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Sustainable Intensification of Cereal Livestock Systems in Australia

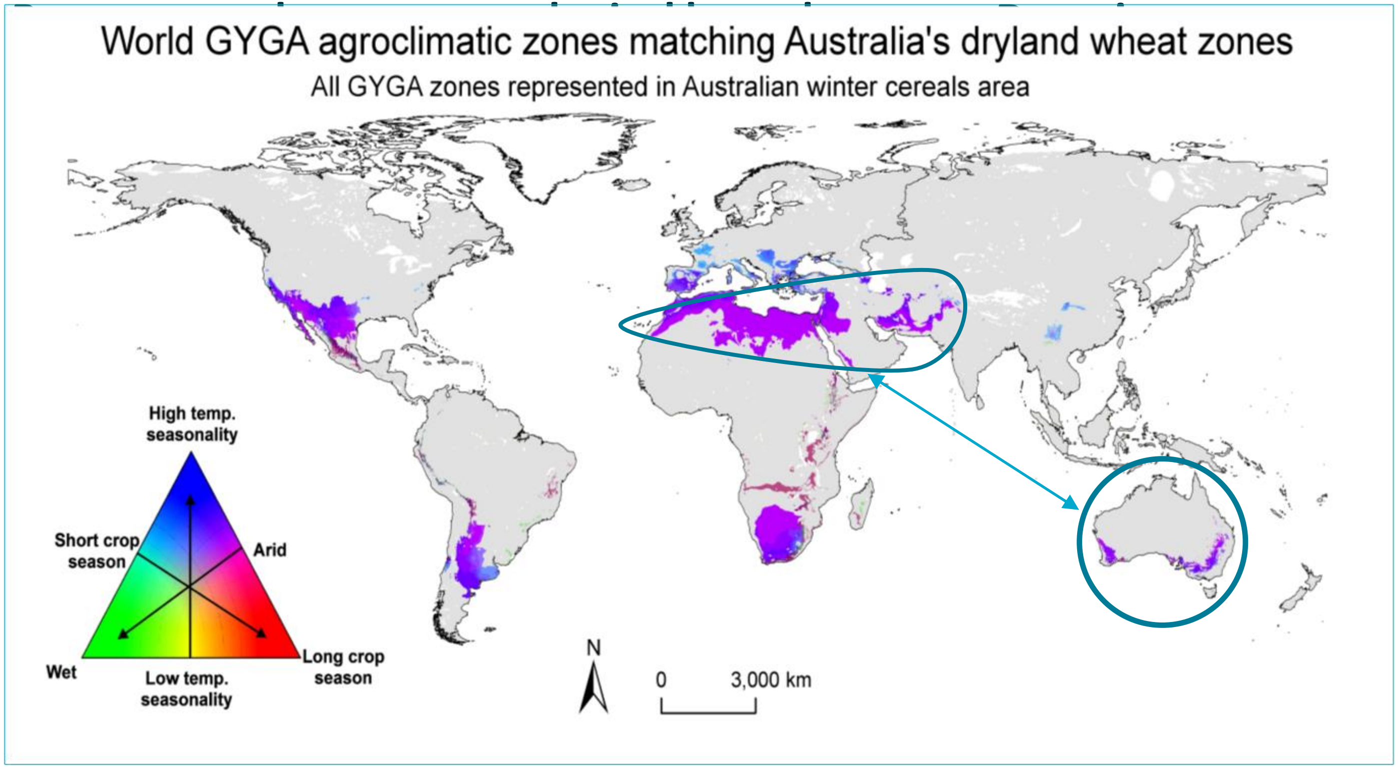
Zvi Hochman
CSIRO, Agriculture and Food

August 18, 2020

Outline

- The potential for Technology extrapolation between Australia and the Dry Arc
- Resilience to a variable and warming climate
  - Quantifying risk
  - Quantifying impacts of climate change
  - Emerging technologies
    - Early sowing with longer season varieties
    - Integration of crop-livestock systems
- Opportunities to transform cropping systems
  - Quantifying and diagnosing causes of crop yield gaps
  - Sustainable intensification of cropping systems

What is the potential for technology extrapolation between Australia's grain zone and the Dry Arc?



Caution!

Technology extrapolation is subject to consideration of farmers' social, economic and cultural differences.

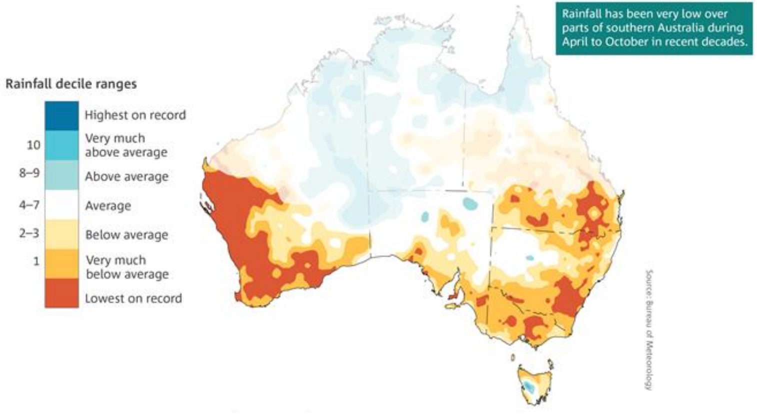
Past experience serves as a warning that we can't assume that technologies developed for Australia can be adapted to the Dry Arc.

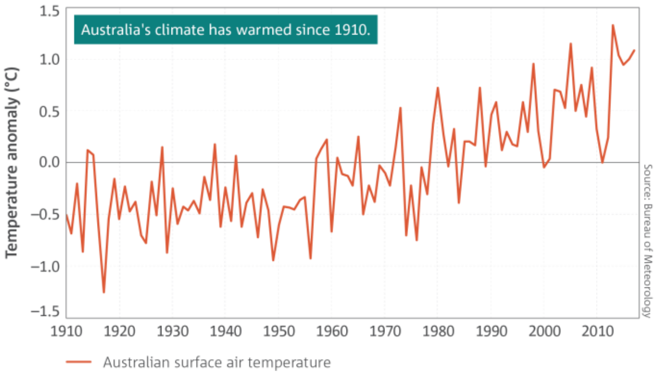
Rattalino Edreira, et al. 2018. Beyond the plot: technology extrapolation domains… Environmental Research Letters 13, 054027.

van Wart et al. 2013. Use of agro-climatic zones to upscale simulated crop yield potential. Field Crops Research. 143, 44-55.

Can climate trends account for stagnant wheat yields?

