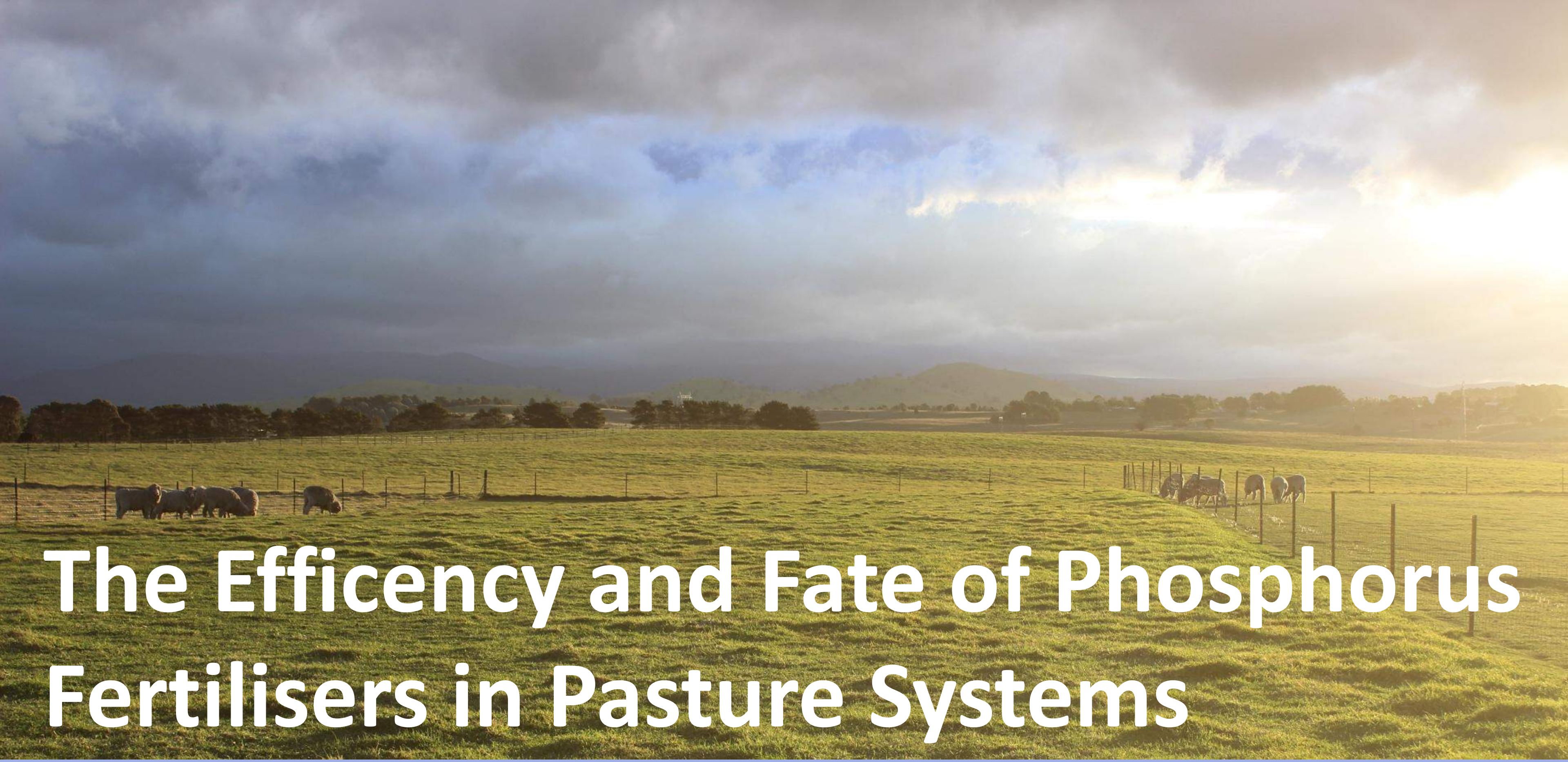

The Efficency and Fate of Phosphorus Fertilisers in Pasture Systems

Therese McBeath, **Tim McLaren, Richard Simpson**, Ron Smernik, Mike McLaughlin, Alan Richardson, Chris Guppy, Caroline Johnston, Adam Stefanski, Jan Carruthers

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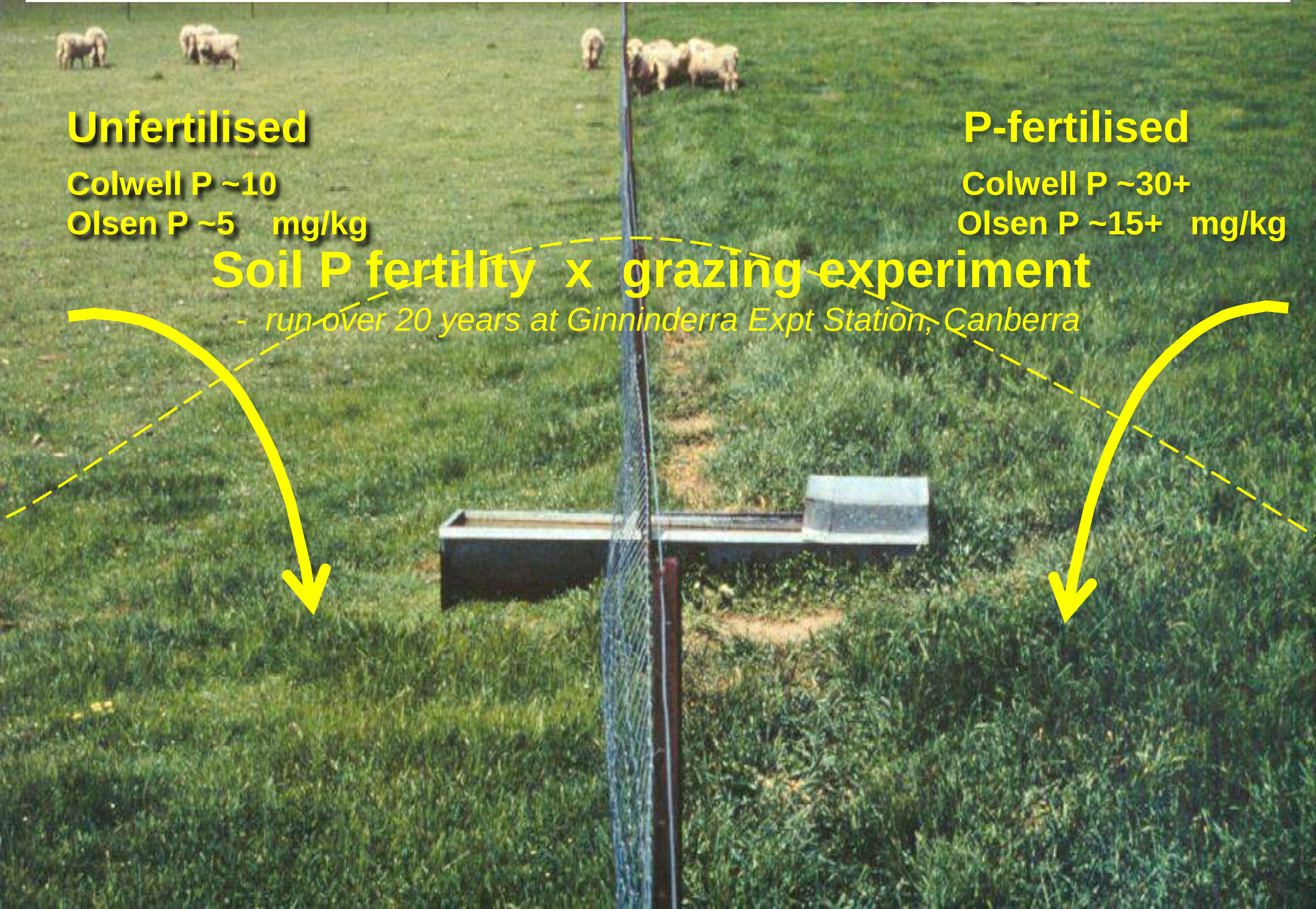
P has a role for increased biomass and quality in pasture systems



The Efficiency of Fertiliser P

$$\text{P use efficiency (\%)} = \frac{\text{P output (products)}}{\text{P input (fertiliser/feed)}} \times 100$$

