Skill and Benefit of Seasonal Climate Forecast in Managing the Risk of Extreme Weather Events in Australian Wheat Industry

Qunying Luo, Li Wen, Tim Cowan and Dale Schilling

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Research Aims

- Assess the skill of SCF system in predicting the occurrence of extreme weather events (EWEs) and in predicting wheat grain yield
- Identify optimal management options in dealing with the risk of EWEs in Oz wheat industry
- Quantify the yield benefits of using SCF

Background

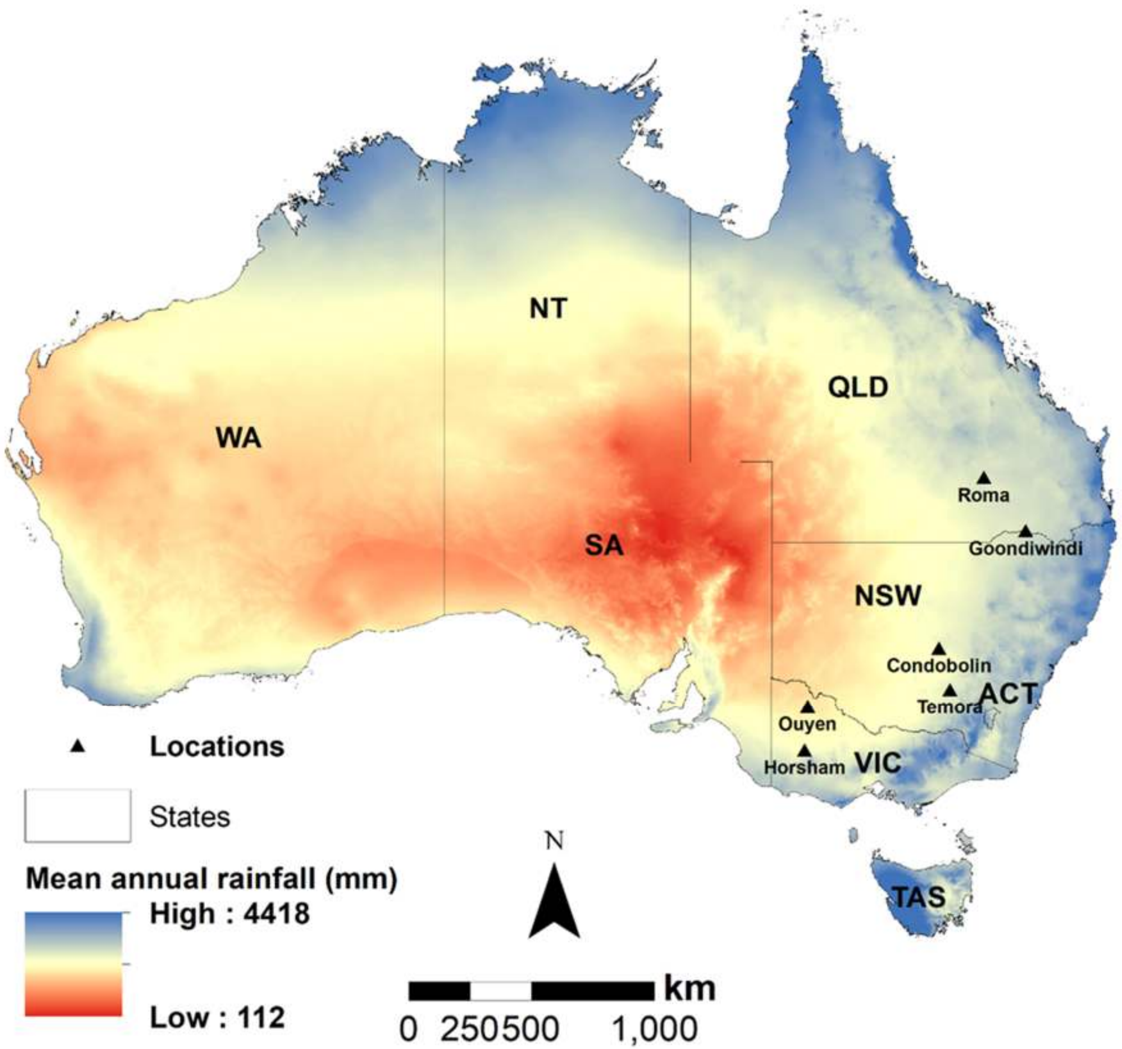
- EWEs such as heat stress, frost and drought at reproductive stages are key risk factors in Australian cropping industries
  - annual average economic losses from heat stress in OZ wheat industry: A$ 1.1 billion (GRDC, 2015)
- Reproductive stages and SCF
  - Beyond 4~5 months after sowing
  - In line with SCF lead time (3-5 months)

