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Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

The role of break crops and pastures in improving water use efficiency of wheat in Western Australian dryland farming systems

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Introduction

- Provide some background on recent changes in farming systems in Western Australia
- Describe a field survey conducted across the Western Australian (WA) grain belt
- Look at what was affecting water use efficiency (WUE) of wheat within these fields, particularly the role of break crops and pastures
- Make some observations about the challenges ahead

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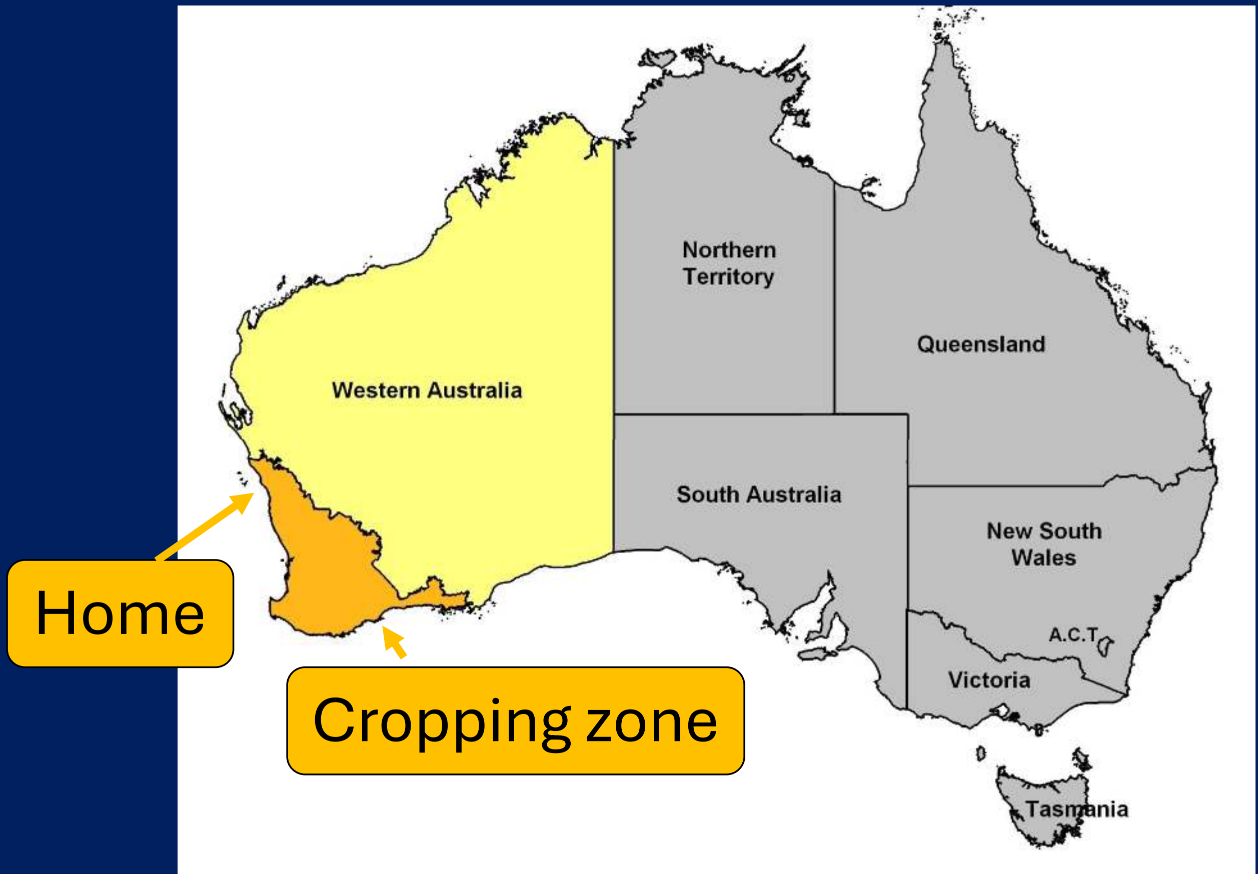
THE WESTERN AUSTRALIAN CROPPING ZONE



- ~ 16 million hectares
- ~ 9 million hectares cropped p.a.
- ~ 18 million tonnes of grain p.a.

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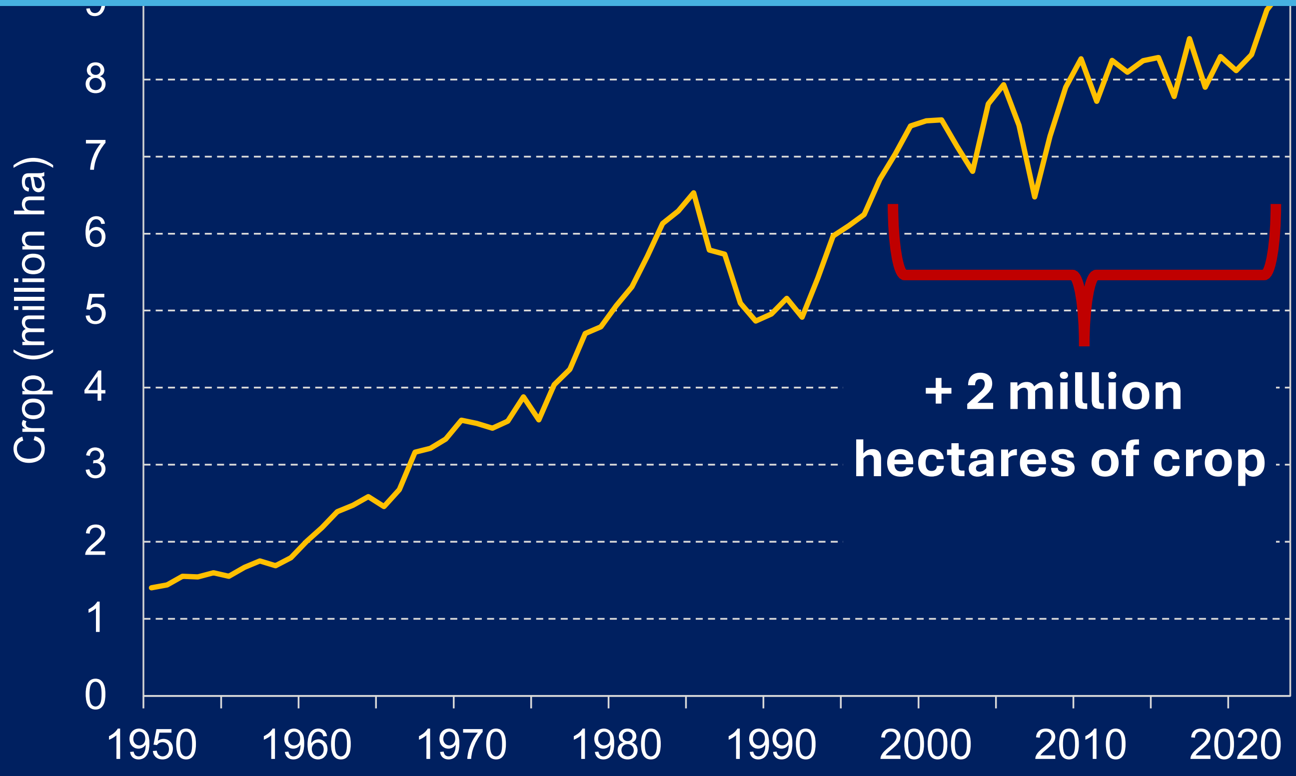
Western Australian farming systems have changed in the past two decades

More intensive cropping with fewer legumes



Source: Australian Bureau of Statistics

- Less sheep: 22 million to 12 million
- In some regions farm area dedicated to legume pasture declined from 30% to <10%
- Less grain legumes 1.5 to 0.3 mill ha
- More canola 0.5 to 2.0 mill ha
- More cereal production

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What are the impacts of changed rotations?

Traditionally break crops (crops other than wheat)
and pastures are used within rotations to manipulate;

- Weeds; rotation of chemicals and different techniques
- Pathogens; non-host year for wheat pathogens
- Nutrients; N and cycling of other elements

Other legacy effects; soil water, soil biology, soil structure
Interactions between these biophysical variables

Angus, J, Kirkegaard, J, Hunt, J, Ryan, M, Ohlander, L, Peoples, M (2015) Break crops and rotations for wheat. Crop and Pasture Science 66, 523-552
Kirkegaard, JA, Peoples, MB, Angus, JF, Unkovich, MJ (2011) Diversity and evolution of rainfed farming systems in southern Australia. In 'Rainfed Farming Systems. (Eds P Tow, I Cooper, I Partridge, C Birch.) pp. 715-754. (Springer: Dordrecht, The Netherlands)
Kirkegaard, J, Christen, O, Krupinsky, J, Layzell, D (2008) Break crop benefits in temperate wheat production. Field Crops Research 107, 185-195.