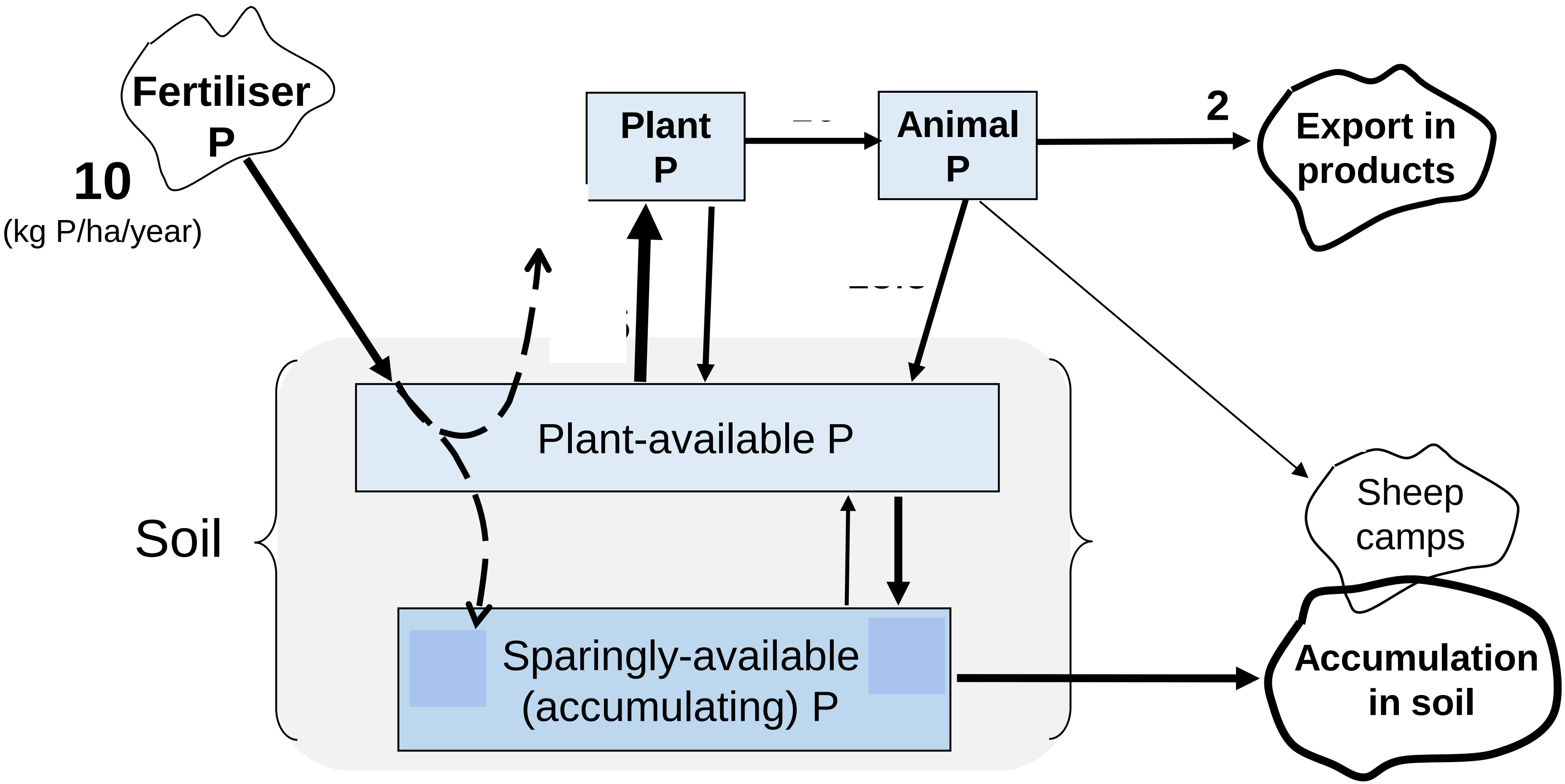
Enterprise	PUE (%)
Cropping	48%
Dairy	29%
Beef	19%
Sheep	11%

Weaver and Wong (2011)

Average for grazing= **20%**

10 units of P applied as fertiliser
-2 unit of P exported in animal products
+8 units of P accumulated in pasture soils

The Fate of Fertiliser P



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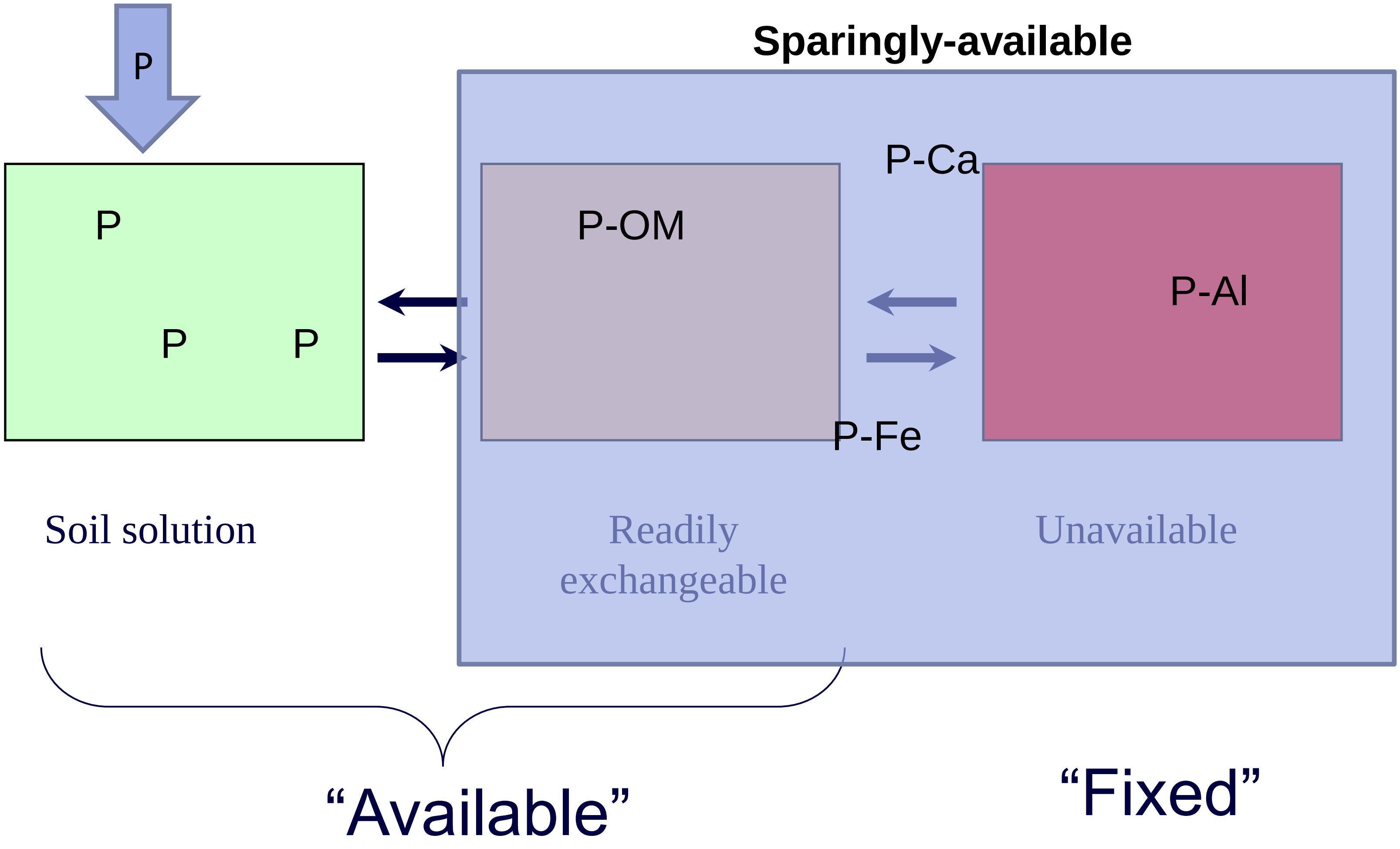
P Species and Phosphorus Buffering Index



What we Thought We Knew About Fertiliser P

- In general, between 9 – 12 kg P/ha/yr is applied to leguminous pastures, often early in the season and to the surface
- Only about 1 – 2 kg P/ha/yr is exported in animal products (e.g. meat fibre)
- Hence, the recovery of fertiliser P by pastures in the year of application is thought to be low (10-20 %)
- It is assumed that much of the fertiliser P becomes rapidly transformed to ‘sparingly-soluble’ forms of soil P upon application
- About half of this P was though to be in the organic form.

