Legumes in the rotation *(can)* increase profit and resilience

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Take home messages

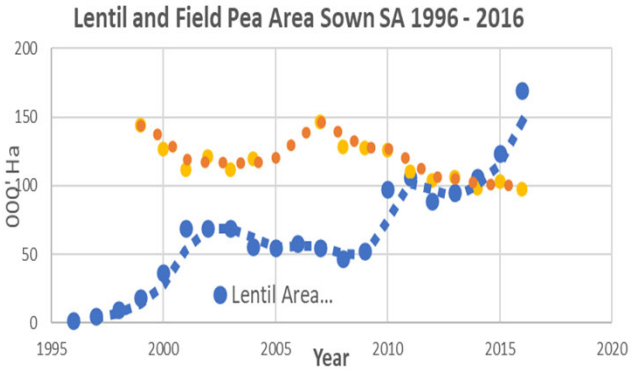
- Sth NSW dominated by canola-wheat systems: 2 to 4% pulse
- Compared to baseline (C-W-B) diverse systems with legumes:
  - More profitable
  - Less risky
  - Stable or declining weed and diseases
  - Robust in the longer term
- Improved environmental outcomes
- Barriers persist - individual business decision

Rationale and profitable inclusion

Lupin in WA (1990s)

1.2 Mill ha in 1998

Lentils in SA (2000s)



Chickpea in NNSW (2020s)

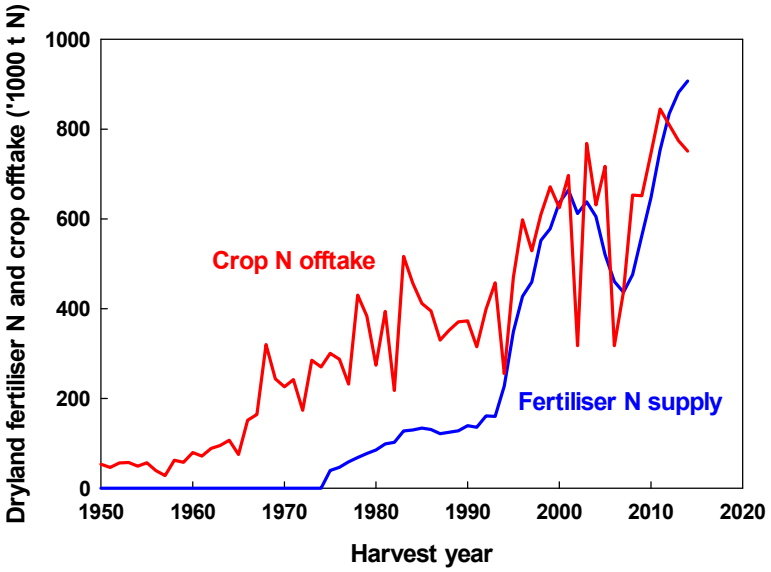
"I plant chickpea because unlike wheat, I don't need a planting rain to sow.

I plant them at the same time each year and the wheat fits around them."

Dave Ricardo, Grower, Walgett NSW

What's wrong with what I am doing now?

- N supply - fertiliser or legumes



(Angus and Grace, 2017)

- Increasing diversity with legumes:
  - Weed management
  - Disease management
  - Water balance
  - Risk management
  - Economic benefits
  - Environmental benefits (e.g. GHG)
  - **Individual whole-farm fit?**

Nitrogen supply

N fixation

Healthy, profitable legume

N benefits to next crops

20 kg N/ha per tonne biomass

How much N is fixed by commercial legume crops?

- 61 commercial crops sampled between 2001 and 2017

(faba bean, lupin, chickpea, field pea, lentil, vetch)

- Average **N-fix 65%** (range 8% to 98%)
- Average **90 kg N/ha** (range 12 to 306 kg/ha)
- 20% of paddocks had < 50% N fix

- Restricted legume growth

Subsoil constraints, drought, herbicide residues, low P

- Low N-fix

Acid soils, poor/no inoculation, high soil mineral N

Peoples et al., (2017)

Contribution of N to following crops?

- Legume end use – removal in grain?

