Transitioning Cereal Systems to Adapt to Climate Change

November 13-14, 2015

Funded through Award #2011-68002-30191 from USDA National Institute of Food and Agriculture

Innovations in Australian mixed cropping systems under climate change

John Kirkegaard
Senior Principal Research Scientist
CSIRO, Australia

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Dr JA Kirkegaard

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Your GRDC working with you

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An early agricultural revolution......

The **Norfolk** system (Young 1771)

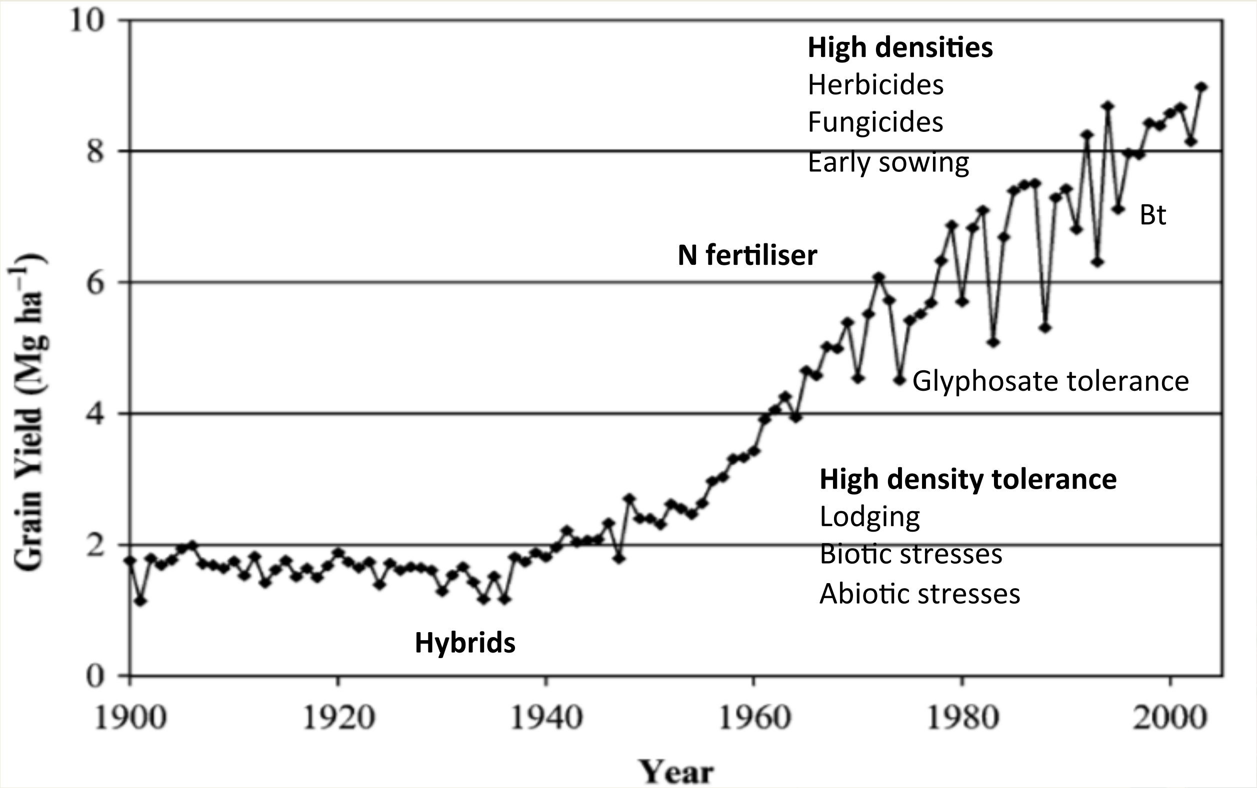
(1) enclosures without Government assistance
(2) use of marl (lime) and clay *(known to Romans)*
(3) rotation of crops *(Ancient Greeks)*
(4) culture of turnips, hand hoed (in rows) *(Chinese in 6th century)*
(5) culture of clover and rye *(Ancient Greeks)*
(6) long leases
(7) large farms

4 course rotation [turnips (for fodder) - wheat/barley – clover/rye – wheat/barley]

"individual components of the revolution had a long history but the ***synergistic interactions*** *in the Norfolk system made it such an effective agent of improvement"*

in Evans LT (1998) *Feeding the 10 Billion*

US Maize – a modern agricultural revolution..

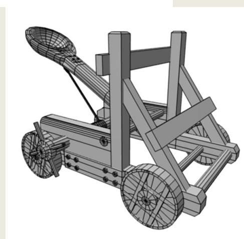


"On average, about 50% of the increase is due to management and 50% to breeding. The two tools interact so closely that neither of them could have produced such progress alone."

Duvick (2005) Advances in Agronomy 86

The bad old days....

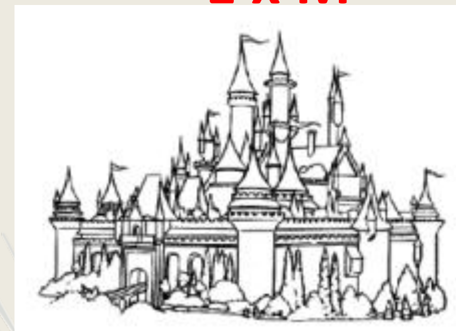
G x E

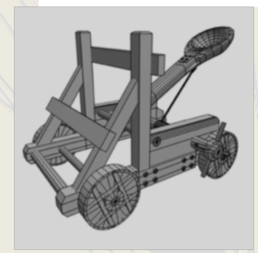


Molecular biology
Plant cell biology
Crop physiology

Genetics
Plant breeding

E x M



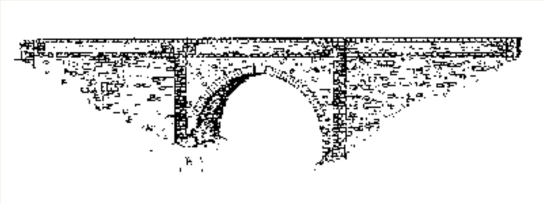


Farmers
Consultants
Input resellers

Agronomy
Farming systems

A better way....

