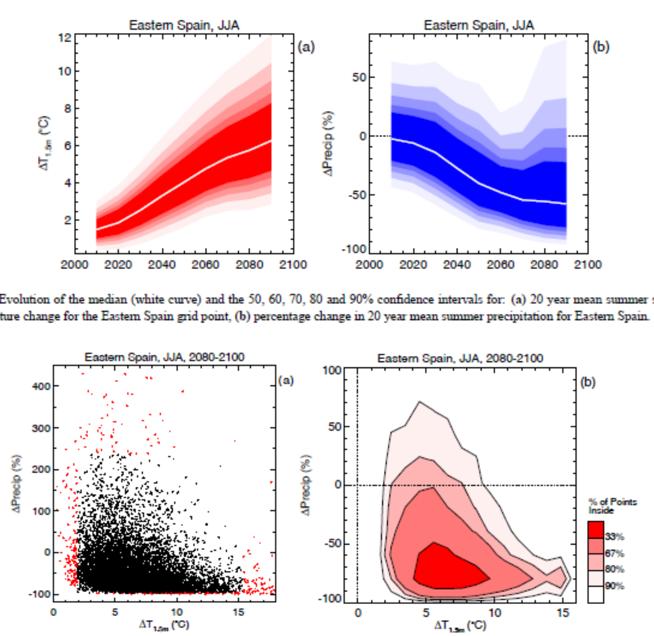
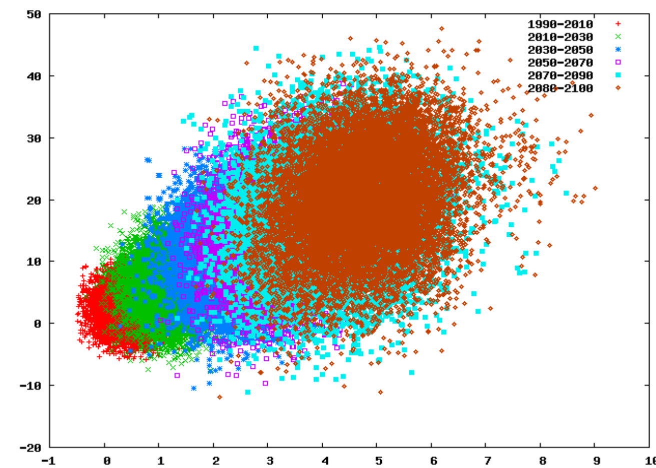

2016 G. R. Harris et al.: Probabilistic projections for 21st century European climate

Fig. 5. Evolution of the median (white curve) and the 50, 60, 70, 80 and 90% confidence intervals for: (a) 20 year mean summer surface temperature change for the Eastern Spain grid point, (b) percentage change in 20 year mean summer precipitation for Eastern Spain.

Fig. 6. (a) Scatter plot of 10 000 sampled data points from the joint PDF of surface temperature change and percentage precipitation change for the summer season for Eastern Spain, for the period 2080–2099 relative to the 1961–1990 baseline period. Points that lie in the top and bottom 1% of the marginal distributions are shown in red. (b) Contours of the Winsorised sampled joint probability distribution function in (a).

Harris et al., 2010



Joint probabilities of Temperature and Precipitation changes for the next century. Data from: Hadley Centre