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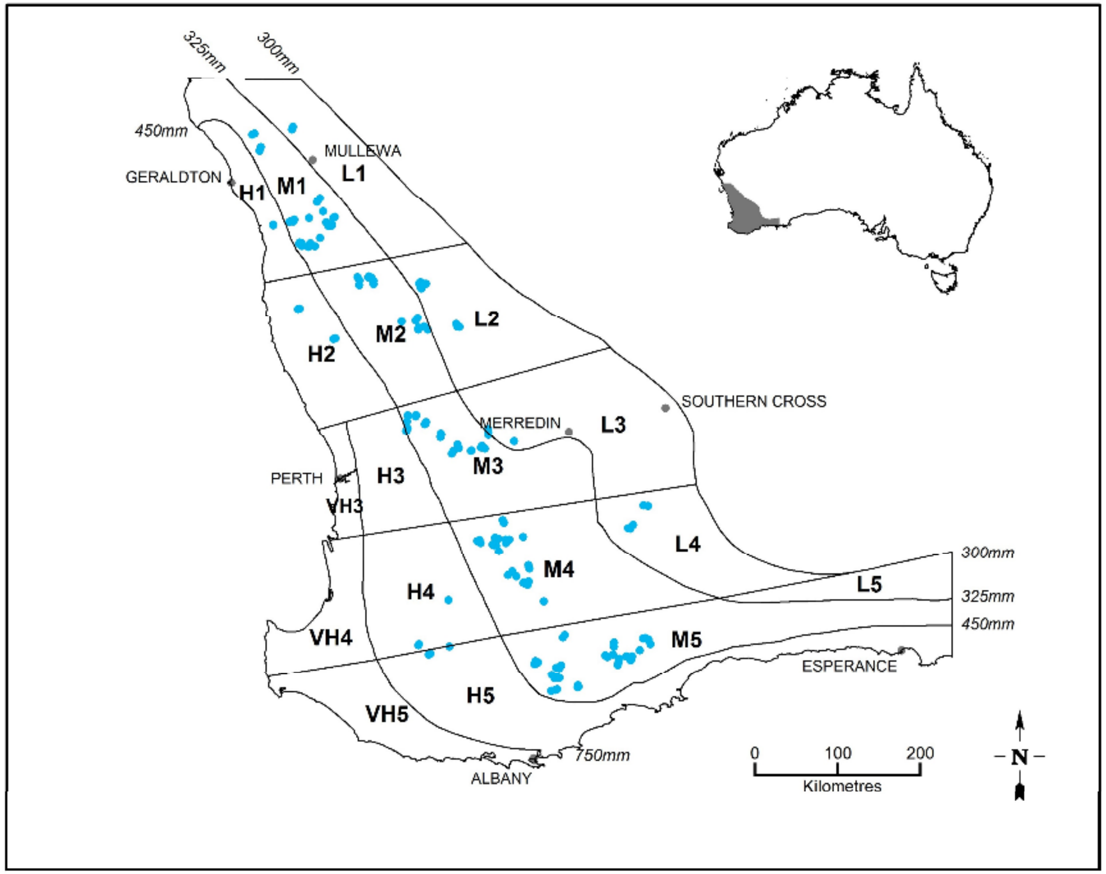
Survey of farmers' fields

Aim: better understand links between biophysical constraints and rotations



- 184 fields (blue dots)
- 3720 field visits (2010-2015)
- Measurement of
  - Weeds
  - Plant diseases
  - Soil nutrients
  - Yield
- Management records (rotation, inputs & weather data)

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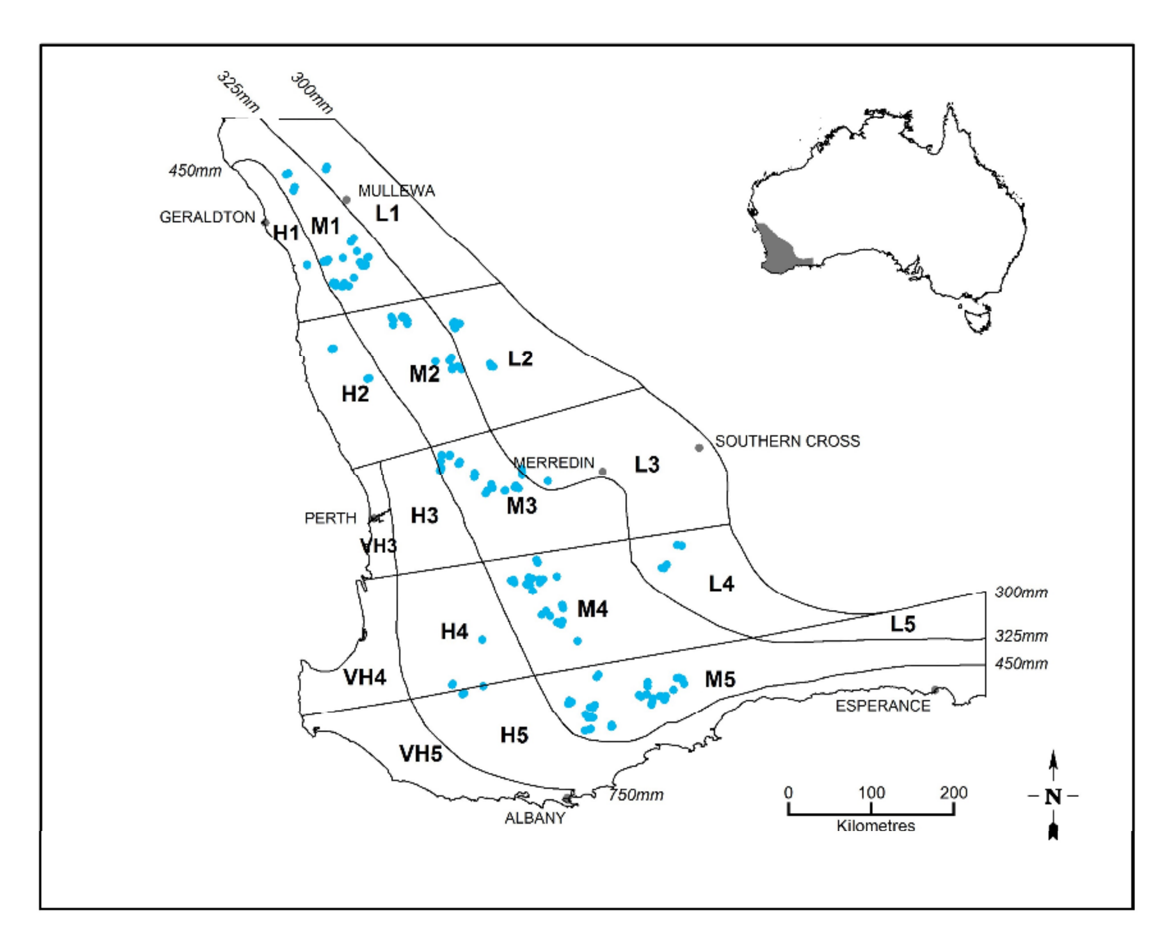
Land uses in the survey



Land use	% of fields
Wheat	58
Canola	14
Pasture	12
Lupin	7
Barley	6
Other	3

Other = Pulse crops, oats and fallow

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Rotations

Dominated by wheat but...

Few fields of monoculture wheat

- 20% fields Wheat/Wheat/Wheat
- 5%   fields W / W / W / W

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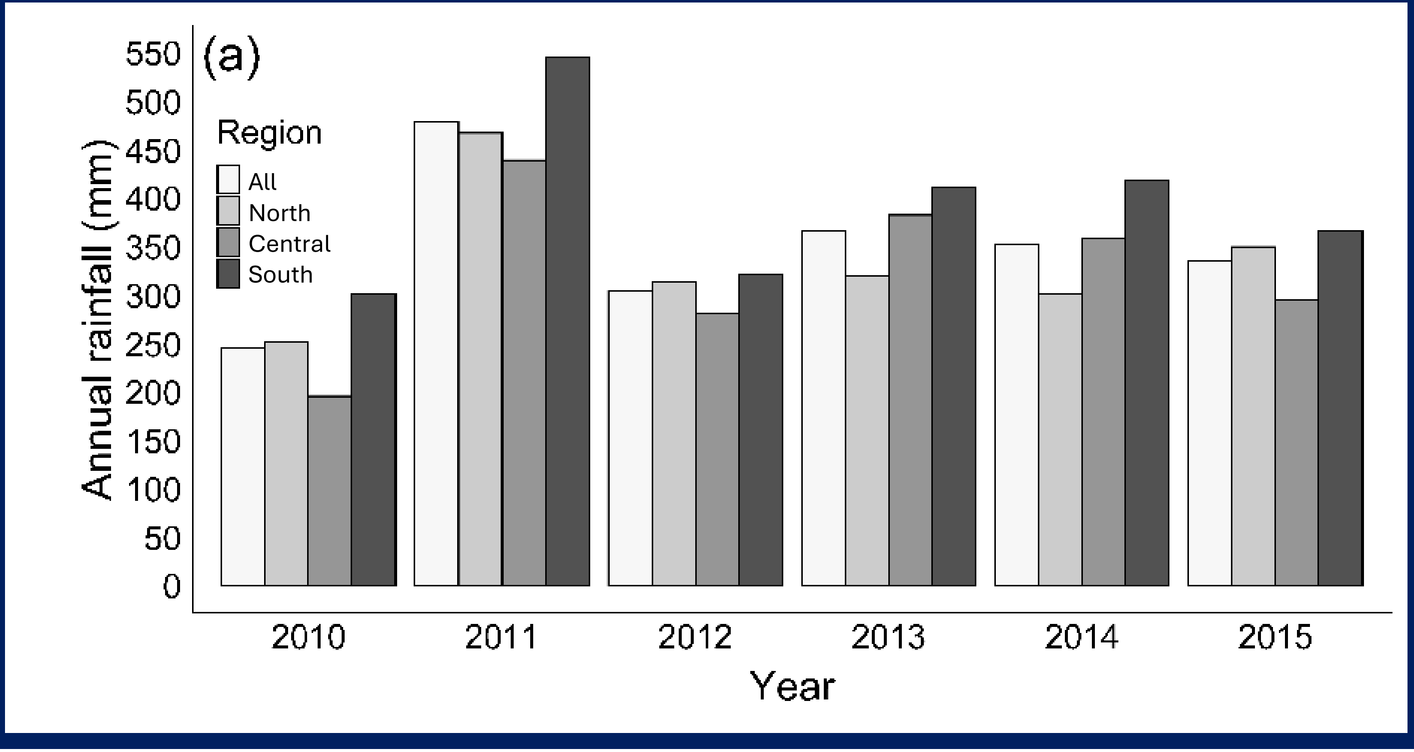
Rainfall for fields in our survey

- Annual rainfall ranged 196–546 mm
- GSR < 300 mm in 83% of field-years
- Mediterranean climate, WUE is a key measure of productivity

    we need to make every mm count!