- Reduced rainfall in SW and SE Australia and rising air surface temperatures have been observed since the 1970s



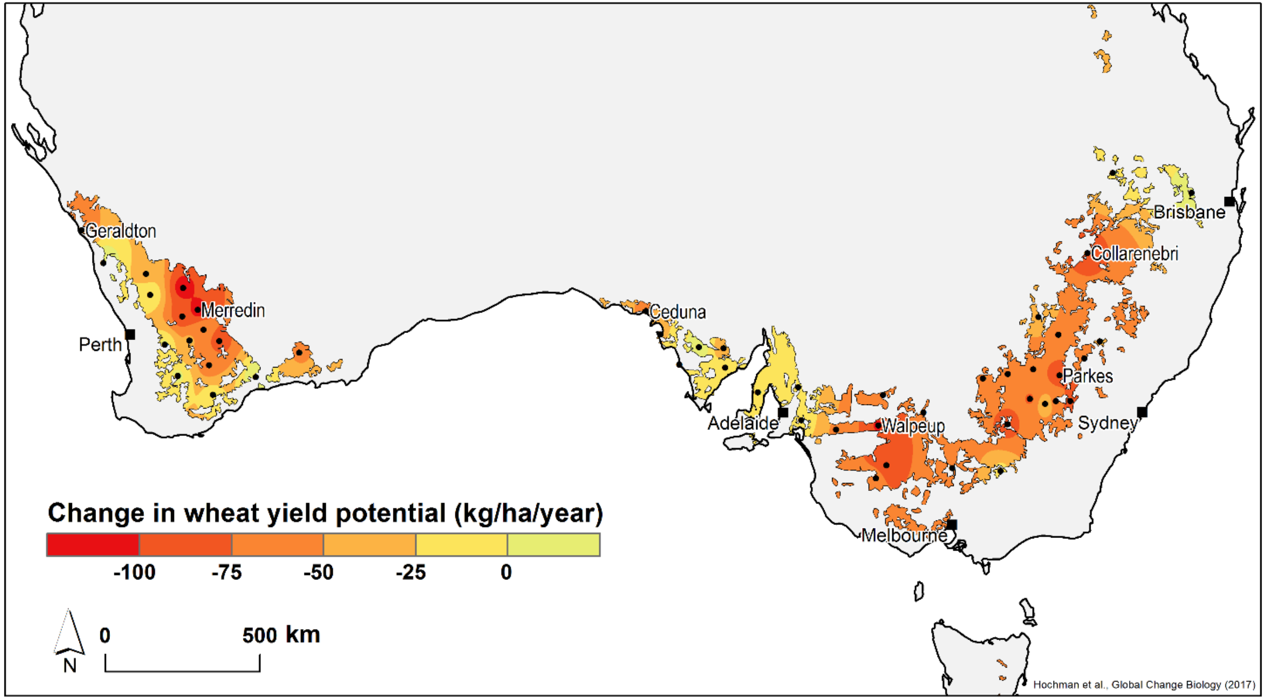


Australia's surface air temperature has warmed by around 1°C since 1910

- Atmospheric CO_2 increased, between 1990 and 2015, from 345.4 to 400.8 micromol/mol (NOAA, 2016)

CSIRO & BOM 2018. The State of the Climate Report

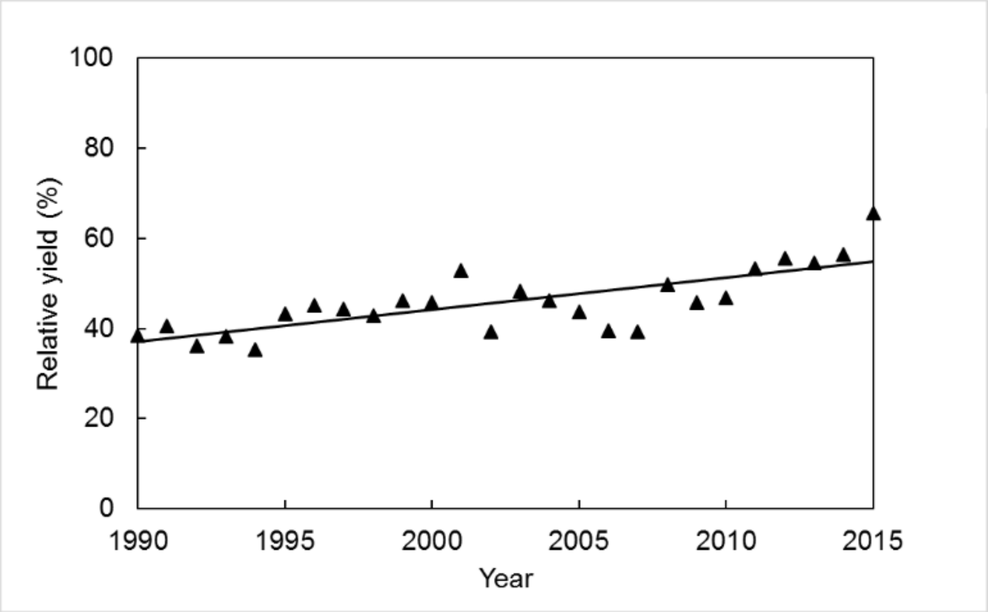
Water limited wheat yield (Yw) trend (1990-2015) interpolated from 50 sites (black dots) in the Australian Grain Zone



- The yield trend is not evenly distributed through the grain zone

Hochman et al. 2017. Climate trends account for stalled wheat yields in Australia since 1990. Global Change Biology, 23, 2071-2081.

While yield potential declined, actual yields have remained stable over this period: faced with declining yield potential farmers have narrowed the gap between potential and actual yields.



Relative yield (Y% = 100*Actual yield/Potential yield) has increased from 39% to 55%

Emergent Yw: Productivity from the water we have is increasing due to adoption of early sowing systems..

Photo: Barry Haskins

LETTERS

https://doi.org/10.1038/s41558-019-0417-9

nature climate change

Early sowing systems can boost Australian wheat yields despite recent climate change

- Stored water
- Phenology
- Timeliness
- Sequence
- Fertility

National Impact (wheat) + 0.54 t/ha + 7.1 Mill tonnes/annum (Hunt et al. 2019)

Earlier sown crops can be grazed – “Dual Purpose”

Grain-only crop

Sow (M); Grain $$ (N)

Jan	F	M	A	M	J	J	A	S	O	N	Dec

Dual-purpose crop

Sow (M, A); Graze $$ (J, J, A); Grain $$ (N)

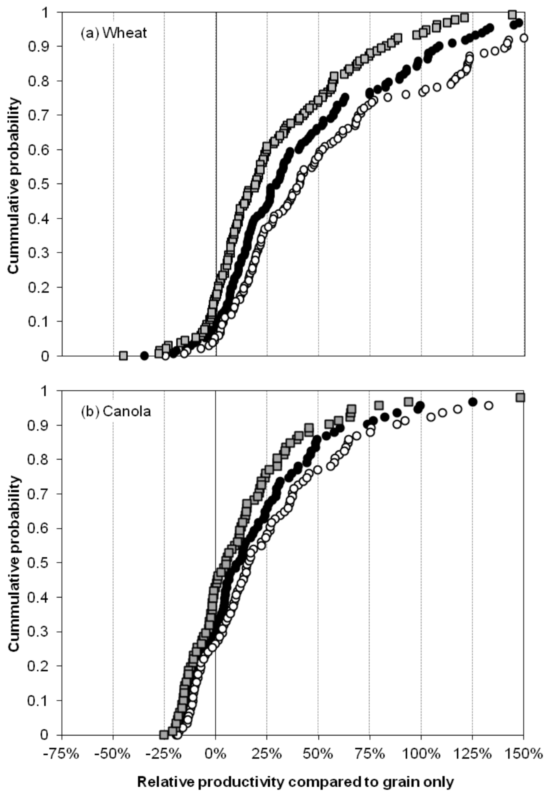
Jan	F	M	A	M	J	J	A	S	O	N	Dec

Andy Fowler, Condingup, WA reported whole-farm profitability increases of ~$100 per farm hectare

An opportunity to turn more biomass into income while achieving greater soil protection