G x E x M



Molecular biology
Plant cell biology
Crop physiology

Farmers
Consultants
Input resellers

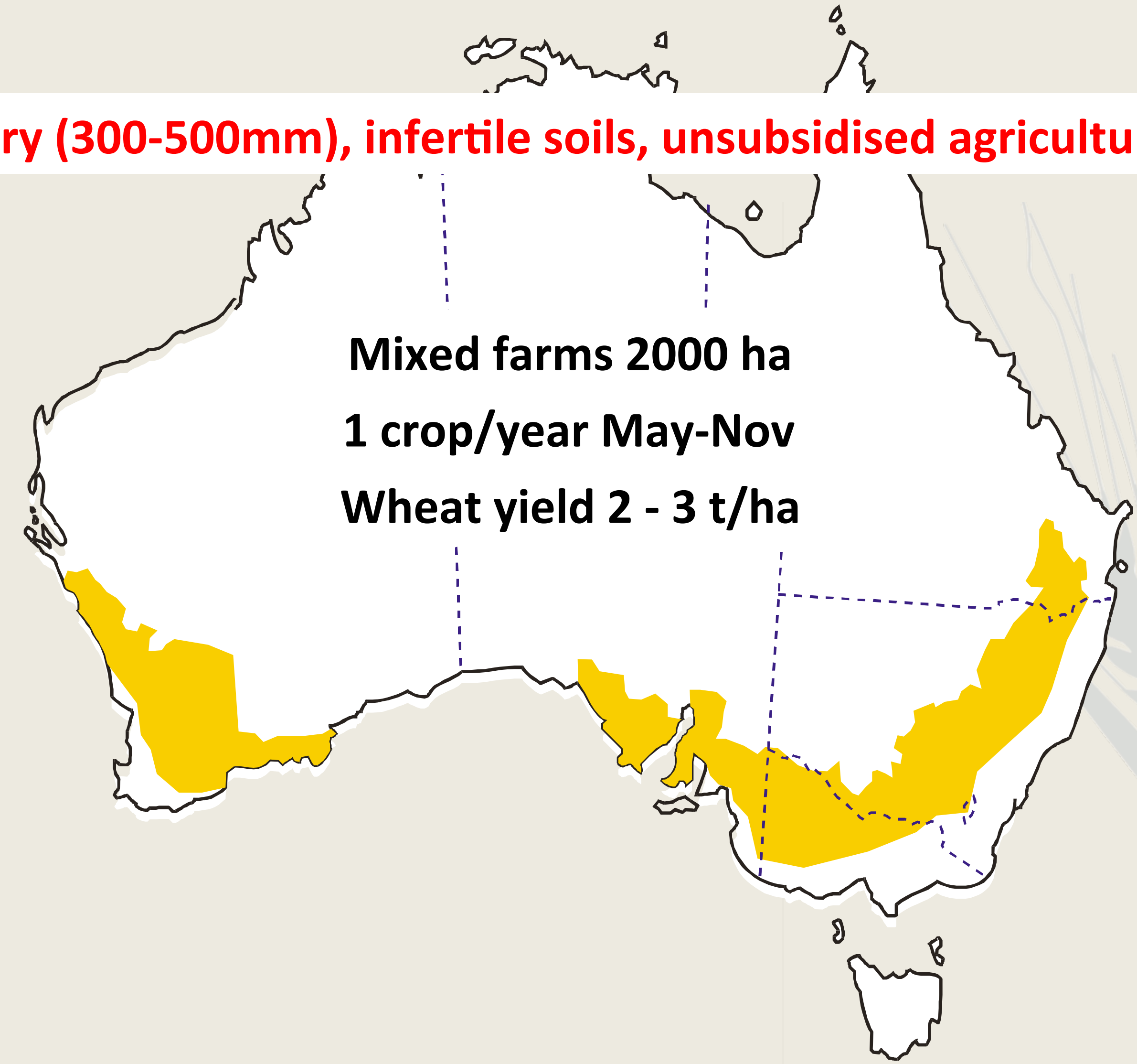
- *Not which has delivered more, but how to identify best synergies*
- *What traits will suit the systems of the future (not just the climate)?*
- *What systems are needed to capitalise on new traits?*

So what is the obstacle?

• Conceptual	- just how we think about things?
• Structural	- how we organise ourselves?
• Cultural	- how we approach research?
• Statistical	- how we analyse data?
• Institutional	- how we are rewarded?