The Importance of P to Pasture Production

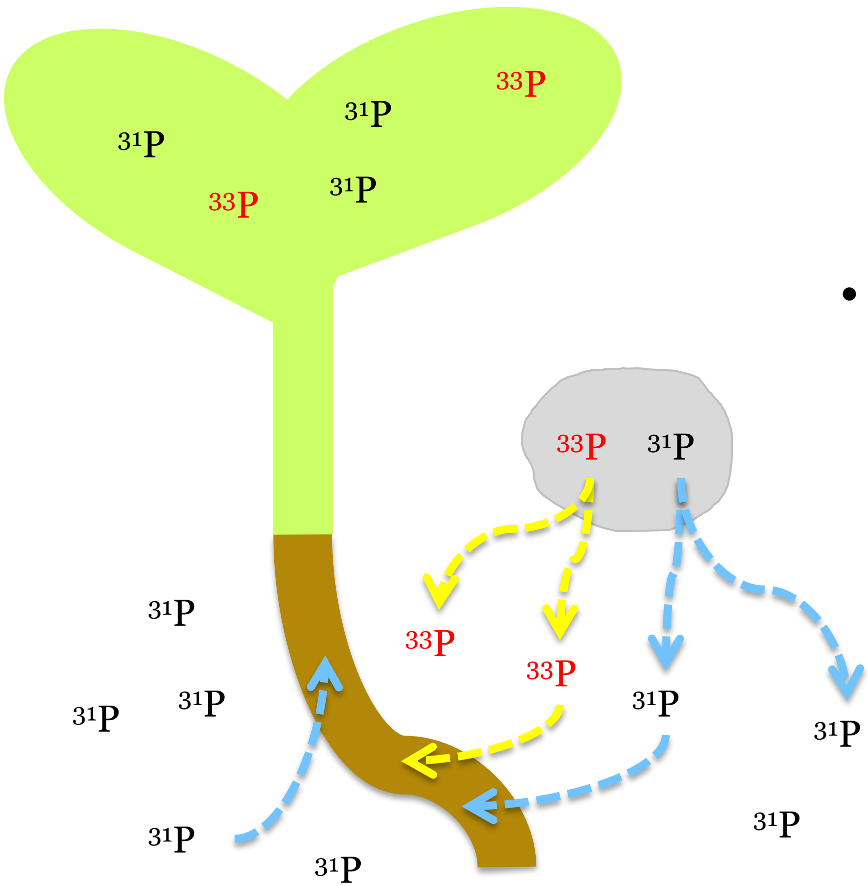
- Timing and placement of P applied, and starting soil P fertility are big drivers of fertiliser P efficiency.
- Measuring the fate of fertiliser P in these systems tells us how efficient the system is on short and long timescales.

Short-Term Fate of Fertiliser P

Aims

- Determine the recovery of fertiliser P in all components of the pasture during a single growing season
- Investigate the effect of placement and timing on clover growth and fertiliser P efficiency

Giving SSP a Unique Fingerprint – ^{33}P



- We developed a simple and rapid procedure to add a ‘fingerprint’ to SSP using radiotracers

- A radioactive isotope of P can be made (i.e. ^{33}P) and distinguished from all other P in the environment

Short-Term Fate of Fertiliser P

- Two field sites under permanent pasture
  - Ginninderra (ACT), LTA rainfall of 687 mm/yr (sandy-loam in the 0 – 20 cm layer)
  - Inman Valley (SA), LTA rainfall of 743 mm/yr (sand in the 0 – 20 cm layer)

Field site location	pH_w (1:5)	TOC (%)	Colwell P (mg/kg)	PBI	Critical Colwell P (mg/kg)
Ginninderra, ACT	5.5	3.4	11	57	23
Inman Valley, SA	5.8	2.1	10	19	15

Ginninderra

Inman Valley

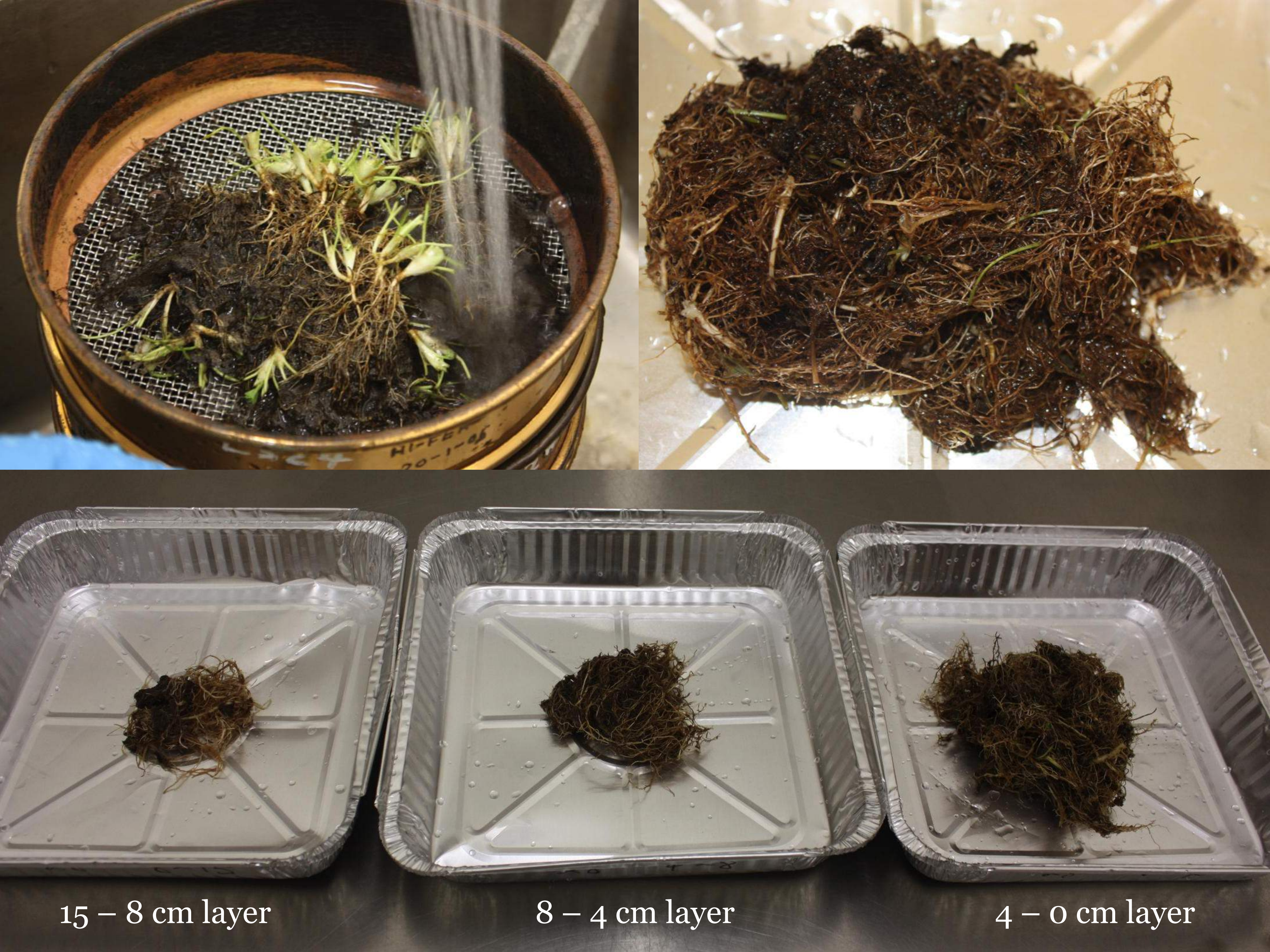
Short-Term Fate of Fertiliser P- Effect of Placement and Timing

- A subterraneum clover sward was established (5 m × 7 m area)

- Open-ended PVC cylinders (15 cm Ø × 18 cm high) were inserted into the soil to a depth of 15 cm from the soil surface, 4 reps

- Treatments (six replicates) included:
  - No added fertiliser P (control)
  - A surface application of ^{33}P-labelled SSP at early-season
  - A surface application of ^{33}P-labelled SSP at mid-season
  - A 'deep' application (6 cm below soil surface) of ^{33}P-labelled SSP at early-season
- Fertiliser P was added to pastures to supply 20 kg P/ha
- Irrigated when rainfall received was less than decile 5.