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Weeds and soil pathogens were well managed

There were few grass weeds in cropped fields

- 72% of cropped fields <10 grass weeds/m^2 spring

  n > 30,000 weed counts

Most plants had few symptoms of root disease

- 72% of plants had either no damage or a trace of root damage
- Only 1% were severely damaged

  n = 26,300 plants assessed

Pathogen DNA concentration in the soil was also low for > 80% samples

n = > 30,000

Harries, M, Flower, KC, Renton, M, Collins, SJ, Hüberli, D (2022) Links between soilborne pathogens, plant parasitic nematodes, farm management and biophysical constraints in a southern Australian rainfed cropping system. Crop and Pasture Science 73, 1291-1307.doi.org/10.1071/CP21778

Harries, M, Flower, KC, Scanlan, CA, Rose, MT, Renton, M (2020) Interactions between crop sequences, weed populations and herbicide use in Western Australian broadacre farms: findings of a six-year survey. Crop and Pasture Science 71, 491–505.10.1071/CP19509

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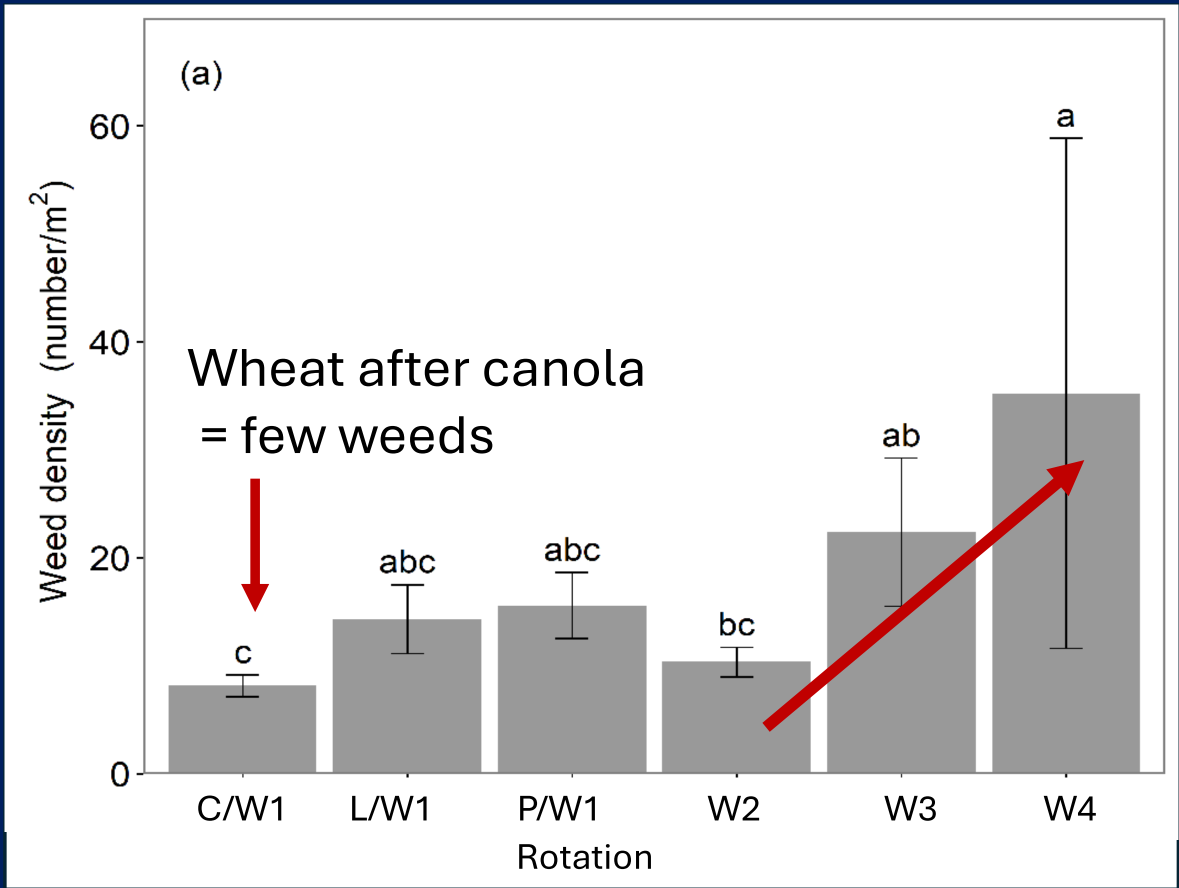
Rotations were used to keep weed numbers low



C = canola, L = Lupin, P = pasture, W = wheat

- 80% of canola fields < 5 grass weeds/m^2 in spring
- Weeds tended to increase in monoculture wheat

Rotation + Herbicides + IWM
= low weeds in most fields

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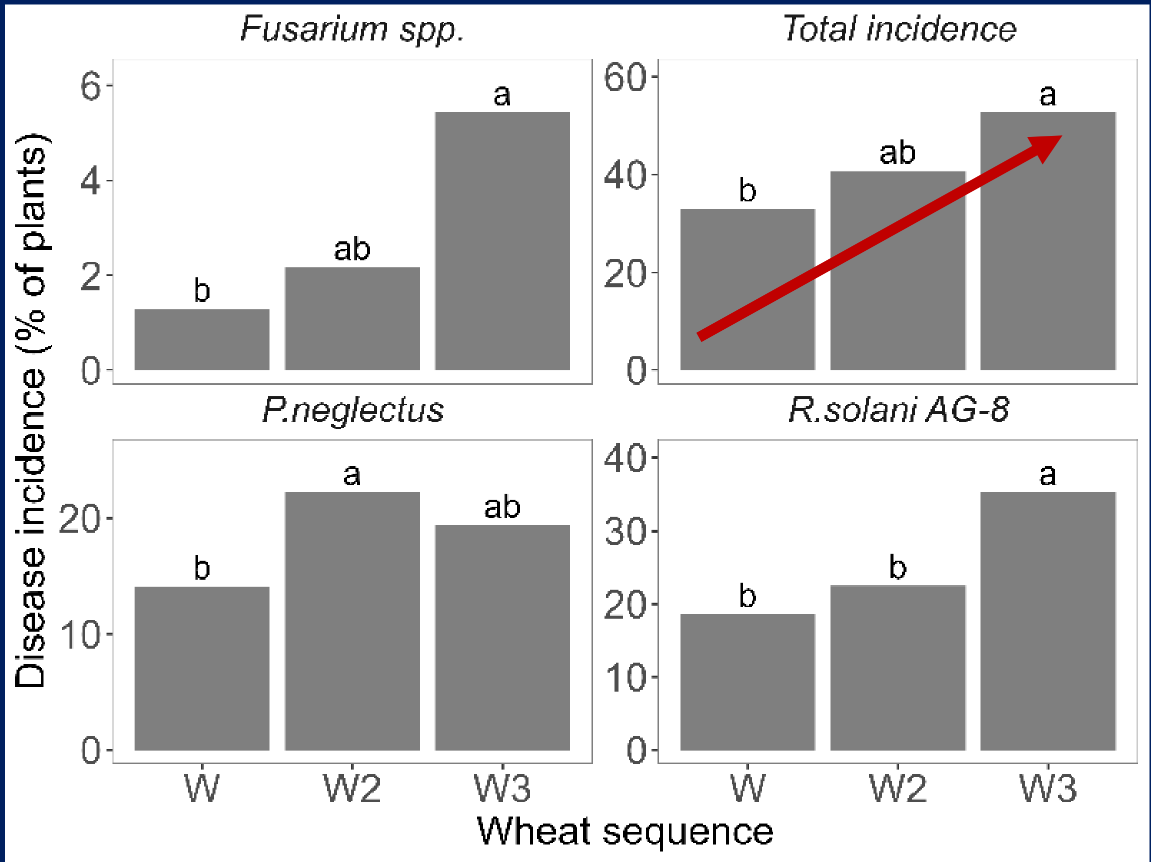
Rotations were used well to manage pathogens



Plant root observations (n = 26,300)

Incidence of plants with disease increased in longer sequences of wheat.

After 3 wheat crops, 55% of plants had root damage, but severity was low.

Low grass weeds help keep wheat pathogens low.

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Nitrogen nutrition

N balance for each land use (kg/ha)

Land use	N
Barley	-24
Canola	-15
Lupin	47
Pasture	48
Wheat	-20
W2	-24
W3	-8
W4	1

- Negative N budget for barley, canola, wheat:
  more N harvested than provided with fertiliser.
- 60% fields had negative rotational N balance (over study years).
- Legumes were not always compensating for the N exported in barley, canola and wheat.
- Mean deficit ~10 kg N/ha/year

n > 50,000 soil test records

Harries, M, Flower, KC, Scanlan, CA (2021) Sustainability of nutrient management in grain production systems of south-west Australia. Crop and Pasture Science 72, 197-212.10.1071/CP20403

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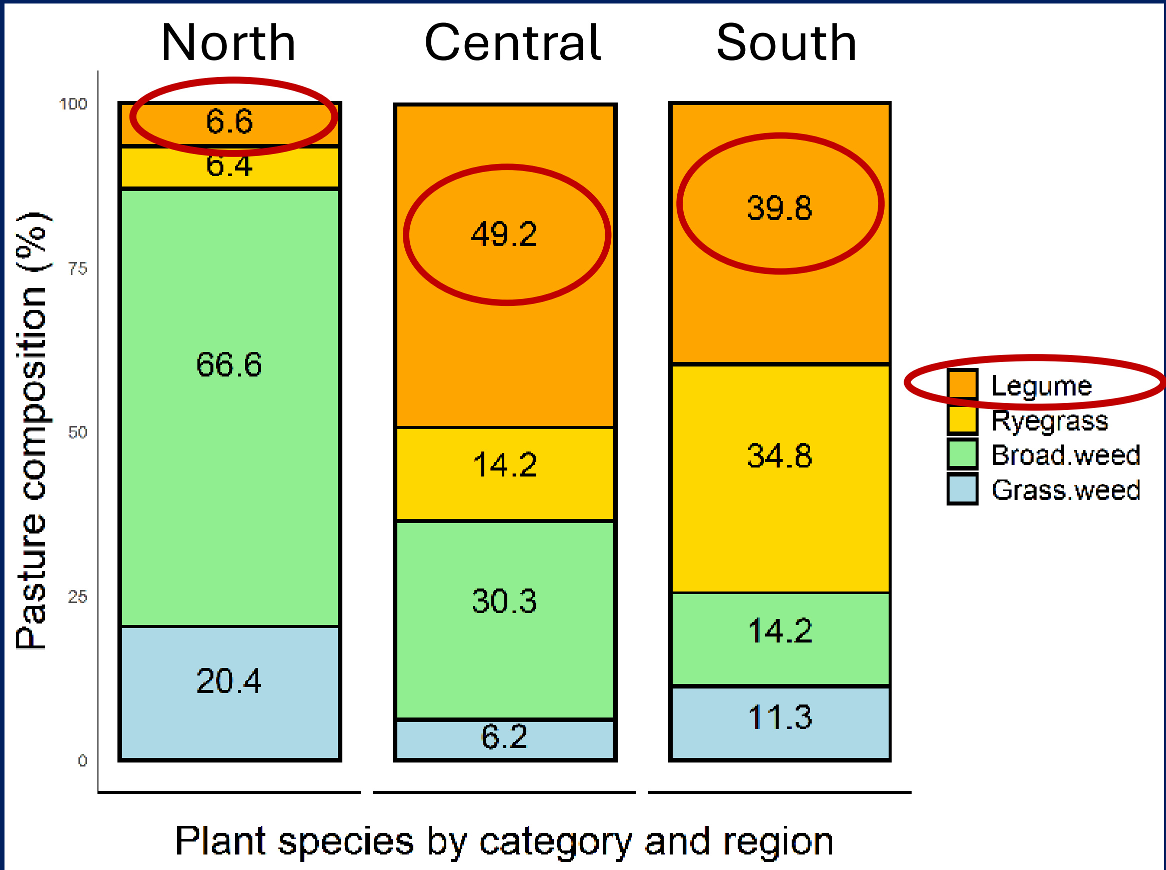
Nitrogen from pastures