Australian environment, soils and system

Dry (300-500mm), infertile soils, unsubsidised agriculture, risky

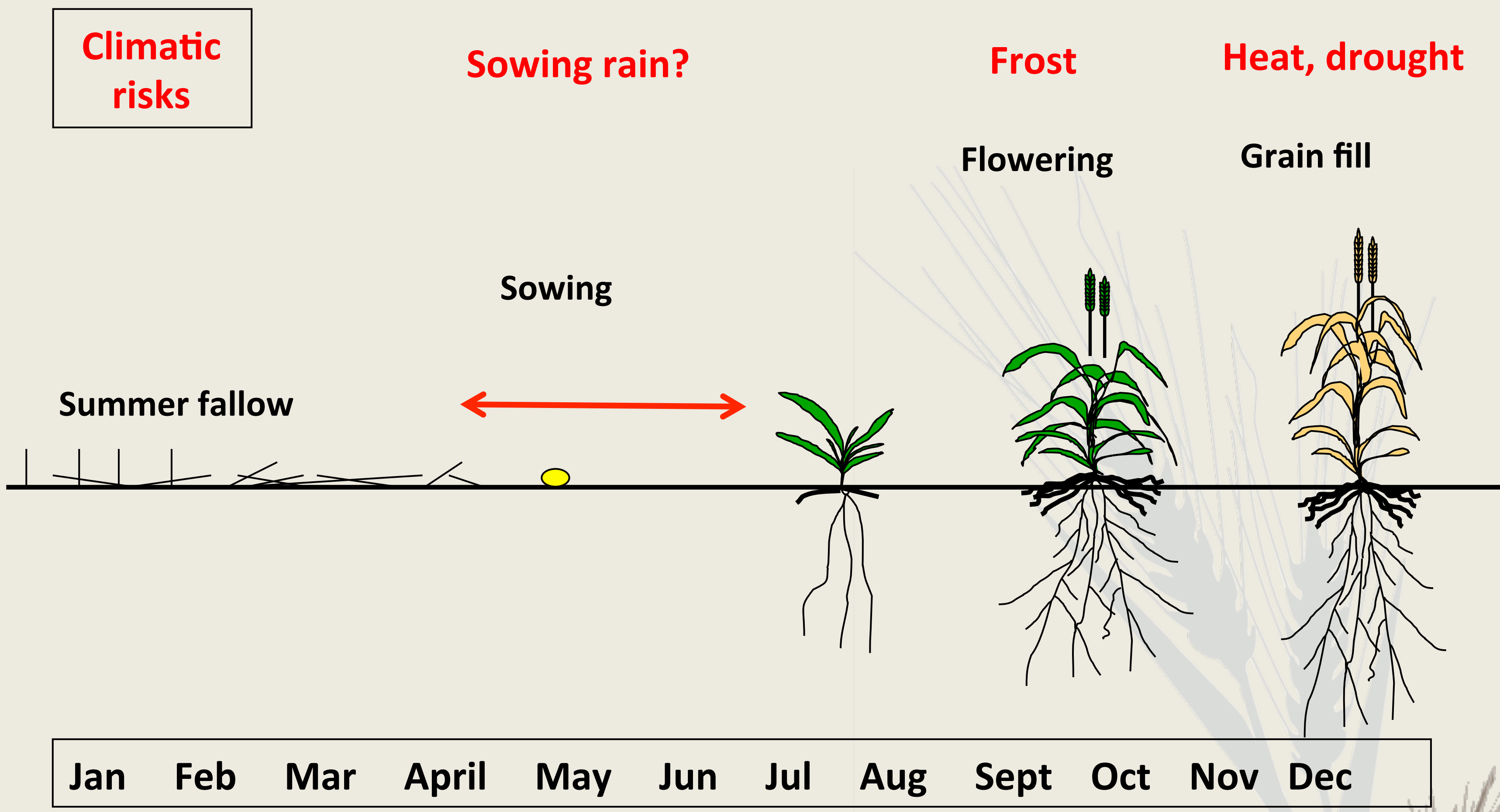


Mixed farms 2000 ha

1 crop/year May-Nov

Wheat yield 2 - 3 t/ha

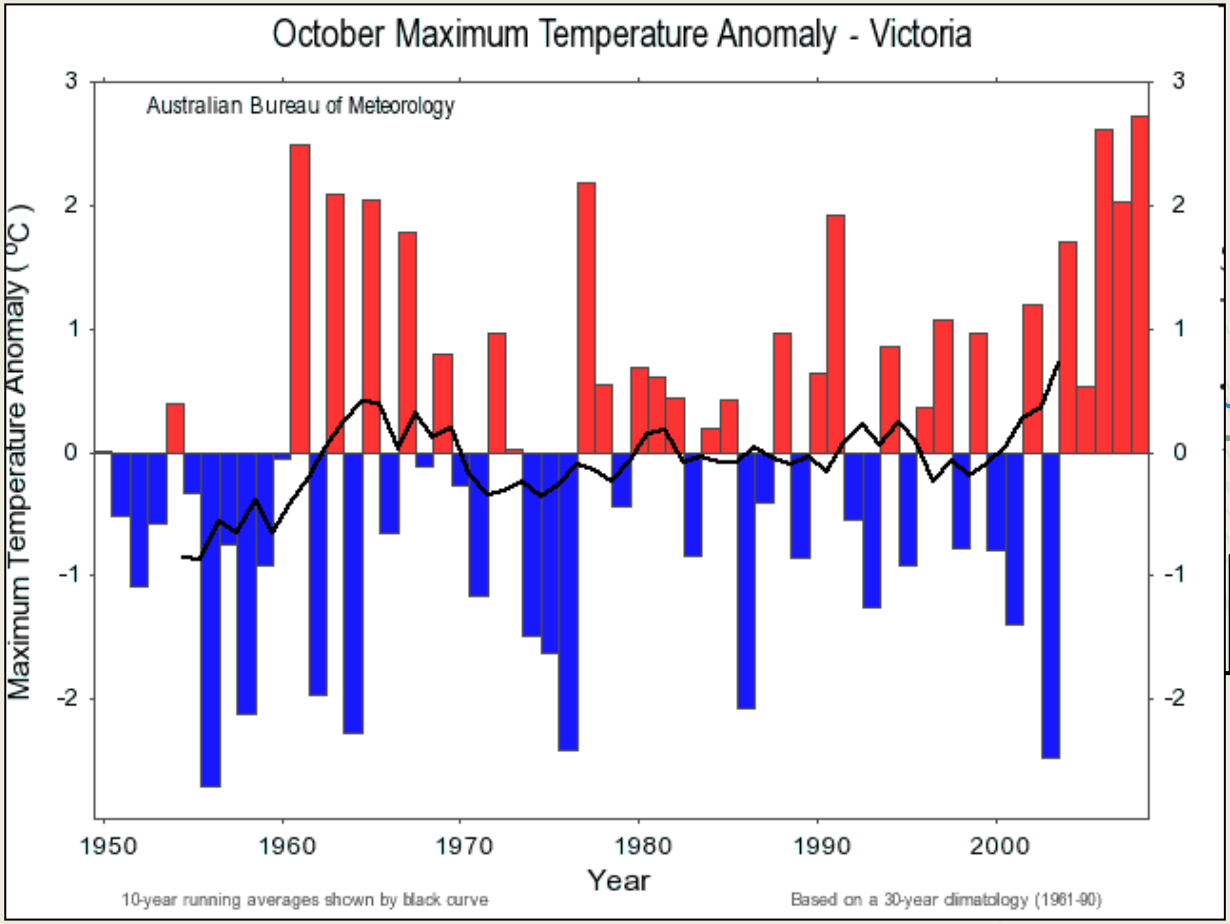
The cropping year…

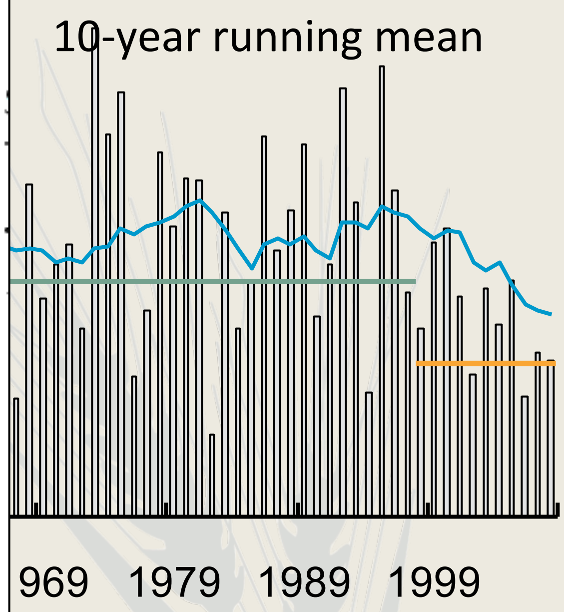


Modern, no-till cropping