Hypothesis

Timely and skillful SCF may have benefits in managing the risk of EWEs in cropping industries

- Informing decision-making at key decision-making point (e.g., pre-sowing)
  - Where, when and what to sow
- By identifying the optimal combination of cultivar and time of sowing (TOS)
  - a safe flowering window corresponding to optimal TOS with the least adverse impact of the three EWEs on crop yield
  - Crop modeling is well suited for this situation
- By comparing the difference in simulated crop yield between
  - Optimized management scenario
  - baseline management scenario

Study Locations



Key Research Tool

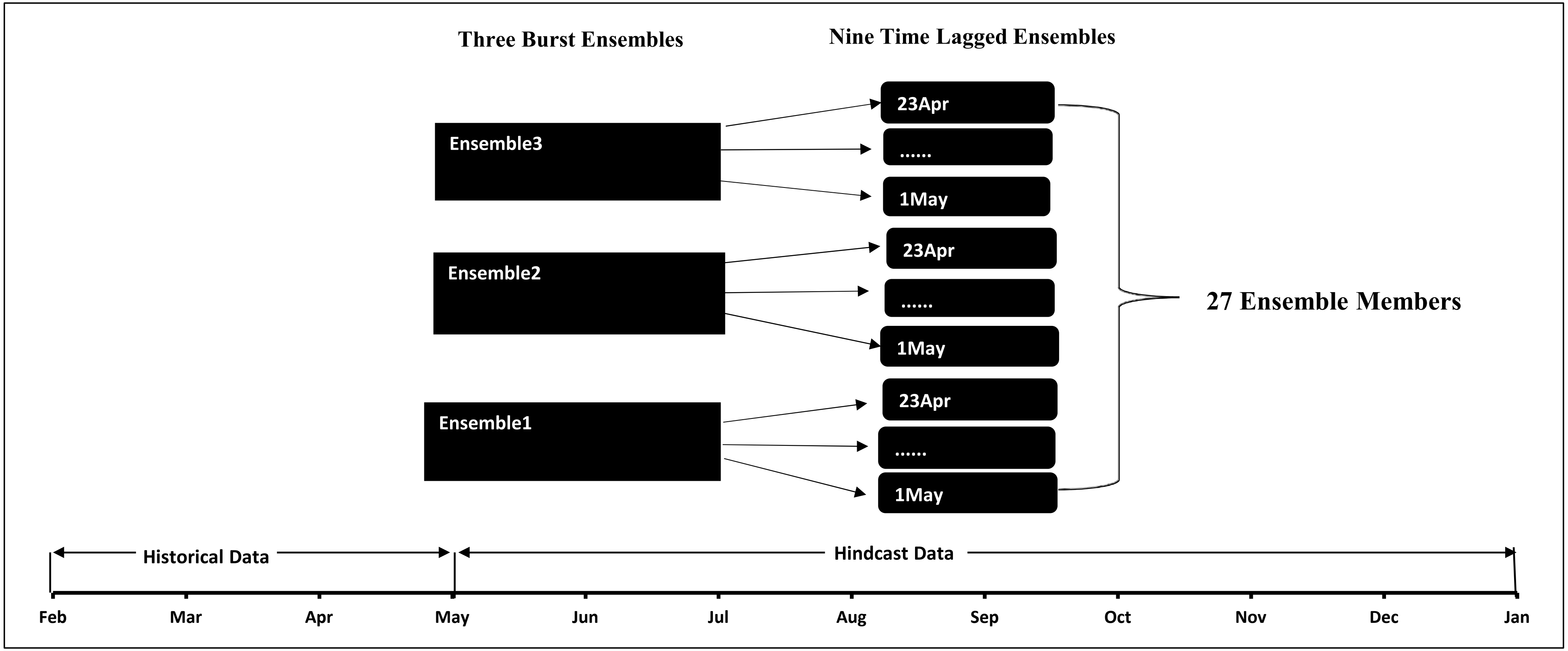
The Agricultural Production System sIMulator (APSIM)-Wheat model (Version 7.8) to simulate