15 – 8 cm layer
8 – 4 cm layer
4 – 0 cm layer

The Effect of Timing and Placement

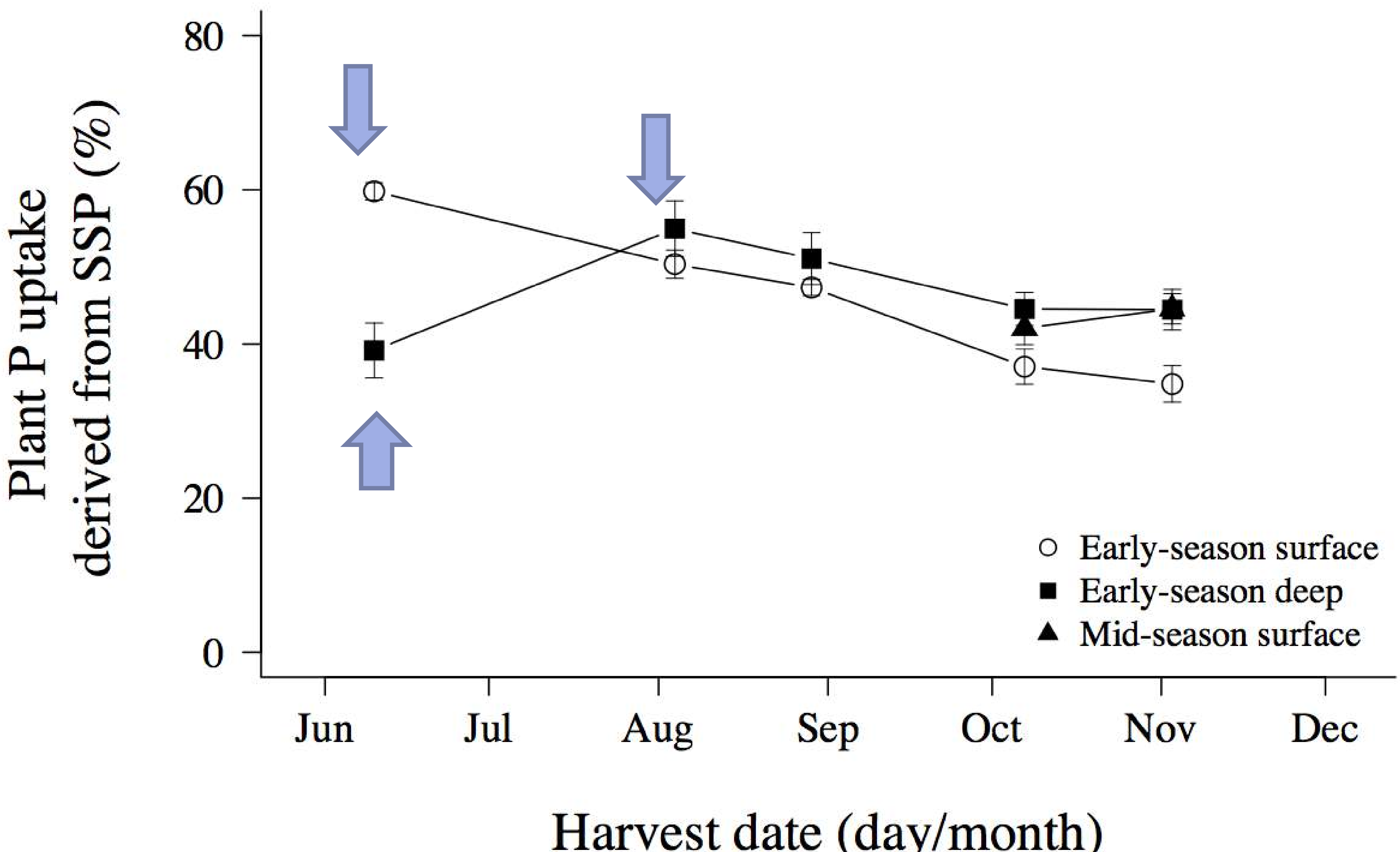
Cumulative biomass, clover P uptake, and recovery of fertiliser P in above ground clover shoots (> 0 cm)

Field site	Treatments: Timing of fertiliser P	Treatments: Placement of fertiliser P	Cumulative biomass (t DM/ha)	Cumulative P uptake (kg P/ha)	Recovery of fertiliser P (as a % of applied)
Ginninderra	Early-season	Surface	14.8 (0.7)	17.9 (0.6)	38.4 (2.1)
	Early-season	Deep	14.3 (0.3)	17.7 (0.6)	40.0 (1.5)
	Mid-season	Surface	11.1 (0.4)	13.7 (0.6)	28.5 (0.5)
	Nil	Nil	8.0 (0.4)	7.0 (0.8)	
Inman Valley	Early-season	Surface	11.3 (0.3)	25.5 (0.7)	42.4 (1.1)
	Early-season	Deep	9.5 (0.6)	21.8 (0.8)	24.7 (2.3)
	Mid-season	Surface	11.4 (0.8)	28.3 (1.3)	28.6 (1.3)
	Nil	Nil	8.8 (0.7)	16.5 (1.5)	

Values in parentheses are standard errors.

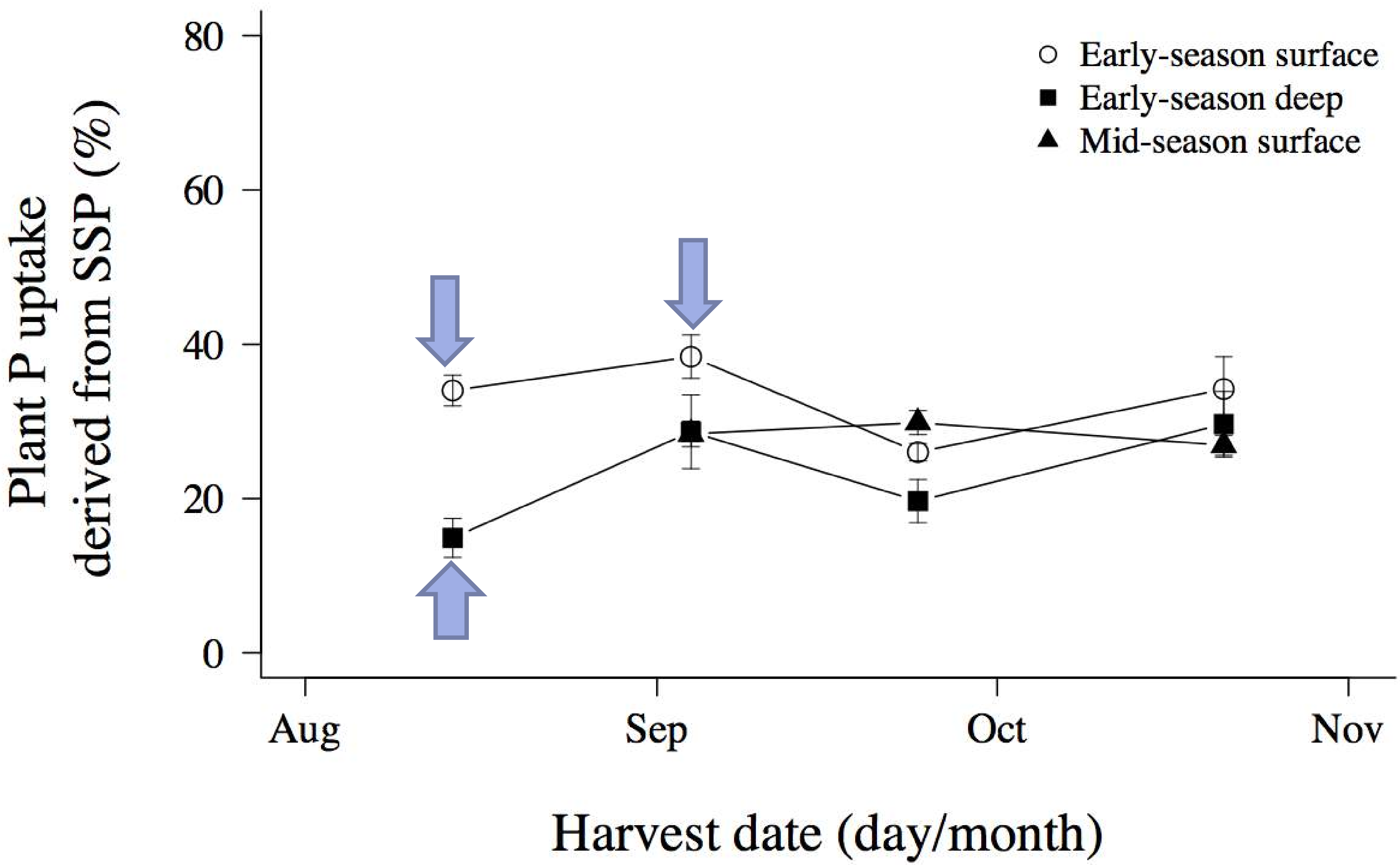
Ginninderra

The proportion of plant P that is derived from the ^{33}P-labelled SSP for each harvest (> 3 cm)