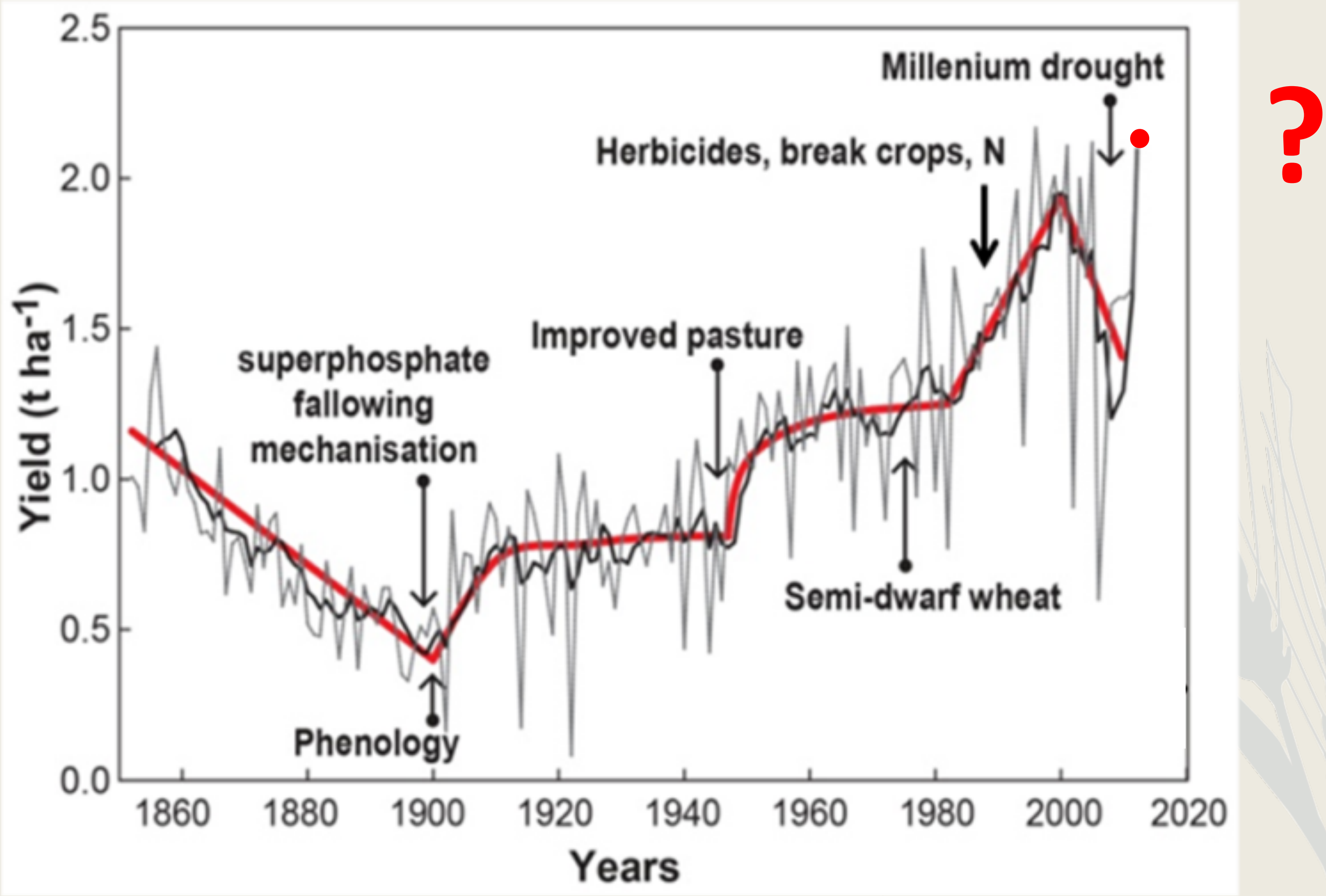
Stubble-retained, disc-seeder, controlled-traffic, inter-row sowing, 2cm precision

Changing climate....





Australian wheat production



National WUE Initiative

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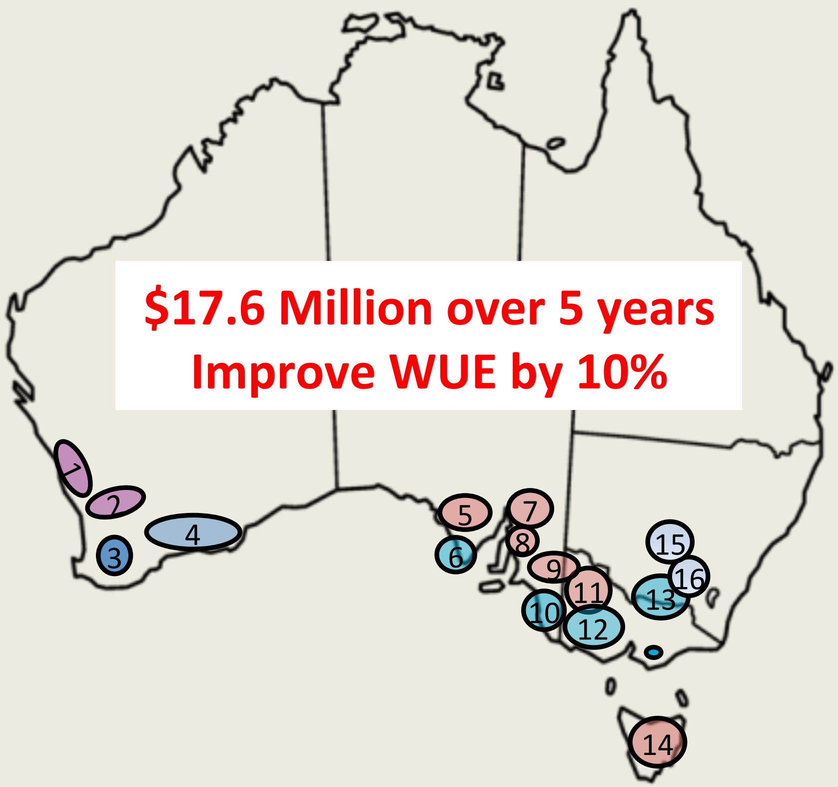
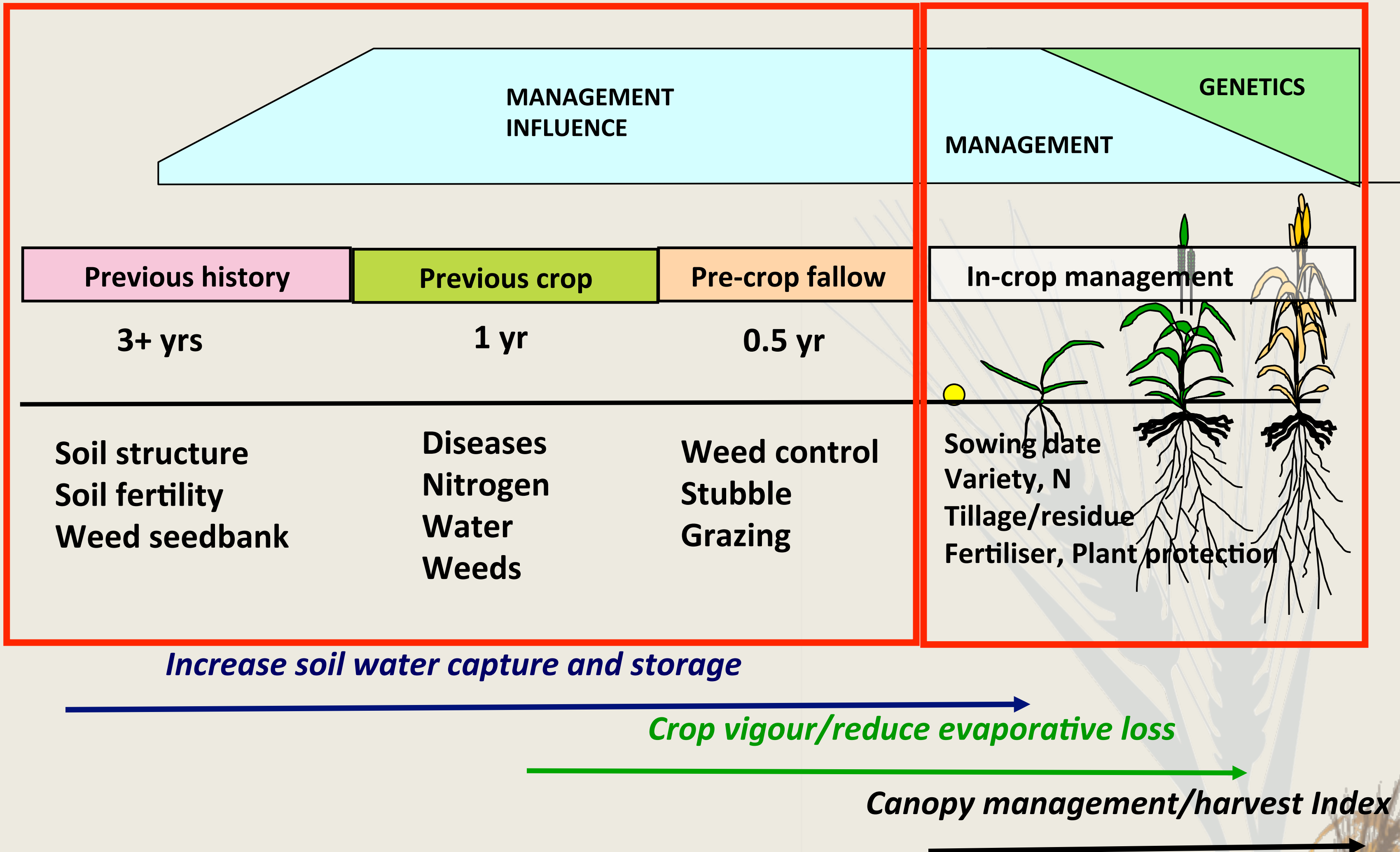