Coupling PP and ARS for probabilistic assessment

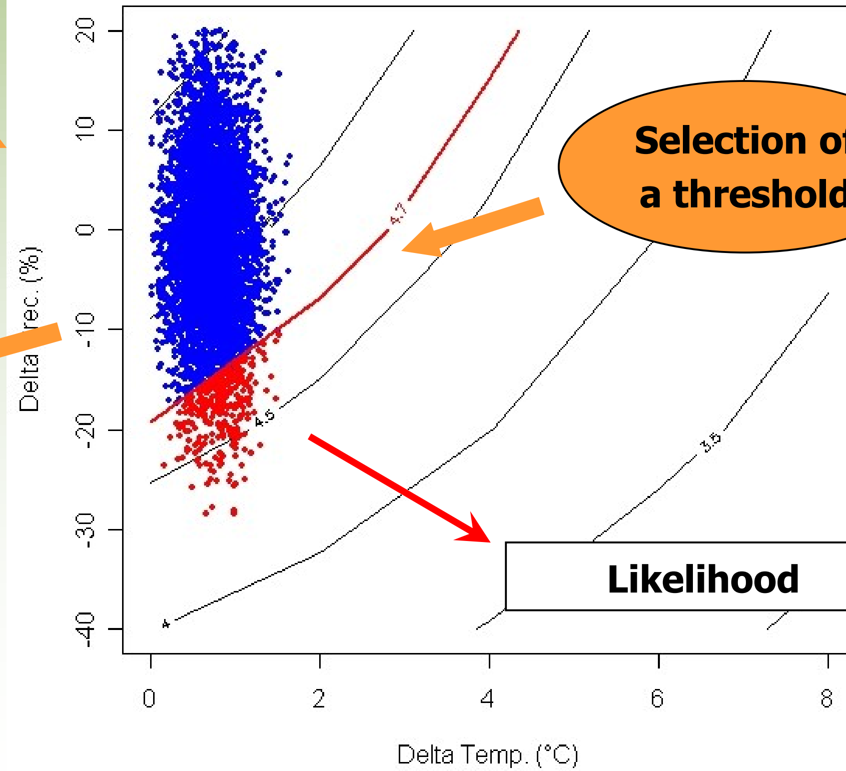
Ensemble of Crop Growth Simulation Models

Probabilistic Projections of Climate Change

Response Surfaces

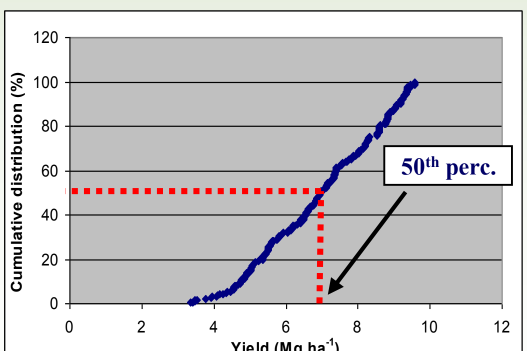
Bilinear interpolation

Selection of a threshold



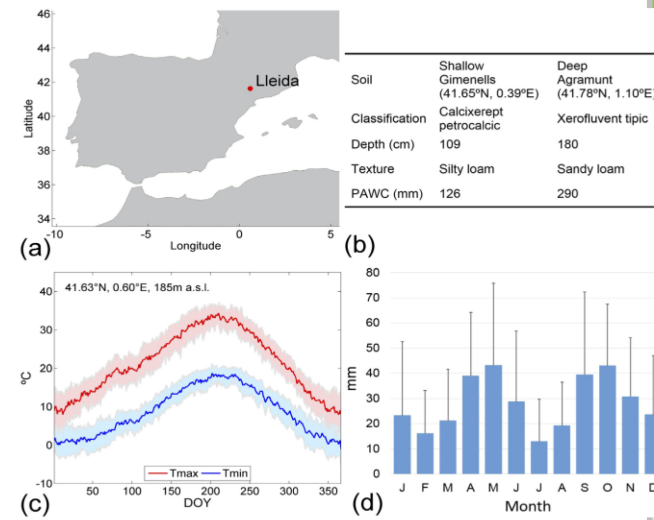
Likelihood

Cumulative distribution of the effect



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



Ruiz-Ramos et al., 2017

- 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 CO_2 (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