Pasture composition data B. Nutt & R. Yates (Focus Paddock Survey)

Mean N added = 46 kg N/ha/year

North = 6 kg

Central = 65 kg

Southern = 50 kg

In fields with long cropping sequences & strong weed control pastures are not regenerating well

Overall:

- Fewer fields of pasture &
- Less N fixation within many of these

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Nitrogen from lupins

Mean N added = 41 kg N/ha/year

High harvest index of new lupin cultivars = less nitrogen added

Study	Year	HI	N added (kg/ha)
Unkovich	1986	0.11	96
Evans et al.	2001	0.23	80
*Harries et al.	2010-16	0.31	41

*n = 70 lupin fields

Overall
- Fewer fields of lupin &
- Less N fixation within many of these

Unkovich, M, Pate, J, Hamblin, J (1994) The nitrogen economy of broadacre lupin in southwest Australia. Australian Journal of Agricultural Research 45, 149-164.
Evans, J, McNeill, A, Unkovich, M, Fettell, N, Heenan, D (2001) Net nitrogen balances for cool-season grain legume crops and contributions to wheat nitrogen uptake: a review. Australian Journal of Experimental Agriculture 41, 347-359.
Harries, M, Flower, KC, Scanlan, CA (2021) Sustainability of nutrient management in grain production systems of south-west Australia. Crop and Pasture Science 72, 197-212.

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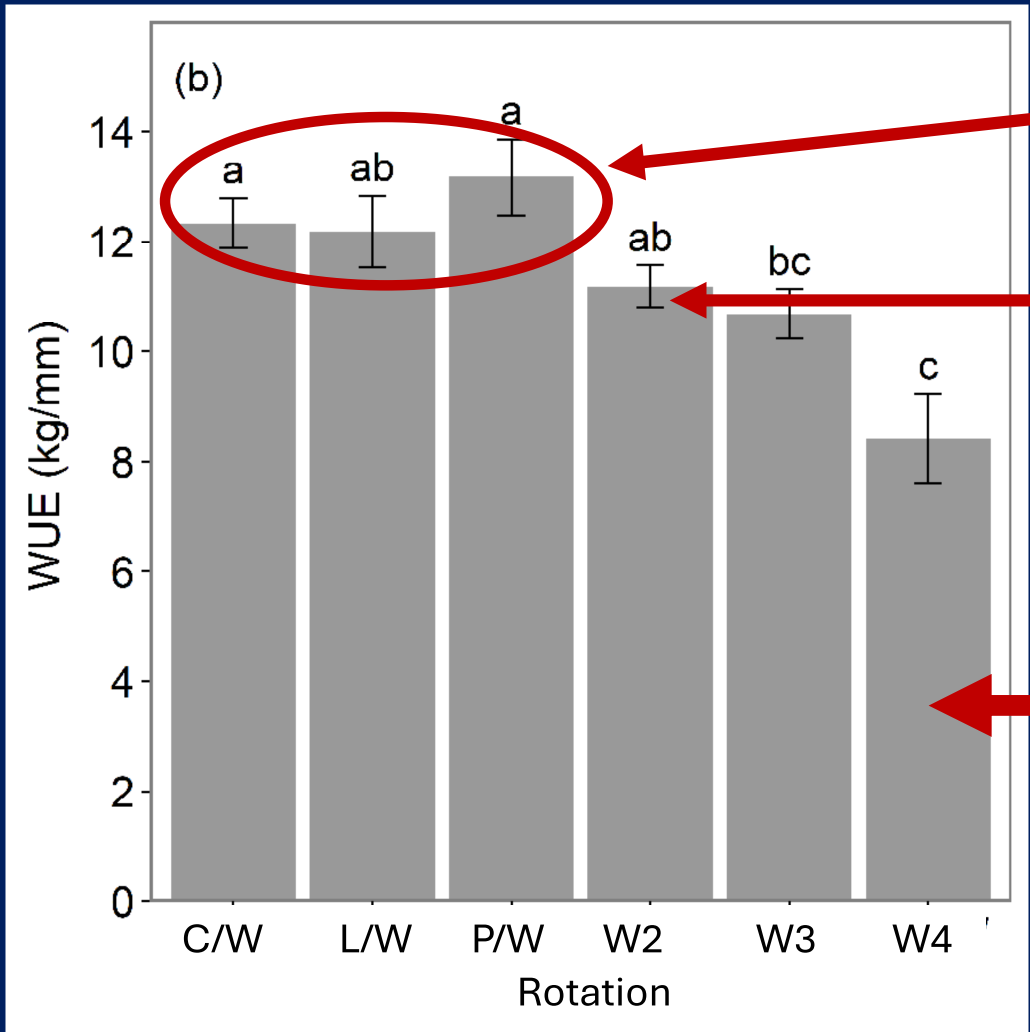
Wheat WUE and rotation

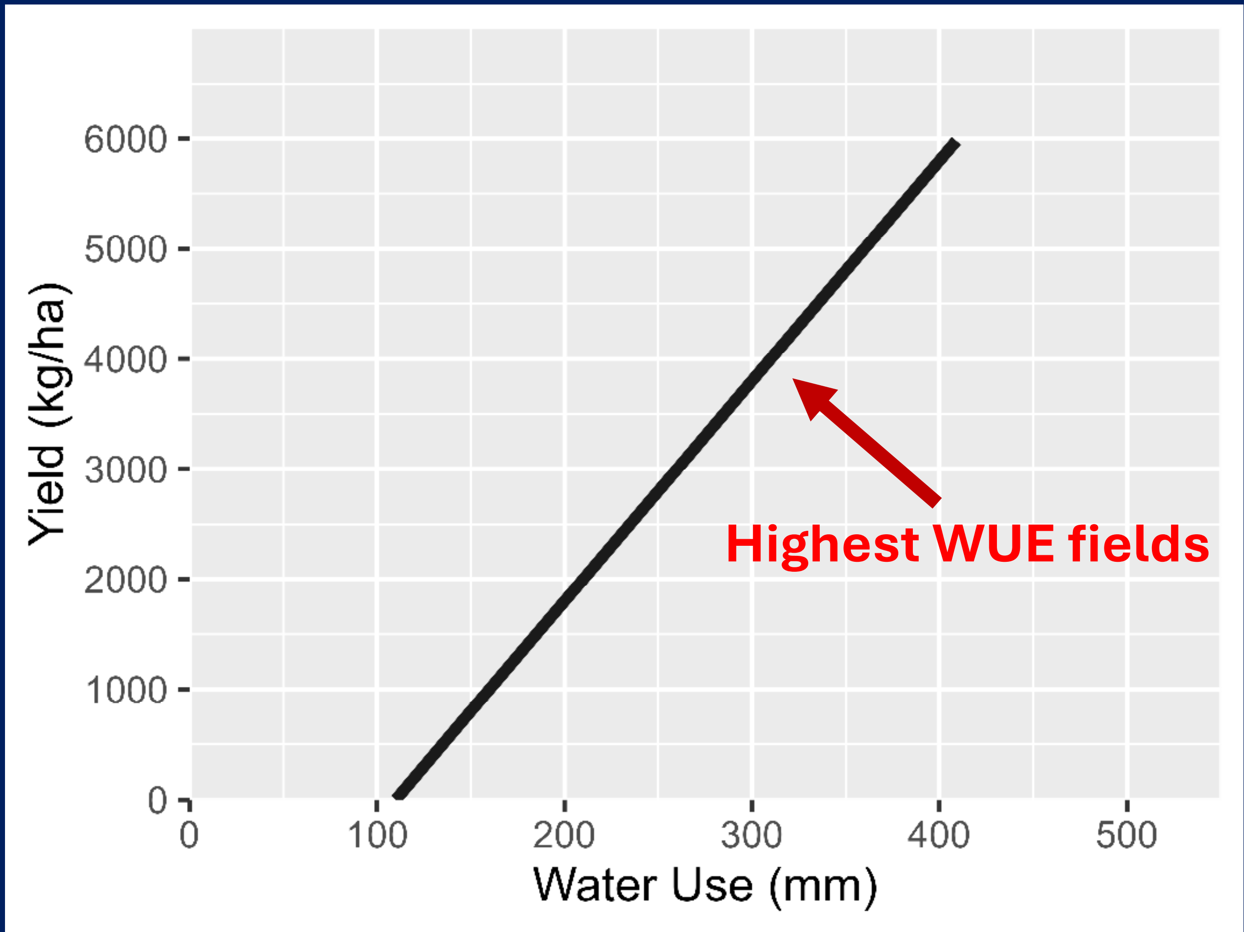


Wheat grown after canola or lupin or pasture had high WUE ~ 12.5 kg/mm

- Wheat after wheat = 11.2 kg/mm
- So a small initial break effect, because fields had low levels of biotic constraints
- Fourth wheat crop = 8.4 kg/mm

C = canola, L = Lupin, P = pasture, W = wheat

Comparing boundary functions of previous studies



Yield = 20 (Water Use – 110)
(French & Schultz 1984)