16 regional farmer groups

1. WA Sandplain
2. WA Central
3. WA South West
4. WA South Coast
5. EP Farm Systems
6. Lower Eyre Ag. Dev. Assoc.
7. Upper North FS
8. Hart Field Site Group
9. Mallee SFS
10. MacKillop Farm Management
11. Birchip CG
12. Southern FS
13. Riverine Plains
14. The University of Tasmania
15. Central West FS
16. FarmLink Research

Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601.

A systems approach to water productivity



Kirkegaard and Hunt (2010) J. Exp. Bot. 61, 4129-4143

Predicted management synergies

Baseline Scenario (Kerang, Victorian Mallee)

Continuous wheat, grazed weedy fallow, burn/cultivate, sow > 25 May (1980s)

Baseline Mean Wheat Yield = 1.6 t/ha

System change	Mean Yield (t/ha)	
	Single effect	Additive effect
1. No-till	1.84	1.84
2. Fallow weed control	2.37	2.80
3. Pea break crop	1.76	3.45
4. Sow earlier (from 25 April)	2.10	4.01
5. Long coleoptile wheat (sow 25 April)	1.45	4.54

Kirkegaard and Hunt (2010) Journal Experimental Botany 61, 4129-4143

Management and genotype synergy

Capitalising on early sowing opportunities to optimise water use

Kirkegaard and Hunt (2010) Journal Experimental Botany 61, 4129-4143

Under climate change (2000 to 2009)

<u>Baseline Scenario (Kerang, Victorian Mallee)</u>

Continuous wheat, grazed weedy fallow, burn/cultivate, sow > 25 May (1980s)