Dove and Kirkegaard (2014) J. Sci. Food Agric. 94, 1276-1283

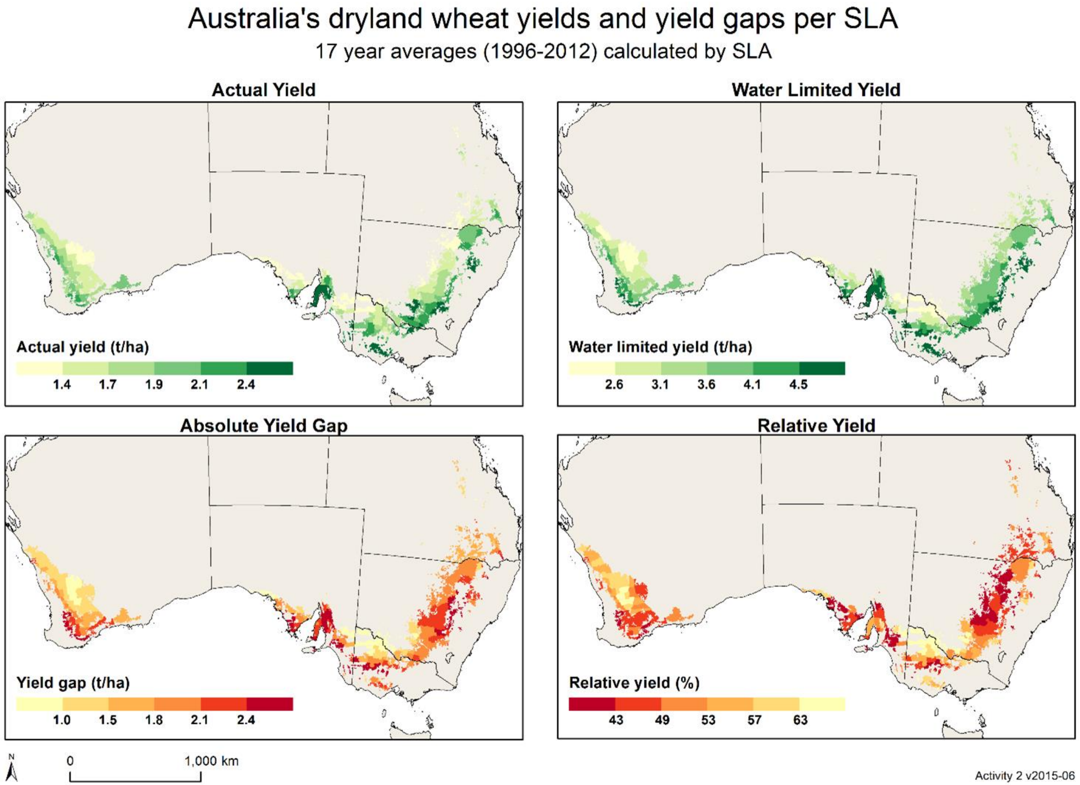
Dual purpose cropping is moderately sensitive to livestock : grain price ratios



- Sensitivity analysis for dual purpose cropping of wheat and canola with 3 livestock : grain price ratios
- For wheat:
  - ❑ 10 $/kg LW:$/kg wheat
  - • 8 $/kg LW:$/kg wheat
  - ○ 6 $/kg LW:$/kg wheat
- For canola:
  - ❑ 5 $/kg LW:$/kg wheat
  - • 4 $/kg LW:$/kg wheat
  - ○ 3 $/kg LW:$/kg wheat

Dr Lindsay Bell, CSIRO, unpublished analysis

Yield Gaps in Australia: Wheat



Hochman *et al*. 2016. Data rich yield gap analysis of wheat in Australia. Field Crops Research

www.yieldgapaustralia.com.au

Simulated Causes of Wheat Yield Gaps

Treatment Number	Treatment	Mean (t/ha)	St Dev (t/ha)	CV (%)	Y% (%)
1	Yw (water-limited yield)	4.28	0.91	21	100
2	seedling density (50 plants/m^2)	3.78	1.10	29	88
3	Late Sowing (2 week delay)	3.97	1.04	26	93
4	Summer weeds	3.18	1.17	37	74
5	Tillage	2.86	1.08	38	67
6	N fertiliser (45 kgN/ha)	2.57	0.78	30	60
7	N Fertilizer (90 kgN/ha)	3.30	0.96	29	77
8	Combined N Fertilizer (45 kgN/ha) & Summer weeds	2.55	0.92	36	60
9	Frost and Heat	3.15	1.00	32	74
10	Frost and Heat 2 (moderate impact)	3.60	0.95	26	84
11	Optimal TOS & Var	5.06	0.47	9	118
12	Optimal TOS & Var + N	5.58	0.64	12	130
13	Optimal TOS & Var + N with NFH2[a]	4.84	0.79	16	113

[a] Note that treatment 13 should be compared with treatment 10 over which it has a 34% advantage.

Results are not additive

Emergent Yw

Hochman and Horan, Field Crops Research, 2018

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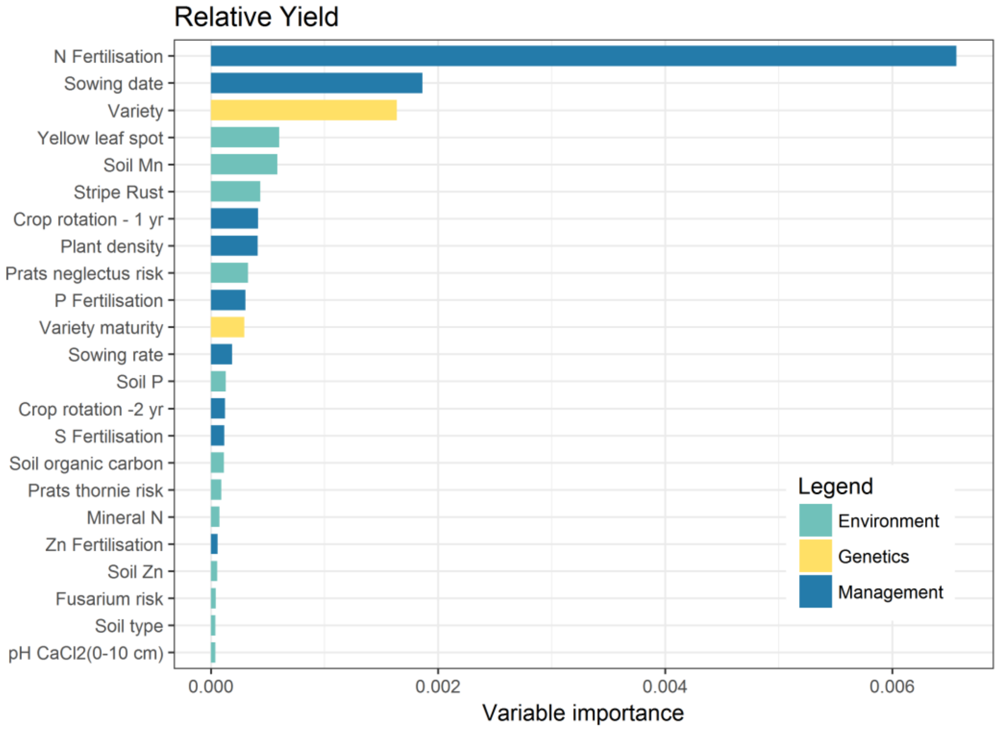
Importance of attributes explaining relative yields in high, medium and low yielding zones of 136 fields in Victoria: Conditional Inference Forest Analysis