System	N fixed (kg/ha)	Net N input (kg/ha)
Pulse-grain	134 *(65 to 310)*	45 *(**-40** to 96)*
Pulse-BM	144 *(86 to 246)*	144 *(86 to 246)*
Pasture	174 *(102 to 256)*	132 *(70 to 199)*

Fababean/Chickpea (biomass vs grain removed)

Vetch – graze, hay, BM

Peoples et al., (2017)

- Extra N supply to following crops

Legume grown	Extra Mineral N (kg/ha)
Field pea	23
Lentil	26
Chickpea	35
Lupin	37
Faba-bean	47
Average pulse	**35**
Brown manure	60

Peoples et al., (2017)

Weed management

Big 6

Rotate crops and pastures →

Weeds love predictable rotations. They find it easy to evolve resistance to herbicides when they are used in a predictable manner.

Double knock to preserve glyphosate →

What's better than an attack on weeds? A second one. Come at them with a different strategy and any survivors left over don't stand a chance.

Mix and rotate herbicides →

Rotating buys you time, mixing buys you shots. Mix and rotate buys you time and shots.

Stop weed seed set →

Annual weeds must set seed if the species is to persist, so stopping weed seed set is a critical strategy to manage herbicide-resistant weeds.

Increase crop competition →

Help your crops win the war against weeds by increasing their competitiveness against them.

Implement harvest weed seed control →

Capture weed seed survivors at harvest using chaff lining, chaff tramlining, chaff carts, narrow windrow burning or integrated weed seed destructors.

- Legumes in rotation to add diversity
- "Double breaks" – legume - canola
- Diversity allows herbicide rotation
- Legume hay cut and BM options
- Spray topping in lupins

Managing weeds – double breaks

Sequence and input treatments (Junee, NSW) (initial ARG 1815 pl/m^2)

CROP SEQUENCE (Management intensity)	3 Yr System Financials				2017* ARG (/m^2)
	Herb. cost ($/ha/yr)	Total cost ($/ha/yr)	Profit ($/ha/yr)	Profit/Cost ratio	
Wheat-Wheat-Wheat (conservative)	59	317	388	1.20	**3146**
Wheat-Wheat-Wheat (aggressive)	128	560	585	1.04	366
Canola-Wheat-Wheat (aggressive)	96	609	883	1.45	219
Lupin-Canola-Wheat (aggressive)	78	414	790	1.91	63

Swan et al., 2022 (in review)

Diversity – balance profit with risk

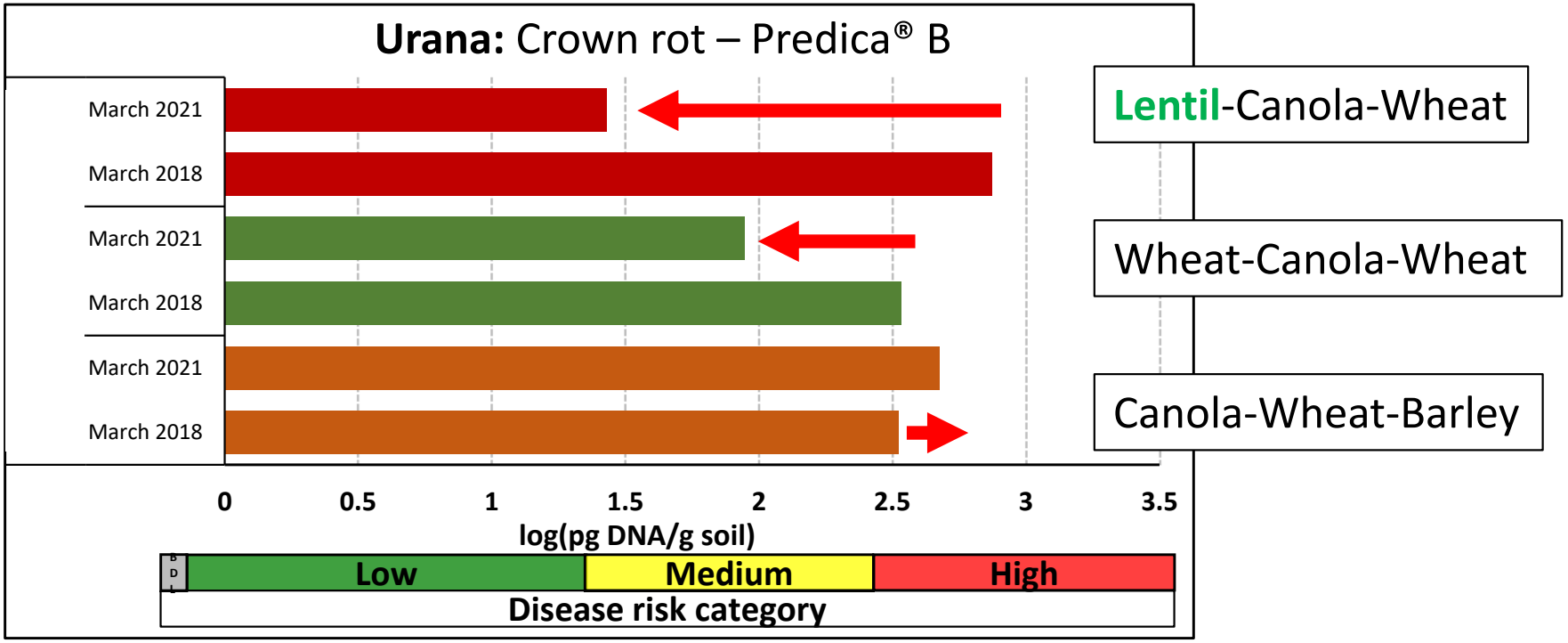
Sequence and input treatments (Temora, NSW) (initial ARG 1864 pl/m^2)