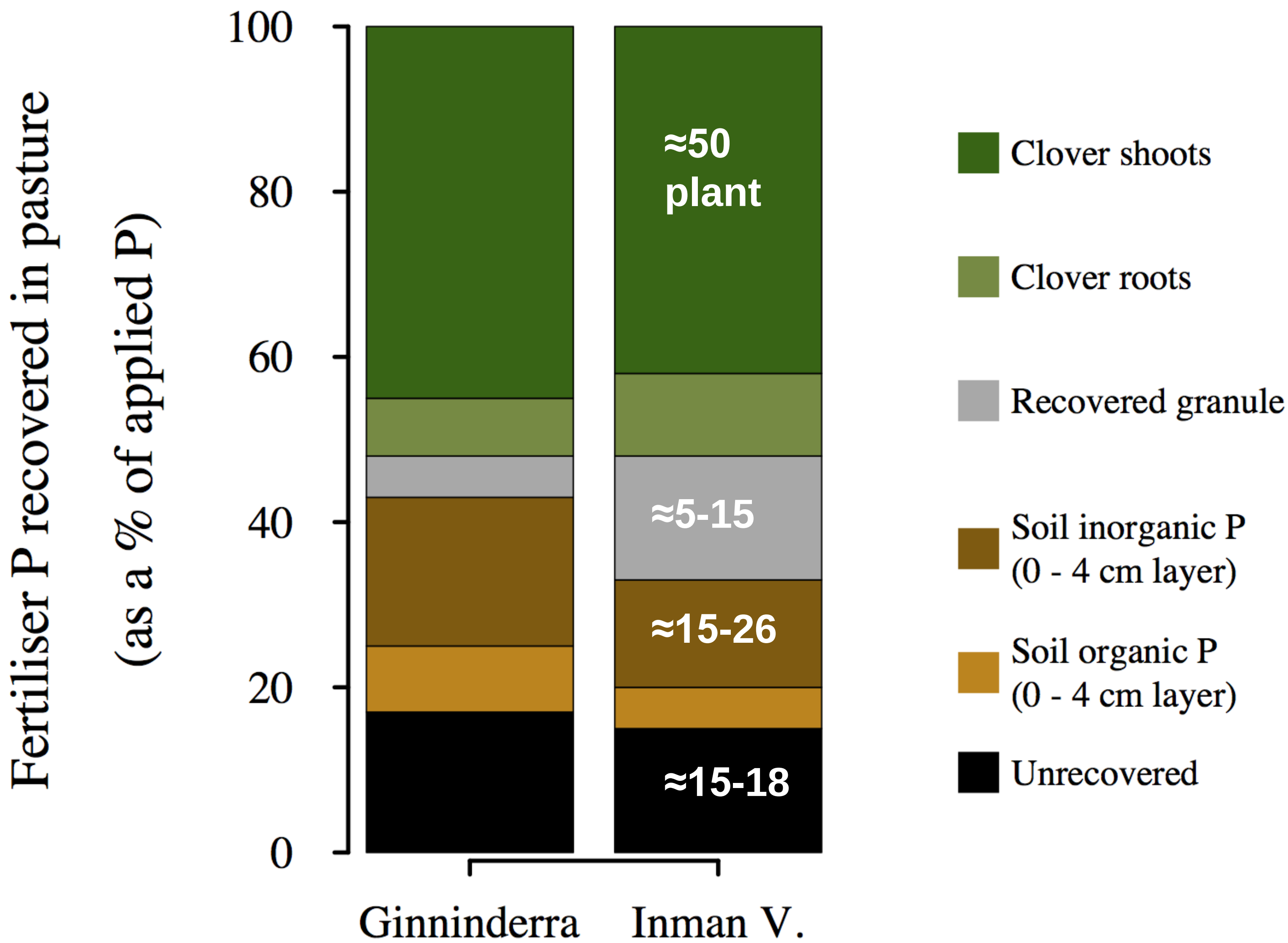


Inman Valley

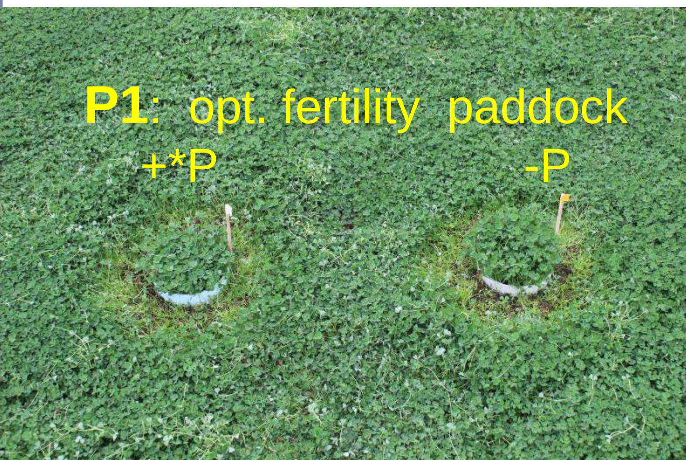
The proportion of plant P that is derived from the ^{33}P-labelled SSP for each harvest (> 3 cm)



Short-Term Fate of Fertiliser P



The Effect of Fertility Level

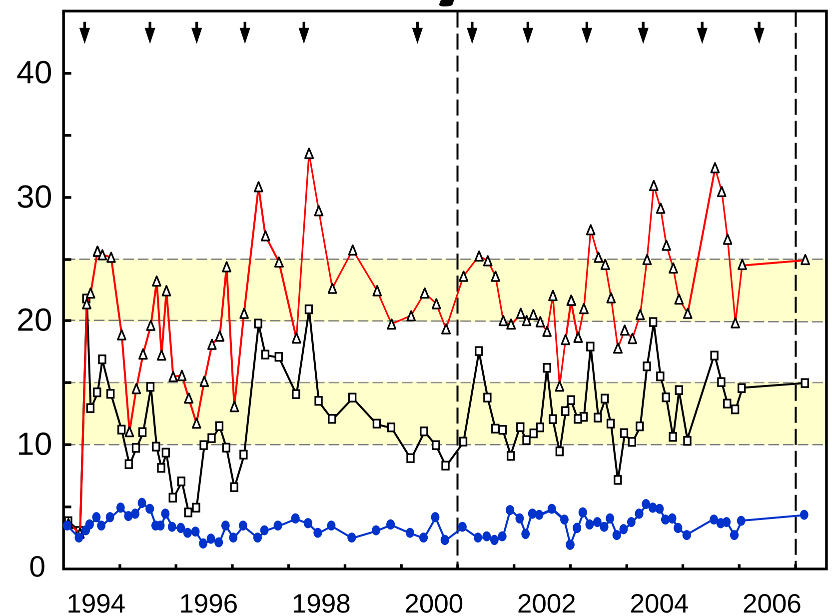


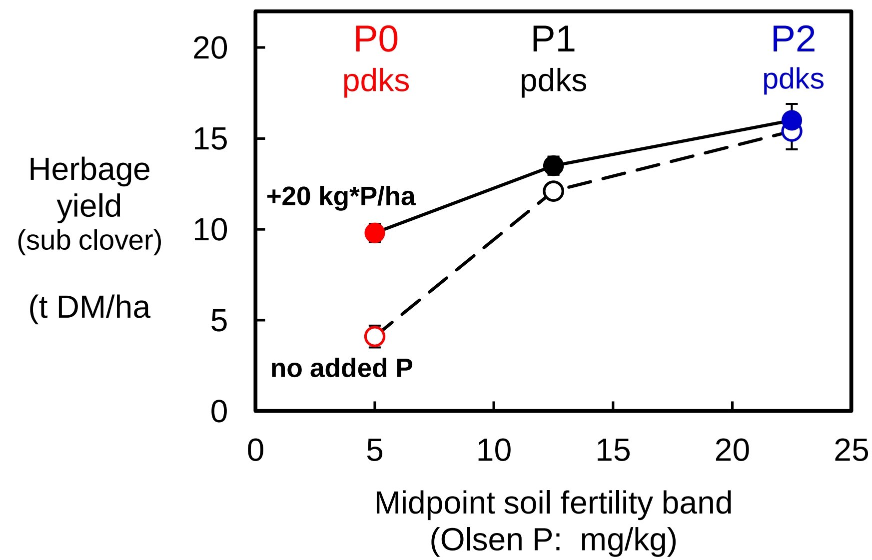
Olsen P
(mg/kg)