French, R, Schultz, J (1984) Water use efficiency of wheat in a Mediterranean-type environment. I. The relation between yield, water use and climate. Australian Journal of Agricultural Research 35, 743-764.
Sadras, VO, Angus, JF (2006) Benchmarking water-use efficiency of rainfed wheat in dry environments. Australian Journal of Agricultural Research 57, 847-856.10.1071/AR05359
Harries, M, Flower, KC, Renton, M, Anderson, GC (2022) Water use efficiency in Western Australian cropping systems. Crop and Pasture Science - .https://doi.org/10.1071/CP21745

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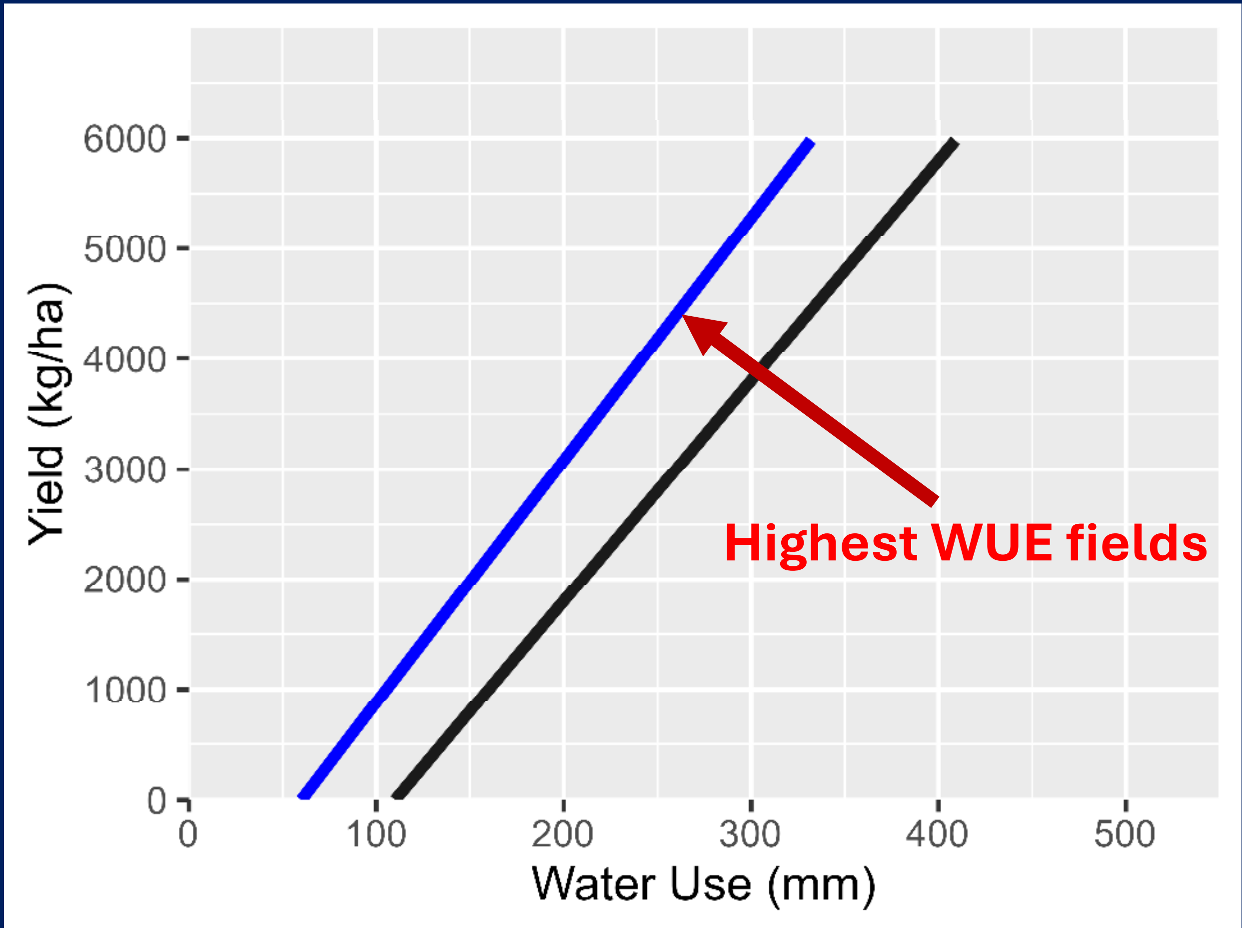

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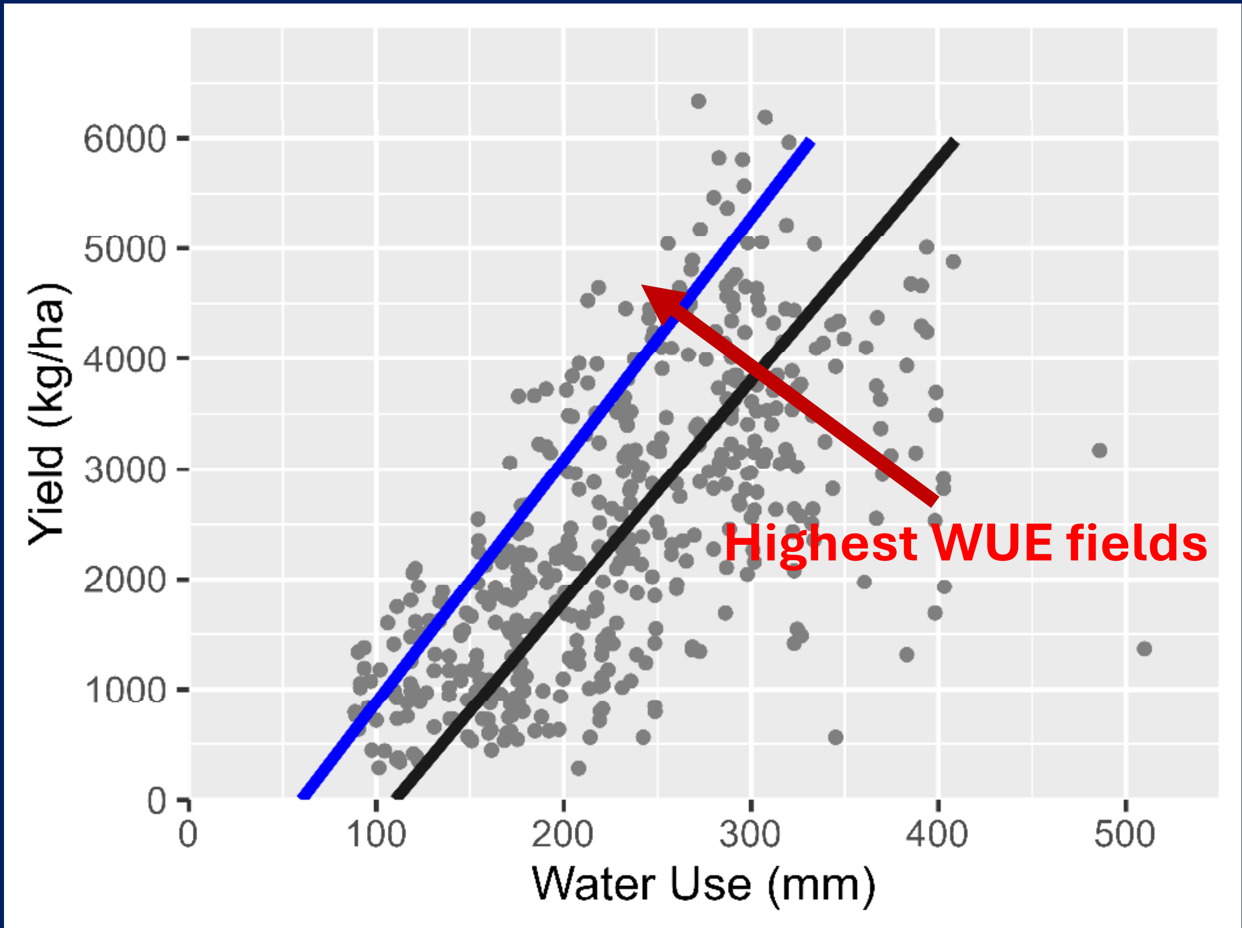

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Our study, each field

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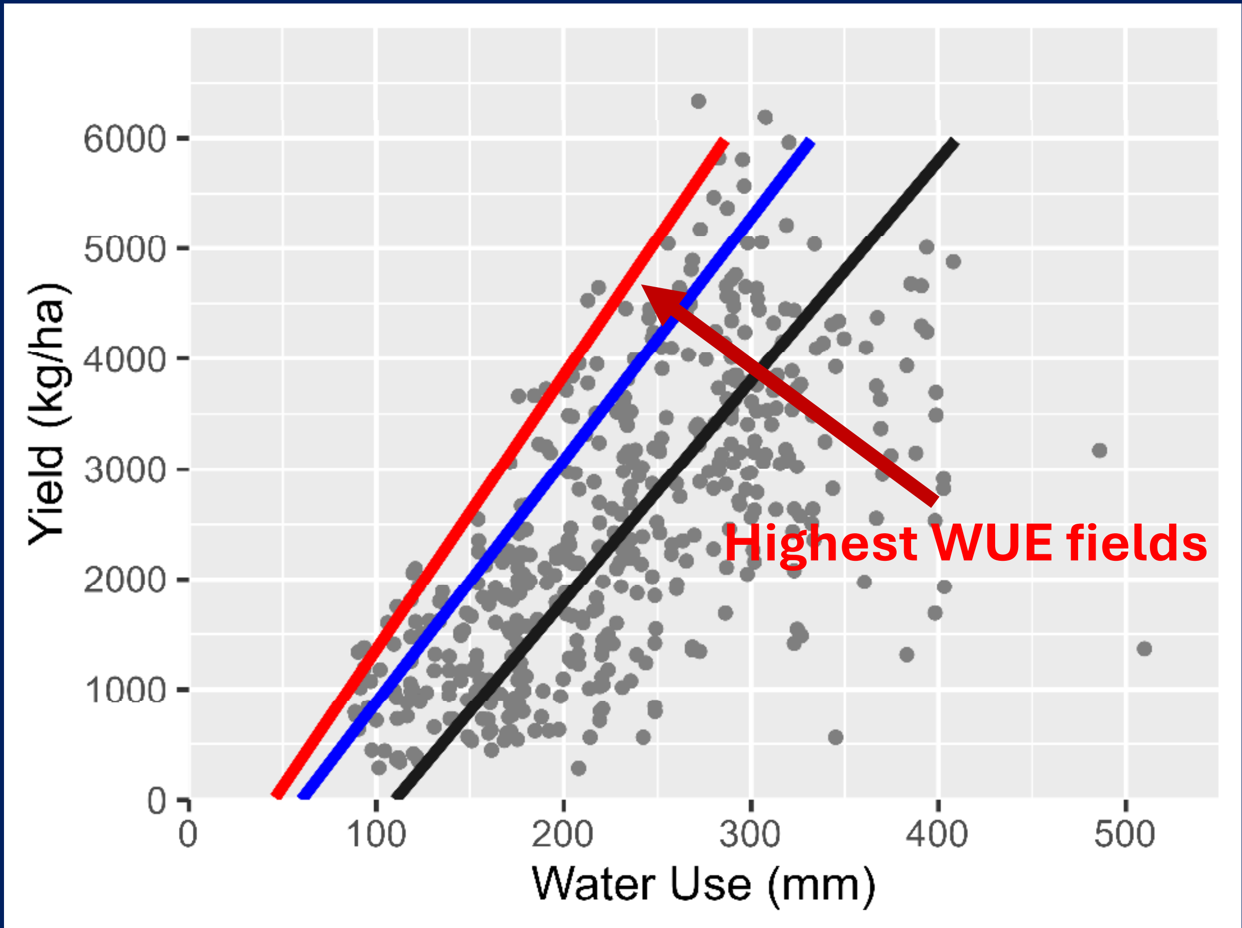