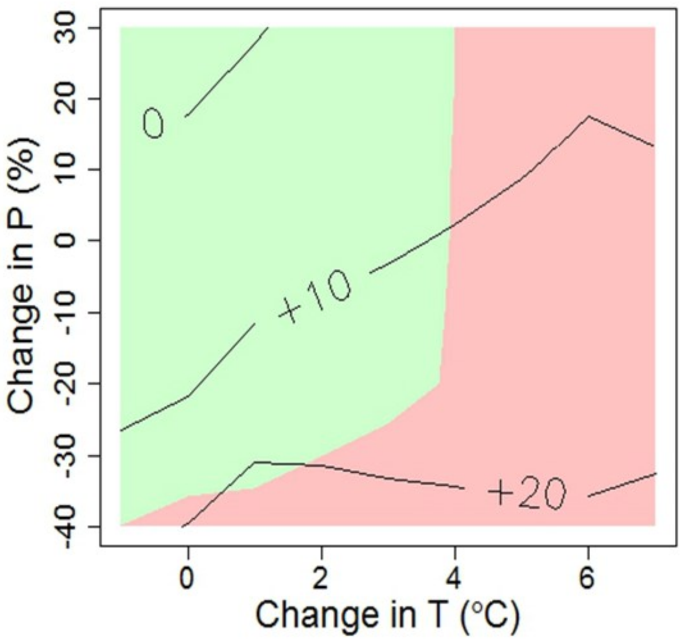
- Vernalisation:
  - Standard: Winter
  - Spring wheat
- Sowing date
  - Standard: 302 DOY, 28th October
  - Sowing at -15d (earlier)
  - Sowing at +30d (later)
- Phenology
  - The standard cultivar
  - A cultivar with a crop cycle 10% shorter, for WW and SW
  - A cultivar with a crop cycle 10% longer, 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