Conservative: **TT canola–wheat–wheat** (low density; treflan/diuron IBS; 20 kg N/ha up-front)
Aggressive: **RR canola–wheat–wheat** (high density; Sakura/Boxer Gold; 40 kg/N ha up-front)
Diverse: **Vetch hay–TT canola–wheat–barley** (low density; Sakura; 20 kg/N ha up-front)

SYSTEM	System Financials				2017* ARG (/m^2)
	N cost ($/ha/yr)	Total cost ($/ha/yr)	EBIT ($/ha/yr)	Profit/Cost ratio	
Conservative (C-W-W)	103	429	415	0.95	4188
Aggressive (C-W-W)	109	517	498	0.96	573
Diverse (Vetch-C-W-B)	70	465	512	1.12	145

Pulses and disease management

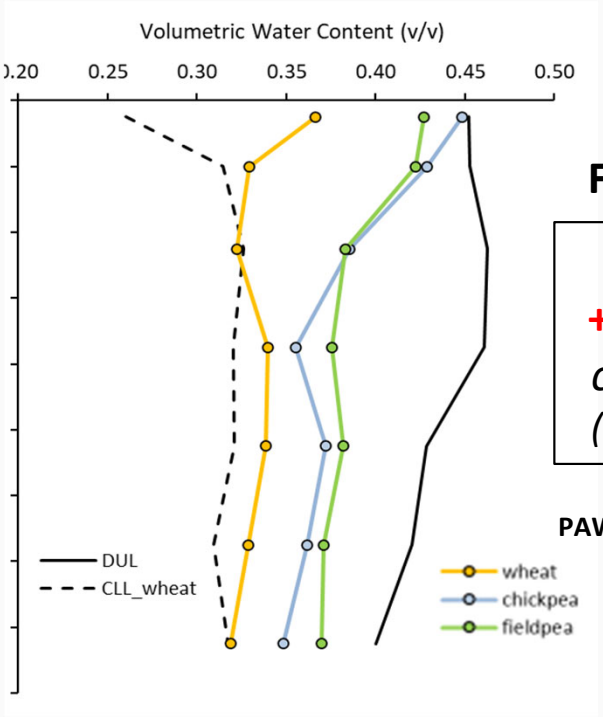
- Increased diversity reduces crown rot inoculum over 3 years



(Courtesy: Mat Dunn, NSWDPI)

Water legacies of legumes?

- Legumes can use less water
(shallow roots, less biomass, early maturity)



From 20+site years

Legumes leave
+20 to 40 mm extra
cf wheat or canola
(Range -5 to + 80mm)

Bell et al., 2021

- But leave less cover!

legume | canola | wheat

Lower fallow efficiency; Higher erosion risk

Water legacies of legumes?