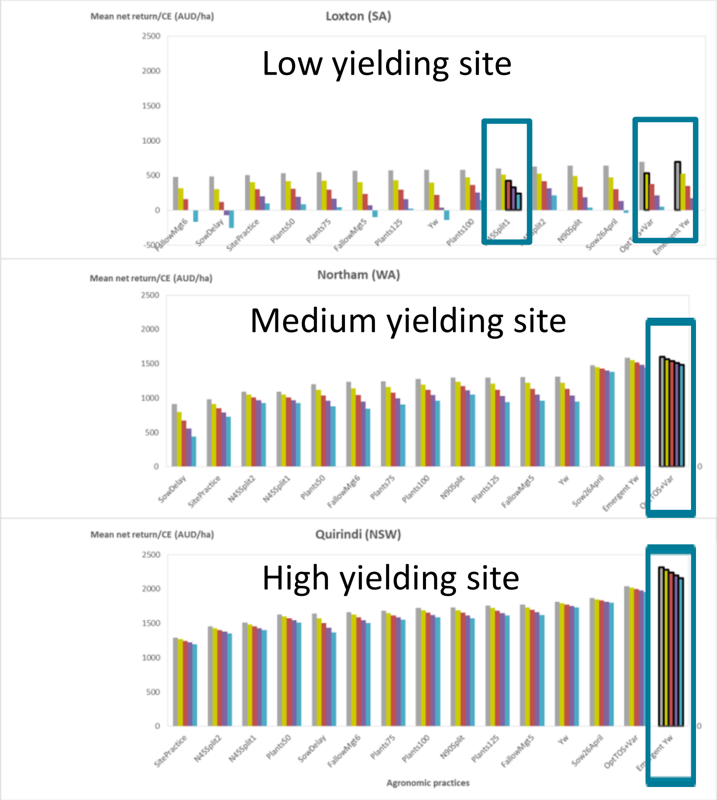
53 management, environmental and genetic variables were measured at each site.

This complements the simulation approach as it also accounts for biotic factors (e.g. yellow leaf spot, stripe rust, etc.)

variation accounted for: 53.2%

Risk-neutral profit (lightest grey bars) and associated risk-adjusted profit for the 15 agronomic practices across 4 levels of risk aversion

- The most profitable treatment varies according to site yield potential
- The ”moderately to highly risk averse” producer will make different choices to a risk neutral producer but only in sites with lower yield potential



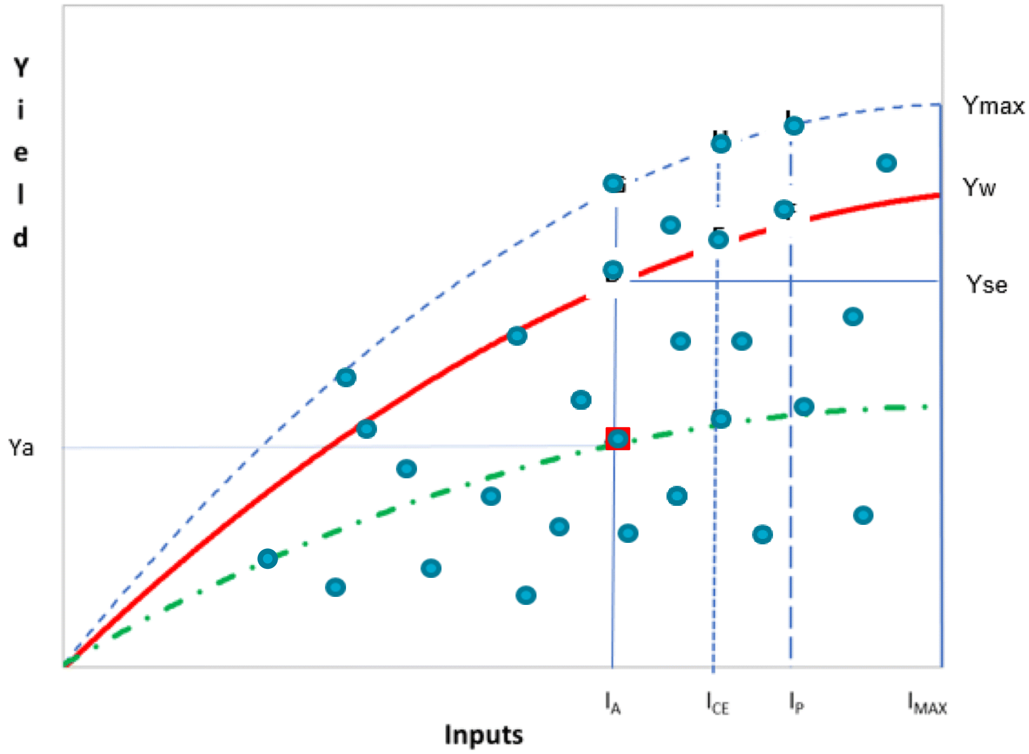
N applied = 22.5 kgN/ha/yr

Optimal TOS x Var

Emergent Yw

Monjardino et al. 2019. Yield potential determines Australian wheat growers’ capacity to close yield gaps while mitigating economic risk. Agron. Sustain. Dev. 39:49.