- the occurrence of EWEs at reproductive stages
  - Heat stress
  - Frost
  - Terminal drought
- final wheat yield

Climate data

- Historical daily climate data
  - SILO data
  - Variables: solar radiation, maximum/minimum T, rainfall, evaporation, vapor pressure
  - https://www.longpaddock.qld.gov.au/silo/
- Daily outputs of ACCESS-S2
  - ACCESS-S2: Australian Community Climate and Earth System Simulator-Seasonal Version 2
  - Hindcast variables: maximum/minimum temperature and rainfall
  - Seasonal hindcast initialized on the 1st May: up to next 9 months, 1981-2018
  - Accessed from https://dapds00.nci.org.au/thredds/catalog/ux62/access-s2/hindcast/calibrated/atmos/catalog.html

Integration of Historical and Hindcast Climate Data



Management Specification in the APSIM-Wheat Model

Locations	Nitrogen Fertilizer Rate (kg/ha)*	Surface Organic Matter (kg/ha)	Sowing Information		
			Density (plant/m^2)	Depth (mm)	Row Spacing (mm)
Roma	80	1000	100	30	250
Goondiwindi	120	1500			
Condobolin	80	1000			
Temora	120	1500			
Ouyen	80	1000			
Horsham	120	1500			

*Urea_N at sowing

Skill Assessment of ACCESS-S2: APSIM Simulation Design

- Crop management
  - Cultivar: EGA-Gregory
  - TOS: 1st May
- Climate
  - Hindcast climate data: 27 hindcast ensemble members: 1981-2018
  - Climatological reference: SILO gridded historical climate data: 1981-2018

Skill Assessment of ACCESS-S2: SEDI (I)

- Symmetric Extremal Dependence Index (SEDI)
  - assessing the skill of ACCESS-S2 in predicting the occurrence of EWEs
- SEDI = [logF - logH - log(1-F) + log(1-H)] / [logF + logH + log(1-F) + log (1-H)]
  - H: hit rate; F: false alarm rate

Skill Assessment of ACCESS-S2: BSS (II)

- Brier Skill Score (BSS): assessing the skill of ACCESS-S2 in predicting wheat grain yield via APSIM-Wheat. It describes the relative skilfulness of a prediction relative to a reference forecast.

$$BS = \frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2$$

$$BSS = 1\text{-}BS/BS_{ref}$$

- Pi is the hindcast probability of exceeding the climatological median of the wheat grain yield over the hindcast period, Oi is the observed outcome, N is the total number of hindcasts based on the 1st of May start date (38 years)

Quantification of Yield Benefits: Simulation Design

- Baseline scenario (without the use of SCF)
  - Three cultivars
    - EGA-Gregory: mid-late maturing
    - Suntop: mid maturing
    - Mace: early maturing
  - 17 TOSs: 10 April – 31st July (1 week interval)
  - Historical climate data
- Hindcast scenario
  - Three cultivars
  - 17 TOSs
  - Hindcast climate data

Classification of Hindcast Rainfall

- Dry, neutral and wet categories
- the 30^{th} and 70^{th} percentile values of historical rainfall data for the period 1981-2018