Yield = 20 (Water Use – 110)
(French & Schultz 1984)

Yield = 22 (Water Use – 60)
(Sadras & Angus 2006)

Yield = 25 (Water Use – 45)
(Harries et al. 2016)

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Sadras, VO, Angus, JF (2006) Benchmarking water-use efficiency of rainfed wheat in dry environments. Australian Journal of Agricultural Research 57, 847-856.10.1071/AR05359
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Mean water use efficiency of wheat crops

- WUE of our survey averaged 10.7 kg/mm
- This compared to 9.9 kg/mm previously reported in south east Australia, Sadras & Angus (2006).
- So ~1kg/mm increase, around 250 kg/ha extra per wheat crop

(250 mm average water use in our survey)

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What was affecting WUE in the fields we studied?

- Principal component analysis using > 40 variates
- Using meteorological variates principal components 1 and 2 accounted for 69% of the variability in the WUE data.
- Using management and biotic variates PC 1& 2 only accounted for 23% of the variability in the WUE data.
- So climatic constraints were influencing WUE more than biological constraints.
- The main climate factors driving WUE were rainfall, vapour pressure and temperature around flowering.

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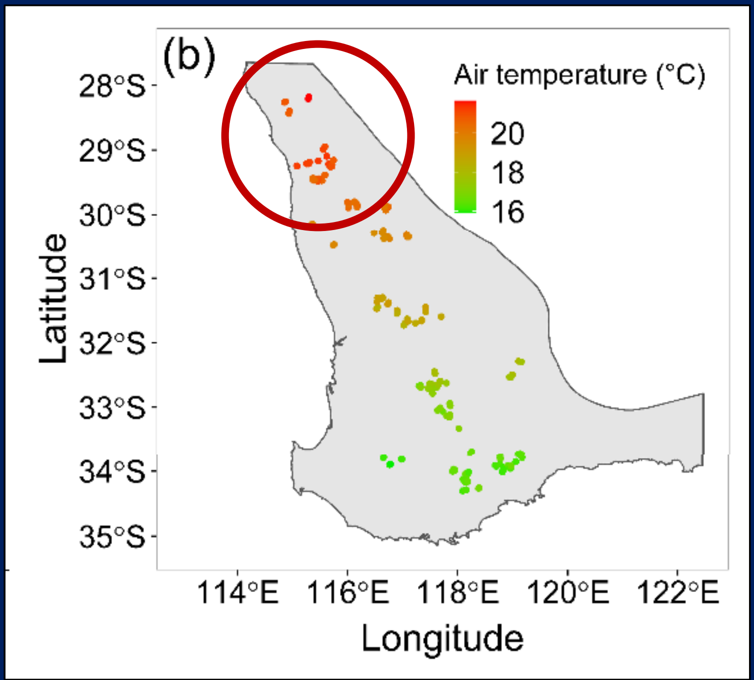
This affected the northern region the most



Mean WUE of all crops in each region

Region	Yield (kg/ha)	GSR (mm)	WU (mm)	WUE (kg/mm)
North	1865 c	221	238	7.8 b
Central	2393 b	205	224	10.7 a
South	3397 a	294	318	10.7 a

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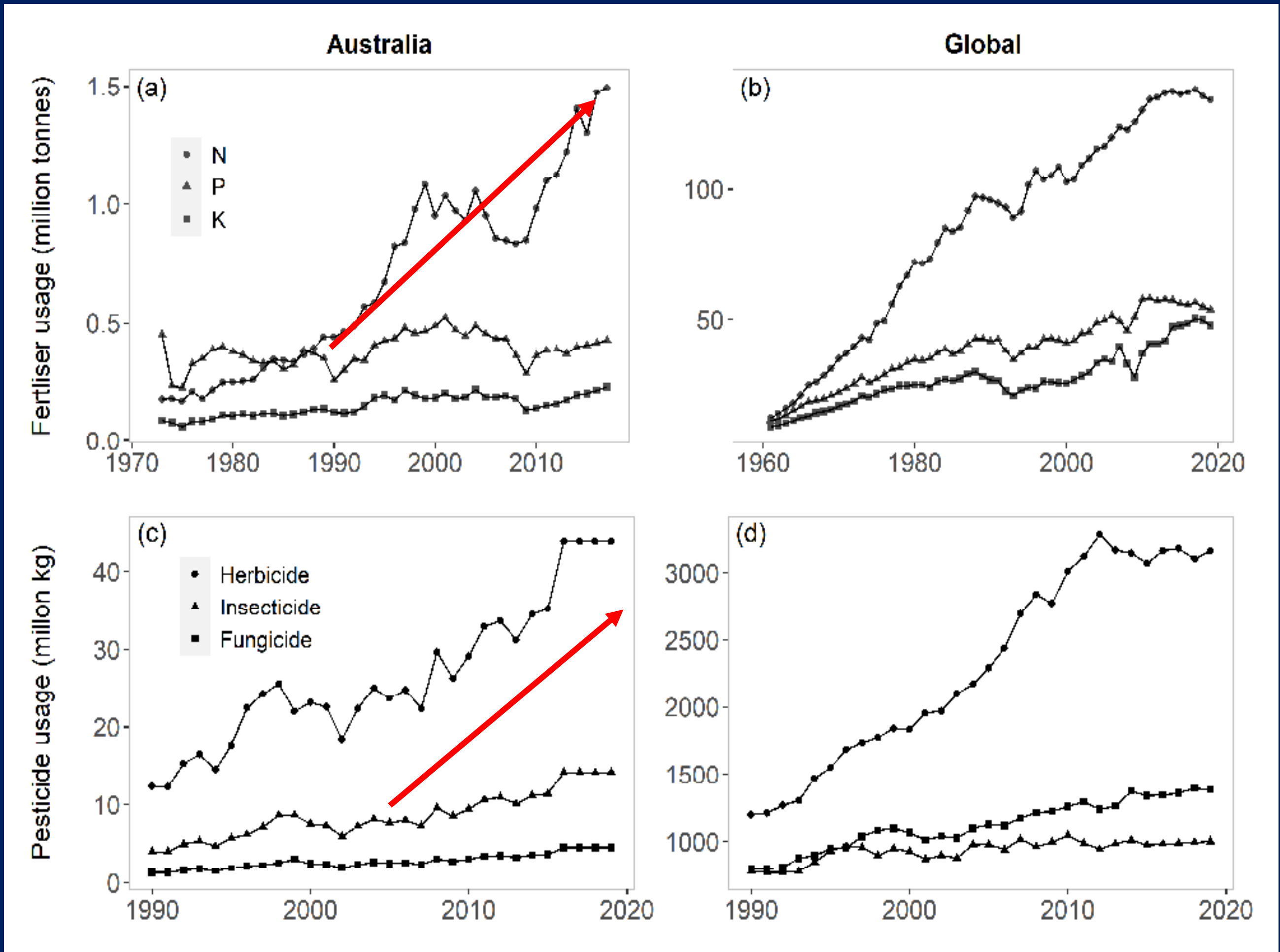
What can we do about spring weather?

- Sow as early as possible…
- In 2015, 71% of large farms (>5000 ha crop) sowed crop into dry soil (Fletcher *et al*.)
- Dry seeding ensures all rainfall is captured and crops mature in milder conditions
- It is **only possible when biotic constraints are low & using no-till stubble retention**

Fletcher, A, Lawes, R, Weeks, C (2016) Crop area increases drive earlier and dry sowing in Western Australia: implications for farming systems. Crop and Pasture Science 67, 1268-1280.10.1071/CP16200

The weaknesses… high inputs & lower legume N



- Fert N & herbicide use tripled in Aus since early 1990s
- This increases financial risk and will come under increased scrutiny regarding sustainability and GHG emissions.

Sources ABARES, FAOSTAT Fertiliser by Nutrient database http://www.fao.org/faostat/en/#data/RFN FAOSTAT Pesticide Use database, http://www.fao.org/faostat/en/#data/RP

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In summary WUE was high because…

- Rotations were simple, but actively managed to reduce long sequences of wheat
- Excellent control of biotic constraints gives flexibility to sow early, into dry soil
- Break crops and pastures remain fundamental to this, but their use has changed

The future

- Can we find ways to integrate more legumes effectively…
- Will this help to reduce inputs & GHG while maintaining productivity?
- We have some new farming systems trials to try and test this.