Yield gaps in an efficiency frontier framework



Each ○ represents the yield of an individual wheat field in relation to inputs

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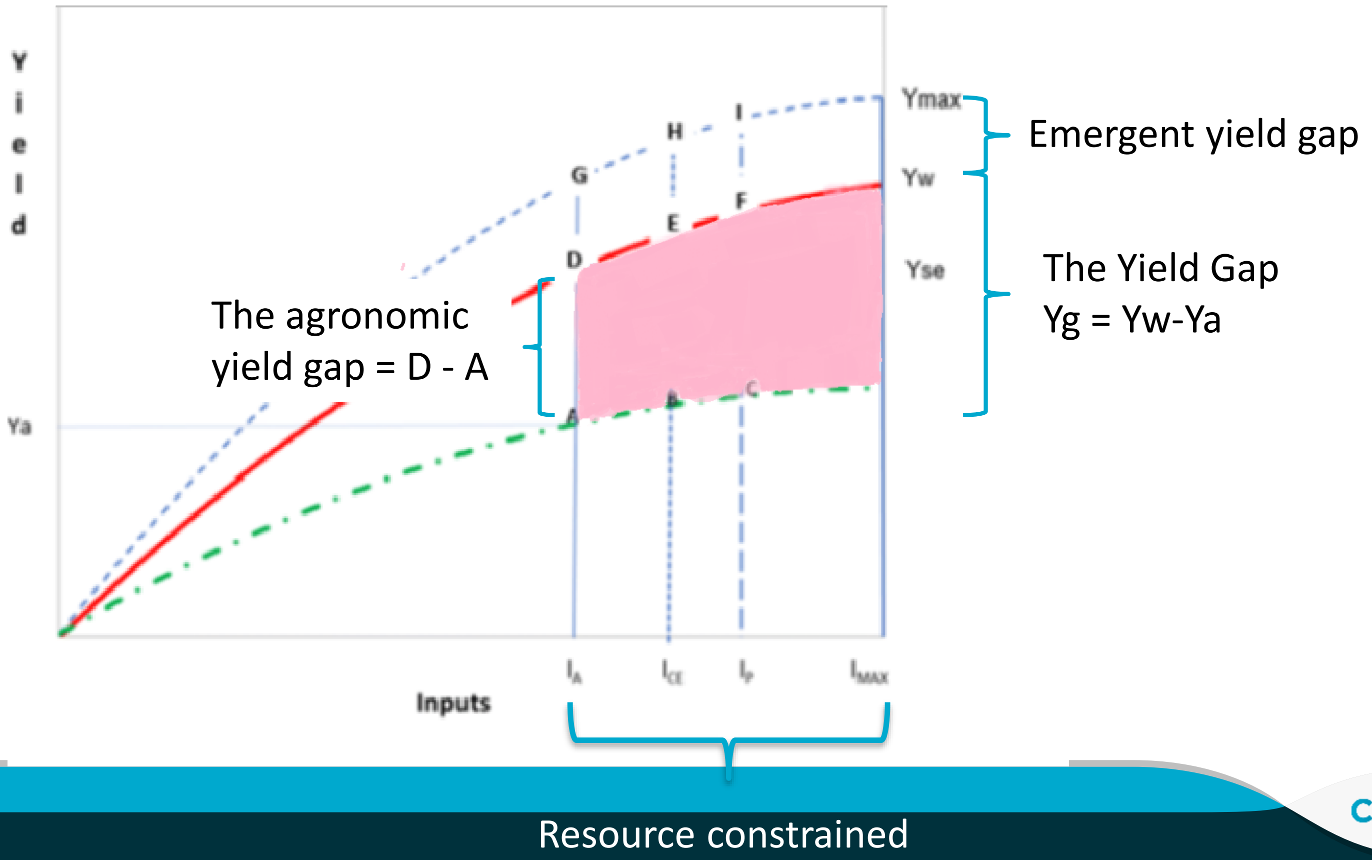
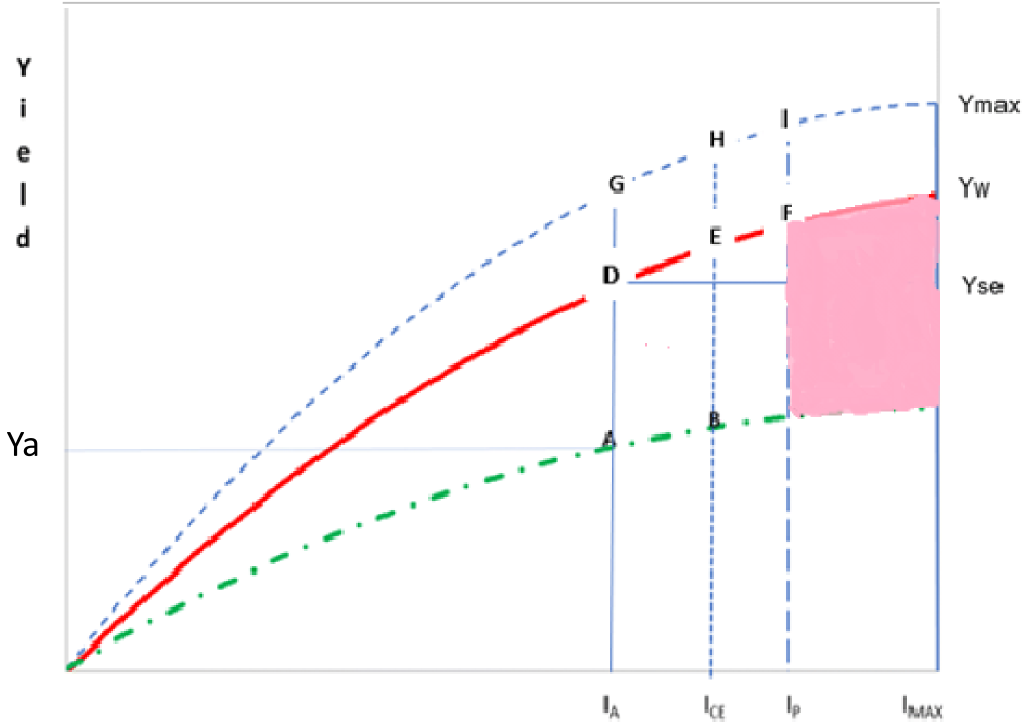
Monjardino et al. 2019. Agron. Sustain. Dev. 39:49.