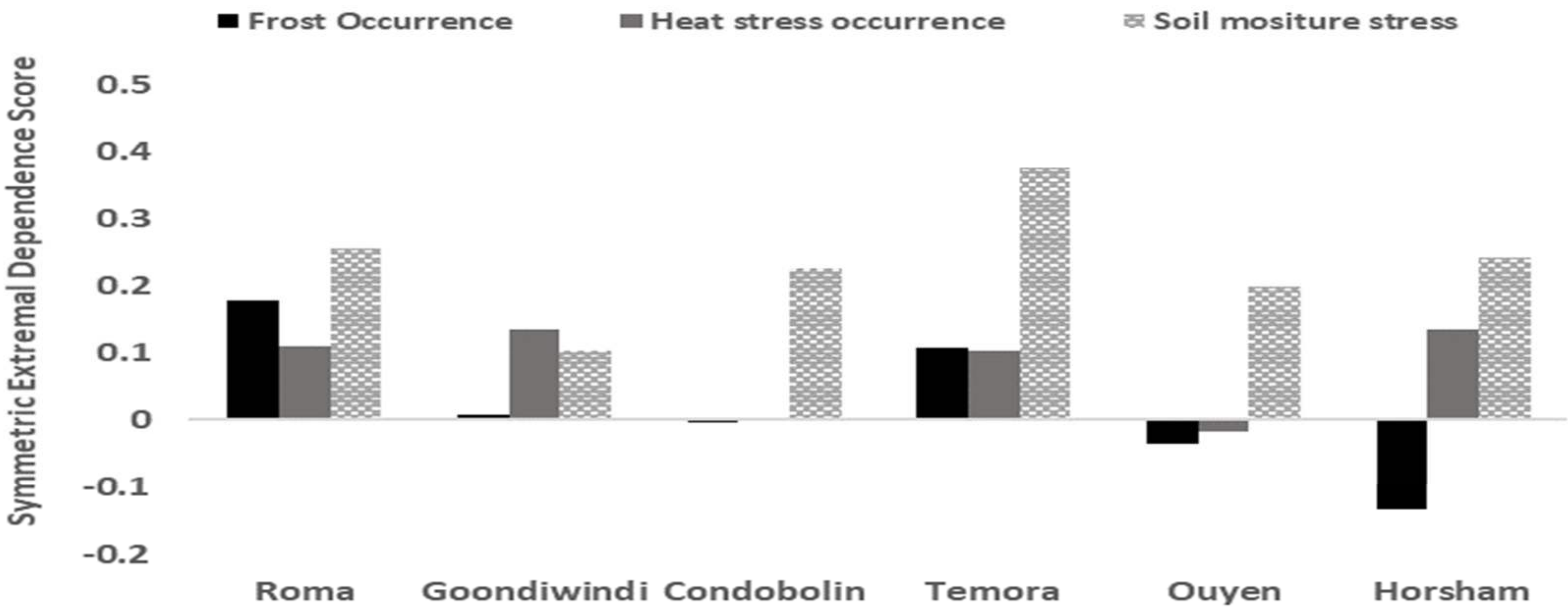
Quantification of Yield Difference

- Identifying optimal management strategies: the best combination of cultivars and TOS associated with the highest wheat yield using hindcast information
- Determining baseline management scenario: the combination of cultivar and TOS corresponding to the mean wheat yield for the period 1981-2018 within optimal sowing windows based on historical climate data
- The benefits in using SCF for a specific year were calculated as the yield difference between the two steps described above