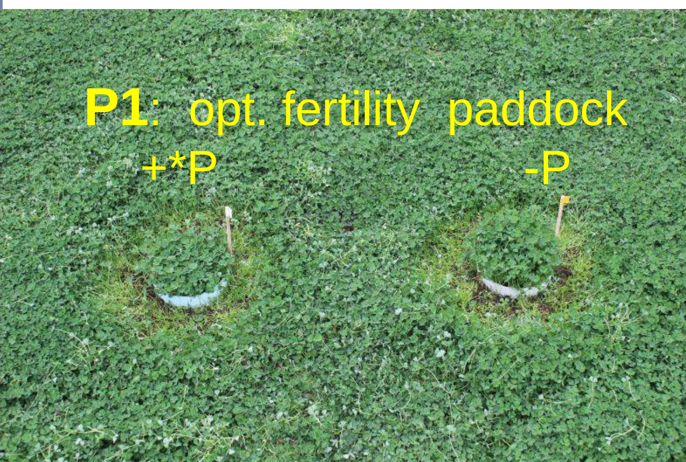
supra-optimal: P2
(18 sheep/ha)

near-optimum: P1
(9 or 18 sheep/ha)

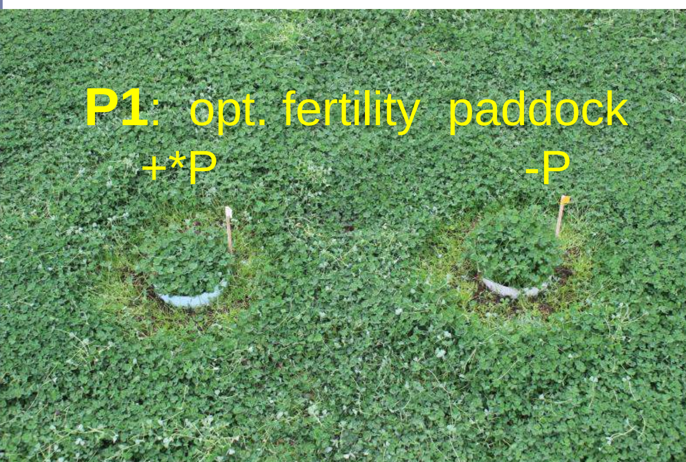
unfertilised: P0
(9 sheep/ha)







		Proportion of fertiliser P recovered in clover shoots	Proportion of herbage P derived from fertiliser	DM yield (t/ha)
supra-optimal Olsen P 20-25 mg/kg *carried18 sheep/ha*	**P2:**	**49** (±2)**%**	**21%**	**16.0** (±0.9)
near-optimum Olsen P 10-15 mg/kg *carried 18 sheep/ha*	**P1:**	**52** (±1)**%**	**28%**	**13.5** (±0.5)
unfertilised Olsen P 4-6 mg/kg *carried 9 sheep/ha*	**P0:**	**45** (±2)**%**	**58%**	**9.8** (±0.5)



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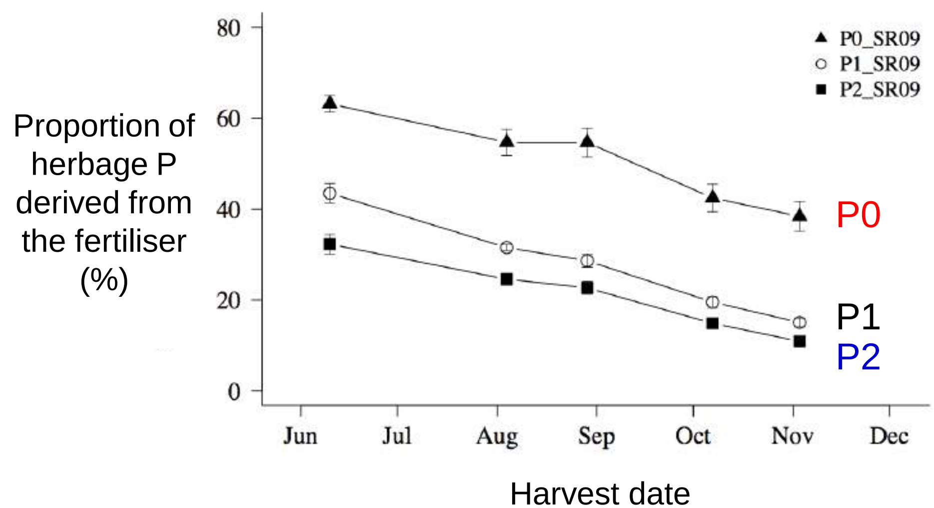


The Effect of Fertility Level- 2014

Cumulative biomass, clover P uptake, and recovery of fertiliser P in above ground clover shoots (> 0 cm) at Ginninderra.

Initial soil P status (early-season surface)	Cumulative biomass (t DM/ha)	Cumulative P uptake (kg P/ha)	Recovery of fertiliser P (as a % of applied)
P0 (4 – 6 mg Olsen P/kg)	15.3 (0.4)	19.9 (1.5)	40.3 (1.3)
P1 (10 – 15 mg Olsen P/kg)	18.0 (0.6)	41.7 (2.3)	45.5 (0.8)
P2 (20 – 25 mg Olsen P/kg)	20.5 (1.1)	51.9 (2.6)	42.5 (1.5)

Application of fertiliser P to pastures with a soil P fertility above the agronomic optimum level has little benefit

Short-Term Fate of Fertiliser P- Low PBI Soils

1. Clover growth and P uptake was most reliable for early applications of fertiliser P to the soil surface

2. The proportion of clover P that was derived from the fertiliser was generally high and reflected placement strategies and root activity

3. Recoveries of up to 42 % of added fertiliser P were detected in clover shoots, and were generally higher for early-season surface applications

4. Recoveries of up to 26 % of the added fertiliser P were detected in the soil surface (0 – 4 cm) and most was Colwell extractable.

Long-Term Fate of Fertiliser P

Aims

- A soil P audit of a long-term field experiment under different levels of P fertility
- Identify the forms of soil P that accumulate in pastures
- Determine the proportion of fertiliser P applied that accumulates in fertilised soil