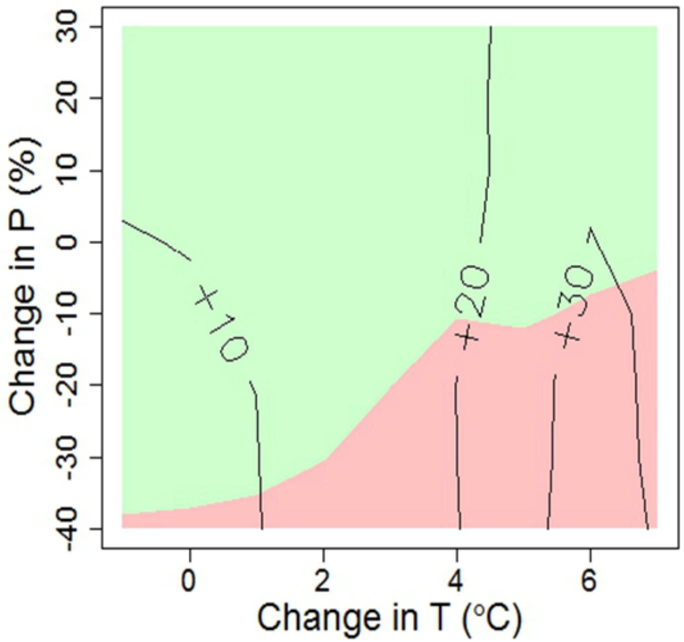
CO_2 522 / Shallow soil / Rainfed

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

SW/early SD/Shorter cv



SW/early SD/Longer cv



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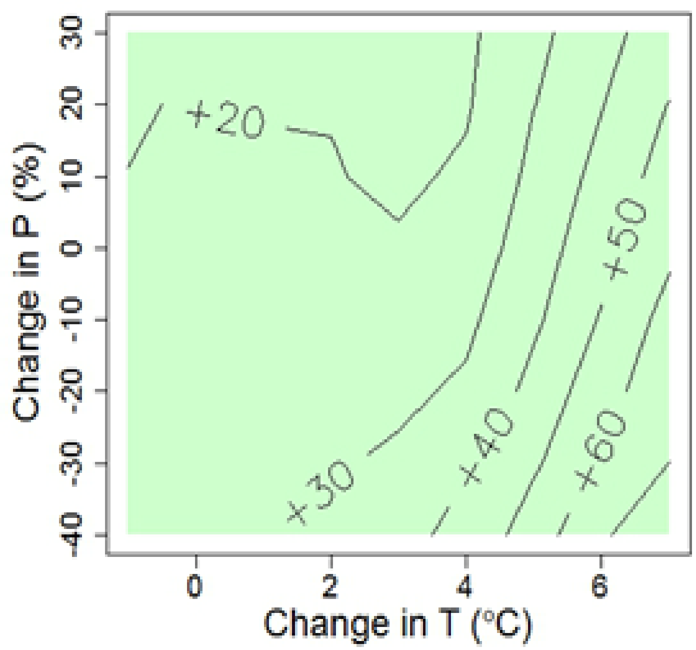
ARS combined adaptations: Suppl. Irr.

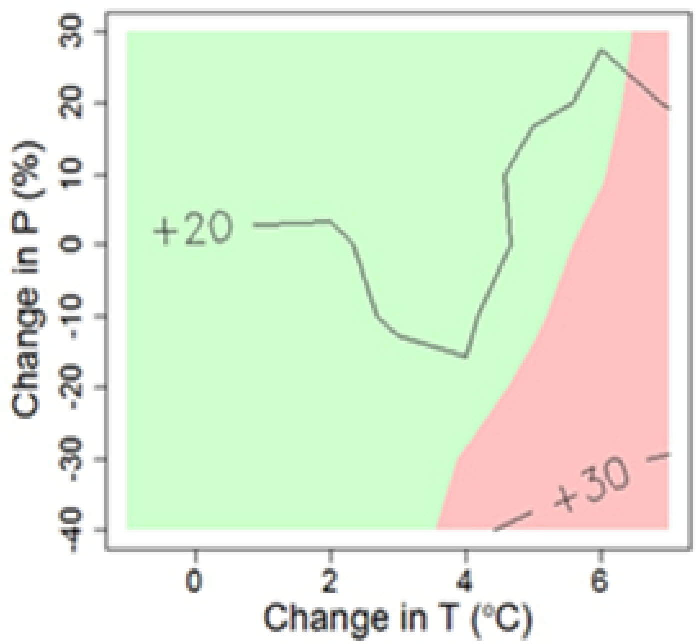
CO_2 522 / Shallow soil / Supplementary Irrigation

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

SW/early SD/Longer cv



WW/early SD/Std cv



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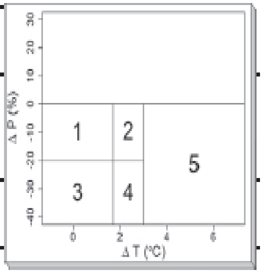
Adaptation potential: Qualitative assessment

	Water mgnt	Cultivar	Sowing date	Shallow Adaptation	Shallow Recovery	Deep Adaptation	Deep Recovery	Recommendations
WW	R	None	None	None	–	None	–	To be avoided
	sI	cv1	Earlier	1,2,3,4,5	1,2,3,4	1,2,3,4,5	1,2,3,4	Only under sI and -Standard cultivar whatever the sowing date -Shorter cultivars own earlier -Same recommendations for both soils
		cv0	All	1,2,3,4,5	1	1,2,3,4,5	1,2,3	
		cv2	None	None	–	None	–	To be avoided
SW	R	cv1	Earlier	1,2,3,4,5	1	3,4	–	
			Standard	2,3,4,5	None	2,4,5	None	
		cv0	Standard & earlier	1,2,3,4,5	1,2	1,2,3,4,5	1	
		cv2	Earlier	1,2,3,4,5	1	1,2,3,4,5	1,2,3	Avoiding latest sowing Advancing sowing whatever the cultivar Standard sowing with sI,and with standard cultivar under rainfed conditions Shorter cultivar not recommended on deep soil
	sI	cv1	Earlier	1,2,3,4,5	1,3	None	–	
			Standard	2,3,4,5	2,3	Not recommended	–	
		cv0	Standard & earlier	1,2,3,4,5	1,2,3,4	1,2,3,4,5	1,2,3,4	
		cv2	Standard & earlier	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	



Abbreviations: rainfed (R), supplementary irrigation (sI), 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 (–).