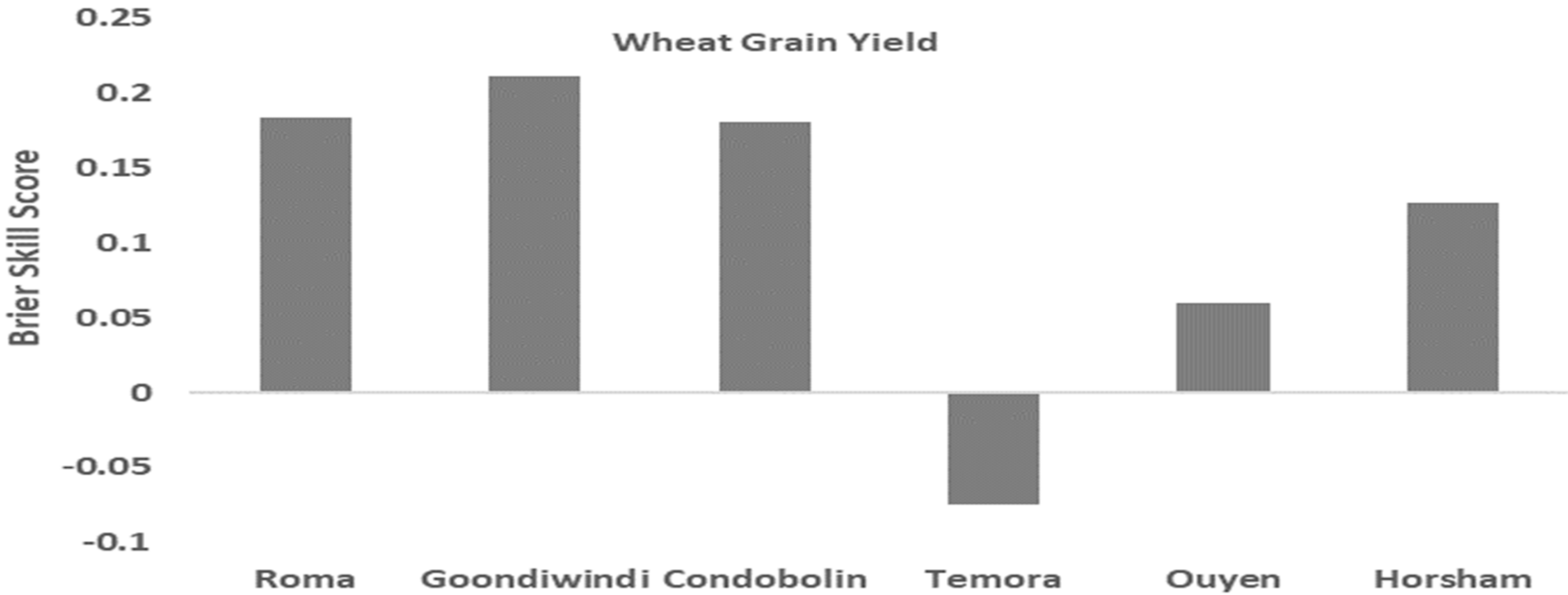
Statistical Tests

- Test if there is significant difference in the mean yield between optimized and baseline management scenarios
  - the Wilcoxon-test across all years
  - the One Way ANOVA across the dry, neutral and wet years