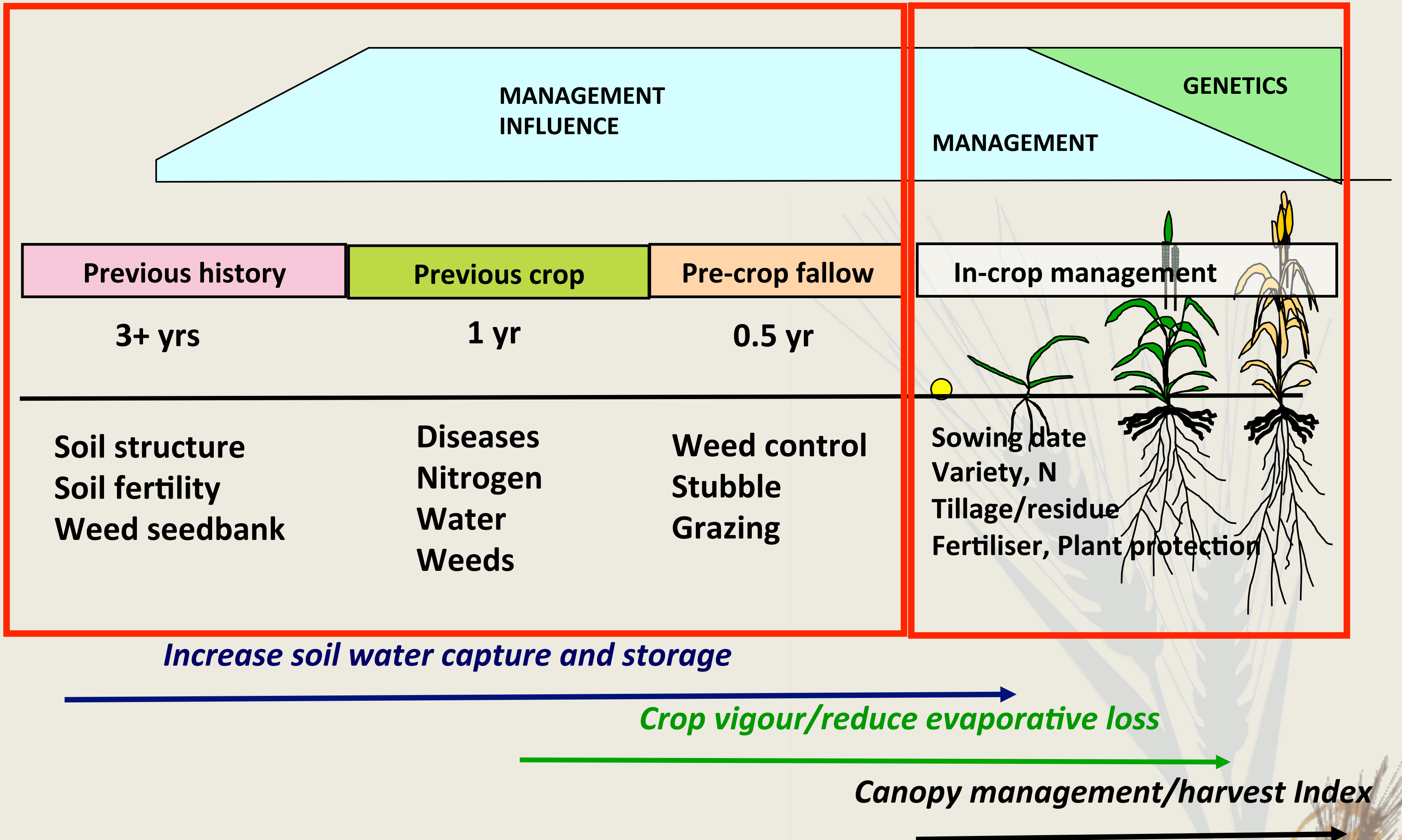
Baseline Mean Wheat Yield = 1.6 t/ha

Millenium Drought

System change	Mean Yield Additive (t/ha)	
	1962-2009	2000-2009
1. No-till	1.84	1.65
2. Fallow weed control	2.80	2.69
3. Pea break crop	3.45	3.20
4. Sow earlier (from 25 April)	4.01	3.52
5. Long coleoptile wheat (sow 25 April)	4.54	4.46

Kirkegaard and Hunt (2010) Journal Experimental Botany 61, 4129-4143

A systems approach to water productivity



Kirkegaard and Hunt (2010) J. Exp. Bot. 61, 4129-4143

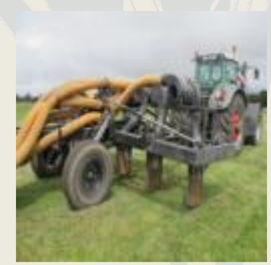
Four linked research Themes

1. Break crops and crop sequence

2. Summer fallow management

3. Managing in-season water-use

4. Managing variable or constrained soils



Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601.

Theme 2 - Summer fallow management

- Fallow weed control – important?

6 regional groups across all 4 mainland states

- Sheep grazing – soil damage?

- Stubble management – critical?

Theme 2 - Summer fallow management

- Pre-experimental modelling (37 sites)

  Summer rainfall contributes **33% (1 t/ha)** to yield (0.1 to 2.0 t/ha)

- Experimental validation (20 experiments, 6 regional groups)

  Strict weed control, stubble > 70% cover

  Extra 37mm water and 44 kg N/ha

- Rapid adoption

  Low risk strategy; Widely and rapidly adopted

  $5.70 return on $1 investment

Hunt and Kirkegaard (2011) Crop and Pasture Science 62, 915-929

Theme 3 – Managing in-season water use

- **Strict summer weed control, stubble >70% cover**

  In 20 experiments, extra 37 mm water and 44 kg N/ha = ($5.70 return)

- Early sowing of later-maturing wheat (same flowering window)

  Deeper roots, reduced evaporation, higher yield potential

- Wider rows/lower density and deferred N to maintain high HI

  Avoid excessive early biomass from early sowing

- Whole-farm multiplying effect from improved timeliness

  Increases in whole farm wheat yield of **11 to 47%**

***Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601*.**

Experiment 2012 - 177 mm rainfall

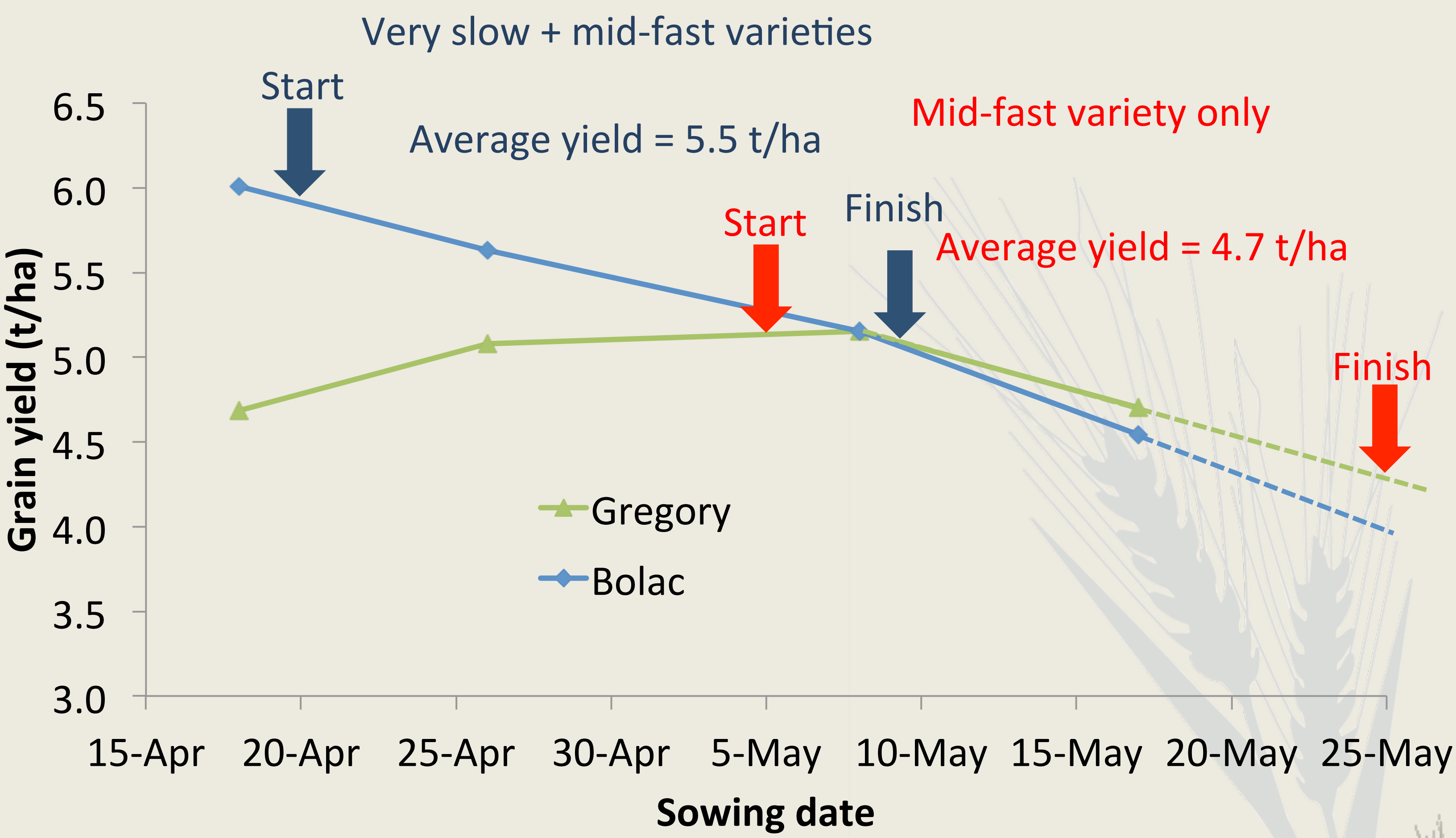
- Yield increase 0.6 to 1.9 t/ha, $562/ha increase in gross margin