Ruiz-Ramos et al., 2017

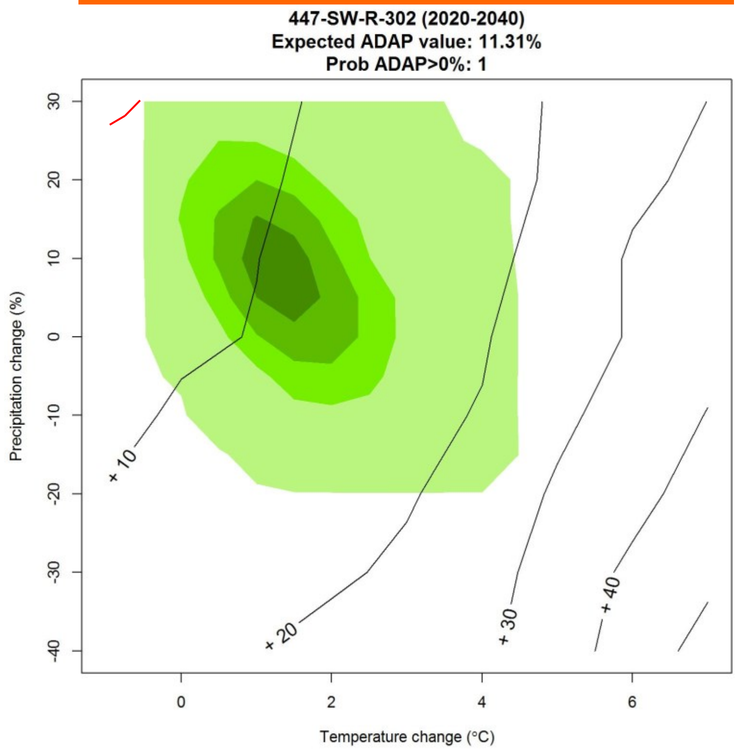
Likelihood of adaptation

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

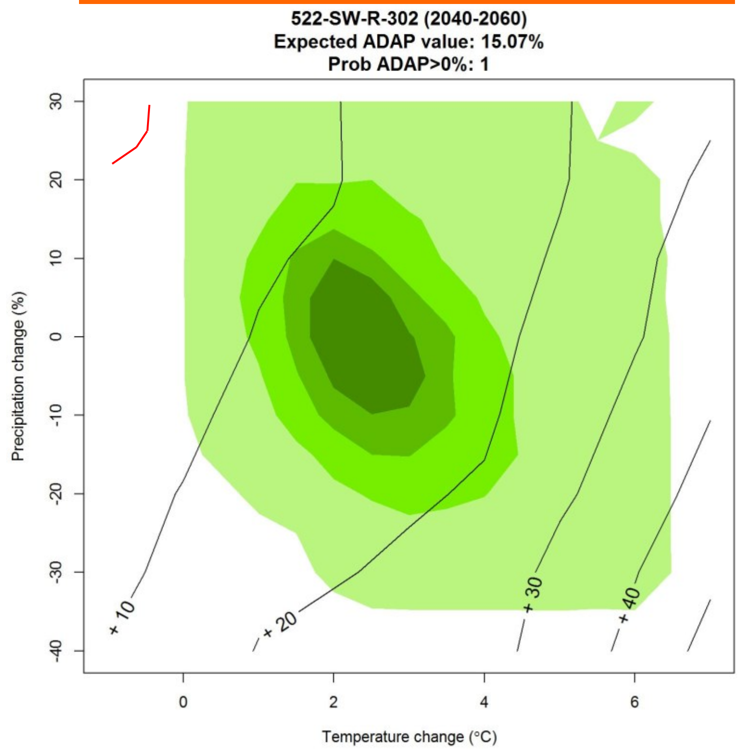
PP: HADCM3 A1B (Harris et al. 2010)