Acknowledgements

Department of
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- Many Colleagues:
- WA Department of Primary Industries and Regional Development, CSIRO, SARDI, UWA, Curtin Uni
- 70 farmers, 10 farming groups & staff for their work in the focus paddock project.
- Funding from DPIRD and the GRDC
- PhD supervisors Ken Flower, UWA
  Michael Renton, UWA
  Darshan Sharma, DPIRD
  Myrtille Lacoste, Curtin

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More information

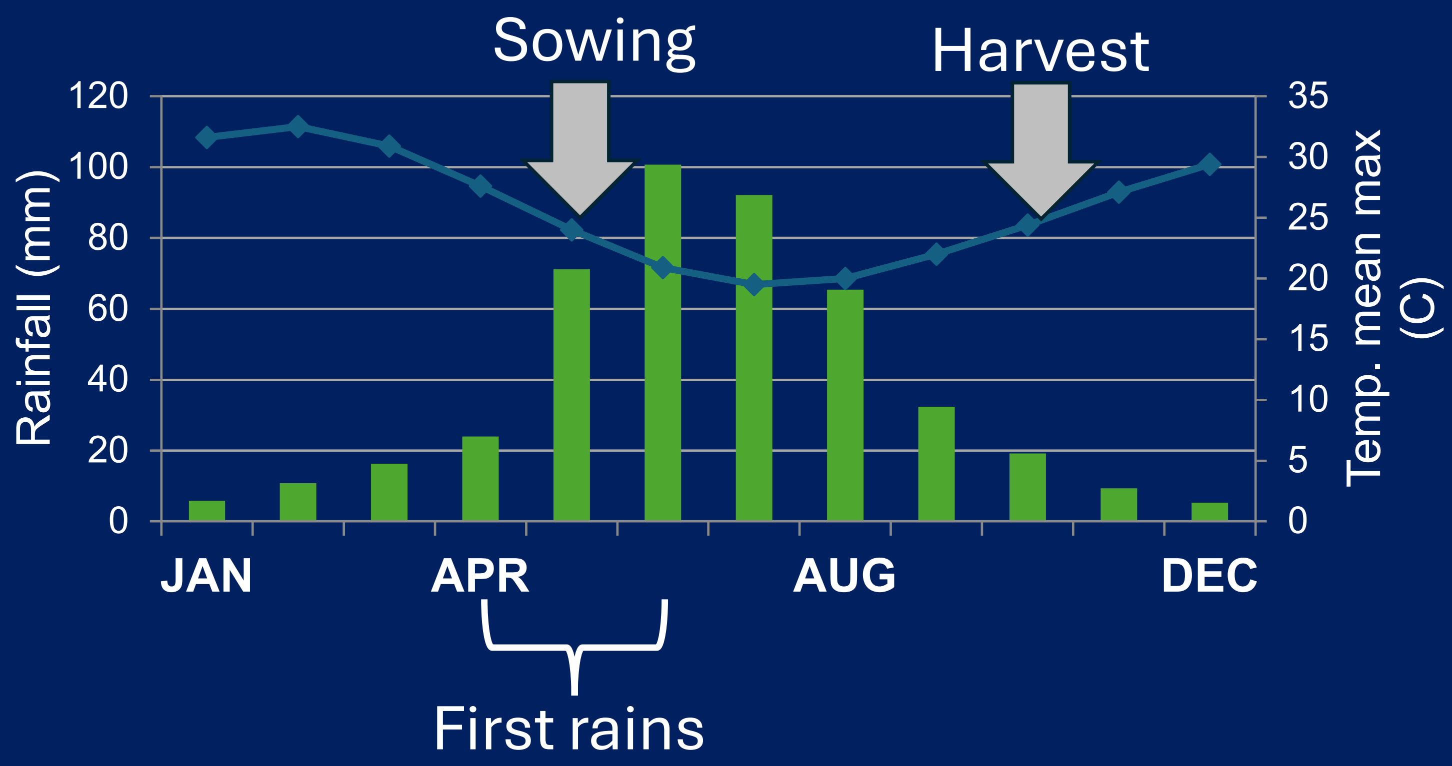
Harries, M (2023) Interactions between biophysical constraints and land use in rainfed cropping systems of southwest Australia. PhD thesis, University of Western Australia.

https://api.research-repository.uwa.edu.au/ws/portalfiles/portal/250316545/THESIS_DOCTOR_OF_PHILOSOPHY_HARRIES_Martin_John_2023.pdf

Thank you

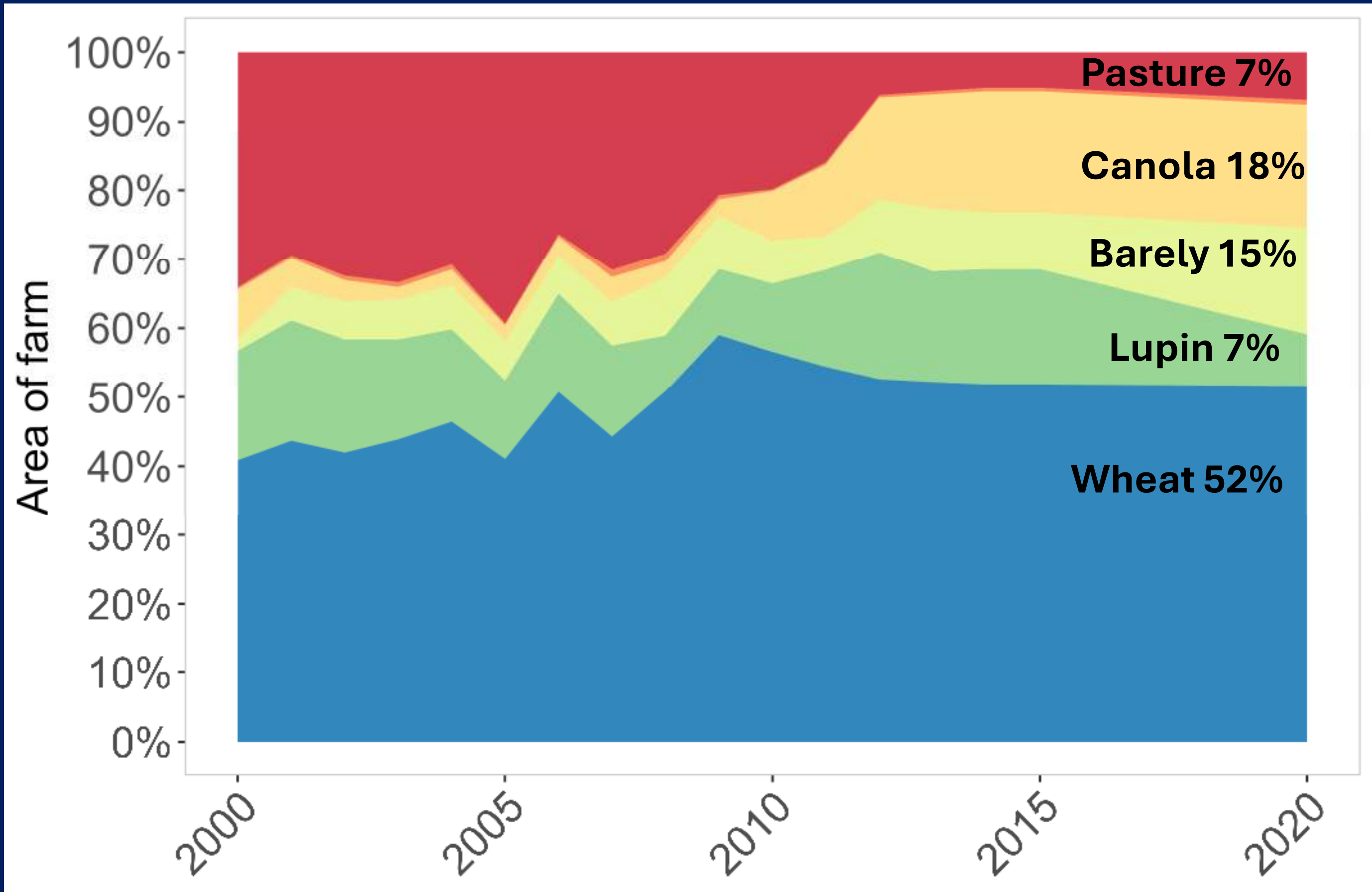
Mediterranean climate

- Winter grown crop
- 5-7 month growing period
- Average growing season rainfall 200-500 mm



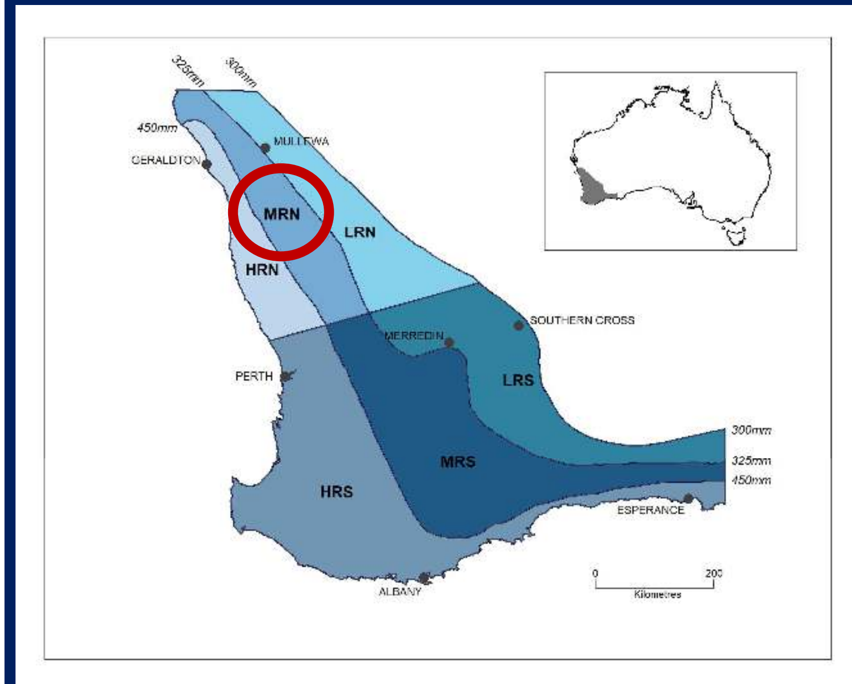
i.e., Largest changes in the north

Medium rainfall north zone (MRN)



2000 to 2020

- Pasture 34% to 7%
- Canola 7% to 18%
- Barley 3% to 15%
- Lupins 16% to 7%
- Wheat 40% to 53%