- Persistence of residual water and effect on following crops

Site – year	Crop	Residual PAW (mm)	
Gr'thorpe 2018 (Kandosol)	Chickpea	76	+40
	Wheat	59	
Urana 2018 (Sodosol)	Lentil	170	+40
	Wheat	130	
Urana 2018 (Sodosol)	Fababean	184	+25
	Wheat	159	
Trangie 2017 (Chromosol)	Chickpea	50	+35
	Wheat	15	
D. Downs 2017 (Vertosol)	Chickpea	95	+10
	Wheat	-10	

Bell et al., 2021

Water legacies of legumes?

- Persistence of residual water and effect on following crops

Site – year	Crop	Residual PAW (mm)		PAW prior to next crop (mm)	
Gr'thorpe 2018 (Kandosol)	Chickpea	76	+40	101	-16
	Wheat	59		117	
Urana 2018 (Sodosol)	Lentil	170	+40	217	+9
	Wheat	130		208	
Urana 2018 (Sodosol)	Fababean	184	+25	153	+6
	Wheat	159		147	
Trangie 2017 (Chromosol)	Chickpea	50	+35	35	+10
	Wheat	15		25	
D. Downs 2017 (Vertosol)	Chickpea	95	+105	160	+20
	Wheat	-10		140	

Bell et al., 2021

Water legacies of legumes?

- Persistence of residual water and effect on following crops

Site – year	Crop	Residual PAW (mm)		PAW prior to next crop (mm)		Following crop & year	Grain yield (t/ha)
Gr'thorpe 2018 (Kandosol)	Chickpea	76	+40	101	-16	Wheat, 2019	2.6
	Wheat	59		117			2.8
Urana 2018 (Sodosol)	Lentil	170	+40	217	+9	Canola, 2019	1.0
	Wheat	130		208			1.0
Urana 2018 (Sodosol)	Fababean	184	+25	153	+6	Canola, 2019	1.0
	Wheat	159		147			1.0
Trangie 2017 (Chromosol)	Chickpea	50	+35	35	+10	Barley, 2018	1.6
	Wheat	15		25			1.7
D. Downs 2017 (Vertosol)	Chickpea	95	+105	160	+20	Wheat, 2020	4.3
	Wheat	-10		140			3.4

Bell et al., 2021

Current Project Objectives

- convert rainfall into more profit <u>across a crop sequence</u>
- manage soil fertility, weeds, diseases, costs and risk

Diversity

Nitrogen

Early Sow/Graze

Systems compared

Sown early May

Nitrogen strategy

Baseline	Barley	Canola	Wheat	Top-dress for Decile 2 
	Barley	Canola	Wheat	Top-dress for **Decile 7** 
Diverse	Legume	Canola	Wheat	Top-dress for Decile 2 
	Legume	Canola	Wheat	Top-dress for **Decile 7** 

- High value, high risk (chickpea, lentil)
- Low value, low risk (lupin, fababean, pea)
- Multiple use - hay, graze (vetch)

Diverse systems, lower N - profitable

- All sites a more profitable diverse, low N option
  + $100 to $300/ha/year

- Legume crops were profitable
  the right legume for the site, grown well

- Residual N and water benefits
  +50 kg N/ha (15-77); **+30 mm water** at depth

- More N fertiliser didn't match legumes for $$$

Value of the legumes

- Urea savings and extra canola yield

Prices	Urea saving		Extra canola yield		Total Value ($/ha)
	(kg/ha)	Value	(kg/ha)	Value	
Urea $600/t *Canola $650/t*	78	$47/ha	220	$143/ha	**$190/ha**

Value of the legumes

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Urea $600/t Canola $650/t	78	$47/ha	220	$143/ha	**$190/ha**
Urea $1200/t Canola $650/t	78	$94/ha	220	$143/ha	**$237/ha**

Value of the legumes

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Urea $1200/t Canola $650/t	78	$94/ha	220	$143/ha	**$237/ha**
Urea $1200/t Canola $1000/t	78	$94/ha	220	$220/ha	**$314/ha**