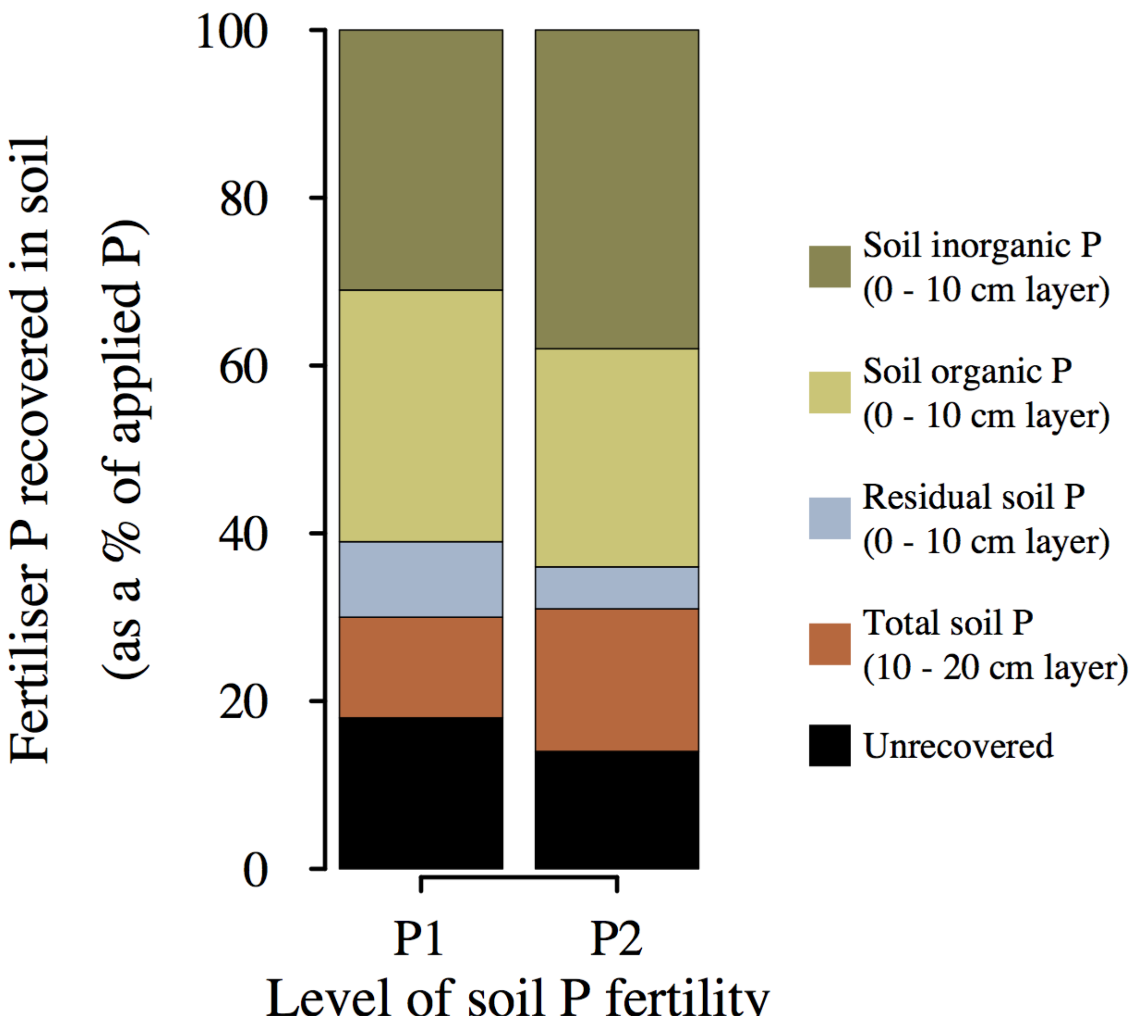
Long-Term Fate of Fertiliser P

In 2007 following 13 years of P fertiliser management to target fertility, a soil sample was collected at two depths (0 – 10 cm and 10 – 20 cm) and analysed for soil P

- P0 fields received on average 0 kg P/ha/yr
- P1 fields received on average 15 kg P/ha/yr
- P2 fields received on average 19 kg P/ha/yr

Long-Term Fate of Fertiliser P

- Approximately 85 % of the fertiliser P was recovered in the 0 – 20 cm soil layer



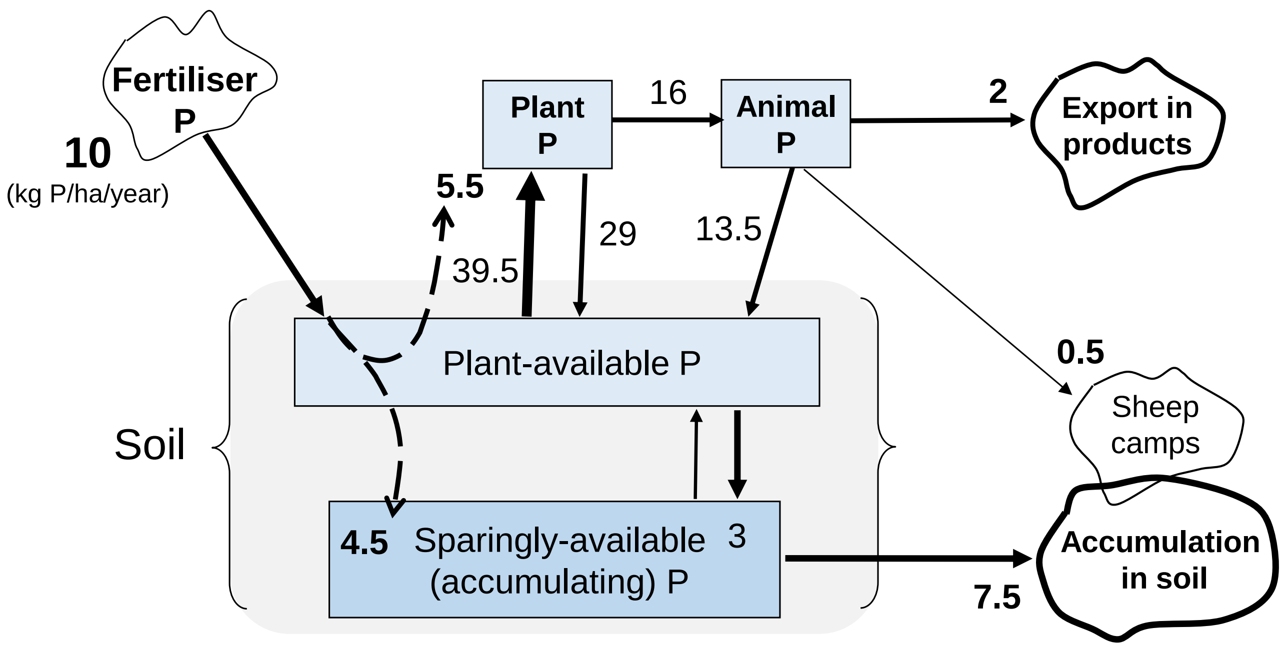
Long-Term Fate of Fertiliser P- Low PBI Soil

- The majority of fertiliser P was recovered in the 0 – 20 cm soil layer

- Both inorganic and organic P increased with the addition of fertiliser P

- Soil P audits of long-term field experiments reveal that much of the fertiliser P does accumulate in the soil surface layers

The Fate of Fertiliser P



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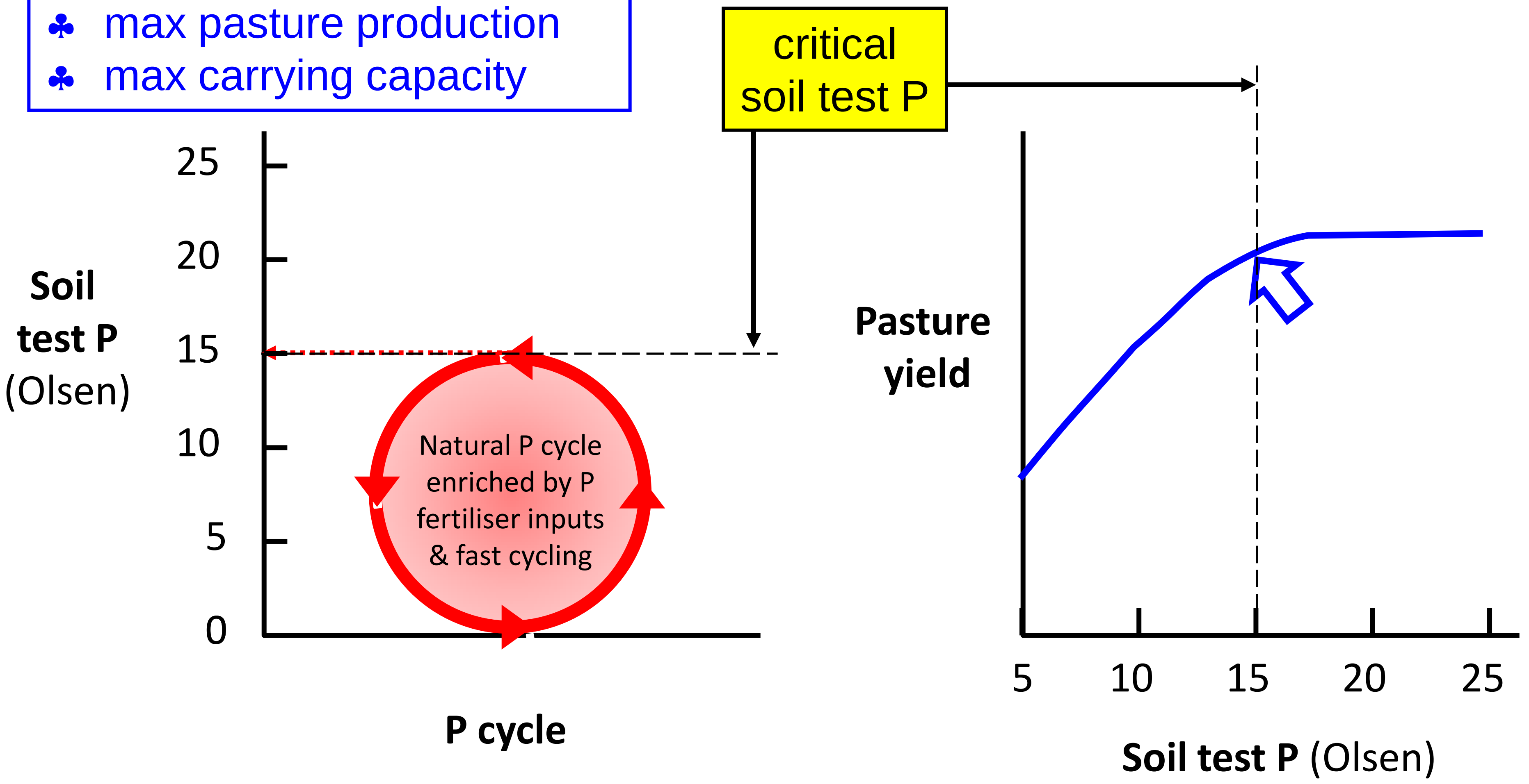
What Does This Mean for Pasture Management?