Yield gaps in an efficiency frontier framework

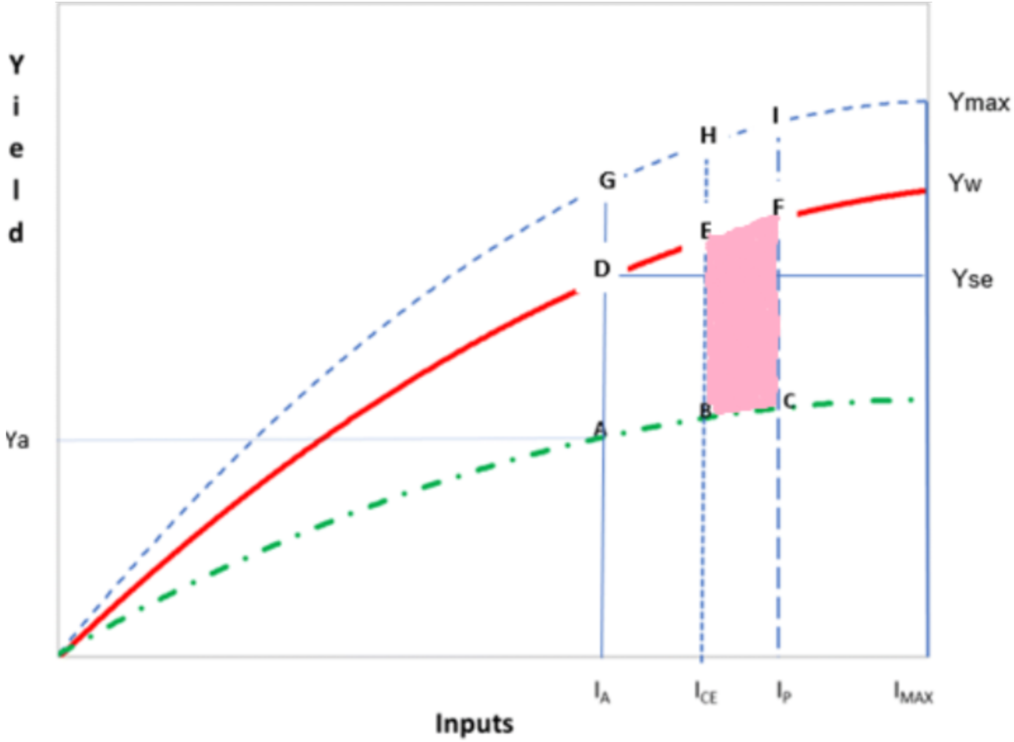


Yield gaps in an efficiency frontier framework



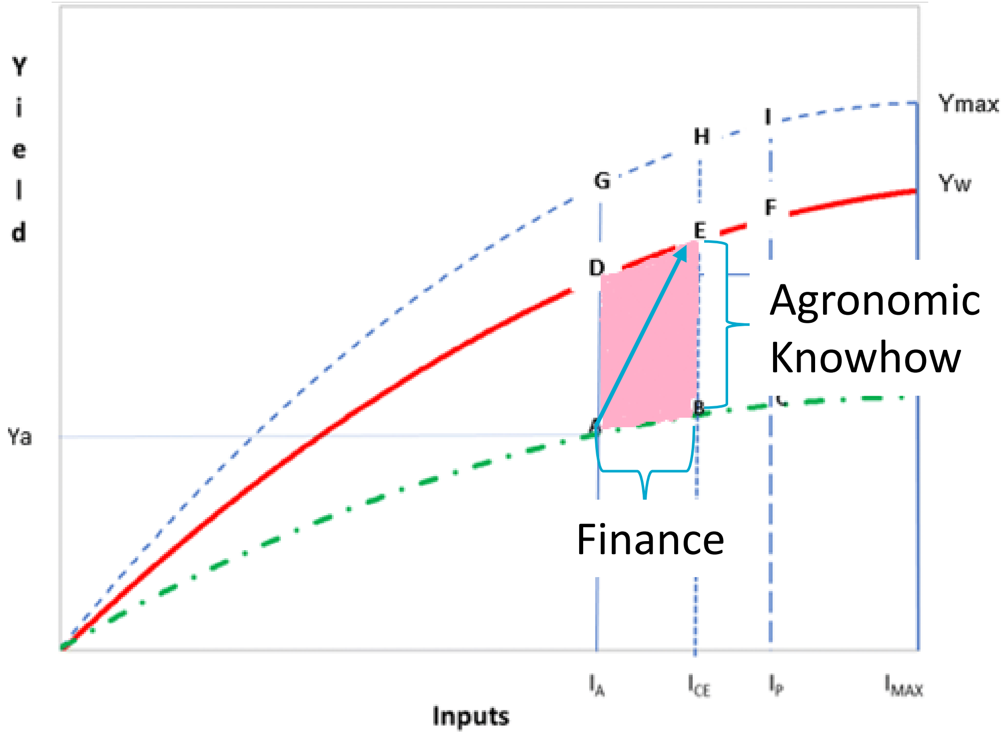
Economic yield gap
= Yw-F

Yield gaps in an efficiency frontier framework



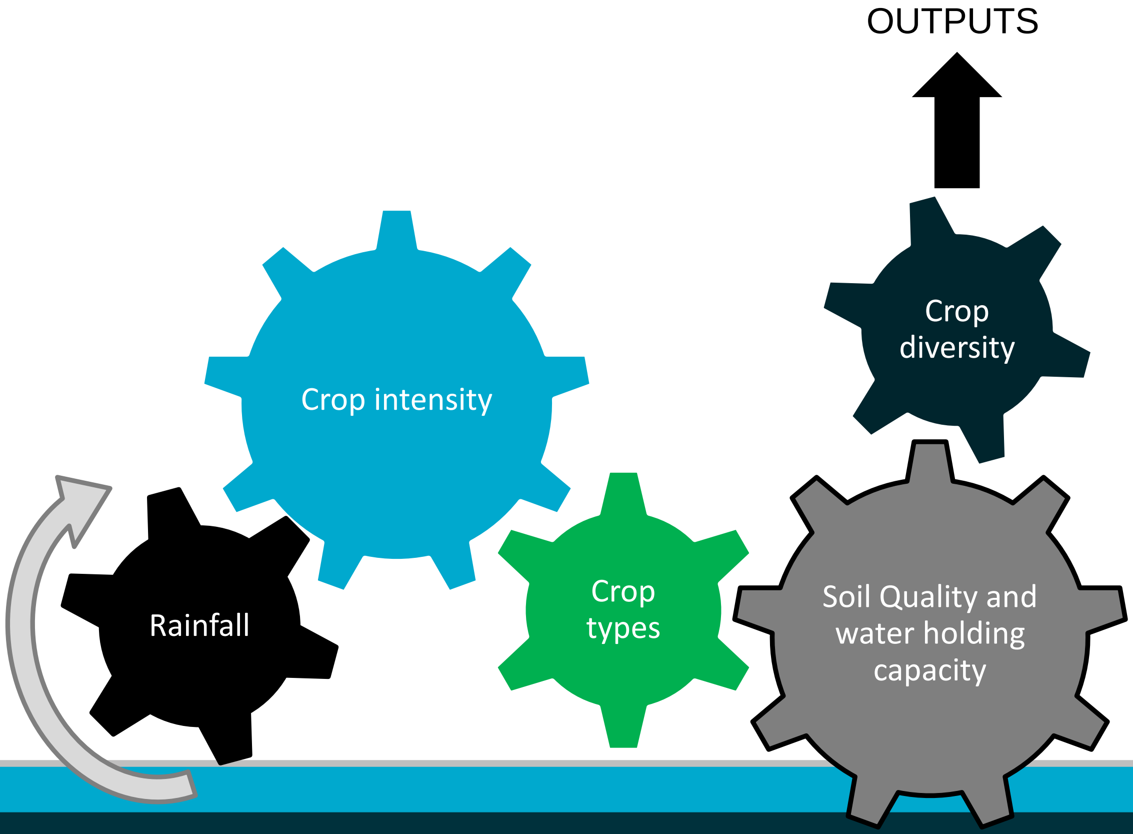
Risk Aversion yield gap
= F - E

Yield gaps in an efficiency frontier framework



Financial yield gap
= E - D

Crops grow in cropping sequences or rotations
What drives these systems?



After Bell et al. Proceedings of the 2019 Agronomy Australia Conference, 25-29 August 2019, Wagga Wagga, Australia.

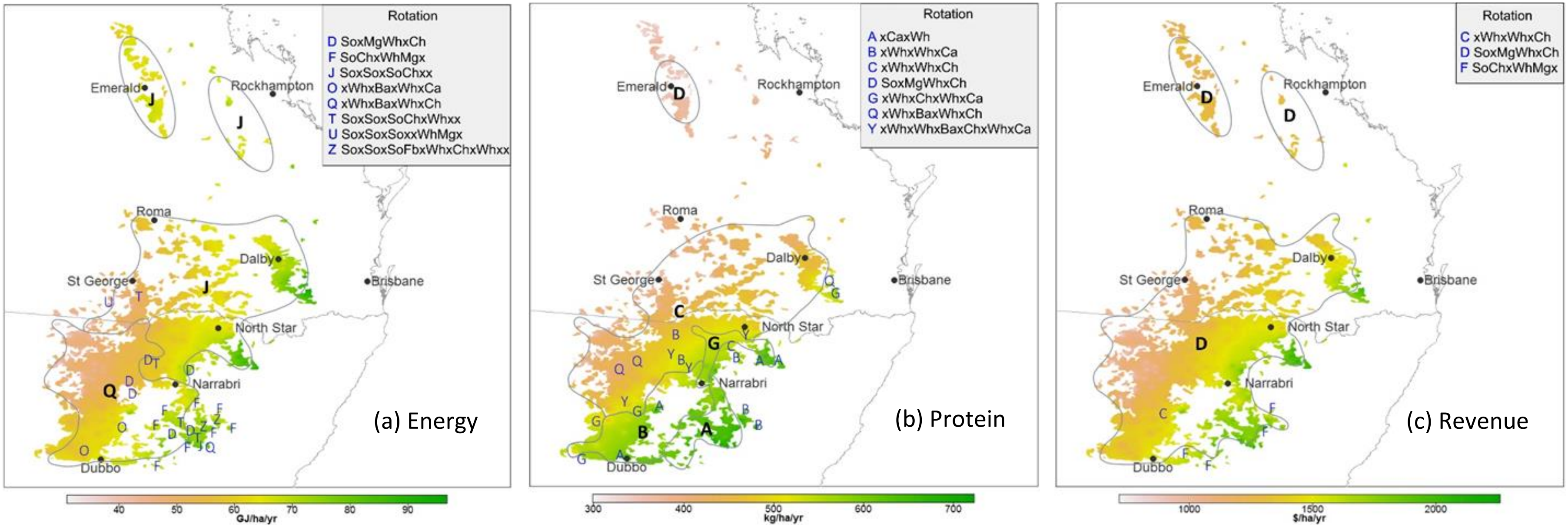
Field and Simulation Studies of Cropping Systems in the Subtropical Grain Zone