Grain yield (t/ha)	50 plants/m^2	100 plants/m^2
EGA Eaglehawk (18 April)	**5.9***	6.1
Bolac (26 April)	**5.8**	5.5
EGA Gregory (8 May)	5.1	**5.2**
Lincoln (17 May)	4.3	**4.0**
P-value	0.034	
LSD (p=0.05)	0.3	

- Deeper roots, less evaporation, better water use, higher yield potential

***Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601*.**

Yield increase scales up at whole-farm level



***Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601*.**

Whole-farm benefits

Whole-farm yield increase 11 to 47%

Demonstrated benefits to WUE >10%

Theme	Innovation	WUE Increase
1	Break crops	16 to 83%
2	Summer weed control	60%
3	Early sowing	21 to 33%
3	Wider rows	-6 to -13%
3	Irrigation timing	12 to 23%
3	Disease control	20 to 25%
4	Variable N rates	up to 91%
4	Responsive systems	22%
4	Gypsum	15 to 54%
4	Subsoil manuring	28%
4	Mouldboard/spade	20 to 80%

Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601.

Earlier-sown crops can also be grazed!

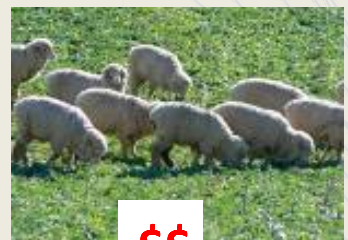
Grain-only crop

Sow

Grain

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

Dual-purpose crop



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Sow

Graze

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

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

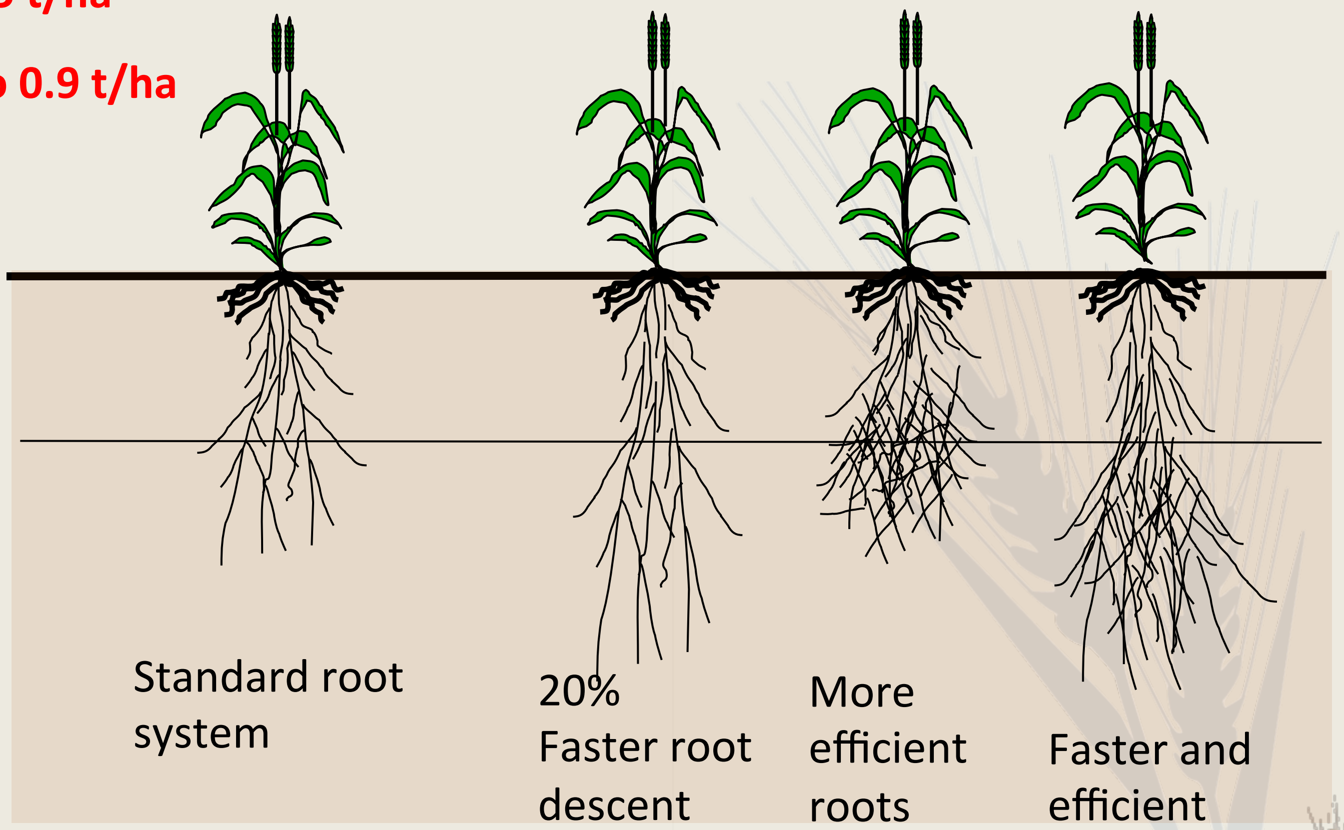
Improved roots interact with management

Preceding crop: 0.5 to 1.8 t/ha

Fallow weeds: 0.65 t/ha

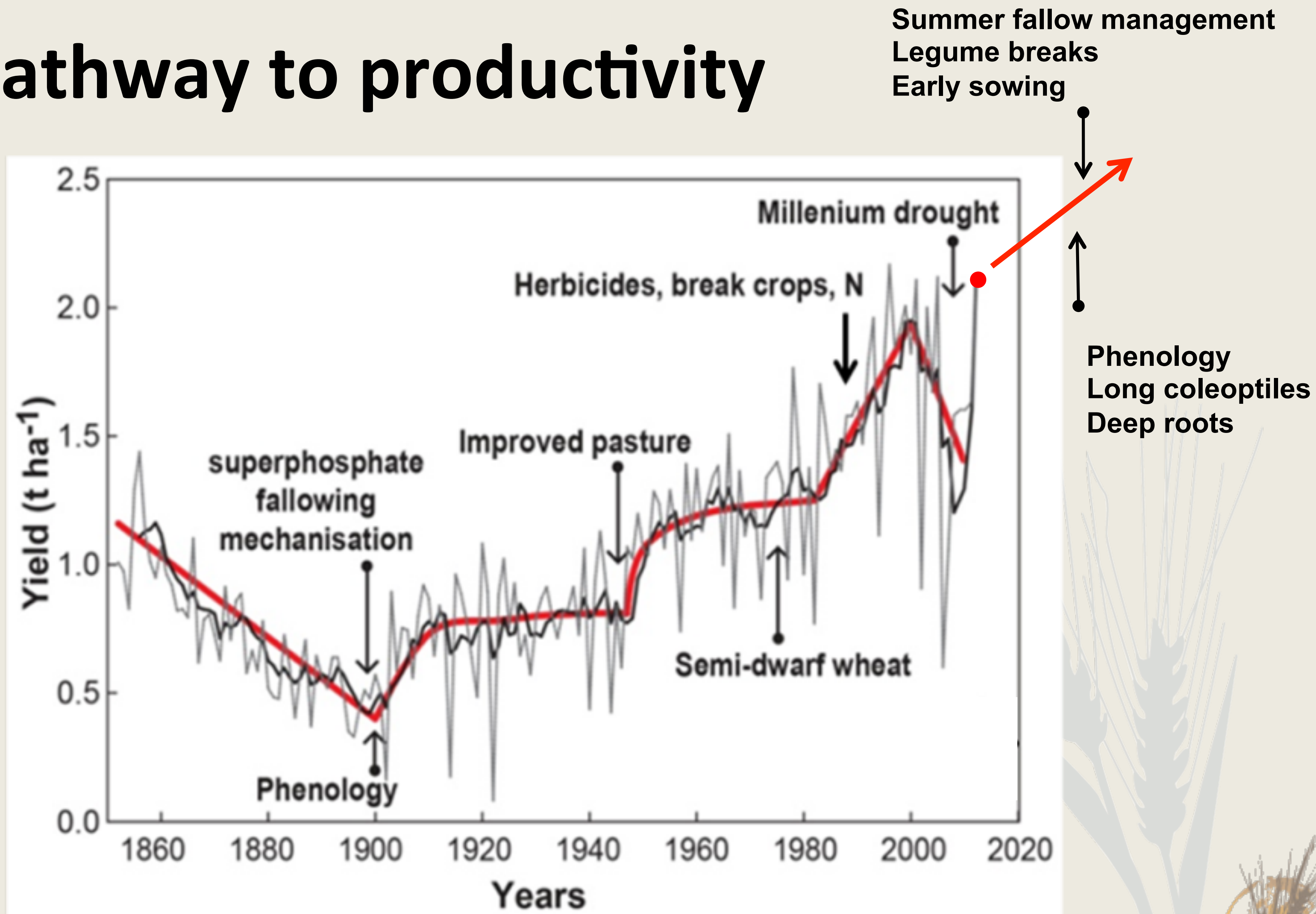
Sowing date: 0.1 to 0.9 t/ha

Impact of improved roots = 0.3 - 0.4 t/ha



Lilley and Kirkegaard (2011) Field Crops Research 122, 118-130

Pathway to productivity



Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601.

Achievements on farm?

3.7 t/ha in 2014

…ean Yield (t/ha)	
…ffect	Additive effect
	1.84
	2.80
	3.45
	4.01
	4.54

Elements of success

- Industry and growers involved from the outset
- Adopted a **G x E x M** approach at system level
- Multi-disciplinary, but linked to a non-disciplinary goal
- Effective “integrators” needed; valued for broad knowledge
- Longer-term funding horizons

Kirkegaard et al., (2014) Crop and Pasture Science 65, 583-601.

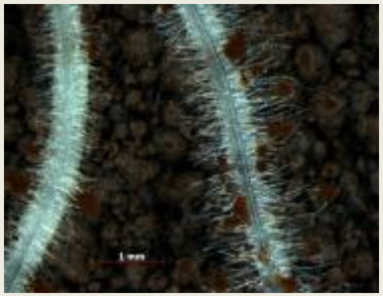
All traits interact with management

G

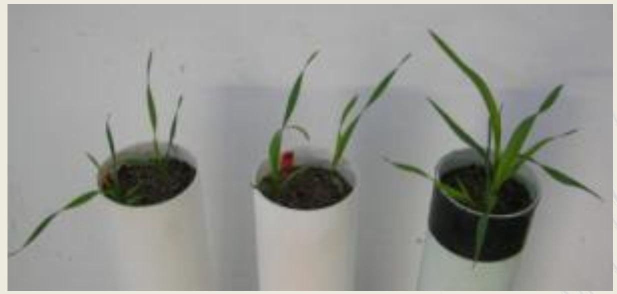
x

M

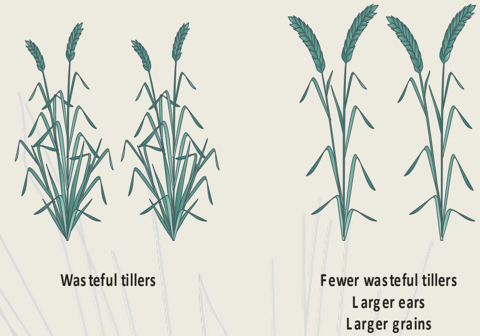
Long root hairs = PUE



Early Vigour = WUE/NUE



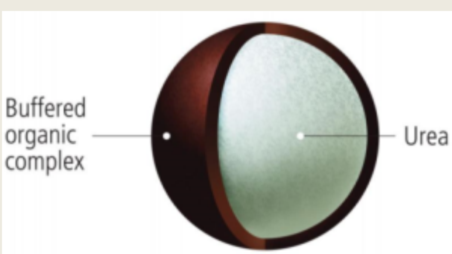
Restricted tillers = WUE



Precision placement
Formulation

Weed management
N uptake
Grazing

Row spacing
Inter-row sowing



Ultimately the pathway to impact is personal

- Conceptual - think more broadly - GxExM
- Structural - reward "integrators" as specialists
- Cultural - partner for impact
- Statistical - consider the interactions
- Institutional - impact, not "impact-factor"

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

CSIRO AGRICULTURE FLAGSHIP

Thank-you

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Your GRDC working with you

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Regional Approaches to Climate Change –
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Thank you!

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National Institute of Food and Agriculture

Oregon State University OSU

CHS

Pacific Northwest Farmers Cooperative

Monsanto