Reduced input costs in diverse systems

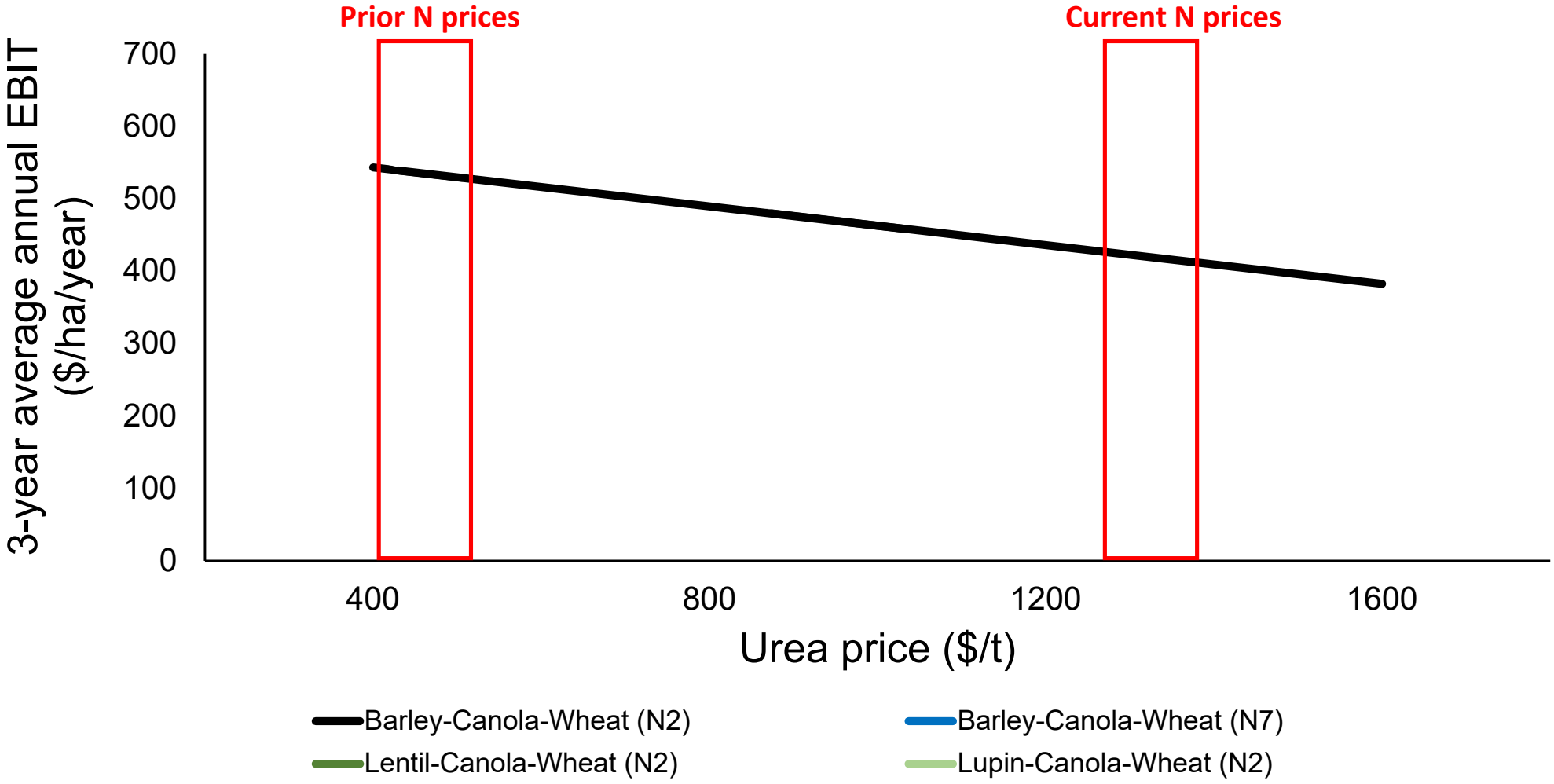
- Nitrogen costs reduced √
- Herbicide costs reduced by **~$30/ha pa/yr**
- Stable/declining weed and disease levels

Sequence profit (Wagga Wagga)

					Urea rate (kg/ha/year)	Sequence Profit ($/ha/year)
Baseline						
Barley	Canola	Wheat	N2		134	$528
Barley	Canola	Wheat	N7		220	$542
Diverse N2						
Vetch hay	Canola	Wheat			79	$543
Lentil	Canola	Wheat			92	$588
Lupin	Canola	Wheat			86	$626