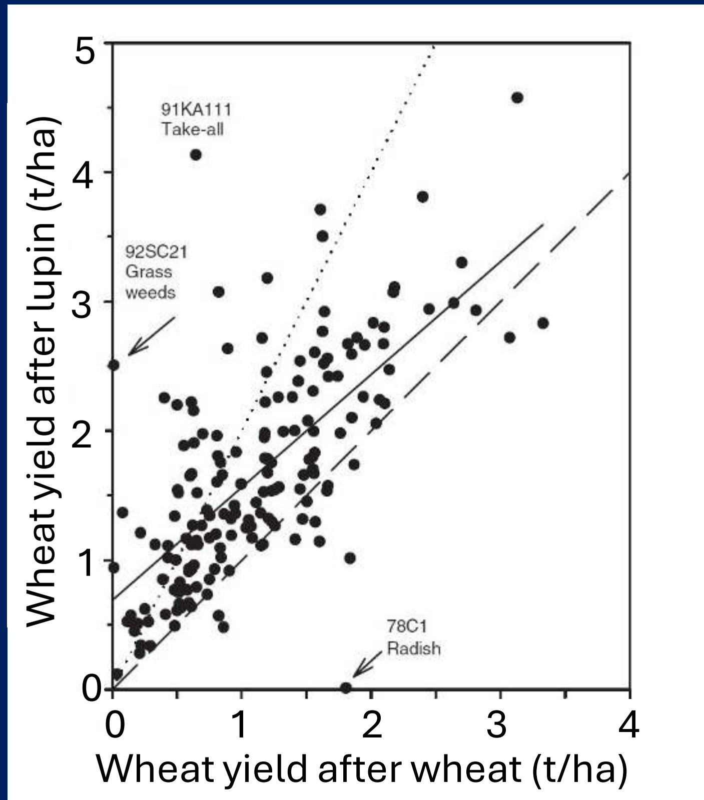
Source: Planfarm Bankwest benchmarks 2020, Perth, WA, Australia.

Break crop effect on wheat yield

Traditionally results are reported as wheat yield after a previous wheat crop verses wheat yield after a break crop

Many reports of yield increases, not always

The response depends on whether there was a production constraint ameliorated by, or introduced by, the break



1) Seymour, M, Kirkegaard, JA, Peoples, MB, White, PF, French, RJ (2012) Break-crop benefits to wheat in Western Australia; insights from over three decades of research. Crop and Pasture Science 63, 1-16.10.1071/CP11320

2) Lawes, R (2010) 'Using industry information to obtain insight into the use of crop rotations in the Western Australian wheat belt and quantifying their effect on wheat yields, The 15th ASA Conference; Food security from sustainable Agriculture. .' Lincoln, New Zealand, 15-18 November. (Australian society of Agronomy: Lincoln, New Zealand)

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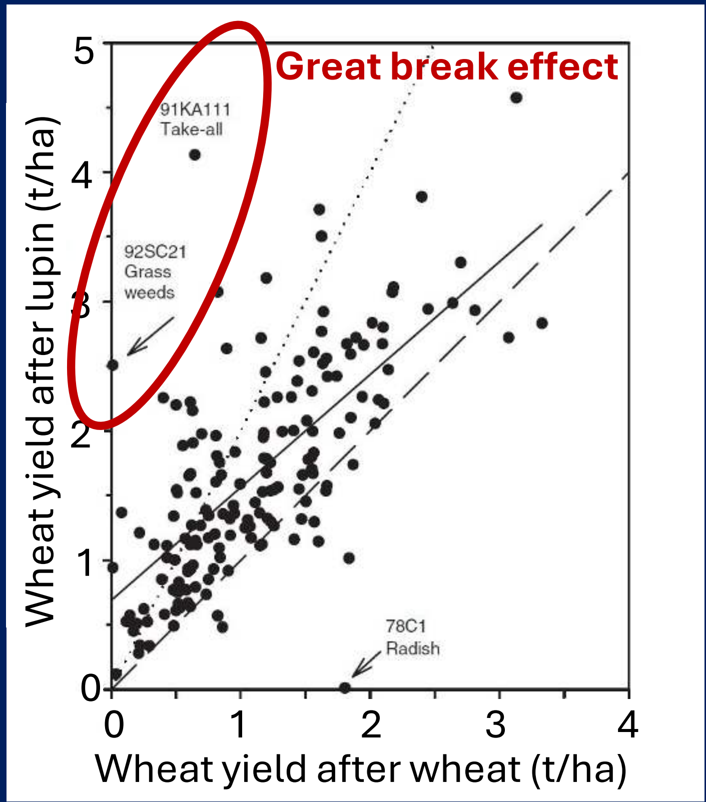

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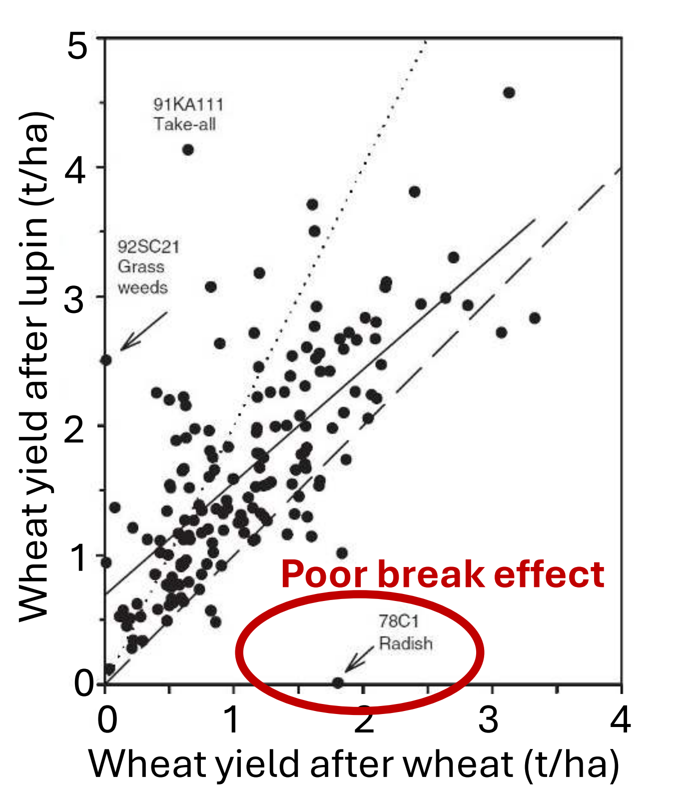
How have changed rotations affected this?



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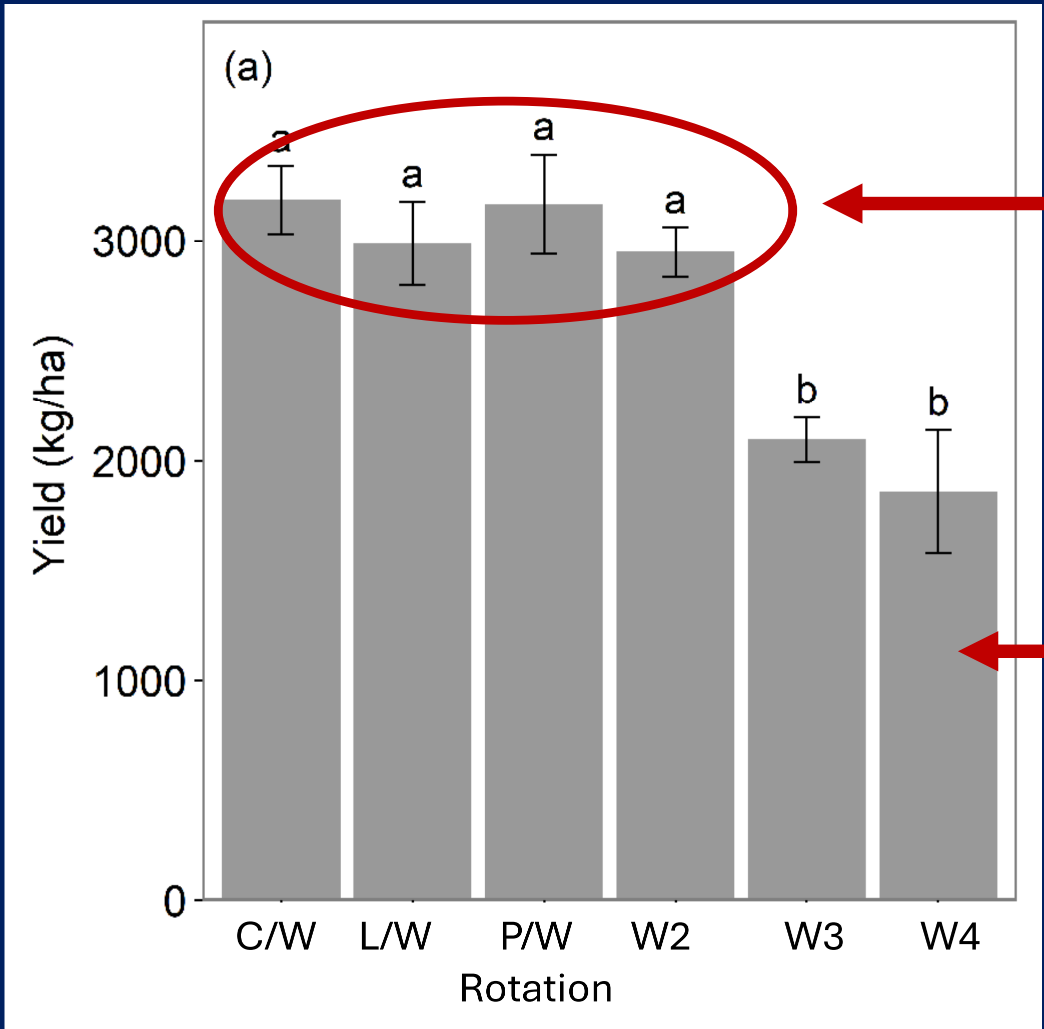
Wheat yield and rotation



- Wheat yielded around 3.0 t/ha after a canola, lupin, pasture or one previous wheat crop (W2).
- No initial break effect
- Wheat yield declined to 1.9 t/ha in the fourth wheat crop in a row (W4).

C = canola, L = Lupin, P = pasture, W = wheat