Core Experimental site
Eastern Darling Downs, QLD

26 Crop Rotations for Australia's Subtropical Grain zone

Rotation	Coded Description	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7	
		Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
A	xCaxWh	Fallow	Canola	Fallow	Wheat										
B	xWhxWhxCa	Fallow	Wheat	Fallow	Wheat	Fallow	Canola								
C	xWhxWhxCh	Fallow	Wheat	Fallow	Wheat	Fallow	Chickpea								
D	SoxMgWhxCh	Sorghum	Fallow	Mungbeen	Wheat	Fallow	Chickpea								
E	SoChxWhxx	Sorghum	Chickpea	Fallow	Wheat	Fallow	Fallow								
F	SoChxWhMgx	Sorghum	Chickpea	Fallow	Wheat	Mungbeen	Fallow								
G	xWhxChxWhxCa	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Fallow	Canola						
H	xWhxChxWhMgx	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Mungbeen	Fallow						
I	SoxSoChxWhxx	Sorghum	Fallow	Sorghum	Chickpea	Fallow	Wheat	Fallow	Fallow						
J	SoxSoxSoChxx	Sorghum	Fallow	Sorghum	Fallow	Sorghum	Chickpea	Fallow	Fallow						
K	SoxSoxMgWhxx	Sorghum	Fallow	Sorghum	Fallow	Mungbeen	Wheat	Fallow	Fallow						
L	SoxxChxWhxx	Sorghum	Fallow	Fallow	Chickpea	Fallow	Wheat	Fallow	Fallow						
M	SoxxWhxWhxx	Sorghum	Fallow	Fallow	Wheat	Fallow	Wheat	Fallow	Fallow						
N	xWhxxxChxx	Fallow	Wheat	Fallow	Fallow	Fallow	Chickpea	Fallow	Fallow						
O	xWhxBaxWhxCa	Fallow	Wheat	Fallow	Barley	Fallow	Wheat	Fallow	Canola						
P	xWhxBaxChxCa	Fallow	Wheat	Fallow	Barley	Fallow	Chickpea	Fallow	Canola						
Q	xWhxBaxWhxCh	Fallow	Wheat	Fallow	Barley	Fallow	Wheat	Fallow	Chickpea						
R	SoxxWhxChxWhxx	Sorghum	Fallow	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Fallow	Fallow				
S	SoxxWhxChxWhMgx	Sorghum	Fallow	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Mungbeen	Fallow				
T	SoxSoxSoChxWhxx	Sorghum	Fallow	Sorghum	Fallow	Sorghum	Chickpea	Fallow	Wheat	Fallow	Fallow				
U	SoxSoxSoxxWhMgx	Sorghum	Fallow	Sorghum	Fallow	Sorghum	Fallow	Fallow	Wheat	Mungbeen	Fallow				
V	SoxxChxWhxChxWhxx	Sorghum	Fallow	Fallow	Chickpea	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Fallow	Fallow		
W	SoxxChxWhxFbxWhxx	Sorghum	Fallow	Fallow	Chickpea	Fallow	Wheat	Fallow	Fababean	Fallow	Wheat	Fallow	Fallow		
X	SoxSoxSoxxChxWhxx	Sorghum	Fallow	Sorghum	Fallow	Sorghum	Fallow	Fallow	Chickpea	Fallow	Wheat	Fallow	Fallow		
Y	xWhxWhxBaxChxWhxCa	Fallow	Wheat	Fallow	Wheat	Fallow	Barley	Fallow	Chickpea	Fallow	Wheat	Fallow	Canola		
Z	SoxSoxSoFbxWhxChxWhxx	Sorghum	Fallow	Sorghum	Fallow	Sorghum	Fababean	Fallow	Wheat	Fallow	Chickpea	Fallow	Wheat	Fallow	Fallow

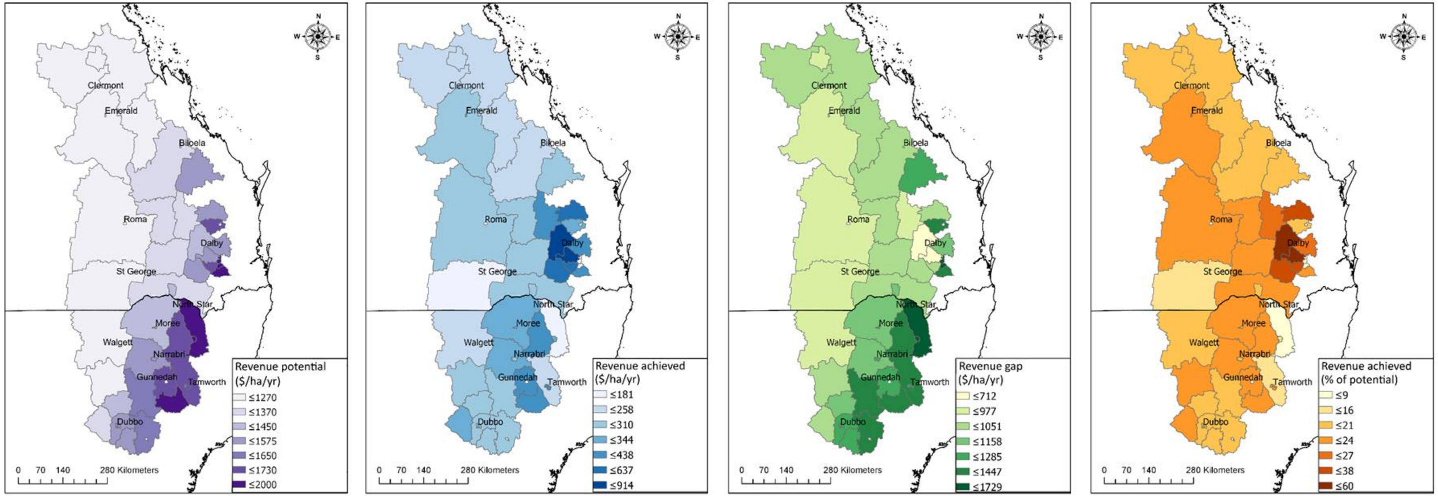
Maps showing (a) the maximum energy (GJ/ha/yr) achieved, (b) the maximum protein (kg/ha/yr) achieved and (c) the maximum revenue ($/ha/yr) achieved, and the rotations that achieved them



- For any location, rotations that optimise energy don’t tend to optimise protein
- It’s often the case that price is an good integrator of overall nutrition
- Hence, Revenue (= Price x Yield) is a good indicator of feed value per hectare

Rotation Revenue Gaps at SA2 Resolution

Water-limited Revenue | Actual Revenue | Revenue Gap | Relative Revenue



- Rotation Revenue Gaps averaged at 970 $A/ha/yr.
- This gap is much larger than implied by adding up individual crop yield gaps
- i.e. There is a big revenue penalty for choosing the “wrong rotation”.