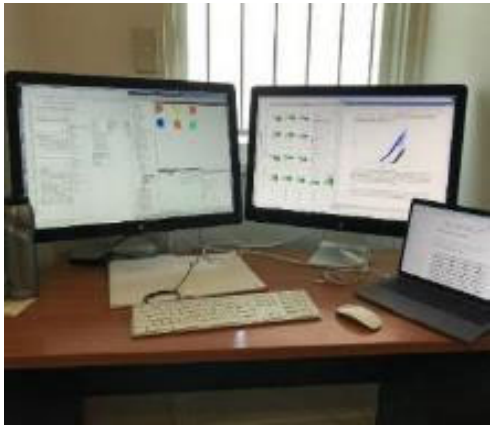
+$100/yr

Effect of N prices on system profit (2018-2020)

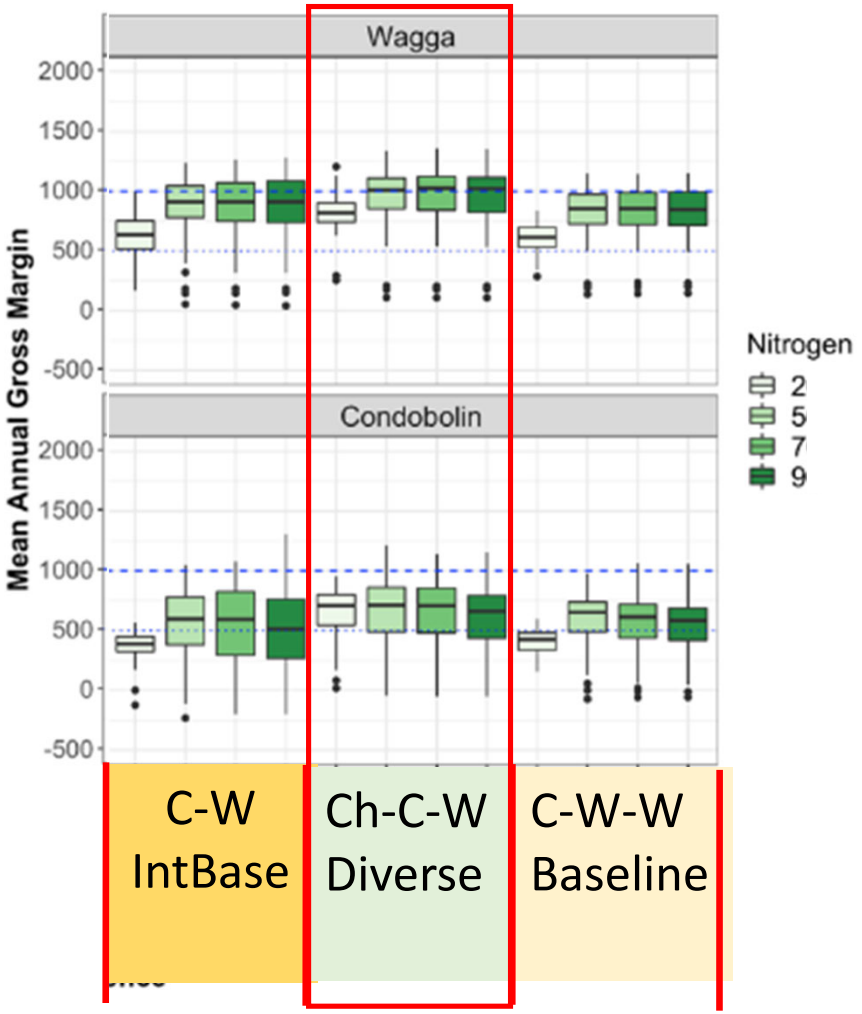


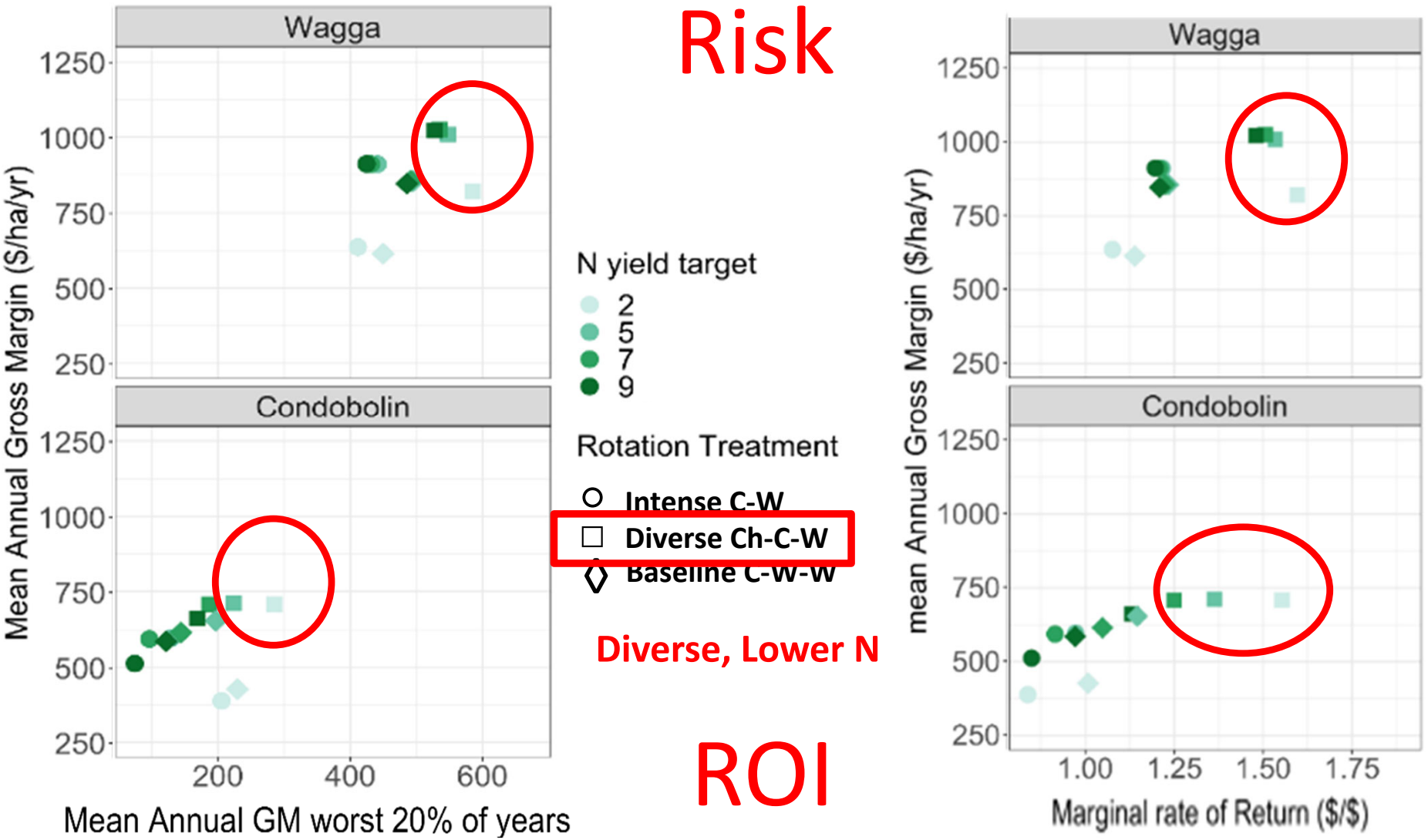
Longer term….simulation

Profit



Courtesy:
Jeremy Whish, CSIRO




Risk
Wagga
Condobolin
Mean Annual Gross Margin ($/ha/yr)
1250
1000
750
500
250
200
400
600
Mean Annual GM worst 20% of years
N yield target
2
5
7
9
Rotation Treatment
Intense C-W
Diverse Ch-C-W
Baseline C-W-W
Diverse, Lower N
ROI
Wagga
Condobolin
mean Annual Gross Margin ($/ha/yr)
1.00
1.25
1.50
1.75
Marginal rate of Return ($/$)