Skill Assessment - SEDI



Skill Assessment - BSS

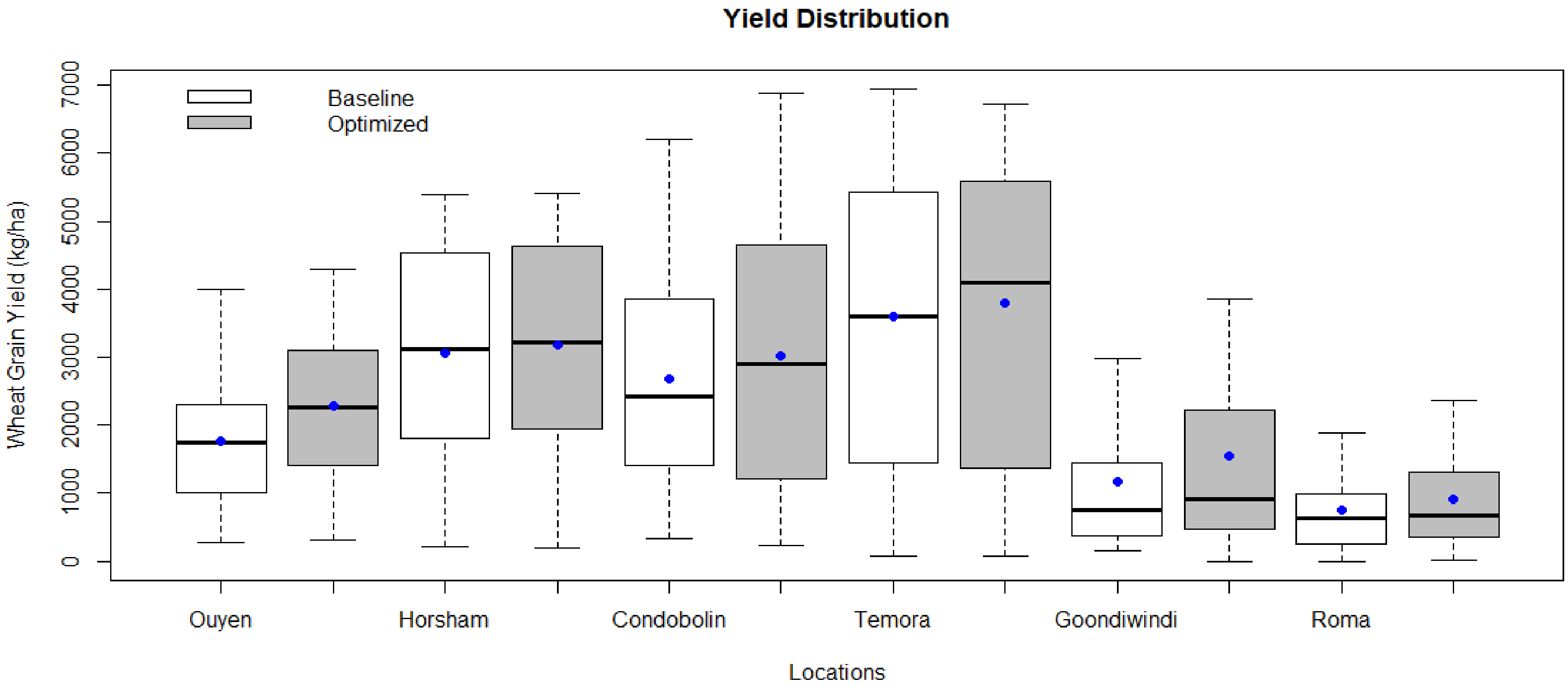


Management strategies in achieving yield gain across locations

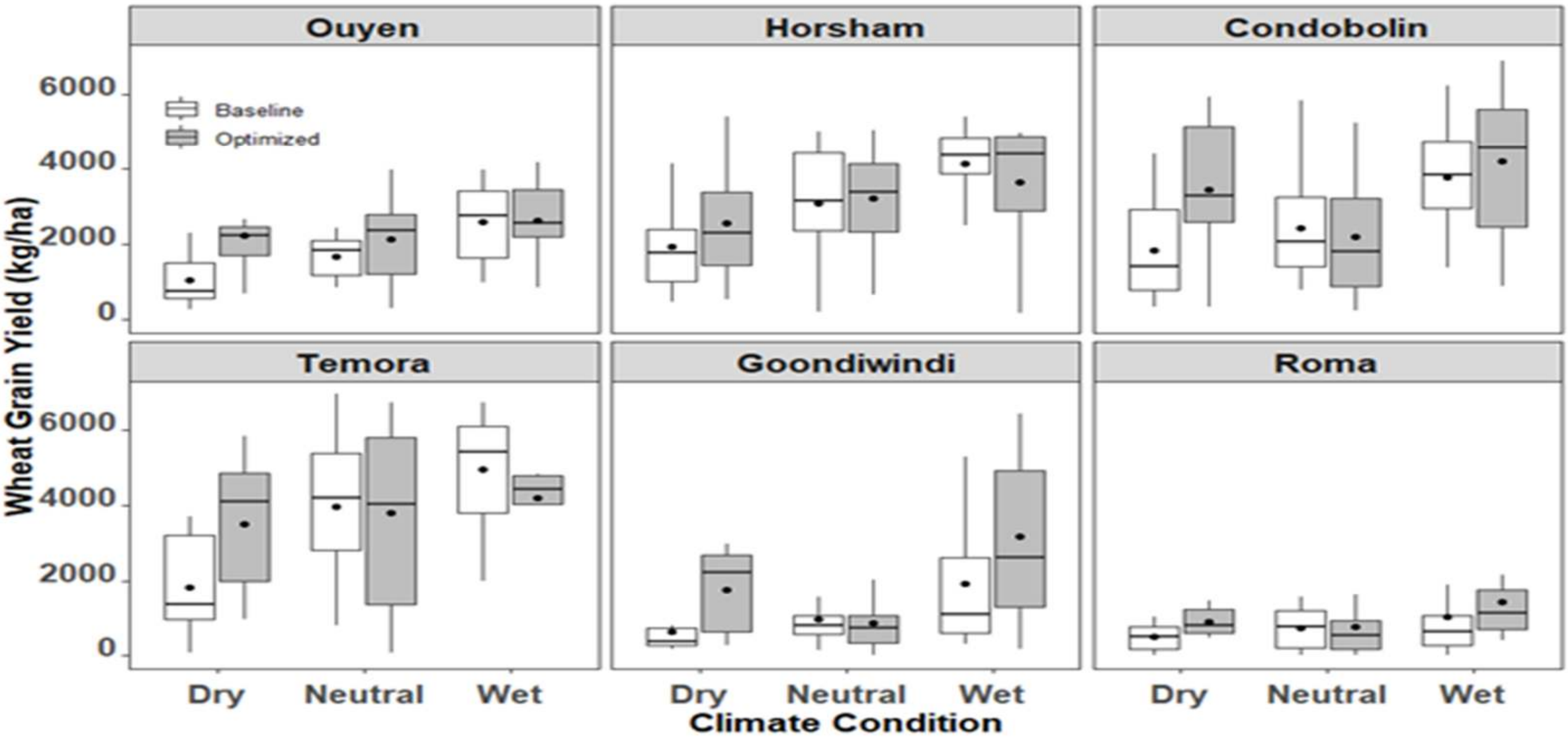
Locations	Baseline Management		Optimized management	
	TOS*	**Cultivars**	**TOS***	**Cultivars**
Roma	8th May	suntop	Earlier/later sowing	both suntop and gregory
Goondiwindi	12th Jun	gregory	Earlier sowing	mainly suntop
Condobolin	15th May	suntop	Earlier sowing	mainly gregory
Temora	15th May	suntop	Mainly earlier sowing	both suntop and gregory
Ouyen	15th May	suntop	Earlier (mainly 24th Apr) sowing	mainly gregory
Horsham	15th May	gregory	Mainly earlier sowing	both suntop and gregory

*TOS: time of sowing

Wheat Yield Distribution under Baseline and OMS - All Years



Wheat Yield Distribution under Baseline and OMS across Rainfall States



Statistical Test Results (p values)

Locations	All Years[1]	Dry Years[2]	Neutral Years[2]	Wet Years[2]
Roma	0.00197**	0.05*	0.91	0.46
Goondiwindi	0.0045**	0.02*	0.74	0.17
Condobolin	0.0168*	0.03*	0.68	0.56
Temora	0.161	0.03*	0.79	0.35
Ouyen	<0.001***	0.01**	0.20	0.96
Horsham	0.0015**	0.33	0.79	0.44
All locations	0.0016**			

**: mean of yield difference is significant at 0.05 level; **: significant at 0.01 level; ***significant at 0.001 level;*
1: Wilcoxon- test; 2:one-way ANOVA

Frequency of yield gain

Case Categories	Number of Cases	Cases with yield gain	Proportion (%)
All years	228	154	**68**
Wet year cases	49	34	**69**
Neutral year cases	136	89	**65**
Dry year cases	43	31	**72**

Conclusions

- The devastating impact of EWEs in the Australian wheat industry can be mitigated by combining skilful SCF information with a robust decision-making tool;
- This will lead to substantial yield gain in the Australian wheat industry especially in drier environments through contingent decision-making.

Thank you for your attention!

Email: qunying.luo@hillridge.io