Hochman et al. 2020. Cropping system yield gaps can be narrowed with more optimal rotations in dryland subtropical Australia, Agricultural Systems, Volume 184, 102896,

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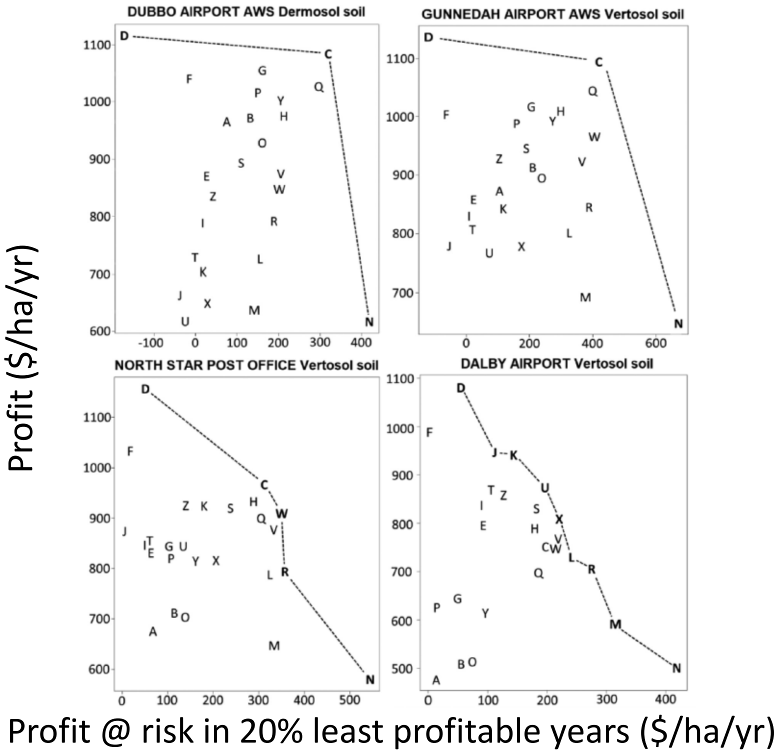
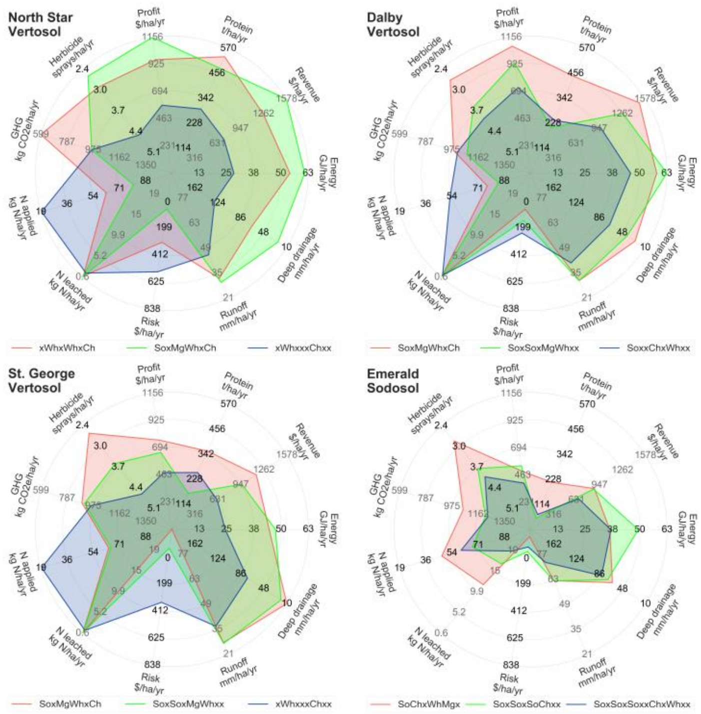
Risk-Profit trade-off frontier plots help explain system yield gaps



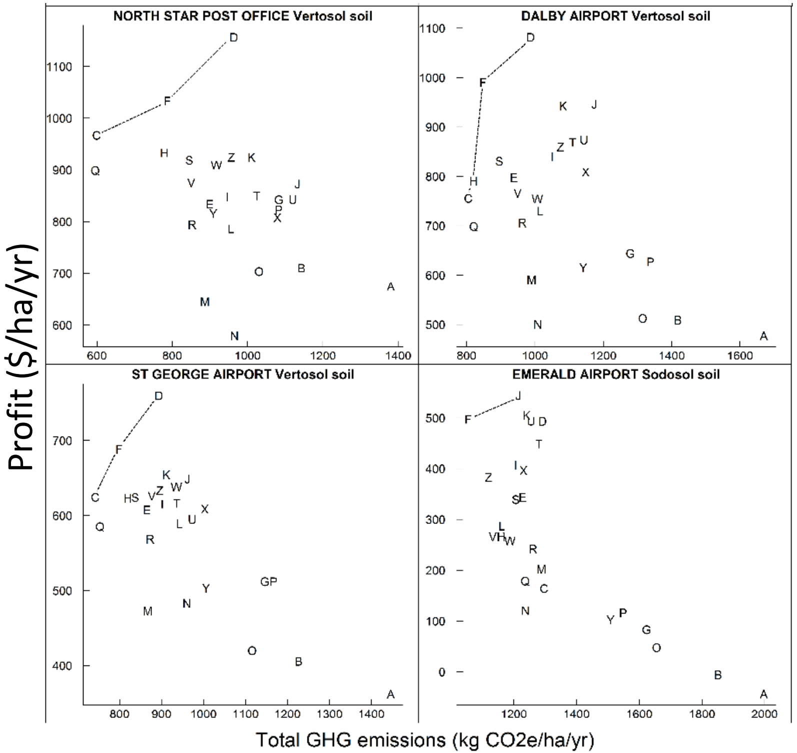
- Most rotations are not on the frontier. They offer an inefficient trade-off between profit and risk
- Rotation D is profitable but risky at these 4 sites
- For Dubbo and Gunnedah rotation C is a lot less risky and slightly less profitable
- For North Star lower risk offered by Rotation C (as well as W,R & N) comes at a higher price
- At Dalby Rotation J offers little reduction in risk compared to foregone profit
- Rotation N is an efficient but extremely risk averse tradeoff at all 4 sites

Sustainability Polygons at 4 sites

- At each site we compared 3 rotations
- Rotations chosen were efficient tradeoffs between profit and risk
- There are always tradeoffs between some desired attributes
- Site affects are large
- Rotations choice depends on subjective weights ascribed to sustainability indicators and weights may well vary between different stakeholders



Efficient trade-offs: Profit VS GHG Emissions



- Here too, most rotations offer an inefficient trade-off between profit and GHG emissions
- To equitably compensate a North Star grower to move from rotation D to rotation C would cost about \$500/t CO2e/ha/yr. At St George this would cost about twice as much. At Emerald, J to F would cost ~\$150/t CO2e/ha/yr.

Conclusions

- Shared agro-ecological zones offer an opportunity for technology exchange between Australia and the Dry Arc.
- Enabling resilience to a variable and warming climate is an ongoing RD&E challenge for dryland agriculture in Australia
- Adaptation will require closing yield gaps while developing transformational technologies to better suit our changing climate
- Sustainable intensification requires a whole farming system approach: taking into account the multiple facets of productivity and environmental impacts
- Trade-offs are inevitable and need to made efficiently using tools such as sustainability polygons and trade-off frontier plots

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Thank You

Zvi Hochman

Chief Research Scientist/Team Leader
CSIRO Agriculture and Food
Queensland Bioscience Precinct
306 Carmody Road, St Lucia QLD 4067

Zvi.Hochman@csiro.au

www.yieldgapaustralia.com.au

Twitter: @YieldGapAus

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