Environmental Concerns

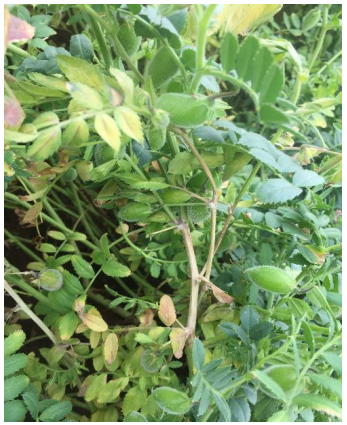
	Legumes	N-fertilised crops	*References*
N losses from the system (N15)			
Crop Uptake (%)	**15** (5-27)	**36** (17-50)	*Peoples et al. (2009)*
Recovered in soil (%)	**62** (37-90)	**31** (21-40)	
Unrecovered (assumed lost)	**23** (4-54)	**33** (16-62)	
Energy Use (MJ/ha)	**6,990**	**12,660**	*Jensen et al. (2012)*
CO_2 Emissions ($TgCO_2$/year)	**>1,000** (recycled)	**>300** (fossil fuel)	*Jensen et al. (2012)*
N_2O Emissions (kg N_2O-N/ha)	**1.0** (0.1-7.1)	**2.7** (0.1-12.7)	*Jensen et al. (2012)* *Schwenke et al. (2015)*

Barriers at the whole-farm scale

- Few legumes are widely adapted to a range of soil types
- Disease epidemics, fungicides sprays, harvesting issues etc

Chickpea 2021:
Early Ascochyta
Low temperature stress Sept.
Late lodging
Late Sclerotinia, Ascochyta and Botrytis

10 Sprays



- **Marketing, price volatility**, storage requirements

More from the experts later!

Thank you

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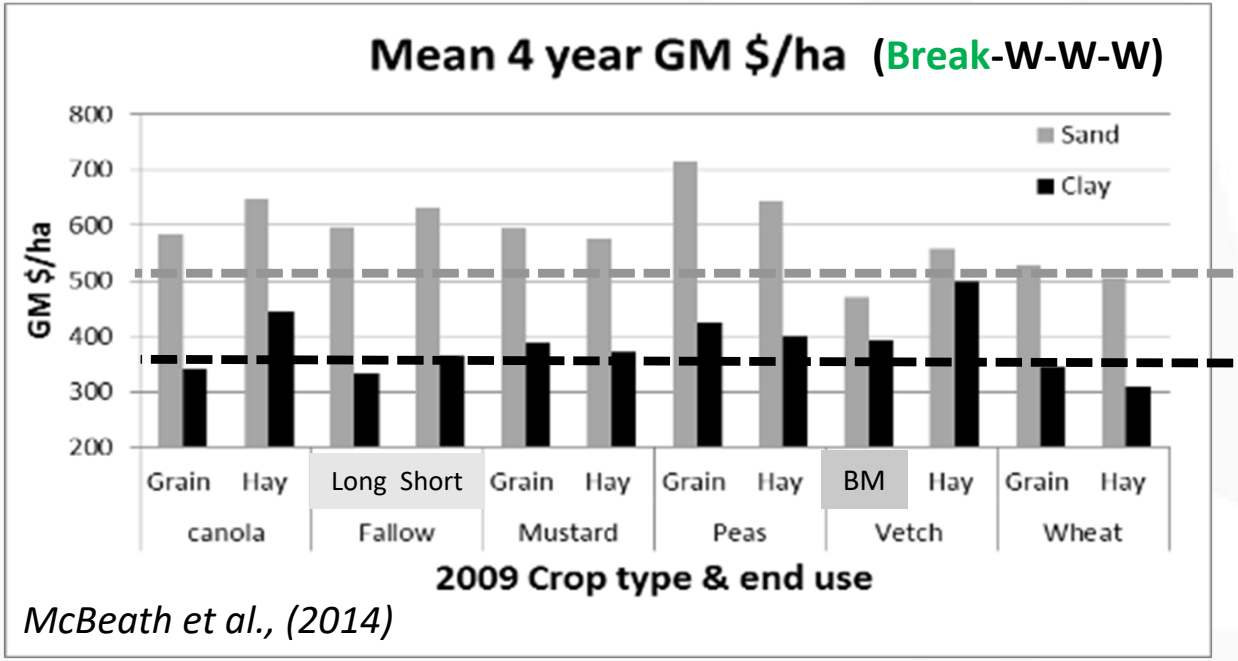
Profitability of legume for hay

- Hopetoun, 350mm rainfall – several break options competitive over 4 yrs



McBeath et al., (2014)

- Legume brown manure benefits water (Yr 2)
- N supply (Yr 2-4) in a risky environment