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

Likelihood: 1.00
Median adapt. resp: 11.3%



Likelihood: 1.00
Median adpt. resp.: 15.1%

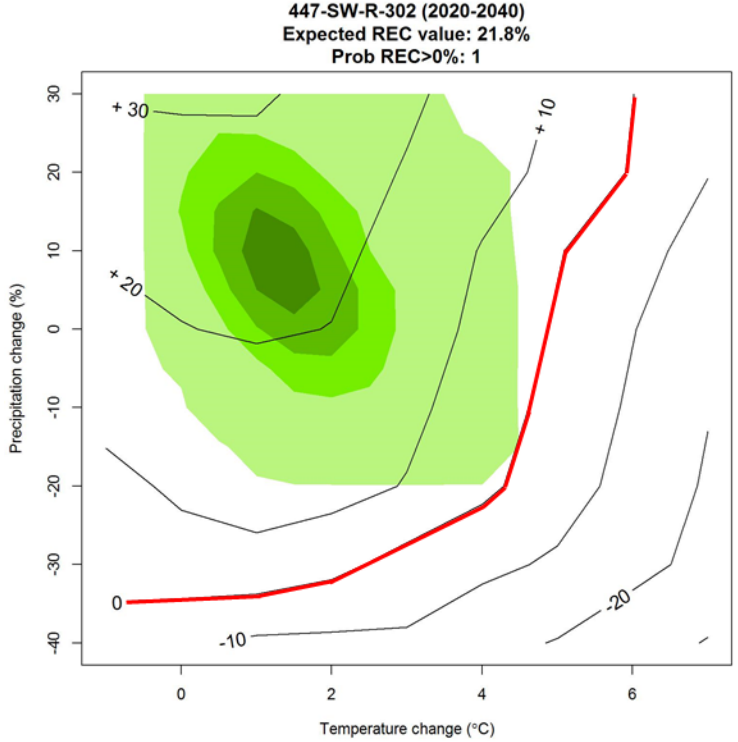


Likelihood of recovery

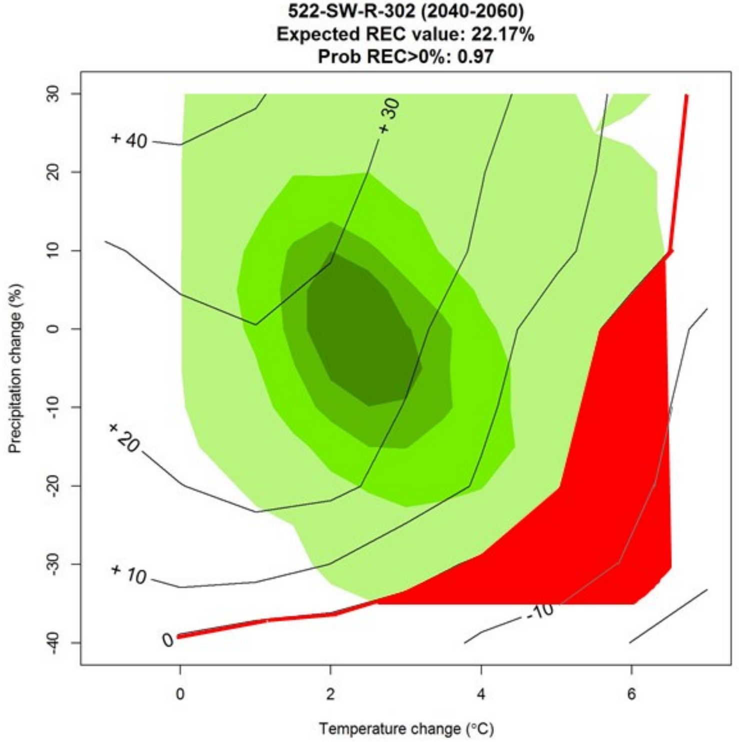
Shallow soil/Spring Wheat/std SD and CV

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

Likelihood: 1.00
Median recovery: 21.8%



Likelihood: 0.97
Median recovery: 22.2%



Adaptation potential: Quantitative assessment

Shallow Soil				2020-2040 (447 ppm)				2040-2060 (522 ppm)			
				Adaptation		Recovery		Adaptation		Recovery	
	Water mgnt	**Cultivar**	**Sowing date**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**
WW	sl	Short	Earlier	1.00	8.1	0.98	10.0	1.00	7.4	0.95	10.5
		Std	Earlier	1.00	18.8	1.00	22.6	1.00	19.6	0.95	18.6
			Standard	1.00	20.2	1.00	22.2	1.00	22.4	0.97	20.4
SW	R	Short	Earlier	0.98	5.7	0.97	14.5	0.99	8.7	0.78	12.4
			Standard	0.88	5.8	0.86	10.3	0.99	9.0	0.78	7.3
		Std	Earlier	1.00	19.6	0.98	22.2	1.00	14.9	0.89	19.0
			Standard	1.00	11.3	1.00	21.8	1.00	15.0	0.97	22.2
		Longer	Earlier	1.00	13.8	0.96	13.5	1.00	15.7	0.92	10.8
	sl	Short	Earlier	0.98	6.7	0.89	11.3	1.00	9.7	0.79	7.8
			Standard	0.88	5.0	0.98	13.6	0.98	9.2	0.93	11.7
		Std	Earlier	1.00	30.6	1.00	27.4	1.00	37.5	1.00	27.1
			Standard	1.00	28.0	1.00	26.2	1.00	33.1	0.95	23.5