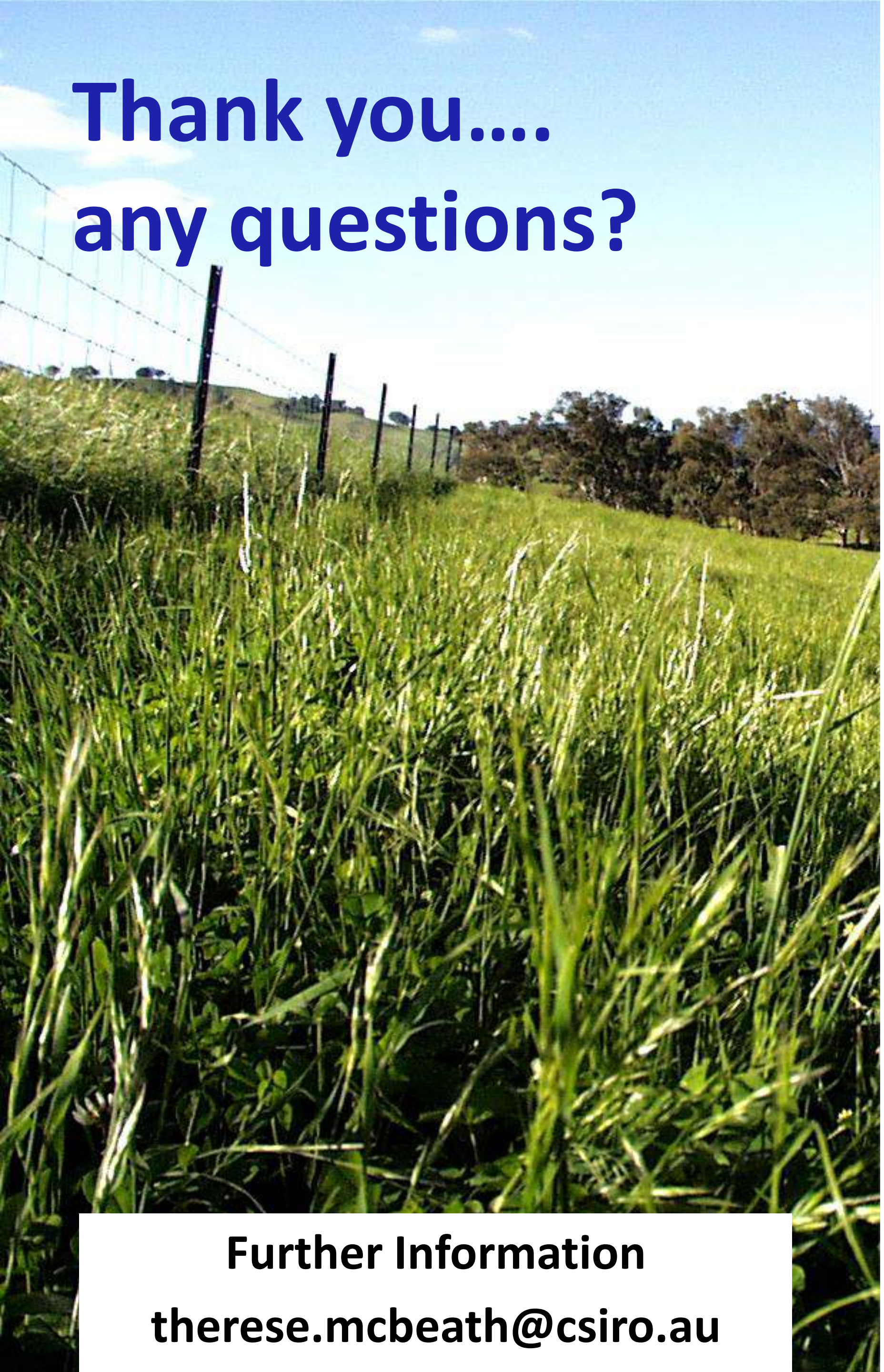
Optimum soil P fertility

- ♣ soil test P at "critical" level
- ♣ max pasture production
- ♣ max carrying capacity



What Does This Mean for Pasture Management?

1. Fertiliser P does not become immediately unavailable to plants when added to soils under pasture
2. A considerable proportion of the fertiliser P used for pasture growth is recycled and returned to the soil surface
3. The most efficient strategy appears to be early-season applications on the surface but the low balance efficiency remains
4. Soil testing is important to manage build (sub-optimal) and maintenance (optimal) phases and avoid waste (supra-optimal)
5. There is more to learn about P in pasture systems especially in higher PBI soils



Thank you.... any questions?

Further Information

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MLA-AWI Project (B.PUE.0102)

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Papers

- McLaren TI (2015) Improving phosphorus efficiency in pastures. Proceedings of the 56th Annual Conference of the Grassland Society of Southern Australia Inc.
- Simpson RJ, Sandral GA, Ryan MH, McLaren TI, Smernik RJ, McLaughlin MJ, McBeath TM, Lambers H, Guppy CN, Richardson AE (2015) New insights into phosphorus cycling in pastures: implications for fertiliser management and for closing the phosphorus efficiency gap roceedings of the Annual Conference of the Grassland Society of New South Wales Inc.
- McLaren TI, McBeath TM, Simpson RJ, McLaughlin MJ, Smernik RJ, Guppy CN, Richardson AE (2015) Which fertiliser phosphorus management strategy for maximum clover production and fertiliser phosphorus efficiency. Proceedings of the 17th ASA Conference.
- McLaren TI, Smernik RJ, Simpson RJ, McLaughlin MJ, McBeath TM, Guppy CN and Richardson AE (2015) Spectral sensitivity of solution 31P NMR spectroscopy is improved by narrowing the soil to solution ratio to 1:4 for pasture soils of low organic P content. Geoderma **(257-258)** 48-57.
- McLaren TI, Simpson RJ, McLaughlin MJ, Smernik RJ, McBeath TM, Guppy CN and Richardson AE (2015) An assessment of various measures of soil P and the net accumulation of P in fertilized soils under pasture. Journal of Plant Nutrition and Soil Science. Accepted 7th April 2015.
- McLaren TI, McLaughlin MJ, McBeath TM, Simpson RJ, Smernik RJ, Guppy CN and Richardson AE (2015) The fate of fertiliser P in soil under pasture and uptake by subterranean clover- a field study using 33P-labelled single superphosphate. Plant and Soil. Accepted 15th July 2015
- McLaren TI, Smernik RJ, McLaughlin MJ, McBeath TM, Kirby JK, Simpson RJ, Guppy CN, Doolette AL and Richardson AE (2015) Complex forms of soil organic phosphorus- a major but overlooked component of soil phosphorus. Environmental Science and Technology. Accepted with revisions 28th July 2015

What is inorganic and organic P?

Inorganic P

Orthophosphate anions in the soil solution (i.e. H_2PO4^-)

The only P form plants can take up!

Orthophosphate anions sorbed to Al and Fe metals on clay surfaces

Al and Fe mineral phosphates (e.g. $AlPO_4.2H_2O$ or $FePO_4.2H_2O$)

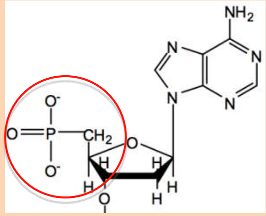
Ca mineral phosphates (e.g. $Ca_5(PO_4)_3OH$ or $Ca_5(PO_4)_3F$)

'Residual P' (i.e. unknown)

Organic P

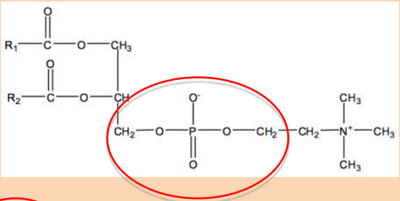
Nucleic acids (i.e. DNA and RNA)

from plants and micro-organisms



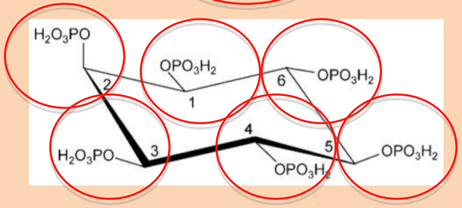
Phospholipids

from plants and micro-organisms



Phytate

from plant seeds



Humus P

soil organic matter

$R\text{-}OPO_3^{2-}$

(R = organic C moiety)

Increasing gradient of stability and abundance in soil