		Longer	Earlier	1.00	22.0	1.00	40.5	1.00	24.3	1.00	40.1
			Standard	1.00	12.2	1.00	26.3	1.00	14.9	1.00	27.0

Adaptation potential: Quantitative assessment

Shallow Soil				2020-2040 (447 ppm)				2040-2060 (522 ppm)			
				Adaptation		**Recovery**		**Adaptation**		**Recovery**	
	Water mgnt	**Cultivar**	**Sowing date**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**	**Likelihood**	**Median (%)**
WW	sI	Short	Earlier	1.00	8.1	0.98	10.0	1.00	7.4	0.95	10.5
		Std	Earlier	1.00	18.8	1.00	22.6	1.00	19.6	0.95	18.6
			Standard	1.00	20.2	1.00	22.2	1.00	22.4	0.97	20.4
SW	R	Short	Earlier	0.98	5.7	0.97	14.5	0.99	8.7	0.78	12.4
			Standard	0.88	5.8	0.86	10.3	0.99	9.0	0.78	7.3
		Std	Earlier	1.00	19.6	0.98	22.2	1.00	14.9	0.89	19.0
			Standard	1.00	11.3	1.00	21.8	1.00	15.0	0.97	22.2
		Longer	Earlier	1.00	13.8	0.96	13.5	1.00	15.7	0.92	10.8
	sI	Short	Earlier	0.98	6.7	0.89	11.3	1.00	9.7	0.79	7.8
			Standard	0.88	5.0	0.98	13.6	0.98	9.2	0.93	11.7
		Std	Earlier	1.00	30.6	1.00	27.4	1.00	37.5	1.00	27.1
			Standard	1.00	28.0	1.00	26.2	1.00	33.1	0.95	23.5
		Longer	Earlier	1.00	22.0	1.00	40.5	1.00	24.3	1.00	40.1
			Standard	1.00	12.2	1.00	26.3	1.00	14.9	1.00	27.0

Summary & Conclusion

- **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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